PORT OF LOS ANGELES INVENTORY OF AIR EMISSIONS 2005

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Prepared by:
STARCREST CONSULTING GROUP, LLC

Starcrest dedicates its work on this project to the loving memory of Kelly O'Reilly Ray

THE PORT OF LOS ANGELES INVENTORY OF AIR EMISSIONS FOR CALENDAR YEAR 2005

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TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D)

LIST OF FIGURES

LIST OF FIGURES (CONT'D)

LIST OF FIGURES (CONT'D)

LIST OF FIGURES (CONT'D)

LIST OF TABLES

LIST OF TABLES (CONT'D)

LIST OF TABLES (CONT'D)

LIST OF TABLES (CONT'D)

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ACRONYMS & ABBREVIATIONS

Act	Activity
AAPA	American Association of Port Authorities
ABS	American Bureau of Shipping
AMP	alternative maritime power
ANPRM	Advance Notice of Proposed Rulemaking
APL	American Presidents Line
APM	A. P. Moeller
AS	actual speed
ATB	articulated tug and barge
BACT	Best Available Control Technology
BAEI	Baseline Air Emissions Inventory
BNSF	Burlington Northern Santa Fe Railroad
BTH	Business Transportation and Housing Agency
Cal/EPA	California Environmental Protection Agency
CARB	California Air Resources Board
CF	control factor
CHE	cargo handling equipment
CO	carbon monoxide
D	distance
DF	deterioration factor
DMV	Department of Motor Vehicles
DMVT	daily vehicle miles of travel
DOC	diesel oxidation catalyst
DPF	diesel particulate filter
DPM	diesel particulate matter
DR	deterioration rate
DWT	deadweight tonnage
E	emissions
EEIA	Energy and Environmental Analysis
EF	emission factor
EI	emissions inventory
EMD	(GE) Electromotive Division
EPA	U.S. Environmental Protection Agency
FCF	fuel correction factor

ACRONYMS & ABBREVIATIONS (CONT'D)

g/day	grams per day
g/hr	grams per hour
g/kW-hr	grams per kilowatt-hour
g/mi	grams per mile
GM	goods movement
GMP	Good Movement Plan
GVWR	gross vehicle weight rating
HC	hydrocarbons
HDDV	heavy-duty diesel vehicle
HDV	heavy-duty vehicles
hp	horsepower
hrs	hours
HVAC	heating/ventilation/air conditioning
ICTF	Intermodal Container Transfer Facility
IFO	intermediate fuel oil
IMO	International Maritime Organization
ITB	integrated tug and barge
kW	kiloWatt
L.A.	Los Angeles
LAXT	Los Angeles Export Terminal
lbs/day	pounds per day
LF	load factor
LLA	low load adjustment
Lloyd's	Lloyd's Register of Ships
LPG	liquefied petroleum gas
M&N	Moffatt & Nichol Engineers
MaRex	Marine Exchange of Southern California
MCR	maximum continuous rated
MDO	marine diesel oil
MGO	marine gas oil
MMA	Meyer, Mohaddes Associates, Inc.
MOU	Memorandum of Understanding
mph	miles per hour
MS	maximum speed

ACRONYMS & ABBREVIATIONS (CONT'D)

MTC	Marine Terminals Corporation
NAAQS	National Ambient Air Quality Standards
nm	nautical miles
NO_x	oxides of nitrogen
NPRM	Notice of Proposed Rulemaking
NYK	Nippon Yusen Kaisha
OBD	on-board diagnostics
OGV	ocean-going vessel
PCEEI	Pleasure Craft Exhaust Emissions Inventory
PCST	Pacific Cruise Ship Terminals
PHL	Pacific Harbor Line
PM	particulate matter
PM_{10}	particulate matter less than 10 microns in diameter
$PM_{2.5}$	particulate matter less than 2.5 microns in diameter
PMSA	Pacific Merchant Shipping Association
POLA	Port of Los Angeles
POLB	Port of Long Beach
ppm	parts per million
PWBAEI	Port-wide Baseline Air Emissions Inventory
PZ	precautionary zone
Reefer	refrigerated vessel
RH	relative humidity
RIA	Regulatory Impact Analysis
RL	Rail Locomotives
RO	residual oil
ROG	reactive organic gases
Ro-Ro	roll-on/roll-off
rpm	revolutions per minute
RSD	Regulatory Support Document
RTG	rubber tired gantry crane
RTL	rich text language
S	sulfur
SCAG	Southern California Association of Governments
SCAQMD	South Coast Air Quality Management District

ACRONYMS & ABBREVIATIONS (CONT'D)

SFC	specific fuel consumption
SO_x	oxides of sulfur
SoCAB	Southern California Air Basin
SSA	Stevedoring Services of America
SUV	sport utility vehicle
T&M	tampering and mal-maintenance
TEU	twenty-foot equivalent unit
TICTF	Terminal Island Container Transfer Facility
TOG	total organic gases
tpd	tons per day
tpy	tons per year
U.S.	United States
ULCC	ultra large crude carriers
ULSD	ultra low sulfur diesel
UP	Union Pacific Railroad
USCG	U.S Coast Guard
VBP	vessel boarding program
VLCC	very large crude carrier
VLCS	very large cargo ship
VMT	vehicle miles of travel
VOCs	volatile organic compounds
VSR	vessel speed reduction
VTS	vessel traffic service
ZH	zero hour
ZMR	zero mile rate

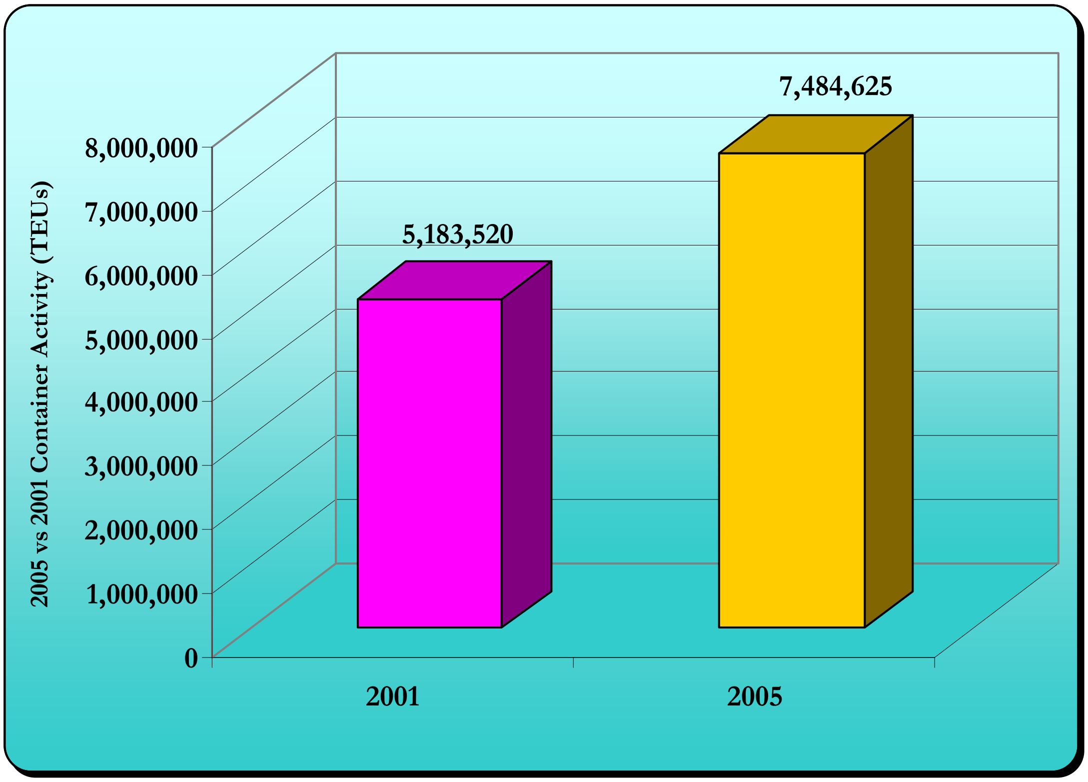
EXECUTIVE SUMMARY

The Port of Los Angeles (Port) shares San Pedro Bay with the neighboring Port of Long Beach (POLB). Together, the San Pedro Bay Ports comprise a significant regional and national economic engine. The San Pedro Bay Ports customs district accounts for approximately $300 billion in annual trade. More than 40% of all containerized trade in the nation flows through the San Pedro Bay Ports. Economic forecasts suggest that the demand for containerized cargo moving through the San Pedro Bay region will more than double by the year 2020. The economic benefits of the Ports are felt throughout the nation.

The Ports recognize that their ability to accommodate the projected growth in trade will depend upon their ability to address adverse environmental impacts (and, in particular, air quality impacts) that result from such trade. Therefore, in November 2006, the San Pedro Bay Ports adopted their landmark, joint Clean Air Action Plan designed to reduce air emissions and health risks while allowing port development to continue. The detailed annual activity-based inventory, with associated emissions estimates, is a critical and integral component to the success of the Clean Air Action Plan.

The Port released its first activity-based inventory of maritime related air emissions in 2004, documenting activity levels in the baseline year of 2001 (Port of Los Angeles 2001 Baseline Air Emissions Inventory). The 2001 Emissions Inventory evaluated emissions from five port-related mobile source categories: ocean-going vessels, harbor craft, off-road cargo handling equipment, railroad locomotives and on-road heavy-duty vehicles. The 2001 Emissions Inventory evaluated operations at all Port terminals. During the time between 2001 and 2005, the Port has experienced nearly a 44% increase in container throughput/activity, as presented in Figure ES.1 below.

Figure ES.1: Container Activity 2005 vs. 2001



In 2005 there was a reduction of total ship calls (all vessel types) by nearly 14%, as shown in Table ES.1. Although 2005 was a record year for total TEUs handled with ~7.49 million TEUs and other cargoes. As shown below, the average number of TEUs per containership call increased from 3,272 TEUs/call to 5,260 TEUs/call. This translates to a 10% reduction in containership calls and a 61% increase in the number of TEUs moved per ship call. The largest container vessel that called at the Port in 2005 was an 8,468 TEU container vessel.

Table ES.1: TEUs per vessel call in 2005 and 2001

Year	All Calls	Containership Calls	TEUs	Average TEUs/Call
2001	2,717	1,584	5,183,520	3,272
2005	2,341	1,423	7,484,625	5,260

This Port of Los Angeles Inventory of Air Emissions for Calendar Year 2005 has been prepared by the Port as a follow-up to the 2001 Emissions Inventory. This document presents emission estimates based on 2005 activity levels and also includes a discussion of emission reduction technologies and strategies used in 2005 to reduce emissions from Port facilities. The 2005 inventory includes the same five source categories that were included in the 2001 inventory. For each source category, emission estimates were developed for oxides of nitrogen (NO_x), total organic gases (TOG), carbon monoxide (CO), particulate matter less than 10 microns (PM_{10}) and 2.5 microns ($PM_{2.5}$) in diameter, diesel particulate matter (DPM), and oxides of sulfur (SO_x). The inventory does not include stationary sources, as these are included in stationary source permitting programs administered by the South Coast Air Quality Management District (SCAQMD).

Development of this inventory was coordinated with the U.S. Environmental Protection Agency - Region 9 (EPA), California Air Resources Board (CARB), and SCAQMD. The Port appreciates the time and effort taken by the agencies' staff to discuss, review and provide comments to the inventory.

Future updates, starting with the 2006 Port-wide Emissions Inventory (which is currently being compiled), will include greenhouse gases (GHGs) from port-related mobile sources. The Port is commencing work on a comprehensive 2006 Port-wide GHG inventory including all Port of Los Angeles mobile and stationary sources (such as buildings and other facilities). Completion of this inventory is planned for later this year.

The geographical extent of the 2005 inventory is described in section 1 and in each source category section of the report. The extent of the port-related emissions includes emissions from all source categories within the harbor district; emissions from rail locomotives and on-road trucks transporting cargo to or from the Port up to the cargo's first point of rest within the South Coast Air Basin (SoCAB) or up to the basin boundary, whichever comes first; and emissions from commercial marine vessels within the harbor and up to the study area boundary. Figure ES.2 shows the SoCAB boundary which is the gray shaded area, while Figure ES.3 shows the geographical extent for the ocean-going vessels and harbor craft. The over-water boundary is 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

Figure ES.2: South Coast Air Basin Boundary

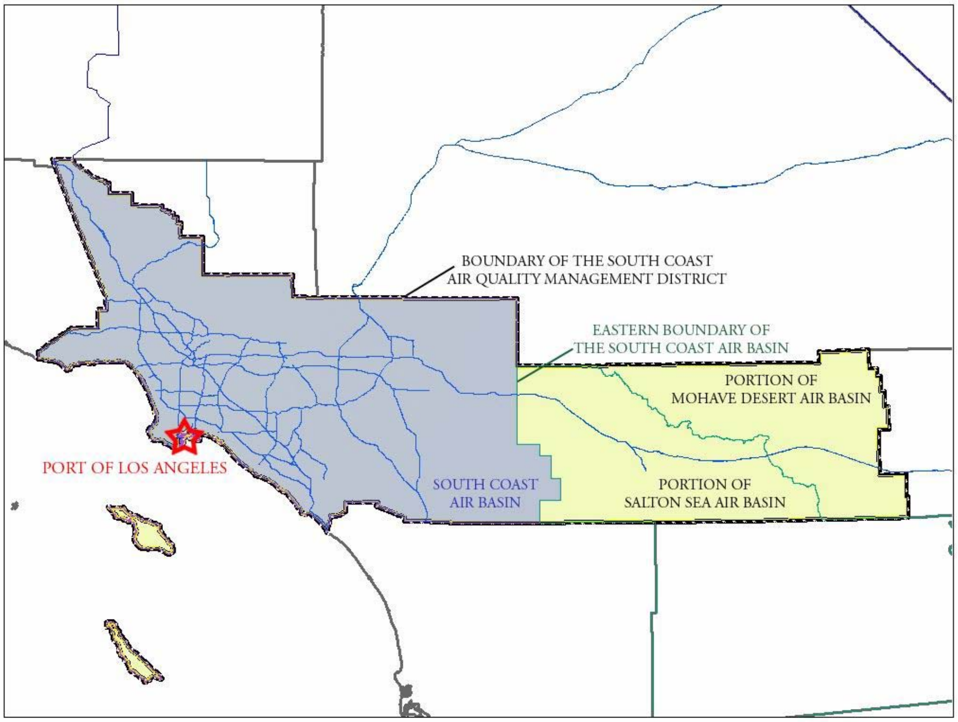
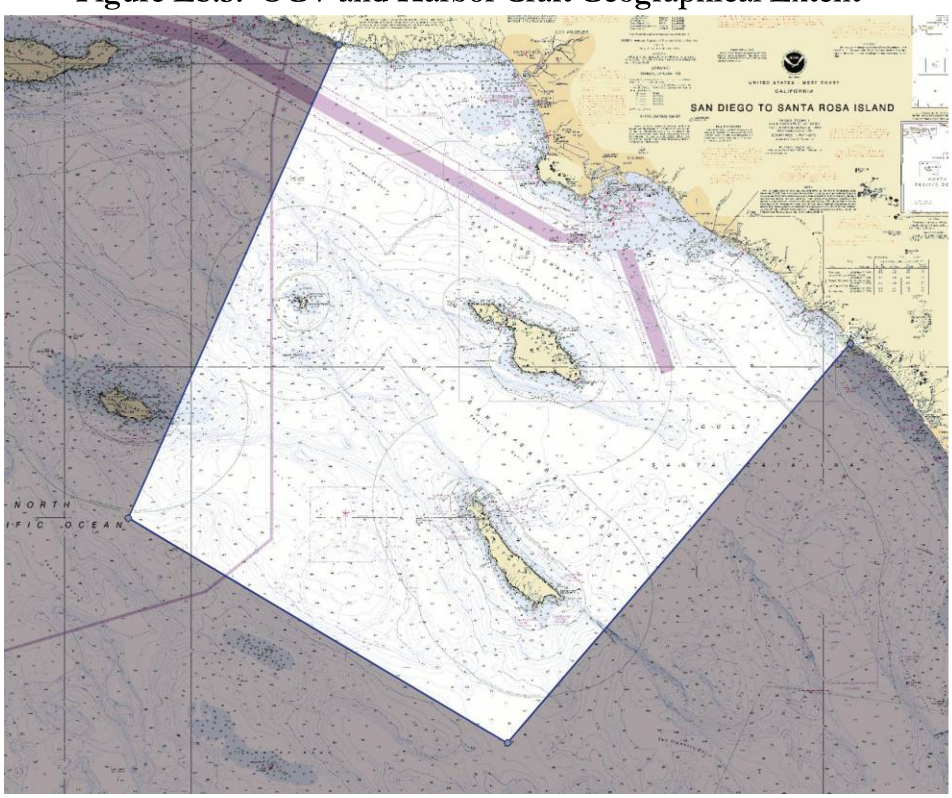


Figure ES.3: OGV and Harbor Craft Geographical Extent



Methodology Overview
Port tenants and shipping lines play an essential role in the development of an activity-based Emissions Inventory (EI) by providing the most accurate activity and operational information available. The activity and operational data collected is input into a database for storage. Emissions estimates are developed for each of the various source categories in a manner consistent with the latest estimating methodologies agreed upon by the Port and the participating regulatory agencies. The information gathered, analyzed, and presented in this 2005 EI continues to improve the understanding of the nature and magnitude of Port-related emission sources.

Findings
Based on 2005 Marine Exchange data, there were 2,341 inbound calls to the port in 2005. Figure ES.4 shows the percentage of inbound calls by vessel type.

Figure ES.4: Distribution of Vessel Types by Inbound Calls

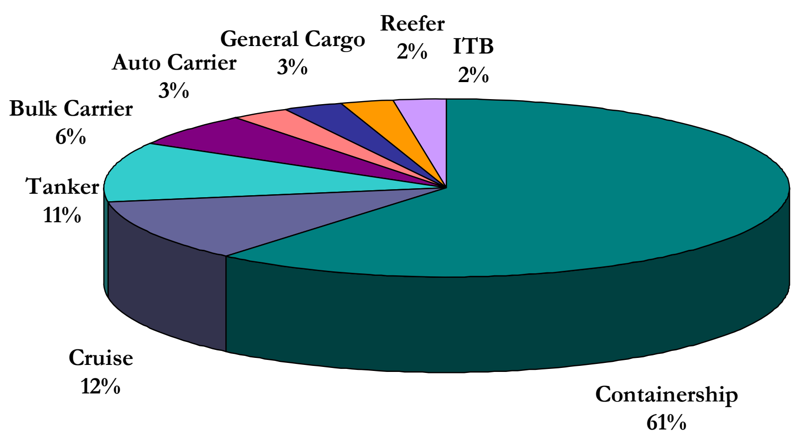


Figure ES.5 presents the distribution of the 255 commercial harbor craft inventoried for the Port of Los Angeles in 2005. About one third or 29% of all the engines in this inventory have been replaced by lower-emitting new engines. Figure ES.6 shows the percentage of the total number of main and auxiliary engines replaced by vessel type. Ocean-going vessels and harbor craft were estimated on an engine-by-engine basis for each vessel, which allowed the newer propulsion and auxiliary engines to be included in the emissions estimates.

Figure ES.5: Distribution of 2005 Commercial Harbor Craft at the Port

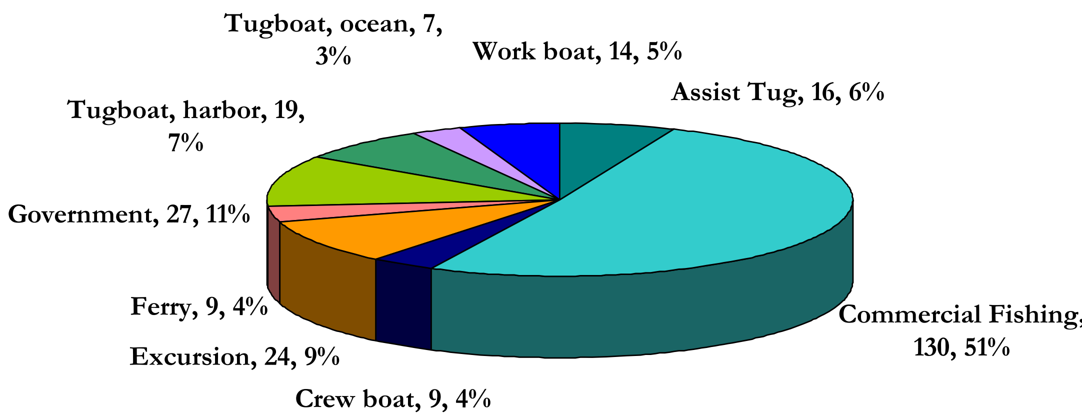
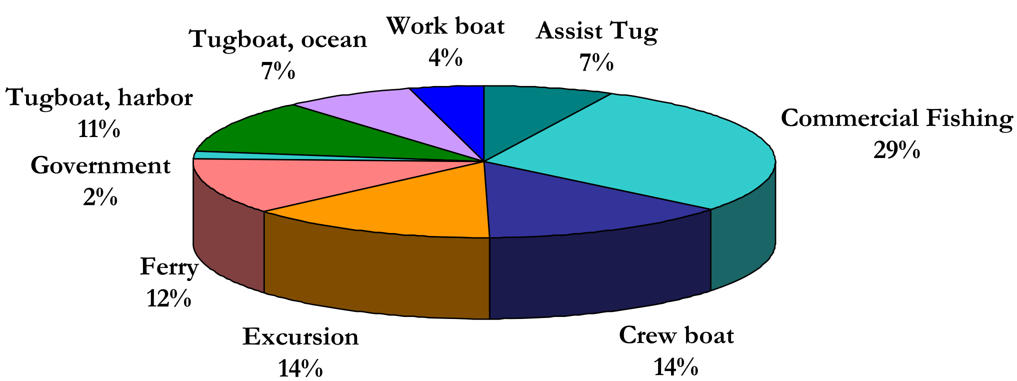


Figure ES.6: Distribution of Replaced Engines by Vessel Type



By the end of 2005, the Port and its tenants purchased and installed almost 600 diesel oxidation catalysts and purchased 164 yard tractors with on-road engines, which emit less than the off-road versions. In addition, over 200 pieces of cargo handling equipment (CHE) used emulsified fuel and over 800 pieces of CHE used ultra-low sulfur diesel. There were also 267 forklifts which used propane engines. These emission reduction strategies were started after 2001 and have been implemented voluntarily at Port or tenant expense. The following table summarizes the emission reduction technologies for cargo handling equipment at the Port. The emission reduction technology and actual date of implementation for each piece of cargo handling equipment were included in the emission calculations.

Table ES.2: Summary of 2005 CHE Emission Reduction Technologies

Equipment	Pieces of Eqmt	DOC Installed	Total Count On-road engine	Emulsified Fuel	ULSD
Yard tractor	848	520	164	129	596
Top handler	127	48	0	36	79
Side pick	41	14	0	10	16
RTG	98	0	0	28	36
Forklift	422	3	0	15	27
Other	114	0	1	0	65
Totals	**1,650**	**585**	**165**	**218**	**819**

Port-related 2005 Emission Estimates

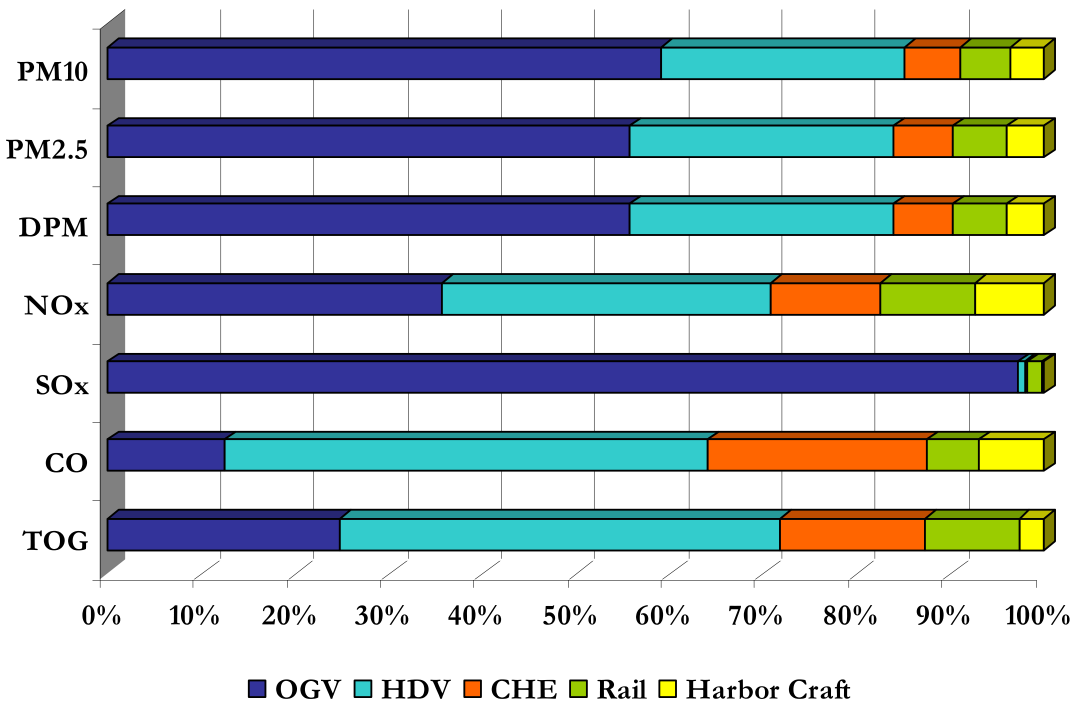
The emission results for the Port of Los Angeles Inventory of Air Emissions for calendar year 2005 are presented below. Table ES.3 summarizes the 2005 total Port-related emissions in the South Coast Air Basin by category in tons per year.

Table ES.3: 2005 Total Port-Related Emissions by Category, tpy

Category	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
Ocean Going Vessels	634	507	552	6,206	5,609	540	247
Harbor Craft	38	35	38	1,259	7	297	26
Cargo Handling Equipment	63	58	63	2,037	14	1,010	153
Locomotives	57	53	57	1,783	97	244	100
Heavy-Duty Vehicles	280	257	280	6,104	43	2,226	469
Total	**1,072**	**910**	**990**	**17,389**	**5,770**	**4,318**	**995**

Figure ES.7 shows the distribution of the 2005 total port-related emissions for each pollutant and category.

Figure ES.7: Distribution of 2005 Port-related Emissions by Category



Port-related emissions compared to other emissions in SoCAB

In order to put the Port of Los Angeles' port-related emissions into perspective with the other regional emissions, the following figures compare the Port's contribution to the total emissions in the South Coast Air Basin for the year 2005 as presented in Figures ES.8 – ES.10. Figure ES.8 below shows that approximately 9% of the total DPM emissions in the South Coast Air Basin are attributable to 2005 Port of Los Angeles port-related activities.

Figure ES.8: Distribution of 2005 DPM Emissions in the South Coast Air Basin

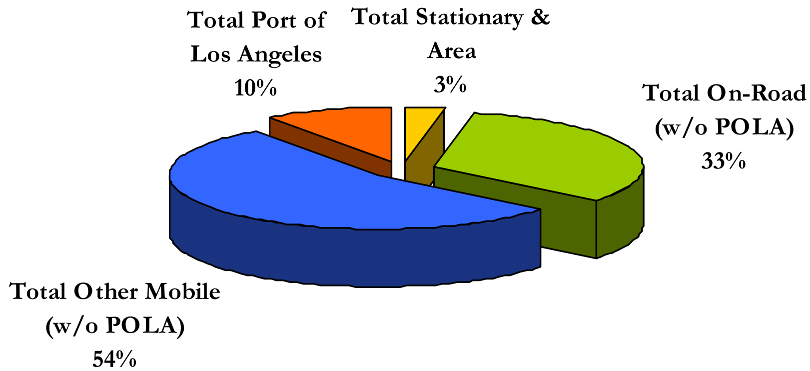


Figure ES.9 shows that approximately 5% of the total NO_x emissions in the South Coast Air Basin are attributable to 2005 Port of Los Angeles port-related activities.

Figure ES.9: Distribution of 2005 NO_x Emissions in the South Coast Air Basin

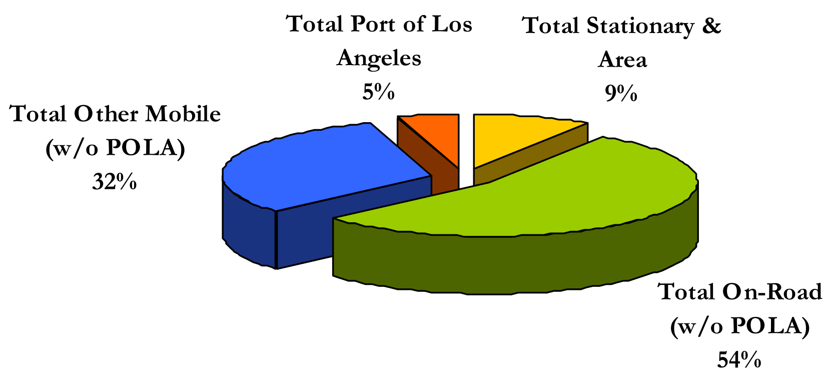
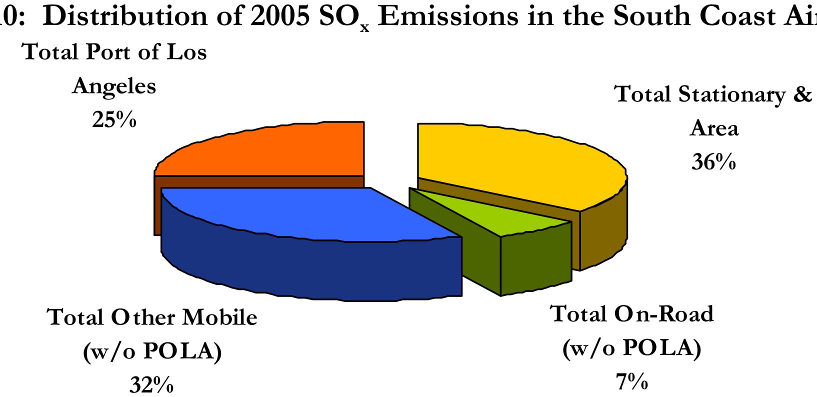


Figure ES.10 shows that approximately 25% of the total SO_x emissions in the South Coast Air Basin are attributable to 2005 Port of Los Angeles port-related activities.

Figure ES.10: Distribution of 2005 SO_x Emissions in the South Coast Air Basin



Port-related 2005 Emission Estimates vs. Adjusted 2001 Emission Estimates

In order to compare the 2005 emissions with the 2001 baseline inventory, the 2001 emission estimates were adjusted with respect to the changes/improvements of methodologies used for the 2005 inventory. The resulting comparison of total 2005 emissions with adjusted 2001 emissions is summarized in the following summary table by source category.

Table ES.3: 2005 vs. Adjusted 2001 Emission Estimates by Category (tpy and %)

Category	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
Adj. 2001 Ocean Going Vessels	567	453	na	6,594	5,857	633	219
2005 Ocean Going Vessels	634	507	552	6,206	5,609	540	247
Change (tpy)	**67**	**54**	**na**	**-389**	**-248**	**-92**	**27**
Change (%)	**12%**	**12%**	**na**	**-6%**	**-4%**	**-15%**	**12%**
Adj. 2001 Harbor Craft	49	46	49	1,578	21	266	34
2005 Harbor Craft	38	35	38	1,259	7	297	26
Change (tpy)	**-11**	**-10**	**na**	**-319**	**-14**	**31**	**-8**
Change (%)	**-22%**	**-22%**	**na**	**-20%**	**-67%**	**12%**	**-23%**
Adj. 2001 CHE	71	66	71	1,818	14	1,054	149
2005 CHE	63	58	63	2,037	14	1,010	153
Change (tpy)	**-8**	**-8**	**-8**	**219**	**-0.2**	**-44**	**4**
Change (%)	**-12%**	**-12%**	**-12%**	**12%**	**-1%**	**-4%**	**3%**
Adj. 2001 Locomotives	34	31	34	1,413	55	145	57
2005 Locomotives	57	53	57	1,783	97	244	100
Change (tpy)	**24**	**22**	**24**	**371**	**41**	**99**	**44**
Change (%)	**70%**	**70%**	**70%**	**26%**	**75%**	**68%**	**77%**
Adj. 2001 Heavy-Duty Vehicles	224	205	224	4,501	37	1,632	288
2005 Heavy-Duty Vehicles	280	257	280	6,104	43	2,226	469
Change (tpy)	**56**	**52**	**56**	**1,603**	**6**	**594**	**181**
Change (%)	**25%**	**25%**	**25%**	**36%**	**17%**	**36%**	**63%**
Adj. 2001 Total Emissions	945	801	na	15,904	5,985	3,730	747
2005 Total Emissions	1,072	910	990	17,389	5,770	4,318	995
Change (tpy)	**127**	**109**	**na**	**1,485**	**-215**	**588**	**248**
Change (%)	**13%**	**13%**	**na**	**9%**	**-4%**	**16%**	**33%**

Figure ES.11 presents the total (all source categories combined) change in emissions from 2005 vs. adjusted 2001 emissions for each pollutant. Note that DPM was not originally calculated in 2001 and just that comparison can not be made at this time. This will be added in the 2006 inventory.

Figure ES.11: 2005 vs. Adjusted 2001 Emissions for All Source Categories

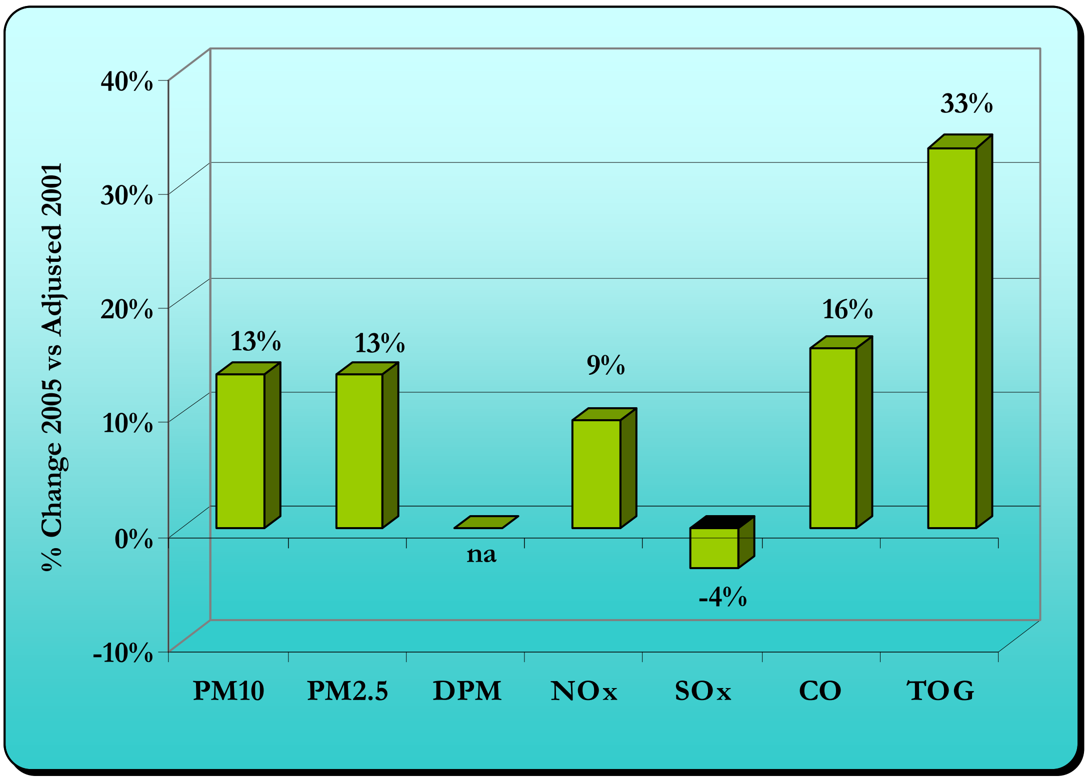
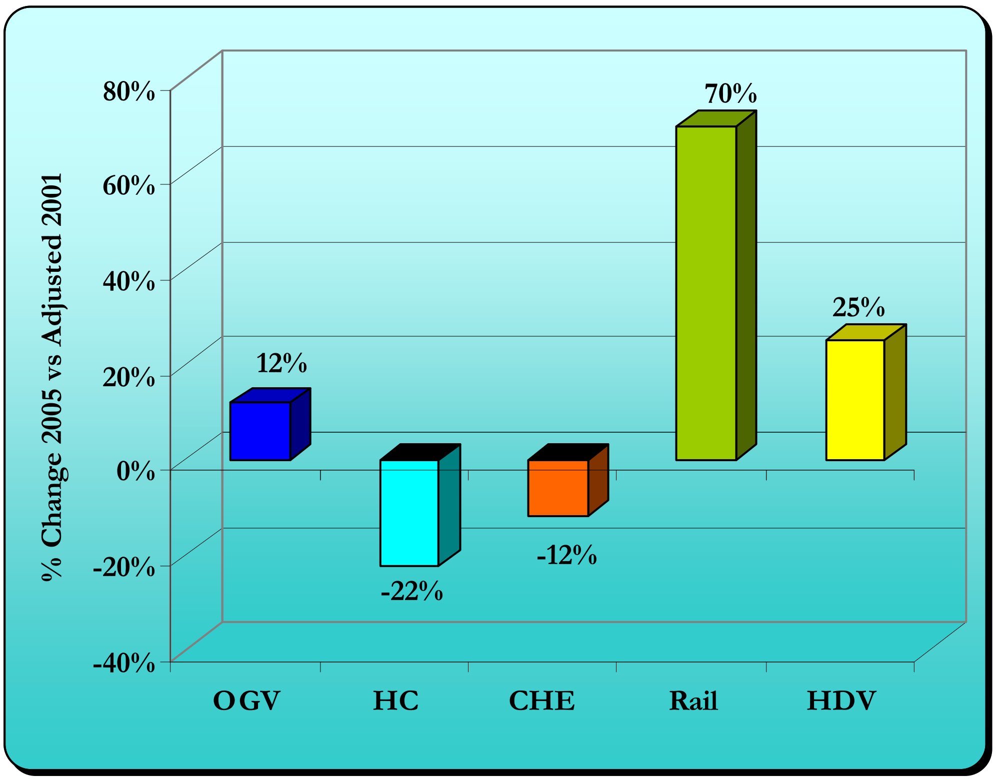


Figure ES.12 illustrates the relative magnitude of PM increases and decreases from each source category.

Figure ES.12: PM_{10} & $PM_{2.5}$ Emissions Changes 2005 vs. Adjusted 2001 by Source Category



The overall PM emission increases presented in Figure ES.11 are influenced by the following increases and decreases in source category emissions shown in Figure ES.12:

Increases from:

- OGV – due to the shift from main engine power to auxiliary engine power
- HDV – increased activity (miles traveled) caused by increase port throughput, despite newer fleet
- Rail – significantly increased on-dock activity and overall port TEU throughput. It should be noted that increases in on-dock rail activity means that more cargo is moving via rail and thus limiting increases in cargo moving by truck.

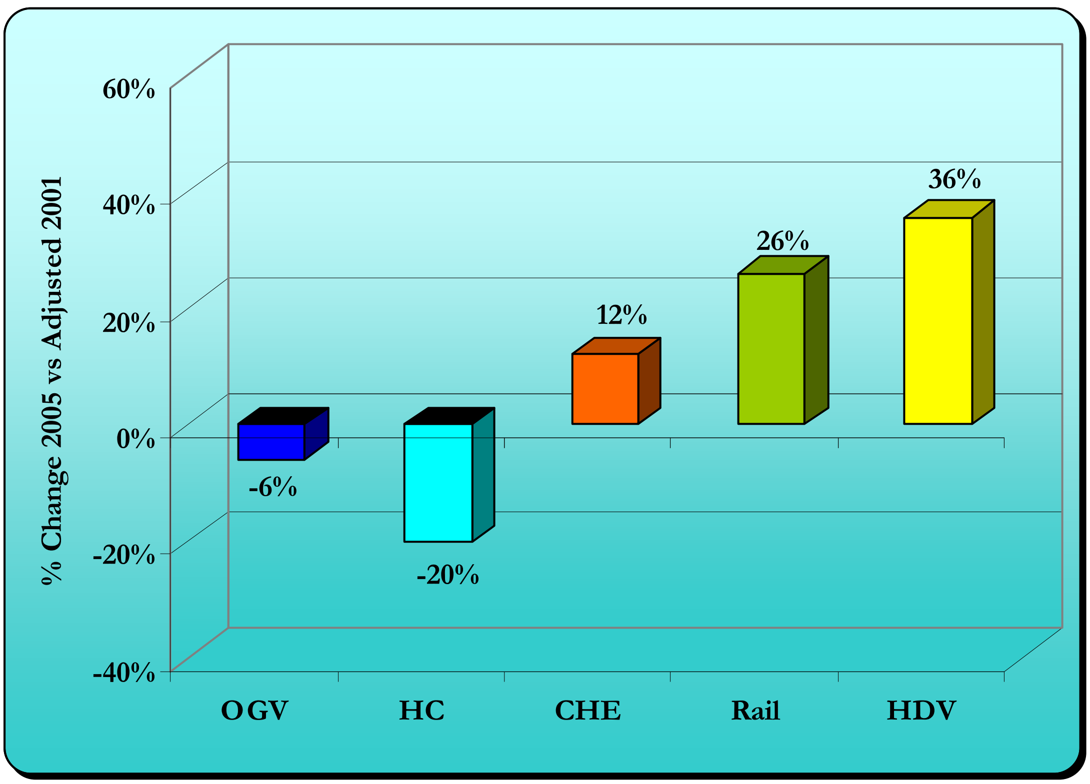
Reductions from:

- CHE – due to emission reduction programs, fleet turnover to cleaner engines, and the use of cleaner fuels

- Harbor Craft – reduced number of vessels (and, therefore, lower operating hours) from the fishing fleet and the use of lower sulfur fuels

Figure ES.13 illustrates the relative magnitude of NO_x increases and decreases from each source category.

Figure ES.13: NO_x Emissions Changes 2005 vs. Adjusted 2001 by Source Category



The overall NO_x emission increase presented in Figure ES.11 is influenced by the following increases and decreases in source category emissions shown in Figure ES.13:

Increases from:

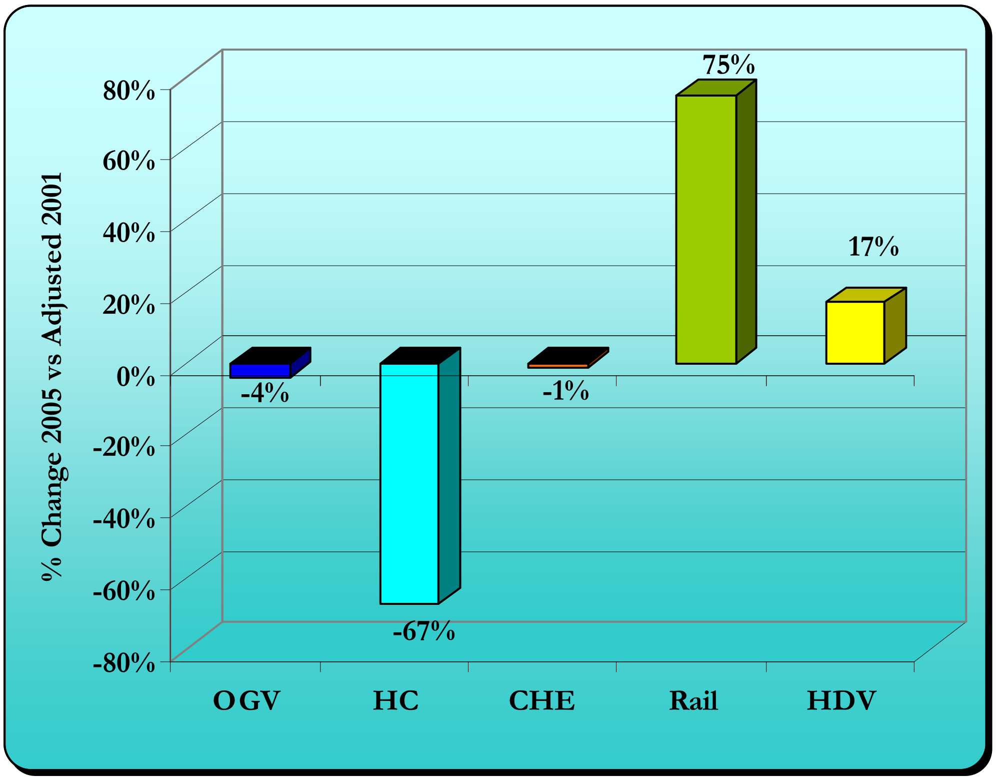
- HDV – increased emissions due to increased activity despite newer fleet
- CHE - increased emissions due to increased activity despite newer equipment
- Rail – significantly increased on-dock activity and overall port TEU throughput

Reductions from:

- OGV – greater compliance with VSR program, use of slide valves, and fewer vessel calls
- HC - engine replacements and lower operating hours from the fishing fleet

Figure ES.14 illustrates the relative magnitude of SO_x increases and decreases from each source category.

Figure ES.14: SO_x Emissions Changes 2005 vs. Adjusted 2001 by Source Category



The overall SO_x emission decrease presented in Figure ES.11 is influenced by the following increases and decreases in source category emissions shown in Figure ES.14:

Increases from:

- HDV – increased emissions due to increased activity despite newer fleet
- Rail – significantly increased on-dock activity and overall port TEU throughput

Reductions from:

- OGV – Fewer vessel calls and vessels that switched to cleaner fuels
- CHE - emission reduction programs and the use of cleaner fuels
- HC – use of cleaner fuels and lower operating hours from the fishing fleet

As noted in the beginning of this section, container throughput increased approximately 44% between 2001 and 2005. However, overall container-related emissions grew at lesser rates, due to the combined effects of regulations, voluntary emission reduction efforts (by the Port and Port tenants), improvements in terminal operations, and other factors. When looked at as the ratio of overall emissions to container throughput (i.e., tons of emissions from all five source categories per 10,000 TEUs throughput) the movement of containers was accomplished with lower emission levels per container moved. The following table presents the magnitudes of these improved efficiencies for PM_{10}, NO_x, and SO_x.

Table ES.4: Changes in Ratios of Emissions to Throughput (tons per 10,000 TEU)

Pollutant	Tons of Emissions / 10,000 TEU 2001	2005	Percent Change
PM_{10}	1.2	1.0	17% decrease
NO_x	21.2	17.5	17% decrease
SO_x	5.9	4.3	27% decrease

While Figure 8.2 shows that the total mass of emissions of PM_{10} and NO_x has increased between 2001 and 2005, Table 8.14 shows that the combined effects of the efforts made to improve operational efficiencies and to reduce emissions over that period have improved the emissions performance related to the movement of containers through the Port. The Port and the regulatory agencies are implementing additional, far-reaching measures and regulations that will result in continued improvements in the emissions-to-throughput ratios.

SECTION 1 INTRODUCTION

The Port of Los Angeles (the Port or POLA) shares San Pedro Bay with the neighboring Port of Long Beach (POLB). Together, the San Pedro Bay Ports comprise a significant regional and national economic engine for California and the United States (U.S), through which more than 40% of all U.S. containerized trade flows. The San Pedro Bay Ports customs district accounts for approximately $300 billion in annual trade. Economic forecasts suggest that the demand for containerized cargo moving through the San Pedro Bay region will more than double by the year 2020. The economic benefits of the Ports are felt throughout the nation.

The Ports recognize that their ability to accommodate the projected growth in trade will depend upon their ability to address adverse environmental impacts (and, in particular, air quality impacts) that result from such trade. Therefore, in November 2006, the San Pedro Bay Ports adopted their landmark, joint Clean Air Action Plan designed to reduce the air health risks and emissions associated with port-related operations, while allowing port development to continue. This detailed annual activity-based inventory, with associated emissions estimates, is a critical and integral component to the success of the Clean Air Action Plan.

The Port is a landlord port; it builds terminal facilities and leases them to shipping lines and stevedoring companies. The Port does not operate the terminals, ships, yard equipment, trucks or trains that move the cargo.

The Port is an industry leader in its commitment to the environment. Its efforts to reduce emissions associated with commercial activities related to port operations are unsurpassed. The Port has recently won several awards for its environmental stewardship, including:

- 2005 Clean Air Excellence Award, EPA
- 2005 Environmental Achievement Award, EPA Region 9
- 2005 City of LA Quality and Productivity Award for the Alternative Maritime Power Program (AMP)

1.1 Reason for Study

This activity-based inventory includes port-related equipment, vehicle, and marine operations within the study's geographical boundary (discussed in Section 1.5.3). The inventory includes physical parameters (source specifics such as engine size, age, fuel type, model, make, etc.), activity parameters (source specifics such as hours of operation, speed, transit times, number calls, date operational, etc.), and emissions reduction device parameters (type, reduce efficiency, etc.). Emissions estimates and reductions from control strategies are generated based on these parameters that have been collected for a specific calendar year. The annual emissions inventory will be a critical component to the Clean Air Action Plan.

The inventory will be used to track and report the progress of the plan and provide the information needed to track efficiency improvements at all levels of port-related operations. The inventories will also be used for environmental impact analyses and reporting. Finally, the relationships identified between activity, cargo throughputs, and emissions will be used as the basis for developing improved emissions forecasts based on potential cargo demands.

The Port released its first activity-based emissions inventory in 2004, documenting activity levels in the baseline year of 2001 (Port of Los Angeles 2001 Baseline Air Emissions Inventory). The 2001 Emissions Inventory evaluated emissions from five port-related source categories: ocean-going vessels, harbor craft, off-road cargo handling equipment, railroad locomotives and on-road heavy-duty vehicles. The 2001 Emissions Inventory evaluated operations at all Port terminals.

This Port of Los Angeles Air Emissions Inventory has been prepared by the Port as a follow-up to the 2001 Emissions Inventory. This document presents emission estimates based on 2005 activity levels and also includes a discussion of emission reduction technologies and strategies used in 2005 to reduce emissions from Port facilities. Significant improvements have been made such that the annual inventories, emissions estimates, and reports can be published within six months of the conclusion of a calendar year. All future updates, starting with the 2006 Port-wide emissions inventory (which is currently being compiled), will include green house gases (GHGs) from port-related sources. The Port is commencing work on a comprehensive 2006 Port-wide GHG inventory including all Port of Los Angeles mobile and stationary sources (such as buildings and other facilities). Completion of this inventory is planned for later this year.

1.2 Goods Movement

Goods Movement (GM) has become a key issue associated with both growth of the California economy and the significant challenges to meeting the National Ambient Air Quality Standards (NAAQS) in the South Coast Air Basin (SoCAB). Business, Transportation and Housing Agency (BTH) and the California Environmental Protection Agency (Cal/EPA) has recently updated their Goods Movement Action Plan (GMP)[1]. The purpose of the GMP is to develop an action plan to address GM related issues such as current and future infrastructure needs, impact on environment, adverse impact mitigation measures to protect public health and community concerns, public safety and security issues, and workforce development opportunities regarding goods movement.

[1] From Goods Movement Action Plan dated January 11, 2007. *http://www.arb.ca.gov/gmp/gmp.htm.*

As stated in the GMP, "it is the policy of this Administration to improve and expand California's goods movement industry and infrastructure in a manner which will:

- Generate jobs.
- Increase mobility and relieve traffic congestion.
- Improve air quality and protect public health.
- Enhance public and port safety.
- Improve California's quality of life."

The GMP is focused to address goods movement in California's four major "port-to-border" goods movement corridors:

- Los Angeles-Long Beach/Inland Empire
- Bay Area
- San Diego/Border
- Central Valley

Over decades, these corridors have been major routes for ship to rail, ship to truck, and truck to rail exchanges to move millions of containers per year to their ultimate destinations.

As stated in the GMP, "to help develop order of magnitude estimates of how effort should be distributed among the corridors, the agencies compiled a series of indices to compare and contrast key indicators among the corridors. Items included:

- Value by customs district
- Maritime container volume
- Port of Entry tonnage
- Logistics jobs
- Daily vehicle hours of delay
- Mean average annual daily truck volume
- Total emissions per day
- Population

While the relative fractions or contributions of each of these factors vary by corridor, an unweighted aggregate of the fractions indicate that the Los Angeles/Long Beach-Inland Empire corridor in southern California ranks first by a large margin with about 60 percent of the aggregate shares. The Bay Area, Central Valley, and San Diego corridors represent 19 percent, 13 percent, and 8 percent, respectively. More specific analysis will be necessary to determine the relative allocation of effort among the corridors to achieve simultaneous and continuous improvement."[2]

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[2] From Emissions Reduction Plan for Ports and Goods Movement approved by CARB's Board on April 20, 2006. *http://arb.ca.gov/planning/gmerp/gmerp.htm;*

As a part of the GMP, the CARB is responsible to develop an emissions reduction plan from international as well as domestic goods movement related future activities of the four corridors mentioned above. In April of 2006, CARB adopted an Emissions Reduction Plan for Ports and Goods Movement in California. The international goods movement category includes emissions from all on-port sources, including:

- All ocean-going vessels up to 24 nautical miles,
- All harbor craft up to 24 nautical miles,
- All cargo handling equipment,
- All on-port trucks operation,
- All on-port rail operations,
- International goods movement portion of off-port truck operation, and
- International goods movement portion of off-port rail operation.

Again as stated in the GMP, "as set forth by the ARB Board on April 20, 2006, the State's five specific goals for addressing the air pollution associated with goods movement are:

A. Reduce total statewide international and domestic goods movement emissions to the greatest extent possible and at least back to 2001 levels by year 2010;

B. Reduce the statewide diesel particulate matter (PM) health risk from international and domestic goods movement 85 percent by year 2020;

C. Reduce NO_x emissions from international goods movement in the South Coast 30 percent from projected year 2015 levels, and 50 percent from projected year 2020 levels based on preliminary targets for attaining federal air quality standards;

D. Apply the emission reduction strategies for ports and goods movement statewide to aid all regions in attaining air quality standards; and

E. Make every feasible effort to reduce localized risk in communities adjacent to goods movement facilities as expeditiously as possible."[3]

This inventory will be utilized by the state to track emissions from port-related sources and to document reductions from both regulatory and Port lead reduction efforts.

[3] From Emissions Reduction Plan for Ports and Goods Movement approved by CARB's Board on April 20, 2006. *http://arb.ca.gov/planning/gmerp/gmerp.htm;*

There are two types of control that the Port has over port-related sources: direct and indirect. The Port has direct control through lease agreements with tenants/terminals located on port property and through tariffs. Using leases for example, the Port can negotiate conditions that could directly affect equipment operated on their leased terminal. There are limits however, to the frequency that this type of direct control can be utilized since most leases are signed for 20 or more years. The second type of direct control the Ports can utilize are changes to the tariff. A Port Tariff is the published set of rates, charges, rules and regulations for those doing business with a port. Each Port publishes its own tariff. A tariff is generally applicable to all tenants. However, individual operating leases may set requirements to a specific version of the tariff (i.e., later changes don't apply). All potential tariff changes will need to go through legal evaluation prior to being enacted.

Indirect control is again through the use of leases and tariff changes; however, the targets would be vessels, locomotives, and vehicles that call on the terminal which are not owned by the tenant. The Port can potentially affect these sources, for example, by negotiating standards for trucks calling at a terminal. There are some limitations to the extent at which this control mechanism can be used and legal review and analysis is required. The Clean Air Action Plan utilizes both direct and indirect control of port-related sources.

1.3 Marine Container Cargo Movements

Container terminals and their associated cargo movements are complex intermodal operations that are critical to international trade. Containerized cargo has significantly increased the efficiency and capacity of the transportation system over the prior general cargo/break bulk cargo models (which still exist for non-containerized cargo). Due to the inherent efficiencies of containerized cargo, the types of cargo shipped via containers are growing yearly. To better understand the operations of the international transportation network associated with ports, this subsection describes overseas container transport, import cargo containers and their distribution locally and nationally, export cargo containers (locally and nationally), and how empty cargo containers are dealt with.

Overseas Container Transport

Imported cargo generally starts at an overseas manufacturer, supplier, or consolidation facility, where items are boxed and placed inside metal shipping containers. Containers generally come in two common sizes 20' or 1 twenty-foot equivalent (TEU), or 40' or 2 TEUs. Other sizes such as 53' are also used. The U.S. buyer may contact an industry professional known as a "freight forwarder," or logistics company, to coordinate transportation of the cargo. The container will then be transported to a foreign port, assessed for possible security risks, and then placed on board container ships which are specialized specifically to carry containerized cargo. Containers ships calling at the San Pedro Bay Ports range from 2,000 – over 8,000 TEU per ship. The container ships transport the containerized cargo to the San Pedro Bay Ports, where it is unloaded, and forwarded to local or national destinations. The figure below, presents the steps that are associated with overseas cargo movements.

Figure 1.1: Overseas Container Transport

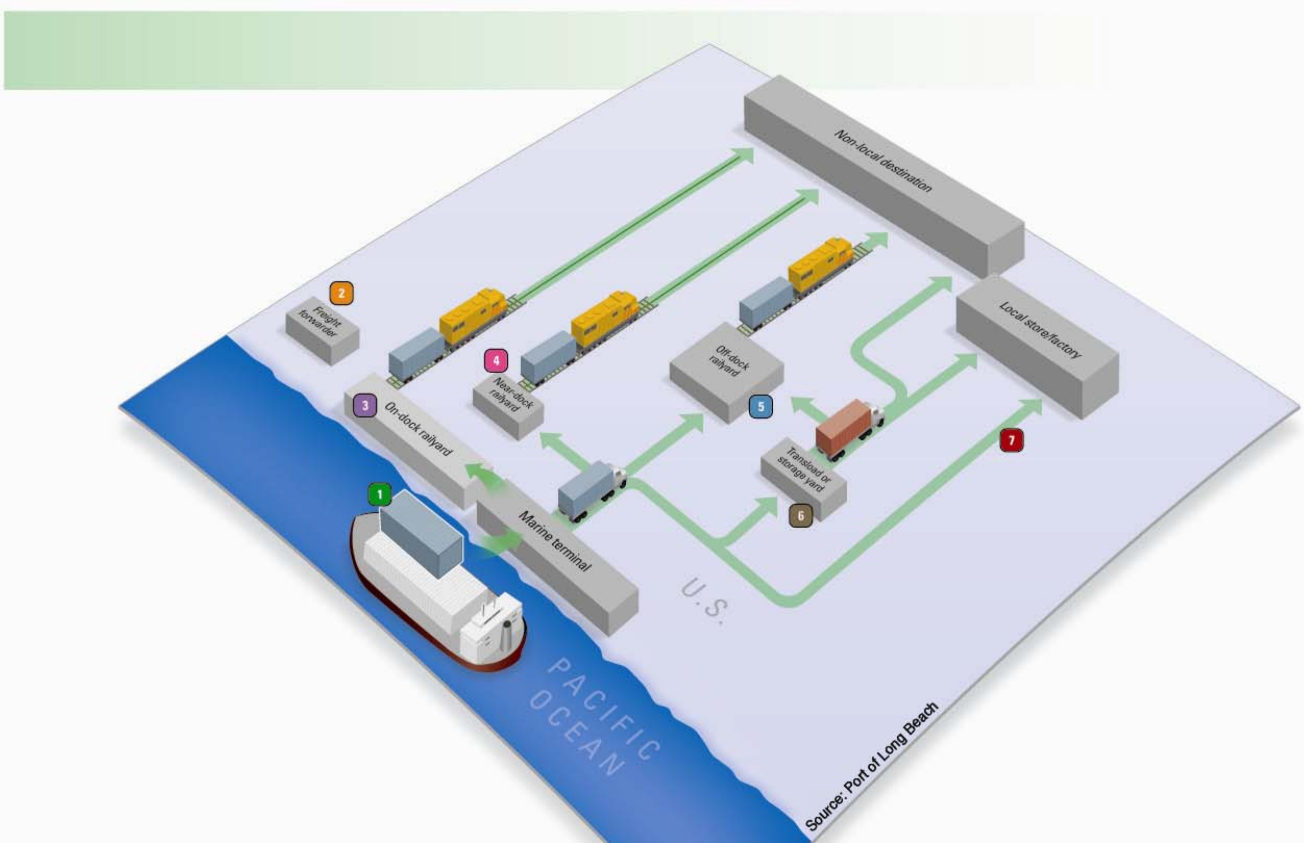
Notes:

1) Product ordered
2) Container to foreign port (not shown)
3) Security checks by U.S. Customs Agents based at foreign ports
4) Container loaded onboard
5) Coast Guard review of ship, crew, and cargo manifests
6) Port pilots board and dock the container ship
7) Unloading the ship with unionized longshore workers (see Figure 1.2 for further details)
8) Security checks by U.S. Customs Agents
9) Radiation detection

Import Container Transport

Once the ship arrives at the Port, the imported containers are either transported by train or by truck to their final destination, or to one of several intermediate destinations such as a railyard, warehouse, distribution center, or "transload" facility (a sorting, routing, and short-term storage facility). A container's final destination will determine exactly what path it will take once it leaves the dock. The figure below, presents the steps that are associated with imported container cargo movements.

Figure 1.2: Import Container Transport



Notes:

1) Unloading ship. The marine terminal operator will arrange for unionized longshore workers to unload the ship. Containers are place on trucks, rail, or terminal cargo handling equipment for storage on terminal.

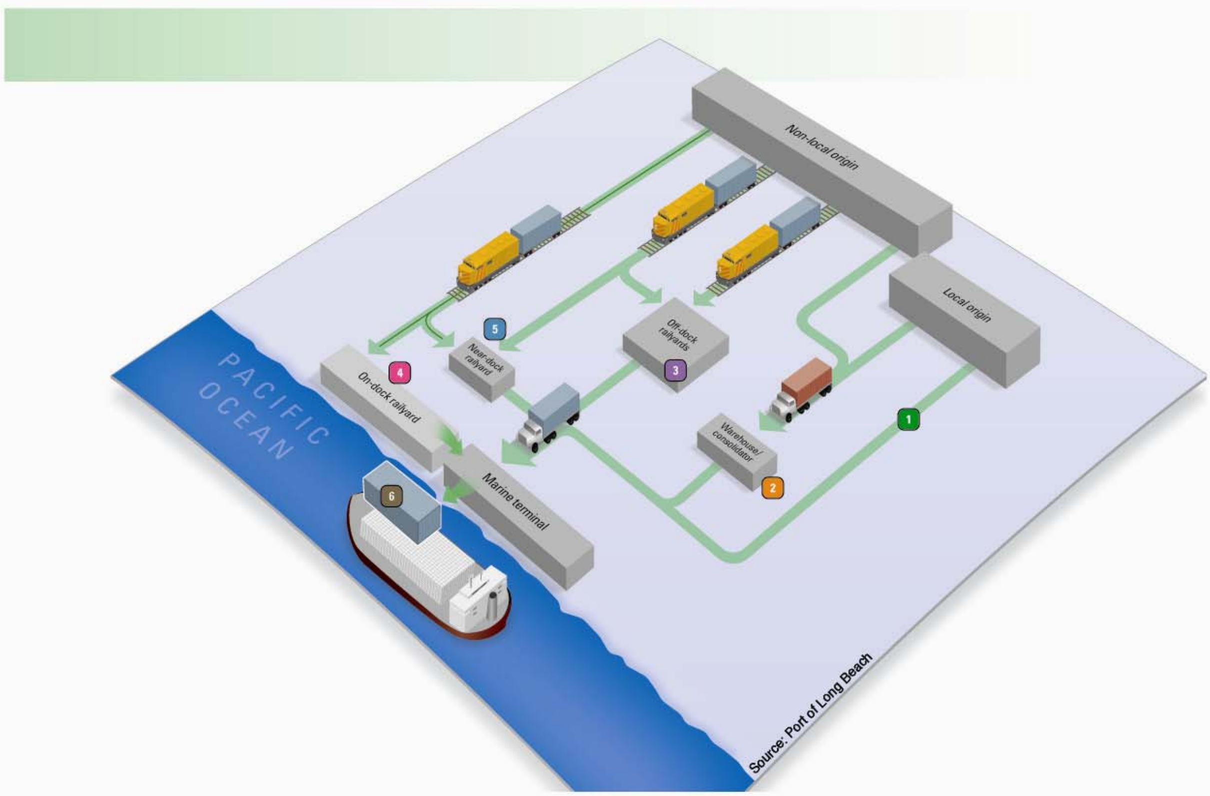
2) Freight forwarder or logistics provider will provide directions to the marine terminal operators and contact a trucking company or train operator to move the container out of the Port.

3) Cargo placed directly on rail using "on-dock" rail (as available).
4) Near-dock rail yards are used for terminals without on-dock rail or if additional rail capacity is needed. Trucks are used to "dray" containers from terminals to railyard.
5) Off-dock railyards are used to coordinate rail deliveries to national destinations. Containers are delivered by truck, then sorted and grouped by final destination. These railyards handle Port cargo as well as domestic cargo form other sources.
6) Shipping containers are often moved initially to a "transload" facility where cargo is unloaded, sorted, and repackaged into larger-sized truck trailers. The cargo is then delivered from the facility to regional distribution centers, local stores, or off-dock railyards.

Export Container Transport

Export container cargo is similar to import containers; however, the flow is in the opposite direction. As with imported cargo, exported cargo may require multiple intermediate stops between its producer/manufacturer of the cargo and the Port. The figure below, presents the steps that are associated with exported container cargo movements.

Figure 1.3: Export Container Transport



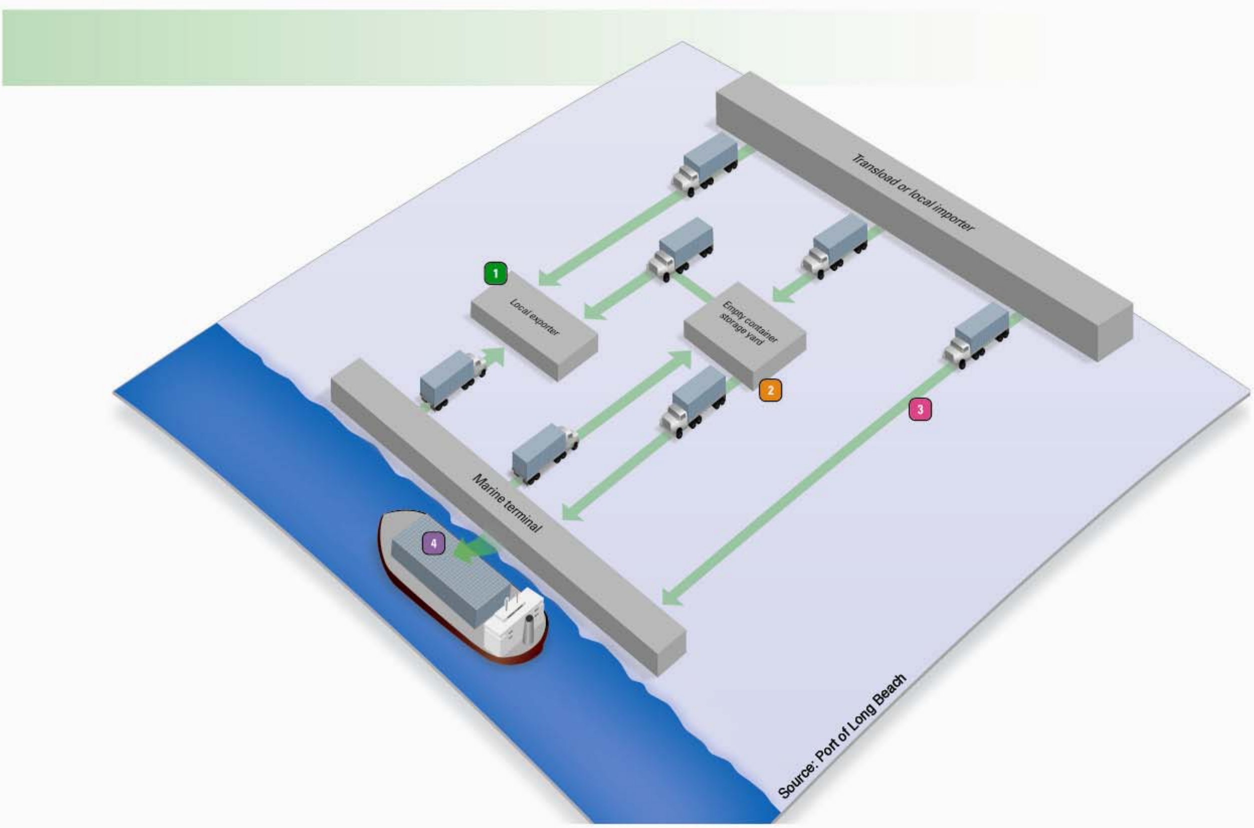
Notes:

1) Local origin direct delivery to the marine terminal from the producer, manufacturer, or exporting company.
2) Local or non-local origin cargo is delivered to a warehouse/consolidator where the cargo may be temporarily stored with other cargo bound for export. Cargo may also be transferred from domestic truck trailers to marine shipping containers.
3) Some non-local origin cargo is shipped by rail are delivered to off-dock railyards where the cargo is placed onto truck for final delivery to marine terminals.
4) Some non-local origin cargo is shipped by rail directly to the marine terminal where it is loaded onto a ship or stored temporarily for the appropriate ship to arrive.
5) Some non-local origin cargo is shipped by rail to near-dock railyards, where the cargo is picked up by truck for a short trip to the marine terminal.
6) Vessel loading of export cargo is conducted after the ship has been unloaded of its import cargo.

Empty Containers

Since the U.S. imports more goods than it exports, many empties are sent overseas to be reused or used for other purposes domestically. Typically, about a third of the containers loaded onto a ship at the San Pedro Bay Ports will be filled with cargo, while about two-thirds will be empty. The figure below, diagrams the movement of empty containers after the delivery of full, imported containers to local businesses and/or transload facilities. Intermodal containers returning to the local area empty are not depicted; they would enter the system at the marine terminal or empty container storage yard.

Figure 1.4: Empty Container Transport



Notes:

1) Delivery to a local exporter who needs to fill empty containers. Direct delivery of containers between importers and exporters is encouraged to reduce the number of truck trips a container takes in the South Coast (also known as a "virtual container yard").
2) Empty containers are delivered to container storage yards from a transload facility or local importer to an empty container storage yard. From the storage yard, containers are moved by truck to the marine terminal for export or to a local exporter to be filled with cargo.
3) Direct delivery from a transload facility or local importer to the marine terminal for export.
4) Empty containers are loaded onto a container ship to be exported and reused overseas.

1.4 Regulatory Measures Addressing Port-Related Activities

Almost all of the emissions at the ports come from five diesel fueled source categories. In addition to ocean-going vessels (OGVs), these are On-Road Heavy-Duty Vehicles (HDVs), Cargo Handling Equipment (CHE), Harbor Craft and rail locomotives. The responsibility for the emissions control of the majority of these sources falls under the jurisdiction of local SCAQMD, state (CARB) or federal (EPA) agencies. Below is a list of recently adopted and proposed regulatory measures that will reduce emissions from the Ports over the next five fiscal years and beyond.

1.4.1 Ocean-Going Vessels

EPA Advance Notice of Proposed Rulemaking for Standards for Marine Diesel Engines Up to 30 liters/cylinder

EPA has published an Advance Notice of Proposed Rulemaking (ANPRM) regarding its plan to propose new emission standards for marine diesel engines up to 30 liters per cylinder displacement. According to the ANPRM, EPA is considering standards modeled after the 2007/2010 highway and Tier 4 non-road diesel engine programs, with an emphasis on achieving large PM emission reductions as early as possible through the use of advanced emission control technology starting as early as 2011. This technology, based on high-efficiency catalytic after treatment, is enabled by the availability of clean diesel fuel with sulfur content capped at 15 ppm. EPA is currently developing the Notice of Proposed Rulemaking (NPRM) for this program.

Emission Standards for Marine Diesel Engines Above 30 l/cyl (Category 3 Engines)

EPA is pursuing two parallel, related actions for emission standards for Category 3 marine diesel engines. (1) EPA is a member of the U.S. delegation that is participation in negotiations at the International Maritime Organization (IMO) with regard to amendments to Annex VI that consider additional NO_x limits for new engines; additional sulfur content limits for marine fuel; methods to reduce PM emissions; potential NO_x and PM limits for existing engines; and potential volatile organic compounds (VOCs) limits for tankers. The Sub-Committee on Bulk Liquids and Gases is expected to make recommendations to the Marine Environment Protection Committee by mid-2007. (2) EPA is planning to develop new national standards for Category 3 marine diesel engines over the next few years, taking into consideration the state of technology that may permit emission reductions and the status of international action for more stringent standards.

Emissions Standard for Marine Propulsion Engines
The IMO adopted limits for NO_x in Annex VI to the International Convention for the Prevention of Pollution from Ships in 1997. These NO_x limits apply to marine engines over 130 kilowatts (kW) installed on vessels built on or after 2000. The NO_x standards are from 17.0 g/kW-hr [for < 130 revolutions per minute (rpm)] to 9.8 grams per kilowatt hour (g/kW-hr) (for <2000 rpm), depending upon the engine speed in rpm. The required number of countries ratified the Annex in May 2004 and it went into force for those countries in May 2005. The Annex has not yet been ratified by the U.S. Engine manufacturers have been certifying engines to the Annex VI NO_x limits since 2000 as the standards are retroactive.

Vessel Speed Reduction (VSR) Program
In May of 2001, a Memorandum of Understanding (MOU) between the POLA, POLB, EPA Region 9, CARB, SCAQMD, the Pacific Merchant Shipping Association (PMSA), and the Marine Exchange of Southern California was signed. This MOU calls for OGVs to voluntarily reduce speed to 12 knots at a distance of 20 nautical miles (nm) from Point Fermin. Reduction in speed demands less power on the main engine, which in turn reduces NO_x emissions and fuel usage.

Low Sulfur Fuel for Marine Auxiliary Engines
In December of 2005, CARB adopted low sulfur fuel requirements for marine auxiliary engines within 24 nm of the California coastline. Starting in January of 2007, it requires use of marine diesel oil (MDO) or marine gas oil (MGO) with sulfur content of equal or less than 0.5% S by weight, followed by use of marine gas oil with sulfur content of equal or less than 0.1 % S in 2010. The use of low sulfur fuel will reduce emissions of NO_x, DPM and oxides of SO_x.

1.4.2 Harbor Craft

Emission Standards for Harbor Craft Engines
EPA has established new engine standards for new "category 1 & 2" diesel engines – engines rated over 50 horsepower (hp) used for propulsion in most harbor craft. These standards are to be phased in between 2004 and 2007 and limit NO_x, hydrocarbon, CO and DPM, but the emissions reductions achieved are modest in the next five years. EPA expects 24% reduction in NO_x and 12% reduction in DPM in 2030 when the harbor craft engine fleet is fully turned over to these new engines.

Low Sulfur Fuel Requirement for Harbor Craft
In 2004, CARB adopted a low sulfur fuel requirement for harbor craft. Starting January 1, 2006 (in SoCAB) harbor craft are required to use on-road diesel fuel (e.g., ultra-low sulfur diesel [ULSD]), which has sulfur content limit of 15 parts per million (ppm) and lower aromatic content. Use of lower sulfur and aromatic fuel will result in NO_x and DPM reduction benefits. In addition, use of low sulfur fuel will facilitate retrofitting of harbor craft with emissions control devices such as diesel particulate filters (DPFs) that have potential to reduce PM by 85%.

DPM and NO_x Emission Reductions from In-Use Harbor Craft
As a part of Diesel Risk Reduction Plan and Goods Movement Plan, CARB staff is proposing a regulation to reduce DPM and NO_x from new and in-use commercial harbor crafts. Under CARB's definition, commercial harbor crafts include tug boats, tow boats, ferries, work boats, crew boats, military vessels and fishing vessels. The goal of this regulation is to achieve reduction in DPM and NO_x by 25% in 2010, 30% in 2015 and 40% in 2020. Currently, CARB staff is soliciting public comments and updating the emissions inventory.

1.4.3 Cargo Handling Equipment

Emissions Standards for Non-Road Diesel Powered Equipment
The EPA's and CARB's Tier 1, Tier 2, Tier 3, and Tier 4 (interim Tier 4 and final) emissions standards for non-road diesel engines require compliance with progressively more stringent standards for hydrocarbon, CO, DPM, and NO_x. Tier 4 standards for non-road diesel powered equipment complement the latest 2007+ on-road heavy-duty engine standards requiring 90 percent reduction in DPM and NO_x when compared against the current level. To meet these standards, engine manufacturers will produce new engines with advanced emissions control technologies similar to those already expected for on-road heavy-duty diesel vehicles. These standards for new engines will be phased in starting with smaller engines in 2008 until all but the very largest diesel engines meet NO_x and PM standards in 2015. Currently, the interim Tier 4 standard includes 90% reduction for PM and a 60% reduction in NO_x.

Cargo Handling Equipment Regulation
In December of 2005 CARB adopted a regulation to reduce emissions from CHE such as yard tractors and forklifts starting in 2007. The regulation calls for the replacement or retrofit of existing engines with engines that use Best Available Control Technology (BACT). Beginning January 1, 2007 the regulation will require that newly purchased, leased, or rented CHE be equipped with either a 2007 or later on-road engine, a Tier 4 off-road engine or the cleanest verified diesel PM emissions control system which reduces DPM by 90% and NO_x by at least 70% for yard tractors. For non-yard tractors, cargo handling equipment currently verified technologies reduced PM by 85%.

1.4.4 Railroad Locomotives

Emissions Standards for New and Remanufactured Locomotives and Locomotive Engines

In 1998, EPA adopted Tier 0 (1973-2001), Tier 1 (2002-2004), and Tier 2 (2005+) emissions standards applicable to newly manufactured and remanufactured railroad locomotives and locomotive engines. These standards require compliance with progressively more stringent standards for emissions of hydrocarbon, CO, NO_x, and DPM. Although the most stringent standard, Tier 2, results in over 40% reduction in NO_x and 60% reduction in DPM compared to Tier 0, full potential of these reductions will not be realized in the next five years because of the long life of diesel locomotive engines.

EPA Advance Notice of Proposed Rulemaking for Locomotives

EPA has published an ANPRM regarding its plan to propose new emission standards for locomotives. According to the ANPRM, EPA is considering standards modeled after the 2007/2010 highway and Tier 4 non-road diesel engine programs, with an emphasis on achieving large PM emission reductions as early as possible through the use of advanced emission control technology starting as early as 2011. This technology, based on high-efficiency catalytic after treatment, is enabled by the availability of clean diesel fuel with sulfur content capped at 15 ppm. EPA is currently developing the NPRM for this program.

Low Sulfur Fuel Requirement for Intrastate Locomotives

In 2004, CARB adopted a low sulfur fuel requirement for intrastate locomotives. Intrastate locomotives are defined as those locomotives that operate at least 90 percent of time within borders of the state, based on hours of operation, miles traveled, or fuel consumption. Mostly applicable to switchers, starting January 1, 2006, statewide, intrastate locomotives are required to use CARB off-road diesel fuel that has a sulfur content limit of 15 ppm sulfur (S) and lower aromatic content. Use of fuel with lower sulfur and lower aromatics will result in NO_x and DPM reductions. In addition, use of low sulfur fuel will facilitate retrofitting of locomotives with emissions control devices such as DPFs that have potential to reduce DPM by 85%.

Statewide 2005 Memorandum of Understanding

In order to accelerate the implementation of Tier 2 engines in SoCAB, CARB and EPA Region 9 entered into an enforceable MOU in 1998 with two major Class 1 freight railroads [Union Pacific (UP) and Burlington Northern Santa Fe (BNSF)] in California. This MOU requires UP and BNSF to concentrate introduction of the Tier 2 locomotives in the SoCAB which will achieve 65% reduction in NO_x by 2010.

In 2005, CARB entered into another MOU with UP and BNSF whereby these two railroads have agreed to phase out non-essential idling and install idling reduction devices, identify and expeditiously repair locomotives that smoke excessively and maximize the use of 15 ppm S fuel.

1.4.5 On-Road Heavy-Duty Vehicles

Emission Standards for New 2007+ On-Road Heavy-Duty Vehicles

In 2001, CARB adopted EPA's stringent emission standards for 2007+ HDV, which will ultimately result in 90% reductions in emissions of NO_x and PM. Per this regulation, HDV engine manufacturers will be meeting a PM standard of 0.01 g/bhp-hr starting in 2007, which is 90% lower than the 2004 PM standard of 0.1 g/bhp-hr. The NO_x standard requires a phase-in of the 0.2 g/bhp-hr NO_x standards between 2007 and 2010. By 2010, all engines have to meet the 0.2 g/bhp-hr NO_x standard, which is over 90% lower than the 2004 NO_x standard of 2.4 g/bhp-hr. It is expected that between 2007 and 2010, on average, manufacturers will be producing HDV engines meeting the PM standard of 0.01 g/bhp-hr and a NO_x standard of 1.2 g/bhp-hr. This latter standard is referred to as the 2007 interim standard.

Heavy-Duty Vehicle On-Board Diagnostics (OBD) Requirement

In 2005, CARB adopted a comprehensive HDV OBD regulation, which ensures that the increasingly stringent HDV emissions standards being phased in are maintained during each vehicle's useful life. The OBD regulation requires manufacturers to install a system in HDVs to monitor virtually every emissions related component of the vehicle.

Ultra-Low Sulfur Diesel (ULSD) Fuel Requirement

In 2003, CARB adopted a regulation requiring that diesel fuel produced or offered for sale in California for use in any on-road or non-road vehicular diesel engine (with the exception of locomotive and marine diesel engines) contain no more than 15 ppm of S by weight, beginning June 2006 statewide. This ULSD fuel is needed in order for retrofit technologies, such as diesel particulate filters, to work successfully.

Reducing Emissions from On-Road Heavy-Duty Diesel Trucks Dedicated to Goods Movement at California Ports

As a part of CARB's emissions reduction plan for ports and goods movement in California, staff of CARB is proposing a control measure to reduce emissions from on-road heavy-duty diesel trucks dedicated to goods movement at California ports. CARB staff is proposing three steps to reduce truck emissions: (1) replace older trucks with cleaner trucks; (2) install verified emissions control devices and; (3) establish emissions criteria for trucks entering the ports. Currently, CARB staff is conducting public meetings to obtain comments from stakeholders and expects to take the final regulation to their board's approval in late 2007.

As stated at the beginning of this section, in addition to these regulations, CARB is pursuing additional regulations that would reduce emissions from port-related equipment sources. These include equipment in the following categories:

- Port trucks (through a fleet rule and incentive program)
- Harbor craft
- Ship main engines (through fuel, engine emissions requirements, and mandatory speed reduction)
- Ship auxiliary engines at dock (through shore-powering, engine controls, or other effective technologies)
- Ship incinerators (banned within 3 miles of the shore)

CARB anticipates completing these rulemaking actions by the end of 2007. The recently adopted CARB regulations (listed in 1.3.1-1.3.5), anticipated CARB rulemakings, and the measures in the Clean Air Action Plan will provide a vital and complementary combination to the overall effort to meet both State and San Pedro Bay Ports air quality improvement goals.

One non-regulatory program that is also helping to significantly reduce emissions from sources including those associated with ports is the Carl Moyer Program. This program is a CARB administered grant program implemented in partnership with local air districts to fund the replacement of older, "dirty" engines or to cover the incremental cost of purchasing cleaner-than-required engines and vehicles. Under this program, owners/operators of mobile emissions sources can apply for incremental funding to reduce emissions. The program is also being expanded to include a fleet modernization component. Emissions source categories at the Ports that have been successful in obtaining Carl Moyer funding includes: heavy-duty vehicles, cargo handling equipment, harbor craft, and rail locomotives. It is important to note that only emission reductions that are surplus to regulatory requirements are eligible for Carl Moyer funding. As regulations are developed which require retrofit or replacement of specific equipment and/or vehicles, those projects will no longer be eligible for funding.

1.5 Scope of Study

The scope of the study is described in terms of the year of activity used as the basis of emissions estimates, the pollutants quantified, the included and excluded source categories and the geographical extent. The purpose of the 2005 Emissions Inventory of Air Emissions (2005 EI) is to develop emission estimates based on activities that occurred in calendar year 2005.

1.5.1 Pollutants

Exhaust emissions of the following pollutants 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)
- Total Organic Gases (TOG)
- Carbon monoxide (CO)

The listed pollutants are criteria pollutants, with the exception of DPM, which is considered a toxic air contaminant. In 1988, the CARB identified DPM as a toxic air contaminant[4].

Organic compound emissions can be reported in various ways depending on the end use of the emissions estimates. Some examples of organic compounds include total hydrocarbon (HC), reactive organic gases (ROG), total organic gases (TOG), and VOCs. CARB defines total organic gases as a means of total hydrocarbon plus oxygenated components such as alcohols and aldehydes that take part in ozone formation reactions. In this study, some of the tables and text may list and discuss hydrocarbons and total organic carbons depending on what is being discussed.

1.5.2 Emission Sources

The 2005 scope includes the same five source categories that were included in the 2001 EI:

- Ocean-Going Vessels
- Harbor Craft
- Cargo Handling Equipment
- Railroad Locomotives
- Heavy-Duty Vehicles

The inventory does not include stationary sources, as these are included in stationary source permitting programs administered by the SCAQMD.

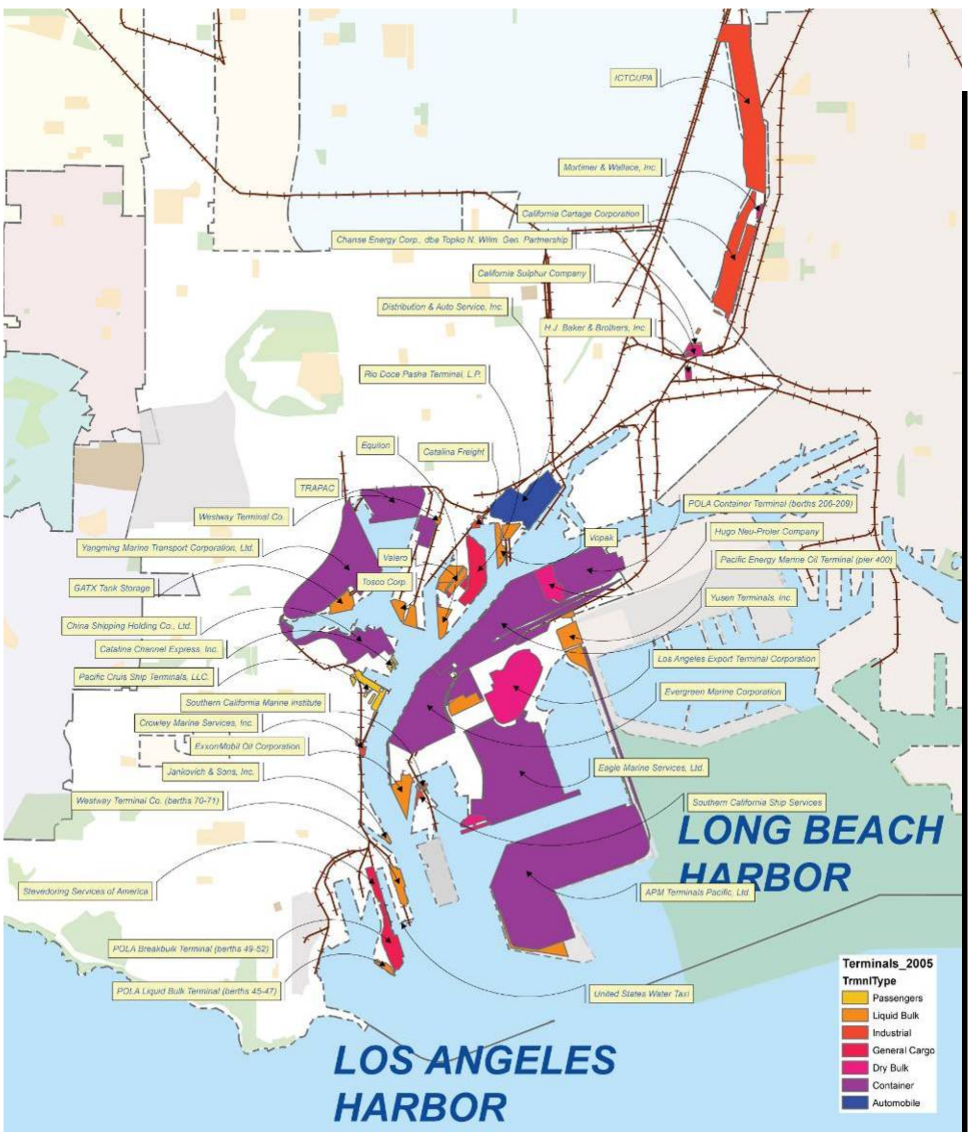
[4] California Environmental Protection Agency Air Resources Board, Resolution 98-35, 27 August 1998. See *http://www.arb.ca.gov/regact/diesltac/res98-35.pdf.*

1.5.3 Geographical Extent

The 2005 EI includes tenant source category emissions that occur on Port-owned land within the Port boundary/district. An overview of the geographical extent is provided below for each of the source categories.

Figure 1.5 shows the land area of active Port terminals in 2005, designated in yellow, including the area to the northeast. This figure illustrates the in-Port area of study. The geographical scope for cargo handling equipment is the terminals and facilities on which they operate.

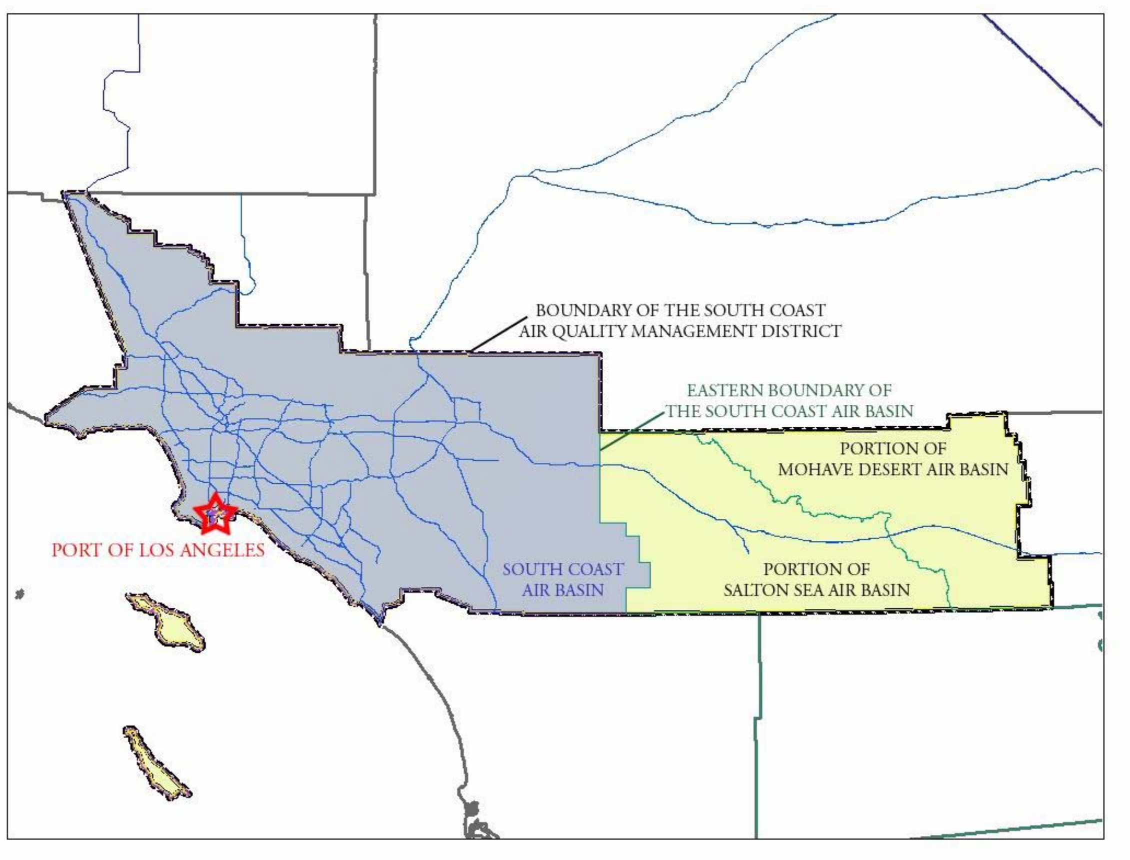
Figure 1.5: 2005 Inventory Port Boundary Area of Study



Emissions from switching and line haul railroad locomotives were estimated for on-dock rail yards, off-dock rail yards, intermodal yards, and the rail lines linking these facilities. For heavy-duty trucks related to the hauling of cargo, emissions from queuing at terminal entry gates, for travel and idling within the terminals, and for queuing at the terminal exit gates have been included. In addition to emissions that occur inside the Port facilities, emissions from locomotives and on-road trucks transporting Port cargo have been estimated for Port-related activity that occurs within the SoCAB boundaries. Emissions are estimated up to first point of rest within the SoCAB or up to the basin boundary.

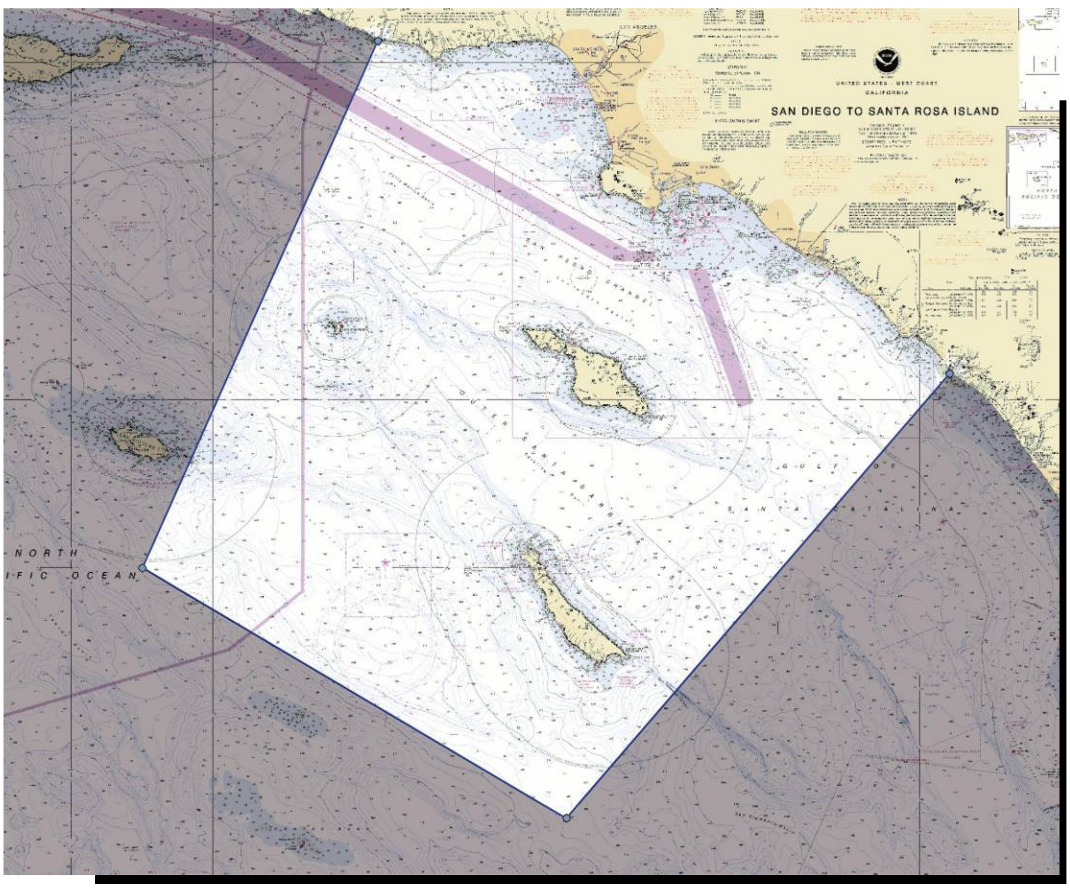
Figure 1.6 shows the SoCAB boundary in grayish blue and the location of the Port. Since both the Port and the Port of Long Beach are interconnected with intermodal transportation linkages, every effort was made to only account for freight movements originating from or having a destination at the Port.

Figure 1.6: South Coast Air Basin Boundary



For marine vessels, OGVs and commercial harbor craft, the geographical extent of the EI is based on the same boundary that was used in previous marine vessel inventories developed for the SCAQMD and in the 2001 Baseline EI. Emissions for OGVs that called at the Port include transit within the study area, maneuvering inside the harbor, and hotelling at berth and at anchorages. Figure 1.7 shows the geographical extent of the study area for marine vessels.

Figure 1.7: OGV and Harbor Craft Inventory Geographical Extent



1.6 General Methodology

The basic approach to developing an activity-based EI is through interactive interviews and conversations with Port tenants, who own, operate and maintain equipment and own or charter vessels. Port tenants and shipping lines play an essential role in the development of an EI by providing the most accurate activity and operational information available. The activity and operational data collected is input into a database for storage. Emissions estimates are developed for each of the various source categories in a manner consistent with the latest estimating methodologies agreed upon by the Port and the participating regulatory agencies. The information gathered, analyzed, and presented in this 2005 EI continues to improve the understanding of the nature and magnitude of Port-related emission sources. Specific data collection and analytical approaches unique to each of the five source categories are summarized below, along with a summary of the key updates to the 2005 EI.

In general, emissions estimates are quantified by multiplying units of activity (estimated using the activity and operational information described above) by an emission factor Emission factors are standard values that express the mass of emissions in terms of a unit of activity. For example, some emission factors are expressed in terms of pounds of emissions (of a particular pollutant) per horsepower-hour. Horsepower-hours are the product of in-use horsepower times hours of operation. Emissions estimates can be calculated, then, by multiplying hours of operation per year (activity data) by in-use horsepower (operational information) by an emission factor (such as pounds per horsepower-hour) to provide a result of emissions in pounds of emissions per year. The actual calculations are often more complex than this example, because such parameters as in-use horsepower must be estimated as part of the calculations. In addition, the emission factors often vary depending on equipment-specific factors such as the model year and the accumulated hours of use.

1.6.1 Ocean-Going Vessels

The basic methodologies for estimating emissions from the various types of ocean-going vessels that call on the Port utilize local activity-based data to the greatest extent possible. This includes call records from the Marine Exchange of Southern California, which tracks and records the movement of all OGVs entering or departing San Pedro Bay. In addition, the Port undertakes a Vessel Boarding Program that focuses on gathering specific vessel characteristics and operational data from ships visiting the Port, to gain the most complete and detailed understanding of how the different types of OGVs arrive, depart, and transit San Pedro Bay and the harbor, as well as how they operate while at dock ("hotelling").

Additional ship-specific OGV data was obtained from Lloyd's Register of Ships (Lloyd's), a marine vessel data system that can provide vessel specific data for virtually every OGV in the world fleet. Lloyd's data was also used to develop profiles for parameters that are not known for every ship. The general vessel classifications included in the 2005 EI include the following.

- Automobile carriers
- Bulk carriers
- Containerships
- Cruise ships
- General cargo ships
- Ocean-going tugboats
- Refrigerated vessels
- Roll-on roll-off ships
- Tankers

Emission factors were developed for different types of OGV engines by review of the literature and discussion/coordination with the regulatory agencies. Emissions were calculated by multiplying the emission factors by vessel-specific activity parameters such as in-use horsepower and hours of operation on a per engine basis. Numerous calculations were made for each port visit to adequately characterize the complicated activities of OGVs; (e.g., separate calculations were made for vessel transit, maneuvering, and hotelling activities for propulsion, auxiliary engines and auxiliary boilers). The results of all the calculations were summed to produce the overall emission estimates.

The emission estimates presented in the 2005 EI include the effects of the following emission reduction measures in place in 2005.

- The vessel speed reduction (VSR) program requiring 12 knots during transiting outside the harbor
- The use of AMP at China Shipping's Berth 100
- Switching to a lower sulfur fuel near the coast or at berth on a voluntary basis by various shipping lines
- Newer vessels calling at the Port with cleaner and more fuel-efficient engines that meet or exceed standards set by the IMO
- New technologies added to vessels that reduce emissions such as slide fuel valves

1.6.2 Harbor Craft

Harbor craft operators whose vessels work within Port waters were interviewed to update the inventory of harbor craft developed for the 2001 Baseline EI. The harbor craft are separated into the following categories:

- Assist tugboat
- Towboats and push boats
- Ferries
- Excursion vessels
- Crew boats
- Work boats
- Government vessels
- Commercial fishing vessels
- Recreational vessels

Emission factors were developed for different types of harbor craft engines by review of the literature and discussion/coordination with the regulatory agencies. Emissions were calculated by multiplying the emission factors by the appropriate measure of activity (such as annual hours of operation) on an engine by engine basis for each vessel included in the inventory. The emission reductions accounted for in this 2005 EI are the vessels that were replaced as of 2005, which make up approximately one third of all the engines inventoried; and vessels use lower sulfur fuel in 2005.

1.6.3 Cargo Handling Equipment

CHE consists of various types of equipment and vehicles that fall within the off-road designation and are used to move cargo within terminals and other off-road areas. The emission estimates for this group followed the OFFROAD[5] model methodology, which has been developed by the CARB to estimate emissions from off-road equipment fleets. Equipment operators and owners were interviewed and the equipment lists with detailed specifications developed for the 2001 EI and other uses were updated for 2005. Significant improvements were seen for the 2005 CHE inventory. In 2005, newer pieces of equipment and various emission reduction technologies and programs were in place at the various terminals.

[5] California Air Resources Board, OFFROAD, 2003. See *http://www.arb.ca.gov/msei/off-road/off-road.htm.*

1.6.4 Railroad Locomotives

Railroad operations are typically described in terms of two different types of operations, line haul and switching. Line haul operations involve long-distance transportation of a whole (unit) train between the Port and points across the country, whereas switching is the local movement of individual railcars or train segments to prepare them for line haul or to distribute them to destination terminals upon their arrival in port. Different companies conduct switching (Pacific Harbor Line) and line haul (Burlington Northern Santa Fe, Union Pacific) operations within the port. The line haul companies also operate switching locomotives at off-port rail yards.

The on-port switching company operates a dedicated fleet of locomotives, while the line haul locomotives that service the port are part of a nation-wide fleet– meaning that individual locomotives are not assigned specifically to port or South Coast Air basin service. Therefore, the types of information available for these two types of activity differs–for the on-port switching locomotives, information on each locomotive and its activity (e.g., fuel use and throttle notch setting) can be used to estimate emissions, whereas for the line haul locomotives the information is more general (e.g., in terms of fuel use per ton of cargo and total tons of cargo carried). The EPA has published emissions information for switching and line haul locomotive operations in both throttle notch and fuel consumption modes, so this information was used to estimate emissions and to cross-check between the estimating methods. Emission reductions accounted for in the 2005 emission estimates include the use of emulsified fuel in one on-port switching locomotive.

1.6.5 Heavy-Duty Vehicles

Heavy-duty on-road vehicles transport cargo between the port and off-port locations such as rail yards, warehouses, and distribution centers. To develop emission estimates, truck activities have been evaluated as having three components:

- On-terminal operations, which include waiting for terminal entry, transiting the terminal to drop off and/or pick up cargo, and departing the terminals.
- Off-terminal Port operations, consisting of travel on public roads within the Port jurisdictional boundaries.
- On-road operations outside the Port boundaries but within the SoCAB. This includes travel within the boundaries of the adjacent Port of Long Beach, because the routes many trucks take run through both ports on the way to and from Port terminals.

For estimating on-road HDV emissions, activity information was developed by a traffic consultant using the trip generation and travel demand models that were used in the 2001 Baseline EI and in previous Port traffic studies[6]. For estimating on-terminal HDV emissions, terminal operators were interviewed with regards to on-terminal traffic patterns, including time spent waiting at the entry gate, time and distance on terminal while dropping off and/or picking up cargo, and time spent waiting at exit gates. A Port-specific HDV model year distribution was developed by the Port by querying about 35,000 unique license plate numbers obtained from local terminals against the California Department of Motor Vehicles (DMV) registration database.

Emissions from HDVs were estimated by multiplying the speed-specific emission factor derived from CARB's emission factor model EMFAC 2007 by the distance parameters established for the terminals (on-terminal emissions) or road segments (on-road emissions). On-terminal idling emissions were estimated by multiplying the EMFAC idling emission factor by estimated idling times.

1.7 Report Organization

This report presents the 2005 emissions and the methodologies used for each category in each of the following sections:

- Section 2 discusses ocean going vessels
- Section 3 discusses harbor craft
- Section 4 discusses cargo handling equipment
- Section 5 discusses locomotives
- Section 6 discusses heavy-duty vehicles
- Section 7 discusses findings and results
- Section 8 compares 2005 emissions to adjusted 2001 emissions
- Section 9 discusses limitations, strengths and recommendations

The report also includes:

- Appendix A includes OGV input
- Appendix B includes harbor craft input
- Appendix C includes CHE input
- Appendix D includes rail input
- Appendix E includes HDV input
- Appendix F includes the adjustments to 2001 OGV Emissions
- Appendix G includes validation support for Section 8

[6] Meyer, Mohaddes Associates, Inc., June 2001. Ports of Long Beach/Los Angeles Transportation Study, and Meyer, Mohaddes Associates, Inc., April 2004. Port of Los Angeles Baseline Transportation Study.

SECTION 2 OCEAN-GOING VESSELS

This section presents in detail estimates of emissions from OGVs calling at the Port in 2005, whether inbound from the open ocean or transiting from the neighboring POLB. OGVs calling only at the POLB or bypassing both ports without physically stopping at a POLA dock have not been included. Harbor vessels, including tugboats, excursion vessels, and other workboats, are discussed in Section 3. This section includes the geographical delineation of the emissions inventory area, the vessel types and characteristics of ships that called on the Port, data and information sources used to estimate activity and emissions, the emission estimation methodology, and emission estimates.

Section 2 is organized as follows:

- Section 2.1 presents the geographical delineation
- Section 2.2 describes the vessel types
- Section 2.3 discusses data acquisition
- Section 2.4 describes vessel activity
- Section 2.5 discusses the emission estimation methodology
- Section 2.6 presents the emission estimates
- Section 2.7 presents data facts and findings

2.1 Geographical Delineation

The geographical extent of the emissions inventory for marine vessels is the boundary for the (SoCAB). The portion of the study area outside the Port's breakwater is four-sided, and geographically defined by the following:

- The northwest corner is located where the Ventura County and Los Angeles County lines intersect the Pacific Ocean [34°02'42.4" north (N) latitude by 118°56'41.2" west (W) longitude]
- The southwest corner is located over the water, just south of the Territorial Sea boundary, south of San Nicolas Island (33°00'00.0" N latitude by 119°30'00.0" W longitude)
- The southeast corner is located over the water, south of the Territorial Sea, south of San Clemente Island (32°30'00.0" N latitude by 118°30'00.0" W longitude)
- The northeast corner is located where the Orange County and San Diego County lines intersect the Pacific Ocean (33°23'12.7" N latitude by 117°35'46.4" W longitude)

Figure 2.1 shows this portion of the study area as well as the major shipping routes. The Marine Exchange of Southern California (MarEx) ship routes were used along with their estimates of travel distances offshore from Point Fermin. These trip segments were organized into four routes (each comprised of both inbound and outbound traffic) reflecting north, east (El Segundo), west, and south routes, as designated by the MarEx[7]:

- North: The predominant trade route for OGVs in terms of ship calls, involving coastwise trade to the U.S. continental ports as far as Seattle (Straits of San Juan de Fuca) but also to Alaska and the Far East (Great Circle Route).
- South: The second most traveled direction for ship calls, serving not only Mexico and other ports but also traffic through the Panama Canal.
- West: Mainly involved with travel to Hawaii, but may include some towboat trips to the Channel Islands.
- East: This is a short trip between the Port and El Segundo, the location of a petrochemical complex to the north which has an extensive anchorage area; it never has an "at-sea" trip leg. Note that the "east" trip is a slight misnomer because it is really towards the north, but was so designated for purposes of distinguishing it from the other routes.

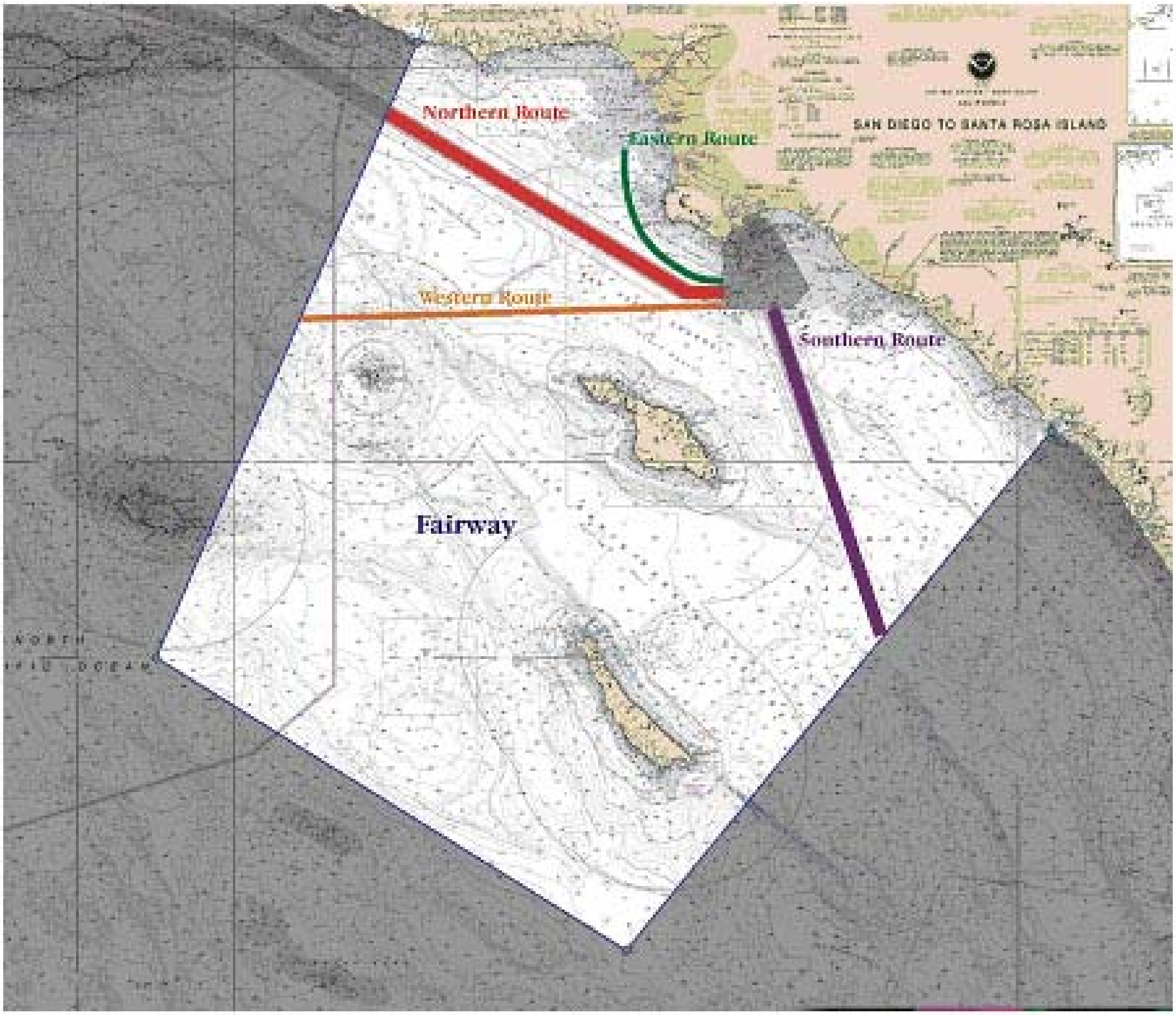
The study area is divided into several zones that represent different operational modes that impact vessel characteristics and emissions estimates. These zones are:

- the fairway,
- the precautionary zone, and
- the harbor.

The fairway extends from the SoCAB boundary to the precautionary zone. In this area, the vessels transition between sea speed and the voluntary 12 knots for the VSR. Also, those vessels that switch fuel 24 nm outside the Port area do so. The fairway is the white area in Figure 2.1.

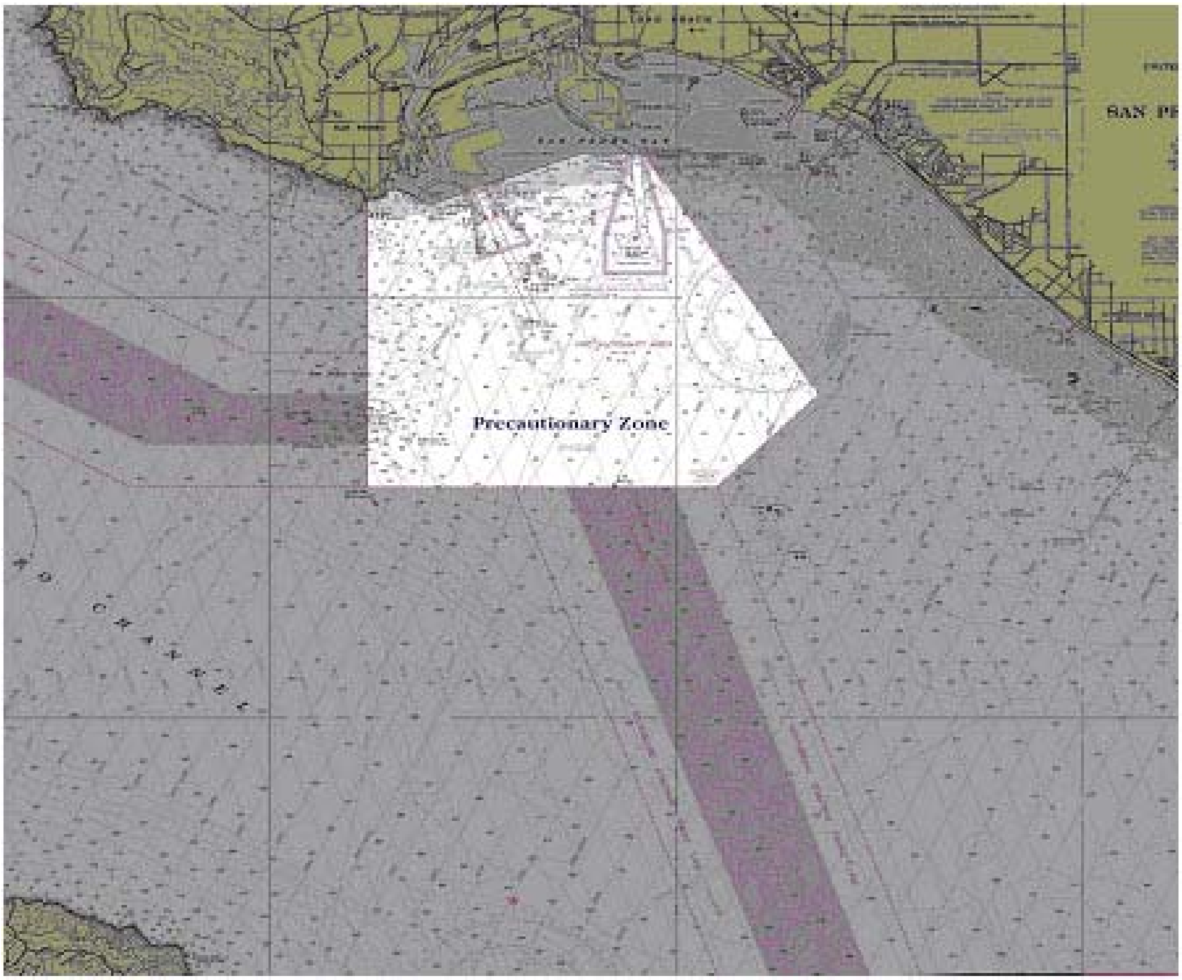
[7] Marine Exchange of California Vessel Tracking Service. See: *http://www.mxsocal.org/vessel-traffic-service.aspx*.

Figure 2.1: Geographical Extent, Fairway and Major Shipping Routes



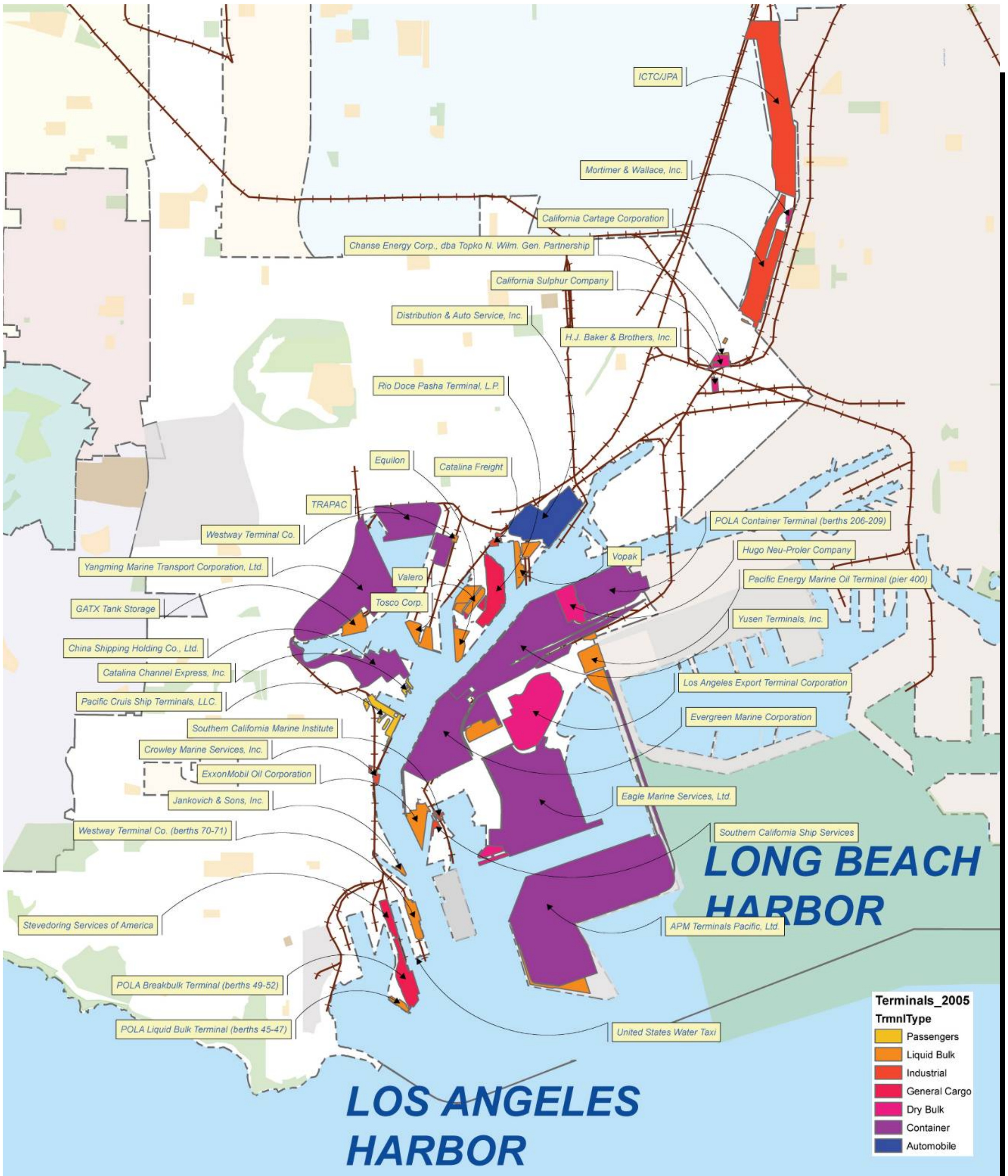
The precautionary zone (PZ) is a designated area where ships are preparing to enter or exit a port. In this zone the pilots are picked up or dropped off. The precautionary zone is the small grey area in Figure 2.1 and can be seen in greater detail in Figure 2.2.

Figure 2.2: Precautionary Zone



The harbor is located within the breakwater and is characterized by the slowest vessel speeds. In the harbor, the vessels may be maneuvering to dock or undock or they may be hotelling while the cargo is loaded and/or unloaded. Figure 2.3 shows the port's terminals.

Figure 2.3: Port of Los Angeles Terminals



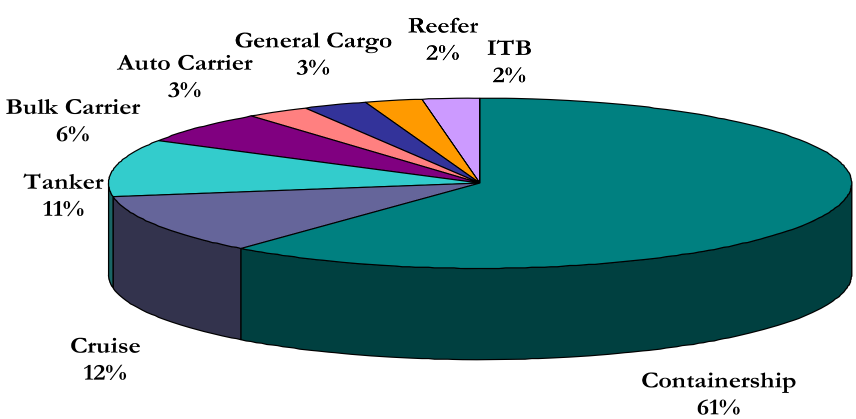
2.2 Vessel Descriptions

Ocean-going vessels are categorized by the following main vessel types for purposes of this EI:

- Auto Carrier
- Bulk Carrier
- Containership
- Passenger Cruise vessel
- General Cargo
- Ocean-going tugboat
- Miscellaneous vessel
- Refrigerated vessel (Reefer)
- Roll-on roll-off vessel (RoRo)
- Tanker

For this study, an inbound call is when the vessel first enters the port area under its jurisdiction. Since anchorages are used by vessels calling at either the Port of Los Angeles and Long Beach, if the vessel first arrives to anchorage, the next port or terminal would determine if it is a Port of Los Angeles or Port of Long Beach inbound call. Ship calls and movements are discussed in greater detail in Subsection 2.4. Based on 2005 Marine Exchange data, there were 2,341 inbound calls to the port in 2005. Figure 2.4 shows the percentage of inbound calls by vessel type. Containerships made the majority of the (61%) of the inbound calls; followed by cruise ships (12%), tankers (11%), and bulk carriers (6%). Auto carriers, RoRo, reefers, miscellaneous vessels, ocean-going vessels, and general cargo made the last 10% of the inbound calls. Miscellaneous and RoRos are not shown in the figure because their percentage of calls was less than 0.3%. There were only 3 miscellaneous vessels for the Port of Los Angeles.

Figure 2.4: Distribution of Vessel Types by Inbound Calls



2.2.1 Auto Carriers

Transportation of imported vehicles is the primary use of the auto carrier, although a few domestic vehicles are exported overseas. Auto carriers are very similar in design to a RoRo (discussed below) because they have drivable ramps. Both can have substantial ventilation systems so as to prevent vehicle fuel vapors from pooling in the lower decks, which could present a major risk for explosion or fire. Auto carriers are typically configured with direct drive propulsion engines and separate auxiliary engines to supply electrical needs. Figure 2.5 presents a typical car carrier.

Figure 2.5: Auto Carrier

2.2.2 Bulk Carriers

Bulk carriers have open holds with giant hatches to carry dry goods that can be loaded from a conveyor belt and chute, such as coal, coke, salt, sugar, cement, gypsum, lime mix, agricultural products, alumina, and other similar fine-grained commodities that can be poured, scooped or augured. Bulk carriers span the range between small "tramp" ships and the Panamax (approximately 50,000+ DWT) and Capesize (approximately 140,000+ DWT) bulk carriers that can also haul containers as well as general cargo. Bulk carriers are typically configured with direct drive propulsion engines and separate auxiliary engines to supply electrical needs. Figure 2.6 presents a typical bulk carrier.

Figure 2.6: Bulk Carrier

2.2.3 Containerships

Ships that carry 20- and 40-foot containers on their decks are known as containerships and are the most frequent caller of OGVs at the Port. These vessels are primarily used by shipping lines to transport retail goods across the Pacific Rim, mostly originating in Asia. These ships are some of the largest ships that call at the Port, ranging from approximately 8,300 DWT to 101,900 DWT. Because of their efficiency as a mode of ocean transportation, containership calls will continue to grow at the Port. Cargo types include almost everything that can be made to fit in the 20- or 40-foot containers. The container business operates on tight margins and high volume so OGVs need to be fast and efficient to compete in the market place, thus the trend to newer, larger containerships. The container vessels have been divided into eight subtypes based on their TEU capacity, between 1,000 and 8,000+ TEU. Typical containerships are shown in Figures 2.7 and 2.8.

Figure 2.7: Containership

Figure 2.8: Containership

2.2.4 Passenger Cruise Vessels

There is a significant passenger cruise service operating from the Port. These boats are known not only for their speed but also their heavy auxiliary engine demands, since they often provide heating and electricity for over a thousand people at times. Cruise vessels vary significantly in overall size, onboard auxiliary power, engine configuration, and frequency of calls. Typically, newer cruise ships work on a diesel-electric configuration with some using turbines to generate electricity, while older cruise ships use direct drive and auxiliary engines. A typical passenger cruise ship is presented in Figure 2.9.

Figure 2.9: Cruise Vessels

2.2.5 General Cargo vessels

Like the bulk carriers, general cargo ships tend to be slower. They can carry diverse cargoes such as steel, palletized goods, turbines, a few containers (usually on the top deck), large excavating machinery, and other heavy loads. Most general cargo ships have electric boom cranes for loading and unloading. General cargo ships are typically configured with direct drive propulsion engines and separate auxiliary engines to supply electrical needs. A typical general cargo ship is shown in Figure 2.10.

Figure 2.10: General Cargo Ship

2.2.6 Ocean-going Tugboats

Ocean-going towboats and tugboats, which are considered harbor vessels, are not included in this section and are discussed in Section 3 of this report. But, integrated tug and barge (ITB) and articulated tug and barge (ATB) vessels are included in the ocean going vessel inventory since the ITB and ATBs are seen as a specialized single vessel. The barge stern is notched to accept a special tug which can be rigidly connected to the barge, forming a single vessel. The barge is built in the form of a normal ships hull. The tugboats, like all other ocean going tugs, are typically configured with two propulsion engines and separate auxiliary engines to supply electrical needs. ITB and ATB may have larger horsepower in their engines than the typical ocean-going tug. Figure 2.11 shows an integrated tug and barge, which are included in this section.

Figure 2.11: Integrated Tug and Barge

2.2.7 Refrigerated Vessels

Refrigerated vessels, often called "reefers," are dominated by fruit carriers, which require cooling to prevent cargo spoilage. These are similar to bulk or general cargo carriers, but these ships typically carry fruits, vegetables, meats, and other perishable cargos. Most of the cargo is stored below deck on pallets or transported inside refrigerated containers that are placed on top of the closed cargo hold. Reefers are typically configured with direct drive propulsion engines and separate auxiliary engines to supply electrical needs for the vessel and the refrigeration units. A typical refrigerated vessel is presented in Figure 2.12.

Figure 2.12: Refrigerated Vessel

2.2.8 Roll On – Roll Off Vessels (RoRo)

These OGVs are similar to the automobile carrier but can accommodate larger wheeled equipment – they are a favorite for use by the military when transporting large, heavy military equipment. RoRo ships are typically configured with direct drive propulsion engines and separate auxiliary engines to supply electrical needs. A typical RoRo vessel is presented in Figure 2.13.

Figure 2.13: Roll On – Roll Off Vessel

2.2.9 Tanker Vessels

The tanker activity at the Port is comprised mainly of crude oil tankers, as well as a few chemical tankers. Tankers range from approximately 10,000 deadweight tonnage (DWT) to over 100,000 DWTs (very large cargo ship, or VLCS). A limited number of petroleum bulk and refinery terminals are located in the Port. In addition, there is some significant tanker trade with the Port of El Segundo where another petrochemical complex is located. Tankers are typically configured with direct drive propulsion engines and separate auxiliary engines to supply electrical needs. The tankers have been divided into subcategories of tanker (general), chemical and crude tankers. The various types of tankers that do not fall into the crude or chemical tanker category are included in the general tanker category. These tankers may include:

- Ore/Bulk/Oil carriers
- Oil product tankers
- Tankers with specialty products such as molasses and tallow

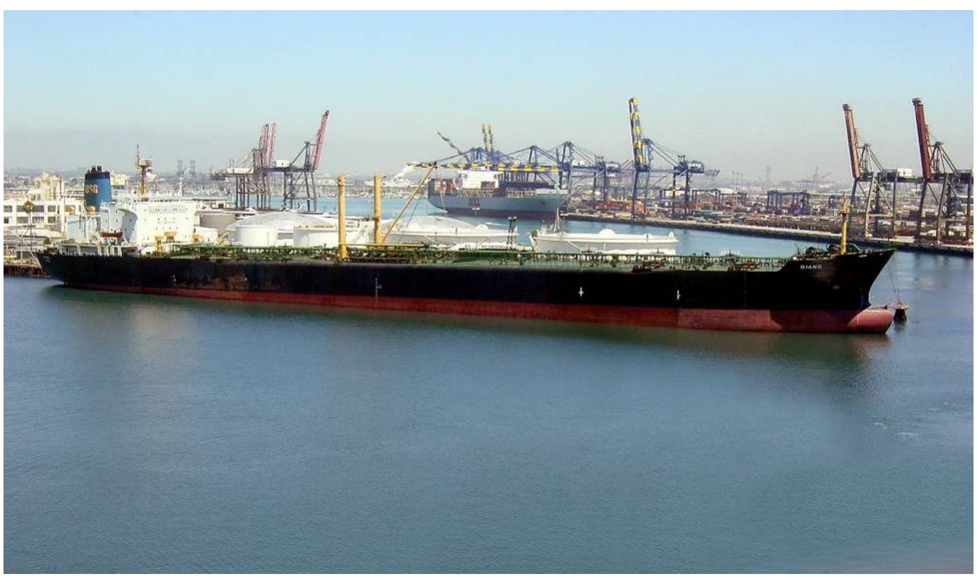
The crude tankers fall into several size categories depending on their dimensions. The following are crude tankers categories and their typical DWT.

- Handyboat 400 to 60,000 tons
- Panamax 60,000 to 80,000 tons
- Aframax 80,000 to 120,000 tons
- Suezmax 120,000 to 200,000 tons
- VLCC 200,000 to 300,000
- ULCC 300,000 tons

Very Large Crude Carriers (VLCC) and Ultra Large Crude Carriers (ULCC) are the large ships that cannot fit through most canals and hence they are also known as "Capesize" ships. Figure 2.14 presents a typical chemical tanker and Figure 2.15 presents a typical crude tanker.

Figure 2.14: Chemical Tanker

Figure 2.15: Crude Tanker



2.3 Data and Information Acquisition

Various sources of data and operational knowledge about the Port of Los Angeles marine activities were used to compile the data necessary to prepare emission estimates. These sources included:

- Marine Exchange of Southern California
- Vessel Speed Reduction Program speed data
- Los Angeles Pilot Service
- Lloyd's Register of Ships
- Port Vessel Boarding Program data
- Nautical charts and maps

Each data source is detailed in the following subsections.

2.3.1 Marine Exchange of Southern California

The Marine Exchange of Southern California[8] operates the Vessel Traffic Service (VTS) in cooperation with the U.S. Coast Guard (USCG), the Ports of Los Angeles and Long Beach, and the State of California. The VTS was established in 1994 to provide traffic safety, traffic monitoring and security functions for the two ports, and is the first private/public VTS partnership in the country that is funded by industry. MarEx requires ships to report their activities to the VTS upon arrival and departure and tracks ship route taken.

The MarEx data that was evaluated in developing the emission estimates includes vessel names, arrival and departure dates and times, transit speeds and directions, berth of destination, and other information. This data source was the primary basis for establishing:

- vessel types
- estimated hotelling time
- distribution of arrival and departure travel directions by route
- number of ship calls
- names of vessels
- vessel origination and destination

[8] The Marine Exchange of Southern California Vessel Traffic Service can be accessed at: *http://www.mxsocal.org.*

2.3.2 Vessel Speed Reduction Program data

MarEx monitors OGV speeds over the four routes into and out of the Port as part of a VSR program that was started in May 2001. For the 2005 EI, the actual speeds in the fairway are used and thus the full effect of the VSR program is taken into consideration for the fairway speeds.

2.3.3 Los Angeles Pilot Service

The Los Angeles Pilot Service maintain an automated database which documents the time when the pilot took control of the ship's bridge and when the pilot relinquished control back to the ship's officers. The date and time data was used to estimate transit time profiles for harbor maneuvering for the following modes:

- Inbound from sea
- Outbound to sea
- Anchorage shifts
- Other shifts (e.g., inter-port and intra-port shifts)

The profiles are defined as average trip times for each of these modes, in addition to ship type and terminal. The various modes are discussed in greater detail in section 2.4.

2.3.4 Lloyd's Register of Ships & American Bureau of Shipping

Lloyd's[9] is considered to be the leading resource for obtaining ship characteristics such as tonnage, speed, engine power plant configuration, age, and other parameters. The company is known as a classification society for the purpose of insuring many of the vessels on an international basis; for the vessels classified by Lloyd's the data are quite complete, however, for other ships using a different insurance certification authority, the data are less complete and/or accurate. Lloyd's was used for obtaining information such as main and auxiliary engine power and vessel speed ratings because it is the best available source of such information. The survey results from the Port of Los Angeles Vessel Boarding Program suggest that the current Lloyd's data are fairly accurate for propulsion horsepower and vessel speed.

The company Fairplay has the rights to Lloyd's ship data and sells the software containing information on commercial marine vessels, which include ocean-going vessels. The software allows users to download the IMO number along with other ship information. The version used in this report was an October 2004 edition updated in January 2005. The worldwide fleet of OGVs was assembled in a common database and a query was completed to match with the MarEx vessel data.

[9] Lloyd's – Fairplay, Ltd., *Lloyd's Register of Ships*, Version 2.10 (January 2003). See: *http://www.lr.org/code/home.htm.*

There were a high percentage of matches, over 95%, between the Lloyd's data and MarEx data.

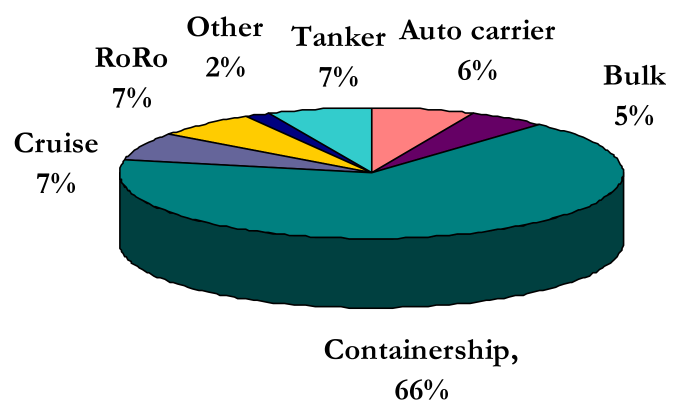
Another source of ship data that was used to a minimal extent for U.S. flagged domestic vessels, including the integrated tug barges (ITB and ATB), was the American Bureau of Shipping (ABS), a major classification society. Data obtained included engine information for ocean-going tugboats such as horsepower.

2.3.5 Vessel Boarding Program Survey data

The Vessel Boarding Program (VBP) was an in-depth survey of OGVs during which surveyors actually rode on the ship and interviewed the ship's executive and engineering staff, usually the Captain and Chief Engineer. For the 2005 inventory, the boardings were mainly done in conjunction with the Port of Long Beach since ninety six percent of vessels calls are shared by the two Ports. Data collected from a similar effort in the Puget Sound of Washington State was also shared, as some vessels that call on the Ports of Long Beach and Los Angeles also call on ports in the Puget Sound.

Figure 2.16 presents the percent of vessels by vessel type for the vessels boarded at the Ports of Los Angeles and Long Beach in 2005 and 2006.

Figure 2.16: Percent of Vessels Boarded in 2005-2006



At both ports, there were a total of 71 vessel boardings on 60 vessels for 30 shipping lines, of which the Port of Los Angeles boardings alone accounted for 42 boardings on 33 vessels for 17 shipping lines.

Table 2.1 summarizes the Port of Los Angeles vessel boarding program statistics.

Table 2.1: Port of Los Angeles Vessel Boarding Program Statistics

Boarding Statistics
42 boardings
9 arrivals
27 at berths
6 departures
33 vessels
17 shipping lines

One way to maximize data collected from vessel boardings is to apply data to known sister ships. Sister ships are vessels that are in the same class and have identical engine parameters. Shipping lines may order several vessels of the same vessel class at the same time, therefore "sister ships" have the same engine specifications and vessel characteristics. During vessel boarding, vessel captains were asked if there were any sister ships and if so, vessel names were noted to later see if they matched with vessels calling at the Port.

In addition to the vessel data gathered through the Vessel Boarding Program, several companies provided main and auxiliary engine data on their fleet by submitting the information electronically. Table 2.2 presents the source of the data for the almost 300 vessels that the Port had access to vessel data. Many of the vessels boarded in Puget Sound or prior to 2003 or before did not necessarily make a call in to the Port of Los Angeles in 2005 and therefore not all of the 200+ data listed below could be used.

Table 2.2: Vessel Boarding Programs Data

Number of Vessels	Program
58	Ports of Los Angeles and Long Beach VBP (2005 – 2006)
80	Vessel Fleet Data Provided (2003-2006)
35	Sister Vessel Specifications Provided
32	Puget Sound Boarding Program (2006)
65	Port of Los Angeles Boarding Program (2001 - 2003)
270	**Vessels Total**

The following VBP survey data was used specifically for emission estimation methodology in this study:

- Main engine power
- Auxiliary engine power
- Auxiliary engine load
- Boiler fuel consumption
- Vessels that switched fuels
- Emission reduction technologies such as slide valves

The specific values used for emission estimation methodology are discussed in subsection 2.5. Other data collected, such as time in mode, most predominant engine make and model, and other findings are summarized in subsection 2.7.

It should be noted that for main engine data, the match with Lloyd's and ABS data was greater than 98%, so defaults for main engine power were only used for 2% of the vessels and if actual VBP data was available, it was used for that vessel.

Auxiliary Engine Data

Due to the fact that auxiliary engine information is usually not provided to Lloyd's by vessel owners since it is not required by IMO or the classification societies, Lloyd's contains minimal auxiliary engine information. For the 2005 vessels that called at the Port, 12% of the discrete vessels had matching auxiliary engine information found in Lloyd's data and an additional 10% of the data came from the information gathered by vessel boardings. Table 2.3 provides a summary of the count of auxiliary engine data used by vessel type.

Table 2.3: Auxiliary Engine Information Used from VBP and Lloyd's Data

Vessel Type	VBP	Sister Ships	LLoyds	Default	Total
Auto Carrier	1	0	0	29	30
Bulk - General	0	0	13	142	155
Bulk - Heavy Load	0	0	2	0	2
Bulk Wood Chips	0	0	0	3	3
Container - 1000	6	0	1	22	29
Container - 2000	2	0	2	38	42
Container - 3000	8	2	3	32	45
Container - 4000	23	11	2	37	73
Container - 5000	3	4	0	29	36
Container - 6000	2	4	4	7	17
Container - 7000	9	0	1	2	12
Container - 8000	0	0	0	2	2
Cruise	1	0	10	14	25
General Cargo	1	0	6	42	49
Ocean Tugs	0	0	9	0	9
Miscellaneous	0	0	0	4	4
Reefer	1	2	6	28	37
RoRo	0	0	0	3	3
Tanker - General	0	0	11	48	59
Tanker - Chemical	0	0	2	33	35
Tanker - Crude - Aframax	0	0	1	4	5
Tanker - Crude - Handyboat	0	0	5	14	19
Tanker - Crude - Panamax	0	0	5	8	13
Tanker - Oil Products	0	0	6	51	57
Total	**57**	**23**	**89**	**592**	**761**
Percentage of total	**7%**	**3%**	**12%**	**78%**	**100%**

2.4 Vessel Activity

Vessel activity is defined as the number of ship trips by trip type and segment. These trips are then processed so as to define time in mode, where a mode is an engine type, and geographical segment. The purpose of this step is to estimate power demand for that mode of operation and multiply it by the amount of time spent in that particular mode, which estimates available power (e.g., kilowatt-hours, kW-hrs). Unlike previous inventories in which ship trips were aggregated by average power and time, a vessel-by-vessel analysis was conducted in this study. The only need for average power or time-in-mode was for vessels that lacked data for those fields. Vessel activity was drawn from three sources:

- MarEx trip tables which define arrivals, departures, and shifts
- MarEx speed tables which define at-sea speeds for the VSR Program
- Los Angeles Pilot Services data which provide transit times for harbor maneuvering

Before merging the data, the column headings were checked and date/time stamps were put into a standard format. Pre-processing also involved creation of a new MarEx variable to estimate elapsed time for the purposes of estimating hotelling.

There are a variety of definitions for the term ship call. The basic definition of a ship call is an arrival from the sea followed by loading and unloading at the dock (hotelling) and then a departure to sea. This study includes anchorage calls associated with the Port and thus may not completely match the Port statistics on ship calls for 2005. For example, if a ship arrived at an anchorage, its associated port would be the next port; if a ship was departing from an anchorage, the associated port would be the last port of call.

While many vessels make only one arrival and departure at a time, some ships make multiple terminal calls within a port. There are three broad categories of shifts:

- Intra-port shifts– movements within a port from one berth to another.
- Inter-port shifts– movements between adjacent ports. This is a common occurrence in co-located ports such as Los Angeles and Long Beach.
- Anchorage shifts– movements between a terminal and anchorage. One example is: a vessel went to a terminal, did a partial load, went to anchorage, and then came back to the terminal to complete loading.

To assist with preparation of the marine emissions inventory, all shifts were grouped together, since they do not have an "at-sea" component as with arrivals and departures. Ship movements are tracked as to:

- Arrivals (inbound trip)
- Departures (outbound trip)
- Shifts (inter-port, intra-port, and anchorage shifts)
- Total movements (sum of all the above)

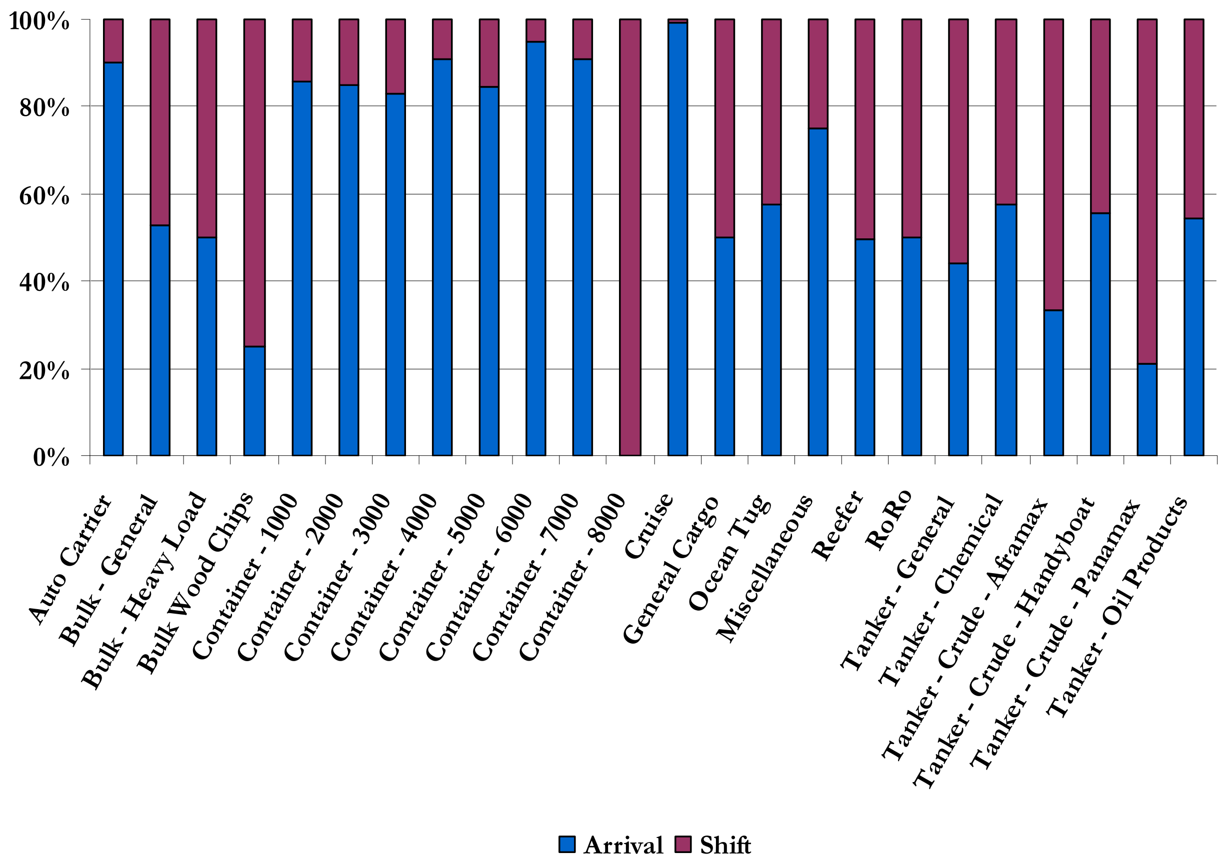
Arrivals approximate the true number of vessel port calls, but may under-estimate the number of terminal calls. The main difference between a port call and a terminal call is that terminal calls include the shifts. Table 2.4 presents the arrivals, departures, shifts and total movements for vessels at the Port in 2005. Arrivals and departures do not match because the activity is based on a calendar year.

Table 2.4: Total OGV Movements for 2005

OGV Type	Arrival	Departure	Shift	Total
Auto Carrier	65	67	7	139
Bulk - General	144	140	129	413
Bulk - Heavy Load	1	2	1	4
Bulk Wood Chips	1	3	3	7
Container - 1000	199	205	33	437
Container - 2000	180	188	32	400
Container - 3000	285	296	58	639
Container - 4000	377	397	38	812
Container - 5000	205	206	38	449
Container - 6000	128	131	7	266
Container - 7000	49	52	5	106
Container - 8000	0	2	2	4
Cruise	271	271	2	544
General Cargo	63	70	63	196
Ocean Tug	57	35	42	134
Miscellaneous	6	6	2	14
Reefer	58	62	59	179
RoRo	2	4	2	8
Tanker - General	81	61	103	245
Tanker - Chemical	39	30	29	98
Tanker - Crude - Aframax	2	2	4	8
Tanker - Crude - Handyboat	20	5	16	41
Tanker - Crude - Panamax	4	7	15	26
Tanker - Oil Products	104	70	87	261
Total	**2,341**	**2,312**	**777**	**5,430**

Figure 2.17 shows the percentage of shifts in relation to inbound calls by vessel type. In general, the figure shows that bulk vessels, reefers, RoRos and tankers have a higher percentage of shifts within the port than auto carriers, container vessels, cruise ships. The reason for the high number of shifts may be due to vessels not being able to proceed directly to the loading/unloading terminal and having to wait at anchorage or lay berth and some vessels may stop at more than one terminal to load/unload their cargo during their Port call. For the 8000+ container vessel category, it may show only shift instead of an arrival because it may have shifted from Port of Long Beach before departing.

Figure 2.17: Percentage of Shifts and Inbound Calls by Vessel Type



2.5 Emission Estimation Methodology

The methodology presented in this report describes an activity-based emissions inventory, meaning that the emission estimates are based on the activity levels of detailed spatial and temporal resolution. In developing an activity-based emissions inventory for marine vessels, emissions are estimated as a function of vessel power demand (expressed in kW-hrs) multiplied by an emission factor, where the emission factor is expressed in terms of grams per kilowatt-hour (g/kW-hr). Emission factors and emission factor adjustments for low propulsion engine load were then applied to the various activity data. The process for estimating emissions from propulsion engines is illustrated as a process flow diagram in Figure 2.18. This diagram indicates the sources of information discussed in the previous subsection and how they are used to develop the components of the emission calculations, as described below.

Equations 2.1 and 2.2 report the basic equations used in estimating emissions, and are labeled in Figure 2.18. The variables are discussed in more detail in this section following Figure 2.18.

$$E = Energy \times EF \qquad \text{Equation 2.1}$$

Where:

E = Emissions from the engine(s) that are included in the "Energy" term discussed below, usually calculated as grams of emissions per unit of time (e.g., per year), but converted to tons of emissions by dividing by 453.6 grams per pound and 2,000 pounds per ton.

Energy = Energy demand, in kW-hrs, calculated using Equation 2.2 below as the energy output of the engine (or engines) over the period of time covered by the estimate.

EF = Emission factor, usually expressed in terms of g/kW-hr, discussed in more detail below.

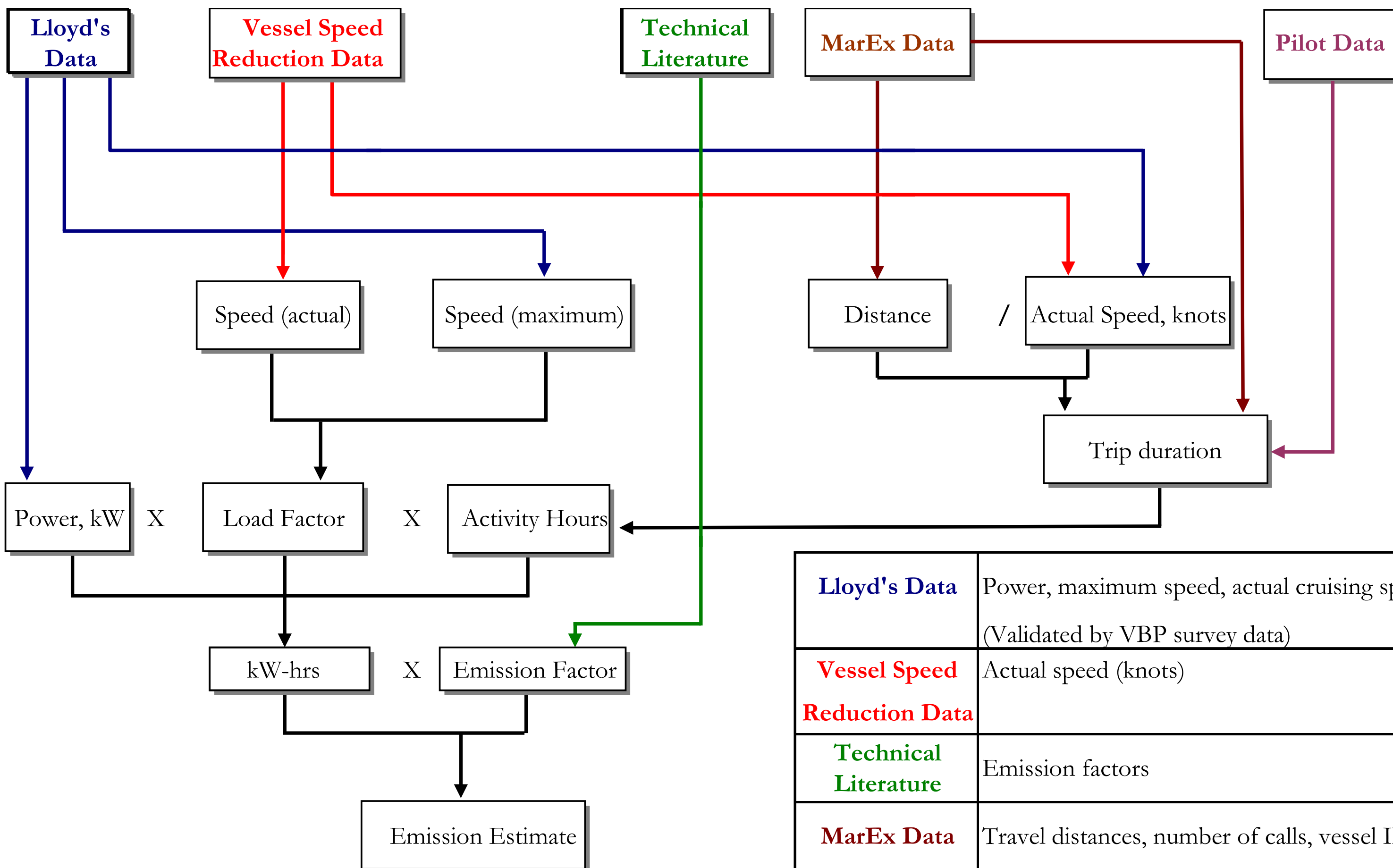
The 'Energy' term of the equation is where most of the location-specific information is used. Energy is calculated using Equation 2.2:

$$Energy = MCR \times LF \times A \qquad \text{Equation 2.2}$$

Where:

MCR = maximum continuous rated engine power, kW
LF = load factor (unitless)
A = activity, hours

Figure 2.18: Propulsion Engine Emission Estimation Flow Diagram



Lloyd's Data	Power, maximum speed, actual cruising speed (Validated by VBP survey data)
Vessel Speed Reduction Data	Actual speed (knots)
Technical Literature	Emission factors
MarEx Data	Travel distances, number of calls, vessel ID
Pilot Data	Trip duration for maneuvering

The emissions estimation methodology section discusses methodology used for propulsion engines (subsections 2.5.1 to 2.5.7), auxiliary engines (subsections 2.5.8 and 2.5.9) and auxiliary boilers (subsections 2.5.10). Propulsion engines are also referred to as main engines.

Incinerators are not included in the emissions estimates because incinerators are not used within the study area. Interviews with the vessel operators and marine industry, in general, report that vessels do not use their incinerators while at berth or near coastal waters.

2.5.1 Propulsion Engine Maximum Continuous Rated Power

MCR power is defined as the manufacturer's tested engine power; for this study, it is assumed that the Lloyd's 'Power' value is the MCR power. The international specification is to report MCR in kilowatts, and it is related to the highest power available from a ship engine during average cargo and sea conditions. However, operating a vessel at 100% of its MCR power is very costly from a fuel consumption and engine maintenance perspective, so most operators limit their maximum power to about 80% of MCR.

2.5.2 Propulsion Engine Load Factor

Load factor is expressed as the ratio of a vessel's power output at a given speed to the vessel's MCR power. As suggested above, at normal service speed, a ship probably has a load factor of close to 80%. For intermediate speeds, the Propeller Law is used to estimate ship propulsion engine loads, based on the theory that propulsion power varies by the cube of speed.

$$LF = (AS / MS)^3 \qquad \text{Equation 2.3}$$

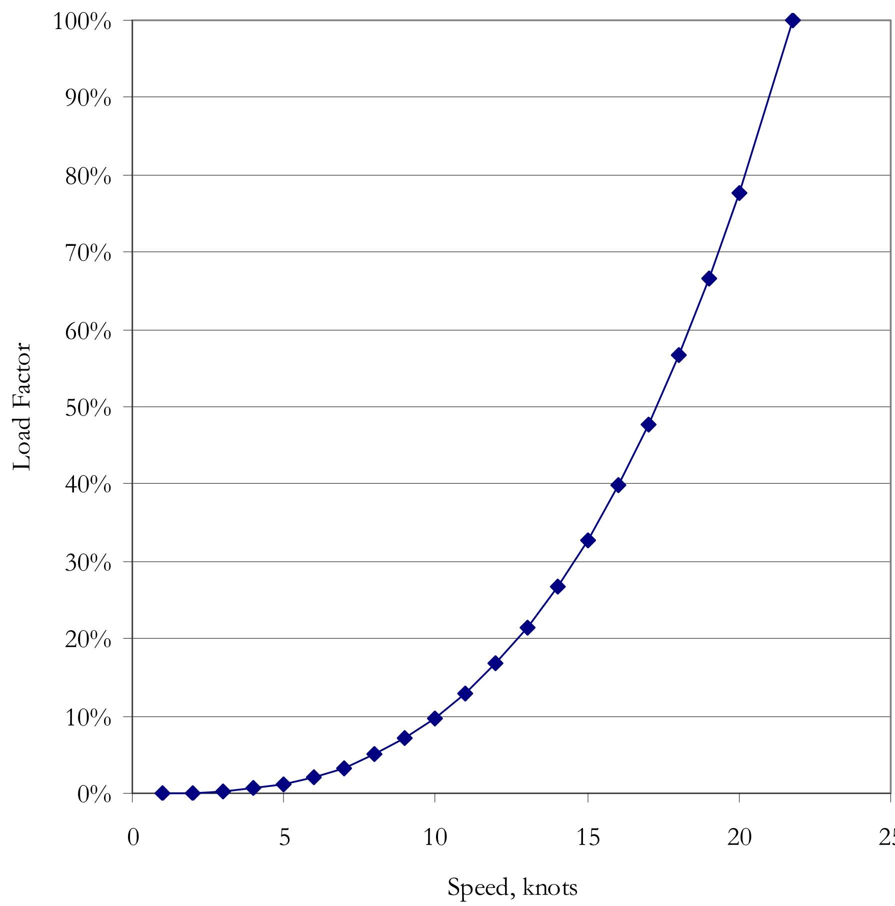
Where:

LF = load factor, percent
AS = actual speed, knots
MS = maximum speed, knots

The output from Equation 2.3 is illustrated in Figure 2.19, showing the load factor curve of a hypothetical ship with 20,000 kW main engine power and a top speed of 22 knots at that power output. The shape of the curve illustrates why vessels typically operate at less than their MCR power – at the top of the curve, the increase in power is much greater than the increase in speed, meaning that the vessel uses comparatively more power (and fuel) to obtain a small increase in speed.

As an example, at a speed of 20 knots, the hypothetical vessel's engine would be operating with a load factor of 75% [$(20/22)^3$ = 0.75, or 75%]. At 21 knots the load factor would be 87% [$(21/22)^3$ = 0.87, or 87%]. That's an increase of 12% of the vessel's power output for a 1-knot increase in speed. At the lower end of the speed range, at a speed of 10 knots, the hypothetical vessel's engine would be operating with a load factor of 9% [$(10/22)^3$ = 0.09, or 9%]. At 9 knots the load factor would be 7% [$(9/22)^3$ = 0.07, or 7%]; this would give a 1-knot speed increase at an increase of only 2% of the vessel's power output. At 6 knots the load factor would be 2% [$(6/22)^3$ = 0.02, or 2%].

Figure 2.19: Propeller Law Curve of Power Demand



2.5.3 Propulsion Engine Activity

Activity is measured in hours of operation. Actual in-harbor maneuvering and transit times were taken from Pilot data. The VSR program requests vessels to travel at or below 12 knots when the vessel is 24 nm out. Vessel speeds are recorded by the Marine Exchange for zones called 10, 15 and 20. The zones are estimated by radius distance from Point Fermin, so the distances are in the 10, 15 and 20 nm range made by the concentric circles, but the actual distance is not exactly 10, 15, and 20. The VSR speed data is used instead of averages for the fairway up to roughly 20 miles out. For the at-sea portion not covered by VSR actual speed data, transit times were estimated by dividing distance traveled by ship speed.

$$A = D/S \qquad \text{Equation 2.4}$$

Where:

A = activity, hours
D = distance, nautical miles
S = ship speed, knots

The PZ uses assigned speeds based on VBP data, as found in Table 2.5.

Table 2.5: Precautionary Zone Speed, knots

Vessel Type	Class	Speed
Auto Carrier	Fast	11.0
Bulk	Slow	9.0
Containership	Fast	11.0
Cruise	Fast	11.0
General Cargo	Slow	9.0
Miscellaneous	Slow	9.0
Ocean Tug	Slow	9.0
Reefer	Slow	9.0
RoRo	Slow	9.0
Tanker	Slow	9.0

2.5.4 Propulsion Engine Emission Factors

The main engine emission factors used in this study were reported in a 2002 ENTEC study[10]. Vessels are assumed to operate their main engines on residual oil (RO) which is intermediate fuel oil (IFO 380) or one with similar specifications with an average sulfur content of 2.7%. This is supported by information collected during the VBP and 2005 ARB survey; exceptions are made for those vessels that use a different fuel other than residual fuel. Three vessel technologies are reported:

- Slow speed diesel engines, having maximum engine speeds less than 130 revolutions per minute (rpm) based on the EPA definition for ship engines as described in a 1999 Regulatory Impact Analysis.[11]
- Medium speed diesel engines, having maximum engine speeds over 130 rpm (and typically greater than 400 rpm).
- Steam boiler turbines.

The emission factors for main engines using residual fuel and built prior to 1999 are listed in Table 2.6.

Table 2.6: Emission Factors for OGV Main Engines built prior to 1999 and using Residual Oil, g/kW-hr

Engine	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC
Slow speed diesel	1.5	1.2	1.5	18.1	10.5	1.4	0.6
Medium speed diesel	1.5	1.2	1.5	14.0	11.5	1.1	0.5
Gas turbine	0.05	0.04	0.0	6.1	16.5	0.2	0.1
Steam turbine	0.8	0.6	0.0	2.1	16.5	0.2	0.1

The emission factors for the newer model main engines using residual fuel and built after 2000 are listed in Table 2.7. The NO_x emission factor is the only one that is changed. All other emission factors stay the same.

10 ENTEC, *Quantification of Emissions from Ships Associated with Ship Movements between Ports in the European Community, Final Report*, July 2002. Prepared for the European Commission.

11 EPA, *Control of Emissions from Marine Diesel Engines, Regulatory Impact Analysis*, November 1999. EPA 420-R-99-026.

Table 2.7: Emission Factors for 2000 and newer OGV Main Engines using Residual Oil, g/kW-hr

Engine	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC
Slow speed diesel	1.5	1.2	1.5	17.0	10.5	1.4	0.6
Medium speed diesel	1.5	1.2	1.5	13.0	11.5	1.1	0.5

NO_X Emission Factor

The IMO established OGV propulsion engine standards in Annex VI and engine manufacturers have been in compliance with the NO_X Technical Code since 2000. The engine standards are baseline standards to prevent back sliding on emission levels from 2000 and newer engine models. In this study, the 17.0 g/kW-hr NO_X emission factor is used for slow speed vessels built after the year 2000.

Medium speed engine standards under the IMO program are based on engine rpm. For medium speed engines built after the year 2000, the 13.0 g/kW-hr NO_X emission factor is used. It should be qualified that the engine manufacturers design their engines to emit well below the calculated standards, but it is difficult to establish an "in-use" average without the benefit of measurements.

CO Emission Factor

CO emission factors were developed from information provided in the ENTEC appendices because they are not explicitly stated in the text. They were confirmed with IVL Swedish Environmental Research Institute Ltd.[12]

PM Emission Factor

CARB developed a statewide emissions estimation methodology for ocean-going vessels operating in California coastal waters and California ports and inland waterways. This effort was undertaken to support the development of a statewide emission control strategy addressing emissions from auxiliary engines on ocean-going vessels. CARB staff developed an alternative PM emission factor for slow and medium speed engines that use residual fuel and used a PM emission factor of 1.5 g/kW-hr. In order to be consistent with CARB's emissions methodology, the Port has agreed to use the 1.5 g/kW-hr for this study until future and better data is available to support a new or alternate PM emission factor. Particular matter less than two microns (PM10) is assumed to be 100% of PM. Fine particulate matter, or particulate matter less than 2.5 microns in diameter (PM2.5), was estimated to be 80% of PM10[13]. For internal combustion diesel engines, the same PM10

[12] Cooper, David, IVL Swedish Environmental Research Institute Ltd., 16 January 2004 e-mail correspondence with C.H. Wells, Starcrest Consulting Group, LLC. (IVL 2004)

[13] Lyyranen et al 1999. 'Aerosol Characterization in Medium-Speed Diesel Engines Operating with Heavy Fuel Oils,' *Journal of Aerosol Science* 30:6.

emission factor is used for diesel particulate matter (DPM). For other types of engines that do not meet the definition of internal combustion, such as steamships and gas turbines, DPM is zero.

SO_x Emission Factor

The emission factor is dependent on the fuel used and the emission factor listed on the 2002 ENTEC report is based on sulfur content of 2.7%, which is an average for residual fuel.

2.5.5 Varying Emission Factors for Low Loads for Propulsion Engines

This section addresses emission factors for main propulsion engines powered by internal compression engines. The discussion does not include steamships or ships having gas turbines because the EPA study (see below) only observed rise in factors for diesel engines.

In general terms, diesel-cycle engines are not as efficient when operated a low loads or, for that matter, very high loads. An EPA study[14] prepared by Energy and Environmental Analysis, Inc. (EEIA) has established a formula for calculating emission factors for low engine load conditions such as those encountered during harbor maneuvering and when traveling slowly at sea such as in the reduced speed zone. While mass emissions (e.g., pounds per hour) tend to go down as vessel speeds and engine loads decrease, the emission factors (e.g., g/kW-hr) increase. This is based on observations that compression-cycle combustion engines are less efficient at low loads. Low load emission factor equations were developed from EPA emission factors for marine vessels at full load.

These equations work well to describe the low-load effect where emission rates can increase, based on a limited set of data from Lloyd's Maritime Program and the USCG. It was first cited in a study conducted for the EPA in 2002 by ENVIRON.[15] The equation is based on the variables provided in Table 2.8.

Table 2.8: Low-Load Emission Factor Regression Equation Variables as Modified

Pollutant	Exponent	Intercept (b)	Coefficient (a)
PM	1.5	0.25	0.0059
NO_X	1.5	10.45	0.1255
CO	1.0	0.15	0.8378
HC	1.5	0.39	0.0667

[14] EEIA for Sierra Research, for EPA, *Analysis of Commercial Marine Vessels Emissions and Fuel Consumption Data,* February 2000. Sierra Research work assignment No. 1-10. EPA420-R-002.

[15] EPA, *Commercial Marine Inventory Development,* July 2002. EPA 420-R-02-019.

The equations were used for the entire spectrum of load factors from 1% to 20% for each pollutant, as follows:

$$\mathbf{y = a(fractional\ load)^{-x} + b} \qquad \text{Equation 2.5}$$

Where:
y = emissions in g/kW-hr
a = coefficient
b = intercept
x = exponent (negative)
fractional load = derived by the Propeller Law

The EEIA equations were used to generate emission factors at loads between one and 20% main engine power. Each of the 20 EEIA factors was divided by the emission factor at 20% EEAI load. This resulted in positive numbers, since emissions increased as load decreased. At 20% load, the value was exactly 1.0 since it was divided into itself. These numbers are called low-load adjustment factors (LLA). The LLA multipliers were then applied to any at sea emission factor. The database then computes the resulting emission factor for each pollutant. The low load adjustment multipliers are reported in Table 2.9.

Table 2.9: Low Load Adjustment Multipliers for Emission Factors

Load	NO_x	CO	HC	PM	SO_x
1%	11.47	19.32	59.28	19.17	1
2%	4.63	9.68	21.18	7.29	1
3%	2.92	6.46	11.68	4.33	1
4%	2.21	4.86	7.71	3.09	1
5%	1.83	3.89	5.61	2.44	1
6%	1.60	3.25	4.35	2.04	1
7%	1.45	2.79	3.52	1.79	1
8%	1.35	2.45	2.95	1.61	1
9%	1.27	2.18	2.52	1.48	1
10%	1.22	1.96	2.20	1.38	1
11%	1.17	1.79	1.96	1.30	1
12%	1.14	1.64	1.76	1.24	1
13%	1.11	1.52	1.60	1.19	1
14%	1.08	1.41	1.47	1.15	1
15%	1.06	1.32	1.36	1.11	1
16%	1.05	1.24	1.26	1.08	1
17%	1.03	1.17	1.18	1.06	1
18%	1.02	1.11	1.11	1.04	1
19%	1.01	1.05	1.05	1.02	1
20%	1	1	1	1	1

Alternative methods were also explored, such as using the EEAI equations to span the entire spectrum between 1% and 100% load, using revised emission factors as the intercept (the starting place at 100% load). Unfortunately, such adjustments cause the shape of the graphed curves to change, and such changes could not be validated with empirical or measurement results. Thus the low load adjustments are used in a relative sense, based on the original published data.

2.5.6 Propulsion Engine Maneuvering Loads

Main engine loads within a harbor tend to be very light, especially when coasting on the way into port. During docking, when the ship is being positioned against the wharf, the assist tugboats do most of the work. Estimation of main engine maneuvering loads is the composite of several factors, such as:

- 2% load during docking
- 15 minute docking duration (based on VBP observations)
- variable loads with inbound and outbound speeds
- docking and harbor transit loads combined by percent time-in-mode

Docking and harbor transits are two subsets of what is called "maneuvering." The docking aspect is fairly routine with the exception that some ships require extra backing and turning, either on entry or exit. As an example, inbound trips can take about an hour and docking would be 15 minutes of that, thus the harbor transit is 45 minutes. Outbound maneuvering takes less time, perhaps 45 minutes total including 15 minutes of undocking and 30 minutes of travel. The port pilot data and VBP support these generalities, although maneuvering times vary by port, terminal, and ship type. To account for faster outbound maneuvering, speeds have been assigned as follows:

- Inbound fast ships (container, auto, and cruise): 7 knots
- Inbound slow ships (all others): 5 knots
- Outbound ships (all): 8 knots

Thus docking is about 2% load, but the harbor transit load has to be calculated by the Propeller Law. Results are then weighted together by percentage of time in docking and harbor transit modes. Results of that operation are shown in Table 2.10. The departure load is typically higher than the arrival load because the engine power is used to leave the dock, while the vessel usually coasts in on arrival.

Table 2.10: Composite Maneuvering Loads

Vessel Type	Max. Rated Speed	Arrival Load	Departure Load
Auto Carrier	19	4.4%	5.7%
Bulk	14	3.7%	11.6%
Container - 1000	19	4.1%	5.0%
Container - 2000	21	3.3%	4.3%
Container - 3000	22	2.9%	3.9%
Container - 4000	24	2.3%	3.1%
Container - 5000	25	2.1%	2.8%
Container - 6000	25	2.1%	2.8%
Container - 7000	25	2.1%	2.8%
Container - 8000	25	2.2%	2.9%
Cruise	22	3.1%	3.9%
General Cargo	16	3.0%	9.6%
Ocean Tug	14	4.1%	13.3%
Miscellaneous	16	3.0%	9.4%
Reefer	19	2.8%	4.8%
RoRo	21	2.3%	4.4%
Tanker	15	3.4%	11.4%

2.5.7 Propulsion Engine Defaults

Approximately 5% of the vessels had unknown main engine power because it could not be obtained from Lloyd's data, VBP data, or any other data files. For this small percentage of vessels, an average main engine power was given by vessel type which is summarized in Table 2.11. There is no default for main engine power for cruise ships since cruise ships are unique and the power would be given on a vessel by vessel basis for this category based on cruise company interviews. The main engine defaults are based on Lloyd's (October 2004 edition) world-wide fleet averages which did not contain too many of the newer and larger container vessels. Therefore, the same default was used for the container subtypes with 6000+ TEUs. Future inventory updates will use the most current Lloyd's data which may provide better data for newer vessels

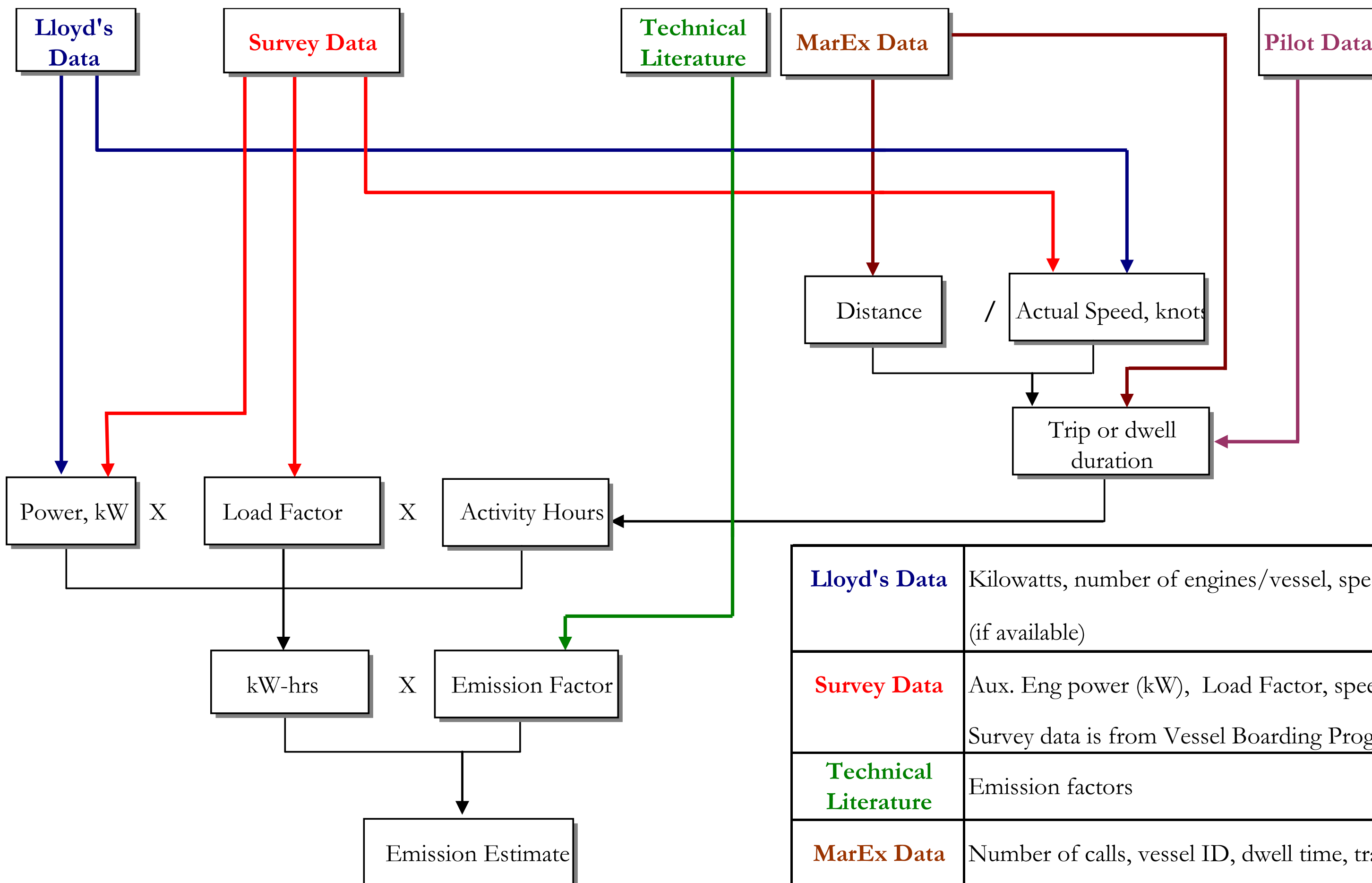
Table 2.11: Main Engine Defaults

Vessel Type	Main Engine Power (kW)
Auto Carrier	11,502
Bulk - General	9,028
Bulk - Heavy Load	9,028
Bulk Wood Chips	9,028
Container - 1000	9,642
Container - 2000	22,028
Container - 3000	27,694
Container - 4000	39,091
Container - 5000	46,574
Container - 6000	61,229
Container - 7000	62,254
Container - 8000	63,898
Cruise	na
General Cargo	8,201
Ocean Tug	9,959
Miscellaneous	10,019
Reefer	9,878
Ro/Ro	19,856
Tanker - General	6,242
Tanker -Chemical	6,242
Tanker - Crude - Aframax	13,784
Tanker - Crude - Handyboat	6,242
Tanker - Crude - Panamax	11,109
Tanker - Oil Products	6,242
Tankers (Diesel/Electric)	13,196

2.5.8 Auxiliary Engine Emission Factors

The process of estimating emissions from auxiliary engines is generally the same as for main engines, with differing details. The process is illustrated in Figure 2.20.

Figure 2.20: Auxiliary Engine Emission Estimation Flow Diagram



Lloyd's Data	Kilowatts, number of engines/vessel, speeds (if available)
Survey Data	Aux. Eng power (kW), Load Factor, speed (knots) Survey data is from Vessel Boarding Program (VBP)
Technical Literature	Emission factors
MarEx Data	Number of calls, vessel ID, dwell time, travel distances
Pilot Data	Maneuvering Time

The most visible difference is that load factor is not calculated but rather is estimated from reports in the technical literature and from discussions with experts such as ships' engineers. Calculating auxiliary engine load factors from empirical data is theoretically possible but would require detailed fuel consumption data that is not typically available.

The ENTEC auxiliary engine emission factors used in this study are presented in Table 2.12. Based on the VBP and CARB's OGV survey results, 71% of the vessels operate their auxiliary engines on residual oil; with average sulfur content of 2.7%, and 29% operate their auxiliary engines on diesel oil with an average sulfur content of 0.5%.

Table 2.12: Auxiliary Engine Emission Factors, g/kW-hr

Engine	Fuel	PM_{10}	$PM_{2.5}$	DPM	NO_X	SO_x	CO[16]	HC
Medium speed diesel	Residual oil	1.5	1.2	1.5	14.7	12.3	1.1	0.4
Medium speed diesel	Diesel oil	0.3	0.2	0.3	13.9	4.3	1.1	0.4

For medium speed engines built after the year 2000, the 13.0 g/kW-hr NO_X emission factor is used.

2.5.9 Auxiliary Engine Defaults

As explained earlier, auxiliary engine information is usually not provided to Lloyd's by vessel owners since it is not required by IMO or the classification societies, thus Lloyd's data contains minimal auxiliary engine information. Therefore, auxiliary engine data gathered from the Vessel Boarding program and Lloyd's data on ships making local calls was used to generate profiles or defaults for the purpose of "gap filling" when there was missing data.

Vessels typically never use the total auxiliary engine installed power when at sea, during hotelling, and during maneuvering. This is due to the design of the auxiliary system and the need for some level of redundancy incase of equipment failures. For each mode and vessel type, a different number of engines may be used and at varying loads depending on several factors, such as weather and number of reefers onboard. Hotelling load is primarily what is needed to meet the power needs of the lights, heating/ventilation/air conditioning (HVAC) systems, communications, computers, ship cranes, pumps, reefer load, and various other power demands while the vessel is at dock. Maneuvering is generally the highest auxiliary load mode for OGVs as the bow thrusters need to be available and used in spurts. The fairway or open sea is generally where the lowest auxiliary loads are found as additional auxiliary power is

[16] IVL 2004.

not required for maneuvering and many vessels have shaft generators and exhaust turbine generators that help provide power to the ship in an effort to reduce operating costs through lower fuel consumption.

From the inception of the VBP, the average or typical number of auxiliary engines used and its corresponding load at sea, during maneuvering and at berth has been studied to gain a better understanding of the how the auxiliary engines are used in relation to the total number and total power installed. The load default in kilowatts is based on the percent load which takes into account the average number of actual engines used and their load. Another way to view auxiliary engine load is to see it as the kilowatts used from the total power available. For example, a 1,000 TEU container vessel may use 1 auxiliary engine at berth for house load at 60% load. The resulting total hotelling load is 0.3 times 0.6 equals 0.18. The 0.3 is for 1 out 3 total engines being used, the 0.6 is the 60% load on that engine. Table 2.13 summarizes the total power and load defaults used for this study by vessel subtype. Cruise ships do not have default values available since each cruise ship is different and was taken into consideration on a per vessel basis.

Table 2.13: Auxiliary Engine Power and Load Defaults

Vessel Type	Total Aux Eng	Load Defaults (%)			Load Defaults (kW)		
	Power (kW)	Sea	Maneuvering	Hotelling	Sea	Maneuvering	Hotelling
Auto Carrier	2,850	15%	45%	26%	428	1,283	741
Bulk - General	2,850	17%	45%	10%	485	1,283	285
Bulk - Heavy Load	2,850	17%	45%	10%	485	1,283	285
Bulk Wood Chips	2,850	17%	45%	10%	485	1,283	285
Container - 1000	2,090	13%	50%	18%	272	1,045	376
Container - 2000	4,925	13%	43%	22%	640	2,118	1,084
Container - 3000	5,931	13%	43%	22%	771	2,550	1,305
Container - 4000	7,121	13%	50%	18%	926	3,561	1,282
Container - 5000	11,360	13%	49%	16%	1,477	5,566	1,818
Container - 6000	13,501	13%	50%	15%	1,755	6,751	2,025
Container - 7000	13,501	13%	50%	15%	1,755	6,751	2,025
Container - 8000	13,501	13%	50%	15%	1,755	6,751	2,025
Cruise	na	na	na	na	na	na	na
General Cargo	1,776	17%	45%	22%	302	799	396
Ocean Tug	600	17%	45%	22%	102	270	134
Miscellaneous	1776	17%	45%	22%	302	799	396
Reefer	3,900	15%	45%	32%	585	1,755	1,248
Ro/Ro	2,850	15%	45%	26%	428	1,283	741
Tanker - General	1,911	24%	33%	26%	459	631	497
Tanker -Chemical	1,911	24%	33%	26%	459	631	497
Tanker - Crude - Aframax	2,544	24%	33%	26%	611	840	661
Tanker - Crude - Handyboat	1,911	24%	33%	26%	459	631	497
Tanker - Crude - Panamax	2,520	24%	33%	26%	605	832	655
Tanker - Oil Products	1,911	24%	33%	26%	459	631	497
Tankers (Diesel/Electric)	1,985	24%	33%	26%	476	655	516

2.5.10 Auxiliary Boiler

In addition to the auxiliary engines that are used to generate electricity for on-board uses, most OGVs have one or more boilers used for fuel heating and for producing hot water. Boilers are typically not used during transit at sea since vessels are equipped with an exhaust gas recovery system or "economizer" that uses exhaust for heating purposes and therefore the boilers are not needed when the main engines are used. Boilers are used at reduced speeds, such as during maneuvering and when the vessel is at Port and the main engines are shut down.

The methodology for estimating emissions from on-board boilers is slightly different from that used in the 2001 Emissions Inventory. Previously, the auxiliary boiler fuel consumption was applied to EPA AP-42 emission factors based on kilograms of pollutant per tonne of fuel (kg/MT)[17].

In the revised method used for this inventory, boiler fuel consumption data was collected for approximately 50 vessels during the VBP, and different values were used for the various vessel types, instead of using a default for all vessels.

The boiler fuel consumption was converted to equivalent kilowatts (kW) using Specific Fuel Consumption (SFC) factors found in ENTEC report. The average SFC value for using residual fuel is 305 grams of fuel per kW-hour. Using the following equation, the average kW for auxiliary boilers was calculated.

$$\text{Average kW} = ((\text{daily fuel}/24) \times 1{,}000{,}000)/305 \qquad \text{Equation 2.6}$$

Auxiliary boiler energy defaults in kW used for each vessel type are presented in Table 2.14. The cruise ships and tankers (except for diesel electric tankers) have much higher auxiliary boiler usage rates than the other vessel types. Cruise ships have higher boiler usage due to the number of passengers and need for hot water. Tankers provide steam for steam-powered liquid pumps, inert gas in fuel tanks, and to heat fuel for pumping. Ocean tugboats typically do not have boilers; therefore their boiler energy default is zero in Table 2.14.

[17] EPA, AP-42, Fifth Edition, *Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Source*, 1998.

Table 2.14: Auxiliary Boiler Energy Defaults

Vessel Type	Boiler Energy Defaults (kW)		
	Sea	Maneuvering	Hotelling
Auto Carrier	0	371	371
Bulk - General	0	109	109
Bulk - Heavy Load	0	109	109
Bulk Wood Chips	0	109	109
Container - 1000	0	506	506
Container - 2000	0	506	506
Container - 3000	0	506	506
Container - 4000	0	506	506
Container - 5000	0	506	506
Container - 6000	0	506	506
Container - 7000	0	506	506
Container - 8000	0	506	506
Cruise	0	1,000	1,000
General Cargo	0	106	106
Ocean Tug	0	0	0
Miscellaneous	0	371	371
Reefer	0	464	464
Ro/Ro	0	109	109
Tanker - General	0	371	3,000
Tanker -Chemical	0	371	3,000
Tanker - Crude - Aframax	0	371	3,000
Tanker - Crude - Handyboat	0	371	3,000
Tanker - Crude - Panamax	0	371	3,000
Tanker - Oil Products	0	371	3,000
Tankers (Diesel/Electric)	0	346	346

2.5.11 Fuel Correction Factors

Fuel correction factors are used to adjust the emission rates from the fuel. Emission factors are based on when the engines are known to switch from one fuel to another or those that purchase fuel with lower sulfur content. As discussed earlier, emission factors were given for engines using residual fuel with an average 2.7% sulfur content and marine diesel oil with an average 1.5% sulfur content. Table 2.15 lists the fuel correction factors which are based on fuel correction factors used in the San Pedro Bay Clean Air Action Plan[18].

[18] See *http://www.polb.com/environment/air_quality/clean_air_action_plan.asp*

Table 2.15: Fuel Correction Factors

Actual Fuel	NO_X	CO	HC	PM	SO_2
HFO (1.5% S)	1	1	1	0.82	0.56
MGO (0.5% S)	0.9	1	1	0.39	0.18
MDO (1.5 % S)	0.9	1	1	0.47	0.56
MGO (0.1% S)	0.9	1	1	0.35	0.04

2.5.12 Emission Reduction Technologies

Correction factors can also be used for emission reduction technologies that the vessel may have. In 2005, slide fuel valves were used by 22 known vessels that made approximately 100 calls to the Port. This new type of fuel valve leads to better combustion process, less smoke, and lower fuel consumption which results in reduced overall NO_x and PM emissions. Some new engines, specifically those manufactured by Man B&W, may have this type of fuel valve. Some companies are retrofitting vessels with Man B&W main engines in their fleet with the slide fuel valve. Since the slide valves are on a vessel by vessel basis, the inventory may not have captured all the vessels with slide valves for 2005 vessels that called at the Port. The emission reductions used for the slide fuel valves are based on MAN B&W Diesel A/S emission measurements of marine vessel Sine Maersk. The reductions are:

- 30% reduction for NO_x
- 25% reduction for PM

2.6 Emission Estimates

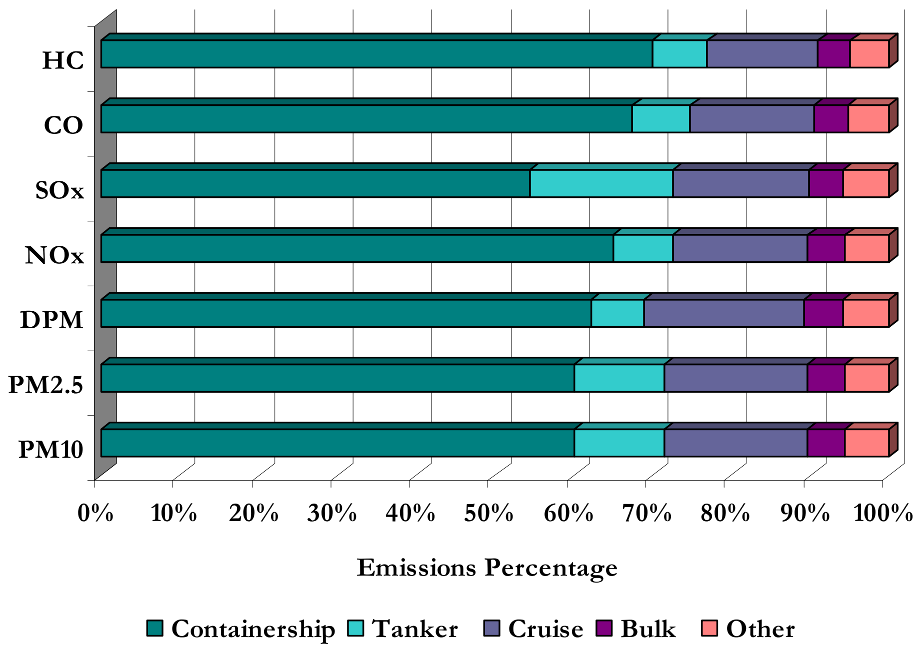
A summary of the ocean-going vessel emission estimates by vessel type for all pollutants for the year 2005 is presented in Table 2.16.

Table 2.16: 2005 Ocean-Going Vessel Emissions by Vessel Type, tpy

Vessel Type	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC
Auto Carrier	**7.1**	**5.7**	**6.6**	**72.9**	**56.8**	**6.2**	**2.8**
Bulk - General	28.6	22.9	26.8	285.4	237.9	23.2	9.8
Bulk - Heavy Load	0.3	0.2	0.2	2.7	2.3	0.2	0.1
Bulk Wood Chips	0.6	0.5	0.5	5.9	5.1	0.5	0.2
Total Bulk Vessels	**29.5**	**23.6**	**27.6**	**294.0**	**245.3**	**23.9**	**10.1**
Container - 1000	22.4	17.9	17.9	195.3	227.5	16.2	7.0
Container - 2000	33.1	26.5	28.4	331.5	289.4	27.6	12.4
Container - 3000	61.4	49.1	55.5	691.9	475.8	59.6	28.5
Container - 4000	105.1	84.1	97.0	1,086.2	832.9	98.3	47.5
Container - 5000	83.0	66.4	75.0	868.8	662.0	79.4	38.0
Container - 6000	47.9	38.3	43.8	590.5	322.5	58.0	27.3
Container - 7000	27.3	21.8	25.8	260.0	237.4	25.2	11.7
Container - 8000	0.5	0.4	0.5	4.5	3.7	0.5	0.3
Total Containership	**380.7**	**304.5**	**343.8**	**4,028.8**	**3,051.3**	**364.7**	**172.6**
Cruise	**115.5**	**92.4**	**112.2**	**1,065.2**	**968.1**	**84.5**	**34.5**
General Cargo	**11.9**	**9.5**	**9.8**	**110.0**	**117.5**	**8.8**	**3.8**
Ocean Tugboat	**4.3**	**3.4**	**4.3**	**40.0**	**32.9**	**3.1**	**1.4**
Miscellaneous	**0.6**	**0.5**	**0.5**	**5.7**	**6.7**	**0.4**	**0.2**
Reefer	**11.8**	**9.4**	**10.4**	**109.3**	**109.0**	**8.7**	**3.7**
RoRo	**0.5**	**0.4**	**0.4**	**4.5**	**3.3**	**0.4**	**0.2**
Tanker - General	23.1	18.5	11.6	147.2	325.7	12.5	5.5
Tanker - Chemical	7.4	6.0	4.1	51.5	98.9	4.4	1.9
Tanker - Crude - Aframax	2.1	1.7	1.5	16.5	24.0	1.4	0.6
Tanker - Crude - Handyboat	5.3	4.2	2.5	33.9	75.9	2.8	1.3
Tanker - Crude - Panamax	4.2	3.4	2.3	28.7	57.9	2.4	1.1
Tanker - Oil Products	29.6	23.7	14.4	197.3	436.0	16.1	7.1
Total Tankers	**71.8**	**57.5**	**36.4**	**475.1**	**1,018.3**	**39.5**	**17.4**
Total	**633.6**	**506.9**	**552.0**	**6,205.6**	**5,609.3**	**540.2**	**246.7**

Figure 2.21 shows percentage of emissions by vessel type for each pollutant. Containerships have the highest percentage of the emissions (approximately 60%) for the vessels, followed by tankers, cruise ships, and bulk. The "other" includes RoRo, general cargo, ocean-going tugboats and miscellaneous vessels.

Figure 2.21: 2005 Ocean-Going Vessel Emissions by Vessel Type, %



2.6.1 Emission Estimates by Engine Type

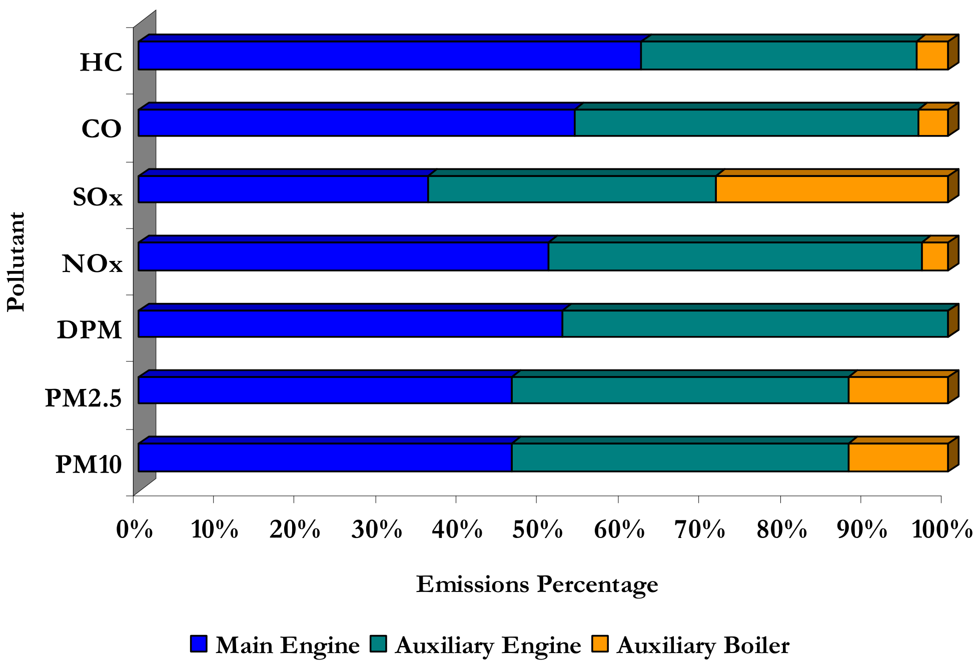
Table 2.17 presents summaries of emission estimates by engine type in tons per year.

Table 2.17: 2005 Ocean-Going Vessel Emissions by Engine Type, tpy

Engine Type	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC
Auxiliary Engine	263.8	211.0	263.8	2,858.4	1,997.0	230.0	83.6
Auxiliary Boiler	78.7	63.0	0.0	209.1	1,615.9	20.0	10.0
Main Engine	291.2	232.9	288.2	3,138.2	1,996.4	290.2	153.1
Total	**633.6**	**506.9**	**552.0**	**6,205.6**	**5,609.3**	**540.2**	**246.7**

Figure 2.22 shows results in percentages for emission estimates by engine type. The auxiliary boilers generally have lower NO_x emission rates and higher SO_x emission rates than diesel engines which may explain the higher SO_x emissions percentage for auxiliary boilers.

Figure 2.22: 2005 Ocean-Going Vessel Emissions by Engine Type, %



2.6.2 Emission Estimates by Mode

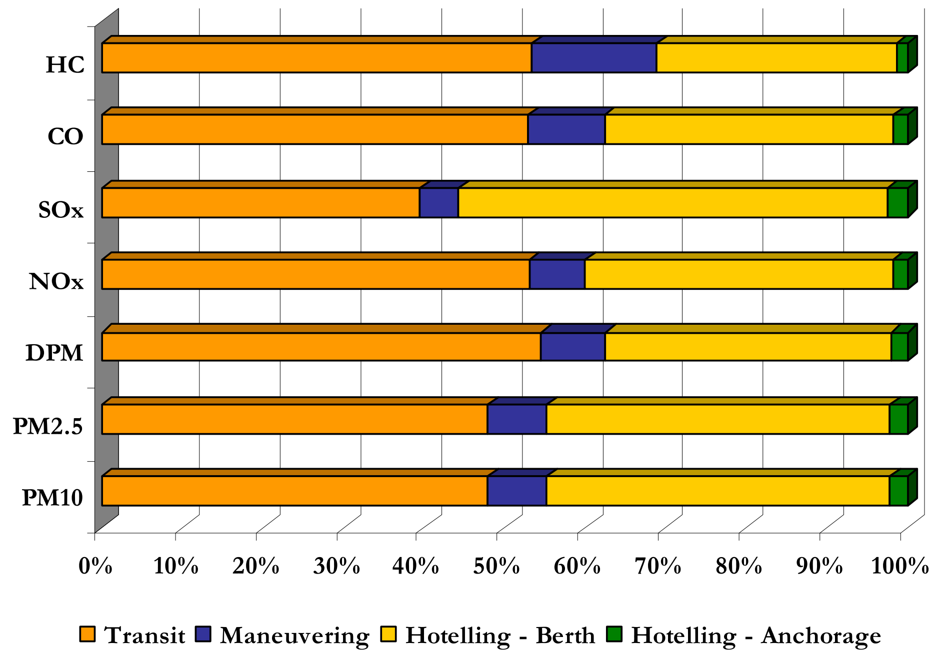
Table 2.18 presents summaries of emission estimates by the various modes in tons per year. For each mode, the vessel type emissions are also listed in the table. Hotelling at terminal berth and at anchorage are listed separately. Transit and maneuvering emissions includes both berth and anchorage calls.

Table 2.18: 2005 Ocean-Going Vessel Emissions by Mode, tpy

Mode	Engine Type	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC
Transit	Auxiliary Engine	33.6	26.8	33.6	330.2	269.4	26.0	9.5
Transit	Auxiliary Boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transit	Main Engine	270.3	216.2	267.4	2,965.6	1,945.6	260.0	122.4
Total Transit		**303.9**	**243.1**	**301.0**	**3,295.9**	**2,215.0**	**286.0**	**131.8**
Maneuvering	Auxiliary Engine	23.3	18.7	23.3	250.2	178.9	20.1	7.3
Maneuvering	Auxiliary Boiler	2.0	1.6	0.0	5.5	41.8	0.5	0.3
Maneuvering	Main Engine	20.9	16.7	20.8	172.5	50.8	30.3	30.7
Total Maneuvering		**46.2**	**37.0**	**44.1**	**428.1**	**271.5**	**50.9**	**38.3**
Hotelling - Berth	Auxiliary Engine	196.1	156.9	196.1	2,174.8	1,462.4	175.7	63.9
Hotelling - Berth	Auxiliary Boiler	74.2	59.3	0.0	196.9	1,522.5	18.8	9.4
Hotelling - Berth	Main Engine	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Hotelling - Berth		**270.3**	**216.2**	**196.1**	**2,371.6**	**2,984.9**	**194.5**	**73.3**
Hotelling - Anchorage	Auxiliary Engine	10.7	8.6	10.7	103.2	86.2	8.1	2.9
Hotelling - Anchorage	Auxiliary Boiler	2.5	2.0	0.0	6.8	51.6	0.6	0.3
Hotelling - Anchorage	Main Engine	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Hotelling - Anchorage		**13.2**	**10.6**	**10.7**	**110.0**	**137.8**	**8.8**	**3.3**
Total		**633.6**	**506.9**	**552.0**	**6,205.6**	**5,609.3**	**540.2**	**246.7**

Figure 2.23 summarizes the percentage of emissions by mode. The hotelling emissions, which include at berth and at anchorage emissions, range from 30% to 55% for the various pollutants. The harbor hotelling emission percentages are higher for PM and SO_x emissions than the other pollutants due to higher boiler emissions rates. Boilers are generally only used at reduced loads and during hotelling.

Figure 2.23: 2005 Ocean-Going Vessel Emissions by Mode



2.7 OGV 2005 Data Facts and Findings

Information gathered during the data collection process, but not necessarily used for emissions calculations, is summarized in this subsection.

In 2005 there was a reduction of total ship calls (all vessel types) by nearly 14%, as shown in Table 2.19, although 2005 was a record year for total TEUs handled with ~7.49 million TEUs and other cargoes. Looking at ship visits in 2001, there were a total 2,717 inbound calls, 1,584 container ship calls, and 5.18 million TEUs. As shown below, the containership fleet servicing the Port is getting newer and larger vessels that are able to transport more containers per call. The average containership density/number of TEUs per call increased from 3,272 TEUs/call to 5,260 TEUs/call. This translates to a 10% reduction in containership calls and nearly a 40% increase in the density/number of TEUs moved per call. The largest container vessel that called at the Port in 2005 was an 8,468 TEU container vessel.

Table 2.19: TEUs per vessel call in 2005 and 2001

Year	All Calls	Containership Calls	TEUs	Average TEUs/Call
2001	2,717	1,584	5,183,520	3,272
2005	2,341	1,423	7,484,625	5,260

2.7.1 Flags of Convenience

Most OGVs are foreign flagged ships, whereas harbor vessels are almost exclusively domestic. Over 95% of the OGVs that visited the Port of Los Angeles in 2005 were registered outside the U.S. Although only 5% of the individual OGVs are registered in the U.S., they comprise 11% of all calls. This is most likely because the U.S. flagged OGVs make shorter, more frequent stops along the west coast.

Figures 2.24 and 2.25 show the breakdown of the ships' registered country or flag by discrete vessel and by the number of calls, respectively.

Figure 2.24: Flag of Ship by Discrete Vessel

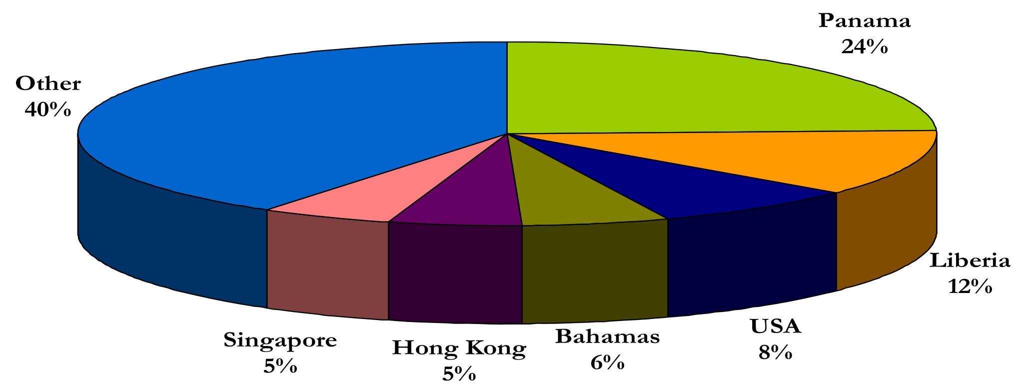
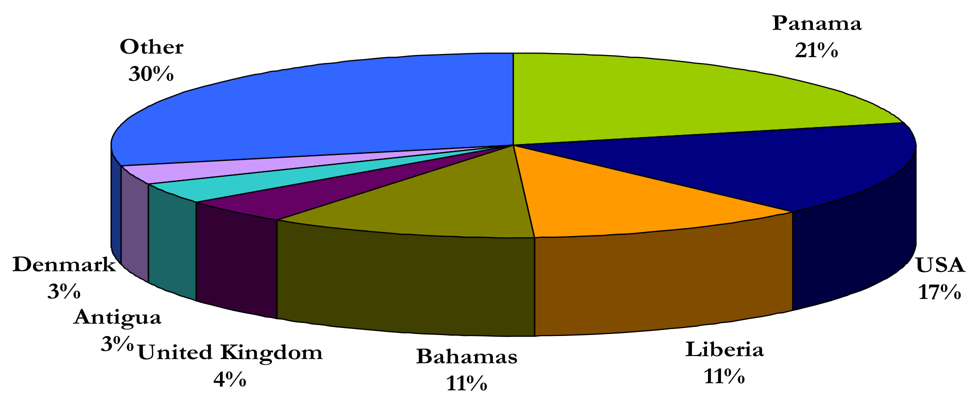


Figure 2.25: Flag of Ship by Vessel Call



2.7.2 Vessel Characteristics

Table 2.20 summarizes the vessel and engine characteristics by vessel type for the Port in 2005. The year built, deadweight, speed, and main engine power are based on the Port specific vessels that called at the Port. Due to the large number of container ships and tankers that call at the Port and their variety, the vessels were divided by vessel types. As can be seen from the data, the larger container ships are newer and faster. In addition, their deadweight and propulsion power vary by TEU class type.

Table 2.20: Vessel Type Characteristics for Vessels that Called the Port of Los Angeles in 2005

Vessel Type	Average Year Built	Average DWT (tons)	Average Speed (knots)	Main Engine Count	Main Engine Power (kW)	Auxiliary Engine Count	Auxiliary Engine Power (kW)
Auto Carrier	1991	15,923	18.7	1.0	11,445	3.0	2,822
Bulk - General	1996	48,211	14.5	1.0	9,024	3.1	1,781
Bulk - Heavy Load	1991	14,667	15.8	1.5	8,213	3.5	1,808
Bulk Wood Chips	1994	42,825	13.8	1.0	8,679	3.0	1,776
Container - 1000	1997	20,495	19.4	1.0	10,621	3.8	2,429
Container - 2000	1994	35,331	21.2	1.0	21,525	3.8	4,903
Container - 3000	1990	47,013	22.2	1.0	28,006	3.9	5,700
Container - 4000	1999	57,786	24.3	1.0	38,441	3.9	7,279
Container - 5000	2000	66,896	25.1	1.0	45,071	3.8	10,873
Container - 6000	2001	80,063	24.9	1.0	56,112	4.2	13,098
Container - 7000	2000	103,015	25.0	1.0	62,429	4.2	13,944
Container - 8000	2004	101,858	25.3	1.0	63,898	3.8	13,501
Cruise	1997	7,702	21.5	4.4	42,337	3.7	10,584
General Cargo	1992	40,834	15.2	1.0	8,425	3.2	1,859
Ocean Tug	1990	55,797	14.2	2.0	7,299	3.0	1,322
Miscellaneous	1986	53,426	14.4	1.7	7,679	3.0	1,436
Reefer	1991	10,615	19.0	1.0	9,931	4.1	3,601
RoRo	2002	18,617	20.2	1.0	19,856	2.0	2,850
Tanker - General	1997	43,818	14.9	1.1	7,241	3.3	2,110
Tanker - Chemical	1999	29,638	15.0	1.1	6,584	3.1	2,012
Tanker - Crude - Aframax	1998	103,573	14.9	1.0	13,233	3.2	2,429
Tanker - Crude - Handyboat	1994	48,660	14.4	1.3	6,885	3.3	1,861
Tanker - Crude - Panamax	1995	63,486	14.5	1.1	10,585	3.5	2,536
Tanker - Oil Products	1993	51,413	14.5	1.4	7,940	3.1	1,782

Figure 2.26: Average Year Built for Vessels that Called the Port of Los Angeles in 2005 by Vessel Type

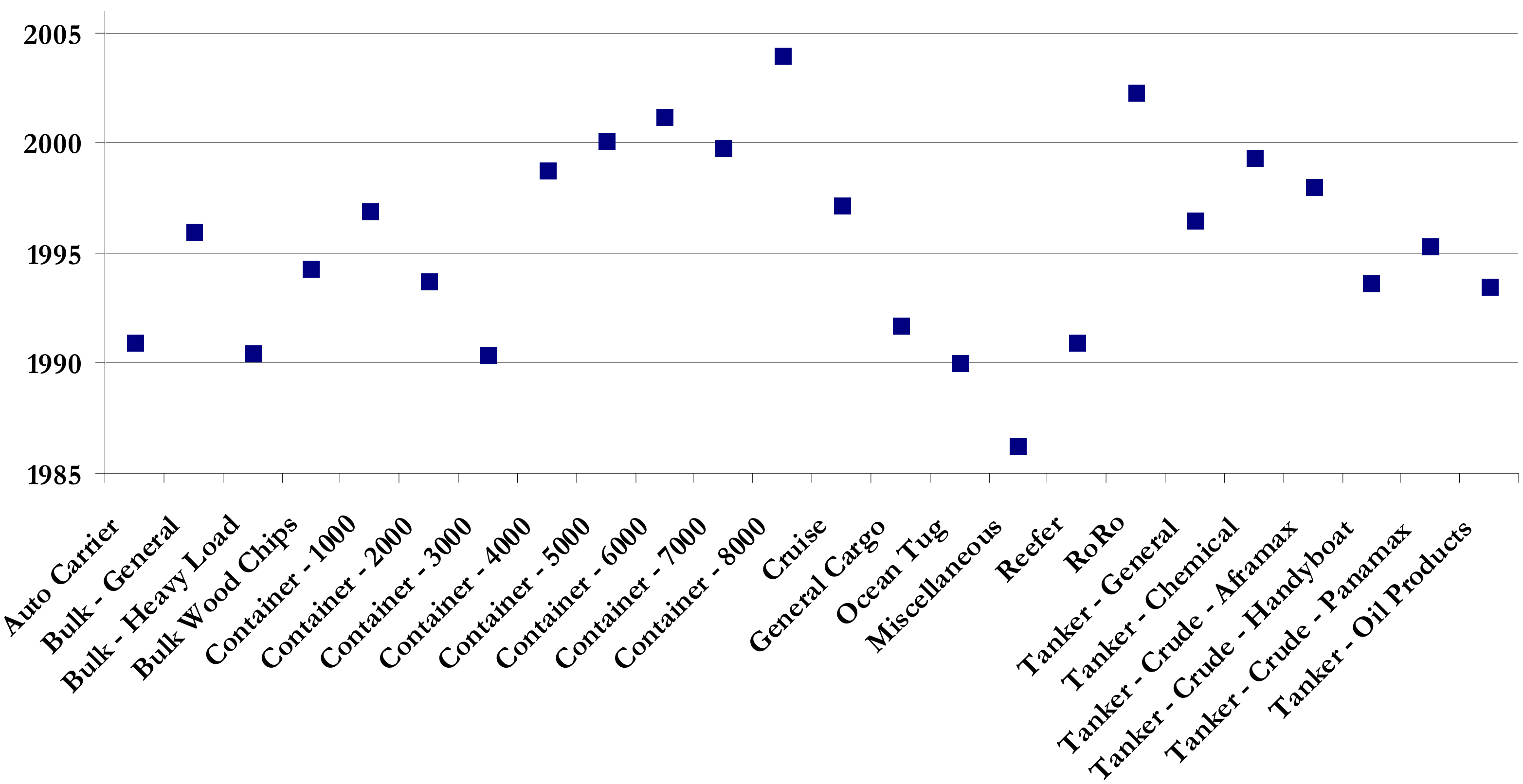


Figure 2.27: Average Deadweight Tonnage for Vessels that Called the Port of Los Angeles in 2005 by Vessel Type

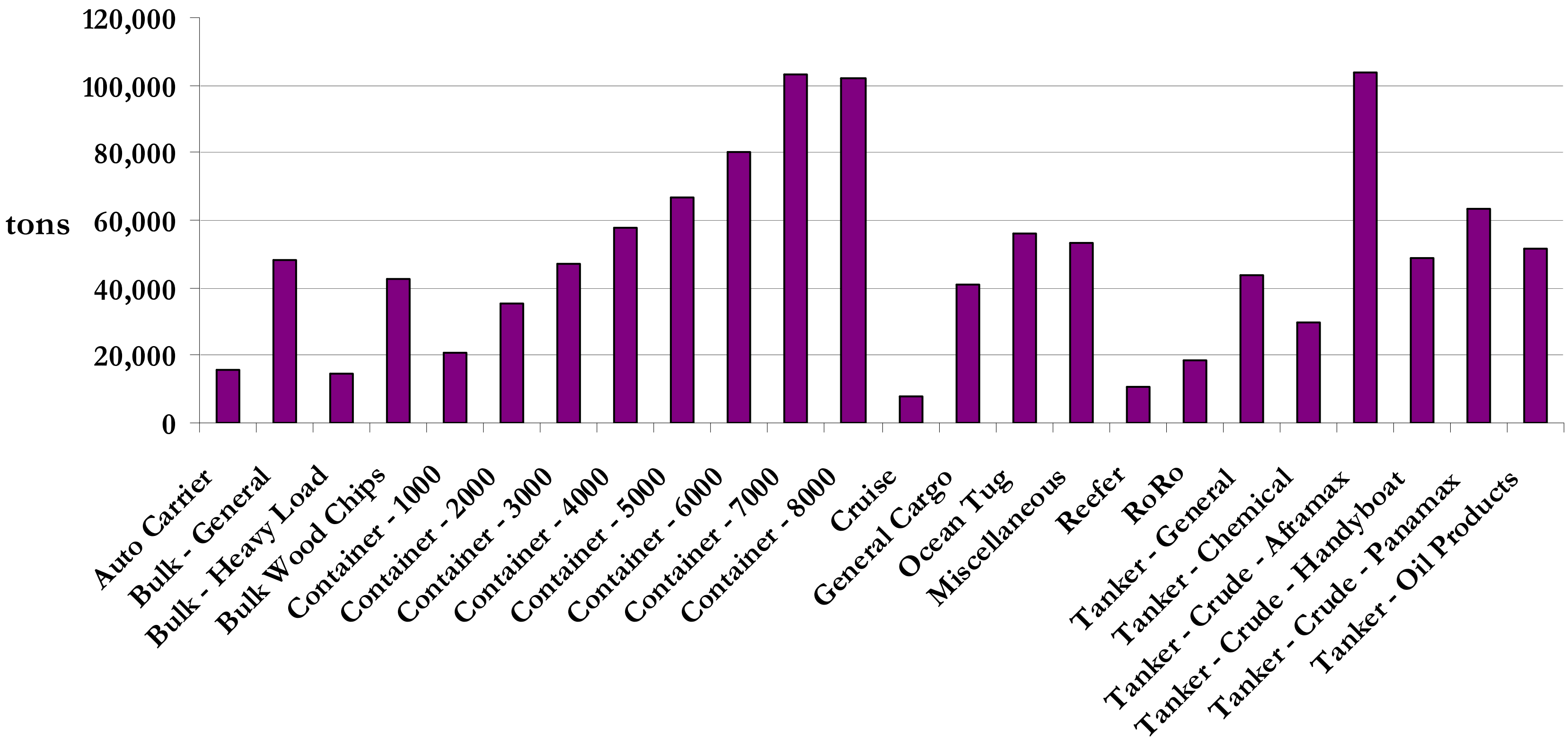


Figure 2.28: Average Main Engine Total Installed Power for Vessels that Called the Port of Los Angeles in 2005 by Vessel Type

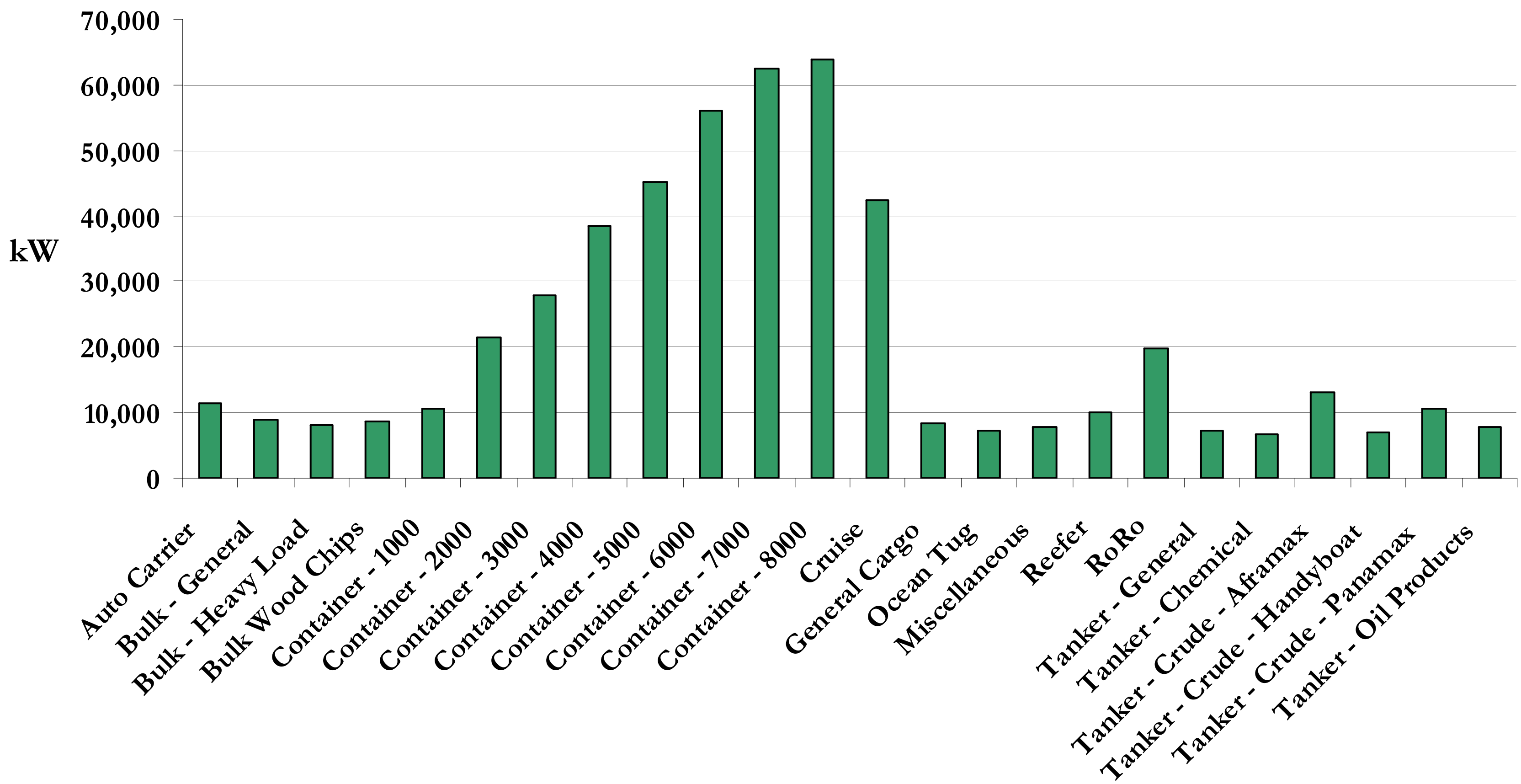
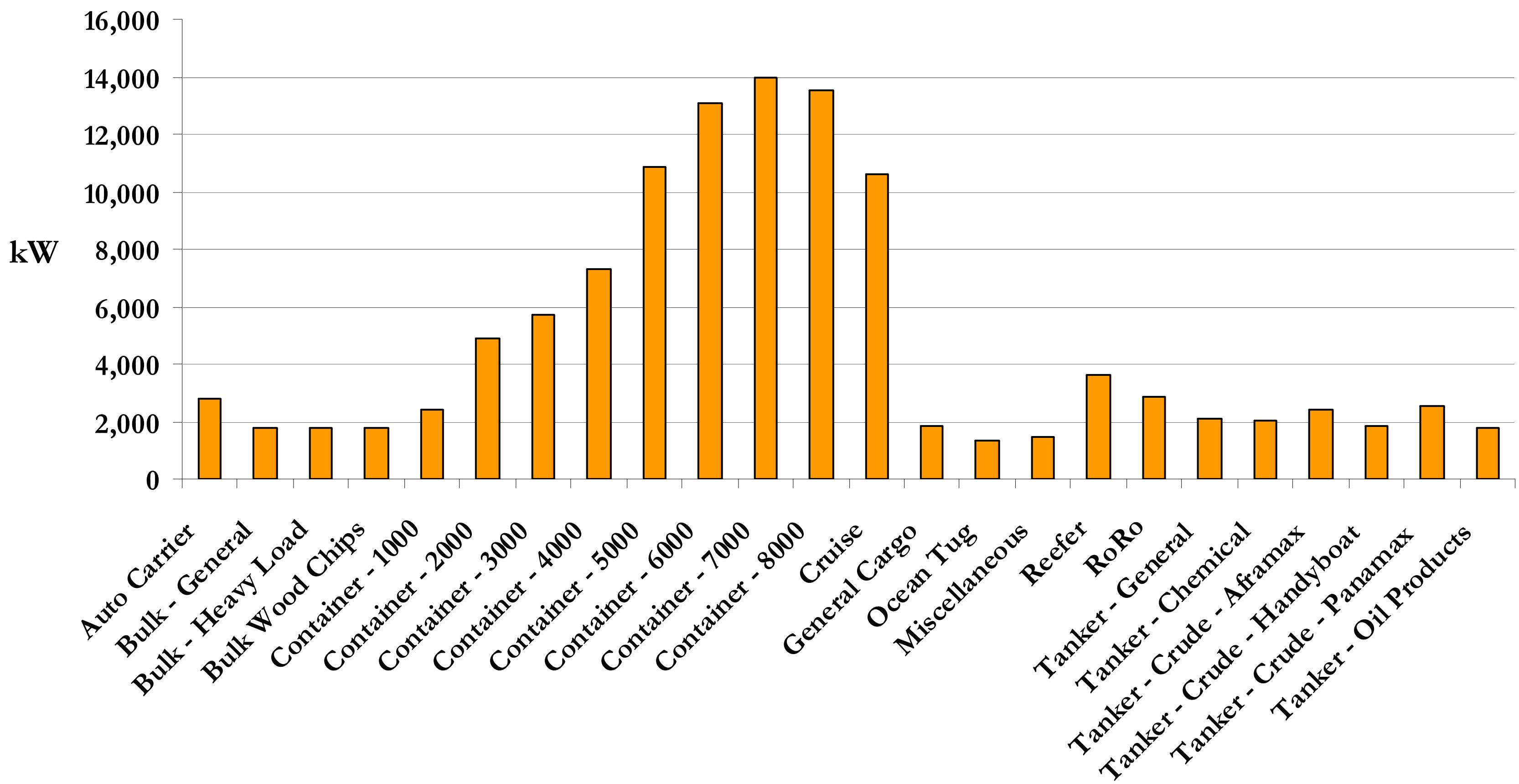


Figure 2.29: Avg. Auxiliary Engine Total Installed Power for Vessels that Called the Port of Los Angeles in 2005 by Vessel Type



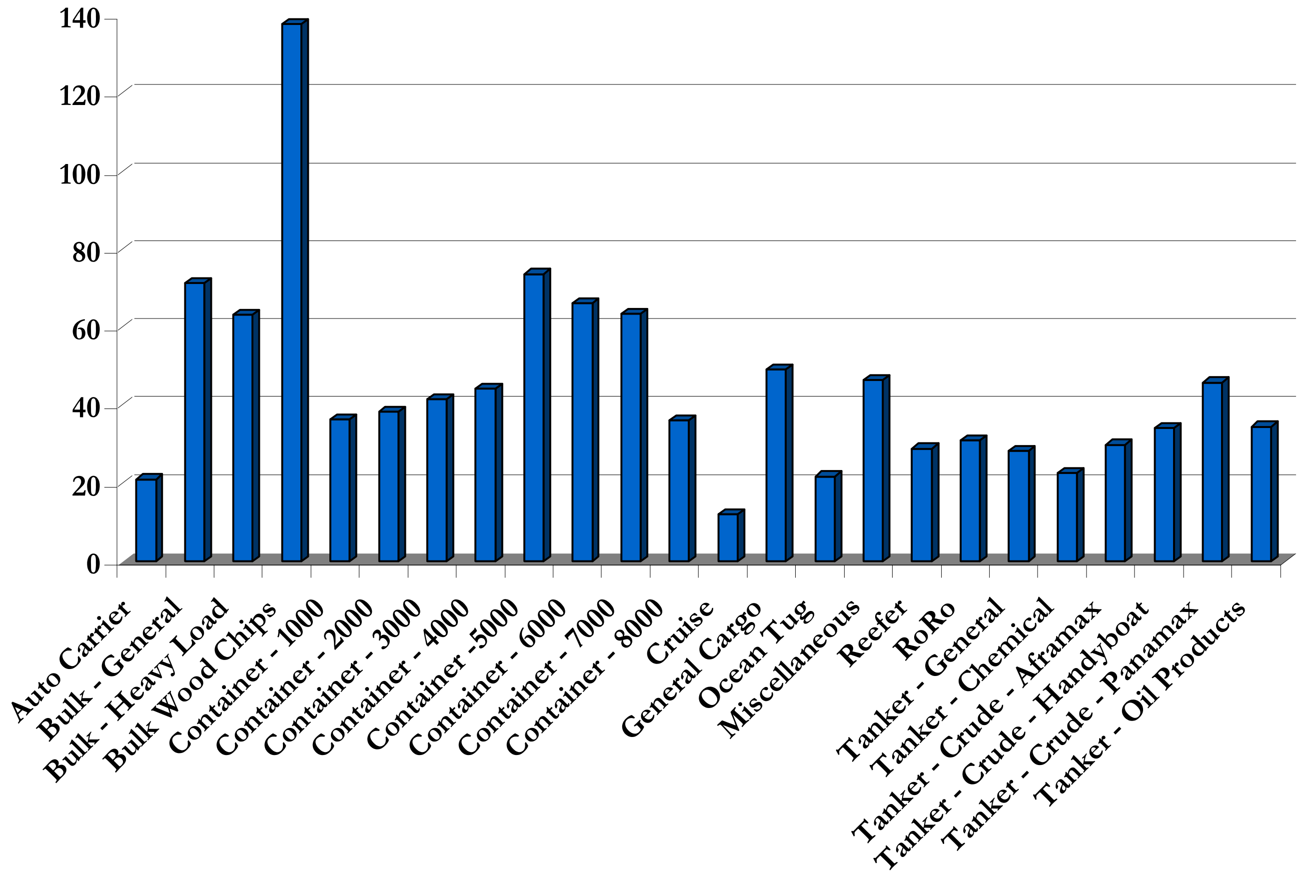
2.7.3 Hotelling Time at Berth

Table 2.21 shows the range and average of berth hotelling times, along with the number of berth calls upon which these values are based, by vessel type. Figure 2.30 shows the average hotelling times by vessel type.

Table 2.21: Hotelling Times at Berth for Vessels that Called the Port of Los Angeles in 2005 by Vessel Type

	Hotelling Time, hours		
Vessel Type	**Minimum**	**Maximum**	**Average**
Auto Carrier	8.0	74.5	21.0
Bulk - General	9.6	408.1	71.3
Bulk - Heavy Load	49.2	77.5	63.3
Bulk Wood Chips	128.5	155.3	137.9
Container - 1000	3.0	478.9	36.5
Container - 2000	10.9	79.5	38.4
Container - 3000	5.1	85.9	41.6
Container - 4000	6.8	114.4	44.2
Container -5000	11.0	130.8	73.7
Container - 6000	8.6	116.1	66.1
Container - 7000	41.3	107.1	63.5
Container - 8000	24.7	47.8	36.2
Cruise	5.1	48.7	12.1
General Cargo	3.1	199.3	49.2
Ocean Tug	7.7	53.0	21.8
Miscellaneous	13.6	123.5	46.5
Reefer	2.5	140.4	28.9
RoRo	18.8	54.7	31.1
Tanker - General	7.6	78.8	28.3
Tanker - Chemical	5.8	64.7	22.7
Tanker - Crude - Aframax	14.7	51.8	29.9
Tanker - Crude - Handyboat	12.4	68.8	34.2
Tanker - Crude - Panamax	15.9	75.5	45.9
Tanker - Oil Products	10.9	98.0	34.6

Figure 2.30: Average Hotelling Time at Berth for Vessels that Called the Port of Los Angeles in 2005, hours



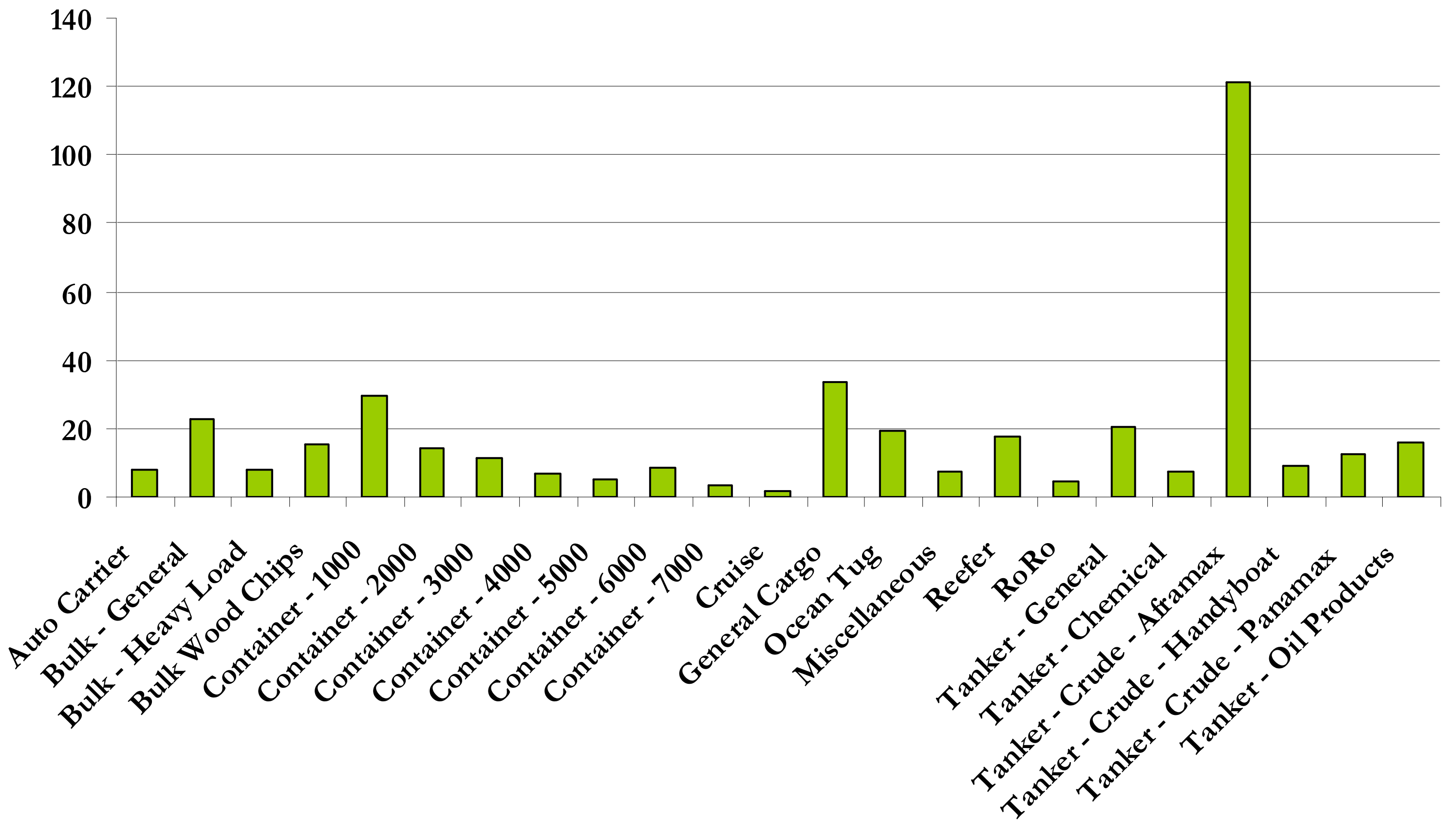
2.7.4 Hotelling Time at Anchorage

Table 2.22 shows the range and average of hotelling times at anchorage, along with the number of anchorages upon which these values are based, by vessel type. Figure 2.31 shows the average anchorage hotelling times by vessel type.

Table 2.22: Hotelling Times at Anchorage by Vessel Type

	Anchorage Hotelling Time, hours		
OGV Type	**Minimum**	**Maximum**	**Average**
Auto Carrier	3.1	28.4	7.9
Bulk - General	0.6	168.6	22.6
Bulk - Heavy Load	7.8	7.8	7.8
Bulk Wood Chips	8.8	27.4	15.6
Container - 1000	1.2	201.1	29.5
Container - 2000	0.4	45.5	14.0
Container - 3000	1.4	48.6	11.6
Container - 4000	1.1	35.3	6.7
Container - 5000	1.8	12.2	5.2
Container - 6000	3.9	12.4	8.3
Container - 7000	0.9	8.5	3.6
Cruise	1.7	1.7	1.7
General Cargo	2.8	144.3	33.4
Ocean Tug	1.7	61.3	19.3
Miscellaneous	7.3	7.3	7.3
Reefer	1.7	44.0	17.7
RoRo	4.8	4.8	4.8
Tanker - General	0.4	218.5	20.4
Tanker - Chemical	1.7	24.2	7.6
Tanker - Crude - Aframax	12.0	275.1	121.1
Tanker - Crude - Handyboat	2.1	41.1	9.3
Tanker - Crude - Panamax	3.9	37.1	12.3
Tanker - Oil Products	1.1	129.3	16.1

Figure 2.31: Average Hotelling Time at Anchorage, hours



2.7.5 Frequent Callers

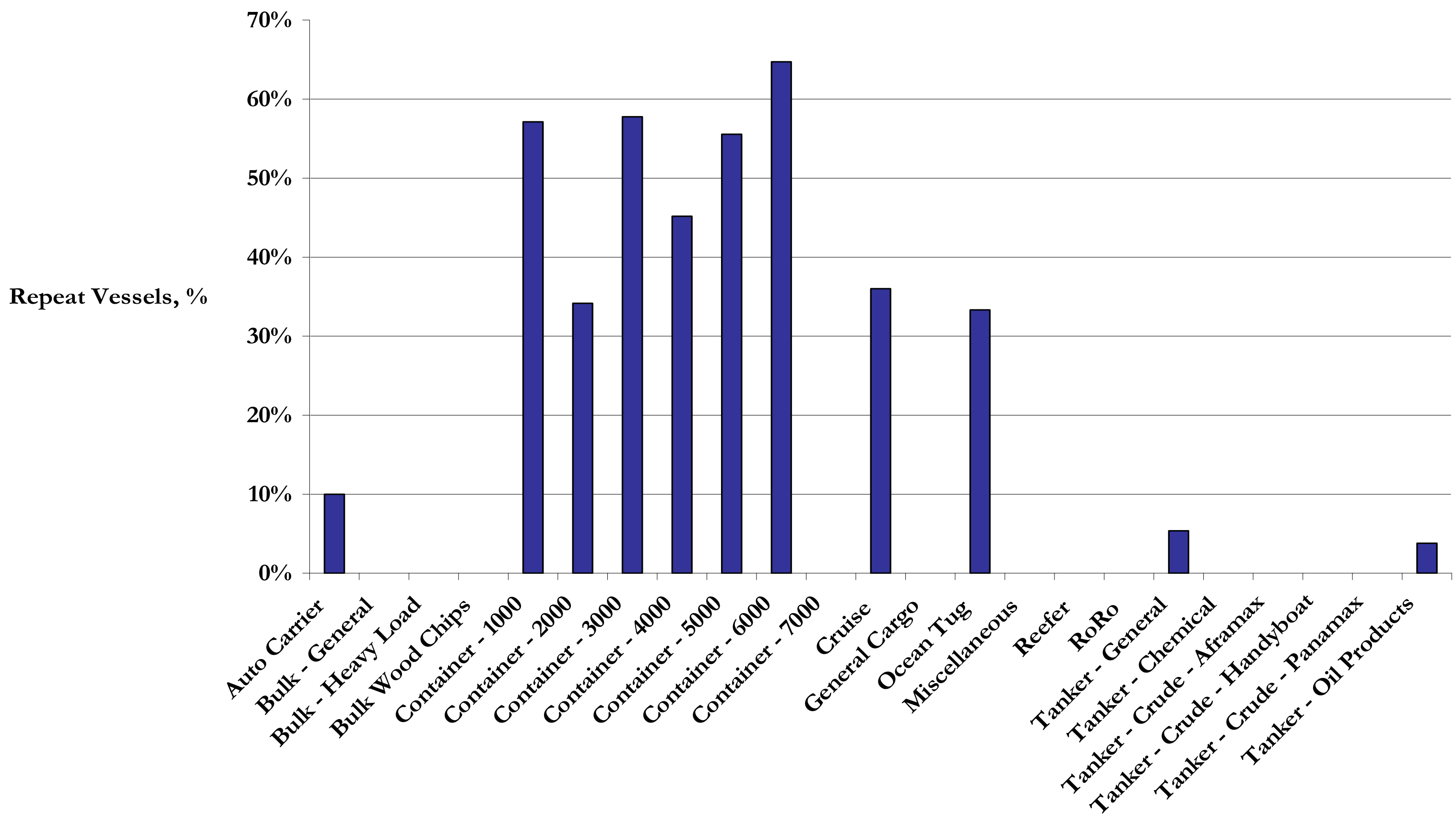
For purpose of this discussion, a frequent caller is a vessel that makes six or more calls. The vessels that made a call to a berth at the Port were included, while the vessels that only went to anchorage were not included. Table 2.23 shows the percentage of repeat vessels and repeat calls. A frequent call is the percentage of calls made by the frequent vessels.

Table 2.23: Percentage of Frequent Callers in 2005

OGV Type	Total Vessel Count	Repeat Vessels (%)	Repeat Calls (%)
Auto Carrier	30	10%	45%
Bulk - General	139	0%	0%
Bulk - Heavy Load	2	0%	0%
Bulk Wood Chips	3	0%	0%
Container - 1000	28	57%	89%
Container - 2000	41	34%	64%
Container - 3000	45	58%	82%
Container - 4000	73	45%	76%
Container - 5000	36	56%	86%
Container - 6000	17	65%	80%
Container - 7000	12	0%	0%
Cruise	25	36%	89%
General Cargo	47	0%	0%
Ocean Tug	9	33%	83%
Miscellaneous	4	0%	0%
Reefer	32	0%	0%
RoRo	3	0%	0%
Tanker - General	56	5%	22%
Tanker - Chemical	32	0%	0%
Tanker - Crude - Aframax	4	0%	0%
Tanker - Crude - Handyboat	18	0%	0%
Tanker - Crude - Panamax	9	0%	0%
Tanker - Oil Products	53	4%	43%
Total	**718**	**20%**	**56%**

Figure 2.37 shows that container vessels had the highest percentage of frequent callers in 2005, while the other vessel types (e.g., bulk vessels, general cargo, tankers, reefers, and RoRos) did not have the same vessel call at the Port six or more times.

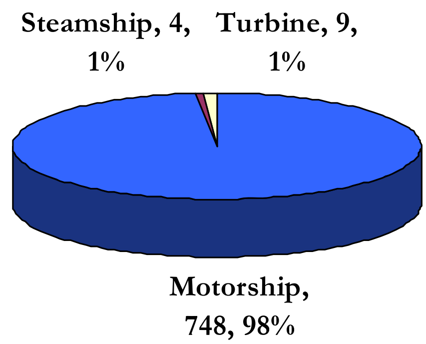
Figure 2.32: Percentage of Frequent Vessels in 2005



2.7.6 Propulsion Technology

Figure 2.33 shows that an overwhelming 98% of the 2005 vessels at the Port are motorships, the other 2% are either steamships or have turbine technology. Motorships are motor-driven and generally have diesel or diesel electric engines. Steamships are steam driven and use main boilers to produce steam which in turn drives the main and auxiliary engines. In 2005, 2 tankers and 2 small container vessels were steam driven. Cruise ships and a couple of tankers had the turbine technology.

Figure 2.33: Types of Propulsion



2.7.7 Engine Make and Model

The following are some of the main engine make and models for primarily container vessels from the VBP survey data:

- MAN B&W 6S60MC
- MAN B&W 8K80MC
- MAN B&W 9K90MC
- Sulzer 9RTA84C
- Sulzer 9RTA96C
- MAN B&W 10K90MC
- MAN B&W 10K98MC
- MAN B&W 12K90MC
- MAN B&W 12K98MC
- Sulzer 9RTA84C
- Sulzer 10RTA96C
- Sulzer 12RTA84C
- Sulzer 12RTA96C

The following are some of the auxiliary engine make and models for container vessels from the VBP survey data:

- Daihatsu 8dk28
- Daihatsu 8dk32
- Daihatsu 6dk
- MAN B&W 6L27/38
- MAN B&W 6L32
- MAN B&W 7L32/40
- MAN B&W 9L27/38
- Yanmar 8N2801
- Wartsila 6R32LN

The first value in the model is the number of cylinders (e.g., 9RTA84C is 9 cylinders). The list of engine make and model is not a complete list and is only based on the vessels surveyed during the VBP.

SECTION 3 HARBOR CRAFT

Section 3 gives an overview of the harbor craft at the Port of Los Angeles, describes the methodology used to estimate emissions, and summarizes the emission estimates for this source category. Harbor craft are commercial vessels that spend the majority of their time within or near the Port and harbor.

3.1 Source Description

The harbor craft examined in this inventory are the following vessel types:

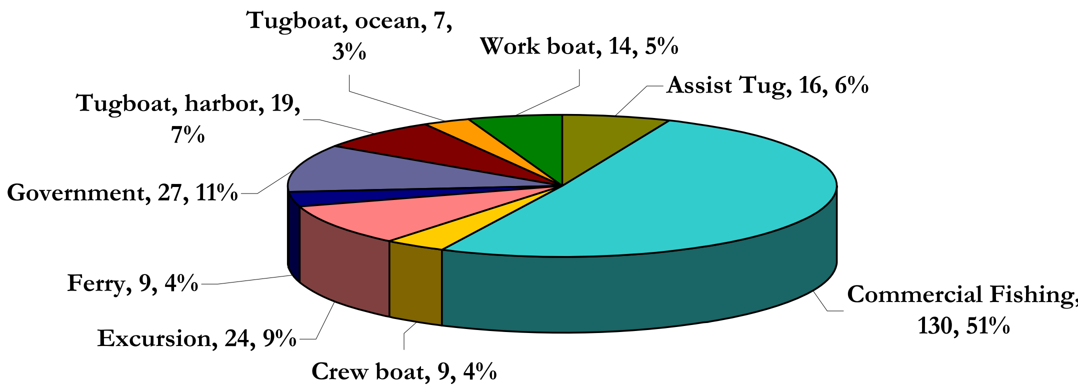
- Assist Tugboats
- Commercial Fishing Vessels
- Crew Boats
- Ferry Vessels
- Excursion Vessels
- Government Vessels
- Harbor Tugboats
- Ocean Tugboats
- Work Boats

This inventory covers harbor craft that operate in the Port of Los Angeles most of the time. 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 2005 for the Port of Los Angeles harbor only[19]. Recreational vessels are not considered to be commercial harbor craft; therefore their emissions are presented separately in this report from the overall harbor craft emissions.

Figure 3.1 presents the distribution of the 255 commercial harbor craft inventoried for the Port of Los Angeles in 2005. Commercial fishing vessels are 51% of the harbor craft inventoried, followed by the government vessels (11%), and excursion vessels (9%).

[19] This inventory should not be compared to other inventories that may cover a wider area and include vessels at nearby Ports.

Figure 3.1: Distribution of 2005 Commercial Harbor Craft for Port of Los Angeles



3.2 Data and Information Acquisition

To collect data for the harbor craft inventory, vessel owners and operators were identified and interviewed on key operating parameters. The operating parameters of interest included the following:

- Vessel type
- Number, type and horsepower (or kilowatts) of main engine(s)
- Number, type and horsepower (or kilowatts) of auxiliary engines
- Activity hours for 2005
- Information on percentage of time operating within harbor, up to 25 miles and 50 miles
- Annual fuel consumption
- Qualitative information regarding how the vessels are used in service
- Engine model year
- Replaced engines

Emission reduction strategies are included but not limited to: alternative fuels, retrofits with after-treatment, and shore power.

The following companies were contacted to collect information on their fleet:

Excursion vessels:
- L.A. Harbor Sportfishing
- 22nd St. Partners, Sportfishing
- Los Angeles Harbor Cruise
- Spirit Cruises
- Fiesta Harbor Cruises
- Seahawk Sportfishing

Commercial Fishing Vessels:
- Berth 73 and Fish Harbor, Port-owned marinas

Ferry vessels:
- Catalina Channel Express
- Seaway Co. of Catalina

Government Vessels:
- L.A. Fire Department
- L.A. Police Department
- U.S. Coast Guard
- Harbor Department
- Port of Los Angeles Pilots

Workboats:
- Clean Coastal Waters
- Pacific Tugboat Services
- Jankovich

Crewboats:
- U.S. Water Taxi
- American Marine Corp.
- Southern California Ship Services

Assist Tugboats and Harbor Tugs:
- Crowley Marine Services
- Foss Maritime Company
- Millenium Maritime
- Amnav

Harbor and Ocean Tugs:

- Sause Brothers Ocean Towing
- Westoil Marine Services
- Peninsula Tugboat Services

3.3 Operational Profiles

Commercial harbor craft companies were identified and contacted to obtain the operating parameters of their vessels. The companies provided relevant information on their vessels for this inventory and are summarized in this section.

Tables 3.1 and 3.2 summarize the main and auxiliary engine data, respectively, for each vessel type. The tables below include specific engine information from operators for those vessels included in this inventory. The averages by vessel type in these tables were used as defaults for those that had vessels with unknown model year, horsepower, or operating hours. The hours for some of the vessels that were not at the Port the full year reflect the partial time they worked in the harbor for 2005 calendar year. For those vessels with "na", there was not enough data to include a model year minimum, maximum and average for model year.

Table 3.1: Main Engine Data by Vessel Category

		Propulsion Engines								
Harbor	Number	Model year			Horsepower			Annual Operating Hours		
Vessel Type	Vessels	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Assist Tug	16	1982	2004	1997	900	3,125	2,050	150	2,290	1,509
Commercial Fishing	130	na	na	na	50	940	239	45	459	179
Crew boat	9	1966	2004	1985	210	550	347	300	1,100	750
Excursion	24	1959	2004	1995	150	530	351	350	6,600	2,150
Ferry	9	1997	2004	2001	600	2,300	1,833	750	1,200	1,115
Government	27	1963	2003	1996	24	1,800	445	25	1,200	450
Tugboat, harbor	19	1974	2005	1994	200	2,540	1,067	80	3,066	1,027
Tugboat, ocean	7	1968	2002	1988	805	2,000	1,530	50	750	260
Work boat	14	na	na	na	200	800	380	26	2,000	309

Table 3.2: Auxiliary Engine Data by Vessel Category

		Auxiliary Engines								
Harbor	Number	Model year			Horsepower			Annual Operating Hours		
Vessel Type	Vessels	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Assist Tug	16	1982	2004	1997	89	200	131	150	3,000	1,519
Commercial Fishing	130	na	na	na	10	200	74	8	149	55
Crew boat	9	1980	2003	1991	13	300	154	100	1,000	713
Excursion	24	1981	2003	1997	7	54	39	125	4,260	2,264
Ferry	9	1990	2003	1998	18	120	56	750	750	750
Government	27	na	na	na	127	400	212	50	300	158
Tugboat, harbor	19	1970	2003	1996	22	180	84	50	3,066	1,064
Tugboat, ocean	7	1968	2003	1988	60	150	93	50	750	260
Work boat	14	na	na	na	13	83	30	26	2,000	546

Table 3.3 summarizes the time spent in harbor (55%), at 25 miles out (35%) and up to the basin boundary (10%) for all harbor craft and lists it by vessel type.

Table 3.3: Spatial Allocation by Harbor Craft Type

Vessel Type	Harbor	Up to 25 Miles	Up to Basin Boundary
Assist Tug	99%	1%	0%
Commercial Fishing	10%	50%	40%
Crew Boat	52%	48%	0%
Excursion	35%	57%	13%
Ferry	38%	60%	3%
Government	80%	13%	8%
Tugboat, harbor	74%	21%	5%
Tugboat, ocean	50%	25%	25%
Work Boat	57%	43%	0%
Average	**55%**	**35%**	**10%**

3.3.1 Assist and Escort Tugboats

Assist tugboats help ships maneuver in the harbor during arrival, departure, and shifts from berth. In general, the assist tugboats escort the ships from the breakwater to the berth upon their arrival and are dismissed at the outer harbor after escorting from the berth to the breakwater upon departure. Besides escorting, assist tugboats help vessels in making turns, reducing speed, providing propulsion, and docking. Due to the unique role the assist tugboats play at the Port, the assist tugs have been separated from the towboat and tugboat categories. The emissions were calculated and presented separately from the other tugboats. Some of these tugs may also work other jobs within the harbor when not providing assist and escort to the ocean-going vessels.

The harbor assist tugboat companies operated a total of 16 diesel-powered boats. The assist tugboats had two main engines with a horsepower between 900 hp and 3,125 hp per engine. The most common main engine model found was Caterpillar 3516. Out of the sixteen assist tugboats, seven have Category 2 main engines. The annual operating hours for main propulsion engines ranged from 150 hours to 2,290 hours, with an average of 1,500 hours. The main engine model year ranged from 1982 to 2004, with an average model year of 1997. The 1997 average model year is a reflection of not only the 6% of the replaced main engines, but also from newer vessels in the fleet that had new engines.

The average assist tugboat had two 130 hp auxiliary engines used to supply on-board power, navigation systems, and air conditioning/heating for the crew. The most common type of auxiliary engine among the assist tugboats was the Caterpillar 3304. The auxiliary engines ranged from 89 hp to 200 hp. The annual hours of usage for the auxiliary engines ranged from 150 hours to 3,000 hours, with an average of 1,390 hours. The auxiliary engines model year ranged from 1982 to 2004, with an average model year of 1997. Twenty five percent of the auxiliary engines were replaced.

3.3.2 Commercial Fishing Vessels

For 2005, there are approximately 130 commercial fishing vessels at the Port of Los Angeles. These vessels mostly berth at two locations within the Port harbor, at the Fish Harbor in Terminal Island and at Berth 73. For this inventory, the method of accounting for commercial fishing vessels associated with the Port is from a list of commercial fishing vessels that pay a fee to berth at the Port. The number of commercial fishing vessels went down 50% since the 2001 baseline inventory. The reduction in commercial fishing vessels has been a trend in the area for many years. Some vessels are not replaced when damaged, others may have moved to other ports. For this inventory, there was more engine and vessel data available from the Port-funded and state repower program. Defaults were used for those vessels without any specific information. The average fishing vessel had one propulsion engine ranging from 50 hp to 940 hp, with an average 239 hp. The activity hours ranged from 45 hours to 459 hours, with an average 179 hours. Nineteen percent of the main engines were replaced.

The auxiliary engines ranged from 10 hp to 200 hp, with an average 74 hp. The annual hours of usage for auxiliary engines ranged from 8 hours to 150 hours, with an average of 55 hours. Thirty seven percent of the auxiliary engines were replaced.

3.3.3 Crew Boats

Crew boats and supply boats are used for carrying personnel and supplies to and from off-shore and in-harbor locations. They may go to vessels at anchorage, construction sites, and off-shore platforms. Nine crew boats were inventoried for 2005. Most crew boats have two main engines with a horsepower range of 210 hp to 550 hp, averaging 350 hp per engine. The annual hours of use range from 300 hours to 1,100 hours, with an average of 750 hours. The main engines model year range from 1966 to 2004, with an average model year of 1985. Sixty one percent of the crew boat main engines were replaced.

Most crew boats only have one auxiliary engine and the most prominent manufacturer was Northern Lights. The auxiliary engine power ranged from 13 hp to 300 hp, with an average of 154 hp. The annual hours of use ranged from 100 hours to 1,000 hours, with an average of 713 hours. The auxiliary engine model year ranged from 1980 to 2003, with an average model year of 1991. Forty percent of the crew boat auxiliary engines were replaced.

3.3.4 Ferry and Excursion Vessels

There are numerous excursion vessels and ferries operating at the Port of Los Angeles. The excursion vessels include the harbor cruises and the charter vessels that are for hire by the general public. Ferries were included in the same category as excursion vessels. Ferries are vessels that transport people and property to the nearby islands. There are daily ferry trips from Los Angeles to Santa Catalina Island, or Catalina, that take approximately one hour and 30 minutes to transit one way.

The excursion vessels include daily 45-minute harbor cruises, and seasonal (January through March) whale watching cruises just outside the breakwater. Some excursion boat operators have specific routes and times. In general, there are fewer excursion trips during the winter months. Charter vessels are used seasonally and the inventory includes the charter boats operated by the local charter companies based in or operating from the Port. Sport-fishing charters include half-day boat trips and overnight trips. They usually travel 25 miles from the coast for local fishing including Catalina Island or as far as 100 miles to sea to fish for tuna.

For the 24 excursion vessels inventoried, the horsepower ranged from 150 hp to 530 hp with an average 350 hp. The operating hours ranged from 350 to 6,600 hours with an average 2,150 hours. The excursion vessels main engine model year ranged from 1959 to 2004, with an average 1995 model year. Thirty percent of the excursion vessels main engines were replaced.

The horsepower of the excursion vessel auxiliary engines ranged from 7 hp to 54 hp with an average 39 hp. The operating hours ranged from 125 to 4,260 hours for excursion vessels with an average 2,264 hours. The model year for the auxiliary engines ranged from 1981 to 2003, with an average 1997 model year. Thirty eight percent of the auxiliary engines were replaced for the excursion vessels.

The nine ferry vessels inventoried for the Port of Los Angeles had an average two main engines per vessel. The horsepower ranged from 600 hp to 2,300 hp with an average 1,800 hp. The operating hours ranged from 750 to 1,200 hours with an average 1,115 hours. The ferries main engine model year ranged from 1997 to 2004, with an average 2001 model year. Ninety percent of the main engines for ferry vessels were replaced.

For ferries, the horsepower of the auxiliary engines ranged from 18 hp to 120 hp with an average 56 hp. The operating hours averaged 750 hours. The model year for the auxiliary engines ranged from 1990 to 2003, with an average 1998 model year. Seventeen percent of the auxiliary engines were replaced for the ferry vessels.

3.3.5 Government Vessels

The 27 vessels included in the inventory belong to the City of Los Angeles Fire Department and the harbor department vessels, including the two pilot boats. The vessels mostly have one main engine with horsepower ranging from 24 hp to 1,800 hp. The operating hours ranged from 25 hours to 1,200 hours with an average 450 hours. The main engine model year ranged from 1963 to 2003, with an average 1996 model year. Six percent of the main engines were replaced.

The auxiliary engines ranged in horsepower from 127 hp to 400 hp, with an average 212 hp. The operating hours ranged from 50 hours to 300 hours with an average 158 hours. Ten percent of the auxiliary engines were replaced.

3.3.6 Harbor and Ocean Tugboats

Harbor tugboats which work within the harbor moving and positioning barges and ocean (or coastal) tugboats which mainly work outside of the harbor to/from other ports are included in this category. These self-propelled vessels engage in two common operations: line haul and unit tow and may be referred to as tugboats, towboats and push-boats since they tow or push barges. Their emissions were estimated and shown together regardless of their mode of operation or how they are referred to. The ocean tugs may vary from year to year; some have a dedicated service to the port while others may only visit the port once. Most of the ocean tugs do not consider the Port of Los Angeles their home port.

Nineteen harbor tugboats worked at the Port in 2005. The vessels have two main engines, each having between 200 hp and 2,540 hp, averaging 1,067 hp. The annual hours of use ranged from 80 hours to 3,000 hours, with an average of 1,000 hours. The main engine model year ranged from 1974 to 2005, with an average 1994 model year. Twenty seven percent of the main engines were replaced.

Most harbor tugboats had two auxiliary engines with the horsepower ranging from 22 hp to 180 hp, with an average of 84 hp. The annual hours of use for auxiliary engines ranged from 50 to 3,000 hours, with an average of 1,000 hours. The auxiliary engine model year ranged from 1970 to 2003, with an average 1996 model year. Thirty five percent of the auxiliary engines were replaced.

The Marine Exchange data showed seven ocean tugs making several trips to the Port in 2005. These ocean tugs had two main engines, each having between 800 hp and 2,000 hp, averaging almost 1,530 hp. The annual hours of use ranged from 50 hours to 750 hours, with an average of 260 hours. The main engine model year ranged from 1968 to 2002, with an average 1998 model year. Forty three percent of the main engines were replaced.

The ocean tugboats had two auxiliary engines with the horsepower ranging from 60 hp to 150 hp, with an average of 93 hp. The annual hours of use for auxiliary engines ranged from 50 to 750 hours, with an average of 260 hours. The auxiliary engine model year ranged from 1968 to 2003, with an average 1988 model year. Forty three percent of the ocean tugboats' auxiliary engines were replaced.

3.3.7 Work Boats

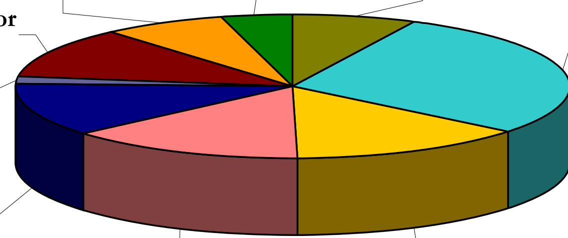
Work boats are vessels that perform numerous duties within the harbor, such as utility inspection, survey, spill/response, research, training and construction. Diving boats are used five days a week inside the harbor to survey piers and underground obstructions. Fourteen work boats were inventoried in 2005. The engine power ranged from 200 hp to 800 hp, with an average of 380 hp. The annual hours of use ranged from 26 to 2,000 hours, with an average of 300 hours. Fifteen percent of the main engines were replaced.

The auxiliary engine horsepower ranged from 13 hp to 83 hp, with an average of 30 hp and the activity hours averaged 546 hours. Twenty percent of the auxiliary engines were replaced.

3.4 Engine Replacement

Harbor vessel owners and operators were asked to identify replaced engines from their fleet. In addition to the responses from vessel owners and operators regarding replaced engines, lists for Port funded and state funded engine replacement were reviewed to ensure the inventory included the new engines. A list of South Coast vessels that replaced their engines through the Carl Moyer program and other state-funded programs was provided by CARB. About one third or 29% of all the engines in this inventory have been replaced. Figure 3.2 shows the percentage of the total number of main and auxiliary engines replaced by vessel type.

Figure 3.2: Distribution of Replaced Engines by Vessel Type



A breakdown of the main and auxiliary engines is shown in the following tables by vessel type. Table 3.4 shows 27% of the main engines in the Port of Los Angeles 2005 inventory were replaced.

Table 3.4: Count of Replaced Main Engines

	Propulsion Engines		
Harbor Vessel Type	Engine Count	Engines Repowered	Repowered Engines, %
Assist Tug	32	2	6%
Commercial Fishing	137	26	19%
Crew boat	31	19	61%
Excursion	44	13	30%
Ferry	20	18	90%
Government	35	2	6%
Tugboat, harbor	37	10	27%
Tugboat, ocean	14	6	43%
Work boat	27	4	15%
Total	**377**	**100**	**27%**

Table 3.5 shows 33% of the auxiliary engines were replaced.

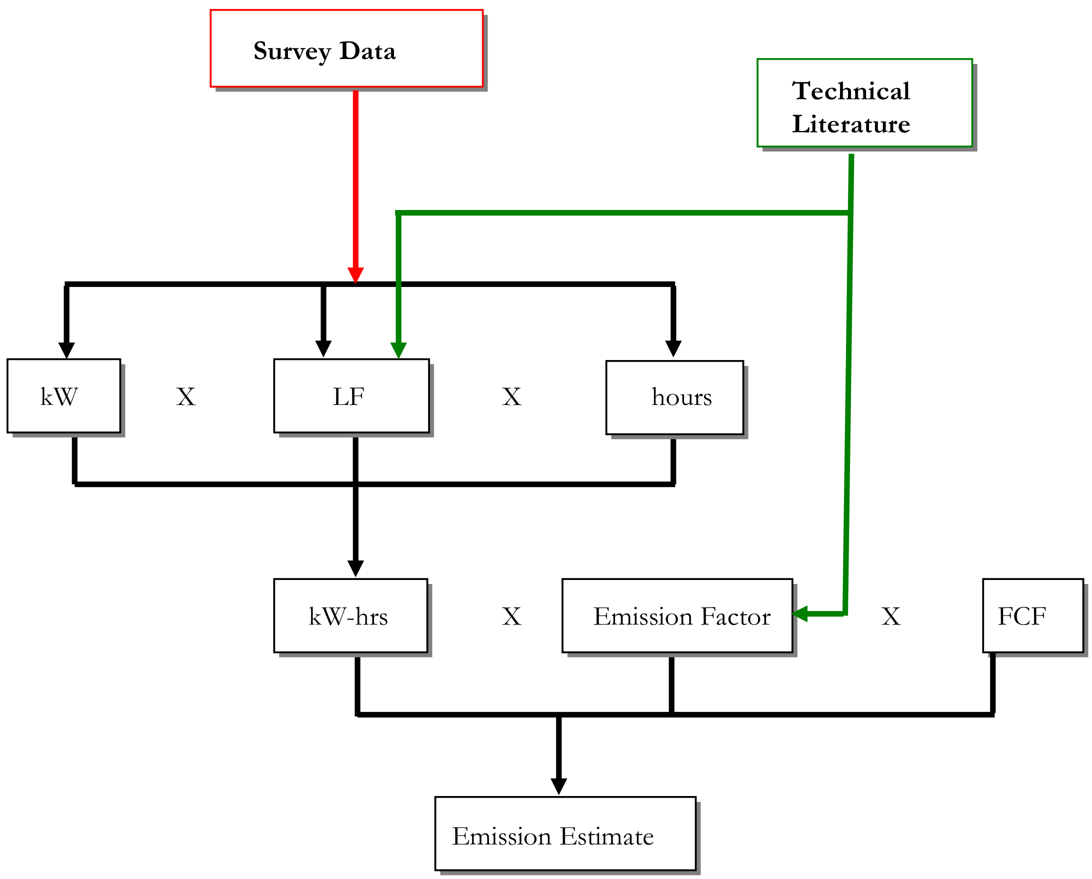
Table 3.5: Count of Replaced Auxiliary Engines

	Auxiliary Engines		
Harbor Vessel Type	**Engine Count**	**Engines Repowered**	**Repowered Engines, %**
Assist Tug	32	10	31%
Commercial Fishing	60	22	37%
Crew boat	10	4	40%
Excursion	26	10	38%
Ferry	12	2	17%
Government	10	1	10%
Tugboat, harbor	26	9	35%
Tugboat, ocean	14	6	43%
Work boat	11	3	27%
Total	**201**	**67**	**33%**

3.5 Emission Estimation Methodology

The emission factors, engine load factors, and emission equations are described in this section. The flow chart in Figure 3.3 graphically breaks down the steps taken to estimate the harbor vessel emissions. Survey data mainly includes the data collected from vessel owners for each main and auxiliary engine. Technical literature was required for the emission factors and load factors which are discussed further in this section. Emissions were estimated on a per engine basis, i.e., the main and auxiliary engines for each vessel were estimated for each vessel.

Figure 3.3: Harbor Craft Emission Estimation Flow Chart



Technical Literature - Emission factors and load factors
Survey Data - number of engines, power, LF for assist tugs only, activity hours
kW is engine power in kilowatts, LF is load factor, FCF is fuel correction factor

3.5.1 Emission Equations

The basic equation used to estimate harbor vessel emissions is:

$$E = kW \times Act \times LF \times EF \times FCF \qquad \text{Equation 3.1}$$

Where:

E = Emission, g/year
kW = Kilowatts
Act = Activity, hours/year
LF = Load Factor
EF = Emission Factor, g/kW-hr
FCF = Fuel Correction Factor

The EPA emission factors are in g/kW-hr, therefore the engine horsepower was converted to kilowatts by dividing the horsepower by 1.341 (one horsepower is equal to 0.746 kilowatts). The activity hours are annual hours of use in 2005 within the Port. Total emissions were converted to tons per year by dividing the emissions by 907,200 (which is 2,000 lb/ton x 453.6 g/lb).

3.5.2 Emission Factors

Based on the best available data to date, the following sources for emission factors were used:

- 1999 EPA *Regulatory Impact Analysis*[20] (RIA) for pre-1999 Category 1 main and auxiliary engines; and the Tier II emission standards for 2004 and above engines
- 2002 ENTEC Study[21] for Category 2/medium speed main engines
- IMO NO_X Emission Factor for model year 2000 to 2003 engines
- CARB's Pleasure Craft Exhaust Emissions Inventory[22] (PCEEI) for the recreational vessels' main and auxiliary engines

There are three categories for commercial marine vessel main propulsion engines and auxiliary engines:

- Category 1: 1-5 liters per cylinder displacement
- Category 2: 5-30 liters per cylinder displacement
- Category 3: over 30 liters per cylinder displacement

[20] EPA, 1999 *Final Regulatory Impact Analysis: Control Emissions from Compression-Ignition Marine Engines,* EPA420-R-99-026.
[21] ENTEC, 2002 *Quantification of Emissions from Ships Associated with Ship Movements between Ports in the European Community, Final Report.*
[22] ARB, 1998 *Proposed Pleasure Craft Exhaust Emissions Inventory*, MSC 98-14, Tables 3a and 3b.

The majority of the harbor craft engines falls under Category 1 engines, with the exception of some of the main engines for ocean-going tugs and assist tugboats which may have Category 2 engines. For vessels inventoried with Category 2 engines, the emission factors reported in a 2002 ENTEC study for medium speed vessels using diesel oil are used.

With the new engine standards, the engine model year plays a significant role in determining which emission factor should be used. The EPA RIA emission factors for Category 1 engines were developed specifically for commercial marine engines and are based on a blend of 1999 and older marine engines. Therefore, the EPA RIA emission factors are used for the 1999 and older Category 1 marine engines. It should be noted that CARB uses different emission factors for the pre-1999 engines in their harbor craft inventory. ARB uses the off-road emission factors, which are based on off-road engines, and applies a factor for marine engine applicability.

For engines with model year 2000 to 2003, the IMO NO_X emission factor is used. There is no engine standard for PM or other pollutants, therefore only NO_X emission factor is applied for these newer engines. For future inventories, there may be lower emission factors or reduction factors used for the other pollutants as emission tests are performed on the older and newer marine engines and emission reductions can be scientifically established.

Although the Tier II marine engines standards don't come into effect until later, the inventory shows that many of the replaced engines at the Port with a 2004 and above model year have Tier II engines. Therefore, the EPA Tier II engine standards were applied to the 2004 and 2005 engines. This may not be the case at other ports outside of California, but due to the government-funded repower programs, Tier II engines are already in use at the Port ahead of the regulations. In summary, the use of a specific emission factor is dependent on engine power, engine model year, and engine cylinder displacement. A tiered approach was used and the source of emission factors is listed in Table 3.6.

Table 3.6: Source of Emission Factors

Engine Standard	EPA Eng Category	Model Year Range	Source of Emission Factor
Tier 0	Cat 1	1999 and older	1999 EPA RIA
Tier 0	Cat 2	1999 and older	2002 Entec
Tier 1	Cat 1	2000 to 2003	1999 EPA RIA, IMO NO_X
Tier 1	Cat 2	2000 to 2003	2002 Entec, IMO NO_X
Tier 2	Cat 1	2004 and newer	1999 EPA RIA
Tier 2	Cat 2	2004 and newer	2002 Entec, 1999 EPA RIA

The emission factors used are listed in Table 3.7 for diesel-fueled main propulsion and auxiliary engines. The emission factors units are in grams per kilowatt-hour.

Table 3.7: Harbor Craft Emission Factors, g/kW-hr

	Tier 0 Engines g/kW-hr				
min. kW	**NO_X**	**CO**	**HC**	**PM**	**SO_2**
37	11.0	2.00	0.27	0.90	0.15
75	10.0	1.70	0.27	0.40	0.15
130	10.0	1.50	0.27	0.40	0.15
225	10.0	1.50	0.27	0.30	0.15
450	10.0	1.50	0.27	0.30	0.15
560	10.0	1.50	0.27	0.30	0.15
1,000	13.0	2.50	0.27	0.30	0.15
Category 2 engines	13.20	1.10	0.50	0.72	0.15
	Tier 1 Engines g/kW-hr				
min. kW	**NO_X**	**CO**	**HC**	**PM**	**SO_2**
37	9.8	2.00	0.27	0.90	0.15
75	9.8	1.70	0.27	0.40	0.15
130	9.8	1.50	0.27	0.40	0.15
225	9.8	1.50	0.27	0.30	0.15
450	9.8	1.50	0.27	0.30	0.15
560	9.8	1.50	0.27	0.30	0.15
1,000	9.8	2.50	0.27	0.30	0.15
Category 2 engines	9.8	1.10	0.50	0.72	0.15
	Tier 2 Engines g/kW-hr				
min. kW	**NO_X**	**CO**	**HC**	**PM**	**SO_2**
37	6.8	5.00	0.27	0.40	0.15
75	6.8	5.00	0.27	0.30	0.15
130	6.8	5.00	0.27	0.30	0.15
225	6.8	5.00	0.27	0.30	0.15
450	6.8	5.00	0.27	0.30	0.15
560	6.8	5.00	0.27	0.30	0.15
1,000	6.8	5.00	0.27	0.30	0.15
Category 2 engines	9.8	5.00	0.50	0.72	0.15

The CO emission factor for Tier 0 and Tier 1 was reconstructed from the ENTEC appendices because they are not explicitly stated in the text. They were confirmed with IVS Swedish Environmental Research Institute Ltd. The CO emission factor for Tier II is from the same EPA RIA source as the NO_X EF, and it increases in CO for the new engines.

EPA's list of emission factors did not include a SO_x emission factor, so one was estimated based on the sulfur content of the EPA onroad diesel fuel which has an average 350 ppm sulfur content. The emission factor for SO_x from diesel-powered engines was estimated to be 0.15 g/kW-hr.

The emission factor for SO_x was estimated using the following calculation:

Calculation 3.1

$$\frac{350 \text{ g S}}{1{,}000{,}000 \text{ g fuel}} \times \frac{210 \text{ g fuel}^{23}}{\text{kW-hr}} \times \frac{2 \text{ g } SO_x}{\text{g S}} = 0.15 \text{ g } SO_x/\text{kW-hr}$$

3.5.3 Fuel Correction Factors

Fuel correction factors were used to take into account the use of CARB on-road diesel fuel by most harbor craft vessels and the ULSD used by the Port-owned harbor craft and government vessels, such as USCG, police department and fire department vessels in 2005. Fuel correction factors used for NO_X, HC, and PM take into account California diesel fuel which is different from EPA diesel fuel. In 2005, California or CARB on-road diesel fuel averaged 130 ppm sulfur content; therefore, a ratio 130 ppm and 350 ppm was used for the CARB on-road FCF for SO_x. For the ULSD, a ratio of 15 ppm (ULSD fuel sulfur content) and 350 ppm (onroad fuel sulfur content) was used. There is no hydrocarbon correction factor between ULSD and EPA on-road diesel. Table 3.8 summarizes the fuel correction factors used for harbor craft.

Table 3.8: Fuel Correction Factors

Fuel Reduction	NO_X	CO	HC	PM	SO_x
CARB On-road diesel	0.93	1	0.72	0.75	0.37
ULSD	0.93	1	0.72	0.72	0.043

[23] ENTEC, 2002 *Quantification of Emissions from Ships Associated with Ship Movements between Ports in the European Community, Final Report.*

3.5.4 Engine Load Factors

Engine load factor represents the load applied to an engine or the percent of rated engine power that is applied during the engine's operation. Depending on the duration period that is being estimated, the load factor can represent the hourly average, daily average, or annual average load applied to an engine while it is operating. Table 3.9 summarizes the average engine load factors that were used in this inventory for the various harbor vessel types for their propulsion and auxiliary engines.

Table 3.9: Engine Load Factors

Harbor Vessel Type	Engine LF
Assist Tug	0.31
Commercial Fishing	0.27
Crewboat	0.45
Excursion	0.76
Ferry	0.76
Government	0.51
Tugboat, harbor	0.68
Tugboat, ocean	0.68
Workboat	0.45
Auxiliary engines	0.43

The 31% engine load factor for assist tugboats is based on actual vessel engine load readings published in the 2001 POLA Port-wide Baseline Air Emissions Inventory (PWBAEI). In order to use similar methodology to ARB, the load factors listed in CARB's Carl Moyer Program Guidelines[24] are used for tugboats, commercial fishing vessels, crew boats, ferries, excursion vessels, and government vessels. The 43% engine load factor used for the auxiliary engines is obtained from the EPA NONROAD model[25] which used some direct measurements and has been used in previous studies[26].

[24] ARB, "Carl Moyer Program Guidelines", Part IV, 17 Nov 2005.

[25] EPA, "Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling", EPA 420-P-02-014.

[26] ERG and Starcrest Consulting Group, "Update to the Commercial Marine Inventory for Texas to Review Emission Factors, Consider a Ton-mile EI Method, and Revise Emissions for the Beaumont-Port Arthur Non-Attainment Area", January 2004.

3.6 Emission Estimates

Table 3.10 summarizes the estimated emissions harbor craft vessels by vessel type and engine type. The harbor vessel inventory list can be found in Appendix B.

Table 3.10: 2005 Commercial Harbor Craft Emissions by Engine Type

Vessel Type	Engine Type	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC
Assist Tug	Auxiliary	0.7	0.6	0.7	19.4	0.1	4.4	0.4
	Propulsion	9.0	8.3	9.0	283.8	1.4	53.7	5.5
Assist Tug Total		**9.7**	**8.9**	**9.7**	**303.2**	**1.5**	**58.1**	**5.9**
Commercial Fishing	Auxiliary	1.3	1.2	1.3	24.0	0.1	7.4	0.5
	Propulsion	3.6	3.3	3.6	116.2	0.7	22.1	2.5
Commercial Fishing Total		**5.0**	**4.6**	**5.0**	**140.3**	**0.8**	**29.5**	**3.0**
CrewBoat	Auxiliary	0.2	0.1	0.2	4.3	0.0	0.7	0.1
	Propulsion	0.7	0.7	0.7	23.5	0.1	6.0	0.5
Crewboat Total		**0.9**	**0.8**	**0.9**	**27.7**	**0.2**	**6.8**	**0.6**
Excursion	Auxiliary	0.6	0.6	0.6	8.9	0.1	1.9	0.2
	Propulsion	5.4	5.0	5.4	208.8	1.2	37.7	4.5
Excursion Total		**6.1**	**5.6**	**6.1**	**217.6**	**1.3**	**39.5**	**4.7**
Ferry	Auxiliary	0.1	0.1	0.1	1.7	0.0	0.3	0.03
	Propulsion	5.8	5.4	5.8	200.4	1.4	101.9	5.0
Ferry Total		**5.9**	**5.4**	**5.9**	**202.1**	**1.4**	**102.2**	**5.1**
Government	Auxiliary	0.0	0.0	0.0	0.8	0.0	0.1	0.02
	Propulsion	0.7	0.7	0.7	29.6	0.0	5.4	0.6
Government Total		**0.7**	**0.7**	**0.7**	**30.4**	**0.0**	**5.5**	**0.6**
Ocean Tug	Auxiliary	0.1	0.1	0.1	1.3	0.0	0.3	0.0
	Propulsion	1.1	1.0	1.1	39.4	0.2	6.3	0.6
Ocean Tug Total		**1.2**	**1.1**	**1.2**	**40.7**	**0.2**	**6.5**	**0.7**
Tugboat	Auxiliary	0.4	0.4	0.4	7.8	0.0	1.7	0.2
	Propulsion	8.0	7.4	8.0	270.5	1.4	44.4	5.0
Tugboat Total		**8.4**	**7.8**	**8.4**	**278.4**	**1.4**	**46.1**	**5.2**
WorkBoat	Auxiliary	0.1	0.1	0.1	1.4	0.0	0.3	0.0
	Propulsion	0.4	0.4	0.4	17.4	0.1	2.8	0.4
WorkBoat Total		**0.5**	**0.5**	**0.5**	**18.8**	**0.1**	**3.1**	**0.4**
Harbor Vessel Total		**38.4**	**35.3**	**38.4**	**1,259.2**	**7.0**	**297.5**	**26.1**

Figures 3.4 through 3.6 present the distribution of DPM, NO_x and SO_x emissions by vessel type, respectively.

Figure 3.4: DPM Emissions by Vessel Type, tpy

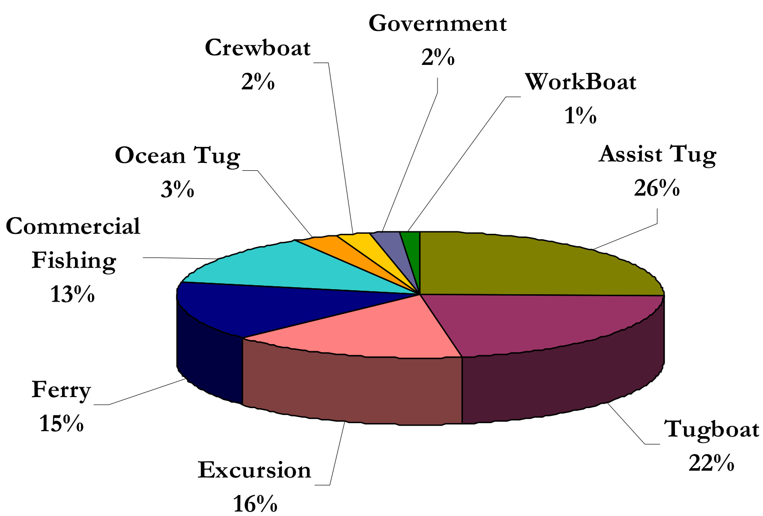


Figure 3.5: NO_x Emissions by Vessel Type, tpy

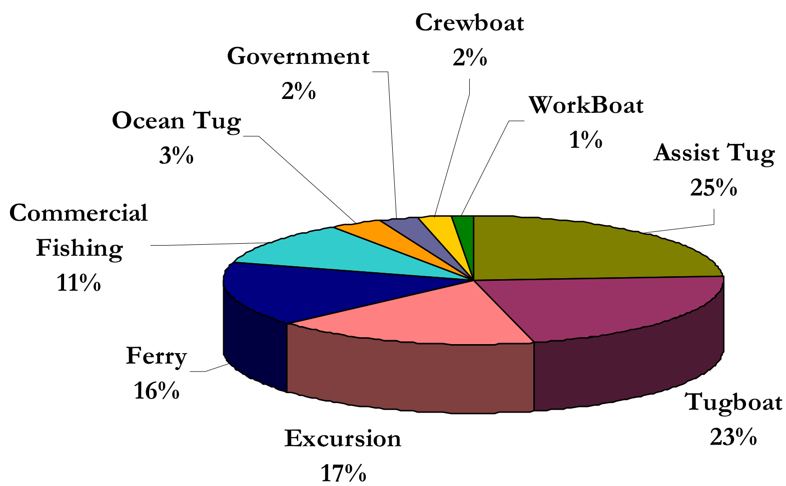


Figure 3.6: SO_x Emissions by Vessel Type, tpy

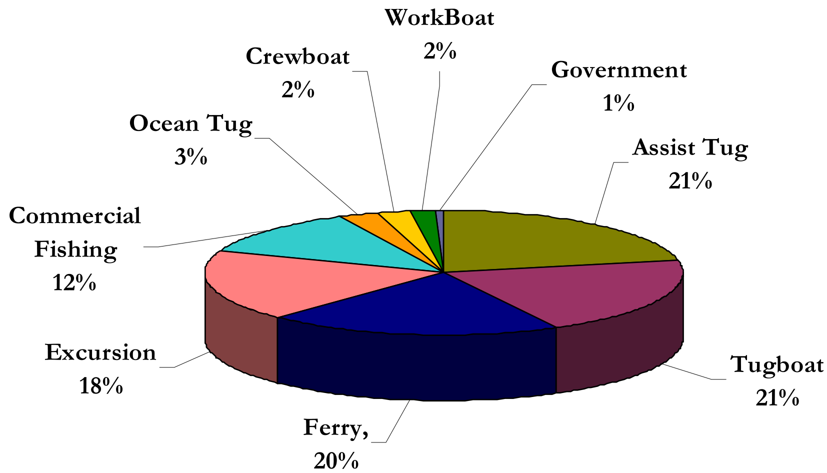
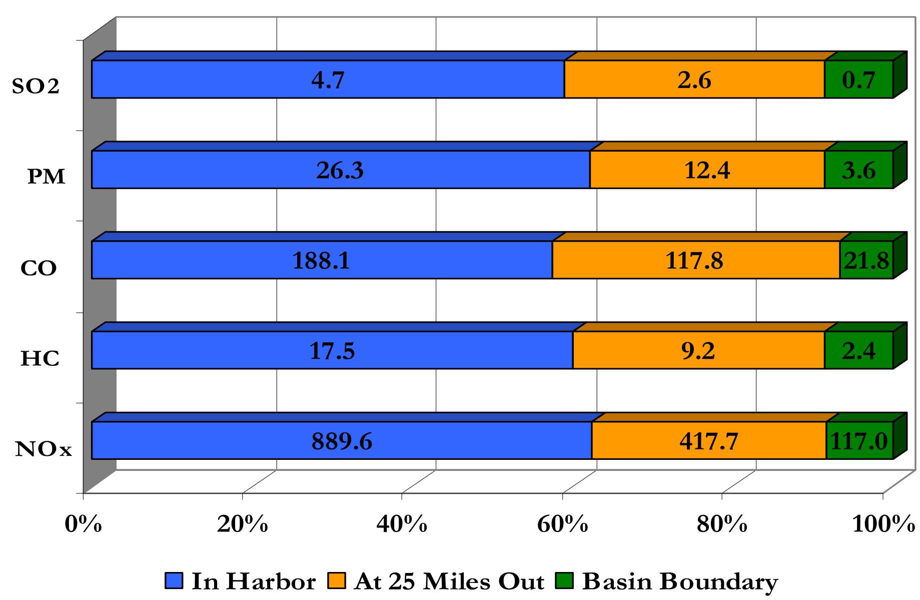


Figure 3.7 depicts the harbor craft emissions within the Port harbor, within the breakwater and up to 25 miles out, and to the basin boundary. Roughly 55% to 60% of the emissions occur within the harbor.

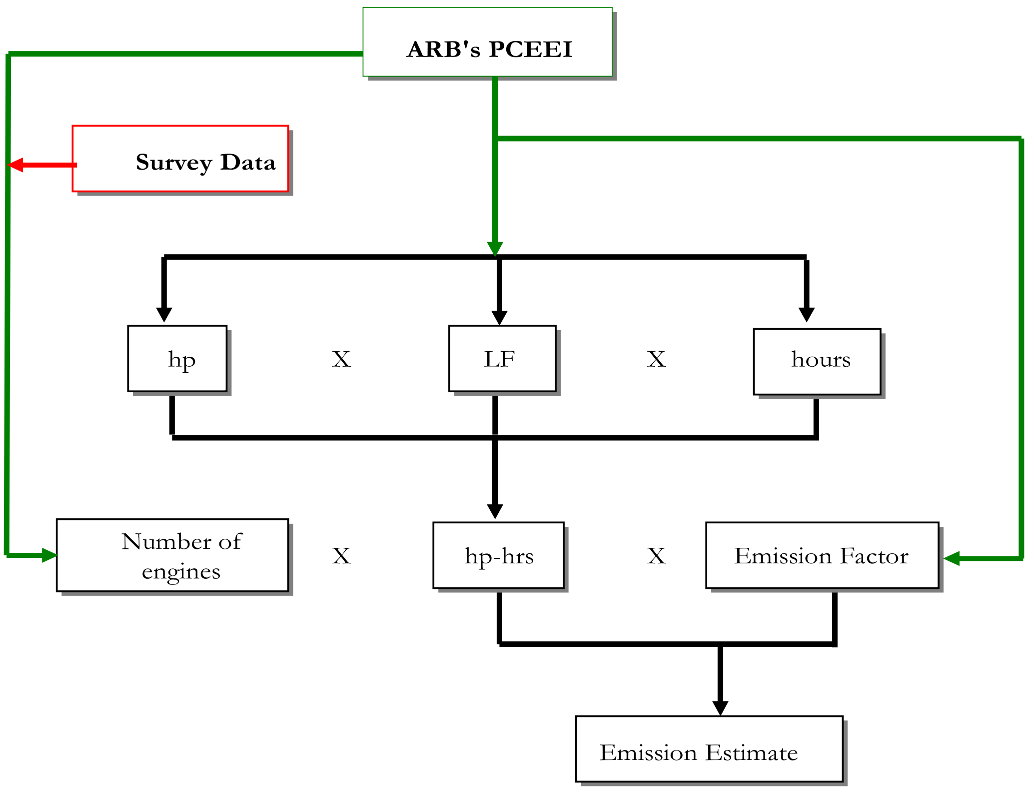
Figure 3.7: Spatial Emissions, tpy



3.7 Recreational Vessels

As previously mentioned, the recreational vessels are not considered commercial harbor vessels and their emissions estimate methodology and results are provided in this separate subsection. The recreational vessel estimation methodology and number of vessels did not change from the baseline inventory for recreational vessels. The flow chart in Figure 3.8 graphically summarizes the steps taken to estimate recreational vessel emissions as discussed above.

Figure 3.8: Recreational Vessel Emission Estimation Flow Chart



ARB's PCEEI - Avg horsepower, activity hours, load factor, % of types of engines
Survey Data - number of recreational vessels at Port, type of fuel used for SO_2 EF

Using data from the ARB PCEEI, Table 3.11 below summarizes the load factors, average horsepower, hours of operation, and emission factors used for the 2005 Port inventory. 'G2' is 2-stroke gasoline engine, 'G4' is 4-stroke gasoline engine, and 'D' is for diesel engine. The recreational vessels' engine load factors are from CARB's PCEEI, Attachment D.

Table 3.11: Average LF, HP, Hours, and EF for Recreational Vessel

Vessel Type		POLA Population	LF	HP (avg.)	Hours (avg. annual)	Total (hp-hrs)	NO_x EF (g/bhp-hr)	CO EF (g/bhp-hr)	HC EF (g/bhp-hr)	PM EF (g/bhp-hr)	SO_2 EF (g/bhp-hr)	SO_2 EF (g/kW-hr)
Vessels w/Outboard Engines	G2	1,656	21%	95	48	1,586,129	1.1	213	107	7.1	0.04	0.05
Sailboat Auxiliary Outboard Engines	G2	26	32%	27	10	2,250	1.1	215	107	7.1	0.04	0.05
Vessels w/Inboard Engines	G4	355	21%	211	93	1,461,594	5.4	151	9.1	0.07	0.02	0.03
Vessels w/Outboard Engines	G4	80	21%	36	48	29,160	5.4	151	9.1	0.07	0.02	0.03
Vessels w/Sterndrive Engines	G4	1,006	21%	211	73	3,254,300	5.4	151	9.1	0.07	0.02	0.03
Sailboat Auxiliary Inboard Engines	G4	20	32%	27	10	1,698	5.4	151	9.1	0.07	0.02	0.03
Vessels w/Inboard Jet Engines	G4	137	21%	211	73	441,764	5.4	151	9.1	0.07	0.02	0.03
Vessels w/Inboard Engines	D	61	21%	211	88	238,422	11.3	4.7	2.6	0.34	0.11	0.15
Sailboat Auxiliary Inboard Engines	D	52	32%	27	10	4,502	11.3	4.7	2.6	0.34	0.11	0.15
Totals		**3,393**										

Table 3.12: 2005 Recreational Vessel Emissions

Vessel Type		NO_x (tpy)	CO (tpy)	HC (tpy)	PM_{10} (tpy)	$PM_{2.5}$ (tpy)	DPM (tpy)	SO_2 (tpy)
Vessels w/Outboard Engines	G2	1.92	372.40	187.08	12.41	11.42	0.00	0.06
Sailboat Auxiliary Outboard Engines	G2	0.003	0.53	0.27	0.02	0.02	0.00	0.0001
Vessels w/Inboard Engines	G4	8.70	243.28	14.66	0.11	0.10	0.00	0.03
Vessels w/Outboard Engines	G4	0.17	4.85	0.29	0.00	0.00	0.00	0.001
Vessels w/Sterndrive Engines	G4	19.37	541.67	32.64	0.25	0.23	0.00	0.07
Sailboat Auxiliary Inboard Engines	G4	0.01	0.28	0.02	0.0001	0.0001	0.00	0.00004
Vessels w/Inboard Jet Engines	G4	2.63	73.53	4.43	0.03	0.03	0.00	0.01
Vessels w/Inboard Engines	D	2.97	1.24	0.68	0.09	0.08	0.09	0.03
Sailboat Auxiliary Inboard Engines	D	0.06	0.02	0.01	0.00	0.002	0.002	0.001
Totals		**35.8**	**1,237.8**	**240.1**	**12.9**	**11.9**	**0.1**	**0.2**

3.8 Findings and Facts

Some of the main observations that can be made between 2005 and 2001 are:

- Approximately 1/3 of the engines in the inventory were replaced
- As a result of replacement, there are cleaner and more fuel efficient engines
- The commercial fishing vessel count went down by 50% in the 2005 inventory
- Oxides of sulfur emissions are considerably lower, about 90%, due to the use of CARB on-road diesel fuel and ULSD by government vessels
- Although the vessel count may have stayed the same for some of the vessel types, harbor craft were added and dropped from the harbor companies' local fleets as new arrivals came and other vessels left the area.

3.9 Differences in Methodology

Differences in methodology between the 2005 and 2001 inventories are:

- Many of the load factors in 2005 EI changed to be more consistent with CARB's load factors
- The number of ocean tugs are based on 2005 Marine Exchange in order to only include those tugs that made calls at the Port

Differences in methodology between the 2005 EI and CARB harbor craft inventory are:

- CARB uses OFFROAD model emission factors that are adjusted for marine cycles
- The Port uses EPA RIA emission factors for unregulated Tier 0 marine engines
- CARB may include vessels not associated with the Port of Los Angeles and therefore vessel and repower count will not match when compared

SECTION 4 CARGO HANDLING EQUIPMENT

This section discusses the Port facilities and the CHE identified through the inventory process. This section also describes the emission estimate methodology and the results for this source category.

4.1 Source Description

Cargo handling equipment includes equipment used to move cargo (containers, general cargo, and bulk cargo) to and from marine vessels, railcars, and on-road trucks. The equipment typically only operates at marine terminals or at rail yards and is assumed not to operate on public roadways or lands. This inventory includes cargo handling equipment of 25 hp or greater using diesel, gasoline, or alternative fuels. Due to the diversity of cargo, there is a wide range of equipment types. The majority of the equipment can be classified into one of the following equipment types:

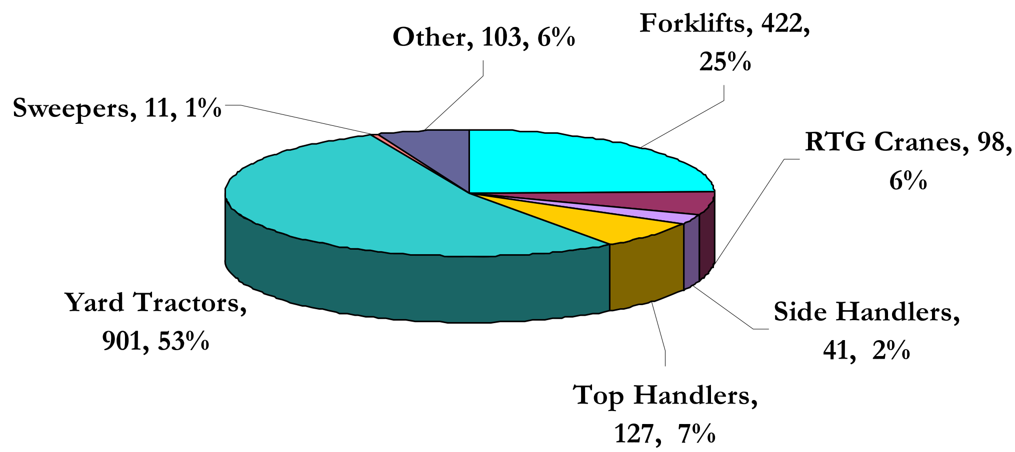
- Forklift
- Rubber tired gantry (RTG) crane
- Side handler
- Sweeper
- Top handler
- Yard tractor
- Other

The "other" category contains the following list of equipment:

- Bulldozer
- Dump Truck
- Excavator
- Fuel Truck
- Loader
- Man Lift
- Rail Pusher
- Roller
- Skid Steer Loader
- Truck (propane, utility, water, vacuum)

Figure 4.1 presents the distribution of the 1,703 pieces of equipment inventoried at the Port for 2005. Out of the equipment inventoried at all Port facilities for 2005, 53% were yard tractors, 25% were forklifts, seven percent were top handlers, six percent were RTG cranes, two percent were side handlers and six percent were other equipment (not typical cargo handling equipment).

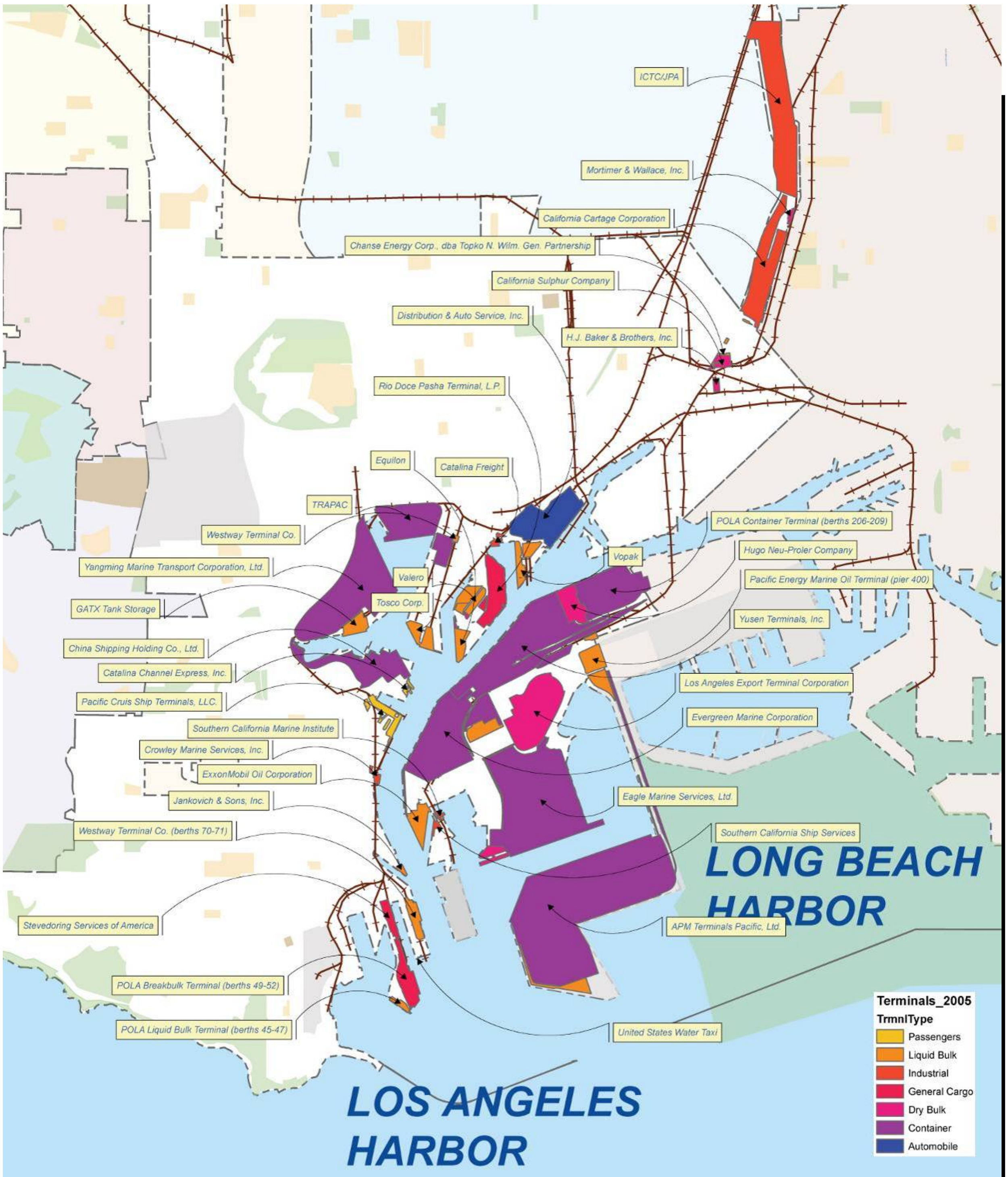
Figure 4.1: Distribution of 2005 Port CHE by Equipment Type



4.2 Geographical Delineation

The 2005 EI for CHE includes container terminals; dry bulk and break bulk terminals; liquid bulk terminals; auto terminal, cruise ship terminal; UP Intermodal Container Transfer Facility (ICTF); and smaller facilities located within Port boundaries. Figure 4.2 presents a map illustrating the geographic boundaries of the CHE EI.

Figure 4.2: CHE EI Geographic Boundaries



Following is the list of the terminals, by cargo type, inventoried in 2005:

Container Terminals:

- Berth 100: West Basin Container Terminal (China Shipping)
- Berths 121-131: West Basin Container Terminal
- Berths 136-139: Trans Pacific Container (Trapac) Container Terminal
- Berths 212-225: Yusen Container Terminal
- Berths 226-236: Seaside Terminal (Evergreen)
- Berths 302-305: APL Terminal (Global Gateway South)
- Berths 401-406: APM Terminals (Pier 400)

Break-Bulk Terminals:

- Berths 49-53, 87-89, 153-155 and 174-181: Pasha Stevedoring and Terminals
- Berths 54-55: Stevedore Services of America (SSA)
- Berths 153-155: Crescent Warehouse Company
- Berths 210-211: Hugo Neu-Proler Company
- Berth 301: Los Angeles Export Terminal (LAXT)

Dry Bulk Terminals:

- BP Wilmington Calciner
- California Sulfur
- LA Grain
- Berths 165-166: U.S. Borax

Liquid Terminals:

- Berths 70-71: Westway
- Berths 118-119: Kinder Morgan
- General Petroleum
- Berths 187-191: Vopak
- Berths 167-169: Equillon/Shell Oil
- Berths 238-240: ExxonMobil
- Berths 148-151: ConocoPhillips
- Ultramar/Valero

Auto Terminals:

- Berths 195-199: WWL Vehicle Services Americas (formerly DAS)

Passenger Terminals:

- Berths 91-93: Pacific Cruise Ship Terminals (PCST)

Other Facilities:

- Al Larson
- Union Pacific Intermodal Containers Transfer Facility (ICTF)
- Cal Cartage
- Southern California Ship Services
- Tri-Marine Fish Company
- U.S. Coast Guard
- Harbor Ice
- Southern California Marine Institute
- San Pedro Forklifts

4.3 Data and Information Acquisition

The terminal's maintenance and/or CHE operating staff were contacted either in person or by telephone to obtain information on the CHE specific to their terminal for the calendar year 2005. Information collected for each piece of equipment is listed below:

- Equipment type
- Equipment identification number
- Equipment make and model
- Engine make and model
- Rated horsepower
- Model year
- Type of fuel used (Diesel, ULSD, Gasoline or Propane)
- Alternative fuel used, start date (examples include emulsified fuel, O2 fuel)
- Fuel consumption
- Annual hours of operation (some terminal operators use hour meters)
- Diesel Oxidation Catalyst (DOC) installed (y or n)
- Date DOC installed
- Onroad engine installed (y or n)
- Any other emissions control devices installed

Table 4.1 summarizes the data collected, including equipment count, horsepower, model year, and annual operating hours for each equipment type. The data is discussed by terminal and equipment type in the next subsection.

Table 4.1: CHE Characteristics for 2005 for All Terminals

Equipment	Count	Power (horsepower) Range			Power (horsepower) Average	Model Year Range			Model Year Average	Annual Operating Hours Range			Annual Operating Hours Average
Bulldozer	9	140	-	460	243	1979	-	1999	1986	0	-	3,195	858
Crane	14	43	-	750	202	1965	-	2004	1986	257	-	3,141	818
Excavator	12	85	-	428	349	1980	-	2002	1996	71	-	3,358	2,656
Forklift	422	40	-	330	106	1968	-	2005	1995	0	-	2,816	1,001
Loader	16	98	-	458	278	1972	-	2003	1993	25	-	5,588	1,617
Man lift	16	60	-	275	96	1994	-	2002	1997	92	-	1,136	474
Rail Pusher	3	130	-	300	243	1993	-	2004	1999	354	-	2,000	1,451
Roller	1	20		20	20	1980		1980	1980	51		51	51
RTG crane	98	0	-	625	316	1983	-	2005	1998	0	-	5,315	1,432
Side pick	41	152	-	233	182	1987	-	2005	2000	0	-	2,400	1,531
Skid steer loader	10	30	-	85	51	1994	-	2004	1999	63	-	1,443	656
Sweeper	11	35	-	325	135	1995	-	2005	2000	156	-	1,373	526
Top handler	127	174	-	350	279	1972	-	2005	1999	0	-	4,500	1,925
Truck	22	80	-	493	301	1963	-	2005	1987	63	-	2,543	1,061
Yard tractor	901	147	-	250	201	1980	-	2005	2001	0	-	8,138	2,050
Total	**1,703**												

4.4 Terminal Description and Equipment Types

4.4.1 Container Terminals

Containerized cargo is any kind of cargo that is packed in standardized boxes for transport and handling. The Port of Los Angeles and other West Coast ports are the major ports of entrance for containerized cargo coming from the Far East to the U.S. The top trading port partners are China, Japan, Taiwan South Korea and Thailand. The Port of Los Angeles is the busiest container Port in the U.S. Together with Port of Long Beach; the Port of Los Angeles serves the Los Angeles Basin, Southern California and other destinations in the continental U.S. OGVs transport refrigerated cargo, consumer goods and other unique product cargo in containers. The top five containerized imports included furniture, apparel, toys and sporting goods, vehicles and vehicle parts, and electronic products. In 2005, seven major container terminals at the Port handled the majority of the 7.5 million TEUs[27]:

- Berth 100: West Basin Container Terminal (China Shipping)
- Berths 121-131: West Basin Container Terminal
- Berths 136-139: Trans Pacific Container (Trapac) Container Terminal
- Berths 212-225: Yusen Container Terminal
- Berths 226-236: Seaside Terminal (Evergreen)
- Berths 302-305: APL Terminal (Global Gateway South)
- Berths 401-406: APM Terminals (Pier 400)

Operational Characteristics

The basic layout of a container terminal consists of: docks where vessels berth; an area alongside the docks for cranes to load/unload a vessel; a container storage area where CHE moves and organizes cargo; gates for trucks that are delivering or picking up containers; and an intermodal rail yard.

The operation of a container terminal depends on the amount of land the terminal has to operate on. There are three basic types of operations that can be found in Port container terminals: wheeled, grounded, and a combination of the two which represents how the containers are physically stored and kept on a terminal. The type of operation at any specific terminal is generally dictated by the amount of land available and the number of containers that the terminal processes per year. Most terminals employ a mix of wheeled and grounded operations as land permits.

[27] Container capacity is measured in twenty-foot equivalent units (TEU)

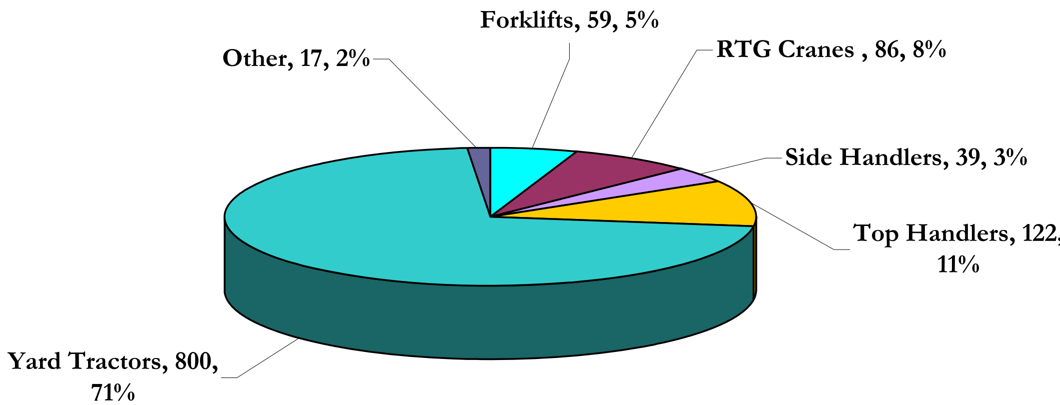
Wheeled operations are generally the most efficient operations as all the containers are kept on chassis and can be moved anywhere on or off the terminal by the use of a yard tractor or HDV. However, wheeled operations have low container per acre densities and thus require significantly more land than grounded operations, which have high container densities. Wheeled operations require high use of yard tractors. Grounded operations are where containers are stored onsite in "stacks." Stacks can be several containers wide by two to four containers high, thus requiring the use of RTG, top handlers and side handlers to move the containers to/from and within the stacks. RTG cranes are cranes that can move about the stacks and straddle the containers to lift them up and move them around. Top and side handlers are equipment used to pick up the full and empty containers.

Some containers are used to transport perishable goods such as fruits and meats, and therefore are equipped with a refrigeration unit that has a small diesel generator that can provide power to the cooling system when external power is not available. These refrigerated container units (reefers) were investigated during the course of data collection for this inventory to determine their potential air quality impact from ship to yard to distribution. Through the interviews, it was found that there are no emissions associated with the diesel units on the containers. While on board ships, reefers are powered by the ship's auxiliary generators, and once ashore, reefers that are stored for any length of time in the terminal are plugged into the utility grid at special slots designated for reefers. A reefer that is removed from an external power source, such as when it is loaded onto a trailer for truck transport, will hold its temperature for approximately eight hours before the diesel generator would need to be operated to power the refrigeration unit. Therefore, it is reasonable to conclude that the containers' diesel generators are not turned on within the Port boundary or when traveling within the study area because truck travel time within the study area is far less than eight hours.

Equipment Types

The equipment inventoried at the container terminals are mostly diesel-powered landside equipment and not licensed for highway use. The equipment used directly in handling cargo at container terminals consists mainly of yard tractors, top handlers, and forklifts. Figure 4.3 shows the distribution of container terminals' cargo handling equipment at the Port of Los Angeles.

Figure 4.3: Distribution of Container Terminals CHE



The majority, 66%, of all CHE equipment at the Port are used by container terminals. Table 4.3 shows the percentage of container terminal CHE count to the total Port CHE count.

Table 4.2: Percentage of Container Terminal Equipment as Compared to Total Equipment Type in 2005

Equipment	Total Count	Container Terminal Count	Percentage
Forklifts	422	59	14%
RTG Cranes	98	86	88%
Side Handlers	41	39	95%
Top Handlers	127	122	96%
Yard Tractors	901	800	89%
Sweepers	11	6	55%
Other	103	11	11%
Total	**1,703**	**1,123**	**66%**

The equipment characteristics for the CHE found at the Port's container terminals are summarized in Table 4.3. The average side pick, sweeper, top handler and yard tractors at container terminals are less than 5 years old. This is indicative of the high equipment turnover at container terminals over the last few years.

Table 4.3: Characteristics of Container Terminal Cargo Handling Equipment in 2005

Container Terminals		Power (horsepower)		Model Year		Annual Operating Hours	
Equipment	Count	Range	Average	Range	Average	Range	Average
Forklift	59	45 - 275	151	1972 - 2005	1992	0 - 2,816	742
Manlift	5	80 - 125	98	1994 - 1995	1995	181 - 400	282
Rail Pusher	2	300 - 300	300	1993 - 2000	1997	2,000 - 2,000	2,000
RTG crane	86	0 - 625	318	1983 - 2005	1998	0 - 3,660	1,239
Side pick	39	152 - 233	184	1987 - 2005	2000	100 - 2,400	1,610
Sweeper	6	100 - 215	158	1995 - 2005	2000	235 - 1,000	404
Top handler	122	250 - 330	279	1987 - 2005	2000	0 - 4,500	1,966
Truck	4	100 - 100	100	1975 - 2005	1995	299 - 1,714	708
Yard tractor	800	170 - 245	205	1987 - 2005	2001	0 - 8,138	2,019
Total	**1,123**						

Yard Tractors

Yard tractors are also referred to as terminal tractors and yard hostlers. They account for 71% of the CHE used at the Port container terminals and 89% of total yard tractors inventoried at the Port in 2005. The typical off-road yard tractor is a close relative of the on-road truck tractor chassis. In 2001, all of the yard tractors were equipped with off-road diesel engines. In 2005, 165 yard tractors were equipped with on-road emissions standards certified engines and 53 were equipped with propane engine. In 2006, some terminals purchased LNG yard tractors, however, 2006 equipment are not included in this inventory.

Yard tractors are designed for the movement of containers at the terminal in both stacked and wheeled operations. Common uses of yard tractors are to move containers to and from the ship; move containers within the terminal; move reefer containers into position; and move containers to RTGs for placement or removal from the stacks. Yard tractors operate throughout the terminal and spend most of their time loading and unloading containers from ships. When a vessel is at dock, the yard tractors line up next to the vessel. A crane is used to place an unloaded container on the yard tractor while another crane lifts a container from another yard tractor to load the vessel. The yard tractors are in constant motion from the dock to the container storage area. They work primarily between the ship and the locations of stacked containers or chassis. In addition, yard tractors are also used for intermodal rail container transfers.

At the container terminals, the model years of yard tractors ranged from 1987 to 2005, with an average model year of 2001 implying an average age of four years. Engine power ranged from 170 hp to 245 hp, with an average of 206 hp. Annual operating time ranged from zero to 8,138 hours, with an average of 2,020 hours. Figure 4.4 shows a typical yard tractor.

Figure 4.4: Yard Tractor

Top Loaders

Approximately eleven percent, or 122 pieces, of the equipment inventoried at the Port container terminals were diesel powered top loaders, also known as top handlers by terminal operators. Top loaders move, stack and load containers using an overhead telescopic boom. They can be used in place of or in conjunction with RTGs to lift heavy containers within a terminal. Model years ranged from 1987 to 2005, with an average model year of 2000. Engine power ranged from 250 hp to 330 hp, with an average of 279 hp. Annual operating time ranged from zero to 4,500 hours, with an average of 1,796 hours. Figure 4.5 shows a typical top loader.

Figure 4.5: Top Loader

Forklifts

The container terminals had a total 59 forklifts, accounting for 5% of the equipment inventoried at container terminals and 14% of forklifts at the Port. The forklifts at the container facilities may be used for cargo and non-cargo handling activities. Forklifts, of various capacities, use an under lift principle to move loads of varying sizes. The forklifts used at the container terminals had model years ranging from 1972 to 2005, with 1992 being the average model year. Engine power ranged from 45 hp to 275 hp, with an average of 151 hp. Annual operating hours ranged from zero to 2,816 hours, with an average of 742 hours. In 2005, fifteen forklifts at the container terminals had LPG engines and 11 diesel-powered forklifts used ULSD. Figure 4.6 illustrates a typical forklift.

Figure 4.6: Forklift

Side Handlers

Side picks, side handlers and side loaders are three names used to refer to the cargo handling equipment that typically move and stack the empty containers at a terminal. Side handlers usually have lower horsepower engines than that of a top handler. Three percent, or 39 units, of the equipment inventoried at container terminals were side handlers. The majority of the side handlers at the port, 95%, are used at the container terminals. Model years ranged from 1987 to 2005, with an average model year of 2000. Engine power ranged from 152 hp to 233 hp, with an average of 184 hp. Annual operating time ranged from 100 to 2,400 hours, with an average of 1,610 hours. Figure 4.7 presents a Taylor side handler.[28]

[28] *http://www.cal-lift.com.*

Figure 4.7: Side Handler

Rubber Tired Gantry Cranes

The 86 RTG cranes made up eight percent of the equipment inventoried at the container terminals, of which 12 are actually electric rail mounted gantry (RMG) cranes used at one terminal. The RTG crane moves containers to and from the container stacks in a grounded operation; it is designed like a ship-loading crane without the horizontal extended boom. The RTG crane straddles the stacks of containers and has room for a Heavy Duty Diesel Vehicle (HDDV) truck/yard tractor to pull under, and moves containers to and from stacks. It is also used to consolidate the stacks weekly as containers are added and removed from the terminal Model years range from 1983 to 2005, with an average model year of 1998. Engine power ranged from 0 hp to 625 hp, with an average 318 hp. The zero hp is for the 12 diesel-electric RTG cranes at the Port that are accounted for in the inventory, but have zero emissions. The annual operating hours ranged from zero to 3,660 hours, with an average of 1,239 hours. Figure 4.8 illustrates a typical RTG crane (in gray).

Figure 4.8: Rubber Tired Gantry Crane

4.4.2 Break Bulk Terminals

Break bulk cargo includes steel, lumber, large machinery and other large product cargo. Generally, break bulk terminals that receive cargo have to be unloaded from a ship's hold and then assembled/disassembled on the dock for distribution. Steel products, such as plates or rolls are placed in a ship's hold and are then removed one by one. Large machinery may also be carried on special RoRo vessels with large roll-on/roll-off ramps suitable for driving equipment on and off the ship directly by a large ramp that is part of the ship. Lumber and lumber products are often carried by specified vessels and barges. Some vessels that call on break bulk terminals may mix containerized cargo with break bulk cargo and are called "combination" ships. The containers are stacked on the hatch covers that cover the cargo holds during sailings. In general, the ships that call at break bulk terminals are much smaller than the ships that call at the container terminals.

Due to their weight and characteristics, heavy lift machines are used for handling bulk cargo at the terminal and for loading rail or truck. Cargo is discharged either by onboard or shore-side cranes. In addition, bulk cargo is discharged by ship-to-shore cranes or large boom cranes that operate on the dock. Most break bulk cargo leaves the terminals by truck. The most common break bulk and dry bulk cargos at the Port include scrap metal, paper and petroleum coke. The break-bulk terminals are listed below.

- Berths 49-53, 87-89, 153-155 and 174-181: Pasha Stevedoring and Terminals
- Berths 54-55: Stevedore Services of America (SSA)
- Berths 153-155: Crescent Warehouse Company
- Berths 210-211: Hugo Neu-Proler Company
- Berth 301: Los Angeles Export Terminal (LAXT)

Figure 4.9 shows the distribution of cargo handling equipment for the break-bulk facilities at Port of Los Angeles.

Figure 4.9: Distribution of Break-Bulk Terminals CHE

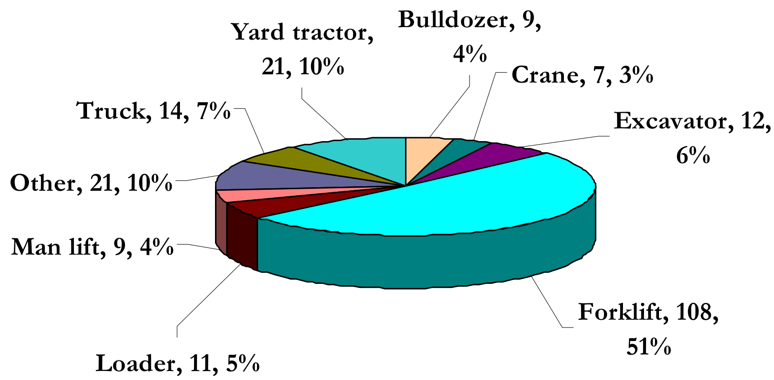


Table 4.4 shows the equipment characteristics of break-bulk terminal equipment.

Table 4.4: Equipment Characteristics of Break-Bulk Terminal Equipment

Break Bulk Terminals Equipment	Count	Power (horsepower) Range			Power (horsepower) Average	Model Year Range			Model Year Average	Annual Operating Hours Range			Annual Operating Hours Average
Bulldozer	9	140	-	460	243	1979	-	1999	1986	0	-	3,195	858
Crane	7	100	-	750	284	1965	-	2004	1981	257	-	3,141	982
Excavator	12	85	-	428	349	1980	-	2002	1996	71	-	5,358	2,656
Forklift	108	40	-	330	141	1979	-	2005	1994	0	-	2,250	922
Loader	11	98	-	458	288	1972	-	2003	1992	272	-	5,588	2,097
Man lift	9	60	-	275	99	1996	-	2002	1999	92	-	1,136	641
Rail Pusher	1	130	-	130	130	2004	-	2004	2004	354	-	354	354
Roller	1	20	-	20	20	1980	-	1980	1980	51	-	51	51
RTG crane	3	300	-	425	342	1987	-	2000	1991	0	-	723	241
Side pick	2	152	-	152	152	2002	-	2002	2002	0	-	0	0
Skid steer loader	6	30	-	45	42	1997	-	2004	2002	128	-	1,443	1,029
Sweeper	5	35	-	325	108	1996	-	2002	1999	156	-	1,373	673
Top handler	3	174	-	250	225	1979	-	1990	1986	200	-	380	320
Truck	14	210	-	493	417	1963	-	2002	1982	188	-	2,543	1,407
Yard tractor	21	174	-	177	176	1980	-	2000	1993	300	-	404	369
Total	**212**												

4.4.3 Dry Bulk Terminals

Dry bulk cargo includes fine, grain-like products that can be processed by bucket loaders, screw loaders, conveyors or suction and are temporally stored in piles, warehouses, or silos on the terminals. The dry bulk terminals include California Sulfur, L.A. Grain, and U.S. Borax.

Figure 4.10 shows the distribution of cargo handling equipment for the dry bulk facilities at Port of Los Angeles.

Figure 4.10: Distribution of Dry Bulk Terminals CHE

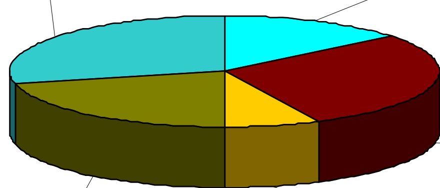


Table 4.5 shows the equipment characteristics of dry bulk terminal equipment. When there is insufficient data or if data is not available, NA is used in the table.

Table 4.5: Equipment Characteristics of Dry Bulk Terminal Equipment

Dry Bulk Terminals		Power (horsepower)		Model Year		Annual Operating Hours	
Equipment	Count	Range	Average	Range	Average	Range	Average
Forklift	2	80 - 149	115	1995 - 1995	1995	250 - 1,200	725
Loader	4	110 - 311	233	1995 - 1995	1995	350 - 1,040	695
Skid steer loader	1	85 - 85	85	1995 - 1995	1995	63 - 63	63
Truck	3	80 - 233	131	1995 - 1995	1995	63 - 600	261
Yard tractor	4	250 - 250	250	1995 - 1995	1995	2,080 - 2,080	2,080
Total	**14**						

4.4.4 Passenger Terminal

The Port of Los Angeles is ranked first on the west coast for cruise traffic and is the fourth busiest port in the nation with 1.2 million passengers in 2005. The Port has agreements with at least 15 cruise lines, such as Royal Caribbean, Princess Cruises, Norwegian Cruise Line and others that make regular calls. Equipment is used to manage the passengers' luggage at the cruise terminal. Forklifts are mainly used to load and unload the passengers' luggage from the cruise ship to the terminal.

In 2005, 32 forklifts were inventoried at the cruise terminal, of which 10 were diesel powered and 22 were powered by propane. The horsepower ranged from 41 hp to 135 hp, with an average 73 hp. The model year ranged from 1968 to 2004, with an average 1992 model year. The annual operating time ranged from 100 hours to 1,278 hours, with an average of 918 hours. One fuel truck was also included in the inventory.

4.4.5 Liquid Bulk Terminals

Liquid bulk terminals predominately import petroleum products to California. The liquid bulk terminals require minimal CHE for their operations. The various liquid bulk terminals at the Port handle crude oil, finished and semi-finished petroleum products, chemicals, petrochemicals, and vegetable oils.

- Berths 70-71: Westway
- Berths 118-119: Kinder Morgan
- General Petroleum
- Berths 187-191: Vopak
- Equillon/Shell
- ExxonMobil

Compared to other types of terminals, liquid bulk cargo operations use limited diesel-powered terminal equipment. Liquid cargo is transported using loading/unloading arms, flexible hoses and valves, and/or booms to load/unload product from the vessels to/from onshore facilities. The emissions from the vessel loading and unloading are not included in the inventory since the landside pumps are stationary and not considered CHE. The ship's diesel/bunker-powered auxiliary and propulsion engines emissions are included in the marine vessel emissions inventory portion of this report.

Five liquified petroleum gas (LPG) forklifts and 2 diesel-powered forklifts were inventoried for the liquid terminals. The forklifts were 1995 model year. The engine power ranged from 100 hp to 122 hp, and annual operating time ranged from 24 hours to 1,000 hours, with an average of 715 hours.

4.4.6 Automobile Terminals

The U.S. is a major importer of motor vehicles and California is an important market. West Coast ports are a port of entry for many automobiles manufactured in Asia and Europe. The Port has one automobile terminal, which mostly serves the local California market. In 2005, the Port handled approximately 280,000 new vehicles including mainly Nissan and Infiniti passenger cars and sport utility vehichles (SUVs). The loading and unloading of motor vehicles do not require the use of heavy cargo handling equipment. The vehicles are discharged (or loaded) by driving them off (or on) the vessel. Terminal workers drive the cars to dedicated parking areas on the terminal. The emissions from the new automobiles are included in the inventory and presented in Section 4.7, along with the CHE emissions.

In 2005, seven forklifts were inventoried at the auto terminal, of which three are diesel powered and four are gasoline powered. These forklifts are mainly used to move auto parts. The horsepower ranged from 45 hp to 175 hp, with an average 83 hp. The model years were 1995 and 1996 and annual operating time ranged from 16 hours to 285 hours, with an average of 204 hours.

4.4.7 Other Terminals and Facilities

There were several facilities within the Port boundary that were included in this inventory that did not fit into the container, dry bulk, break bulk, liquid bulk, or auto terminal categories listed above. Other terminals and facilities include:

- Small facilities/tenants (Southern California Marine Institute, Southern California Ship Services, Tri-Marine Fish Company, USCG, Harbor Ice, Al Larson)
- Union Pacific Intermodal Containers Transfer Facility (ICTF)

Table 4.6: Equipment Characteristics of "Other" Terminal Equipment

Other Terminals		Power (horsepower)		Model Year		Annual Operating Hours	
Equipment	Count	Range	Average	Range	Average	Range	Average
Crane	7	43 - 185	120	1989 - 2004	1997	400 - 1,200	654
Forklift	207	50 - 175	80	1987 - 2002	1996	50 - 1,500	1,169
Loader	1	350 - 350	350	1995 - 1995	1995	25 - 25	25
Man lift	2	80 - 80	80	1995 - 1998	1997	150 - 250	200
RTG crane	9	250 - 300	294	1988 - 2005	1997	606 - 5,315	3,669
Skid steer loader	3	37 - 75	56	1994 - 1995	1995	96 - 125	107
Top handler	2	335 - 350	343	1972 - 1988	1980	41 - 3,562	1,802
Yard tractor	76	147 - 173	167	1995 - 2005	2004	0 - 6,579	2,838
Total	**307**						

4.5 Emission Reduction Technologies

Several initiatives have been started at the Port to reduce emissions from cargo handling equipment. The 2005 inventory includes 585 pieces of equipment installed with DOC, and 165 new yard tractors equipped with on-road certified engines. In addition, 218 pieces of equipment used emulsified fuel in 2005. Some terminals also used ULSD on 819 pieces of equipment in 2005, well in advance of the upcoming regulation.

Table 4.7 is a summary of the emission reduction technologies used on the equipment. It should be noted that some of these technologies may be used in combination with one another. For example, equipment using ULSD or emulsified fuel may also have on-road engines or DOCs installed.

Table 4.7: Summary of 2005 CHE Emission Reduction Technologies

		Total Count			
Equipment	Pieces of Eqmt	DOC Installed	On-road engine	Emulsified Fuel	ULSD
Yard tractor	901	520	164	129	596
Top handler	127	48	0	36	79
Side pick	41	14	0	10	16
RTG	98	0	0	28	36
Forklift	422	3	0	15	27
Other	114	0	1	0	65
Totals	**1,703**	**585**	**165**	**218**	**819**

Twenty percent of equipment inventoried does not have a diesel engine; a total of 320 pieces of equipment have propane engines, 11 have gasoline engines as listed on Table 4.8. The inventory also includes 12 electric cranes. This inventory does not include the electrified equipment such as the electrical ship to shore cranes at the terminals or other smaller electrical equipment.

Table 4.8: 2005 Count of Non-Diesel Fueled Engines

Equipment	Propane	Gasoline
Yard Tractor	53	0
Top Handler	0	0
Side Pick	0	0
Forklift	267	8
Other	0	3
Total	**320**	**11**

4.6 Emission Estimation Methodology

CARB adopted their CHE Regulation in December of 2005. During the development of the rule, CARB's staff estimated the emissions of the CHE using a methodology that was different than what was traditionally used in their OFFROAD model. The most significant change from the OFFROAD methodology was the calculation of deterioration rates for CHE equipment. At the time of this CHE emissions inventory development, CARB was not ready to make public the revised CHE emissions inventory calculation tool. In order to be consistent with CARB's latest methodology, CARB staff volunteered to estimate the emissions for the cargo handling equipment in operation at the Port

The basic equation used to estimate CHE emissions in tons is as follows.

Equation 4.1

$$E = Pop \times EF \times HP \times LF \times Act \times FCF$$

Where:

E = emissions in short tons
Pop = population of equipment
EF = emission factor, grams of pollutant per horsepower-hour (g/hp-hr)
HP = rated horsepower for the equipment
LF = load factor (ratio of average load used during normal operations as compared to full load at maximum rated horsepower)
Act = equipment activity, hours of use per unit of time
FCF = fuel correction factor to reflect changes in fuel properties that have occurred over time

The emission factor (EF) is a function of zero hour (ZH) emission rate for the equipment model year (g/hp-hr) in the absence of any malfunction or tampering of engine components that can change emissions, plus a deterioration rate. The deterioration rate reflects the fact that base emissions of engines change as the equipment is used due to wear of various engine parts or reduced efficiency of emission control devices. The emission factor is calculated as:

Equation 4.2

$$EF = ZH + (DR \times \text{Cumulative Hours})$$

Where:

ZH = emission rate when the engine is new and there is no component malfunctioning for a given horsepower category and model year
DR = deterioration rate (rate of change of emissions as a function of equipment age)
Cumulative hours = annual operating hours times age of the equipment

If the equipment has an emission control technology, then the emission factor is calculated as:

Equation 4.3

$$EF = (ZH \times CF) + (DR \times \text{Cumulative Hours})$$

Where:

ZH = emission rate when the engine is new and there is no component malfunctioning for a given horsepower category and model year
CF = control factor to reflect changes in emission due to installation of emission reduction technologies or use of alternative fuels not originally included in the emission factors
DR = deterioration rate (rate of change of emissions as a function of equipment age)
Cumulative hours = annual operating hours times age of the equipment

4.6.1 Emission Factors

CARB used the same zero hour (ZH) emission rates as used in the OFFROAD model. The ZH emission rates are a function of fuel, model year and horsepower group as defined in the OFFROAD model.

ZH emission rates vary by engine horsepower to reflect the fact that depending upon the size of the engines, different engine technologies are used and thus emission output is different. Basic emission rates vary by model year to reflect change in engine technology due to change in emissions standards. CARB's ZH emission factors by horsepower and engine year were used for:

- diesel engines certified to off-road diesel engine emission standards
- diesel engines certified to onroad diesel emission standards
- gasoline engines certified to off-road gasoline emission standards
- LPG off-road emission factors

Due to the absence of CHE specific emission data, CARB staff used on-road heavy-duty diesel specific deterioration rates used in EMFAC 7G (an older version of the on-road emissions inventory model). Since the release of EMFAC 7G, CARB staff has updated EMFAC including on-road heavy-duty diesel deterioration rates. As far as deterioration rate is concerned, the basic assumption used by CARB staff is that the emissions from diesel powered trucks remain stable in the absence of tampering and mal-maintenance (T&M). In other words, diesel engine emissions do not increase over time if the equipment is well maintained. Changes in emissions (normally increase) with equipment usage occur if the equipment is not maintained properly which causes various engine components affecting emissions to malfunction.

CARB staff estimate deterioration using the so called "Radian Model" which identifies various diesel engine components malfunctions, the frequency of malfunction and the related impact on emissions. Based on this information, staff calculates the change in on-road heavy-duty engine emissions over time.

For CHE equipment, CARB staff estimated the emissions increase over the cumulative mileage of the on-road engines and assumed that the emissions for CHE will deteriorate in the similar manner over the equipment's useful life. This useful life estimate was determined through CHE surveys conducted by CARB staff.

The equation for the deterioration rate is:

Equation 4.4

$$DR = (DF \times ZH) / \text{cumulative hours at the end of useful life}$$

Where:

DR = deterioration rate (expressed as g/hp-hr^2)
DF = percent increase in emissions at the end of the useful life (expressed as %)
ZH = emission rate when the engine is new and there is no component malfunctioning for a given horsepower category and model year
Cumulative hours at the end of useful life = annual operating hours times useful life in years

The Port believes that the use of CARB's deterioration rates results in an overestimate of CHE emissions. In discussions with terminal operators, the Port determined that the CHE are well maintained compared to on-road heavy-duty trucks. CARB staff needs to further refine their methodology to properly account for the CHE maintenance practices of terminal operators.

4.6.2 Load factor, Useful Life, and Deterioration Rates

Load factor is defined as the ratio of average load experienced by the equipment during normal operation as compared to full load at maximum rated horse power. It accounts for the fact that in their normal operations, engines are not used at their maximum horsepower rating.

CARB matched the Port CHE to a CARB equivalent equipment type from their cargo handling equipment model and used the corresponding load factors. The load factors used for yard tractors, top handlers and side picks in this 2005 inventory are different than those load factors used in the 2001 baseline emission inventory. In order to be consistent with the cargo handling regulation for CARB's 2005 inventories, CARB used higher load factors in the Port's 2005 emission inventory. The Port believes the load factors should not be higher for any given equipment and plans to conduct a yard tractor study to determine a more accurate load factor. In the next Port emission inventory, the Port plans to propose a new load factor for yard tractors based on supporting data collected.

The useful life of an engine is defined as the median age of an engine. It is assumed that almost all of the original engine population is gone after two times the useful life. CARB matched the Port CHE to an equivalent type from the cargo handling equipment model and used the corresponding useful life. Table 4.9 lists the equipment type, the useful life and load factor used, respectively.

Table 4.9: Deterioration Rates by Horsepower Group

Equipment Type	Port Equipment	Useful Life	Load Factor
Crane	RTG crane, crane	24	0.43
Excavator	Excavator	16	0.57
Forklift	Forklift	16	0.3
Material Handling Equip	Top Handler, Side Pick	16	0.59
Other General Ind Equip	Aerial lift, truck, other	16	0.51
Sweeper/Scrubber	Sweeper	16	0.68
Tractor/Loader/Backhoe	Loader, Backhoe	16	0.55
Yard Tractor offroad engine	Yard Tractor	12	0.65
Yard Tractor onroad engine	Yard Tractor	12	0.65
Other General Ind Equip onroad	Truck (i.e. fuel, water)	16	0.51

Table 4.10 lists the new deterioration factors used by CARB by horsepower group.

Table 4.10: Deterioration Factors by Horsepower Group

Horsepower Group	PM	NO_X	CO	HC
50	31%	6%	41%	51%
120	44%	14%	16%	28%
175	44%	14%	16%	28%
250	67%	21%	25%	44%
500	67%	21%	25%	44%

4.6.3 Control Factors

Control factors were used to reflect the change in basic emission rates due to use of various emissions reduction technologies such as DOC and alternative fuels (emulsified fuel). Table 4.11 shows the emission reduction percentages used by CARB in the emissions estimates for the various technologies used by the Port equipment. In this table, a positive number is a reduction, while a negative number in the table signifies an increase in emissions. The control factor is 1 minus the emission reduction in decimal. For example, 70% reduction has a control factor of 0.3; while a -10% has a control factor of 1.10.

Table 4.11: CHE Emission Reductions Percentages

Technology	PM	NO_X	CO	HC	SO_x
DOC	30%	0%	70%	70%	na
Emulsified Fuel	30%	15%	-10%	-23%	na
DOC + emulsified fuel	50%	20%	67%	63%	na

CARB's sources for the emission reductions are as follows:

- DOC: CEC Report (Air Quality Implications of Backup Generators in California Volume Two: Emission Measurements From Controlled and Uncontrolled Backup Generators)[29]
- Emulsified Fuel: CARB/POLA Yard Truck Test Program[30]
- DOC + emulsified fuel: CARB Letter to Port (1 May 06) and Verified Technology[31]

Table 4.12 lists the fuel correction factors for diesel fuel and ULSD.

Table 4.12: Fuel Correction Factors

Fuel	PM	NO_X	CO	HC
Pre-1995 model year	0.75	0.93	na	0.72
1996 and newer models	0.82	0.95	na	0.72

[29] See *http://www.enenrgy.ca.gov/pier/final_project_reports/CEC-500-2005-049.html*
[30] See *http://www.arb.ca.gov/msprog/offroad/cargo/documents/yttest.pdf*
[31] See *http://www.arb.ca.gov/diesel/verdev/level2/level2.htm*

4.7 Emission Estimates

A summary of the CHE emission estimates in tons per year by terminal type for the pollutants for 2005 is presented in Table 4.13. The auto terminal emissions include the new vehicles emissions (see subsection 4.7.7). The emissions are presented in further detail in the remainder of this section by terminal and by equipment type.

Table 4.13: 2005 CHE Emissions by Terminal Type, tpy

Terminal Type	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
Auto	0.0	0.0	0.0	0.9	0.0	1.9	0.2
Break-Bulk	11.0	10.1	10.9	258.7	0.5	121.7	28.6
Container	43.8	40.3	42.9	1,525.5	11.5	586.3	82.4
Cruise	0.3	0.3	0.3	8.3	0.0	13.5	2.3
Dry Bulk	0.9	0.8	0.9	17.3	0.1	6.4	1.9
Liquid	0.1	0.0	0.0	1.9	0.0	4.1	0.6
Other	6.7	6.2	6.4	224.7	1.9	276.6	37.3
Total	**62.9**	**57.8**	**61.5**	**2,037.2**	**14.0**	**1,010.5**	**153.3**

Figure 4.11 presents the percentage of cargo handling emissions by terminal type. For PM, NO_x and SO_x emissions, approximately 70% to 80% of the Port's CHE emissions are attributed to the container terminals, followed by break-bulk terminals and the other facilities. The facilities that have propane forklifts and equipment with alternative fuels have higher CO and TOG emissions. Container terminals, which have mainly diesel equipment, attribute to approximately 50 to 55% of the CO and TOG emissions at the Port.

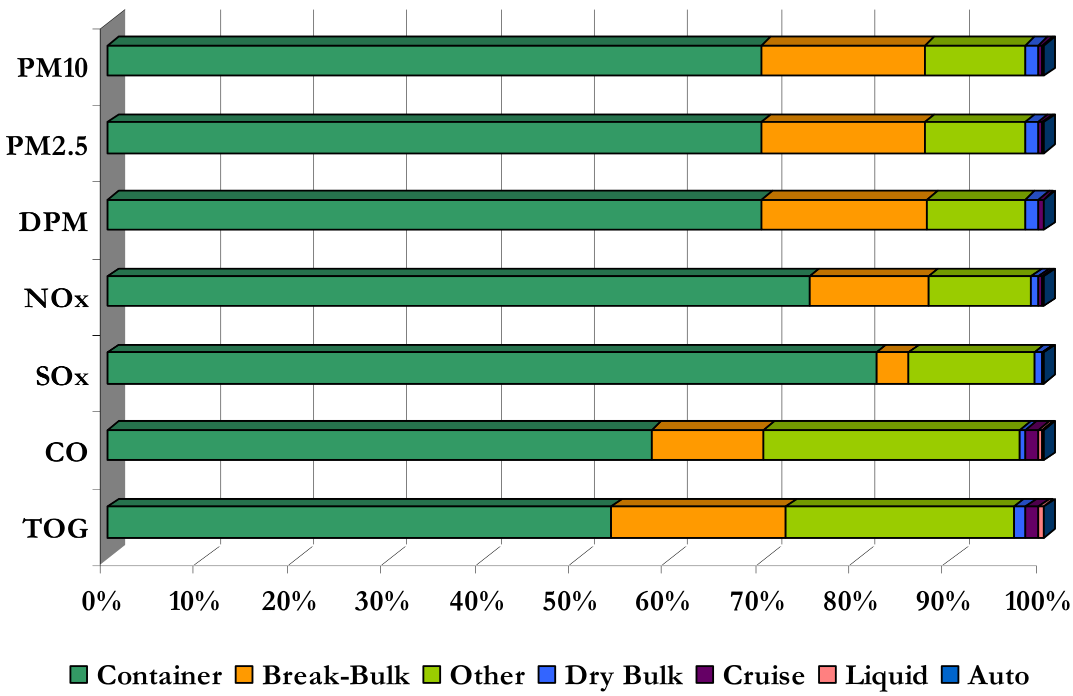


Figure 4.11: Percentage of Port CHE Emissions by Terminal Type

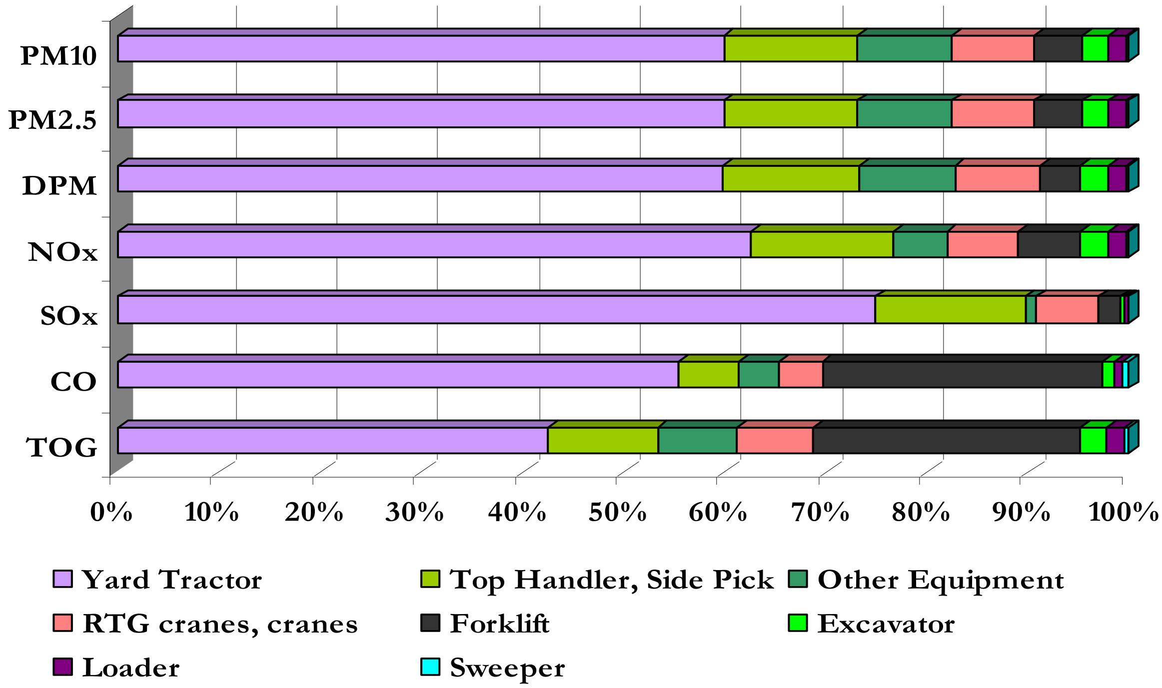
Table 4.14 presents the Port's CHE emissions by equipment type in tons per year. The emissions do not include the new vehicles at auto terminals.

Table 4.14: 2005 Port CHE Emissions by Equipment Type, tpy

Equipment Type	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
RTG cranes, cranes	5.2	4.8	5.2	141.9	0.8	43.3	11.5
Excavator	1.6	1.5	1.6	55.1	0.0	12.1	4.0
Forklift	2.9	2.7	2.5	127.0	0.3	279.4	40.5
Top Handler, Side Pick	8.3	7.7	8.3	287.6	2.1	60.1	16.5
Other Equipment	5.8	5.3	5.8	106.4	0.2	39.7	12.0
Sweeper	0.1	0.1	0.1	4.6	0.0	6.9	0.6
Loader	1.2	1.1	1.2	38.7	0.1	8.1	2.8
Yard Tractor	37.7	34.6	36.8	1,275.2	10.5	560.5	65.3
Total	**62.8**	**57.8**	**61.5**	**2,036.6**	**14.0**	**1,010.1**	**153.3**

Figure 4.12 presents the percentage of the Port's cargo handling emissions by equipment type. Approximately 40% to 70% of the Port's CHE emissions are attributed to yard tractors; 5% of the Port's CHE emissions are attributed to RTG cranes and other cranes; 5 to 15% of the Port's CHE emissions are attributed to top handlers and side picks. Approximately 5% of the PM, NO_x and SO_x emissions; and 25% of the CO and TOG emissions for the cargo handling equipment at the Port are attributed to forklifts.

Figure 4.12: Percentage of Port CHE Emissions by Equipment Type



4.7.1 Container Terminals

Table 4.15 presents the emissions for container terminals in tons per year for each container terminal.

Table 4.15: 2005 CHE Emissions at Container Terminals, tpy

Terminal ID	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
LAC010	6.2	5.7	6.2	256.4	1.5	34.2	11.9
LAC020	11.1	10.2	11.1	352.1	0.4	57.5	12.8
LAC030	5.1	4.7	5.1	168.5	1.6	29.7	8.5
LAC060	6.4	5.9	5.5	229.1	2.0	326.6	21.8
LAC070	12.2	11.3	12.2	347.2	3.6	124.5	24.5
LAC090	2.8	2.6	2.8	172.3	2.4	13.9	3.0
Total	**43.8**	**40.3**	**42.9**	**1,525.5**	**11.5**	**586.3**	**82.4**

Table 4.16 presents the emissions for container terminals in tons per year by equipment type.

Table 4.16: 2005 CHE Emissions by Equipment Type at Container Terminals, tpy

Port Equipment	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
RTG cranes, cranes	2.6	2.4	2.6	86.0	0.6	23.3	6.1
Forklift	0.6	0.6	0.6	17.6	0.1	16.4	2.9
Top Handler, Side Pick	7.8	7.2	7.8	278.4	2.0	56.7	15.5
Other Equipment	0.4	0.3	0.4	7.5	0.0	2.5	0.8
Sweeper	0.0	0.0	0.0	2.4	0.0	6.2	0.4
Yard Tractor	32.3	29.8	31.5	1,133.5	8.8	481.2	56.7
Total	**43.8**	**40.3**	**42.9**	**1,525.5**	**11.5**	**586.3**	**82.4**

4.7.2 Break-Bulk Terminals

Table 4.17 presents the emissions for break-bulk terminals in tons per year for each break-bulk terminal.

Table 4.17: 2005 CHE Emissions at Break-Bulk Terminals, tpy

Terminal ID	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
LAC040	1.5	1.4	1.5	29.7	0.3	10.6	2.9
LAO020	0.4	0.4	0.4	20.3	0.0	46.5	5.9
LAO120	8.8	8.1	8.8	198.1	0.1	62.8	19.1
LAO150	0.3	0.3	0.3	10.7	0.1	1.8	0.6
Total	**11.0**	**10.1**	**10.9**	**258.7**	**0.5**	**121.7**	**28.6**

Table 4.18 presents the emissions for break-bulk terminals in tons per year by equipment type.

Table 4.18: 2005 CHE Emissions by Equipment Type at Break-Bulk Terminals, tpy

Port Equipment	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
RTG cranes, cranes	0.9	0.9	0.9	18.9	0.0	7.5	1.9
Excavator	1.6	1.5	1.6	55.1	0.0	12.1	4.0
Forklift	1.5	1.4	1.4	39.0	0.2	54.8	8.0
Top Handler, Side Pick	0.1	0.1	0.1	1.4	0.0	0.5	0.2
Other Equipment	5.4	4.9	5.4	98.1	0.1	36.9	11.2
Sweeper	0.1	0.1	0.1	2.2	0.0	0.7	0.2
Loader	1.0	0.9	1.0	35.8	0.0	7.0	2.5
Yard Tractor	0.3	0.3	0.3	8.1	0.1	2.2	0.7
Total	**11.0**	**10.1**	**10.9**	**258.7**	**0.5**	**121.7**	**28.6**

4.7.3 Dry Bulk Terminals

Table 4.19 presents the emissions for dry bulk terminals in tons per year for each dry-bulk terminal.

Table 4.19: 2005 CHE Emissions at Dry Bulk Terminals, tpy

Terminal ID	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
LAO040	0.1	0.0	0.1	0.9	0.0	0.4	0.1
LAO260	0.1	0.1	0.1	1.1	0.0	0.4	0.1
LAO270	0.8	0.7	0.8	15.2	0.1	5.6	1.7
Total	**0.9**	**0.8**	**0.9**	**17.3**	**0.1**	**6.4**	**1.9**

Table 4.20 presents the emissions for dry bulk terminals in tons per year by equipment type.

Table 4.20: 2005 CHE Emissions by Equipment Type at Dry Bulk Terminals, tpy

Port Equipment	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
Forklift	0.0	0.0	0.0	0.5	0.0	0.2	0.1
Other Equipment	0.0	0.0	0.0	0.4	0.0	0.2	0.1
Loader	0.2	0.1	0.2	2.9	0.0	1.1	0.3
Yard Tractor	0.7	0.6	0.7	13.5	0.1	4.9	1.5
Total	**0.9**	**0.8**	**0.9**	**17.3**	**0.1**	**6.4**	**1.9**

4.7.4 Passenger Terminal

Table 4.21 presents the emissions for the passenger terminal in tons per year for the passenger terminal.

Table 4.21: 2005 CHE Emissions at Passenger Terminal, tpy

Terminal ID	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
LAO080	0.3	0.3	0.3	8.3	0.0	13.5	2.3
Total	**0.3**	**0.3**	**0.3**	**8.3**	**0.0**	**13.5**	**2.3**

Table 4.22 presents the emissions for the passenger terminal in tons per year by equipment type.

Table 4.22: 2005 CHE Emissions by Equipment Type at Passenger Terminal, tpy

Port Equipment	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
Forklift	0.3	0.3	0.3	8.1	0.0	13.4	2.3
Fuel Truck	0.0	0.0	0.0	0.2	0.0	0.1	0.0
Total	**0.3**	**0.3**	**0.3**	**8.3**	**0.0**	**13.5**	**2.3**

4.7.5 Liquid Bulk Terminals

Table 4.23 presents the emissions for the liquid bulk terminals in tons per year for the liquid-bulk terminals.

Table 4.23: 2005 CHE Emissions at Liquid Bulk Terminals, tpy

Terminal ID	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
LAO100	0.0	0.0	0.0	0.3	0.0	0.8	0.1
LAO130	0.0	0.0	0.0	0.1	0.0	0.2	0.0
LAO230	0.0	0.0	0.0	0.9	0.0	2.9	0.4
LAO290	0.0	0.0	0.0	0.6	0.0	0.3	0.1
Total	**0.1**	**0.0**	**0.0**	**1.9**	**0.0**	**4.1**	**0.6**

Table 4.24 presents the emissions for the liquid bulk terminals in tons per year by equipment type.

Table 4.24: 2005 CHE Emissions by Equipment Type at Liquid Bulk Terminals, tpy

Port Equipment	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
Forklift	0.1	0.0	0.0	1.9	0.0	4.2	0.6
Total	**0.1**	**0.0**	**0.0**	**2.0**	**0.0**	**3.2**	**0.4**

4.7.6 Other Terminals

Table 4.25 presents the emissions in tons per year for the other terminals and facilities at the Port, including the UP ICTF facility.

Table 4.25: 2005 CHE Emissions at Other Terminals, tpy

Terminal ID	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
LAO030	0.0	0.0	0.0	2.0	0.0	4.9	0.7
LAO110	0.0	0.0	0.0	0.8	0.0	2.0	0.3
LAO170	0.0	0.0	0.0	0.3	0.0	1.0	0.1
LAO180	0.1	0.1	0.0	17.3	0.0	51.5	7.1
LAO200	0.0	0.0	0.0	1.7	0.0	5.0	0.7
LAO220	0.1	0.1	0.1	1.8	0.0	0.8	0.2
LAO240	0.0	0.0	0.0	1.4	0.0	4.9	0.5
LAO250	1.3	1.2	1.1	56.2	0.2	127.2	19.1
LAO280	5.1	4.7	5.1	141.2	1.7	77.7	8.1
LAO300	0.1	0.0	0.0	2.0	0.0	1.7	0.5
Total	**6.7**	**6.2**	**6.4**	**224.7**	**1.9**	**276.6**	**37.3**

Table 4.26 presents the emissions for the other terminals and facilities at the Port in tons per year by equipment type.

Table 4.26: 2005 CHE Emissions by Equipment Type at Other Terminals, tpy

Port Equipment	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
RTG cranes, cranes	1.6	1.5	1.6	37.0	0.3	12.5	3.5
Forklift	0.4	0.3	0.1	59.6	0.0	189.0	26.5
Top Handler, Side Pick	0.4	0.4	0.4	7.7	0.0	2.8	0.9
Other Equipment	0.0	0.0	0.0	0.2	0.0	0.1	0.0
Loaders	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Yard Tractor	4.3	4.0	4.3	120.1	1.6	72.1	6.4
Total	**6.7**	**6.2**	**6.4**	**224.7**	**1.9**	**276.6**	**37.3**

4.7.7 Auto Terminal

Emissions for the cargo handling equipment found at the auto terminal and emissions from the new automobiles that are driven out of (or onto) the vessels are included in Table 4.27.

Table 4.27: 2005 CHE Emissions at Auto Terminals, tpy

Port Equipment	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
Forklift	0.0	0.0	0.0	0.2	0.0	1.5	0.1
New Vehicles	0.0	0.0	0.0	0.6	0.0	0.4	0.1
Total	**0.0**	**0.0**	**0.0**	**0.9**	**0.0**	**1.9**	**0.2**

The evaporative and exhaust emissions for the new vehicles at the auto terminal are based on approximately 280,000 vehicles, out of which there are 74% gasoline light duty automobiles, 20% gasoline light duty trucks and 6% heavy duty trucks. The new vehicles travel an average of half a mile at 15 miles per hour (mph) from the ship to the parking area for loading unto trucks or rail. The 2005 EMFAC model was used to estimate the emissions.

4.8 CHE 2005 Data Facts and Findings

The most prevalent engine manufacturers and models are listed below for the most common types of equipment found at the Port. If an engine model was unknown, then only engine manufacturer is included. Table 4.28 describes the most common engine manufacturers and models.

Table 4.28: Most Common Engine Manufacturers by Equipment Type

Equipment Type	Engine Make	Model	Count	Percentage of Equip Type
Yard Tractor	Cummins		210	23%
Yard Tractor	Cummins	5.9L	198	22%
Yard Tractor	Cummins	ISB	122	14%
Yard Tractor	Cummins	6BTA	105	12%
Yard Tractor	Cummins	QSB	55	6%
Yard Tractor	Cummins	LPG 195	53	6%
Yard Tractor	Cummins	QSB 5.9	36	4%
Yard Tractor	Cummins	6BT	31	3%
Forklift	Toyota	4Y	96	23%
Forklift	Cummins		27	6%
Forklift	Mitsubishi		27	6%
Forklift	Caterpillar	565	21	5%
Forklift	Cummins	5.9L	21	5%
Forklift	Mitsubishi	4G64	15	4%
Top handler	Cummins		62	49%
Top handler	Cummins	QSM11	24	19%
RTG	Cummins		40	41%
RTG	Cummins	2002	19	19%
RTG	Cummins	NTA855	10	10%
RTG	Cummins	QSX	5	5%
Side Pick	Cummins		15	37%
Side Pick	Cummins	C8.3	6	15%
Side Pick	Cummins	6BT	5	12%
Side Pick	Cummins	5.9L	4	10%
Side Pick	Volvo	TAD720VE	4	10%
Side Pick	Volvo	7D71	2	5%
Side Pick	Volvo	TWD731ME	2	5%

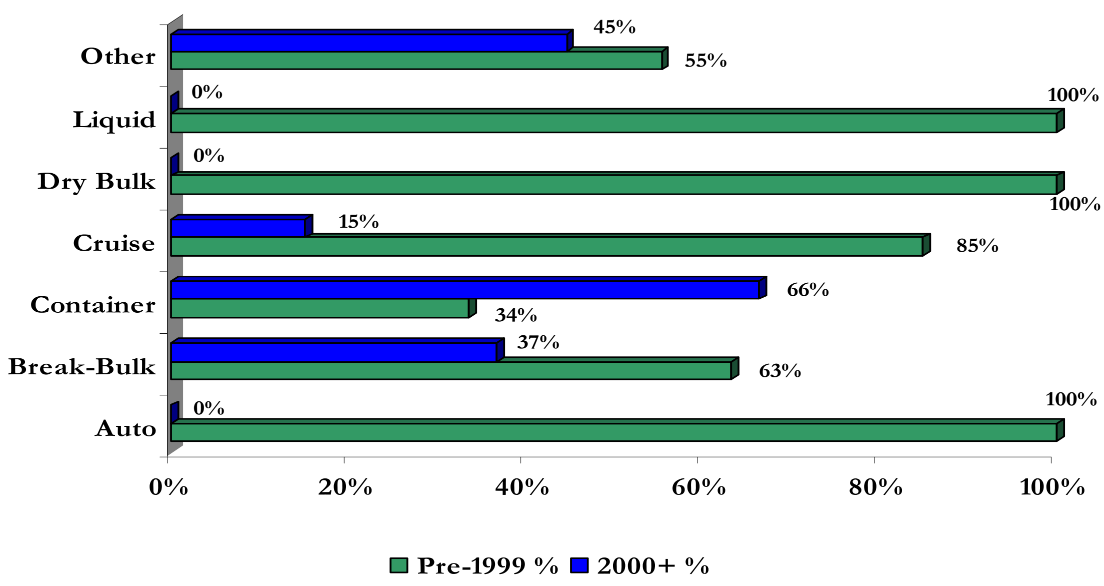
It should be noted that the average engine model year reflects newer pieces of equipment at the terminals. In 2005, 57% of the equipment at the Port has a model year of 2000 and above. This is especially true at the container facilities where 66% percent of the equipment is newer than the year 2000. One interesting fact found during interviews with terminal operators is that newer, cleaner, fuel efficient engines are used more than the older equipment, thus producing fewer emissions. Table 4.29 has a count of the pre-1999 model year equipment and the 2000+ model year equipment in 2005 by terminal.

Table 4.29: 2005 Equipment Year by Terminal Type

Terminal Type	Model Year Pre-1999	Model Year 2000+	Model Year Pre-1999 %	Model Year 2000+ %
Auto	7	0	100%	0%
Break-Bulk	134	78	63%	37%
Container	377	746	34%	66%
Cruise	28	5	85%	15%
Dry Bulk	14	0	100%	0%
Liquid	7	0	100%	0%
Other	170	137	55%	45%
Total	**737**	**966**	**43%**	**57%**

Figure 4.13 illustrates the comparison of older models with newer models for the 2005 equipment.

Figure 4.13: Percentage of 2005 Equipment with Pre-1999 and 2000+ Model Year

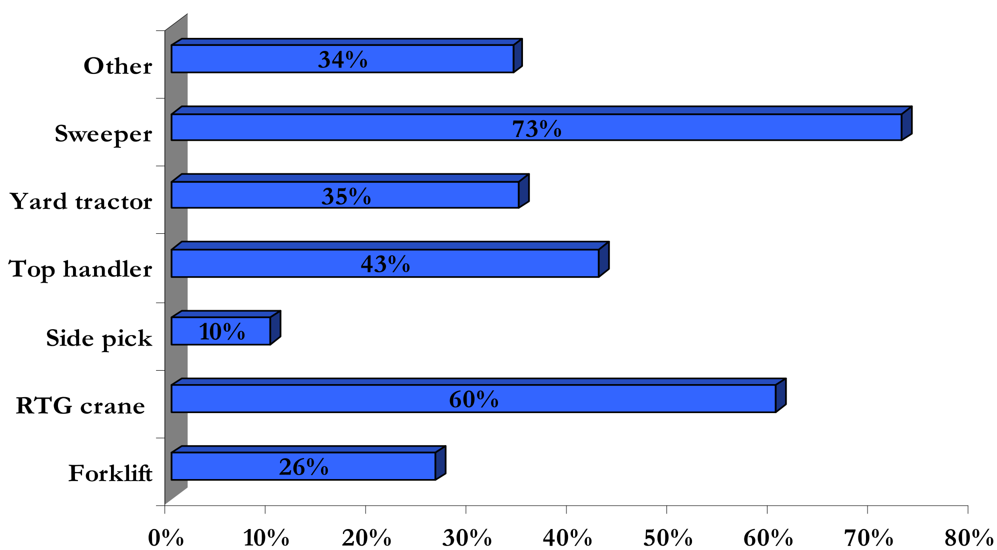


In total, there was a 34% increase in equipment count from 2001 to 2005. The breakdown by equipment type is summarized in Table 4.30. There were some terminal changes between 2001 and 2005 which have an impact on equipment count. Most notably, A. P. Moeller (APM) terminals and West Container Basin Terminal's Berth 100 were not operating in 2001 and therefore the equipment count is included in 2005 inventory. Matson Terminal was included in 2001, but not in 2005 since Matson Terminal is no longer operating at the Port. Table 4.30 shows comparison of 2005 and 2001 equipment count. Figure 4.14 shows the percent increase in equipment count between 2001 and 2005.

Table 4.30: CHE Equipment Count Comparison, 2005 vs. 2001

Equipment	2005 Count	2001 Count	Percent Increase in 2005
Forklift	422	311	26%
RTG crane	98	39	60%
Side pick	41	37	10%
Top handler	127	73	43%
Yard tractor	901	590	35%
Sweeper	11	3	73%
Other	103	68	34%
Total	**1,703**	**1,121**	**34%**

Figure 4.14: Percentage Increase of 2005 Equipment Count since 2001

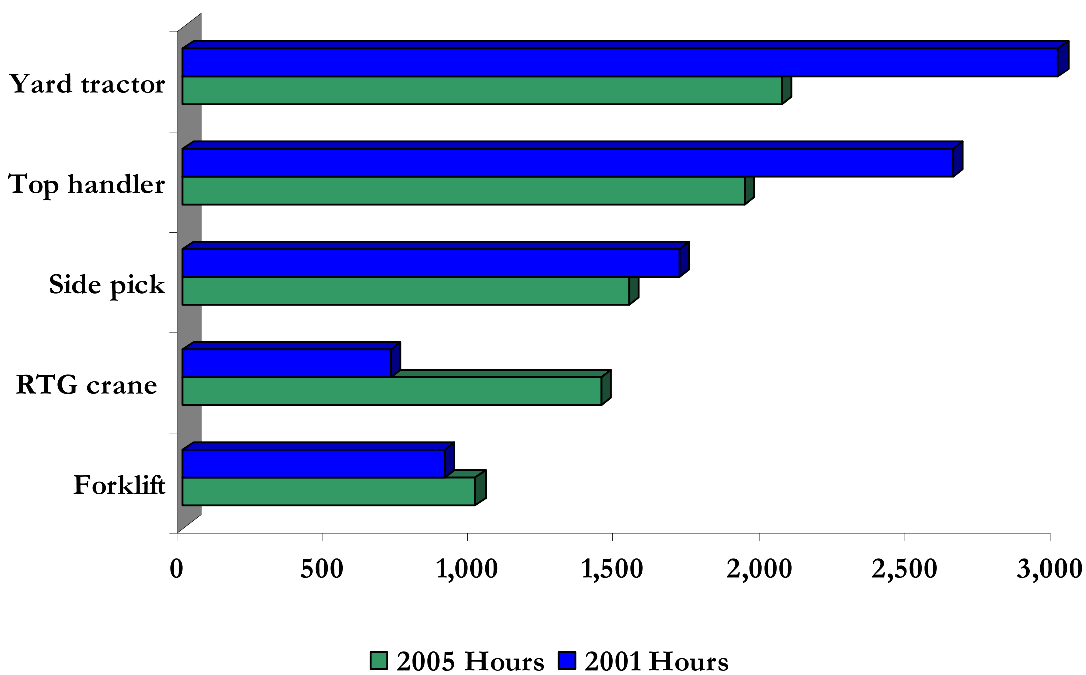


Although the equipment count has increased, the hours of use has decreased for side picks, top handlers, and yard tractors which are the most utilized pieces of equipment at the Port. This may be due to several factors; such as increased terminal efficiency, less use of equipment if there is a large pool to choose from, and better record-keeping of equipment hours using data loggers. Table 4.31 summarizes the 2005 vs. 2001 activity comparison by equipment and Figure 4.15 illustrates the comparison.

Table 4.31: CHE Equipment Activity Comparison, 2005 vs. 2001

Equipment	2005 Hours Avg	2001 Hours Avg	Percent Change in 2005
Forklift	1,002	898	10%
RTG crane	1,432	710	50%
Side pick	1,531	1,700	-11%
Top handler	1,925	2,640	-37%
Yard tractor	2,053	3,000	-46%

Figure 4.15: Comparison of 2005 CHE with 2001 CHE Activity, hours

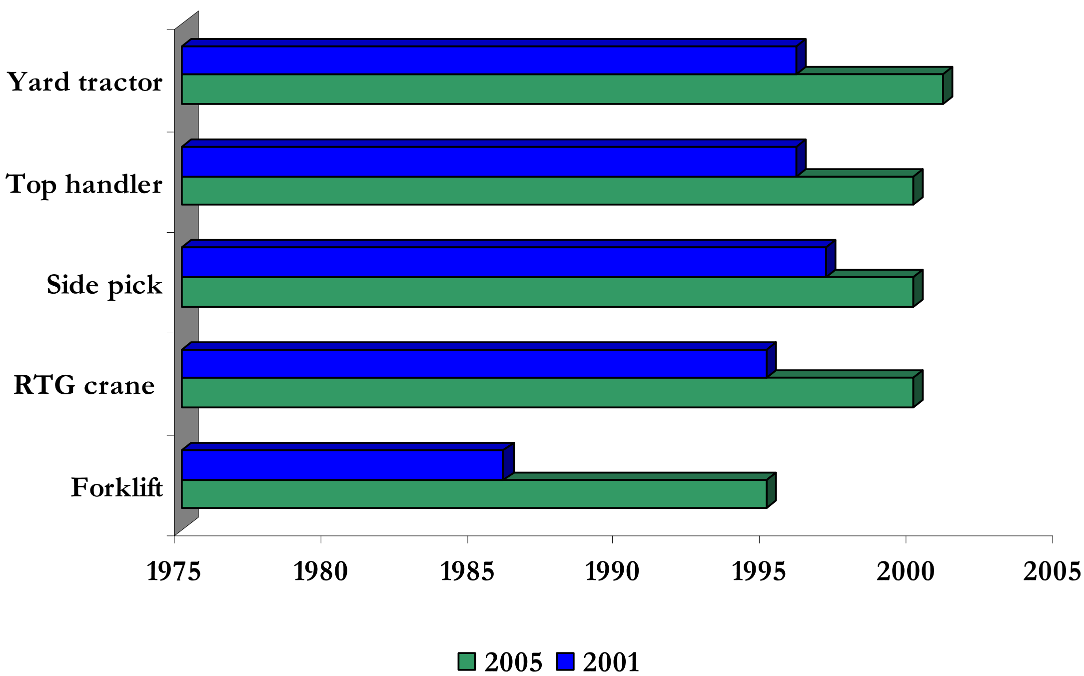


The average model year for the main equipment at the Port in 2005 is compared to the 2001 average model year and summarized in Table 4.32.

Table 4.32: CHE Average Equipment Year Comparison, 2005 vs. 2001

Equipment	2005 Year Avg	2001 Year Avg
Forklift	1995	1986
RTG crane	2000	1995
Side pick	2000	1997
Top handler	2000	1996
Yard tractor	2001	1996

Figure 4.16: Comparison of 2005 with 2001 Equipment Model Year



SECTION 5 RAILROAD LOCOMOTIVES

This section discusses the rail systems that operate in and around the Port, including the types of activities performed, the equipment used, and the methods of estimating emissions. As noted in Section 1.2, different methods have been used for different types of activity to make best use of the available information. This section also provides details of the emission estimating methodology and results/findings for this source category. The section is divided into 5.1 Description of Rail System and Locomotives; 5.2 Methodology; and 5.3 Emission Estimates.

5.1 Description of Rail System and Locomotives

Railroad operations are typically described in terms of two different types of operation, line haul and switching. Line haul refers to the movement of cargo over long distances (e.g., cross-country) and occurs within 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 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."

Locomotives used for line haul operations are typically large, powerful engines of 3,000 to 4,000 hp or more, while switch engines are smaller, typically having 1,200 to 3,000 hp. Older line haul locomotives have often been converted to switch duty as newer line haul locomotives with more horsepower have become available. Figures 5.1 and 5.2 illustrate typical line haul and switching locomotives, respectively, in use at the Port. Note that the switching locomotives in use at the Port, some of which date to the 1950s, are slated for replacement in 2006 as part of an agreement among the Ports of Los Angeles and Long Beach and the Pacific Harbor Line, owners/operators of the switchers.

The Port is served by three railway companies:

- Burlington Northern and Santa Fe (BNSF)
- Union Pacific (UP)
- Pacific Harbor Line (PHL)

These railroads primarily transport intermodal (containerized) freight, with lesser amounts of dry bulk, liquid bulk, and car-load (box car) freight. PHL performs most of the switching operations within the Port, while BNSF and UP provide line haul service to and from Port and also operate switching services at their off-port locations. The two railroads that provide line haul service to the Port are termed Class 1 railroads based on their relative size and revenues.

Figure 5.1: Typical Line Haul Locomotives

Figure 5.2: Typical Switching Locomotive

The locomotive section of the EI presents an estimate of emissions associated with Port-related activities of the locomotives operating within the Port and outside the Port to the boundary of the SoCAB. Information regarding these operations has been obtained from previous emissions studies, Port cargo statistics, and limited input from railroad operators.

The specific activities included in the emission estimates include movement of cargo within Port boundaries or directly to or from port-owned properties (such as terminals and on-port rail yards). Rail movements of cargo that occur solely outside the port, such as switching at off-port rail yards, and movements that do not either initiate or end at a Port property (such as east-bound line hauls that initiate in central LA intermodal yards) are not included in the activities for which emissions are presented in this report.

Unlike the previous Port inventory process that resulted in the 2001 baseline air emissions inventory, during the period that the current inventory was being developed the Class 1 railroads were unable to substantively participate in the process, explaining that their schedule of commitments to provide CARB with data and risk assessments on their California rail yards precluded their developing the port-specific information that was requested in the time frame necessary for use in developing the emission estimates. As a result, a substantial number of assumptions were made for the 2005 inventory. After the development of the emission estimates presented in this report, and the preparation of the report itself, the Class 1 railroads have provided a certain amount of data covering 2005 and 2006 activities which will be incorporated into the 2006 emissions inventory update, and into the comparison of 2005 and 2006 emission estimates. The 2005 component of this information is consistent with the activity estimates described in this report, supporting the validity of the estimating methodology.

Figure 5.3 illustrates the rail track system serving both ports, and Figure 5.4 presents a broader view of the major rail routes in the air basin that are used to move port-related intermodal cargo.

5.1.1 Rail System Description and Operational Characteristics

The rail system is described below in terms of the activities that are undertaken by locomotive operators. Specifically, descriptions are provided for the assembly of outbound trains, the disassembly of inbound trains, and the performance of switching operations, as well as a detailed listing of the activities of line haul and switching operations.

Outbound Trains

The assembly of outbound trains occurs in one of three ways. Container terminals with sufficient track space build trains on-terminal, using flat cars that have remained on site after the off-loading of inbound containers or those brought in by one of the railroads. Alternatively, containers can be trucked (drayed) to an off-terminal transfer facility where the containers are transferred from truck chassis to railcars. A third option is for the terminal to store individual railcars or build a partial train on-terminal, to be collected later by a railroad (typically PHL) and moved to a rail yard with sufficient track to build an entire train.

Within the Port, complete trains can be built at the terminals servicing Yang Ming and American Presidents Line (APL). In addition, the Terminal Island Container Transfer Facility (TICTF) is shared by Nippon Yusen Kaisha (NYK) and Evergreen as a location to build trains. Trains are also built outside of the Port at the Watson Yard, the Dolores Yard, and the Manuel Yard, and at locations within the POLB. If containers to be transported by rail are not loaded onto railcars at the Port, they are typically hauled by truck (drayed) to off-port locations operated by the line haul railroads. The containers are loaded onto railcars at these locations.

Figure 5.3: Port Area Rail Lines

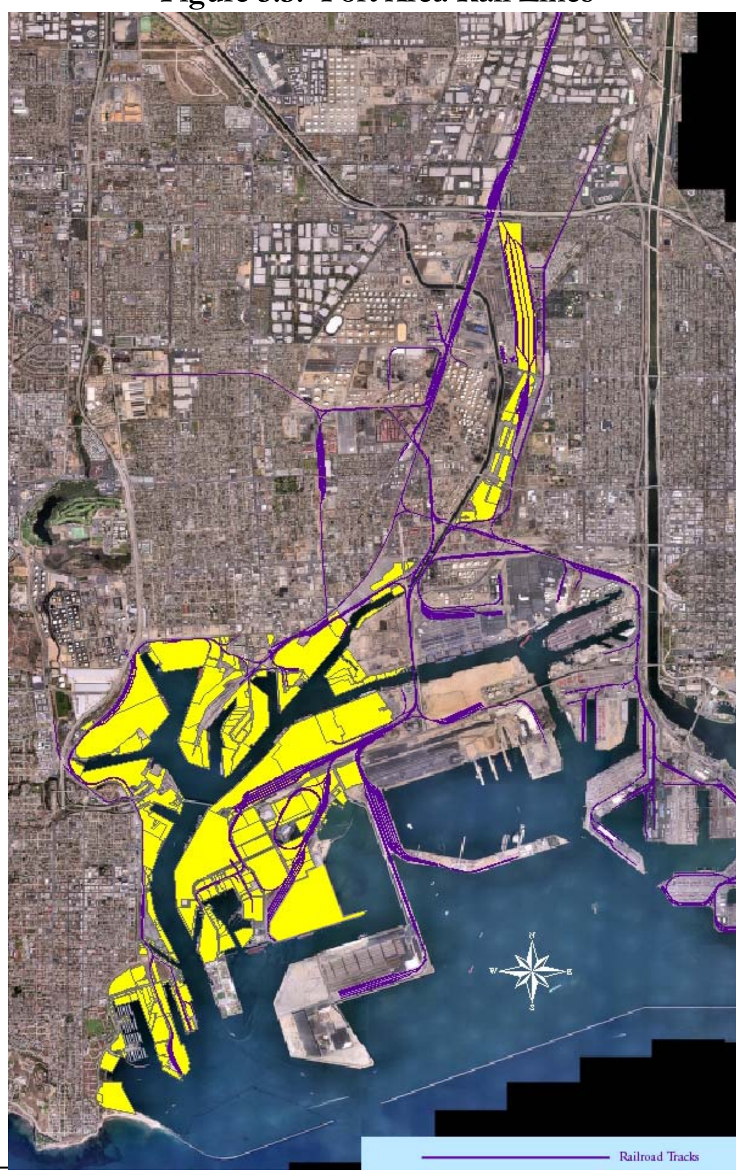
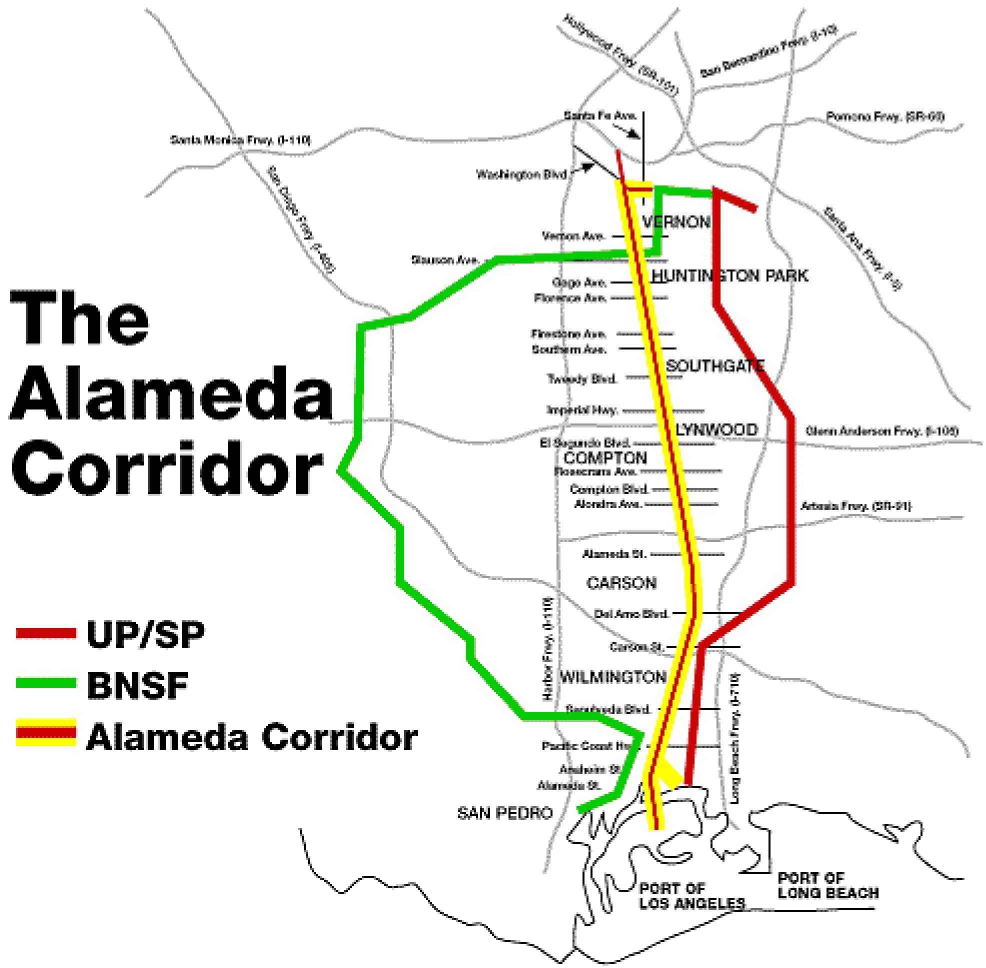


Figure 5.4: Air Basin Major Intermodal Rail Routes

Alameda Corridor

A key difference between current railroad operations and those in place during the 2001 period covered by the baseline emissions inventory is the current operation of the Alameda Corridor, which opened in 2002. The Alameda Corridor is a 20-mile rail line running from the San Pedro Bay area to downtown Los Angeles used by intermodal trains coming into and leaving the South Coast Air Basin. Running largely below grade, the Alameda Corridor provides a more direct route between downtown Los Angeles and the Port than the routes that had previously been used, shortening the travel distance and eliminating many at-grade crossings (reducing traffic congestion). Figure 5.5 shows the Alameda Corridor.

Figure 5.5: Alameda Corridor



Inbound Trains

In-bound trains that carry cargo (or empty containers) that are all destined for the same terminal are delivered directly to the terminal by the Class 1 railroad if the receiving terminal has the track space to accommodate all of the cars at one time (e.g., the TICTF on Terminal Island). Trains carrying cargo that is bound for multiple terminals with one or both Ports are staged by the Class 1 railroads at several locations, where they are broken up, typically by PHL, and delivered to their destination terminals. Inbound trains are also delivered to off-Port locations such as the Watson Yard, the Intermodal Container Transfer Facility (ICTF) operated by UP, the Dolores Yard, and the Manuel Yard. Of these off-Port locations, only the ICTF is included in the emission estimates presented in this emissions inventory, because of its status as a joint powers authority of the Port of Los Angeles and the Port of Long Beach.

Switching

Switching locomotives deliver and pick up railcars transporting containers, liquid and dry bulk materials, and general cargo to and from terminals at the Port. Switching operations take place around the clock, seven days per week, although weekend activity is generally lower than weekday or weeknight activity.

PHL is the primary switching railroad at the Port. PHL operations are organized into scheduled shifts, each shift being dispatched to do specified tasks in shift-specific areas. For example, there is a daily shift that operates on the west side of the Port, servicing liquid bulk terminals and storage facilities in that area. As another example, another daily shift operates in the POLB servicing the Toyota import terminal and various other non-container terminals in the POLB. Other shifts move empty or laden container flat cars to and from container terminals. Much of the work involves rearranging the order of railcars in a train to organize cars bound for the same destinations (inbound or outbound) into contiguous segments of the train, and to ensure proper train dynamics. (Train dynamics can include, for example, locating railcars carrying hazardous materials the appropriate minimum distance from the locomotives, and properly distributing the train's weight.) Although there is a defined schedule of shifts that perform the same basic tasks, there is little consistency or predictability to the work performed during a given shift or at a particular time.

Specific Activities

Locomotive activities of the Class 1 railway companies consist of:

- Delivering inbound trains (and/or empty railcars) to terminals or to the nearby rail yards, using line haul locomotives.
- Picking up trains from the terminals or nearby rail yards and transporting them to destinations across the country, using line haul locomotives.
- Breaking up inbound trains and sorting rail cars into contiguous fragments, and delivering the fragments to terminals, using switch locomotives.

Locomotive switching activities consist of:

- Breaking up inbound trains and sorting railcars into contiguous fragments, and delivering the fragments to terminals.
- Delivering empty container flat cars to terminals.
- Delivering rail cars to non-container facilities, and removing previously delivered rail cars. (For example, delivering full tank cars to a terminal that ships product and removing empties, or delivering empty tank cars to a terminal that receives product and removing full ones.)
- Rearranging full and empty railcars to facilitate loading by a terminal.

- Picking up outbound containers in less than full train configuration and transporting them to a yard for assembly into full trains – to be transported out of the Port by one of the line haul railroads.

5.1.2 Description of Locomotives and Trains

Physical and operational characteristics of the locomotives operating at the Port are discussed in the following paragraphs. Locomotives operate differently from other types of mobile sources with respect to how they transmit power from engine to wheels. While most mobile sources use a physical coupling such as a transmission to transfer power from the engine to the wheels, a locomotive's engine turns a generator or alternator powering an electric motor that, in turn, powers the locomotive's wheels. The physical connection of a typical mobile source means that the engine's speed is dictated by the vehicle's speed through a fixed set of gear ratios, resulting in the highly transient operating conditions (particularly engine speed and load) that characterize mobile source operations. In contrast, the locomotive's engine and drive system operate more independently, such that the engine can be operated at a particular speed without respect to the speed of the locomotive itself. This allows operation under more steady-state load and speed conditions, and as a result locomotives have been designed to operate in a series of discrete throttle settings called notches, ranging from notch positions one through eight, plus an idle position.

Many locomotives also have a feature known as dynamic braking, in which the electric drive engine operates as a generator to help slow the locomotive, with the resistance-generated power being dissipated as heat. While the engine is not generating motive power under dynamic braking, it is generating power to run cooling fans, so this operating condition is somewhat different from idling. Switch engines typically do not feature dynamic braking.

Line Haul Locomotives

Line haul locomotives are operated in the Port by BNSF and UP. Because the function of line haul locomotives is to transport freight to and from destinations across the country, there is no readily identifiable "fleet" of line haul locomotives that call on the Port other than the Class 1 railroads' nation-wide fleets.

The characteristics of BNSF line haul locomotives operating within the Port were estimated from a sampling of BNSF locomotives that called on the Port area in 2001 – BNSF provided this sample of locomotives (for the baseline emissions inventory) as being representative of their line haul locomotives calling on the Port. The sample of locomotives, primarily the 6-axle General Electric (GE) C44-9W (also known as Dash 9's) has an average of 4,256 horsepower.

Basic specifications of UP locomotives were obtained from the railroad's Internet website.[32] The UP website lists approximately 6,500 line haul locomotives in the company's nation-wide fleet, with an average power rating of 3,655 horsepower. Most of the locomotives are six-axle units, the remainder being 4-axle units. Six-axle locomotives are generally more powerful than four-axle locomotives. Most of the UP locomotives calling on the POLB are six-axle, 4,000-horsepower Electromotive Division (EMD) SD70s.

While the Class 1 railroads have undoubtedly updated their fleets in the interval between inventories, no definitive information is available regarding the locomotives that actually call on the Port, so no changes to the locomotive power assumptions have been made.

Line haul locomotives are typically operated in groups of two to five units, with three or four units being most common, depending on the power requirements of the specific train being pulled and the horsepower capacities of available locomotives. Thus, two higher-horsepower locomotives may be able to pull a train that would take three units with lower power outputs. Locomotives operated in sets are connected such that every engine in the set is operated in unison by an engineer in one of the locomotives.

Switching Locomotives

Most switching within the Port is conducted by PHL. The Class 1 railroads also conduct switching at their off-port locations. At times, PHL personnel operate BNSF or UP switch locomotives. PHL's fleet in 2005 consisted of 20 switch engines ranging from 1,200 to 2,000 hp, with an average of 1,823 hp. While the PHL fleet consists of several models, all are powered by 12- or 16-cylinder EMD engines. Early in 2006, PHL, the Port, and the Port of Long Beach concluded an agreement whereby the two ports will help fund the replacement of PHL's locomotives with new locomotives operating with low-emission Tier 2 engines. The existing fleet described above will be removed from Port service.

The Class 1 railroads also operate switch engines in and around the Port, primarily at their switching yards outside of the Port. Table 5.1 lists the switch engines that were reported as working in the area by PHL or by one of the other railroads for the 2001 inventory. They are typically powered by EMD engines, with an average power rating of 2,167 hp. The Class 1 railroads have provided no new information on their switching locomotive fleets.

[32] *http://www.uprr.com*

Table 5.1: Typical On and Off-Port Switching Locomotives

Locomotive Model	Engine Mfr	Engine Model	Horsepower (each)
SW-1200	EMD	12-567-C	1,200
SW-1200	EMD	12-567-BC	1,200
GP-7	EMD	16-567-BC	1,500
GP-9	EMD	16-567-C	1,750
SD-18	EMD	16-567-D3	1,800
SD-20	EMD	16-567-D1	2,000
SD-20	EMD	16-645-CE	2,000
GP-7	EMD	not reported	1,500
GP-9	EMD	not reported	1,750
GP-30	EMD	not reported	2,250
GP-38	EMD	not reported	not reported
GP-39-2	EMD	not reported	2,300
SD-40	EMD	not reported	3,000

Train Configuration

Container trains are the most common type of train seen at the Port. While equipment configurations vary, these trains are typically made up of up to 25 double-stack railcars, each railcar consisting of five platforms capable of carrying up to four TEUs of containerized cargo (e.g., most platforms can carry up to two 40-foot containers). With this configuration the capacity of a train is 500 TEUs or about 278 containers at an average ratio of 1.8 TEU/container. As a practical matter not all platforms carry four TEUs because not all platforms are double stacked; the current capacity or "density" is approximately 80% (meaning a 25-car train would carry 500 TEUs x 80% = 400 TEUs).

In developing off-port line haul locomotive emission estimates, the following assumptions were made regarding the typical make-up of trains traveling the Alameda Corridor and beyond: 23 double-stack rail railcars, 80% density, for a capacity of 368 TEUs or 204 containers (average). These assumptions are consistent with information developed for the No Net Increase Task Force's evaluation of 2005 Alameda Corridor locomotive activities.[33] Average train capacity assumptions for on-port emission estimates are lower based on reported container throughput and weekly/annual train information provided by Port terminals. It is assumed that train

[33] Personal communication, Art Goodwin, Alameda Corridor Transportation Authority, with Starcrest Consulting Group, LLC. February 2005.

sizes are adjusted in the off-port rail yards prior to or after interstate travel to or from the Port.

5.2 Methodology

The following section provides a description the methods used to estimate emissions from switching and line haul locomotives operating within the port and in the South Coast Air Basin. Additional information is provided in Appendix D.

5.2.1 Data Collection

As noted, the Class 1 railroads were not able to provide Port-specific information on their activities in 2005 within a time frame that allowed its use in developing emission estimates. One of the railroads provided overall summaries of fuel use in their line haul and switching locomotives for the year, with an unsubstantiated claim that port-related emissions make up 12% of overall locomotive emissions in the South Coast Air Basin.[34] The other railroad provided no information on their 2005 operations, citing their time commitments as discussed above.

PHL has previously provided data in the form of files downloaded from their locomotives' electronic event recorders. Similar to the "black boxes" installed in aircraft, the event recorders maintain a record of several locomotive operating parameters on a second-by-second basis, including throttle notch setting, locomotive speed, and direction of travel. The recorders have limited storage capacity and typically maintain two to three days of data with the oldest data being overwritten as new data is accumulated. PHL provided a download from each of its locomotives covering the same approximate 2-day period of operation.

In addition to providing event recorder data, PHL also allowed access to their switch engines as they operated. The Port's consultant rode along with the switching crew on seven of the 24 shifts, covering all hours of operation and most areas of the Port to gain an understanding of the work performed and the types of cargo handled.

For the earlier baseline emissions inventory, the line haul railway companies also provided information on their switch engines, including representative fuel usage, as well as emissions data, limited throttle notch data for switching and line haul locomotives, and detailed out-of-Port cargo information (in terms of tons of cargo and fuel usage). In addition, railroad personnel were interviewed for an overview of their operations in the area. As stated previously, certain information related to line haul locomotive fleets has been obtained from railroad companies' Internet websites.

[34] By contrast, the CARB Goods Movement emissions inventory for the South Coast Air Basin indicates that "ports and international" locomotive emissions represent from 27% to 36% of overall goods movement locomotive emissions in the air basin (percentage depending on pollutant).

Additionally, terminal operators have provided information on their rail operations that provides an additional level of understanding of overall line haul rail operations.

It should be noted that data collection is particularly difficult with respect to estimating rail emissions associated with port activities. As a result, the rail data for locomotive operations associated with port activities as presented in the 2005 Port inventory is somewhat less refined and specific than the data for other emission sources. The Port continues to work with the railroads to further enhance the accuracy of the port activity data on which the rail emissions inventory is based. We believe the improvement in locomotive operating information related to Port activities in the 2006 emissions inventory will provide a greater level of accuracy for rail locomotive operating emissions that will be more consistent with the other source categories.

5.2.2 Emission Estimation

It should be noted, that calculating rail emissions associated with port activities is particularly difficult to assemble and calculate. As a result, the rail data for locomotive operations associated with port activities as presented in the 2005 Port inventory is somewhat less refined and specific than the data for other emission sources. We continue to work with the railroads to further enhance the accuracy of the port activity emissions rail inventory data. We believe the ongoing further enhancement of locomotive operating information for port activities in the 2006 emissions inventory will provide an even greater level of accuracy for rail locomotive operating emissions consistent with other source categories.

Emissions have been estimated using the information provided by the railroads and the terminals, and from published information sources such as the EPA's Regulatory Support Document (RSD) published as background to EPA's locomotive rule-making process.[35] For in-Port switching operations, the throttle notch data and schedule/operational information provided by the switching companies has been used along with EPA data on emission rates by throttle notch. Off-Port switching emissions have been estimated using throttle notch, emissions, and fuel use data provided by one of the railroad companies. For the limited line haul operations in the Port, emission estimates have been based on schedule and throughput information provided by terminal operators and on EPA operational and emission factors. Off-Port line haul emissions have been estimated using detailed cargo movement and fuel use information provided by the line haul railroads.

The throttle notch setting approach to estimating locomotive emissions has been selected as the preferred method because it is expected to provide better spatial

[35] EPA Office of Mobile Sources, *Locomotive Emission Standards Regulatory Support Document,* April 1998, revised.

resolution than alternative approaches, which will enhance the value of the emission estimates for subsequent use in health assessments. However, specific throttle notch information has only been provided for switching operations. Therefore, throttle notch information published by EPA and described below has been used to estimate line haul emissions.

A detailed explanation of emission calculation methods is below and back-up data tables are presented in Appendix D.

Different calculation methods were required because different types of information were provided for different activities. For example, an activity and throttle notch-based approach has been used for one company's switching emissions, whereas a fuel use-based approach has been used for another. These methods are described below.

Switching Emissions

Separate emission estimates have been prepared for the companies that provide switching services within and near the Port based on the information each company provided. Estimation methods differ because the companies provided different types of information, as described below.

On-Port Switching Emissions

Emissions from the first company's switching operations have been based on the railroad company's schedule of operations and site-specific throttle notch frequencies, and emission factors from the EPA documents cited above.

First, the characteristics of the railroad company's fleet operating in 2001 were evaluated to develop a fleet average horsepower rating. Because several locomotives normally operate as coupled pairs, these pairs were considered as one "locomotive" when developing the averages. Table 5.2 lists the "in-use" rated horsepower characteristics of this company's 2001 fleet.

Table 5.2: Horsepower Characteristics of PHL Locomotives

Locomotive Model	Engine Model	Number	Each	Rated Horsepower In Use	Total
Pair of SW-1200s	12-567-C	1	1,200	2,400	2,400
Pair of SW-1200s	12-567-C/BC	1	1,200	2,400	2,400
Single SW-1200	12-567-C	1	1,200	1,200	1,200
SD-18	16-567-D3	4	1,800	1,800	7,200
SD-20	16-567-D1	1	2,000	2,000	2,000
SD-20	16-567-CE	2	2,000	2,000	4,000
SD-20	16-645-E	1	2,000	2,000	2,000
SD-20	16-645-CE	1	2,000	2,000	2,000
GP-7/GP-9 Pair	16-567-C/BC	1	1,750/1,500	3,250	3,250
SD-38-2	16-645-E	2	2,000	2,000	4,000
SD-40T	16-645-E3	2	3,000	3,000	6,000
Total		17			36,450
Average locomotive horsepower:					**2,144**

Next, the average notch-specific horsepower values for the "average" switch locomotive operated by this company have been calculated by multiplying the average rated horsepower value by notch-specific percentages derived from the EPA's RSD cited above. The percentages represent the fraction of total rated horsepower that is produced in each throttle setting. This process is illustrated in the example below, for throttle notch setting 1, with results for all throttle settings shown in Table 5.3.

Calculation 5.1

83 hp / 1,750 hp = 0.047, or 4.7%

2,144 hp x 0.047 = 101 hp

In this example, the average notch 1 power in the RSD data is 83 hp, which is divided by the average rated power of the locomotives tested for the RSD, 1,750 hp. The result is 0.047, or 4.7%; this means that 4.7% of the power of the average locomotive (in the RSD dataset) is used at throttle notch position 1. The next step is to multiply the average horsepower rating of the locomotives doing switch duty at the Port (2,144 hp) by the percentage of power used by the RSD locomotives. This result is 101 horsepower, meaning that the switch engines in use at the Port use an average of 101 hp while in throttle notch position 1.

This calculation is repeated for each throttle notch position, as shown in Table 5.3.

Table 5.3: Calculation of Notch-Specific In-Use Horsepower

Notch	RSD Power in Notch, bhp	% of Avg. Rated bhp	Avg. in-use Power, bhp
DB	67	3.8%	81
Idle	14	0.8%	17
1	83	4.7%	101
2	249	14.2%	304
3	487	27.8%	596
4	735	42.0%	900
5	1,002	57.3%	1,229
6	1,268	72.5%	1,554
7	1,570	89.7%	1,923
8	1,843	105.3%	2,258
Average RSD hp:	**1,750**	**Avg. local hp:**	**2,144**

Note: in these tables, "DB" refers to "dynamic braking," a feature of some locomotives' operation that does not apply to this switching locomotive fleet. The term is included because it is part of the published EPA data set.

The next step is to develop notch-weighted hourly emission rates, first by using the in-use horsepower values described above to convert the RSD average switching emission rates from grams per horsepower-hour (g/hp-hr) to pounds per hour (lbs/hr). The conversion is calculated as follows:

Calculation 5.2

(g/hp-hr x hp) / (453.6 g/lb) = lb/hr

The two sets of emission rates (g/hp-hr and lb/hr) are presented in Tables 5.4 and 5.5, where the values in Table 5.5 have been obtained by multiplying those in Table 5.4 by the in-use horsepower figures presented in Table 5.3.

For example, for NO_X emissions and throttle notch setting 1, the Table 5.4 value of 16.63 g/bhp-hr is multiplied by the notch position 1 horsepower value of 101 hp in Table 5.3 and divided by 453.6 g/lb to result in an estimate of 3.70 lb/hr as shown in Table 5.5. This calculation is repeated for each throttle notch position, as shown in Table 5.5.

Table 5.4: Horsepower-Based Emission Factors from RSD

Notch	Power in Notch, bhp	Notch	PM g/bhp-hr	NO_x g/bhp-hr	CO g/bhp-hr	HC g/bhp-hr
DB	81	DB	1.05	40.20	8.49	3.98
I	17	Idle	2.26	77.70	16.81	9.18
1	101	1	0.29	16.63	2.56	1.49
2	304	2	0.37	12.26	1.51	0.67
3	596	3	0.34	13.09	0.83	0.43
4	900	4	0.26	14.27	0.57	0.37
5	1,229	5	0.24	15.10	0.53	0.38
6	1,554	6	0.29	15.88	0.67	0.40
7	1,923	7	0.25	16.37	1.26	0.44
8	2,258	8	0.29	16.15	2.97	0.47

Table 5.5: Hourly Notch-Specific Emission Rates

Notch	PM lb/hr	NO_x lb/hr	SO_x lb/hr	CO lb/hr	HC lb/hr
DB	0.19	7.18	0.02	1.52	0.71
Idle	0.08	2.91	0.004	0.63	0.34
1	0.06	3.70	0.02	0.57	0.33
2	0.25	8.22	0.07	1.01	0.45
3	0.44	17.20	0.13	1.09	0.56
4	0.51	28.32	0.20	1.12	0.72
5	0.64	40.92	0.27	1.43	1.03
6	0.98	54.40	0.34	2.29	1.37
7	1.08	69.41	0.43	5.33	1.86
8	1.42	80.38	0.50	14.80	2.34

Table 5.5 also includes hourly emission rates of SO_x that have been estimated on the basis of a mass balance approach and a typical fuel sulfur content of 330 ppm by weight. The mass balance approach assumes that the sulfur (S) in the fuel is converted to SO_2 and emitted during the combustion process. While the mass

balance approach calculates SO_2 specifically, it is used as a reasonable approximation of SO_x. The following example shows the calculation for throttle notch position 1.

Calculation 5.3

$$\frac{330 \text{ lbs S}}{1{,}000{,}000 \text{ lbs fuel}} \times \frac{0.336 \text{ lbs fuel}}{\text{hp-hr}} \times \frac{2 \text{ lbs } SO_2}{\text{lb S}} \times 101 \text{ hp} = 0.02 \text{ lbs } SO_2/\text{hr}$$

In this calculation, 330 ppm S is written as 330 lbs S per million lbs of fuel. The value of 0.336 lbs fuel/hp-hr is an average brake-specific fuel consumption derived from EPA's technical literature on locomotive emission factors. Two pounds of SO_2 is emitted for each pound of sulfur in the fuel because the atomic weight of sulfur is 32 while that of SO_2 is 64, meaning that the weight of an amount of sulfur doubles when it is expressed as SO_2. Finally, the average in-use horsepower value for throttle notch position 1 is 101 hp, as presented in Table 5.3. This calculation was carried out for each throttle notch position; the results are shown in Table 5.5.

A notch-weighted average emission rate has been estimated using time-in-notch percentages developed from the event recorder data provided by the switching company. Each hourly value in Table 5.5 is multiplied by the percentage corresponding to the respective notch setting. The percentages and resulting fractional emission rates are shown in Table 5.6. Because the time-in-notch fractions together represent all of the locomotives' operating time, the products obtained from the multiplication of pounds per hour by time fraction can be summed to provide a notch-weighted hourly emission rate that is representative of the average locomotive (or pair of locomotives) operating with an average site-specific throttle notch distribution.

Continuing the example of NO_X emissions for throttle notch position 1, the 3.70 lb/hr from Table 5.5 is multiplied by the notch position 1 percentage of 5.9% (or 0.059) listed in Table 5.6 under "wt'd avg % in mode" to obtain the value of 0.22.

Calculation 5.4

$$3.79 \text{ lb/hr} \times 0.059 = 0.22$$

Each of the hourly rates in Table 5.5 is similarly multiplied by the percentage corresponding to each throttle notch position. The results are summed for each pollutant to calculate weighted average emission rates.

Table 5.6: Time-in-Notch and Weighted Average Emission Rates

Notch	wt'd avg % in mode	PM % x lb/hr	NO_x % x lb/hr	SO_x % x lb/hr	CO % x lb/hr	HC % x lb/hr
DB	0.0%	0.00	0.00	0.000	0.00	0.00
Idle	67.4%	0.05	1.96	0.003	0.42	0.23
1	5.9%	0.004	0.22	0.001	0.03	0.02
2	7.7%	0.02	0.63	0.005	0.08	0.03
3	6.7%	0.03	1.16	0.009	0.07	0.04
4	5.3%	0.03	1.49	0.011	0.06	0.04
5	3.0%	0.02	1.24	0.008	0.04	0.03
6	2.0%	0.02	1.11	0.007	0.05	0.03
7	0.9%	0.01	0.64	0.004	0.05	0.02
8	1.1%	0.02	0.88	0.005	0.16	0.03
Weighted average lb/hr		**0.20**	**9.33**	**0.05**	**0.97**	**0.46**

An estimate of the operating hours of these switching locomotives has been developed by evaluating the number and duration of work shifts. The schedule of shifts is well defined, with a total of 40 work shifts during the study period, with an average of 31 work shifts per day. While shifts may last up to 12 hours (the federally mandated limit for railroad crews) they are usually shorter. The monthly average duration of each shift was calculated for a one-year period, and from that a total of approximately 92,000 locomotive operating hours was estimated for the year. With 17 locomotives (or locomotive pairs) operating during the year, the average per locomotive is 5,412 hours per year. Company staff has noted that locomotives are shut off when they are not in use, so shift operations represent the appropriate measure of operating time. Table 5.7 illustrates the estimate of hours per year for switching activities on both Ports.

Table 5.7: Estimate of Annual Switching Locomotive Hours of Operation

Parameter Average	Value
Average shift duration:	8.27
Avg. # shifts/day:	31
Operating hrs/day:	256 (# of shifts x duration)
Avg. days/month:	30
Operating hrs/month:	7,690
Total operating hours per year	**92,000** (rounded to nearest thousand)

PHL operates within both the Port of Los Angeles and the Port of Long Beach. While some of the shifts are focused on activities in only one of the ports, other shifts may work in either or both ports depending upon the day's needs for switching services. Therefore, it is not possible to clearly designate which shifts operate solely within the Port of Los Angeles so a method is required for apportioning emissions between the two ports. To do this, the previous baseline emissions inventory evaluated the work shifts as to whether they are likely to work in either port exclusively or in both ports. The result was a split of 69% of activity within the Port of Los Angeles and 31% within the Port of Long Beach. The difference between the two ports' allocations is so great in part because PHL's main yard is within the Port of Los Angeles, so almost all work shifts involve at least some Port of Los Angeles activity.

As the final step, emissions from the locomotives attributable to the Port have been calculated by multiplying the hourly notch-weighted emission rates shown in Table 5.6 by the annual operating hours shown in Table 5.7 and the Port activity percentage discussed above. The results are shown in Table 5.11 and summarized in Section 5.3. For example, the CO emission rate of 0.97 lb/hr (Table 5.6) multiplied by 92,000 hours/year (Table 5.7) and the 69% Port fraction, and divided by 2,000 lbs/ton, results in the 30.8 tons per year shown in Table 5.8.

Calculation 5.5

$$\frac{0.97\ \text{lb/hr} \times 92{,}000\ \text{hr/yr} \times 0.69}{2{,}000\ \text{lb/ton}} = 30.8\ \text{tpy}$$

Note that the HC emission rate presented in Table 5.6 has been converted to total organic gases (TOG) using a conversion factor of 1.07 (HC x 1.07 = TOG), as recommended by EPA in EPA420-P-03-002, *Conversion Factors for Hydrocarbon Emission Components*, May 2003. In addition, EPA's RSD does not include emission factors for SO_x. Table 5.8 also includes an estimate of SO_x emissions based on PHL's reported use of EPA on-road diesel fuel, which has been assumed to have a sulfur content of 330 ppm.

Table 5.8: Estimated On-Port Switching Emissions, tpy

	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
Totals (tpy)	6.3	5.8	6.3	296.1	1.6	30.8	16.7

Note: All particulate emissions are assumed to be PM-10 and diesel particulate matter (DPM); PM-2.5 emissions have been estimated as 92% of PM-10 emissions.

Off-Port Switching Emissions
UP operates switching locomotives at their intermodal container transfer facility (ICTF) located at the northern end of the Port of Los Angeles to help make up the trains that are hauled out of the air basin. UP provided a report of fuel used in all of their switching locomotives in the South Coast Air Basin but did not indicate which of the locomotives operated at the ICTF. In another report the railroad included the statement that 12% of basin-wide emissions are attributable to port-related traffic, although no reference or rationale was given for the statement.

A fuel-based approach was used to estimate ICTF switching locomotive emissions to make the best use of available data. The average per-locomotive fuel usage from the railroad's report was used as a surrogate for port-related switch locomotive fuel usage, and the number of locomotives in port-related service was assumed to be the same as during the 2001/2002 baseline emissions inventory periods. The assumption of the same number of locomotives is reasonable because the basin-wide number of switching locomotives reported for 2005 by UP was only two more than the number reported for the 2001 and 2002 inventories (110 *vs.* 108, a difference of less than 2%). In contrast to the number of locomotives, the reported average fuel used per locomotive (in the basin-wide data) increased from 46,000 gallons per year in 2001 to 54,000 gallons in 2005, a 17% increase. It is reasonable to assume that increased throughput has been accomplished by more intensive usage of the same number of locomotives.

Rail cargo from both the Port of Los Angeles and the Port of Long Beach are handled at the ICTF, and the complexities of the rail system are such that apportionment of activity (and emissions) between the two ports is difficult. The previous baseline emissions inventories used an allocation of 55% Port of Los Angeles and 45% Port of Long Beach – this allocation has been maintained for the current inventories because it still seems a reasonable assumption, given that the Port of Los Angeles' overall TEU throughput represented about 53% of the two ports' combined throughput in 2005. Regardless of apportionment, the sum of the two ports' emissions represents all of the estimated switching emissions from locomotives operated at the ICTF.

The fuel-based emission factors are from EPA's *Locomotive Rule Technical Highlights*, Table 3. These are EPA's "baseline" emission factors that do not take into account the effects of EPA's recent locomotive emission control rules affecting new and rebuilt locomotives. These appear to be the appropriate emission factors since switch engines are generally older, and lacking detailed information from the railroads the assumption must be made that the locomotives have not yet been rebuilt to meet the new standards.

Table 5.9 illustrates the emissions estimated by multiplying the annual per-locomotive fuel use rate (54,000 gallons) by the estimated number of switching locomotives (6), the port-specific allocated fraction (55% for the Port of Los Angeles) and the pollutant-specific emission factor in grams per gallon (and converting the resulting estimate of grams of emissions to tons of emissions).

Table 5.9: Estimated ICTF Switching Emissions, tpy

`	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
Emission Factors, g/gal	9.2	na	na	362	2.1	38.1	22.5
Emissions, tons per year	1.8	1.7	1.8	71.1	0.4	7.5	4.4

The emission estimates listed above for $PM_{2.5}$ and DPM are based on the standard assumption of $PM_{2.5}$ from diesel engines being 92% of PM_{10}, and all diesel engine PM_{10} emissions being DPM. The HC emission rate published by EPA has been converted to TOG using a conversion factor of 1.07 as previously noted.

5.2.3 Line Haul Locomotive Emissions

Emissions from line haul locomotives operating in the Port have been estimated on an activity basis, i.e., estimates of the number and characteristics of locomotives that arrive and depart with cargo. The information used in developing these estimates has been obtained from the Port and Port terminals.

The number of locomotive trips in the Port has been estimated by evaluating cargo movements, percentage of cargo transported by rail, and typical number of locomotives per train, using a methodology similar to that used for the 2001 baseline emissions inventory. Emission factors have been taken from EPA's RSD documentation representing EPA's projected 2005 nationwide fleet of line haul locomotives, as shown in Table 5.10. The emission factors are presented in terms of grams per horsepower-hour (g/hp-hr) as listed in the RSD documentation as well as grams per gallon of fuel (g/gal). The conversion was made by dividing the g/hp-hr factors by the fuel consumption factor 0.048 gal/hp-hr, which is the value used by EPA to make similar conversions in the RSD. Both sets of emission factors have been used in estimating locomotive emissions, as described below.

Table 5.10: Emission Factors for Line Haul Locomotives

	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
EF, g/bhp-hr	0.31	NA	NA	8.82	0.59	1.28	0.49
EF, g/gal fuel	6.4	5.9	6.4	183.7	12.3	26.7	10.3

On-Port Line Haul Emissions

On-port line haul locomotive activity has been estimated through an evaluation of the amount of cargo reported by the terminals to be transported by rail and their reported average or typical number of trains per week or per year. These numbers have been combined with assumptions regarding the number of locomotives, on average, that are involved with on-port line haul railroad moves, and the average duration of incoming and outgoing port trips, similar to the approach taken for the 2001 baseline emissions inventory. The number of trains per year, locomotives per train, and on-port hours per train were multiplied together to calculate a total of locomotive hours per year. This activity information is summarized in Table 5.11.

Table 5.11: On-Port Line Haul Locomotive Activity

Activity Measure	Inbound	Outbound	Totals
# of Trains per Year	4,092	4,104	8,196
# of Locomotives per Train	3	3	
Hours on Port per Trip	1.0	2.5	
Locomotive Hours per Year	12,276	30,780	43,056

The average load factor for a typical line haul locomotive calling on the Port has been estimated by multiplying the percentage of full power in each throttle notch setting by the average percentage of line haul locomotive operating time in that setting. Both of these sets of percentages are EPA averages listed in the RSD documentation. The resulting products were summed to estimate the average load factor, as illustrated in Table 5.12.

Table 5.12: Estimated Average Load Factor

Notch	% of Full Power in Notch	% of Operating Time in Notch	% Full Power x % Time
DB	2.1%	12.5%	0.003
Idle	0.4%	38.0%	0.002
1	5.0%	6.5%	0.003
2	11.4%	6.5%	0.007
3	23.5%	5.2%	0.012
4	34.3%	4.4%	0.015
5	48.1%	3.8%	0.018
6	64.3%	3.9%	0.025
7	86.6%	3.0%	0.026
8	102.5%	16.2%	0.166
Average line haul locomotive load factor:			**28%**

The estimated number of locomotive hours for the Port was multiplied by an average locomotive horsepower and the average load factor discussed above to estimate the total number of horsepower-hours for the year:

Calculation 5.6

43,056 locomotive hours/year x 4,000 horsepower/locomotive x 0.28

= 47.8 million horsepower-hours (rounded)

Emission estimates for on-port line haul locomotive activity were calculated by multiplying this estimate of horsepower-hours by the emission factors listed in Table 5.13 in terms of g/hp-hr. These estimates are presented in Table 5.13.

Table 5.13: On-Port Line Haul Locomotive Emission Estimates

	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
EF, g/bhp-hr	0.31	NA	NA	8.82	0.59	1.28	0.49
Tons per year	16.2	14.9	16.2	464.6	31.1	67.4	25.9

Out-of-Port Line Haul Emissions

Line haul locomotive activity between the Port and the air basin boundary has been estimated through an evaluation of the amount of Port cargo transported by rail and of average or typical train characteristics such as number of containers and number of gross tons per train. In this way, estimates have been prepared of gross tonnage and fuel usage, similar to the methodology used for the 2001 baseline emissions inventory. However, the current estimates have been prepared without railroad participation, for previously discussed reasons.

The four components to locomotive activity that were estimated to develop the off-port emission estimates are the number of trains, the average weight of each train, the distances traveled within the South Coast Air Basin, and the amount of fuel used per ton-mile of train activity. Using the average train capacities discussed above (average 204 containers per train) and the two San Pedro Bay Ports' 2005 intermodal throughputs, the average number of port-related trains was estimated to be 32 per day through the Alameda Corridor[36] and 43 per day beyond the Corridor. The gross weight (including locomotives, railcars, and freight) of a typical train was estimated to be 5,300 tons, using the assumptions in Table 5.14. The distance assumptions are 21 miles for the Alameda Corridor and 84 miles between the northern end of the Alameda Corridor to the Air Basin boundary. The latter distance is an average of the east and south routes taken by UP trains and the east route taken by most BNSF trains, weighted by the percentage distribution of freight reported in the 2001 baseline emissions inventory, as shown in Table 5.15 (information from 2001 was used because information from both railroads was not available for the 2005 inventory period). Gross ton-miles were calculated by multiplying together the number of trains, the gross weight per train, and the miles traveled, as summarized in Table 5.16. This table also shows the estimated total fuel usage, estimated by multiplying the gross tons by the average 2001 fuel consumption factor for the two line haul railroads (1.328 gallons of fuel per ton-mile), as reported in the 2001 baseline emissions inventory. The railroads' fuel consumption factors may have been lower in 2005 than in 2001, but the railroads declined to provide the 2005 factors for publication, citing confidentiality. The use of the average of their 2001 factors (which have been published in the Port's baseline inventory) will produce a conservatively high estimate of fuel use.

Table 5.14: Assumptions for Gross Weight of Trains

Train Component	Approx. Weight lbs	Weight tons (short)	Number per train	Weight tons (short)
Locomotive	420,000	210	4	840
Railcar (per double-stack platform)	40,000	20	115	2,300
Container		10.6	204	2,160
Total weight per train, gross tons				**5,300**

[36] Overall Alameda Corridor traffic for 2005 was 17,306 trains, for an average of 47 per day. This includes non-port-related traffic; reference www.acta.org/PDF/CorridorTrainCounts.pdf

Table 5.15: Train Travel Distance Assumptions

	Miles	% of freight, 2001	Miles x %
UP - LA east	84	36%	30
UP - LA south	91	10%	9
BNSF - LA east	82	54%	44
Weighted average distance			**84**

Table 5.16: Gross Ton-Mile and Fuel Use Estimate

	Distance miles	Trains per year	MMGT per year	MMGT-miles per year
Alameda Corridor	21	6,424	34	714
Central LA to Air Basin Boundary	84	6,424	34	2,856
Million gross ton-miles				**3,570**
Estimated gallons of fuel (millions)				**4.7**

Emission estimates for out-of-port line haul locomotive activity were calculated by multiplying this estimate of overall fuel use by the emission factors listed in Table 5.10 in terms of g/gallon. These estimates are presented in Table 5.17.

Table 5.17: Out-of-Port Line Haul Locomotive Emission Estimates

	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
EF, g/gal fuel	6.4	5.9	6.4	183.7	12.3	26.7	10.3
Tons per year	33.1	30.5	33.1	951.6	63.7	138.2	53.1

5.3 Emission Estimates

A summary of estimated emissions from locomotive operations related to the Port is presented below in Table 5.18. These emissions include operations within the Port and port-related emissions outside the Port out to the boundary of the South Coast Air Basin. The distribution of emissions is presented graphically in Figures 5.6 through 5.10.

Table 5.18: Port-Related Locomotive Operations Estimated Emissions

	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
On-Port Emissions, tons per year							
Switching	6.3	5.8	6.3	296.1	1.6	30.8	16.7
Line Haul	16.2	14.9	16.2	464.6	31.1	67.4	25.9
On-Port Subtotal	22.5	20.7	22.5	760.7	32.7	98.2	42.6
Off-Port (regional) Emissions, tons per year							
Switching	1.8	1.7	1.8	71.1	0.4	7.5	4.4
Line Haul	33.1	30.5	33.1	951.6	63.7	138.2	53.1
Off-Port Subtotal	35.0	32.2	35.0	1,022.7	64.1	145.6	57.6
Switching Subtotal	8.2	7.5	8.2	367.3	2.0	38.3	21.1
Line Haul Subtotal	49.3	45.4	49.3	1,416.2	94.8	205.6	79.1
Port of Los Angeles Total	**57.5**	**52.9**	**57.5**	**1,783.5**	**96.8**	**243.9**	**100.2**

Figure 5.6: Port-Related Locomotive Operations Estimated Emissions, PM

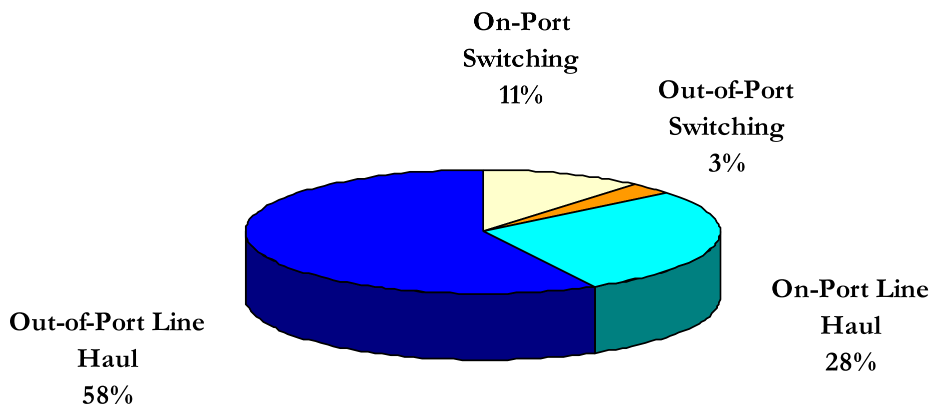


Figure 5.7: Port-Related Locomotive Operations Estimated Emissions, NO_x

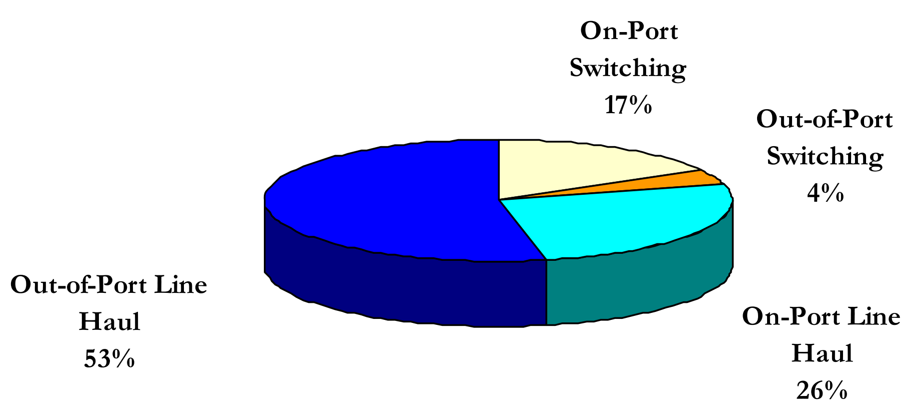


Figure 5.8: Port-Related Locomotive Operations Estimated Emissions, SO_x

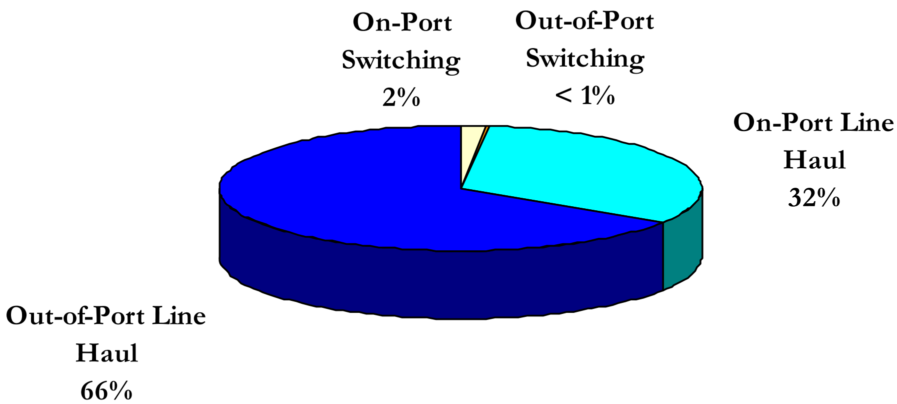


Figure 5.9: Port-Related Locomotive Operations Estimated Emissions, CO

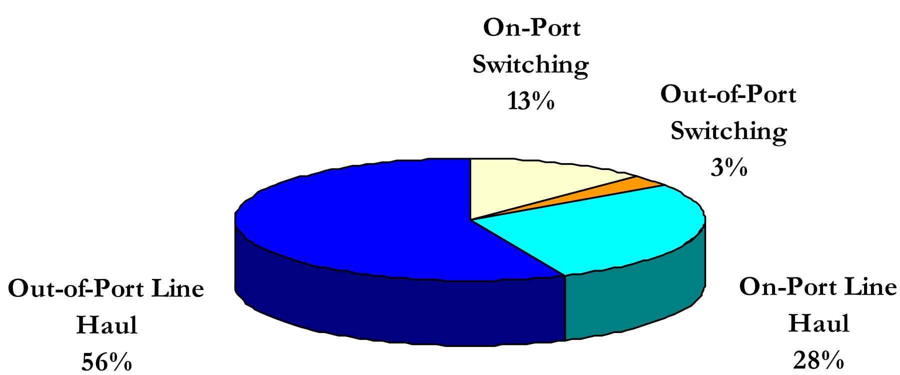
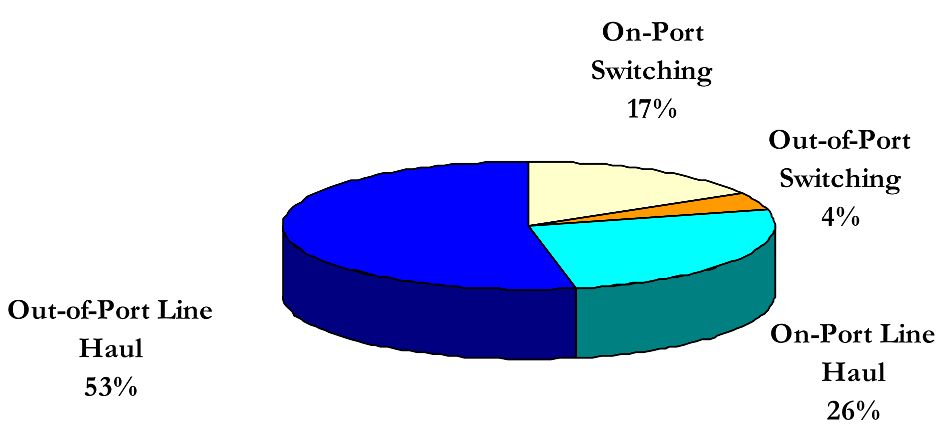


Figure 5.10: Port-Related Locomotive Operations Estimated Emissions, TOG



SECTION 6 HEAVY-DUTY VEHICLES

This section provides estimates of the emissions from heavy-duty vehicles (HDVs) that transport Port-related cargo. The section also describes the operations of these trucks, which are almost exclusively diesel-fueled, and discusses the methodologies used to estimate vehicle activities and emissions. The section is divided into 6.1, Source Description; 6.2, Data and Information Acquisition; 6.3, Methodology; and 6.4, Emission Estimates.

6.1 Source Description

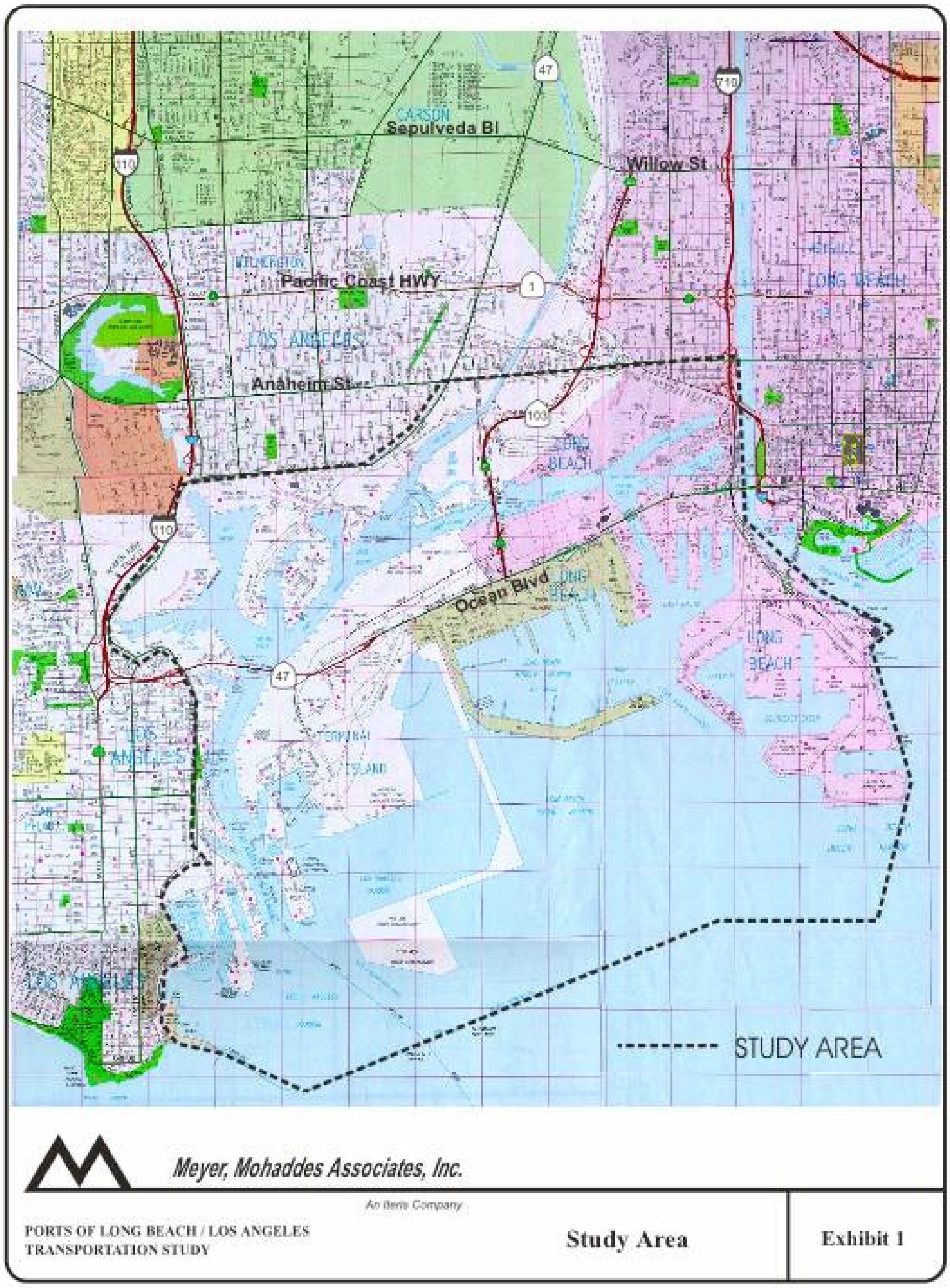
Trucks are used extensively to move cargo, particularly containerized cargo, to and from the terminals that serve as the bridge between land and sea transportation. Trucks deliver cargo to local and national destinations, and they also transfer containers between terminals and off-port railcar loading facilities, an activity known as draying. In the course of their daily operations, 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.

To develop emission estimates, truck activities have been evaluated as having three components:

- On-terminal operations, which include waiting for terminal entry, transiting the terminal to drop off and/or pick up cargo, and departing the terminals.
- Off-terminal Port operations, consisting of travel on public roads within the Port jurisdictional boundaries.
- On-road operations outside the Port boundaries but within the SoCAB. This includes travel within the boundaries of the adjacent Port of Long Beach, because the routes many trucks take run through both ports on the way to and from Port terminals.

Figure 6.1 shows the roadways in and around the Port that the HDVs use in daily operations. The figure presents the scope of a traffic study that evaluated traffic patterns in both the Port of Los Angeles and the Port of Long Beach. That traffic study and its use in developing the HDV emission estimates presented in this report are discussed in more detail in the following subsections.

Figure 6.1: Port and Near-Port Roadways



6.1.1 Vehicle Types

The CARB distinguishes among three types of heavy-duty trucks: light heavy-duty, medium heavy-duty, and heavy heavy-duty. These categories are based on the gross vehicle weight rating of the truck, including its trailer if so equipped.

- Light HDV: 10,000 to 14,000 pounds
- Medium HDV: 14,001 to 33,000 pounds
- Heavy HDV: over 33,000 pounds

This report deals exclusively with diesel-fueled HDVs, as there were few, if any, gasoline-fueled or alternatively-fueled counterparts in use in 2005. 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 trailer, 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." 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.

As examples of typical HDVs, Figure 6.2 shows a container truck transporting a container in a terminal, and Figure 6.3 shows a bobtail. The equipment images shown in the figures are not photographs of actual pieces of equipment used at the surveyed terminals but are for illustrative purposes only.

Figure 6.2: Truck with Container

Figure 6.3: Bobtail Truck (no trailer or load)

6.2 Data and Information Acquisition

Data for the HDV emission estimates came from two basic sources: terminal interviews and computer modeling of on-road HDV volumes, distances, and speeds. These information sources are discussed below.

6.2.1 On-Terminal

The Port and their consultant collected information regarding on-terminal truck activity during in-person and telephone interviews with terminal personnel. This information included their gate operating schedules, on-terminal speeds, time and distance traveled on terminal while dropping off and/or picking up loads, and time spent idling at the entry and exit gates. Most terminals were able to provide estimates of these activity parameters, although few keep detailed records of information such as gate wait times and on-terminal turn-around time. However, the reported values appear to be reasonable and have been used in estimating on-terminal emissions, except as noted in the following text.

Table 6.1 illustrates the range and average of reported characteristics of on-terminal truck activities at Port container terminals. The total number of trips was based on information provided by the terminals.

Table 6.1: Summary of Reported Container Terminal Operating Characteristics

	Speed (mph)	Distance (miles)	No. Trips (per year)	Gate In (hours)	Unload/ Load (hours)	Gate Out (hours)
Maximum	17.5	1.5	NA	0.27	0.62	0.20
Minimum	10	0.9	NA	0.08	0.08	0.00
Average	13	1.2	NA	0.17	0.34	0.08
Total			**4,179,330**			

Table 6.2 shows the same summary data for the terminals and facilities other than container terminals. The total number of trips was based on information provided by the terminals.

Table 6.2: Summary of Reported Non-Container Facility Operating Characteristics

	Speed (mph)	Distance (miles)	No. Trips (per year)	Gate In (hours)	Unload/ Load (hours)	Gate Out (hours)
Maximum	20.0	1.0	NA	0.50	1.00	0.33
Minimum	2	0.0	NA	0.00	0.00	0.00
Average	9	0.3	NA	0.07	0.28	0.06
Total			**1,516,246**			

6.2.2 Off-Terminal

The Port retained a consultant (Iteris, previously known as Meyer Mohaddes Associates) to develop estimates of on-road truck activity inside and outside the Port. To do this, the consultant used trip generation and travel demand models they have used in previous Port transportation studies[37] to estimate the volumes (number of trucks) and average speeds on roadway segments between defined intersections.

The trip generation model was derived from a computer model designed to forecast truck volumes that was developed by Moffatt & Nichol Engineers (M&N), who were team members on the 2001 Port Transportation Study. The Port's consultant developed and validated the trip generation model using terminal gate traffic count data. They reported in their traffic study report that the model validation confirmed that the model was able to predict truck movements to within 2 to 10 percent of actual truck counts for all the container terminals combined, and to within 15 percent or better for the majority of individual terminals (MMA, 2001). These were considered to be excellent validation results considering the variability of operating

[37] Meyer, Mohaddes Associates, Inc., June 2001. *Ports of Long Beach/Los Angeles Transportation Study*, and Meyer, Mohaddes Associates, Inc., April 2004. *Port of Los Angeles BaselineTransportation Study.*

conditions and actual gate counts on any given day. The main input to the trip generation model for this study consisted of the average daily container throughput for the most active month in 2005.

The results of the trip generation model were used as input to a Port-area travel demand model also developed by Iteris. This model was based on the regional model used for transportation planning by the Southern California Association of Governments (SCAG), the federally designated Metropolitan Planning Organization for the SoCAB area. Iteris incorporated port-specific truck travel information from the trip generation model, as well as the results of an origin/destination survey of approximately 3,300 Port-area truck drivers, into the Port-area travel demand model.

The travel demand model produced terminal-specific estimates of truck traffic volumes and speeds over defined Port roadway segments. A brief example is provided in Table 6.3. The traffic volumes and distances were combined to produce estimates of vehicle miles of travel (VMT), which in turn were used with the speed-specific EMFAC emission factors (discussed below) to estimate on-Port on-road driving emissions associated with each container terminal. The same model was used to produce estimates of Port-related truck traffic traveling through the POLB, such as toward the 710 Freeway across Terminal Island.

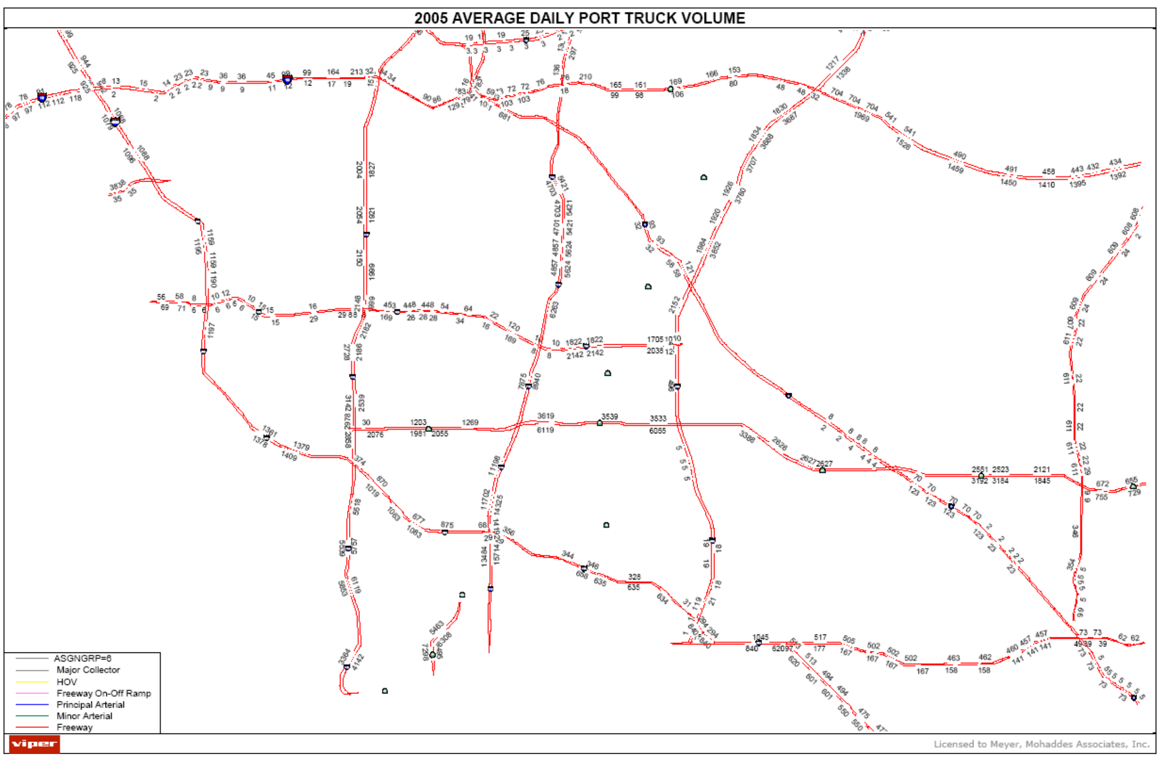
The roadway volumes of truck traffic outside the Port area was estimated by Iteris using a regional analysis that modeled Port-related trucks bi-directionally on highways and major thoroughfares within the greater Los Angeles area until the trucks leave the highways and enter city streets. The intent was to model Port-related trucks on their way from the Port until they make their first stop, whether for delivery of a container to a customer or to a transloading facility, or reach the boundary of the South Coast Air Basin. Transloading is the process of unloading freight from its overseas shipping container and re-packing it for overland shipment to its destination. A more complete description of the modeling process is included in Appendix E.

Table 6.3: On-Road HDV Activity Modeling Results – Example

Roadway Segment	From	To	Direction	Bobtails	Chassis	Con-tainers	Dist. miles	Speed mph
Anaheim St	Anaheim Wy	9th Street	East Bound	313	62	366	0.65	40
Santa Fe	Canal	Santa Fe	East Bound	71	-	57	0.18	20
Canal	Harbor	Canal	East Bound	95	13	131	0.21	29
Henry Ford	SR-47 SB Off Ramp	Henry Ford	East Bound	96	46	301	0.69	40

Figure 6.4 provides a graphical example of the regional analysis, a map of area roadways listing the number of trucks on each segment of road, in each direction of travel. The information on these maps was incorporated into the same calculations as used for the in-port on-road estimates described above. The daily traffic estimates are based on average week-day activity during a peak month. They have been annualized for the emission estimates presented in this inventory by adjusting for peak to average conditions on the basis of 255 weekdays of terminal operation per year, and assuming that weekend activity accounts for 15% of total annual activity. These adjustments are empirically derived factors used by the Port in their planning processes requiring annualization of daily activity measures.

Figure 6.4: Regional Traffic Volume Map



During the Technical Working Group's review of the draft emissions inventory report the traffic modeling discussed above was extensively examined with respect to two key components: the number of truck trips to and from Port terminals and the total number of miles these trips generated within the Air Basin. The review took place over several meetings of the TWG and primarily consisted of reconciling the trip and VMT estimates produced by the terminal and regional models with independent estimates prepared by CARB.

In comparison with the independent activity estimates developed by CARB, the model results on which this inventory is based are somewhat higher, as full reconciliation of the methodologies was not achieved within the time frame of this inventory or of CARB's regulatory development schedule. The CARB model is focused on container truck traffic and estimates considerably lower VMT than the Port models' estimates for container traffic alone. As a result of the discrepancy, the San Pedro Bay Ports and CARB, along with SCAQMD, have pledged to continue working together to understand the differences in the methodologies and to conduct the reviews and studies necessary to reconcile them to ensure the best, most supportable estimates possible for upcoming revisions to the Ports' inventories.

6.3 Methodology

This section discusses how the emission estimates were developed based on the data collected from terminals or developed by traffic modeling. Figure 6.5 illustrates this process in a flow diagram format for the three components of the HDV evaluation previously discussed (on-terminal, on-Port, and regional components).

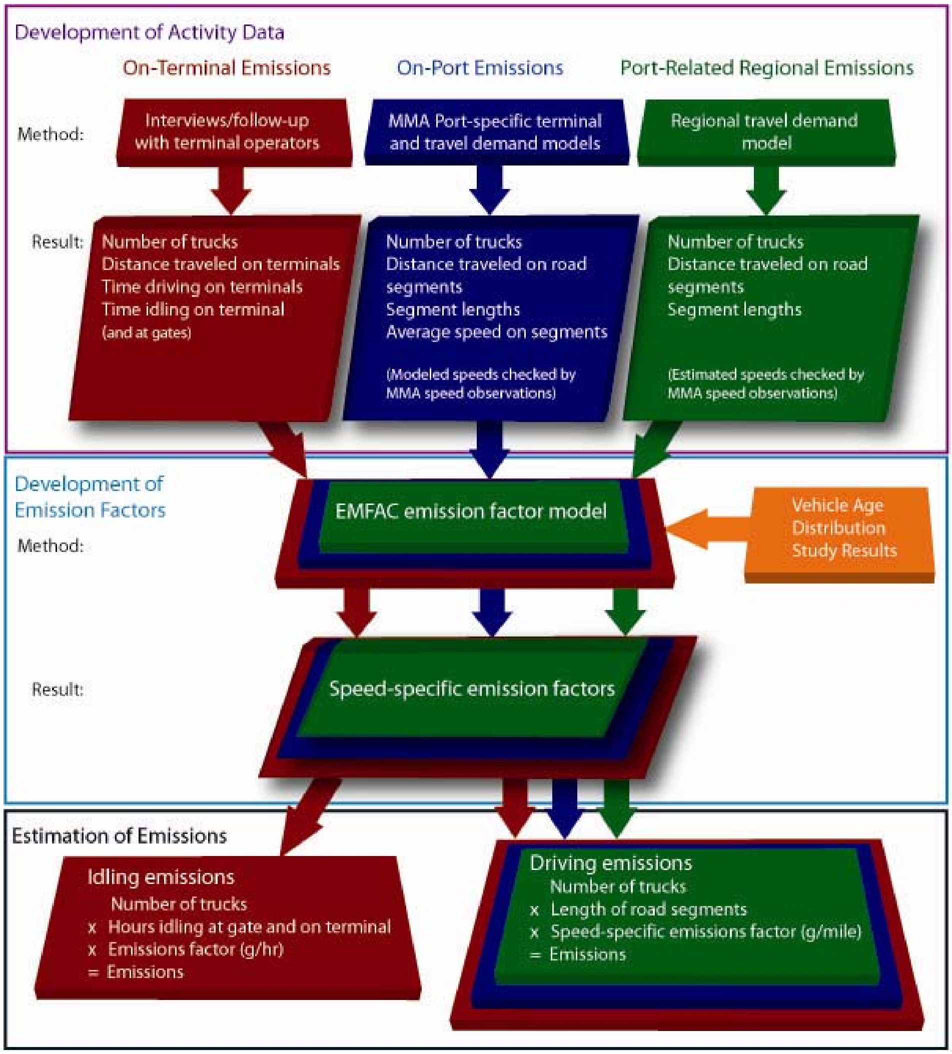
This subsection describes the specific methodology used to develop the emission estimates for HDVs in the various locations described above. The general form of the equation for estimating the emissions inventory for a fleet of on-road vehicles is:

Equation 6.1

Emissions = Population x Basic Emission Rate x Activity x Correction Factor

In the equation above, the population refers to the number of vehicles of a particular model year in the fleet, the basic emission rate is the amount of pollutants emitted per unit of activity (such as grams per mile) for vehicles of that model year, activity is the average number of miles per truck, and the correction factor adjusts the basic emission rate for specific assumptions of activity and/or atmospheric conditions.

Figure 6.5: HDV Emission Estimating Process



The basic emission rate is modeled as a straight line with a "zero mile rate" (ZMR) or intercept representing the emissions of the vehicle when new (well maintained and un-tampered), plus a "deterioration rate" (DR) or slope representing the gradual increase in the emission rate over time or as a function of use (mileage). For heavy duty diesel trucks the deterioration rate is expressed as grams per mile traveled per 10,000 accumulated miles.

Equation 6.2

Basic Emission Rate = ZMR + (DR x Cumulative Mileage /10,000)

In estimating the emissions from heavy-duty trucks, two types of activity can be considered: running emissions that occur when the engine is running with the vehicle moving at a given speed, and idle emissions that occur when the engine is running but the vehicle is at rest. Running emissions are expressed in grams per mile, while idle emissions are expressed in grams per hour. The emission factors (g/mi or g/hr) are multiplied by the activity estimates, vehicle miles of travel (VMT) or hours of idle operation, to derive a gram-per-day (g/day) or gram-per-year inventory.

6.3.1 The EMFAC model

The CARB has developed a computer model to calculate the emissions inventories of various vehicle classes in the California fleet. EMFAC 2007, the latest official version of the model, has been approved by the EPA for use in California and this model, with noted exceptions, was used to estimate the emissions of heavy-heavy-duty diesel trucks that call on the Port of Los Angeles.

Although the EMFAC model produces ton per day estimates of emissions by vehicle class, it is generally a macro-scale model that is inappropriate for estimating inventories at a sub-county level. In order to calculate the inventory of emissions for Port-related heavy-duty trucks, the emission factors and correction factors from EMFAC were coupled with Port specific truck activity estimates.

6.3.2 Basic Emission Rates

The basic emission rates of heavy-duty-diesel trucks included in EMFAC are derived from tests of vehicles randomly selected from the in-use fleet. Because CARB has imposed progressively more stringent standards for the allowable emissions from trucks over many years, different model years of trucks have been certified to specific standards and, therefore, are assumed to emit at different rates. Table 6.4 lists the emission factors used to estimate the emission of trucks visiting the Port.

Table 6.4: Emission Factors in EMFAC 2007 (ZMR in g/mi – DR in g/mi/10,000mi)

Model Years	HC		CO		NO_x		PM		CO_2	
	ZMR	DR	ZMR	DR	ZMR	DR	ZMR	DR	ZMR	DR
Pre-87	1.20	0.027	7.71	0.176	23.0	0.019	1.73	0.028	2237	0.00
87-90	0.94	0.032	6.06	0.209	22.7	0.026	1.88	0.025	2237	0.00
91-93	0.62	0.021	2.64	0.090	19.6	0.039	0.78	0.014	2237	0.00
94-97	0.46	0.024	1.95	0.103	19.3	0.046	0.51	0.011	2237	0.00
98-02	0.47	0.024	1.99	0.103	18.9	0.053	0.56	0.010	2237	0.00
03-06	0.30	0.011	0.87	0.031	12.5	0.052	0.35	0.005	2237	0.00

CARB has included an update to the idle emissions rates for heavy-duty diesel trucks and their "low idle" emission rates were used in developing the emissions inventory for the Port. These factors are presented in Table 6.5.

Table 6.5: Idle Emission Rates in EMFAC 2007 (gm/hr)

Model Years	HC	CO	NO_x	PM	CO_2
Pre-1987	25.9	28.4	45.7	4.76	4,640
1987-90	15.2	23.4	70.2	2.38	4,640
1991-93	12.1	21.5	78.4	1.78	4,640
1994-97	9.68	19.8	85.3	1.33	4,640
1998-02	7.26	17.8	92.1	0.92	4,640
2003-06	5.97	16.6	95.5	0.72	4,640

A more in-depth explanation of CARB's heavy-duty diesel inventory estimation methodology can be found in their document "Revision of Heavy Heavy-Duty Diesel Truck Emission Factors and Speed Correction Factors"[38] dated 4/03/2006.

While most emissions from heavy-heavy duty diesel trucks are estimated on a per-mile or per-hour basis, the inventory of oxides of sulfur (SO_x) was calculated based upon an estimate of the amount of fuel consumed. The following calculation was used to derive the SO_x inventory.

Calculation 6.1

SO_x emissions (tpd) =

$$\frac{(130 \text{ g S}/1{,}000{,}000 \text{ g fuel}) \times (3{,}311.21 \text{ g/gallon}) \times (2 \text{ g } SO_x / \text{g S}) \times (X \text{ miles/day})}{(5.278 \text{ miles/gallon}) \times (453.59 \text{ g /lb} \times 2{,}000 \text{ lbs/ton})}$$

In this calculation, g is grams, S is sulfur, and lb is pounds. Commercially available on-road diesel fuel is assumed to have contained 130 ppm sulfur by weight in 2005. The weight of a gallon of diesel fuel is assumed to be 7.3 pounds or 3,311.21 grams (7.3 lbs x 453.59 g/lb). Based on the EMFAC model, the fleet average fuel economy of the heavy-heavy duty diesel fleet is assumed to be 5.278 miles per gallon. The estimates of daily vehicle miles of travel were from the Iteris trip generation and travel demand modeling for in-Port and regional on-road travel, and were derived through tenant survey for the on-terminal estimates.

6.3.3 Age Distribution

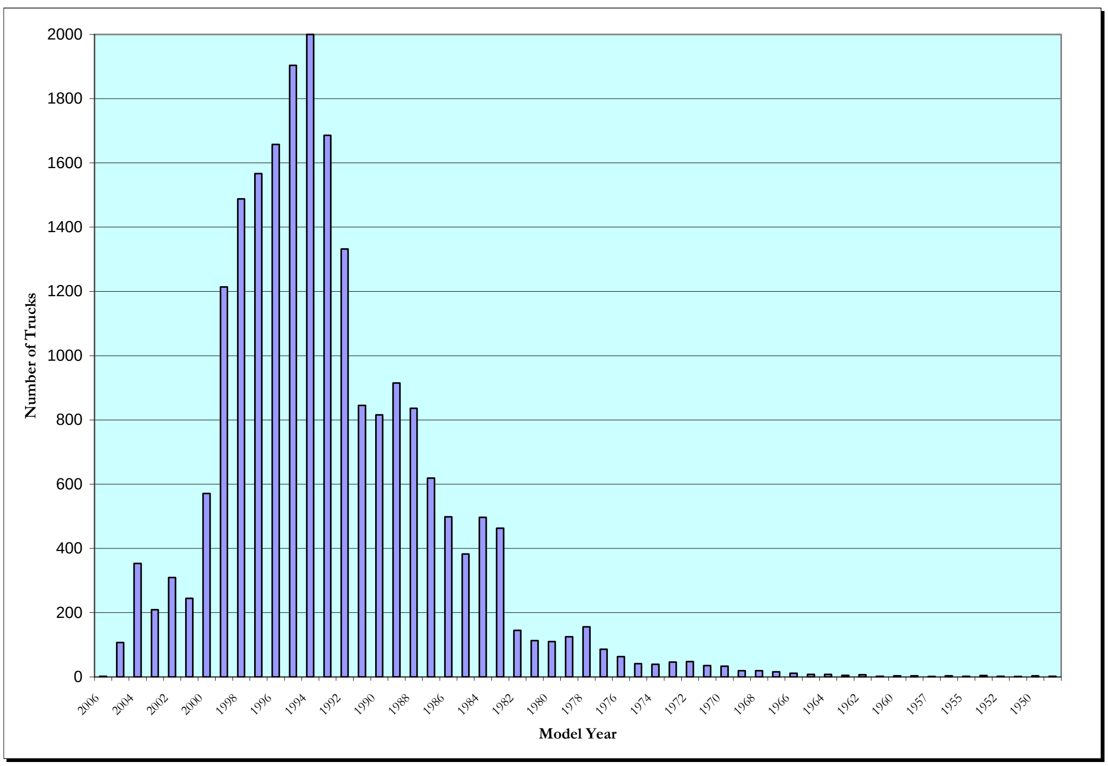
The age distribution (count of vehicles by model year) of trucks calling upon the Port of Los Angeles (and the Port of Long Beach) was determined through evaluation of license plate numbers provided by several container terminals. This is

[38] See *http://www.arb.ca.gov/msei/supportdocs.html#onroad.*

an on-going project of the two ports and the age distribution will be updated periodically as new data is received and evaluated.

Just over 1,000,000 records were received from the terminals, which yielded about 35,000 unique license plate numbers. Registration information was requested from the California DMV and 21,680 records were returned with model year information. The distribution of the truck population by age is presented in Figure 6.6 below. The average age of the port-related fleet was determined to be 11.2 years, which is in reasonable agreement with the EMFAC estimate of heavy-duty diesel trucks in Los Angeles County of 11.5 years. While the average age is similar, the EMFAC distribution includes higher numbers of trucks in the newest age range (up to seven years old) and correspondingly fewer trucks in the eight to 13-year age range.

Figure 6.6: Population Distribution of the Heavy-Duty Truck Fleets



It is important to note that EMFAC carries an estimate of 45 model years of population within each calendar year ranging from the newest, for which the model year is the same as the current calendar year, to the oldest where the model year is the current calendar year minus 45. Therefore, EMFAC does not allow the model year to be greater than the current calendar year. For purposes of this analysis, 2006 model year trucks that were in the sample of license plates provided by the terminals were assumed to have the same activity as 2005 model year trucks.

6.3.4 Mileage Accrual Rates/Cumulative Mileage

Since no data were available to estimate the actual mileage of each truck visiting the Ports, the mileage accrual rates from EMFAC were used. The mileage accrual rates are the estimates of the miles traveled each year by vehicles of a specific age and type of vehicle. When vehicles are new, the mileage accrual rates are assumed to be at their highest. The miles per year tend to decline as the truck ages.

CARB has also modified the mileage accrual rates used in EMFAC as discussed in their document entitled "Redistribution of Heavy-Heavy Duty Diesel Truck Vehicle Miles Traveled in California" dated September 13, 2006[39]. The mileage accrual rates included in the EMFAC 2007 update and used in this analysis are shown in Table 6.6.

Table 6.6: Mileage Accrual Rates Heavy-Heavy Duty Diesel Trucks in EMFAC 2007 (mi/yr)

Truck Age (years)	**Miles/Year**	**Truck Age** (years)	**Miles/Year**	**Truck Age** (years)	**Miles/Year**
1	80,705	13	43,854	25	16,662
2	85,152	14	39,965	26	15,164
3	86,460	15	36,504	27	13,653
4	85,386	16	33,452	28	12,136
5	82,571	17	30,772	29	10,629
6	78,547	18	28,417	30	9,159
7	73,755	19	26,335	31	7,759
8	68,546	20	24,469	32	6,467
9	36,199	21	22,764	33	5,324
10	57,926	22	21,171	34	4,369
11	52,881	23	19,645	35	3,363
12	48,169	24	18,150	36+	3,363

[39] See *http://www.arb.ca.gov/msei/supportdocs.html#onroad*

The cumulative mileage of a vehicle is assumed to be the sum of its mileage accrual rates. That is, for a three year old truck, for example, the average odometer reading would be assumed to be 252,317 miles, or 80,705 + 85,152 +86,386. In turn, the cumulative mileage is used to assess the level of deterioration to be added to the basic emission rate (see above).

In keeping with our example of a three year old truck, the basic emission rate for NO_x would be calculated as follows:

Calculation 6.2

18.9 g/mi (ZMR) + 0.053 g/mi/10K miles (DR) x 252,317 miles (Cumulative Mileage) = 20.24 g/mi

A population weighted basic emission rate for each pollutant was derived performing the calculation above for each model year; the results were then weighted by the population fraction in each model year. These fleet weighted emission rates are presented in Table 6.7.

Table 6.7: Heavy Heavy-Duty Diesel Truck Fleet Weighted Emission Rates (grams/mile)

Pollutant	Emission Rate (g/mile)
HC	0.945
CO	8.449
NO_x	21.481
PM	2.18

6.3.5 Correction Factors

As stated earlier, correction factors are used to adjust the basic emission rates to reflect vehicle specific activity such as speed and type and quality of fuel burned, and specific ambient conditions such as temperature and relative humidity. In order to better reflect the emissions of the Port truck fleet, the basic emission rates were adjusted for both fuel and speed.

Fuel correction factors are applied to adjust for differences in the fuel used during certification or in-use testing, and the fuel used in routine operation. According to CARB's memo in which the EMFAC 2007 heavy-duty diesel emission rates are discussed, the reported emission factors represent pre-Clean Diesel rates. CARB diesel has a lower sulfur and aromatic hydrocarbon content compared to pre-Clean Diesel. According to CARB's memo entitled "On-Road Emissions Inventory Fuel Correction Factors," dated July 26, 2005, a 28 percent reduction in HC, 25 percent reduction in NO_x and a seven percent reduction in PM should be applied to the basic emission rates to reflect the benefits of CARB Diesel. The fuel correction factors are applied as multiplicative modifiers to the basic emission rates. That is, a 25 percent reduction would yield a correction factor of 0.75. Table 6.8 lists the diesel fuel correction factors.

Table 6.8: CARB Diesel Fuel Correction Factors

Pollutant	Fuel Correction Factor
HC	0.72
CO	1.0
NO_x	0.75
PM	0.93

Speed is used as a surrogate for the work of the engine or load and emissions tend to increase or decrease as load increases or decreases. The basic emission rates are derived from testing vehicles over a reference cycle with a single average speed of about 20 miles per hour (the Urban Dynamometer Driving Schedule or UDDS). Speed correction factors adjust the basic emission rates for cycles or trips of differing speeds.

As running emissions are expressed in terms of grams per mile, the speed correction factors tend to be higher at the extremes of speed. At high speeds, the vehicle's engine has to work harder to overcome wind resistance and emissions tend to increase as a consequence. At low speeds, the vehicle has to overcome inertia and rolling resistance. Although emissions tend to be lower at lower speeds, as the distance approaches zero the grams/mile ratio increases. The result is a generally "U" shaped curve describing the impact of speed on emissions.

In the current version of EMFAC, at least two pollutant specific speed correction factors are needed to properly characterize the emissions of the heavy-duty truck fleet. In CARB's document "Revision of Heavy Heavy-Duty Diesel Truck Emission Factors and Speed Correction Factors," discussed earlier, the equation and coefficients needed to derive the speed correction factors included in EMFAC 2007 are described.

Equation 6.3

$$\textbf{Speed Correction Factor} = A + (B \times \text{Speed}) + (C \times \text{Speed}^2)$$

Table 6.9 lists the speed correction factor coefficients.

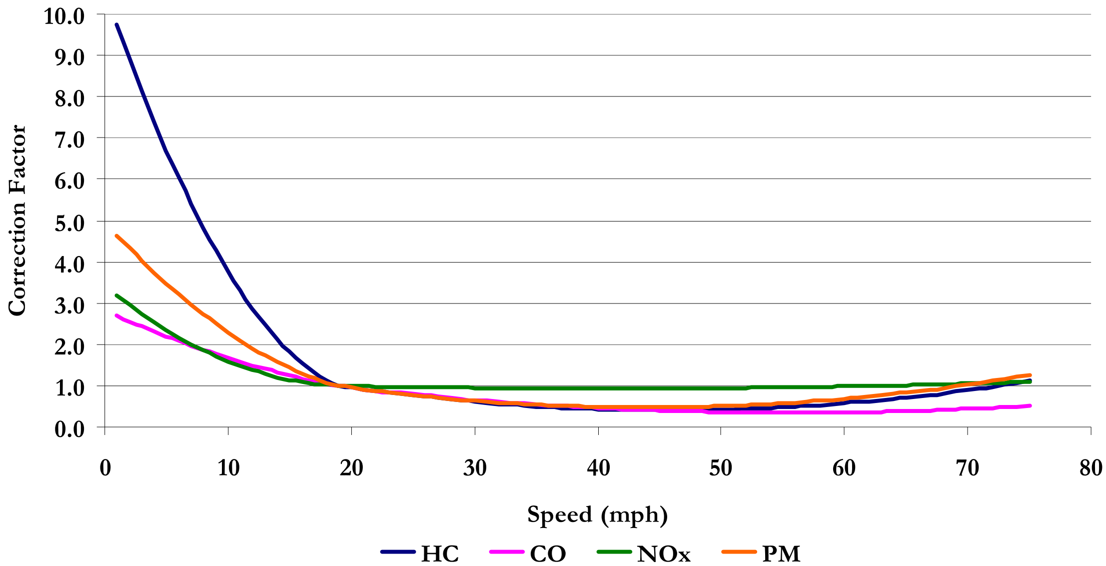
Table 6.9: Speed Correction Factor Coefficients

Pollutant	Model Year Group	Speed Range	A	B	C
HC	**Pre-1991**	5.00 - 18.8	7.1195	-0.4789	0.008159
		18.8 - 65.0	1.6373	-0.04189	0.0003884
	1991-2002	5.00 - 18.8	11.614	-0.9929	0.02278
		18.8 - 65.0	2.3019	-0.08712	0.0009773
	2003+	5.00 - 18.8	10.219	-0.8937	0.02146
		18.8 - 65.0	1.6053	-0.03799	0.0002985
CO	**Pre-1991**	5.00 - 65.0	1.6531	-0.04198	0.0003352
	1991-2002	5.00 - 18.8	3.0388	-0.1511	0.002267
		18.8 - 65.0	1.8753	-0.05664	0.0005141
	2003+	5.00 - 18.8	6.2796	-0.5021	0.01177
		18.8 - 65.0	1.3272	-0.02463	0.000336
NO_x	**Pre-1991**	5.00 - 18.8	2.2973	-0.1173	0.002571
		18.8 - 65.0	1.3969	-0.02658	0.0002725
	1991-2002	5.00 - 18.8	3.7668	-0.2862	0.007394
		18.8 - 65.0	1.0771	-0.005981	0.00009271
	2003+	5.00 - 18.8	2.7362	-0.148	0.002958
		18.8 - 65.0	1.5116	-0.03357	0.0003118
PM	**Pre-1991**	5.00 - 18.8	2.6039	-0.1266	0.002198
		18.8 - 65.0	1.4902	-0.03121	0.0002733
	1991-2002	5.00 - 18.8	5.7807	-0.4032	0.007918
		18.8 - 65.0	2.2766	-0.08661	0.0009948
	2003+	5.00 - 18.8	1.4086	-0.02313	0.00007449
		18.8 - 65.0	1.4881	-0.0408	0.0007894

These speed correction factors were used to derive speed specific emission factors for each pollutant at 5 mile per hour increments for use in this analysis. This was accomplished by deriving the model year and pollutant specific speed correction factors and then weighting each factor by the population of Port trucks in each model year group. Figure 6.7 shows the fleet weighted speed correction factors for each pollutant.

The speeds used in the on-road emission calculations were estimated by the travel demand modeling discussed previously. The on-terminal speeds are those reported as average on-terminal speeds by the respective terminal operators.

Figure 6.7: Fleet Weighted Speed Correction Factors



6.4 Emission Estimates

On-terminal and on-road emissions have been estimated by terminal and are summed to represent Port-wide emissions. As discussed above, on-terminal emissions are based on terminal-specific information such as 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-Port on-road emissions were estimated on a terminal-specific basis for the container terminals, using the travel demand modeling results discussed above, which estimated how many trucks from each container terminal traveled along each section of road within the port. The off-Port on-road emissions were estimated for Port trucks in general (not terminal-specific) in a similar manner to the on-Port estimates, using travel demand model results to estimate how many trucks travel along defined roadways in the SoCAB on the way to their first cargo drop-off point. In most cases, emissions have been allocated to the non-container terminals using a ratio approach based on the number of trucks visiting each non-container terminal relative to the total number of container terminal truck calls. This approach was used because the in-Port travel demand model does not include terminal-specific estimates for Port terminals other than container terminals. The ratio approach assumes that the trucks servicing non-container terminals have the same general activity patterns as trucks servicing the container terminals, in terms of speed and mileage within the Port and in the region. There are five non-container terminal businesses located on Port property to the north of the main Port area whose trucks primarily serve on-Port terminals and make round trips between the business and the Port. Facility-specific estimates have been developed for these businesses, using facility-specific information related to the number of round trips made per day.

Idling emissions were estimated separately for the on-terminal estimates, since the off-terminal traffic modeling analysis reported only volumes, distances, and average speeds, which were used to estimate VMT. This is a valid approach because the average speeds include estimates of normal traffic idling times and the emission factors are designed to take this into account.

Since annual activity was used for the on-terminal analysis, emissions have been calculated as tons per year, with idling and transit activities estimated separately. Table 6.10 summarizes the two modes of on-terminal operation by terminal.

Table 6.10: 2005 On-Terminal VMT and Idling Hours by Terminal ID

Terminal ID	Total Miles Traveled	Total Hours Idling (all trips)
LAC010	771,863	604,626
LAC070	1,393,785	573,001
LAC090	497,700	182,490
LAC030	725,000	120,833
LAC060	1,043,855	382,747
LAC020	756,561	428,718
LAO060	3,750	2,755
LAO230	3,753	17,447
LAO100	78	156
LAO130	22	489
LAO120	58,500	37,050
LAO020	650	1,083
LAO150	37,440	9,360
LAC040	9,125	6,692
LAO180	64	533
LAO240	1,625	217
LAO270	6,500	867
LAO250	222,288	88,915
LAO390	10,140	1,408
LAO400	16,250	13,000
LAO260	1,249	625
LAO290	11,406	28,744
LAO280	991,340	515,497
All Terminals	**6,562,944**	**3,017,252**

Emission estimates for HDV activity associated with Port terminals and other facilities are presented in the following tables, in terms of tons per year. Table 6.11 summarizes emissions from HDVs associated with all Port terminals, while the subsequent two tables (Tables 6.12 and 6.13) show emissions associated with container terminal activity separately from emissions associated with other Port terminals and facilities.

Table 6.11: Summary of HDV Emissions, tpy

Activity Location	VMT	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
On-Terminal	6,562,944	36	33	36	522	1.2	233	109
On-Port On-Road	16,435,918	31	28	31	565	3	240	53
Off-Port On-Road	223,093,138	213	196	213	5,017	39	1,753	307
Totals	**246,092,000**	**280**	**257**	**280**	**6,104**	**43**	**2,226**	**469**

Table 6.12: Summary of HDV Emissions Associated with Container Terminals, tpy

Activity Location	VMT	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
On-Terminal	5,188,764	29	27	29	410	0.9	186	88
On-Port On-Road	14,976,404	28	26	28	515	3	219	48
Off-Port On-Road	200,764,021	192	176	192	4,515	35	1,577	277
Totals	**220,929,189**	**249**	**229**	**249**	**5,439**	**39**	**1,982**	**413**

Table 6.13: Summary of HDV Emissions Associated with Other Port Terminals, tpy

Activity Location	VMT	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
On-Terminal	1,374,180	7	6	7	112	0.2	47	20
On-Port On-Road	1,459,514	3	2	3	50	0.3	21	5
Off-Port On-Road	22,329,117	21	20	21	502	4	175	31
Totals	**25,162,811**	**31**	**28**	**31**	**664**	**4**	**244**	**56**

The following pie charts illustrate the distribution of activity (VMT) and emissions among the on-terminal, on-port/on-road, and off-port/on-road components of HDV activity. Differences in the relative distributions are due to differences in average speeds among the three components of port-related travel.

Figure 6.8: HDV VMT Distribution by Location

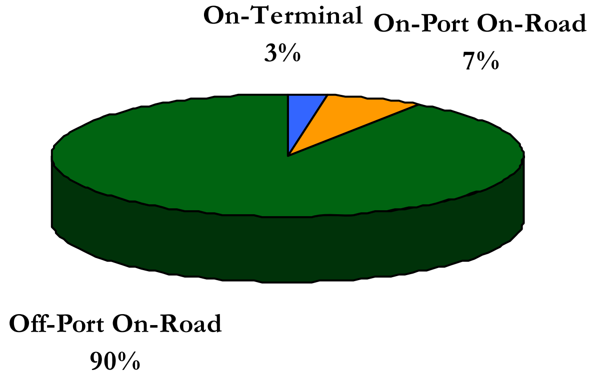


Figure 6.9: DPM Emissions Distribution for HDV

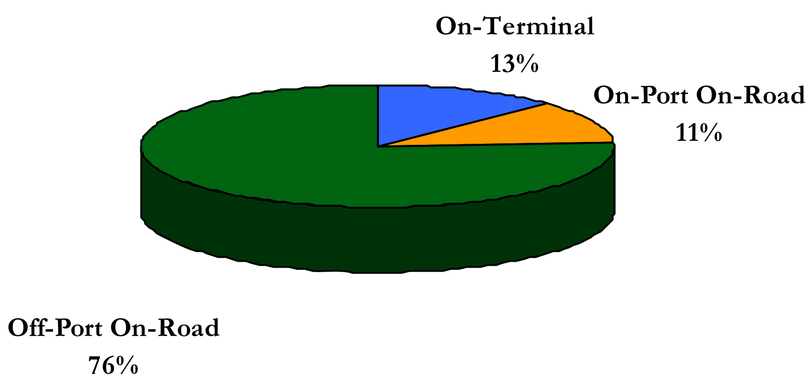


Figure 6.10: NO_x Emissions Distribution for HDV

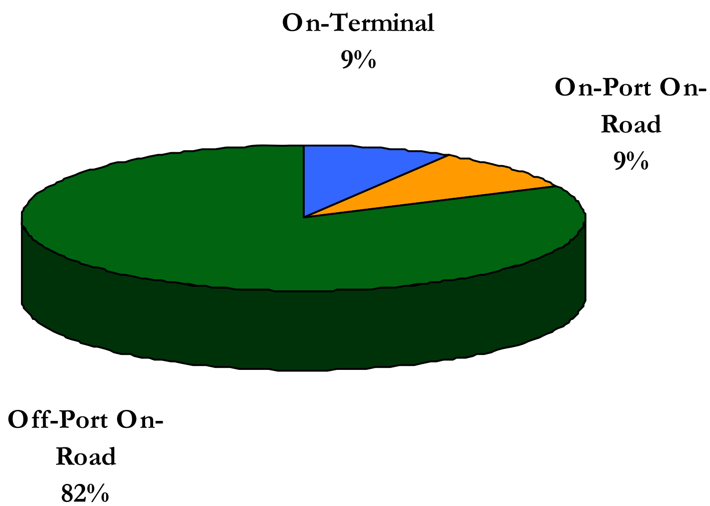


Figure 6.11: SO_x Emissions Distribution for HDV

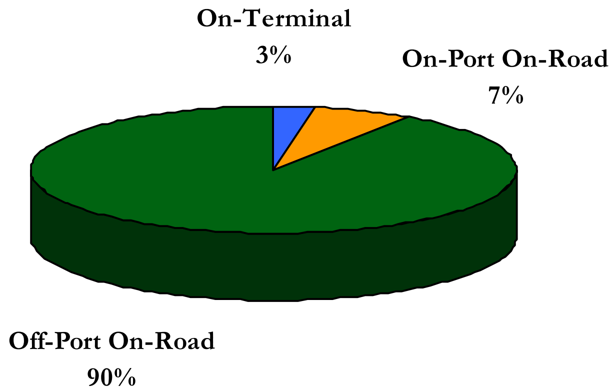


Figure 6.12: CO Emissions Distribution for HDV

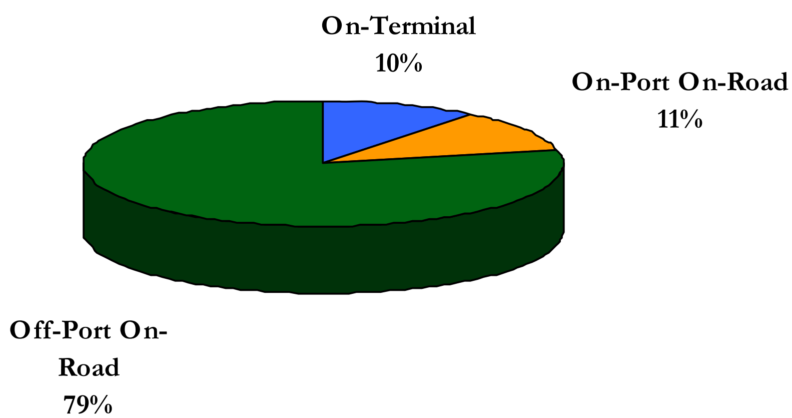
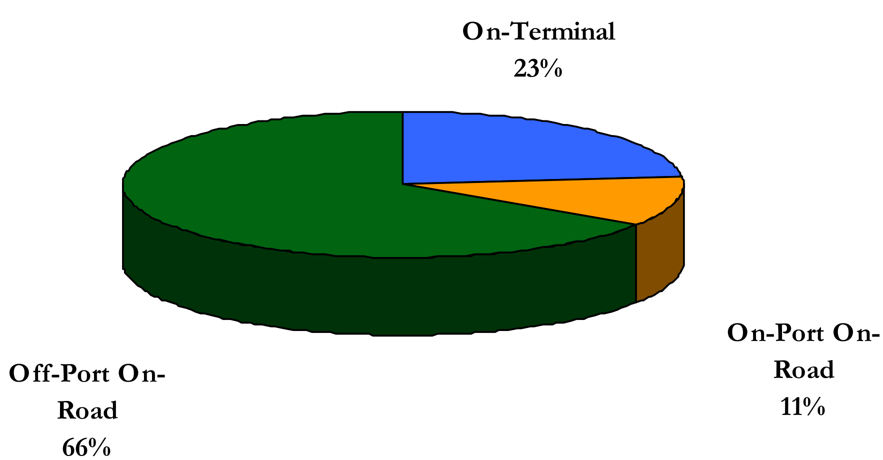


Figure 6.13: TOG Emissions Distribution for HDV



SECTION 7 FINDINGS AND RESULTS

The activity findings and emissions results for all source categories are summarized in this section. These findings and results are provided in more detail in each of the category sections in the report.

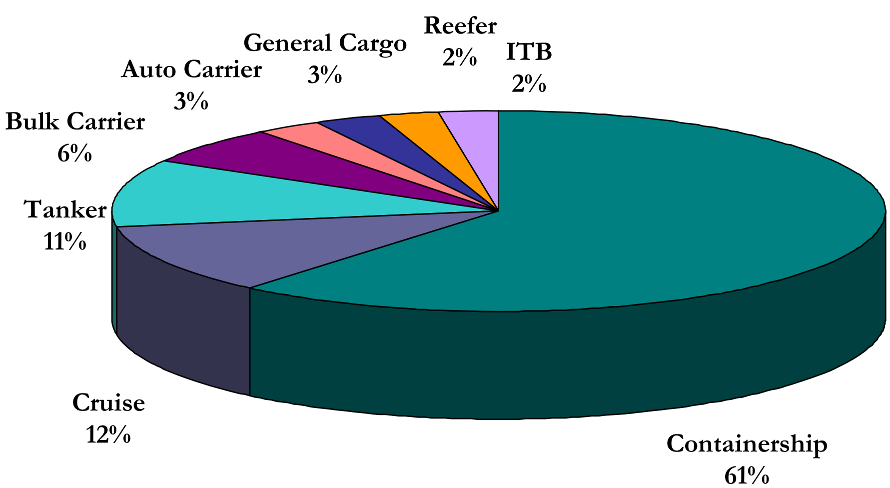
7.1 Findings

This section discusses some of the general findings for the 2005 activity for each category.

7.1.1 Ocean-Going Vessels

Based on 2005 Marine Exchange data, there were 2,341 inbound calls to the port in 2005. Figure 7.1 shows the percentage of inbound calls by vessel type.

Figure 7.1: Distribution of Vessel Types by Inbound Calls



The vessels that called at the Port in 2005 are newer and larger, especially the container vessels. The following figures show the average year, average deadweight, average main engine power and average auxiliary engine power for the vessels that called at the Port in 2005.

Figure 7.2: Average Year Built for Vessels that Called the Port of Los Angeles in 2005 by Vessel Type

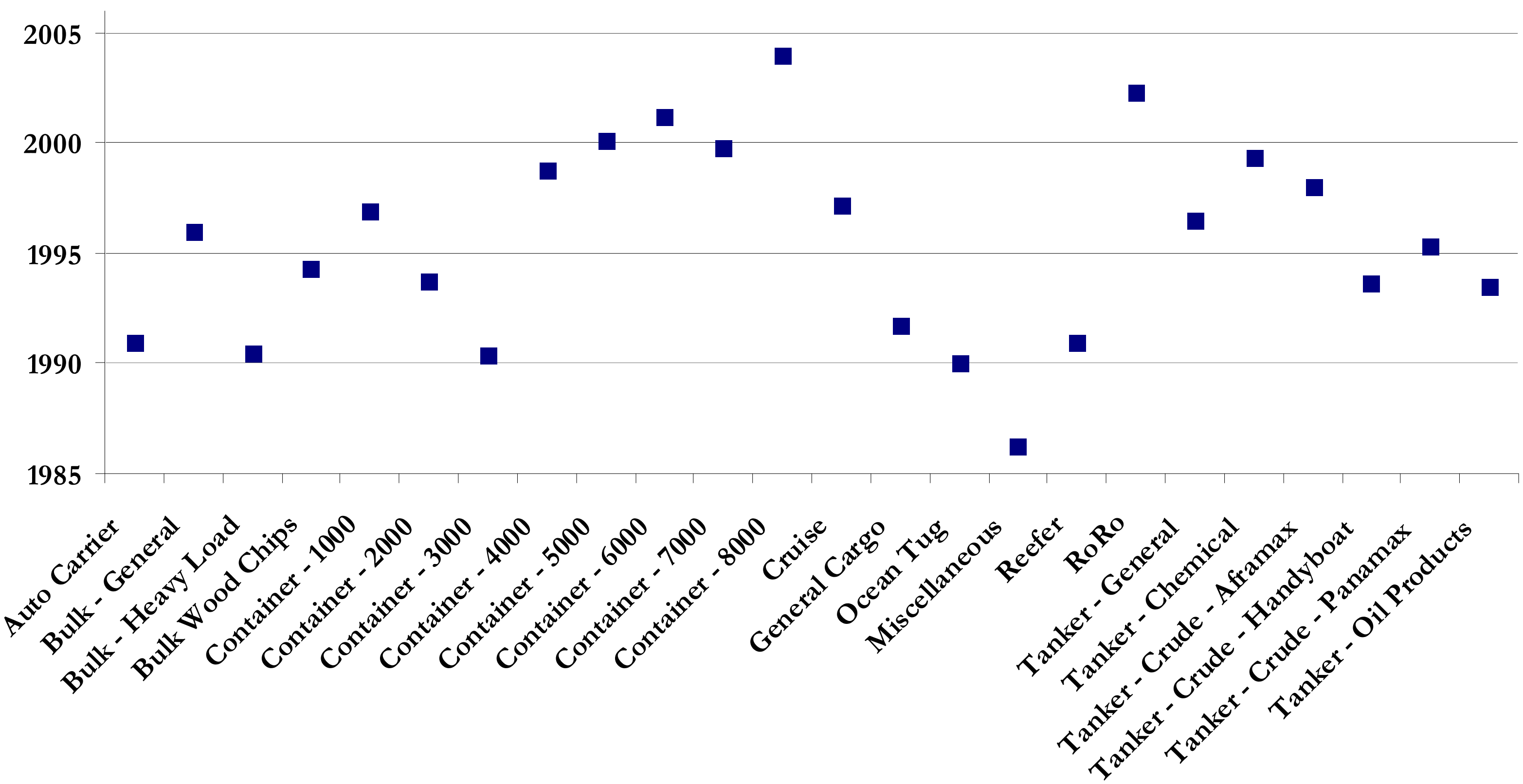


Figure 7.3: Average Deadweight Tonnage for Vessels that Called the Port of Los Angeles in 2005 by Vessel Type

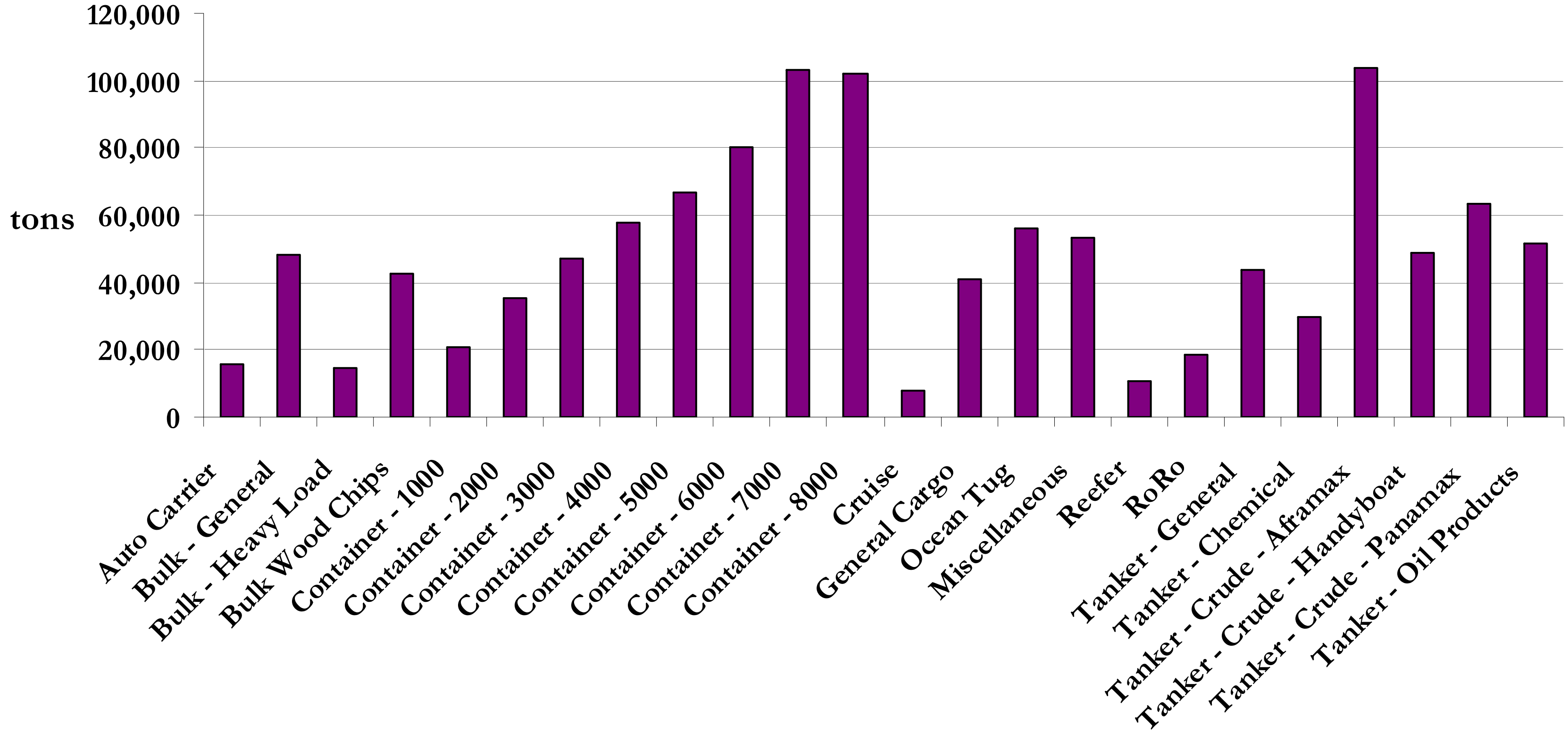


Figure 7.4: Average Main Engine Total Installed Power (kW) for Vessels that Called the Port of Los Angeles in 2005 by Vessel Type

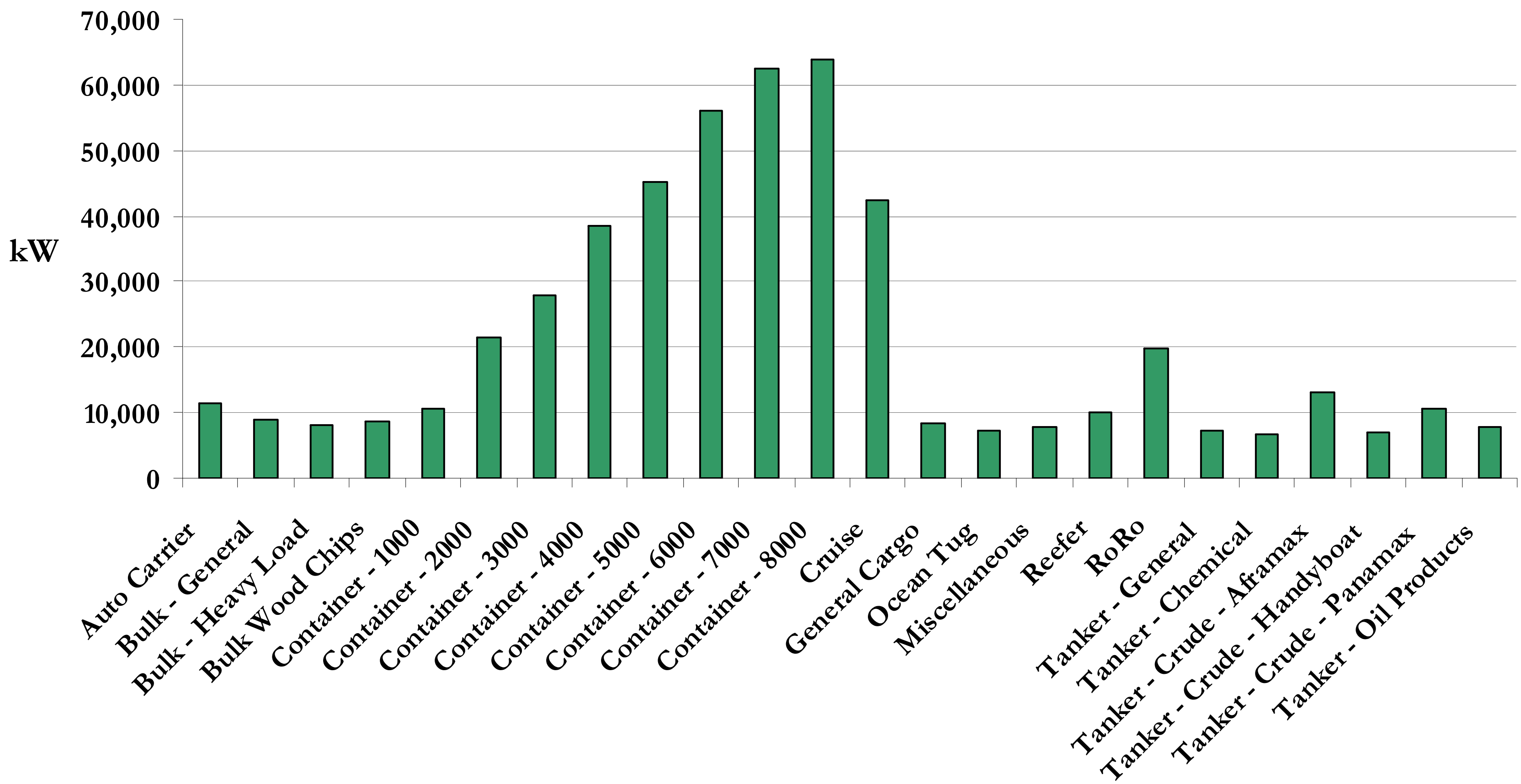
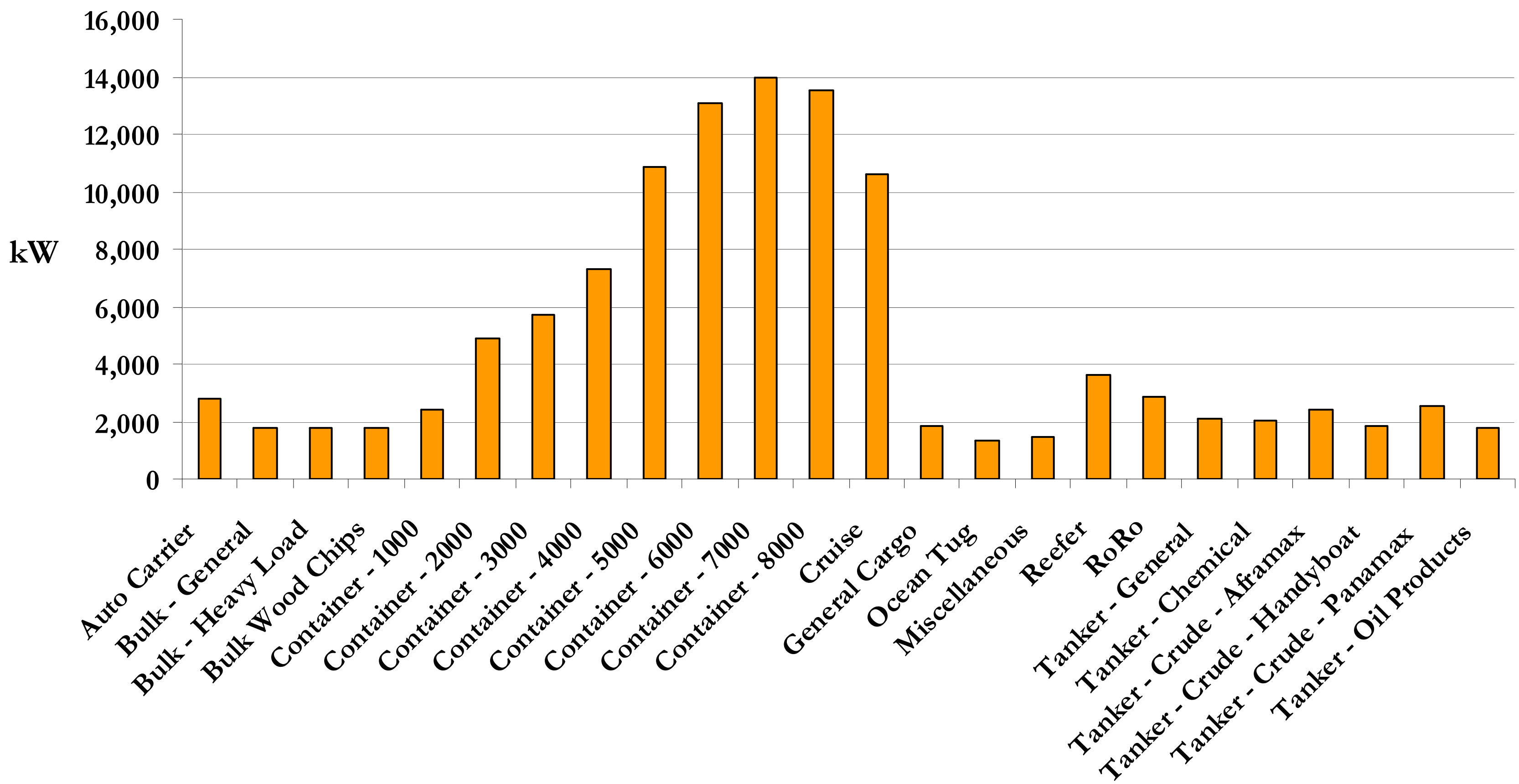


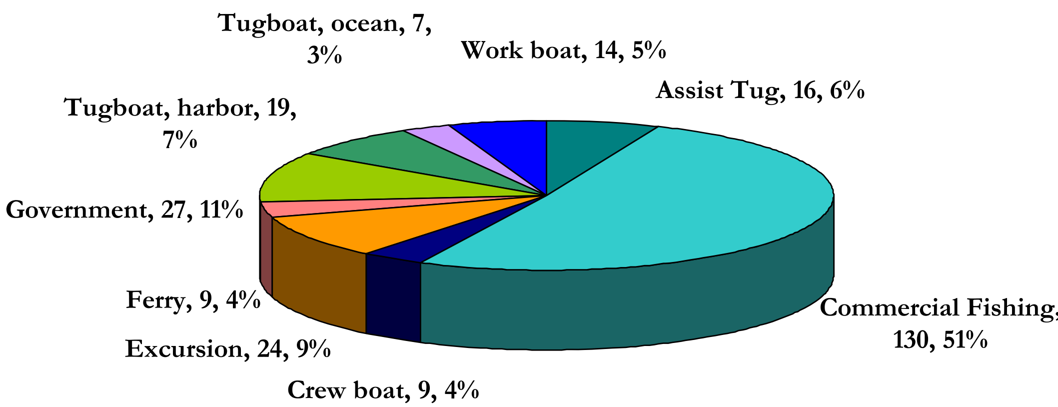
Figure 7.5: Average Auxiliary Engine Total Installed Power (kW) for Vessels that Called the Port of Los Angeles in 2005 by Vessel Type



7.1.2 Harbor Craft

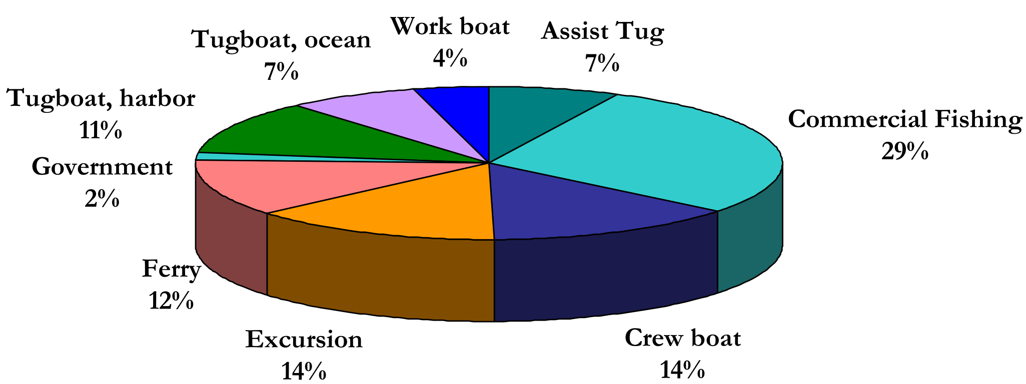
Figure 7.6 presents the distribution of the 255 commercial harbor craft inventoried for the Port of Los Angeles in 2005.

Figure 7.6: Distribution of 2005 Commercial Harbor Craft at the Port



About one third or 29% of all the engines in this inventory have been replaced. Figure 7.7 shows the percentage of the total number of main and auxiliary engines replaced by vessel type.

Figure 7.7: Distribution of Replaced Engines by Vessel Type



7.1.3 Cargo Handling Equipment

By the end of 2005, the Port and its tenants purchased and installed almost 600 diesel oxidation catalysts and purchased 164 yard tractors with on-road engines, which emit less than the off-road versions. In addition, over 200 pieces of CHE use emulsified fuel and over 800 pieces of CHE use ultra-low sulfur diesel. There are also 267 forklifts which have propane engines. These emission reduction strategies were started after 2001 and have been implemented voluntarily at Port or tenant expense. The following table summarizes the emission reduction technologies for cargo handling equipment at the Port.

Table 7.1: Summary of 2005 CHE Emission Reduction Technologies

Equipment	Pieces of Eqmt	DOC Installed	Total Count On-road engine	Emulsified Fuel	ULSD
Yard tractor	848	520	164	129	596
Top handler	127	48	0	36	79
Side pick	41	14	0	10	16
RTG	98	0	0	28	36
Forklift	422	3	0	15	27
Other	114	0	1	0	65
Totals	**1,650**	**585**	**165**	**218**	**819**

7.2 2005 EI Results

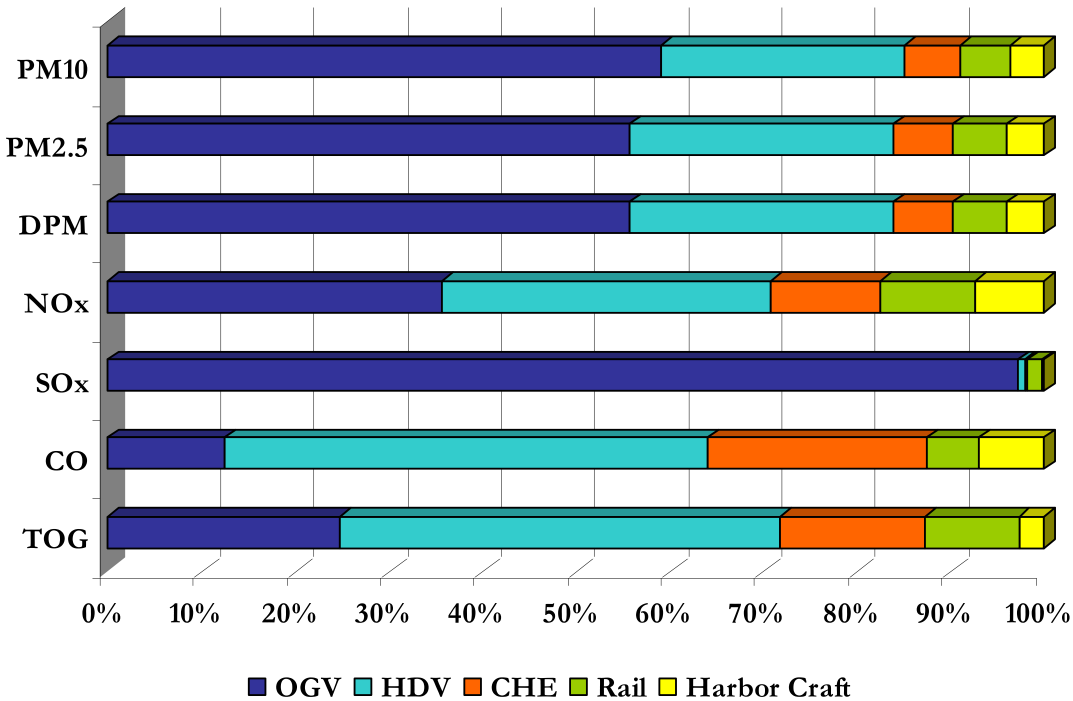
The emission results for the Port of Los Angeles Inventory of Air Emissions for calendar year 2005 are presented in this section. Table 7.2 summarizes the 2005 total Port-related emissions in the South Coast Air Basin by category in tons per year.

Table 7.2: 2005 Total Port-Related Emissions by Category, tpy

Category	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
Ocean Going Vessels	634	507	552	6,206	5,609	540	247
Harbor Craft	38	35	38	1,259	7	297	26
Cargo Handling Equipment	63	58	63	2,037	14	1,010	153
Locomotives	57	53	57	1,783	97	244	100
Heavy-Duty Vehicles	280	257	280	6,104	43	2,226	469
Total	**1,072**	**910**	**990**	**17,389**	**5,770**	**4,318**	**995**

Figure 7.8 shows the distribution of the 2005 total port-related emissions for each pollutant and category.

Figure 7.8: Distribution of 2005 Port-related Emissions by Category



Comparing the contribution of total port-related PM emissions by category shows that ocean-going vessels account for roughly 56%, heavy-duty vehicles account for roughly 27%, rail locomotives and cargo handling equipment account for roughly 6% each, and harbor craft account for approximately 4%.

Comparing the contribution of total port-related NO_x emissions by category shows that ocean-going vessels account for 36%, heavy-duty vehicles account for 35%, rail locomotives account for 10%, cargo handling equipment account for 12%, and harbor craft account for 7% of the emissions.

For SO_x emissions, ocean-going vessels account for 97% of the total port-related emissions. This can be attributed to the fact that compared to OGVs, the other categories use low sulfur diesel, such as CARB's 500 ppm S diesel and ULSD. The engines for ocean-going vessels are designed to run on residual fuel which has much higher sulfur content and the SO_x emissions are directly related to the sulfur content of the fuel. With the California auxiliary engine rule coming into effect in January 2007, which requires use of 0.5% S fuel and the San Pedro Bay Ports Clean Air Action Plan (CAAP) which requires use of 0.2% S fuel for terminals lease renewal, the SO_x emissions from OGVs will decrease.

Comparing the contribution of port-related carbon monoxide (CO) emissions by category shows that ocean-going vessels account for 12%, heavy-duty vehicles account for 52%, rail locomotives account for 6%, cargo handling equipment account for 23%, and harbor craft account for 7% of the emissions.

Comparing the contribution of port-related TOG emissions by category shows that ocean-going vessels account for 25%, heavy-duty vehicles account for 47%, rail locomotives account for 10%, cargo handling equipment account for 15%, and harbor craft account for 3% of the emissions.

Port-related emissions compared to other emissions in SoCAB

In order to put the Port of Los Angeles' port-related emissions into perspective with the other regional emissions, the following figures compare the Port's contribution to the total emissions in the South Coast Air Basin for the year 2005[40] as presented in Figures 7.9 – 7.11. Figure 7.9 below shows that approximately 9% of the total DPM emissions in the South Coast Air Basin are attributable to 2005 Port of Los Angeles port-related activities.

[40] Port emissions as compared to the SCAQMD's "DRAFT 2007 AQMP Appendix III, Base & Future Year Emissions Inventories", February 2007, Tables A-1for NOx & SOx & F-1 for PM2.5 used for DPM.

Figure 7.9: Distribution of 2005 DPM Emissions in the South Coast Air Basin

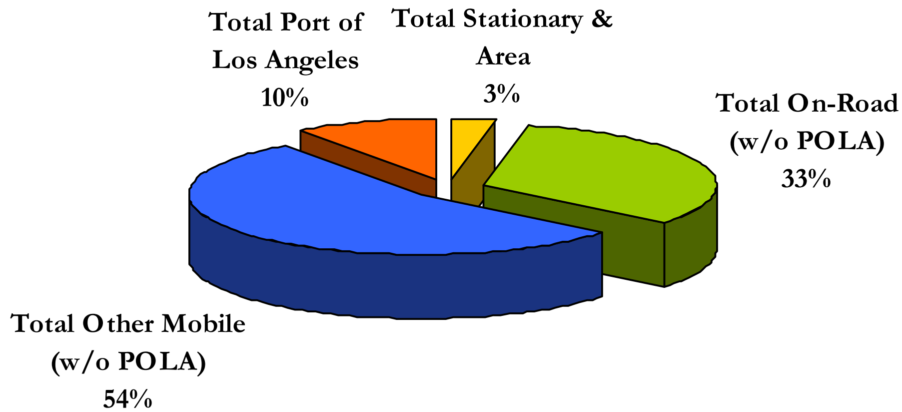


Figure 7.10 shows that approximately 5% of the total NO_x emissions in the South Coast Air Basin are attributable to 2005 Port of Los Angeles port-related activities.

Figure 7.10: Distribution of 2005 NO_x Emissions in the South Coast Air Basin

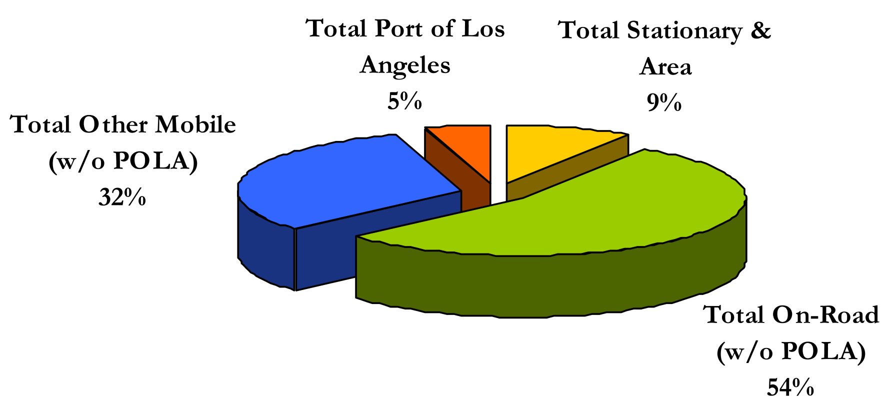
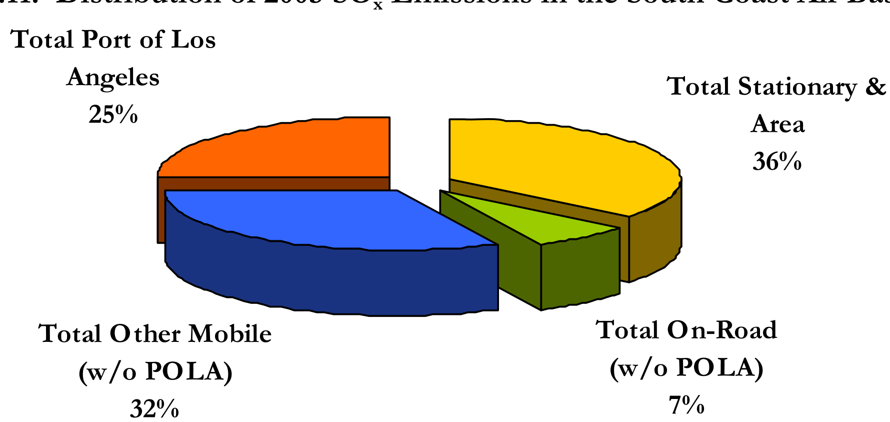


Figure 7.11 shows that approximately 25% of the total SO_x emissions in the South Coast Air Basin are attributable to 2005 Port of Los Angeles port-related activities.

Figure 7.11: Distribution of 2005 SO_x Emissions in the South Coast Air Basin

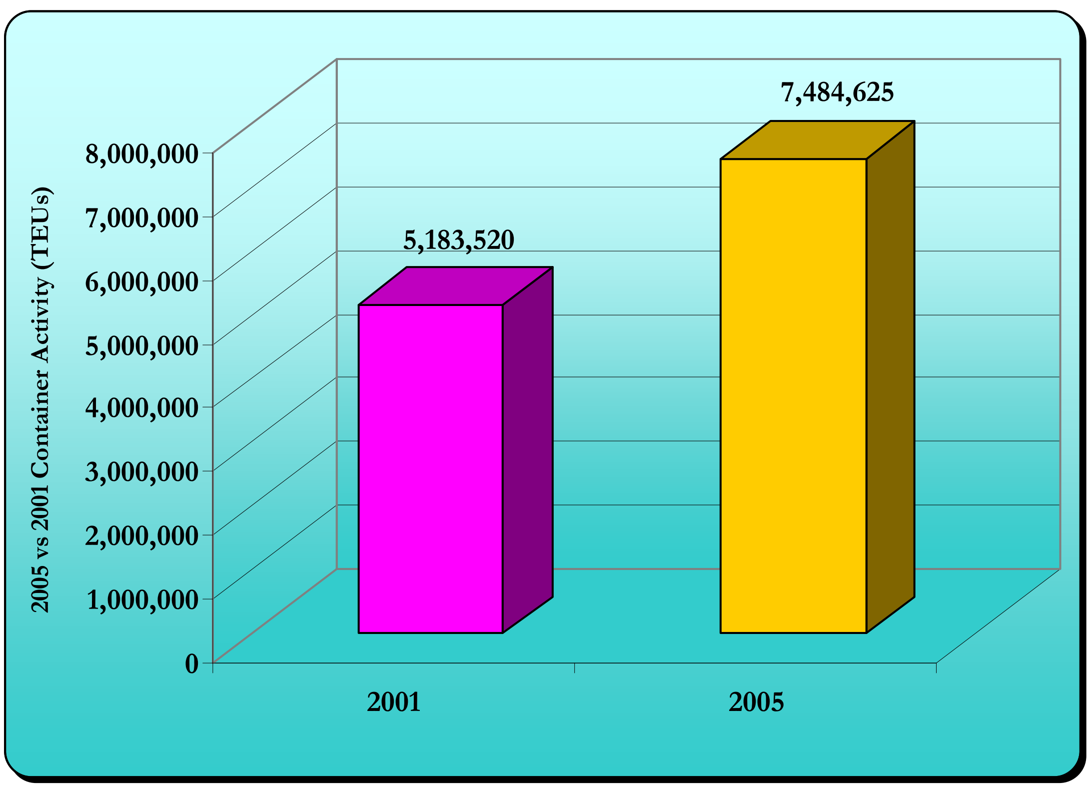


SECTION 8 COMPARISON OF 2005 WITH 2001 EMISSION ESTIMATES

In order to make a meaningful comparison between emissions in 2005 and 2001, the differences in methodological approaches to both inventory assessments require that the 2001 emission estimates be adjusted to allow for direct comparison to 2005 inventory estimates. Section 8.1 details the improvements and methodological changes incorporated during the estimation of the port's 2005 emissions. Section 8.2 describes the adjustment made to the 2001 emissions values and also discusses the validation process undertaken by the Technical Working Group to more fully understand the adjustments and other aspects of the inventory and comparisons (details provided in Appendix G, Validation Insert 1). Section 8.3 compares the 2005 Port-related emissions to the adjusted 2001 inventory values.

To provide context to the comparison, it is also important to look at the operational throughput changes that have occurred since 2001. A comparison of container throughput activity in the Port of Los Angeles in 2001 and 2005 is presented in Figure 8.1. The figure shows the total throughput in containers (measured in TEUs) for both years. This activity growth represents a 44% increase in container throughput at the Port compared to 2001 levels.

Figure 8.1: Container Activity 2001 vs. 2005



As discussed in Section 2.7, in 2005 there was a reduction of total ship calls (all vessel types) by nearly 14% compared with 2001, although 2005 was a record year for total TEUs handled at the port. As shown below, the average number of TEUs per containership call increased from 3,272 TEUs/call to 5,260 TEUs/call. This translates to a 10% reduction in containership calls and nearly a 61% increase in the number of TEUs moved per ship call. The largest container vessel that called at the Port in 2005 was an 8,468 TEU container vessel.

Table 8.1: TEUs per vessel call in 2005 and 2001

Year	All Calls	Containership Calls	TEUs	Average TEUs/Call
2001	2,717	1,584	5,183,520	3,272
2005	2,341	1,423	7,484,625	5,260

8.1 Methodological Differences between 2005 and 2001 Inventories

There have been significant methodological changes and improvements in inventory assessments since 2001 such that a direct comparison between the 2005 inventory estimates and the previously published 2001 inventory values would be inaccurate without some adjustments to the previous inventory. The following subsections detail the improvements made in inventory assessments for the 2005 effort.

8.1.1 Ocean-Going Vessels Methodological Differences

Per CARB's direction, the 2005 OGV emissions are calculated using a PM emission factor of 1.5 g/kW-hr for both propulsion and auxiliary engines burning residual fuel. This approach is consistent with CARB's OGV emissions calculation methodology. Table 8.2 summarizes the emission factor differences between the 2005 and 2001 emission inventories.

Table 8.2: Emission Factor (g/kW-hr) Comparison for OGV Main and Auxiliary Engines using Residual Fuel, 2005 vs. 2001 Inventories

Engine Type	Fuel	2005 PM EF	2001 PM EF	Percent Change 2005 vs. 2001
Main Engine	Residual oil	1.5	1.9	-27%
Auxiliary Engine	Residual oil	1.5	0.8	47%

Additional changes include:

- Emissions were estimated on a per-vessel and per-engine basis in 2005. In 2001, vessels were "binned" based on cargo type and size.
- Vessel types were further sub-categorized within each type by size or subtype. In 2001 vessels were grouped by cargo type, and emissions were estimated using average activity by cargo type.
- Defaults by vessel types for auxiliary boiler load were derived from actual boiler fuel consumption data collected from the Vessel Boarding Program. In 2001, one default value was used for all vessels.
- Anchorage emissions, with their associated shifts and hotelling times, were apportioned to the associated port berth. In 2001, not all anchorage emissions were accounted for, specifically if a vessel shifted from one anchorage to another before calling on a Port terminal.
- Actual vessel speeds from Marine Exchange data collected for the vessel speed reduction program were used for transit speed for each vessel in 2005. In 2001 emissions were estimated without the speed reduction program and it was assumed that average sea speeds (full speed) were used by vessel type.
- Fuel correction factors for fuel switching were applied to only those vessels' engines (main, auxiliary, and boilers) that are known to switch fuel. In 2001, a total percent of auxiliary engines were assumed to switch from residual fuel to marine diesel oil based on the assumption that if vessel had ability to store dual fuel, then auxiliary engines burned MDO.
- If vessel specific information is available, it has been used in 2005 inventory. In 2001, average values were used to develop profiles for the appropriate bins.

8.1.2 Harbor Craft Methodological Differences

In order to be more consistent with load factors used by CARB, the load factors for the various harbor vessel types were revised in 2005. Table 8.3 summarizes the load factor changes. The load factors for most vessel types increased in 2005 except those for assist tugs, auxiliary engines and commercial fishing vessels. CARB cited their harbor craft survey as the source of the harbor craft load factors.

Table 8.3: Load Factor Comparison for Harbor Craft, 2005 vs. 2001 Inventories

Vessel Type	2005 Engine LF	2001 Engine LF	Percent Change 2005 vs. 2001
Assist Tug	0.31	0.31	0%
Commercial Fishing	0.27	0.43	-59%
Crewboat	0.45	0.43	4%
Excursion	0.76	0.43	43%
Ferry	0.76	0.43	43%
Government	0.51	0.43	16%
Tugboat, harbor	0.68	0.43	37%
Tugboat, ocean	0.68	0.43	37%
Workboat	0.45	0.43	4%
Auxiliary engines	0.43	0.43	0%

Additional changes include:

- In 2005, the population of ocean tugs is based on 2005 Marine Exchange data and specific activity data is obtained from companies that operate ocean tugs at the port. Only those ocean tugs that made calls at the Port in 2005 are included. In 2001, U.S. Army of Engineers (USACE) data for towboat activity was used which may have overestimated ocean tug emissions in 2001.

- Fuel correction factors were used to account for the fact that harbor craft use cleaner fuel than the fuel used to obtain emission factors. In 2001, fuel correction factors were not used.

8.1.3 Cargo Handling Equipment Methodological Differences

The 2005 CHE emissions calculation methodology included the following key differences compared with the 2001 baseline emissions inventory:

- Per CARB's direction, revisions were made to the deterioration rate calculation methodology and equipment useful life for the 2005 emission estimate.
- Per CARB's direction, revisions were made to the load factors for various equipment types.
- Consistent with CARB's OFFROAD 2007 model, revisions were made to the fuel correction factors.

Table 8.4 shows the different load factors used for 2005 and 2001 by equipment type.

Table 8.4: Load Factor Comparison for CHE, 2005 vs. 2001 Inventories

Equipment	2005 Engine LF	2001 Engine LF	Percent Change 2005 vs. 2001
Yard Tractor	0.65	0.57	12%
Excavator	0.57	0.51	11%
Top and Side Picks	0.59	0.51	14%

8.1.4 Railroad Locomotives Methodological Differences

The 2005 locomotive inventory included the following key differences compared with the 2001 baseline emissions inventory:

- Different methods of estimating off-port line haul emissions were used because the railroads operating line haul locomotives did not provide the same data as for the previous inventory. The new method is based on the amount of cargo transported by rail and train characteristics such as the number of containers and the number of locomotives per train. In 2001, the railroads provided detailed activity information on rail lines in the Air Basin but did not do so while information was being collected for the 2005 inventory.
- The Port limited the scope of activities included in the emission estimates to include only the emissions associated with the movement of cargo that was loaded onto (or removed from) railcars at locations that are within the ability of the Port to influence or control (such as by lease conditions). The 2001 emission estimates included locomotives transporting cargo that had been drayed by truck from the Port to off-Port locations (e.g., off-port rail yards) that are beyond the ability of the Port to influence or control.

In addition to the methodological changes, the line haul locomotive emission factors published by the EPA were different between 2001 and 2005 because of EPA's assumed penetration of newer locomotives into the national fleet. The emission factors are specific to the year for which emissions are estimated (i.e. there are specific 2005 year emission factors that are based on specific fleet penetration rate assumptions for newer locomotives); therefore, adjusting for the differences is not necessary and would not be appropriate. Table 8.5 shows the different emission factors used for 2005 and 2001 line haul locomotives.

Table 8.5: Emission Factor Comparison for Line Haul Locomotives, 2005 vs. 2001 Inventories

	Emission Factors (g/gal fuel)						
	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
2001	6.7	6.2	6.7	270.0	12.3	26.7	10.7
2005	6.4	5.9	6.4	183.7	12.3	26.7	10.3
% Difference	-5%	-5%	-5%	-32%	0%	0%	-4%

Decreases due to EPA's assumptions about nation-wide fleet penetration of Tier 1 and Tier 2 locomotives as reflected in their supporting documentation for their Regulatory Impact Analysis

EPA's line-haul specific emission factors are in terms of g/hp-hr. These are converted to g/gal by dividing g/hp-hr by the BSFC used by EPA in the RSD.
Average brake specific fuel consumption (from EPA's RSD): 0.048 gal fuel/hp-hr

SO_x emission factor assumes 50% 3,500 ppm S fuel and 50% 350 ppm S fuel based on locomotives entering air basin with high S fuel from out of state and refueling with lower S CA fuel.

8.1.5 Heavy-Duty Vehicles Methodological Differences

Following are the key differences in HDV emissions estimation methodologies between 2005 and the 2001 baseline emissions inventory:

- For 2005, EMFAC 2007 emission factors (zero-mile and deterioration rates) were used for all model years. In 2001, EMFAC 2002 emission factors were used.
- For 2005, EMFAC 2007 speed correction factors were used. In 2001, EMFAC 2002 speed correction factors were used.
- The 2005 inventory is based on a higher resolution for regional roadways due to the inclusion of smaller roadways in the data used in the emission calculations. This increased the number of vehicles miles traveled (VMT) for a give amount of cargo moved. In 2001, only the major regional roadways were included.
- The on-port and regional traffic modeling produces daily estimates of truck activity that were annualized differently in 2005 than in 2001. In 2005, the daily estimates are based on peak month throughputs that were extrapolated to average annual values taking into account gate operating schedules. In 2001, the daily estimates (based on peak month throughputs) were annualized by multiplying by 365 days per year, which overestimated the emissions.

8.2 Steps Used to Adjust 2001 Methodology to be Consistent with 2005 Methodology

Emission inventory methodologies are continuously evolving and improving as better information is collected and methodologies are updated to include the best available methods and data. As discussed in Section 8.1, some source categories had significant methodological changes that made comparison of the 2005 emissions estimates to the published 2001 emission estimates misleading. Therefore, several steps are required to adjust/update the previous inventory in order to provide a consistent approach for comparison purposes. The emissions values for 2001 published and adjusted are listed in section 8.3.

The following sub-sections illustrate the steps required to adjust each source category to be as consistent as possible with the 2005 inventory methods. The changes in estimating methods were made step-by-step and the emissions changes were determined for each step such that the final adjusted emission estimate is cumulative.

8.2.1 Adjustment to 2001 Ocean-Going Vessels Emission Estimates

The following steps were taken to adjust the 2001 emission estimates to be as close as possible to the methodology used in 2005 for ocean-going vessels (see Appendix F for more details).

Step 1: Started out with published 2001 baseline emissions.

Step 2: Emission estimates were adjusted to account for changes in assumptions regarding fuel switching which is the use of a lower sulfur fuel as the vessel nears the coast. For 2005, fuel correction factors were applied to only those vessels' engines (main, auxiliary, and boilers) that are known to switch fuel. For 2001, a percentage of auxiliary engines were assumed to switch from residual fuel to marine diesel oil based on information from Lloyd's. If no specific information could be found (in 2005), then it was assumed that for the 2005 inventory residual fuels were used.

Step 3: Boiler emission estimates were adjusted to account for changes in defaults by vessel types for auxiliary boiler load – for 2005, they were derived from actual boiler fuel consumption data collected from Vessel Boarding Program, while for 2001; one default value based on previously published work was used for all vessels.

Step 4: Main engine emission estimates were adjusted for the change in PM emission factor for diesel main engines when operating on residual fuels oil from 1.9 g/kW-hr (2001 value) to 1.5 g/kW-hr (2005 value).

Step 5: Auxiliary engine emission estimates were adjusted for the change in PM emission factor for diesel auxiliary engines when operating on residual fuels oil from the 0.8 g/kW-hr (2001 value) to the 1.5 g/kW-hr (2005 value).

Step 6: 2001 OGV speeds were adjusted to reflect actual speeds in 2001 based on speed data from February to December 2001.

In 2001, not all anchorage emissions were accounted for because of limitations in the available data, especially if a vessel shifted from one anchorage to another before calling on a Port terminal. The improvement of data and the inclusion of all anchorage activity in the 2005 emission estimates resulted in slightly increased estimates of hotelling emissions. The 2005 anchorage hotelling PM emissions account for approximately 2% of total 2005 OGV PM emissions which illustrates that anchorage emissions are not a significant fraction of overall OGV emissions. There was no adjustment made to 2001 emission estimates for anchorage since there is no reliable data with which to estimate 2001 anchorage emissions.

Table 8.6 compares the 2005 emissions estimates to the adjusted 2001 emission estimates. Please note that diesel particulate matter, DPM, emissions were not included in the 2001 baseline emission estimates; therefore "na" is listed for "not applicable." The 2005 DPM emissions estimates is based on the PM_{10} emissions estimates from internal combustion diesel engines and does not include emissions from steam boilers because they are not internal combustion engines.

Table 8.6: OGV Comparison of 2005 vs. Adjusted 2001 OGV Emission Estimates (tpy and %)

Category	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
Adj. 2001 Ocean Going Vessels	567	453	na	6,594	5,857	633	219
2005 Ocean Going Vessels	634	507	552	6,206	5,609	540	247
Change (tpy)	**67**	**54**	**na**	**-389**	**-248**	**-92**	**27**
Change (%)	**12%**	**12%**	**na**	**-6%**	**-4%**	**-15%**	**12%**

The table shows a 12% increase in PM and TOG emissions between the 2005 emissions and the adjusted 2001 emissions estimates; 6% reduction in NO_x emissions, 4% reduction in SO_x emissions, and 15% reduction in CO emissions. The reductions in NO_x and SO_x emissions are attributed to fewer calls and higher VSR compliance. The increase in PM emissions may be due to the increase in auxiliary engine activity due to more auxiliary power and longer average hotelling times. The SO_x and PM emission changes are not the same because the ships that reported switching fuels used a variety of fuels, and each different type of fuel has a different fuel correction factor which affects PM and SO_x emissions differently. For example, an engine that is switched from residual fuel with an average sulfur content of 2.7% to a lower sulfur residual fuel with 1.5% sulfur content will have an SOx reduction of 44% and a PM reduction of 18%.. Changes of this type reduce SOx more than PM, resulting in the differences seen in Table 8.6. Table 8.7 shows the various fuel correction factors (FCFs) used for OGV fuel switching. The percent reduction associated with these factors is (1 – FCF), expressed as a percentage.

As a clarifying note on the particulate emissions listed in Table 8.6, the values for PM_{10}, $PM_{2.5}$, and DPM are different because the DPM figure includes the PM10 emitted from ships' main and auxiliary engines but not from ships' boilers, because, by definition, DPM is particulate matter emitted from internal combustion engines and boilers are not internal combustion engines. Therefore, the PM_{10} and $PM_{2.5}$ figures include emissions from engines and boilers, while the DPM figure includes emissions (of PM_{10}) only from the engines.

Table 8.7: OGV Fuel Correction Factors

Actual Fuel	NO_X	CO	HC	PM	SO_2
HFO (1.5% S)	1	1	1	0.82	0.56
MGO (0.5% S)	0.9	1	1	0.39	0.18
MDO (1.5 % S)	0.9	1	1	0.47	0.56
MGO (0.1% S)	0.9	1	1	0.35	0.04

8.2.2 Adjustment to 2001 Harbor Craft Emission Estimates

The following steps were taken to adjust the 2001 emission estimates to be as close as possible to the methodology used in 2005 for harbor craft.

Step 1: Started out with 2001 activity data.

Step 2: Subtracted the 2001 dredges and dredging support vessels since dredging emission estimates are not included in 2005 emissions estimates and they were separated from the 2001 total commercial harbor craft emissions in the 2001 published report.

Step 3: Subtracted the 2001 line haul towboats emission estimates since a different method for estimating line haul activity was used in 2001 than the vessel by vessel method used to estimate 2005 emission estimates. (Replacement emissions added back in Step 6 below.)

Step 4: The activity data for the remaining 2001 harbor craft were adjusted to include the load factors used in 2005.

Step 5: The 2001 harbor craft emissions were adjusted using fuel correction factors to account for changes in fuel parameter.

Step 6: Added 2005 line haul emissions to the adjusted 2001 emissions for comparison purposes as explained below.

In order to do an "apples to apples" comparison of adjusted 2001 and 2005 harbor craft emissions, the 2001 line haul towboat emission estimates were replaced with the 2005 line haul towboat (i.e., ocean going tugboat) emissions. In 2001, the U.S. Army Corps of Engineers (USACE) provided data on towboat trips for the Port of Los Angeles area. The data was difficult to interpret and we now believe the interpretation and assumptions made resulted in an overestimation of the total line haul towboat activity and emission estimates apportioned to the Port. Since this type of activity is believed to have been fairly static over the 2001 – 2005 timeframe, the 2005 emissions have been used as a surrogate for 2001 emissions in this comparison.

Table 8.8 shows 22% reduction for PM emissions, 20% reduction for NO_x emissions, 67% reduction for SO_x emissions, 23% reduction for TOG emissions, and a 12% increase for CO emissions in 2005. The changes in emissions are due in part by the replaced engines and by the decreased commercial fishing vessel count at the Port in 2005.

Table 8.8: Harbor Craft Comparison of 2005 vs. Adjusted 2001 Harbor Craft Emission Estimates (tpy and %)

Category	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
Adj. 2001 Harbor Craft	49	46	49	1,578	21	266	34
2005 Harbor Craft	38	35	38	1,259	7	297	26
Change (tpy)	**-11**	**-10**	**na**	**-319**	**-14**	**31**	**-8**
Change (%)	**-22%**	**-22%**	**na**	**-20%**	**-67%**	**12%**	**-23%**

For harbor craft, the number of harbor craft decreased at the Port in 2005 from 2001 due to the 50% decrease of commercial fishing vessels. The decreases seen for harbor craft is also due to the replacement of approximately 30% of the engines included in the 2005 inventory with newer engines since 2001. The SO_x reduction is due to the use of lower sulfur content fuel in 2005 as compared with 2001 and the use of ULSD fuels by various harbor vessels.

8.2.3 Adjustment to 2001 Cargo Handling Equipment Emission Estimates

The following steps were taken to adjust the 2001 emission estimates to be as close as possible to the methodology used in 2005 for cargo handling equipment.

Step 1: Started out with 2001 activity data.

Step 2: The load factors were adjusted to be consistent with those used in 2005.

Step 3: The deterioration rates and useful life values were adjusted to be consistent with those used for the 2005 emission estimates.

Table 8.9 compares the 2005 cargo handling equipment emission estimates with the adjusted 2001 estimates.

Table 8.9: CHE Comparison of 2005 vs. Adjusted 2001 CHE Emission Estimates (tpy and %)

Category	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
Adj. 2001 CHE	71	66	71	1,818	14	1,054	149
2005 CHE	63	58	62	2,037	14	1,010	153
Change (tpy)	**-8**	**-8**	**-9**	**219**	**0**	**-44**	**4**
Change (%)	**-12%**	**-12%**	**-13%**	**12%**	**-1%**	**-4%**	**3%**

The table shows a 12% reduction in PM emissions, 12% increase in NO_x emissions, 4% reduction in CO emissions, and 3% reduction in TOG emissions. There was an increase in the CHE population and changes in operational activity (some equipment types had higher hours and some lower hours as compared with 2001, see Section 4.8 for further details), between 2001 and 2005. However, the emissions associated with CHE decreased for most pollutants due to the following:

- Emission reduction programs undertaken by the terminals and Port which included retrofitting 585 pieces of equipment with diesel oxidation catalysts
- Fleet turnover with newer-cleaner equipment
- 164 yard tractors with on-road engines
- 53 propane yard tractors which emit less than off-road engines
- Use of ULSD in over 800 pieces of equipment
- Use of emulsified fuel in over 200 pieces of equipment

8.2.4 Rail Adjustment to 2001 Emission Estimates

Changes in locomotive emission estimates between 2001 and 2005 were mainly due to changes in activity (hours of operation, number of trains, etc.), changes in fleet average emission factors specific to the year of the inventory, and changes in the type of data used to develop the estimates. The differences in data sources for off-port line haul activity between 2001 and 2005 resulted in a comparison that did not appear to be reasonably consistent with the growth in Port cargo throughput and the concurrent increase in rail activity. Therefore, the methodology used to develop the 2005 activity estimates for off-port line haul locomotive activity was applied to 2001 data to develop a revised estimate of 2001 off-port locomotive emissions for the purpose of comparison with the 2005 estimates. This methodology is believed to accurately characterize 2005 emissions, as discussed in the following subsection on validation, and is therefore presumed to appropriately characterize the level of emissions in 2001 for comparison with 2005. A side-by-side comparison of 2001 and 2005 data and assumptions used in developing these adjusted 2001 emission estimates is included in Appendix G.

The 2001 emissions were adjusted as follows.
Step 1: Started out with published 2001 baseline emission estimates.

Step 2: Subtracted the switching and line haul emissions that were included in 2001, but not in 2005, for locomotives transporting cargo that had been transported by truck to off-port locations out of Port control.

Step 3: Subtracted the remaining off-port line haul emission estimates and replaced them with estimates prepared using the 2005 off-port line haul activity estimating methodology and 2001 throughput data.

Table 8.10 compares the 2005 estimates with the adjusted 2001 locomotive emission estimates.

Table 8.10: Locomotive Comparison of 2005 vs. Adjusted 2001 Locomotive Emission Estimates (tpy and %)

Category	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
Adj. 2001 Locomotives	34	31	34	1,413	55	145	57
2005 Locomotives	57	53	57	1,783	97	244	100
Change (tpy)	**24**	**22**	**24**	**371**	**41**	**99**	**44**
Change (%)	**70%**	**70%**	**70%**	**26%**	**75%**	**68%**	**77%**

The table shows a 70% increase in PM emissions between the adjusted 2001 emissions and 2005 emissions estimates. It also shows 26% increase in NO_x emissions, 75% increase in SO_x emissions, 68% increase in CO emissions and 77% increase in TOG emissions. The increase in rail locomotive emissions in 2005 is due to increased activity at the Port.

8.2.5 Adjustment to 2001 HDV Emission Estimates

The following steps were taken to adjust the 2001 HDV emission estimates to be as close as possible to the methodology used in 2005.

Step 1: Started out with 2001 activity data.

Step 2: The 2001 activity data was rerun using the emission and deterioration factors of the more recent EMFAC revisions (EMFAC 2007). Between the development of the 2001 and 2005 emission estimates the ARB substantially revised the EMFAC emission factors (idle and running) and speed correction factors.

Step 3: The emission factor-adjusted 2001 estimates were further adjusted to account for the change in operating day-per-year assumptions and to adjust from the peak month to average month traffic modeling.

Step 4: The emission estimates adjusted for EMFAC and day-per-year differences were further adjusted to account for the increased level of detail in the traffic modeling results that were used in 2005 compared with 2001. This was done using the ratios of VMTs used in the modeling to Port TEU throughput for 2001 and 2005. This assumes that traffic patterns associated with moving cargo by truck did not change substantially between 2001 and 2005.

Table 8.11 illustrates the overall adjusted 2001 HDV emission estimates with 2005 emission estimates.

Table 8.11: HDV Comparison of 2005 vs. Adjusted 2001 HDV Emission Estimates (tpy and %)

Category	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
Adj. 2001 Heavy-Duty Vehicles	224	205	224	4,501	37	1,632	288
2005 Heavy-Duty Vehicles	280	257	280	6,104	43	2,226	469
Change (tpy)	**56**	**52**	**56**	**1,603**	**6**	**594**	**181**
Change (%)	**25%**	**25%**	**25%**	**36%**	**17%**	**36%**	**63%**

The table shows a 25% increase in PM emissions between the adjusted 2001 emissions and 2005 emissions estimates. It also shows 36% increase in NO_x emissions, 17% increase in SO_x emissions, 36% increase in CO emissions and 63% increase in TOG emissions. The increase in HDV emissions in 2005 is due to the increased truck activity at the Port. The variation in the emission changes are due to the fleet make up. There are more new trucks with cleaner engines and fewer older trucks in 2005 than there were in 2001 so the average fleet emission factors have changed. This is why the change in emissions varies by each pollutant in the above table.

An extensive validation process was undertaken by the Technical Working Group (CARB, AQMD, EPA Region 9, Port, and consultants) to ensure that the 2001 emissions were adjusted in a reasonable manner and reflect the 2005 methodology as closely as possible. In order to achieve concurrence on the comparisons of 2005 emissions with adjusted 2001 emissions, a number of evaluations for each source category were requested and the results reviewed by the Technical Working Group during numerous meetings and telephone conferences. A detailed summary of the validation of the adjustments to 2001 estimates is provided in Appendix G Validation Insert 1.

8.3 Comparison of 2005 Emission Estimates with Adjusted 2001 Emission Estimates

As described in detail in Section 8.2, in order to compare the 2005 emissions with the 2001 inventory, the 2001 emission estimates have been adjusted to normalize them with respect to the changes/improvements in methodologies used for the 2005 inventory. Table 8.12 compares the total adjusted 2001 emission estimates to the published 2001 emission estimates.

Table 8.12: Port-wide Published 2001 vs. Adjusted 2001 Emission Estimates (tpy and %)

Category	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
Published 2001 OGV	561	450	na	6,923	4,118	554	234
Adjusted 2001 OGV	567	453	na	6,594	5,857	633	219
Published 2001 Harbor Craft	178	164	na	3,531	506	1,623	376
Adjusted 2001 Harbor Craft	49	46	49	1,578	21	266	34
Published 2001 CHE	112	103	na	1,863	44	726	205
Adjusted 2001 CHE	71	66	71	1,818	14	1,054	149
Published 2001 Locomotives	60	55	na	2,466	90	249	100
Adjusted 2001 Locomotives	34	31	34	1,413	55	145	57
Published 2001 Heavy-Duty Vehicles	88	78	na	4,464	34	815	186
Adjusted 2001 Heavy-Duty Vehicles	224	205	224	4,501	37	1,632	288
Total Published 2001	999	849	na	19,245	4,791	3,967	1,099
Total Adjusted 2001	945	801	na	15,904	5,985	3,730	747
Change (tpy)	**-54**	**-48**	**na**	**-3,341**	**1,194**	**-236**	**-353**
Change (%)	**-5%**	**-6%**	**na**	**-17%**	**25%**	**-6%**	**-32%**

A comparison of 2005 emissions by source category with adjusted 2001 emissions (based on the changes discussed in Section 8.2) is presented in Table 8.13.

Table 8.13: Port-wide 2005 vs. Adjusted 2001 Emission Estimates by Source Category (tpy and %)

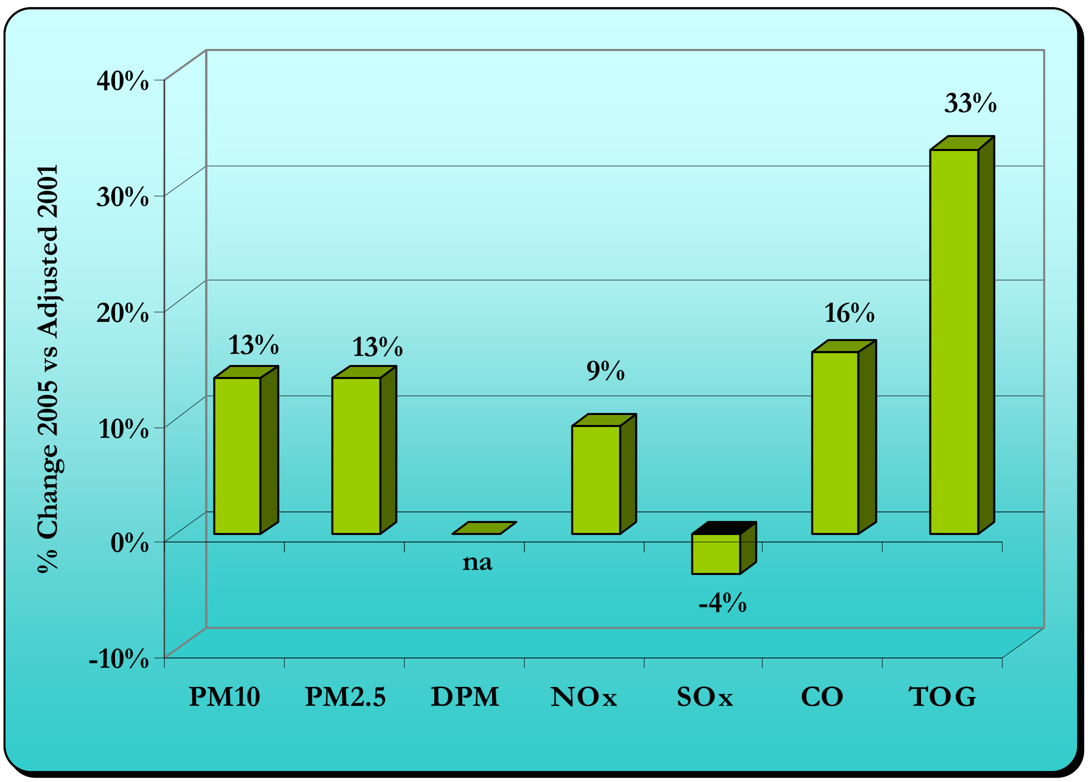
Category	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	TOG
Adj. 2001 Ocean Going Vessels	567	453	na	6,594	5,857	633	219
2005 Ocean Going Vessels	634	507	552	6,206	5,609	540	247
Change (tpy)	**67**	**54**	**na**	**-389**	**-248**	**-92**	**27**
Change (%)	**12%**	**12%**	**na**	**-6%**	**-4%**	**-15%**	**12%**
Adj. 2001 Harbor Craft	49	46	49	1,578	21	266	34
2005 Harbor Craft	38	35	38	1,259	7	297	26
Change (tpy)	**-11**	**-10**	**na**	**-319**	**-14**	**31**	**-8**
Change (%)	**-22%**	**-22%**	**na**	**-20%**	**-67%**	**12%**	**-23%**
Adj. 2001 CHE	71	66	71	1,818	14	1,054	149
2005 CHE	63	58	63	2,037	14	1,010	153
Change (tpy)	**-8**	**-8**	**-8**	**219**	**-0.2**	**-44**	**4**
Change (%)	**-12%**	**-12%**	**-12%**	**12%**	**-1%**	**-4%**	**3%**
Adj. 2001 Locomotives	34	31	34	1,413	55	145	57
2005 Locomotives	57	53	57	1,783	97	244	100
Change (tpy)	**24**	**22**	**24**	**371**	**41**	**99**	**44**
Change (%)	**70%**	**70%**	**70%**	**26%**	**75%**	**68%**	**77%**
Adj. 2001 Heavy-Duty Vehicles	224	205	224	4,501	37	1,632	288
2005 Heavy-Duty Vehicles	280	257	280	6,104	43	2,226	469
Change (tpy)	**56**	**52**	**56**	**1,603**	**6**	**594**	**181**
Change (%)	**25%**	**25%**	**25%**	**36%**	**17%**	**36%**	**63%**
Adj. 2001 Total Emissions	945	801	na	15,904	5,985	3,730	747
2005 Total Emissions	1,072	910	990	17,389	5,770	4,318	995
Change (tpy)	**127**	**109**	**na**	**1,485**	**-215**	**588**	**248**
Change (%)	**13%**	**13%**	**na**	**9%**	**-4%**	**16%**	**33%**

It should be noted that for the OGV comparison presented above, adjusted speeds (as described in Appendix G, Validation Insert 1, Section 1.1) were used to develop the adjusted 2001 emission estimates. Comparing the adjusted 2001 emissions (without including the adjusted speeds) to 2005 OGV emissions would change the OGV PM increase from 12% to 2%, the OGV NO_x decrease from -6% to -15%, and the OGV SOx decrease from -4% to -

10%. Similarly, the total emissions would change the total PM increase from 9% to 3%, the total NO_x increase from 7% to 2%, and the total SOx decrease from -4% to -10%. This illustrates the potential range of actual emission changes between 2001 and 2005, because of limited data on actual speeds in 2001 before implementation of the speed reduction program.

Table 8.19 and Figure 8.2 show that port-wide there was a 13% increase in PM emissions, a 9% increase in NO_x emissions, a 4% reduction in SO_x emissions, a 16% increase in CO emissions, and a 33% increase in TOG emissions between 2001 and 2005.

Figure 8.2: 2005 vs. Adjusted 2001 Emissions for All Source Categories



There are many factors that affect the direction and magnitude of the overall emission changes related to each source category. The overall emissions changes are influenced by a combination of increases and decreases in different source categories. Some of the more significant factors are listed and discussed in the following paragraphs, by pollutant and by source category. Figures 8.3 through 8.5 present the 2005 vs. adjusted 2001 emissions comparison data in graphical form for PM_{10} and $PM_{2.5}$ (the changes are the same for these two pollutants), NO_x, and SO_x respectively by source category.

Figures 8.3 and 8.4 illustrate the relative magnitude of PM increases and decreases from each source category. The overall PM emission increases presented in Figure 8.2 are influenced by the following increases and decreases in source category emissions shown in Figure 8.3:

Increases from:

- OGV – due to the shift from main engine power to auxiliary engine power discussed above in Appendix G, Validation Insert 1, Section 1.1, in reference to Table 1.
- HDV – increased activity (miles traveled) caused by increase port throughput, despite newer fleet
- Rail – significantly increased on-dock activity and overall port TEU throughput. It should be noted that increases in on-dock rail activity means that more cargo is moving via rail and thus limiting increases in cargo moving by truck.

Reductions from:

- CHE – due to emission reduction programs, fleet turnover to cleaner engines, and the use of cleaner fuels
- Harbor Craft – reduced number of vessels (and, therefore, lower operating hours) from the fishing fleet and the use of lower sulfur fuels

Figure 8.3: PM Emissions Changes 2005 vs. Adjusted 2001 by Source Category

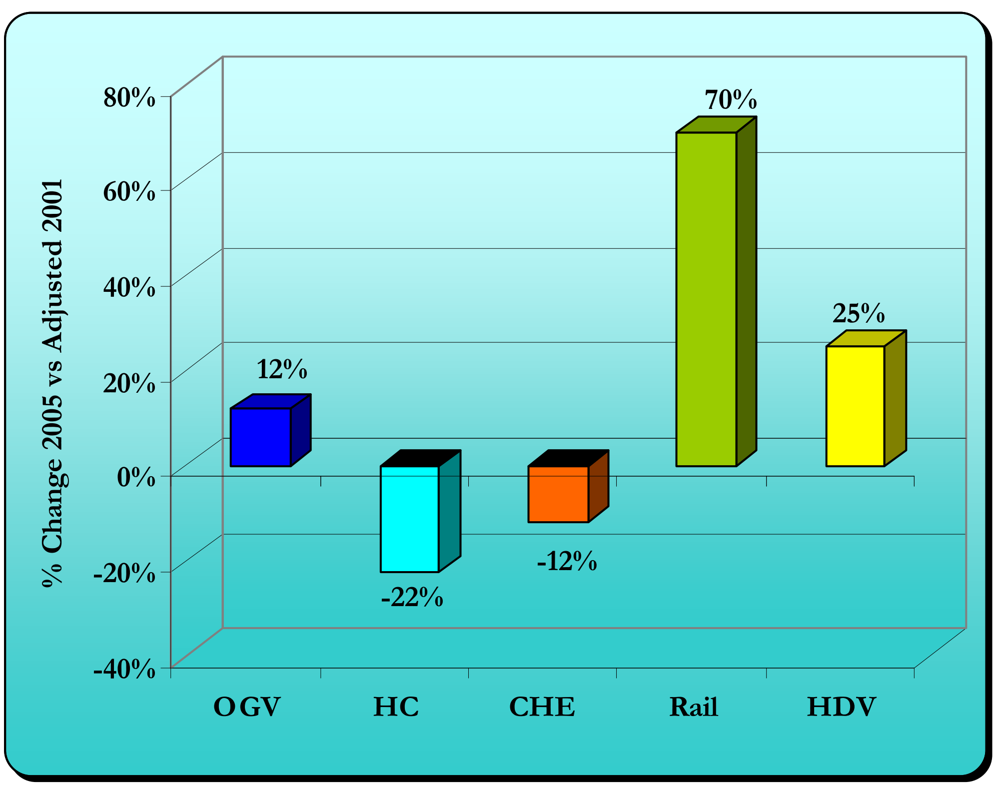


Figure 8.4: PM Emissions Changes 2005 vs. Adjusted 2001 by Source Category, tpy

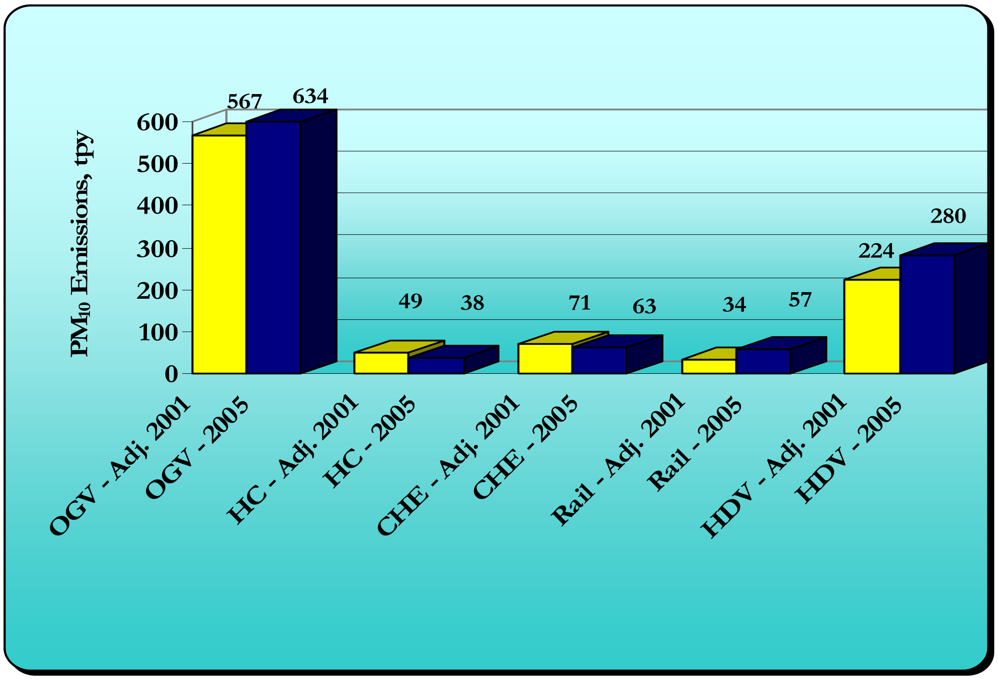


Figure 8.5 and 8.6 illustrate the relative magnitude of NO_x increases and decreases from each source category. The overall NO_x emission increase presented in Figure 8.2 is influenced by the following increases and decreases in source category emissions shown in Figure 8.5:

Increases from:
- HDV – increased emissions due to increased activity despite newer fleet
- CHE - increased emissions due to increased activity despite newer equipment
- Rail – significantly increased on-dock activity and overall port TEU throughput

Reductions from:
- OGV – greater compliance with VSR program, use of slide valves, and fewer vessel calls
- HC - engine replacements and lower operating hours from the fishing fleet

Figure 8.5: NO_x Emissions Changes 2005 vs. Adjusted 2001 by Source Category

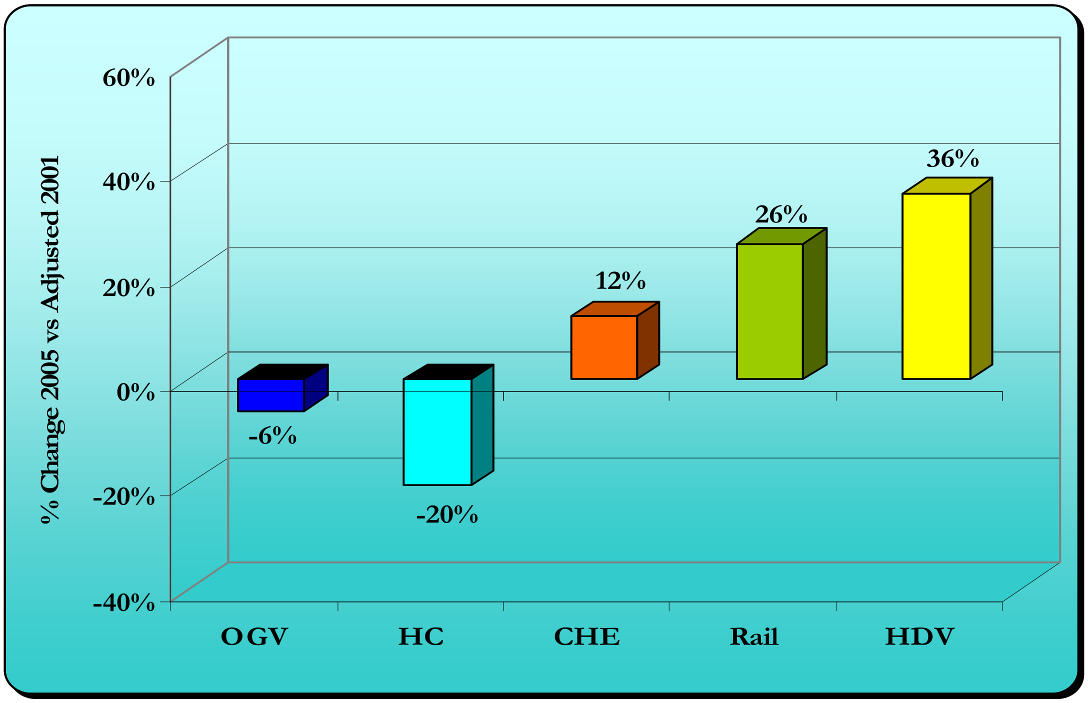
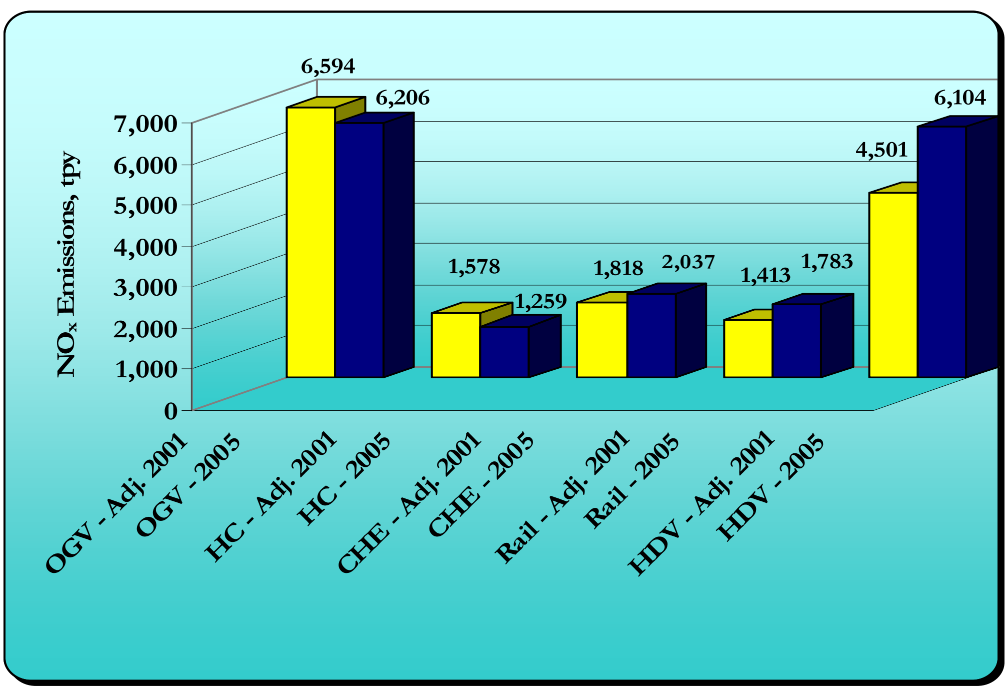


Figure 8.6: NO_x Emissions Changes 2005 vs. Adjusted 2001 by Source Category, tpy



Figures 8.7 and 8.8 illustrate the relative magnitude of SO_x increases and decreases from each source category. The overall SO_x emission decrease presented in Figure 8.2 is influenced by the following increases and decreases in source category emissions shown in Figure 8.7:

Increases from:

- HDV – increased emissions due to increased activity despite newer fleet
- Rail – significantly increased on-dock activity and overall port TEU throughput

Reductions from:

- OGV – Fewer vessel calls and vessels that switched to cleaner fuels
- CHE - emission reduction programs and the use of cleaner fuels
- HC – use of cleaner fuels and lower operating hours from the fishing fleet

Figure 8.7: SO_x Emissions Changes 2005 vs. Adjusted 2001 by Source Category

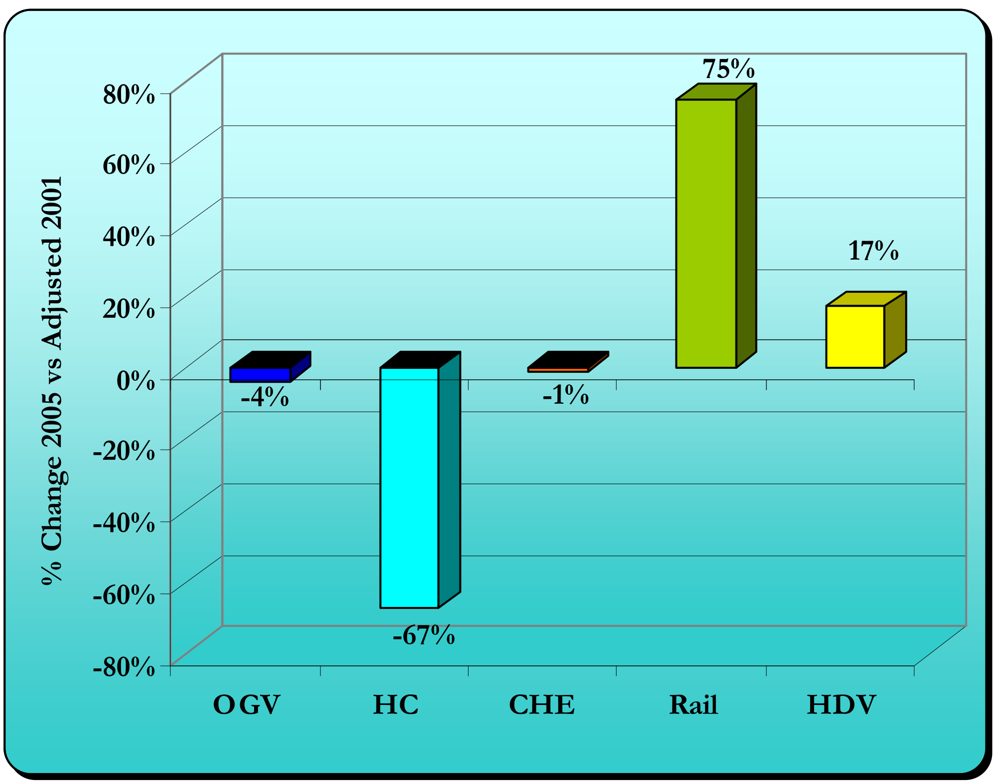
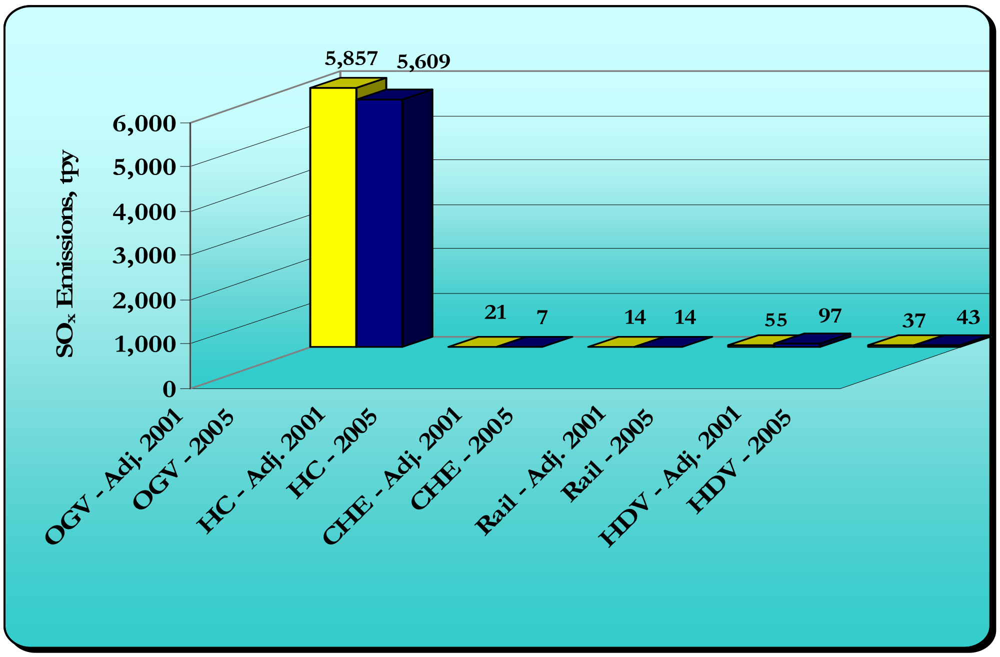


Figure 8.8: SO_x Emissions Changes 2005 vs. Adjusted 2001 by Source Category, tpy



As noted in the beginning of this section, container throughput increased approximately 44% between 2001 and 2005. However, overall container-related emissions grew at lesser rates, due to the combined effects of regulations, voluntary emission reduction efforts (by the Port and Port tenants), improvements in terminal operations, and other factors. When looked at as the ratio of overall emissions to container throughput (i.e., tons of emissions from all five source categories per 10,000 TEUs throughput) the movement of containers was accomplished with lower emission levels per container moved. The following table presents the magnitudes of these improved efficiencies for PM_{10}, NO_x, and SO_x.

Table 8.14 Changes in Ratios of Emissions to Throughput (tons per 10,000 TEU)

Pollutant	Tons of Emissions / 10,000 TEU 2001	2005	Percent Change
PM_{10}	1.2	1.0	17% decrease
NO_x	21.2	17.5	17% decrease
SO_x	5.9	4.3	27% decrease

While Figure 8.2 shows that the total mass of emissions of PM_{10} and NO_x has increased between 2001 and 2005, Table 8.14 shows that the combined effects of the efforts made to improve operational efficiencies and to reduce emissions over that period have improved the emissions performance related to the movement of containers through the Port. The Port and the regulatory agencies are implementing additional, far-reaching measures and regulations that will result in continued improvements in the emissions-to-throughput ratios.

SECTION 9 CONCLUSIONS

This section provides a discussion of the study's strengths and limitations, as well as recommendations.

9.1 Strengths

The strengths of the study include:

- Coordination with the regulatory authorities and neighboring port to agree on scope and emissions estimating methodology.
- Emissions estimated on an engine by engine basis for cargo handling equipment, harbor vessels and ocean-going vessels.
- Detailed data collected for each source category
- Emission reduction efforts identified and included in emissions estimates.
- Vessel-specific data collected during the OGV Vessel Boarding Program used and shared among Port of Long Beach, Port of Los Angeles, and ports in Puget Sound

9.2 Limitations

As the Port continues to conduct activity based emissions inventories and collects more detailed activity data, the emission factors used for each source category become a major limiting factor in the emissions estimation methodology. In general, emission factors are based on limited test data or based on general engine standards. Engine manufacturers design their engines to emit well below the standards, but it is difficult to establish the "in-use" average without the benefit of measurements or test data.

Other limitations include:

- When specific data is not available, profiles are used for each source category, such as for ocean-going vessels' auxiliary engines. Lloyd's Fairplay database, which is used for this EI's ocean going vessel physical parameters, provides limited data on auxiliary engine and boiler information. Therefore, data gathered from the Vessel Boarding Program and Lloyd's limited auxiliary engine data was used to generate profiles to fill in for missing data.
- The rail companies did not provide detailed locomotive engine data to the study and similar assumptions made in the baseline inventory had to be made for this study. The rail companies worked extensively on regional data for the state of California, in preparation for the state's Health Risk Assessment but were not able to provide Port-specific data to the port.
- The on-terminal heavy-duty vehicles activity data at many of the terminals is mainly based on operator's best knowledge of operations instead of actual measurement or detailed recordkeeping.

9.3 Recommendations

Recommendations, based on the discussion presented in the Limitations subsection above, are presented here by source category for further consideration in future emissions inventories and other studies. Implementation of the San Pedro Clean Air Action Plan and upcoming federal and state regulations, such as the auxiliary engine rule for OGVs should further reduce emissions in the future.

Ocean-going Vessels

- Engage the maritime community in additional discussions related to emission reduction methods.
- Collect a more comprehensive list of vessels retrofitted with slide valves and other emission reduction technologies.
- Encourage engine testing for various pollutants, especially NO_x and particulate matter in order to establish "in-use" averages of NO_x and PM emissions.
- Discuss with Lloyd's and classification societies the need for better auxiliary engine data.
- Continue Vessel Boarding Program.
- Coordinate with CARB and SCAQMD to ensure that methods for estimating ship emissions in the San Pedro Bay are consistent and with the highest level of confidence.

Harbor Craft

- Engage the regulators with additional discussion on emission factors and the need to test engines.
- Continue to record which engines were replaced and other emission reduction efforts.

Cargo Handling Equipment

- Engage cargo handling equipment operators such that activity data and other data needed for EI is stored throughout the year and collected in a more efficient manner.
- Engage cargo handling equipment operators, especially those that may not have an emissions reduction strategy, to start or continue emission reduction efforts.
- Engage CARB in discussions to update parameters used in OFFROAD model.

Rail

- Follow-up inventories should use on-site survey work to develop the types of information that the railroads are unable to provide because of their personnel, financial, or confidentiality concerns.
- Engage the railroad companies and regulators in discussions of how best to collect Port-related data for future inventory updates.

Heavy-Duty Vehicles

- Engage the terminal operators to provide more refined estimates of on-terminal parameters such as speeds, distances, and idling times.
- Gather data on on-terminal idling.
- Review with CARB, SCAQMD, and South Coast Area Governments speeds for the road network to determine if the speeds are still appropriate.
- Coordinate with CARB and SCAQMD on the HDV truck models used by the Port to project VMT associated with cargo throughputs.