Appendix B

Emission Inventory Methodology

Hotelling Emissions Estimation Methodology for Ship Auxiliary Engines in California

Table of Contents

LIST OF TABLES AND FIGURES

EXECUTIVE SUMMARY

The California Air Resources Board (ARB) has developed a proposed regulation to reduce diesel PM and NOx emissions from container vessels, cruise ships, and refrigeration vessels that visit the Ports of Los Angeles, Long Beach, Oakland, Hueneme, San Diego, and San Francisco. The Shore Power Regulation is expected to significantly reduce diesel PM emissions, which is necessary for reducing premature mortality, cancer risk and other adverse health effects from exposure to diesel PM. The regulation would also reduce NOx emissions which contribute to violations of ozone and particulate air quality standards in California.

In 2005 ARB staff developed a comprehensive, statewide ocean-going vessel inventory and calculation methodology. That inventory covered eight vessel types over three operating modes (hotelling, maneuvering, and transit) visiting all Ports in California. Emissions estimates developed using that methodology were used to support development of ARB's Auxiliary Engine Regulation, as well as Statewide Implementation Plans and federal plans for development of a sulfur emissions control area.

To develop an inventory of hotelling emissions at California ports, ARB staff revised the 2005 methodology for calculating emissions from ocean-going vessels in California. The inventory update was conducted to achieve several goals:

- Reflect 2006 activity
- Merge new port specific activity data sets that provide port call specific information
- Include improvements to calculation methodologies developed in recent port-specific inventories
- Refine growth assumptions and methods
- Incorporate 2005 Auxiliary Engine Regulation into emission estimates
- Determine the potential emissions benefits of this proposed regulation.

This emission inventory includes emissions from all ports and vessels but focuses on the vessel types, operating modes, and ports that would be affected by the proposed regulation—container ships, passenger ships, and refrigerated vessels (reefers) visiting the Ports of Los Angeles, Long Beach, Oakland, San Diego, San Francisco, and Hueneme.

Whereas ARB's previous inventory covered container ships as one category, new updates to the inventory reflect multiple categories of container ships, based on size, consistent with inventories developed to represent the Ports of Los Angeles and Long Beach.

This inventory integrates information from multiple sources. Information about the characteristics of individual ships, such as engine size, net registered tonnage, and other information, are taken from the 2006 Lloyd's Fairplay Ship Registry. Information about port calls and hotelling times are taken from databases developed by the

California State Lands Commission and from management organizations at many ports in California. Information on engine loads are taken from previous ARB surveys and inventories developed for the Ports of Los Angeles, Long Beach, and Oakland. Emission factors are taken from available studies of ship emissions tests.

Emissions are calculated by estimating ship activity on a ship by ship and a port call by port call basis, using actual ship auxiliary engine power estimates and actual ship hotelling times where possible. This inventory presents NOx, PM, SOx, and other pollutant emissions generated from sources covered by the proposed regulation. Base year emissions are forecasted using a set of growth factors specific to each port and each ship type, and control factors reflecting the shore power regulatory scenario. The regulatory scenario developed for this regulation also includes emissions associated with generating shore power from the electric grid, assuming the use of natural gas fired power plants with selective catalytic reduction, that would be used in place of auxiliary engines.

Using the proposed methodology, we estimate statewide emissions from covered auxiliary engines during hotelling in 2006 were nearly 1.5 tons per day of diesel PM, and about 17 tons per day of oxides of nitrogen (NOx). Detailed emission estimates are presented in Table ES-1.

Table ES-1 Auxiliary Engine Hotelling Emissions in 2006 (Tons/day)

Auxiliary Engine Hotelling Emissions - 2006 (tons/day)					
Vessel Type	**Port Calls**	**NO_x**	**PM_{10}**	**SO_x**	**ROG**
Container	4966	13.8	1.12	8.1	0.32
Cruise	669	2.5	0.24	1.7	0.06
Reefer	288	0.9	0.07	0.5	0.02
Total	**5923**	**17.1**	**1.42**	**10.33**	**0.40**

Container ships account for 83% of covered port calls and 80% of covered NOx emissions. Cruise ships account for 11% of covered port calls and 14% of covered NOx emissions. Reefer vessels account for about 5% of covered port calls and emissions.

Table ES-2 summarizes NO_x and PM_{10} emissions by Port.

Table ES-2 NO_x and PM Emissions by Port

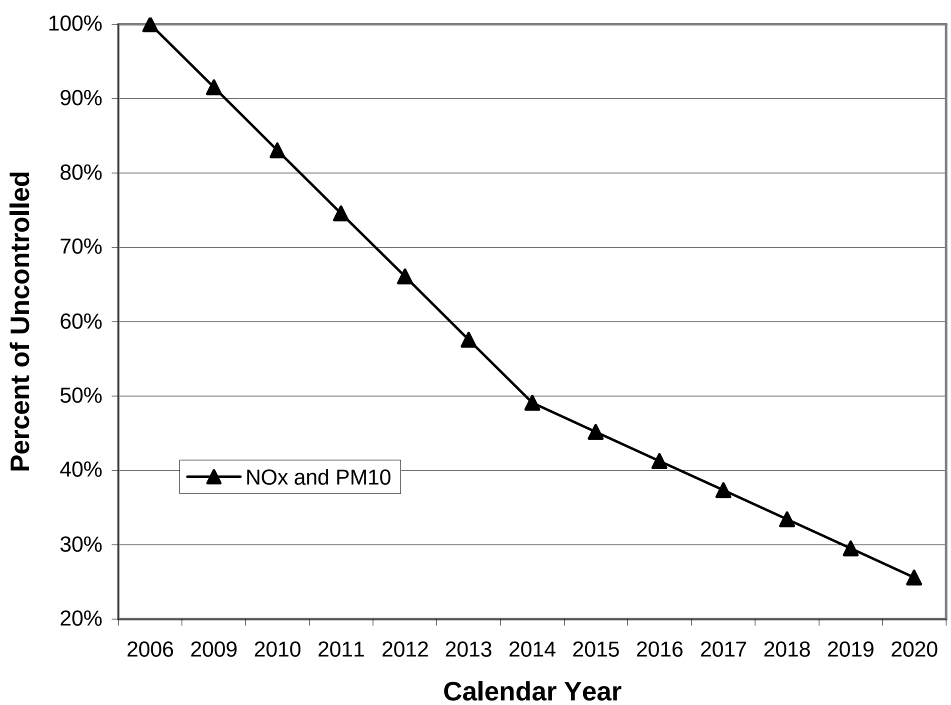
Port	NO_x	PM_{10}
Hueneme	0.6	0.05
Long Beach	5.8	0.5
Los Angeles	6.9	0.6
Total LA-LB	**12.7**	**1.05**
Oakland	2.6	0.2
San Diego	0.9	0.1
San Francisco	0.3	0.03
Total All Ports	**17.10**	**1.42**

About 75% of the emissions occur in the Ports of Los Angeles and Long Beach. Individually, these two ports emit twice as much as the next largest port, Oakland.

The proposed Shore Power Regulation will limit the amount of time that ships can use their auxiliary engines during hotelling. Fleets with at least 25 yearly port calls for a given port will be subject to limited auxiliary engine use for 50% of their visits in 2014 and 80% of their visits in 2020. The main benefit of this regulation is a reduction in emission of NOx, PM10, and SO_x due to limits on engine use. Auxiliary engines emit large amounts of these pollutants due in part to the predominance of the use of heavy fuel oil. Use of shore power will result in the electrical demand of the ship being generated by clean on-shore power plants that are controlled and use cleaner fuel.

The proposed regulation will reduce NOx and PM10 levels to about 49% of their uncontrolled levels in 2014 and to 26% of their uncontrolled levels in 2020. These reductions are shown in Figure ES-1.

Figure ES-1 Estimated Emissions Reductions with Shore Power Regulation



I. INTRODUCTION

This section provides background on ARB's ocean-going vessel emissions inventory as it pertains to this regulation, describes the objectives in preparing this emissions inventory, and provides a general overview of the methodology used to estimate emissions from ship auxiliary engines during hotelling.

A. Background

In 1998, the California Air Resources Board (ARB) identified diesel particulate matter (diesel PM) as a toxic air contaminant. A needs assessment for diesel PM was conducted between 1998 and 2000, which resulted in ARB staff developing and the Board approving the *Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles* (Diesel RRP) in 2000 (ARB, 2000). The Diesel RRP presented information on the available options for reducing diesel PM and recommended regulations to achieve those reductions. The scope of the Diesel RRP was broad, addressing all categories of engines both mobile and stationary, and included control measures for diesel sources, such as those covered by the proposed regulation. The ultimate goal of the Diesel RRP is to reduce California's diesel PM emissions and associated cancer risks by 85 percent from the 2000 baseline levels by 2020.

In January 2005, a Goods Movement Cabinet Workgroup, created by Governor Schwarzenegger and led by the California Environmental Protection Agency and the Business, Transportation and Housing Agency, established a policy for goods movement and ports to improve and expand California's goods movement industry and infrastructure while improving air quality and protecting public health. The workgroup worked collaboratively with the logistics industry, local and regional governments, neighboring communities, business, labor, environmental groups, and other interested stakeholders to create a two-phased Goods Movement Action Plan, which outlines a comprehensive strategy to address the economic and environmental issues associated with moving goods via the state's highways, railways, and ports (ARB, 2007a). In April 2006, the Board approved the Emissions Reduction Plan for Ports and Goods Movement (GMERP) in California (ARB, 2007a).

Ocean-going vessels are a major source of emissions associated with goods movement, and a major source of emissions at California's ports. In order to improve both local air quality around ports and regional air quality as a whole, the ARB has developed a regulation to reduce auxiliary emissions during hotelling operations at major ports in California. This technical document provides the methodology for calculating ocean-going vessel emissions associated with this regulation, and emissions estimates for both baseline and regulatory scenarios.

An ocean-going vessel (OGV) is a commercial vessel greater than or equal to 400 feet in length or 10,000 gross tons; or propelled by a marine compression ignition engine with a displacement of greater than or equal to 30 liters per cylinder. OGV emissions occur during three distinct operating modes: transit (emissions from vessel operations between ports), maneuvering (slow speed vessel operations while in-port areas), and hotelling (also known as berthing; in-port emissions while moored to a dock or anchored near a dock).

There are three major sources of emissions on OGVs; main engines, auxiliary engines, and auxiliary boilers. The main engine is a very large diesel engine used mainly to propel the vessel at sea. Main engines are used during the transit and maneuvering modes. Auxiliary diesel-fueled engines on OGVs provide power for uses other than propulsion (except for diesel-electric vessels). Typically, an OGV will have a single, large main engine used for propulsion, and several smaller auxiliary "generator-set" engines. Auxiliary engines are used during all three operating modes. Auxiliary boilers are external combustion boilers that are used to provide steam for cabin heat, hot water, fuel warming, and product pumping for crude oil tankers.

Passenger cruise vessels, and a few tankers, use a different engine configuration which is referred to as "diesel-electric." These vessels use large diesel generator sets to provide electrical power for both propulsion and ship-board electricity. For the purposes of the proposed regulation, and this emissions inventory, these large diesel generator sets are included in the definition of "auxiliary engines."

There are eight types of ocean-going vessels including: auto carriers, bulk cargo carriers, container vessels, general cargo carriers and other miscellaneous vessels, passenger vessels, reefers (refrigerated vessels), roll-on-roll-off vessels (also known as a Ro-Ro: vessels in which vehicles can be driven on or off the vessel). However, only three vessel types are subject to the proposed Shore Power Regulation. These vessels are shown in Table I-1. These vessels are covered by the proposed Shore Power Regulation if they visited, in 2006, one of the following six ports in California: San Diego, Los Angeles, Long Beach, Hueneme, San Francisco, and Oakland.

Table I-1 Categories of Ocean-Going Vessels Included in the Emissions Inventory

Vessel Type	Description
Container	Container vessels are cargo vessels that carry standardized truck-sized containers.
Cruise	Passenger cruise vessels are passenger vessels used for pleasure voyages.
Reefers	Vessels used to transport perishable commodities which require temperature-controlled transportation, mostly fruits, meat, fish, vegetables, dairy products, and other foods.

Reefer ships are conventional means of transporting perishable commodities and they have been losing market to reefer containers carried by container ships in recent years.

B. Purpose and Overview

The objectives in developing this emissions inventory were to:

- Reflect 2006 activity
- Merge new port specific activity data sets that provide port call specific information
- Include improvements to calculation methodologies developed in recent port-specific inventories
- Refine growth assumptions and methods
- Incorporate 2005 Auxiliary Engine Regulation into baseline emissions estimates
- Assess potential benefits of the proposed Shore Power Regulation.

This technical document provides inventory methodologies and emissions estimates for sources covered by the proposed regulation as described above. This document also provides estimates of the net emissions benefits of the proposed Shore Power Regulation, including estimates of emissions generated to provide power to the electrical grid which would replace power generated by auxiliary engines on board regulated ships.

The base year for this inventory is 2006, which was chosen because it was the latest year for which complete statewide activity data were available. This emissions inventory is forecasted both as a baseline, and with the proposed regulatory benefits.

C. Public Process

Allowing stakeholders and the general public to review and comment on a product associated with a rulemaking process is a critical element of that rulemaking process. The following steps were taken to ensure interested parties could provide input.

Seven public workshops or workgroups were held in 2007 that provided the stakeholders and the general public the opportunity to review and comment on the inventory. A number of teleconferences were conducted with port representatives and port consultants to allow review and comments on proposed inventory methodologies. We provided local air districts the opportunity to review and comment on the methodology and the inventory by conducting meetings and teleconferences. Comments obtained through these meetings, teleconferences and workshops were used to assess and modify the inventory.

II. EMISSION ESTIMATION METHODOLOGY

This technical document focuses on inventory methodologies and emissions estimates associated with auxiliary emissions, generated during hotelling operations, for three selected vessel types at six covered ports in California.

A. Emission Inventory Inputs

Data needed for estimating auxiliary engine emissions include:

- Base year vessel population
- Port call-specific hotelling time
- Auxiliary engine power
- Vessel type specific engine load
- Auxiliary engine emission factors
- Vessel type and port growth rate
- Replacement power emission factors

1. Base Year Vessel Population

There were several sources of activity data that were used in this ocean-going vessel inventory. First, vessel port calls were obtained from a database maintained by the California Lands Commission. This database includes vessel identification, port of arrival, previous port, next port, and date and time of arrival. The Lands Commission compiles this database from information obtained from marine exchanges and port authorities statewide. 2006 was chosen as the base year for this inventory, since it is the most recent data available. Second, vessel specific hotelling times and berth locations were obtained from port officials responsible for ship docking, or Wharfingers, in Los Angeles, Long Beach, Oakland, San Diego, San Francisco and Hueneme. Data were obtained for 2004 through 2006, but only 2006 data were used for this inventory. These data were reconciled to the extent possible with the port call data from the Lands Commission. For all ports, approximately 94-98% of the port calls were reconciled between the two databases. The remaining port calls in the Lands Commission database which could not be reconciled were assigned the port average hotelling times by vessel type. Table II-1 summarizes the number of port calls by ship type and by port.

Table II-1 2006 Port Calls in California

Port	Container	Cruise	Reefer	Total
Hueneme			153	**153**
Long Beach	1445	133	28	**1606**
Los Angeles	1671	260	31	**1962**
Oakland	1844			**1844**
San Diego		194	76	**270**
San Francisco		80		**80**
Total	**4960**	**667**	**288**	**5915**

2. Hotelling Time

Hotelling time can be defined as beginning when a ship ties up at a berth, and ends when it leaves that berth. During this time, vessels use at least one of their auxiliary engines to generate electric power for the ship. Some ships will shift berths during a given port call for various reasons; for the purpose of this inventory, the hotelling time used for calculations combines the total hotelling time for all berths visited during a given port call.

Where possible, vessel visit-specific hotelling times, obtained from Wharfinger data, were used for inventory calculations. Port calls that could not be identified in Wharfinger data were assigned average hotelling times by port and by vessel type from the Wharfinger data that was available. Table II-2 summarizes the average, minimum, and maximum hotelling times by vessel type for 2006.

Table II-2 2006 Hotelling Time Statistics

		Hotelling Time (hours)		
Port	**Vessel Type**	**Average**	**Minimum**	**Maximum**
LA-Long Beach	Container	49.0	0.8	135.2
	Cruise	11.2	5.5	39.0
	Reefer	33.0	3.9	91.6
Oakland	Container	19.9	3.9	103.7
Hueneme	Reefer	66.9	15.0	111.0
San Diego	Cruise	12.6	5.1	145.7
	Reefer	61.6	26.0	119.6
San Francisco	Cruise	11.6	4.0	81.0

Although the number of port calls by container ships to Oakland is roughly equivalent to the number of port calls at either Los Angeles or Long Beach, the hotelling time of these ships in Oakland is much shorter. Often, container ships will call on both Oakland and either Los Angeles or Long Beach; presumably, fewer containers are loaded or unloaded in Oakland than in southern California.

3. Auxiliary Engine Power

A number of sources were used to determine the auxiliary engine power ratings for vessels. The primary source of auxiliary engine power information was the 2005 ARB

Ocean Going Vessel survey. Average total ship auxiliary engine power was determined by vessel type from the 327 ships surveyed. Second, ship specific auxiliary engine power estimates for ships visiting the Port of Oakland in 2005 were obtained from Environ, based on published data on electric generation capacity for these ships. Third, a small number of ship-specific auxiliary power ratings were obtained from a vessel boarding program performed by the Starcrest as a part of emission inventories contracted by the Ports of Los Angeles and Long Beach (see references 4 and 5 below). Finally, a limited number of ship specific auxiliary engine power data were obtained from Lloyds-Fairplay.

Table II-2 summarizes the average auxiliary engine power by ship type. Container ship power ratings are subdivided by cargo capacity of the vessel, which are measured as the number of containers, also known as twenty-foot equivalent units or TEUs.

Table II-3 Average Total Auxiliary Engine Power

Vessel Type	Size	Average Total Auxiliary Power (kw)	Load Factor	Net Hotelling Load (kw)
Container	<2000 TEU	3536	18%	636
	2000-2999 TEU	5235	22%	1152
	3000-3999 TEU	5794	22%	1275
	4000-4999 TEU	8184	22%	1800
	5000-5999 TEU	11811	18%	2126
	6000-6999 TEU	13310	15%	1996
	7000-7999 TEU	13713	15%	2057
	>8000	13084	15%	1963
Cruise		45082	16%	7213
Reefer		3696	32%	1183

4. Vessel type specific engine load

Ocean-going vessel auxiliary engines are almost never operated at full capacity. The load on the engine is a function of the power demand of the vessel itself, as well as the power demand of any refrigerated containers or other power demands for cargo on the vessel. The auxiliary engine load factor represents the actual engine power used divided by the total installed auxiliary engine power. The primary source of data on engine load was the 2005 ARB OGV survey and the vessel boarding program performed by Starcrest for the Port of Los Angeles and the Port of Long Beach emission inventories. Starcrest expanded the load factors from the 2005 ARB survey for the various sizes of container ships by supplementing the survey data with data from the vessel boarding program. Table II-3 above shows the load factors, in percent, by vessel type. The net hotelling load (in kilowatts) is determined by multiplying the average total auxiliary power by the load factor.

5. Auxiliary engine emission factors

OGV emission factors vary by pollutant, operating mode (transit, maneuvering, or hotelling), engine type (main engine/slow speed, main engine/medium speed, or auxiliary/medium speed), and fuel type (HFO or marine distillate). We compiled emission factors for diesel particulate matter (PM), oxides of nitrogen (NO_x), sulfur dioxide (SO_2), hydrocarbons (HC), carbon monoxide (CO), and carbon dioxide (CO_2) from available data sources. Emission factors for ocean-going vessels are expressed as grams of pollutant emitted per kilowatt-hour of energy (g/kW-h).

Two fuel types, marine distillate [marine gas oil (MGO) and marine diesel oil (MDO)] and heavy fuel oil (HFO), are used in OGV auxiliary engines. According to the 2005 ARB OGV survey, 29 percent of the auxiliary engines used marine distillate and 71 percent used HFO, except for passenger vessels that use approximately 8 percent marine distillate and 92 percent HFO.

Table II-4 presents emission factors for OGV auxiliary engines, including diesel-electric vessels. As shown in the table, emission factors for auxiliary engine vary depending on the type of fuel used; a composite auxiliary engine emission factor was used based on the fuel usage percentages by vessel type described above.

Table II-4 Auxiliary Engine Emission Factors – All Modes (g/kW-hr)

Engine Type	Fuel Type	PM	NO_x	SO2	HC	CO
Medium Speed	HFO	1.5	14.7	11.1	0.4	1.1
Medium Speed	Marine Distillate	0.3	13.9	2.1	0.4	1.1
Medium Speed	Marine Distillate @0.1% S	0.25	13.9	0.4	0.4	1.1

These emission factors are consistent with the emission factors used in recent inventories done for the Ports of San Diego, Los Angeles, Long Beach, and Oakland. They were based on a study by Entec (2002). The Entec emission factors were developed using Lloyd's of London (1995) and IVL Swedish Environmental Institute data (2002) that related emissions to engine speed and the type of fuel used. These emission factors were developed by averaging together emission test results performed at a variety of load factors. The emission factor for sulfur dioxide was adjusted from the value in Entec (2002) to account for a HFO fuel content of 2.5%, which was determined from the ARB OGV survey.

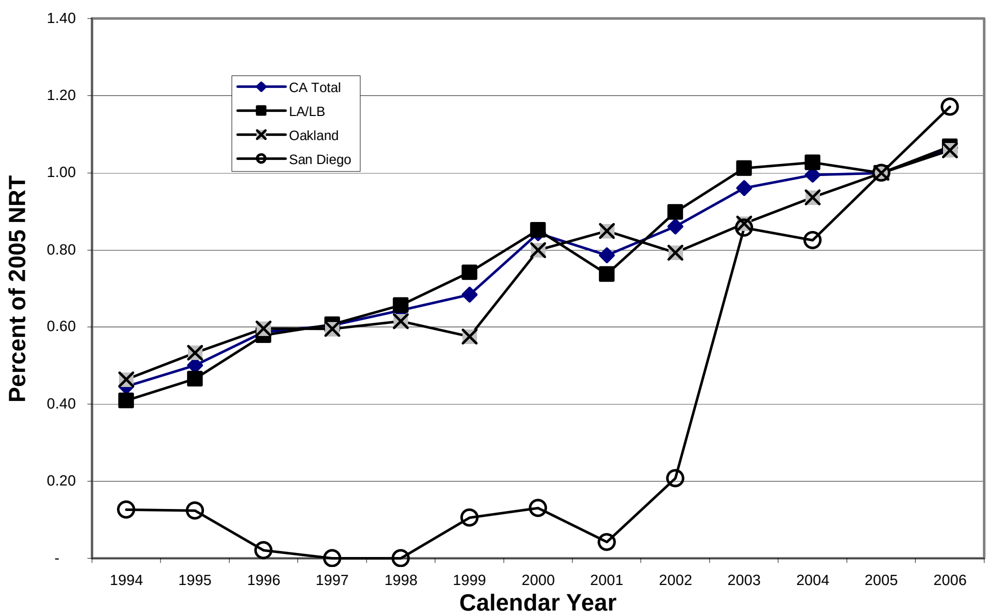
ARB staff developed an alternate particulate matter emission factor for engines burning heavy fuel oil based upon an extensive review of emission tests described in scientific literature. This emission factor, set at 1.5 grams/kilowatt-hour, is based upon the use of HFO fuel with 2.5% sulfur content. The basis of this emission factor is fully described in a white paper written by ARB staff in 2007, which is available on request.

6. Forecasting Growth

Previous growth estimates were based on installed power of propulsion engines, and extrapolated from measured trends between 1997 and 2003. These growth rates were allocated by vessel type or by port. To update the growth rates, foreign vessel activity data was compiled using US Army Corps of Engineers vessel call data between the years 1994 and 2005. Because of the insufficient data for installed power in the additional data years analyzed, a new growth surrogate, net registered tonnage (NRT), was developed. The total NRT, a measure of the volume of cargo a ship can carry, was determined by vessel type and by port. NRT was used to estimate growth because it was not possible to determine main engine power for many of the records; in contrast, NRT data was available for almost 99% of the records analyzed. Net registered tonnage correlates directly to installed power, and are available for a greater number of years.

The growth rates selected are the midpoint between the best fit compounded annual growth rate in NRT between 1994 through 2005 and the best fit linear (arithmetic) growth rate in NRT for the same time period. The sum of growth of all California ports was set to equal to the statewide growth with the assumption that the ports will grow proportionally to their historical NRT growth between the years 1994-2005. Figure II-1 illustrates an example plot of trends in NRT for container ships.

Figure II-1 Example of Container Ship Net Registered Tonnage Trends



Container ship auxiliary engine growth rates were adjusted to account for the growth of reefer containers. Refrigerated cargo growth was based on the analysis of the US Army Corps of Engineers data on tons of foreign cargo for the years 1997 through 2005. Assumptions were made with regard to which cargo types tend to be refrigerated, and the tons of refrigerated cargo by port were determined.

Containerization rate of refrigerated cargo (the percentage of refrigerated cargo transported by reefer containers) was estimated based on US Army Corps of Engineers foreign cargo data and US Department of Commerce data on containerized cargo for years 2003-2005. About 32% of the refrigerated cargo was transported by reefer containers in 2005 to the ports of Los Angeles/ Long Beach combined and 38% of refrigerated cargo was transported by reefer containers in 2005 to the Port of Oakland. Based on this analysis, it is estimated that the containerization rate will grow to 50% and 45% in 2015, and 60% and 55% in 2025 for the ports of Los Angeles/Long Beach and the port of Oakland, respectively. In developing this estimate it was assumed that a refrigerated container can carry 15 metric tons of refrigerated cargo, and that it draws 7 kilowatts of power. This refrigerated cargo data was combined with the NRT-based growth rates to generate a composite auxiliary engine growth rate for container vessels. Although refrigerated cargo is increasingly shifting to containerized ships, refrigerated cargo is not growing as quickly as all containerized cargo. The net result is that the growth rates for auxiliary engines on container ships are slightly less than the growth rates would be for the main engines.

Table II-5 summarizes the auxiliary engine growth rates by port and by vessel type.

Table II-5 Auxiliary Engine Growth Rates

		Growth Rates	
Port	**Vessel Type**	**2014**	**2020**
LA-Long Beach	Container	162%	234%
	Cruise	136%	172%
	Reefer	48%	28%
Oakland	Container	156%	218%
Hueneme	Reefer	114%	127%
San Diego	Cruise	195%	322%
	Reefer	204%	348%
San Francisco	Cruise	150%	204%

Figures II-2, II-3, and II-4 present growth rates, by vessel type and by port, for vessel types covered by the proposed Shore Power Regulation.

Figure II-2 Container Ship Growth Rates by Port

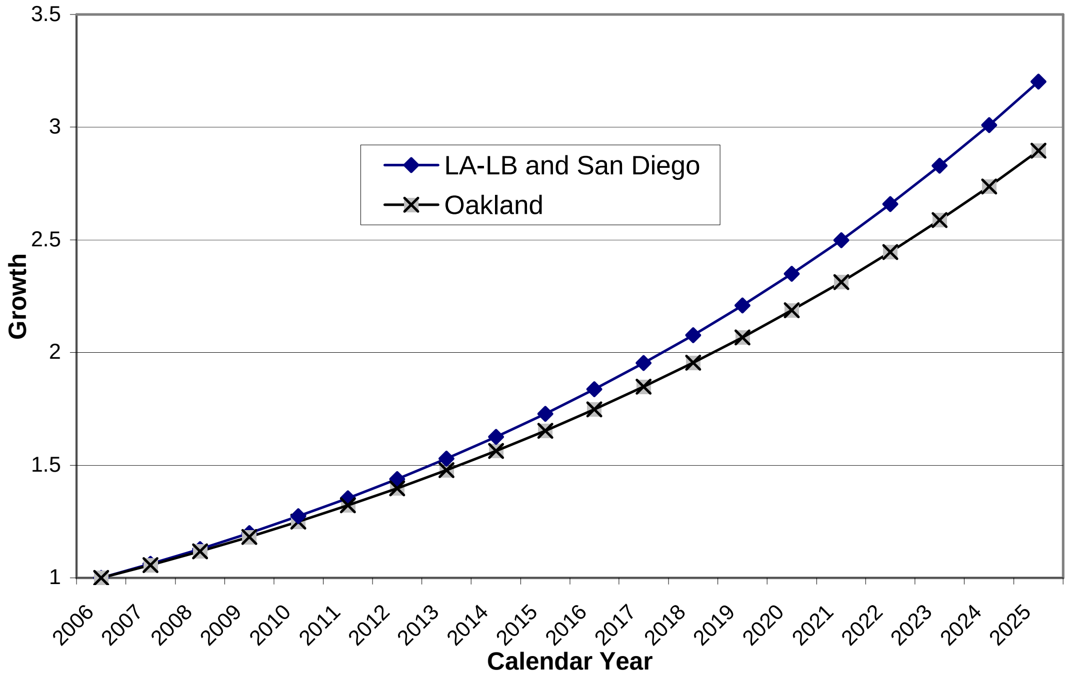


Figure II-3 Cruise Ship Growth Rates by Port

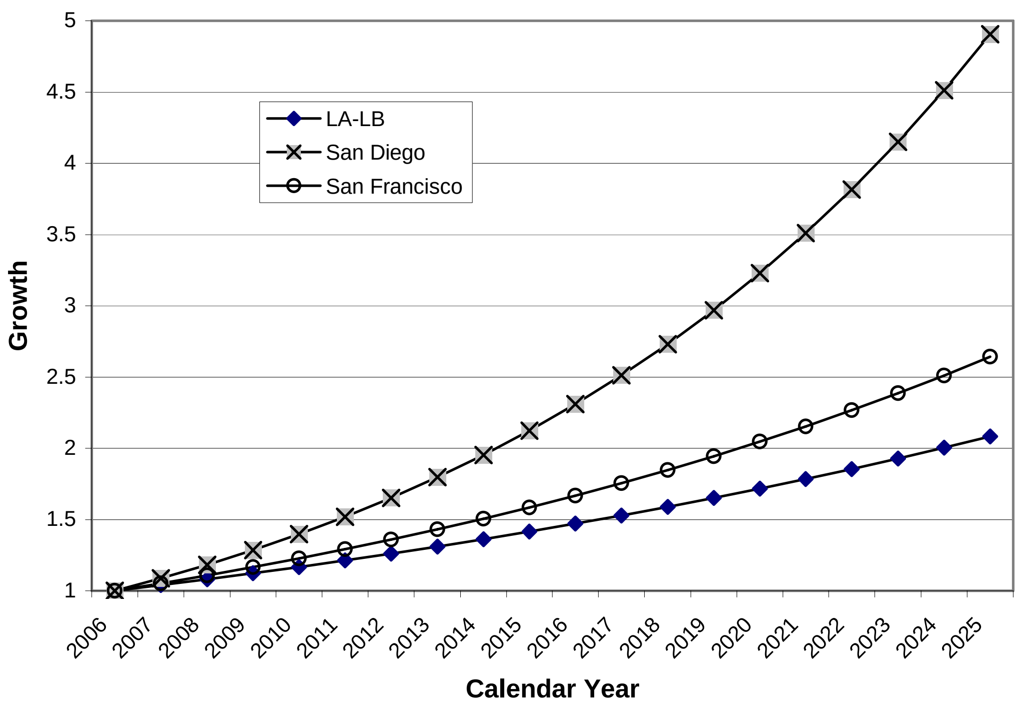
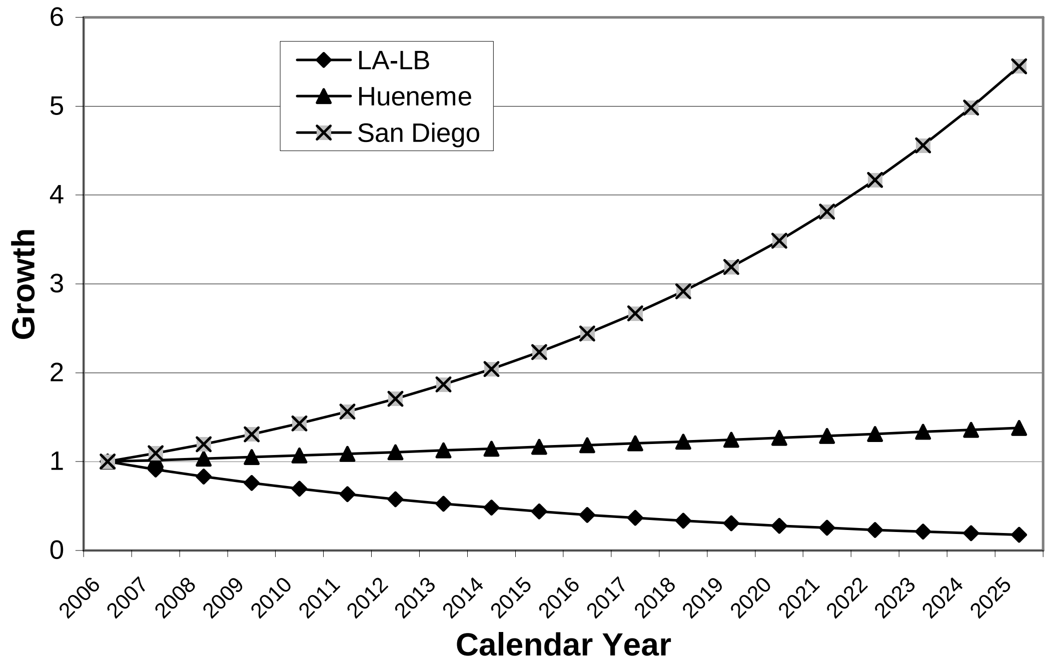


Figure II-4 Reefer Ship Growth Rates by Port



7. Replacement Power Emission Factors

Emission factors associated with replacement shore power were based on a staff review of emission factors for natural-gas fired power plants using selective catalytic reduction. Table II-6 summarizes these emission factors. Replacement power emission factors for NOx and PM10 are considerably lower than those for auxiliary engines due to the use of cleaner fuel and efficient emission controls.

Table II-6 Replacement Power Emission Factors

Replacement Power Emission Factors		
NOx	0.02	gms/kw-hr
PM10	0.11	gms/kw-hr

B. Methodology

The basic equation for the estimating emissions from a ship auxiliary engine during hotelling is:

$$E = EF \times KW \times LF \times Hr$$

Where:

E is the amount of emissions of a pollutant (NO_x, PM_{10}, SO_x, or ROG) emitted during one period;

EF is the auxiliary engine emission factor;

KW is power of the auxiliary engine in kilowatts;

LF is the vessel type and engine use specific engine load factor;

Hr is the hotelling time.

Total emissions for auxiliary engines during hotelling are calculated by summing up the emissions from individual port calls statewide. These summed emissions are then forecasted by applying the vessel type and port specific growth rate for auxiliary engines described above.

In addition to pollutants, electric load was calculated by the above equation, omitting the auxiliary engine emission factor. Electric load was calculated to assess the amount of electricity from the grid that would need to be supplied to ships using shore power under the proposed regulation. Table II-7 summarizes the estimated electric load required under both the uncontrolled and the controlled scenarios.

Table II-7 – Auxiliary Engine Electric Load (megawatts)

Scenario	2006	2014	2020
Uncontrolled	390,622	619,927	885,671
Controlled	-	304,242	226,736
Replacement Power Req'd	-	315,685	658,936

Future year emissions were adjusted to account for the full implementation of the auxiliary engine regulation in 2014 and 2020. This regulation requires the use of auxiliary engine fuel with a sulfur content of no greater than 0.1% for ship operations within 24 nautical miles of shore. The effect of this requirement is that PM_{10} emissions from auxiliary engines using the low sulfur fuel are only 17% of those using heavy fuel oil. For sulfur oxides, auxiliary engine emissions from low sulfur fuel are only 3% of those using heavy fuel oil. NOx is also reduced slightly; emissions are about 95% of engines using heavy fuel oil. These changes are reflected in the baseline inventory.

Controlled future year emissions assumed that fleet activity in the forecasted years was proportional to that of the base year, and that the relative proportions of activity between fleets remained constant. Emissions for replacement power for ships using shore power (assuming the use of clean power plants and the replacement power emission factors described above) were added to the controlled inventory.

III. EMISSION ESTIMATES

Using the revised methodology we can estimate emissions associated with container, cruise, and reefer vessels operating at ports subject to the proposed Shore Power Regulation. Table III-1 provides auxiliary engine hotelling emissions estimates by vessel type; we estimate covered emissions sources emit about 17 tons/day NOx and 1.5 tons/day PM in 2006. Assuming existing controls (without the benefit of the proposed regulation) we estimate NOx emissions will grow in 2020 to approximately 37 tons/day, and in 2020 PM emissions will grow to approximately 0.6 tons/day. As the data suggest, ARB's auxiliary engine regulation that was adopted in 2005 will generate significant reductions in future years.

Table III-1 Auxiliary Engine Hotelling Emissions by Vessel Type without Shore Power Regulation

Emissions - 2006 (tons/day)				
Vessel Type	**NO_x**	**PM_{10}**	**ROG**	**SO_x**
Container	13.8	1.12	0.32	8.1
Cruise	2.5	0.24	0.06	1.7
Reefer	0.9	0.07	0.02	0.5
Total	**17.1**	**1.43**	**0.40**	**10.33**
Emissions - 2014 (tons/day)				
Vessel Type	**NO_x**	**PM_{10}**	**ROG**	**SO_x**
Container	21.5	0.38	0.52	0.57
Cruise	3.6	0.07	0.09	0.09
Reefer	1.0	0.02	0.03	0.03
Total	**26.1**	**0.47**	**0.63**	**0.69**
Emissions - 2020 (tons/day)				
Vessel Type	**NO_x**	**PM_{10}**	**ROG**	**SO_x**
Container	30.8	0.55	0.75	0.82
Cruise	5.2	0.09	0.12	0.13
Reefer	1.3	0.02	0.03	0.04
Total	**37.3**	**0.66**	**0.91**	**0.99**

Table III-2 summarizes uncontrolled auxiliary engine hotelling emissions by port. The ports of Los Angeles and Long Beach account for most of the emissions due to the high number of vessel calls at these ports and the comparatively long hotelling times for container ships there.

Table III-2 Auxiliary Engine Hotelling Emissions by Port without Shore Power Regulation

Emissions - 2006 (tons/day)				
Port	**NO_x**	**PM_{10}**	**ROG**	**SO_x**
Hueneme	0.58	0.05	0.01	0.34
Long Beach	5.81	0.48	0.14	3.47
Los Angeles	6.91	0.57	0.16	4.16
Total LA-LB	**12.71**	**1.05**	**0.30**	**7.63**
Oakland	2.60	0.21	0.06	1.52
San Diego	0.91	0.08	0.02	0.62
San Francisco	0.29	0.03	0.01	0.21
Total All Ports	**17.10**	**1.42**	**0.40**	**10.33**
Emissions - 2014 (tons/day)				
Port	**NO_x**	**PM_{10}**	**ROG**	**SO_x**
Hueneme	0.65	0.01	0.02	0.02
Long Beach	8.91	0.16	0.22	0.24
Los Angeles	10.51	0.19	0.26	0.28
Total LA-LB	**19.42**	**0.35**	**0.47**	**0.52**
Oakland	3.91	0.07	0.10	0.10
San Diego	1.71	0.03	0.04	0.04
San Francisco	0.42	0.01	0.01	0.01
Total All Ports	**26.11**	**0.47**	**0.63**	**0.69**
Emissions - 2020 (tons/day)				
Port	**NO_x**	**PM_{10}**	**ROG**	**SO_x**
Hueneme	0.72	0.01	0.02	0.02
Long Beach	12.73	0.23	0.31	0.34
Los Angeles	14.97	0.27	0.36	0.40
Total LA-LB	**27.70**	**0.50**	**0.67**	**0.74**
Oakland	5.47	0.10	0.13	0.15
San Diego	2.84	0.05	0.07	0.07
San Francisco	0.58	0.01	0.01	0.02
Total All Ports	**37.31**	**0.67**	**0.91**	**0.99**

Table III-3 provides emissions with the benefit of the proposed regulation. With the proposed regulation, we project in 2014 NOx emissions will be reduced by about 13 tons/day, and PM10 emissions would be reduced by about 0.13 tons/day. In 2020, we estimate NOx emissions would be reduced by about 28 tons/day, and PM10 by about 0.5 tons/day. Figures III-1 and Figure III-2 illustrate the changes in emissions over time, assuming a gradual phase in of shore power between 2009 and 2020.

Table III–3 Hotelling Emissions with Shore Power Regulation

Scenario	NOx	PM10	Power Load
	tons/day		megawatts
Emissions - 2014			
Uncontrolled	26.11	0.47	619,927
Controlled - High	12.82	0.23	304,242
Reductions	13.30	0.24	315,685
Emission from Replacement Power	0.02	0.10	
Net Reductions	13.28	0.13	
Emissions - 2020			
Uncontrolled	37.31	0.67	885,671
Controlled - High	9.55	0.17	226,736
Reductions	27.76	0.50	658,936
Emission from Replacement Power	0.00	0.00	
Net Reductions	27.76	0.50	

Figure III-1 Estimation of Auxiliary Hotelling NO_x Emissions 2006-2020

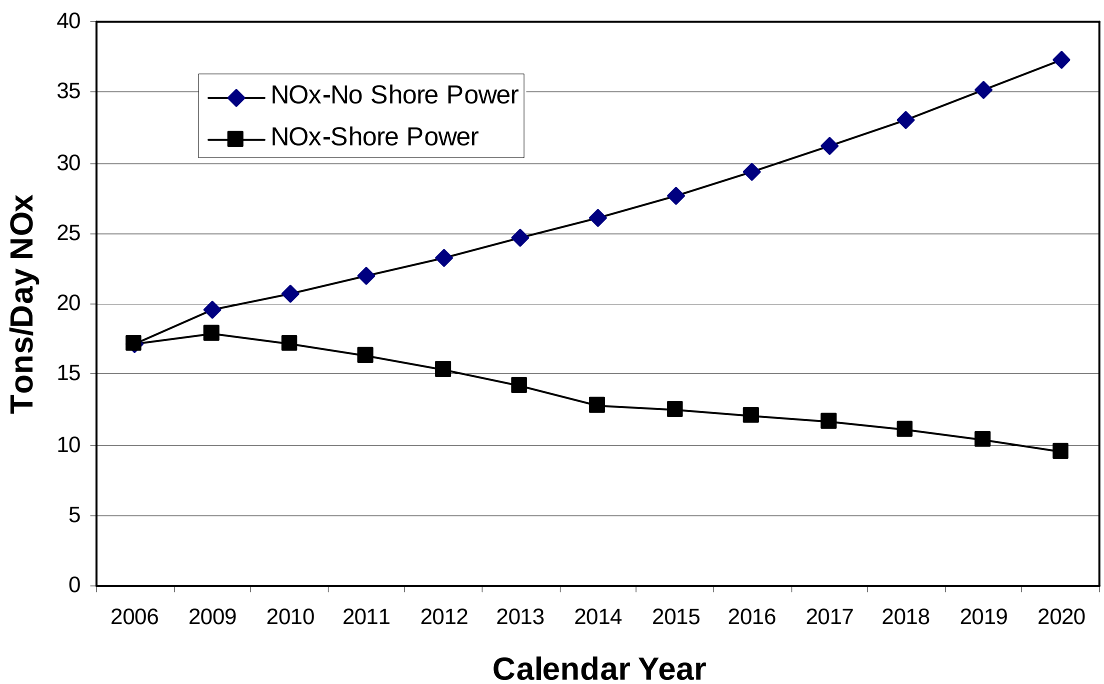
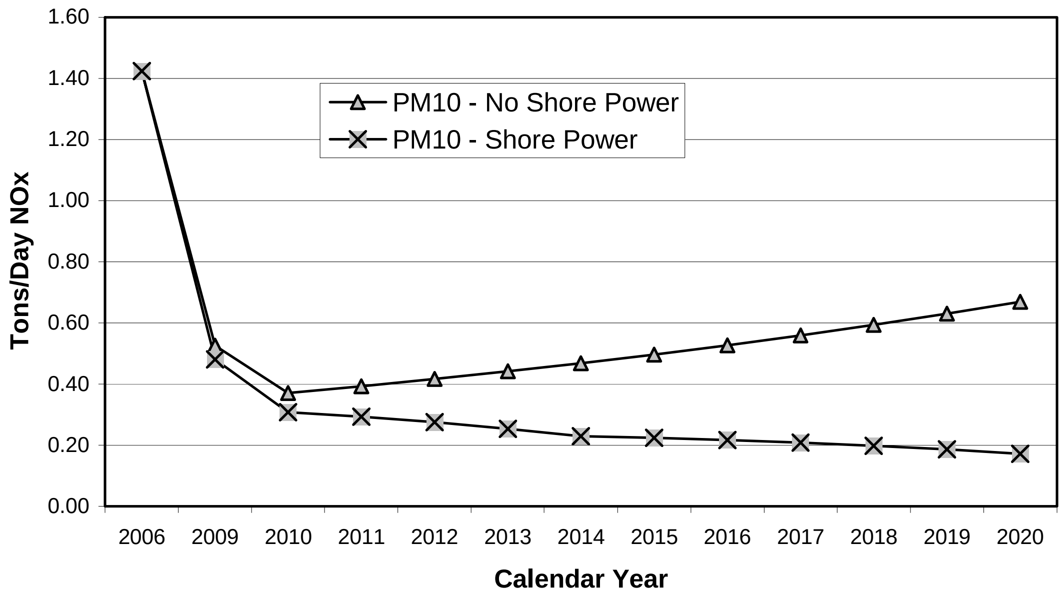


Figure III-2 Estimation of Auxiliary Hotelling PM_{10} Emissions 2006-2020



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