California Environmental Protection Agency

AIR RESOURCES BOARD

TECHNICAL SUPPORT DOCUMENT: INITIAL STATEMENT OF REASONS FOR THE PROPOSED RULEMAKING

Regulations to Reduce Emissions from Diesel Auxiliary Engines on Ocean-Going Vessels while At-Berth at a California Port

Stationary Source Division
Project Assessment Branch

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State of California
AIR RESOURCES BOARD

TECHNICAL SUPPORT DOCUMENT: INITIAL STATEMENT OF REASONS FOR THE PROPOSED RULEMAKING

Public Hearing to Consider

ADOPTION OF PROPOSED REGULATIONS TO REDUCE EMISSIONS FROM DIESEL AUXILIARY ENGINES ON OCEAN-GOING VESSELS WHILE AT-BERTH AT A CALIFORNIA PORT

To be considered by the Air Resources Board on December 6 and 7, 2007, at:

Air Resources Board
Auditorium
9530 Telstar Avenue
El Monte, California 91731

Stationary Source Division
Robert Fletcher, Chief
Robert Barham, Ph.D., Assistant Chief
Project Assessment Branch
Michael Tollstrup, Chief
Health and Exposure Assessment Branch (RD)
Linda Smith, Ph.D., Chief
Technical Analysis Section
Peggy Taricco, Manager
Health and Ecosystems Assessment Section (RD)
Hien Tran, Ph.D., Manager
Project Assessment Section
Michael Waugh, Manager
Regulatory Support Section (PTSD)
Todd Sax, D. Env. Manager

State of California
AIR RESOURCES BOARD

PROPOSED REGULATIONS TO REDUCE EMISSIONS FROM DIESEL AUXILIARY ENGINES ON OCEAN-GOING VESSELS WHILE AT-BERTH AT A CALIFORNIA

Contributing Authors

Andrew Alexis
Alvaro Alvarado, Ph.D.
Raymond Asregadoo, P.E.
Joe Calavita
Grant Chin
Pingkuan Di, Ph.D., P.E.
Reza Mahdavi, Ph.D.
Lori Miyasato, Ph.D.
Brad Penick
Marcelle Surovik
Kelly Weatherford

Legal Counsel

Floyd Vergara, P.E., Office of Legal Affairs

Supporting Divisions

Planning and Technical Support Division (PTSD)
Research Division (RD)

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TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

Contents **Page**

TABLE OF CONTENTS (cont.)

TABLE OF CONTENTS (cont.)

TABLE OF CONTENTS (cont.)

TABLE OF CONTENTS (cont.)

I. INTRODUCTION

A. Overview

The mission of the California Air Resources Board (ARB or Board) is to protect public health, welfare, and ecological resources through the effective and efficient reduction of air pollutants, while recognizing and considering the effects on the economy of the State. The ARB's vision is that all individuals in California, especially children and the elderly, can live, work, and play in a healthful environment—free from harmful exposure to air pollution. To achieve this, ARB has adopted numerous regulations to control emissions from many different sources, including diesel engines. Diesel engine exhaust is a health concern because it is a source of unhealthful air pollutants including gaseous and particulate-phase toxic air contaminants (TAC), particulate matter (PM), oxides of nitrogen (NOx), carbon monoxide, and hydrocarbons.

Staff is proposing a regulation to reduce emissions of diesel particulate matter (PM) and nitrogen oxides (NOx) from diesel-fueled auxiliary engines used aboard ocean-going ships while docked at a California port. Auxiliary engines are run to power lighting, ventilation, pumps, communication, and other onboard equipment while a ship is docked at a berth, or "hotelled." The proposed regulation would require operators of vessels meeting specified criteria to turn off their auxiliary engines for most of their stay in port. We anticipate that such vessels would then receive their electrical power from shore, or would use an alternative, but equally effective, means of emissions reductions. This process of shutting off engines and connecting to power on shore is sometimes referred to as "shore power" or "cold-ironing." The term "cold-ironing" is derived from the metal aboard the ships "going cold" when combustion equipment is shut down.

Staff also estimates the reduction of carbon dioxide (CO_2)—a greenhouse gas (GHG) responsible for much of the global climate change—that the proposed regulation is expected to achieve.

This technical support document (TSD) is an addendum to the Staff Report: Initial Statement of Reasons (Staff Report) and provides more detailed information supporting the development of the proposed regulatory action. As noted in the Staff Report, the proposal consists of two essentially identical regulations, one a regulation developed pursuant to ARB's authority under Health and Safety Code (HSC) sections 43013(b) and 43018, and the other an airborne toxic control measure (ATCM) pursuant to HSC section 39666. Because of this, both regulations will be collectively referred to hereinafter as the "regulation" or "proposed regulation."

The TSD includes the following chapters:

- Need for the regulation, legal authority, and public outreach (Chapter I);
- Preliminary Results of ARB's Draft 2006 Cold-Ironing Evaluation Report (Chapter II);
- Discussion of ocean-going ship categories and California ports (Chapter III);
- Discussion of current shore power activities (Chapter IV);
- Emissions from auxiliary engines on ships idling at berth and associated potential health risks (Chapter V);
- Summary of the proposed regulation and a discuss of the regulatory alternatives that were considered (Chapter VI);
- Discussion of the feasibility of the regulatory requirements and alternative control technologies for marine auxiliary engines (Chapter VII);
- Environmental impacts of the proposed regulation (Chapter VIII);
- Discussion of Shore Power as a greenhouse gas emission reduction measure (Chapter IX): and
- Economic impacts of the proposed regulation (Chapter X)

The text of the proposed regulation and other supporting information are found in the Appendices.

B. Need for Proposed Regulation

The proposed regulation to reduce emissions from hotelling vessels in California's ports will help meet several health-related goals of the Board, including reducing diesel PM, reducing emissions from goods-movement activities, achieving and maintaining ambient air quality standards, and reducing GHG emissions to mitigate the effects of global climate change.

Control of Criteria Air Pollutants

Health and Safety Code (HSC) sections 43013 and 43018 direct ARB to adopt standards and regulations that the Board has found to be necessary, cost-effective, and technologically feasible for various mobile source categories, including off-road diesel engines and equipment such as marine vessels, through the setting of emission control requirements. Specifically, HSC section 43013(b) directs ARB to adopt such standards and regulations for marine vessels to the extent permitted by federal law.

Control of Toxic Air Contaminants

In 1998, the Board identified diesel PM as a TAC with no Board-specified threshold exposure level, pursuant to Health and Safety Code (HSC) sections 39650 through 39675. A needs assessment for diesel PM was conducted between 1998 and 2000 pursuant to HSC sections 39658, 39665, and 39666. This 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.

The Diesel RRP presented information on the available options for reducing diesel PM and recommended regulations to achieve these reductions. The Diesel RRP's scope was broad, addressing all categories of mobile and stationary engines. It included control measures for all off-road diesel sources, such as those covered by the proposed regulation. The ultimate goal of the Diesel RRP is to reduce, by 2020, California's diesel PM emissions and associated cancer risks by 85 percent from the 2000 levels. The proposed regulation would reduce diesel PM emissions and the local health impacts from ships docked in California's ports and would assist the Board with meeting the 2020 Diesel RRP goal.

Control of Emissions from Goods Movement-related Activities

In April 2006, the Board approved the *Emission Reduction Plan for the Ports and Goods Movement in California* (GMERP). The GMERP identifies strategies for reducing emissions created from the movement of goods through California ports and into other regions of the State. The GMERP is part of the broader Goods Movement Action Plan (GMAP) being jointly carried out by the California Environmental Protection Agency and the Business, Transportation, and Housing Agency. Phase I of the GMAP was released in September 2005 and highlighted the air pollution impacts of goods movement and the urgent need to mitigate localized health risk in affected communities. The final GMAP was released in January 2007 and includes a framework that identifies the key contributors to goods movement-related emissions.

The GMERP identifies numerous strategies for reducing emissions from all significant emission sources involved in goods movement, including ocean-going vessels, harbor craft, cargo handling equipment, locomotives, and trucks. The GMERP identifies several strategies for reducing emissions from ocean-going vessels. Specific to hotelling emissions, the GMERP establishes a goal of utilizing shore power for 20 percent of the ship visits to California ports by 2010, 60 percent of visits by 2015, and 80 percent of visits by 2020. The proposed regulation would represent a significant first step toward satisfying the GMERP goals by requiring specific vessel types to shut down their engines while docked. Shutting an engine down is a necessary condition for using shore power; the proposed regulation makes it possible for 50 percent of a fleet's visits to a port to be electrified by 2014, which rises to 80 percent of visits by 2020. Furthermore, emission reductions would begin in 2010 for vessel owners or operators choosing an alternative emission control technology to reduce their hotelling emissions.

Attainment of Ambient Air Quality Standards

The federal Clean Air Act (CAA) requires the United States Environmental Protection Agency (U.S. EPA) to establish National Ambient Air Quality Standards (national standards) for pollutants considered harmful to public health, including fine particulate matter ($PM_{2.5}$) and ozone. Set to protect public health, the national standards are adopted based on a review of health studies by experts and a public process. The South Coast Air Basin (Air Basin), which is home to the two largest ports in California, the Ports of Los Angeles and Long Beach, exceeds the national standards for both ozone and $PM_{2.5}$. Consequently, a State Implementation Plan (SIP) is required for the Air Basin that outlines how and when the region will attain the national standards. The U.S. EPA requires the Air Basin to meet the $PM_{2.5}$ standards by 2015, but the emission reductions must be in place by 2014.

Significant reductions of NOx are crucial to meet the federal standards. For example, at this time, the strategy to achieve attainment of the $PM_{2.5}$ standards in the South Coast Air Basin includes staff estimates that a 55 percent reduction in NOx emissions from 2006 levels (i.e., a total reduction of hundreds of tons per day) and a 15 percent reduction in direct $PM_{2.5}$ emissions from 2006 baseline levels will be necessary for attainment of the $PM_{2.5}$ standards in the South Coast Air Basin. The proposed regulation would reduce hotelling NOx emissions from container ships, passenger ships, and refrigerated cargo ships by 50 percent relative to levels expected to be emitted in 2014 and nearly 75 percent relative to levels expected to be emitted in 2020. Consequently, the emission reductions from the proposed regulation would play an essential role in assisting the South Coast Air Basin with meeting its 2014 $PM_{2.5}$ deadline as well as its future ozone deadlines.

The federal Clean Air Act permits states to adopt more stringent air quality standards, and California has set standards for particulate matter and ozone that are more protective of public health than respective federal standards. The Bay Area, South Coast, and San Diego areas are nonattainment for the State standards for ozone and $PM_{2.5}$. Health and Safety Code (HSC) section 40911 requires the local air districts to submit plans to the Board for attaining the State ambient air quality standards, and HSC section 40924 requires triennial updates of those plans. The NOx and $PM_{2.5}$ emission reductions from the proposed regulation would also assist the local air districts in achieving attainment of the State ambient air quality standards.

The California Global Warming Solutions Act of 2006

In June 2005, Governor Arnold Schwarzenegger signed Executive Order S-3-05, which established targets for reducing greenhouse gas (GHG) emissions in California: roll back GHG emissions to 2000 levels by 2010, to 1990 levels by 2020, and finally to 80 percent below 1990 levels by 2050. In 2006, the

Governor signed Assembly Bill 32 (AB 32) (Stats. 2006, ch. 488), which established the 2020 GHG emission reduction goal in State law (HSC § 38500 et seq.) and made the ARB responsible for monitoring and reducing GHG emissions.

AB 32 requires the Board, by January 1, 2009, to design and adopt an overall plan to reduce GHG emissions to 1990 levels by 2020. The Board has until January 1, 2011, to adopt the necessary regulations to implement that plan. Implementation begins no later than January 1, 2012, and the emission reduction target must be fully achieved by January 1, 2020. AB 32 also required the Board to identify a list of discrete early action GHG reduction measures by June 30, 2007. AB 32 defines discrete early action measures as regulations that are to be adopted by the Board and be enforceable by January 1, 2010.

In April 2007, ARB staff released a report identifying 37 proposed early action items the Board could undertake to mitigate GHG emissions in California. Port electrification was identified as a GHG emission reduction measure in this report. In September 2007, ARB staff recommended reclassifying port electrification (now called Green Ports) from an early action measure to a discrete early action measure. Staff's recommended reclassifications will be considered by the Board at its October 2007 hearing.

The proposed regulation, while primarily aimed at reducing diesel PM and NOx emissions, will also reduce CO_2 emissions as a co-benefit of requiring cleaner electrical generation for ocean-going vessels that "plug in" while docked. These CO_2 emission reductions will help California meet its 2020 greenhouse gas emission reduction goal.

C. Regulatory Authority

Under State and federal law, ARB can regulate both criteria pollutant and toxic diesel PM emissions from marine vessels. The ARB has authority under California law to adopt the proposed regulations. H&SC sections 43013(b) and 43018 provide broad authority for ARB to adopt emission standards and other regulations to reduce emissions from new and in-use vehicular, nonvehicular and other mobile sources. Under H&SC sections 43013(b) and 43018, ARB is directly authorized to adopt emission standards and other regulations for marine vessels, as expeditiously as possible and to the extent permitted by federal law, to meet State standards. The ARB is further mandated by California law under H&SC section 39666 to adopt Air Toxic Control Measures (ATCMs) for new and in-use nonvehicular sources, including marine vessels such as ocean-going vessels, for identified TACs such as diesel PM.

In addition, H&SC section 38500 requires the ARB to adopt rules and regulations that are technologically feasible and cost-effective to achieve the GHG emissions reduction goals of the California Global Warming Solutions Act of 2006 (AB 32).

D. Summary of Proposed Regulation

The proposed regulation would reduce hotelling emissions from diesel-fueled auxiliary engines on at-berth ocean-going vessels. The regulation would apply to any person who owns, operates, charters, rents, or leases any container ship, passenger ship, or refrigerated cargo ship that visits a California port, or any person who owns or operates a port or terminal located at a port where container, passenger, or refrigerated cargo(reefer) ships visit. These ports would include Los Angeles, Long Beach, Oakland, San Diego, San Francisco, and Hueneme.

The proposed regulation allows for two main options to reduce hotelling emissions. First, ship operators can shut down their auxiliary engines while in port, except for three or five permissible hours of total operation per visit ("limited engine use" option). Alternatively, operators can implement a fleet-based option to reduce the emissions from the auxiliary engines in the fleet by specified percentages while docked ("emissions reduction option").

The "limited engine use" option requires that the operators of container ships, passenger ships, and reefers that visit California ports shut down their auxiliary engines for most of their stay while hotelling. Auxiliary engines would be allowed to run for three or five hours per visit. Specifically, these auxiliary engines must be shut down for at least 50 percent of a fleet's total visits to a California port in 2014 and at least 80 percent of the fleet's total visits to a port in 2020. While auxiliary engines are shut down, the ship's onboard electrical needs must be satisfied by some other source of power, presumably the region's electrical grid.

An alternative compliance option is the "emissions reduction option," in which ship operators would be required to reduce their fleet's auxiliary engine emissions at a port by specific percentages and by specific dates. The specified percent reductions apply to the fleet's engines, rather than to individual engines. The compliance dates for this option vary based on the emission reduction technique applied to the fleets.

The emission reduction techniques that could be applied to a fleet include: 1) using selected vessels for grid-supplied power based on potential auxiliary engine emission reductions rather than fleet visit percentages; 2) using distributed generation equipment to provide power to a vessel; 3) using alternative emission controls onboard a vessel or located adjacent to the vessel; and 4) using a combination of these techniques.

E. Public Outreach and Environmental Justice

Environmental Justice

ARB is committed to integrating environmental justice in all of its activities. On December 13, 2001, the Board approved Environmental Justice Policies and Actions, which formally established a framework for incorporating environmental justice into the ARB's programs, consistent with the directives of California State law. Environmental Justice is defined as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies. The environmental justice policies apply to all communities in California, but recognize that environmental justice issues have been raised more in the context of low-income and minority communities.

The environmental justice policies are intended to promote the fair treatment of all Californians and cover the full spectrum of ARB activities. Underlying these policies is a recognition that we need to engage community members in a meaningful way as we carry out our activities. People should have the best possible information about the air they breathe and what is being done to reduce unhealthful air pollution in their communities. The ARB recognizes its obligation to work closely with all stakeholders—communities, environmental and public health organizations, industry, business owners, other agencies, and all other interested parties—to successfully implement these Policies.

The proposed regulation is consistent with the environmental justice policy to reduce health risks in all communities, including those with low-income and minority populations. The regulation will achieve the most significant emission reductions in communities adjacent to the ports of Los Angeles, Long Beach, and Oakland, where the greatest shipping activity occurs. It would also result in emissions and health risk reductions in communities surrounding the ports of Hueneme, San Diego, and San Francisco.

During the regulatory development process, ARB staff searched for opportunities to present information about the proposed regulation at places and times convenient to stakeholders to encourage public participation. These efforts involved conducting meetings during evening hours and at California ports. In addition, ARB staff attended community meetings in Los Angeles and Oakland to educate and receive input from local community members during the development of the regulation.

Outreach Efforts

ARB's outreach efforts for the proposed regulation began during the development of its draft cold-ironing feasibility report (Evaluation Report). This report is discussed in more detail in Chapter II. ARB staff first discussed a plan for analyzing the cost effectiveness of cold-ironing ocean-going vessels at a public consultation meeting on November 9, 2004.

Staff discussed preliminary concepts for the analysis at the May 14, 2005, Maritime Workgroup Meeting. This workgroup was comprised of ARB staff, local air district staff, representatives of the ports, shipping companies, environmental groups, and other interested members of the public.

During the Evaluation Report's development, staff visited four ports in California: Los Angeles, Long Beach, Oakland, and San Diego. Staff also visited three cold-ironing applications in the State: a ship utilizing shore power at the USS POSCO steel plant in Pittsburg, a ship utilizing shore power at the China Shipping Terminal at the Port of Los Angeles, and a Navy ship cold-ironing at the Naval Station in San Diego. During these visits, staff observed the configuration of the ports, terminals, and berths and gained an understanding of the logistics involved in bringing power to the terminals and individual berths.

Staff also held conference calls or met with shipping companies, utility companies, environmental groups, and other organizations interested in cold-ironing applications. These meetings gave staff the opportunity to hear from proponents of cold-ironing as well as hear the concerns from those entities that would be involved with bringing power to the terminals and retrofitting ships for cold-ironing. Staff also held conference calls with South Coast Air Quality Management District (SCAQMD) staff to obtain their input during the development of the Evaluation Report.

ARB staff solicited public input on the Evaluation Report when it was released in March 2006 and considered the comments received when they began developing draft concepts for a shore power regulation. Staff discussed a regulatory approach to controlling hotelling emissions at the September 12, 2006, Maritime Working Group Meeting.

Staff also coordinated with the Ports of Los Angeles and Long Beach in the development of the San Pedro Bay Ports Clean Air Action Plan (CAAP), which was released in November 2006. The CAAP identifies shore power as a measure to control hotelling emissions and identifies specific terminals and berths that will be equipped with shore power capability and the expected completion dates for these projects. ARB staff considered the CAAP's shore power requirements as we began our development of the proposed regulation with a goal of developing a proposed measure that would be consistent with the CAAP and complementary to the ports' ongoing emissions reduction efforts.

ARB staff and interested parties formed a workgroup in early 2007 to assist staff with developing a shore power regulation. Many of the stakeholders that assisted ARB staff with developing the Evaluation Report were also members of the workgroup. ARB staff created a shore power electronic list server and webpage to notify interested parties of the workgroups and to post drafts of the regulation before they were discussed at the meetings. Over 2000 individuals or companies have subscribed to the shore power list server.

Five shore power workgroup meetings were held between January and August 2007. The majority of these meetings were accessible via webcast and teleconference in order to accommodate participants who were unable to attend in person. At the end of that process, ARB staff decided that it was appropriate to transition from the workgroup process to a more formal rulemaking process. Subsequently, staff held four public workshops in September 2007 to discuss the draft proposed regulation. Two of these workshops were evening meetings held in community centers near ports, where staff could seek input from those communities most impacted by hotelling emissions. A listing of ARB's public workgroup meetings, workshops, and community outreach meetings held during the development of the proposed regulation is presented in Table I-1.

Table I-1: Workshop/Outreach Meeting Locations and Times

Date	Meeting	Type	Location
November 9, 2004	Public Workshop	Conference Call	Cal/EPA Building, Sacramento
May 14, 2005	Maritime AQ Technical Working Group	Toll-Free Conference Call	Cal/EPA Building, Sacramento
September 12, 2006	Maritime AQ Technical Working Group	Toll-Free Conference Call	Cal/EPA Building, Sacramento
January 11, 2007	Public Workgroup	Webcast/Toll-Free Conference Call	Cal/EPA Building, Sacramento
March 20, 2007	Public Workgroup	Toll-Free Conference Call	Port of Long Beach
June 1, 2007	Public Workgroup	Webcast/Toll-Free Conference Call	Cal/EPA Building, Sacramento
July 9, 2007	Community Outreach	Conference Call Presentation Q&A	POLA PCAC AQS, Los Angeles
July 12, 2007	Public Workgroup	Toll-Free Conference Call	Cal/EPA Building, Sacramento
August 1, 2007	Community Outreach	Meeting	Seaport Operations and Air Quality community workshop Port of Oakland
August 28, 2007	Public Workgroup	Webcast/Toll-Free Conference Call	Cal/EPA Building, Sacramento
September 24, 2007	Public Workshop	Webcast/Toll-Free Conference Call	Cal/EPA Building, Sacramento
September 25, 2007	Public Workshop	Meeting	Port of Los Angeles
September 25, 2007	Public Workshop/Community Outreach	Meeting	Wilmington Senior Center
September 27, 2007	Public Workshop/Community Outreach	Meeting	West Oakland Senior Center

In addition to the workgroup and workshop meetings, staff's outreach efforts also included hundreds of personal contacts via telephone and electronic mail; numerous individual meetings with interested parties, including port representatives, environmental groups, utility representatives, and shipping representatives; and informational visits to ports. Staff visited the Port of Hueneme in early 2007, where staff had the opportunity to observe refrigerated cargo ships carrying break-bulk products and discuss regulation development with port staff. ARB staff also toured a containerized refrigerated cargo ship at the Port of San Diego. At the Port of Oakland, ARB staff toured a container ship that was equipped with shore power capability and observed a demonstration of a portable distributed generation power source for powering container ships while in port.

REFERENCES:

California Air Resources Board. *Emission Reduction Plan for Ports and Goods Movement in California*; April 2006.
http://www.arb.ca.gov/planning/gmerp/march21plan/march22_plan.pdf

California Air Resources Board. *Evaluation of Cold-Ironing Ocean-Going Vessels at California Ports*; March 2006.
http://www.arb.ca.gov/ports/shorepower/report.pdf

California Air Resources Board. *Expanded List of Early Action Measures to Reduce Greenhouse Gas Emissions in California Recommended for Board Consideration*, October 2007.

California Air Resources Board. *Policies and Actions for Environmental Justice*; December 2001.

California Air Resources Board. *Proposed Early Actions to Mitigate Climate Change in California*, April 2007.

California Air Resources Board. *Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles*; October 2000.
http://www.arb.ca.gov/diesel/documents/rrpapp.htm

Port of Los Angeles and Port of Long Beach. *San Pedro Bay Ports Clean Air Action Plan*; November 2006.
http://www.portoflosangeles.org/DOC/CAAP_Tech_Report_Final.pdf and/or
http://www.polb.com/civica/filebank/blobdload.asp?BlobID=3451

Schwarzenegger, Arnold, “Executive Order S-3-05.” June 1, 2005.

II. PRELIMINARY RESULTS OF THE 2006 DRAFT COLD-IRONING EVALUATION REPORT

Staff is proposing to initially regulate hotelling emissions from three out of the six categories of ocean-going vessels that visit California ports and to address the hotelling emissions from the other three categories at a later date. This bifurcation was based on information presented in an earlier ARB report, *Evaluation of Cold-ironing Ocean-Going Vessels at California Ports* (Evaluation Report), which was released as a draft in March 2006. The purpose of the Evaluation Report was to present an analysis of the feasibility and cost-effectiveness of requiring ships to shut off auxiliary engines while in port and connect to power provided at the berth as a potential emission control measure. While not finalized, the results of the Evaluation Report nevertheless formed a good basis for ARB's further development of the proposed regulation.

ARB staff solicited comments on the draft Evaluation Report when it was released. A number of comments on the draft report were received, but instead of incorporating the comments and suggested changes into a final revised report, staff decided to move forward with developing a shore power regulation while considering the comments received.

This chapter will discuss the draft Evaluation Report. The results of the Evaluation Report formed a basis for ARB's development of the proposed regulation; therefore, a discussion of the preliminary results of the draft report is essential to understanding the development of the proposed regulation.

In the Evaluation Report, ARB staff calculated, for screening purposes, the cost-effectiveness of shore power as an emission reduction strategy using three major sets of variables: ship categories, ship power loads, and pollutants reduced.

Ship Categories

To begin the analysis, ARB staff divided the ocean-going vessels visiting California ports in 2004 into six categories: container ships, passenger ships, refrigerated cargo ships, tankers, bulk/cargo ships, and vehicle carriers. For each ship category, the cost-effectiveness analysis consisted of two parts: an analysis where both the shore-side infrastructure and ship retrofits are considered, and an analysis considering the incremental cost for cold-ironing a ship if the ports have already installed the necessary shore-side infrastructure. For the infrastructure/ship analysis, staff analyzed the following three scenarios: 1) all ships being cold-ironed at all California ports; 2) cold-ironing ships that made at least three visits per year to a California port; 3) and cold-ironing ships that made at least six visits per year to a California port. In addition, the cost-effectiveness scenarios considered whether the necessary electrical transformers are constructed at the port (shore-side) or on the ships (ship-side).

Ship Power Loads

The power load of the ships had to be considered as well when analyzing the cost-effectiveness. Ocean-going vessels typically fall into two categories: low-voltage and high-voltage. Except for passenger ships, high-voltage is nominally 6.6 kilovolts (kV), and low-voltage is around 440 volts (V). For passenger ships, high-voltage is 11.0 kV, while low-voltage is 6.6 kV. Due to these varying power requirements, transformers are needed to supply the proper voltage to nearly all of the ships. These transformers either have to be located within the port infrastructure or on the ships. ARB looked at both of these scenarios.

Pollutants Reduced

ARB staff calculated cost effectiveness using three approaches for air pollutants reduced: (1) “all pollutants” emissions reductions (NOx, PM, volatile organic compounds [VOC], and oxides of sulfur [SOx]); (2) NOx emissions reductions only; and (3) PM emissions reductions only.

The all-pollutants case recognizes that cold-ironing reduces multiple pollutants. For the all-pollutants case, the cost effectiveness was determined by dividing the total annualized costs for cold-ironing by the total annual emissions reduced for the four major pollutants (NOx, PM, VOC, and SOx).

The NOx-only case allowed for comparison to other NOx measures adopted in the State. For the NOx-only case, the cost effectiveness was determined by dividing the total annualized cold-ironing costs by the annual NOx emissions reduced.

The diesel-PM-only case recognizes the importance of reducing diesel PM in California. Overall, diesel engine emissions are responsible for the majority of California's potential airborne cancer risk from combustion sources. For the diesel-PM-only case, the cost effectiveness was determined by dividing the total annualized cold-ironing costs by the annual diesel PM emissions reduced.

At the time the Evaluation Report was developed, most ocean-going vessels were using residual fuel with their auxiliary engines. However, in December 2005, the Board adopted an Ocean-Going Vessel Auxiliary Engine Fuel Regulation (see title 13, California Code of Regulations (CCR), section 2299.1 and title 17, CCR, section 93118). That regulation requires that most of these ships use cleaner distillate fuel when in California waters beginning in January 2007. Because of this requirement, ARB staff calculated cost-effectiveness values based on the use of distillate fuel only.

Conclusions

Based on the screening analysis noted above, the Evaluation Report concluded that the most attractive vessel candidates for cold-ironing at this time are container ships, refrigerated cargo (reefer) ships, and passenger ships, and the most likely locations for cold-ironing in California are the Ports of Los Angeles, Long Beach, Oakland, San Diego, San Francisco, and Hueneme. The most attractive ship candidates were found to be those ships that make frequent visits to a California port, spend a sufficient number of hours at berth, and have an ample power demand while hotelled. These findings formed the foundation on which the proposed rulemaking was based.

Of the three remaining types of vessels that visit California, the Evaluation Report showed that it was not as cost-effective at this time to cold-iron bulk and general cargo ships and vehicle carriers, relative to container ships, passenger ships and reefers, because the former categories generally have a low number of repeat visits to any single port and lower power loads. Further, crude-oil tankers were found to have higher average cost-effectiveness values because there are only a handful of diesel-electric tankers that visit California, and only two are expected to visit frequently. Indeed, most crude-oil tankers use steam turbines to drive their cargo pumps. These cargo pumps represent the majority of the power needed by tankers when they are berthed. The rest of the ship's power needs are modest. Finally, product tankers make few visits to California ports, and their berthing times are short, making them a much less attractive candidate for cold-ironing.

The proposed regulation specifically addresses hotelling emission reduction requirements for categories of ships that were found at this time to be attractive candidates for shore power in the Evaluation Report—container ships, passenger ships, reefer ships— and the California ports where these ships frequently visit. As noted earlier, staff is proposing to develop separate requirements for other ship categories that were not considered to be good candidates at this time for shore power -- bulk ships, tankers, and vehicle carriers—at a later date. Staff anticipates presenting proposed hotelling emission reduction requirements for these other ships to the Board in late 2008. We expect that at-berth emissions from tugboats operating at California ports will also be addressed at that time.

REFERENCES:

California Air Resources Board. *Evaluation of Cold-Ironing Ocean-Going Vessels at California Ports*; March 2006.
http://www.arb.ca.gov/ports/shorepower/report.pdf

III. GENERAL DESCRIPTION OF OCEAN-GOING SHIP CATEGORIES AND CALIFORNIA PORTS

In this chapter, staff will categorize each ocean-going ship category and briefly describe the distinguishing features of each ship type. Images of each ship type are included for ease of identification. The ports of California will also be discussed. Although not all ship categories and California ports will be affected by the proposed regulation, staff wanted to provide an overall perspective of oceangoing ship activity in California.

A. Ship Categories

Container Ships

Container ships are designed to carry cargo stored in standardized containers. Container ships can also carry some refrigerated containers, with the ship's electrical power plant providing the necessary electricity for these containers. The size of these ships is based upon how many twenty-foot-equivalent units (TEUs) can be carried by the ship. The dimensions of a TEU are 20' x 8' x 8.5' and a typical container is 40 feet long, or two TEUs. A 40-foot container fits on the back of an 18-wheeler, so it is common to see these containers being transported on the highway. Ships visiting California typically have a carrying capacity ranging between 1,000 to over 8,000 TEUs, with the "average" ship being able to carry nearly 4,000 TEUs. In general, container ships have increased in size over the last few years, and this trend is expected to continue in the future.

Typically, container ships are propelled by a large low-speed diesel engine and three to five auxiliary diesel engines provide electrical power when the ship is moving. In some cases, a shaft generator provides the electrical power. The auxiliary engines range in size from 500 kW to 3 MW each, with the largest engines used on the largest container ships. In port, the electrical power is provided by the auxiliary engines.

Several older ships use steam-based power plants to both propel the ship and provide electrical power. Unlike diesel engines that can be shut down very quickly, steam-based power plants take several hours to shutdown and to restart. For the short duration that a ship is in port, it would be impractical to shut down the ship's steam-based power plant. Consequently, the steam-based power plant would continue to operate and emit air pollutants even if the ship is cold-ironed. Cold-ironing these types of ships would result in minimal emission reductions.

In 2006, 585 container ships visited California ports and accounted for nearly 46 percent of the total ship visits to California. That is, container ships visited California ports as much as the combined visits of other ship categories, with no other ship category representing more than 20 percent of the total ship visits. If significant emission reductions are to be achieved from cold-ironing, container ships must represent a significant portion of that effort.

Container ships often make their first West Coast call at the Port of Los Angeles or the Port of Long Beach (POLA/POLB). Many will then stop at the Port of Oakland. About 60 percent of the ships that visit POLA/POLB also visit Oakland. Annually, POLA/POLB receive more container ship visits than Oakland, and the ships tend to stay much longer, unloading more containers. In 2006, POLA/POLB processed over one and a half times the amount of container traffic than Oakland: 12.9 million loaded TEUs versus 8.1 million TEUs.

The most important shipping routes for container ships visiting California ports are the routes from Asia to North America. Ships that frequent this route average eight to nine visits annually to the ports in the Los Angeles area and six visits annually to the Port of Oakland. Many ships also bring goods from South and Central America. Another important shipping route is between Hawaii and California ports. Fewer ships travel these routes but, because of the shorter distance, call more often at California ports.

Power needs for a container ship varies between 1 MW to 4 MW, with the high end of the range based upon a ship carrying a substantial number of refrigerated containers. Hotelling times for container ships vary between 20 to 200 hours per visit (average hotelling time is 55 hours per visit) to ports in the Los Angeles area and 10 to 50 hours per visit (average hotelling time is 21 hours per visit) to the Port of Oakland.

Passenger Ships

The passenger-ship category is one of the smallest, with only 52 ships visiting California in 2006. The vast majority of the passenger ships visit the ports of San Francisco, Los Angeles, Long Beach, and San Diego. A few passenger ships visit Monterey and Catalina, but they moor offshore and do not actually berth.

Pleasure cruises have become increasingly popular and significant growth in the cruise-line industry is expected to continue. As with other types of ocean-going vessels, the physical size and carrying capacity of passenger ships have increased steadily over the years.

Unlike most ship categories, passenger ships are diesel-electric. Several diesel engines coupled to generators typically provide propulsion. These generators produce electrical power that drives electric motors coupled to the vessel's propellers. This arrangement provides the option to run the vessel at a slower speed, while operating fewer engines at their peak efficiency, as opposed to a single engine at low, relatively inefficient loads. The same engines that are used for propulsion are also used to generate auxiliary power onboard the vessel for lights, refrigeration, etc.

Passenger ships typically dock in the morning and set sail in the evening. The average time in dock ranges from nine to eleven hours. Passenger ships have the highest power consumption while hotelling of any vessel type: five to eleven megawatts.

Refrigerated Cargo Ships (Reefers)

Refrigerated or reefer ships carry perishable products, such as fruit and meat, to and from California. The products, usually palletized, are stored in large cold-storage cargo holds. Additionally, containers can be stored on the deck of some reefer ships. Unlike container ships, most of these types of ships are equipped with cranes.

Similar to container ships, a reefer ship is propelled by a large low-speed diesel engine and electrical power is provided by two to three auxiliary diesel engines. A reefer ship's electrical load can be considerable due to refrigerating the cargo, supplying power to the cranes, and providing power for lights and ballast pumps.

Reefer ships can use between 1MW to 3 MW when hotelling; the high end of the range includes the use of the on-board cranes. Reefers have hotelling times that are similar to container ships visiting the Los Angeles area, about 53 hours per visit.

Sixty-five reefer ships visited California ports in 2006, representing only three percent of the total ship visits to California.

Vehicle Carriers

Vehicle carriers are specialized ships where vehicles are driven on and off the ship. This category also includes other ships, referred to as “RoRos,” that are designed for cargo to be rolled on and rolled off. Similar to other ocean-going vessels, a vehicle carrier is typically propelled by a large low-speed diesel engine, and the electrical power is provided by two to three auxiliary diesel engines. Vehicle carriers require low power while in port—about 700 kW. The average hotelling time for these ships is approximately 20 hours.

Tankers

Tankers are designed to carry liquid and gaseous products. The major products transported include crude oil, finished petroleum products, and chemicals. There are two types of tankers: crude-oil tankers and product tankers. Tankers visiting

California ports range in size from 15,000 dead weight tons (DWT) to over 200,000 DWT. Tankers larger than 70,000 DWT typically carry only crude oil. The smaller tankers, or product tankers, carry various types of finished petroleum products and chemicals. In 2006, 451 tankers visited California ports, accounting for 22 percent of the total ship calls to California.

Most of this activity supports the operation of California's refineries. Tankers bring crude oil from Alaska and the Middle East to refineries in the Bay Area and Los Angeles. In addition, product tankers transport needed materials from Northern California to Southern California and vice versa, as well as transfer material into and out of the State. The major ports that tankers frequent in California include Benicia, Carquinez, El Segundo, POLA/POLB, Martinez, and Richmond.

Crude-oil tankers come in many configurations. Older tankers transporting crude oil use steam-based power plants to both propel the ship and provide for electrical power, including pumping the crude oil. For a similar steam-powered container ship, cold-ironing one these ships would result in minimum emission reductions since the steam boiler would continue to operate while in port. Newer tankers transporting crude oil typically use a diesel engine to propel the ship, auxiliary diesel engines to provide power for lights and ballast pumps, and a boiler/steam turbine combination to drive the cargo pump. In this case, the lights and ballast pumps activities can be cold-ironed. Finally, five tankers transporting crude oil to a California port are diesel-electric, where on-board power provides the needed electricity for lights, ballast pumps, and cargo pumping. The entire load for this type of tanker can be cold-ironed.

The majority of the power requirements for a crude-oil tanker is for pumping out the crude. Since the majority of ships transporting crude oil use steam turbine/boiler units to pump the crude, this portion of a tanker's operation cannot be electrified. Consequently, except for diesel-electric tankers, the hotelling power requirements for crude-oil tankers will range between 50 KW to 600 kW. For diesel-electric tankers, where electric motors drive the cargo pumps, the power requirements are between 5 MW to 6 MW.

The hotelling times for tankers transporting crude oil range between 10 to 40 hours per visit. Tankers visiting the Port of Long Beach average 37 hours per visit, and tankers visiting ports in the Bay Area average 20 hours per visit. This hotelling time includes time necessary for the safety and operations conference, connecting and disconnecting from the shore piping system, and loading ballast as well as discharging the cargo.

For product tankers, a diesel engine is typically used to propel the ship, while auxiliary diesel engines provide the ship's electrical power needs and product-pumping requirements. Many of the product pumps are either hydraulically driven or directly connected to the auxiliary engine. Electric motor-driven pumping systems (i.e., diesel-electric) are amenable for cold-ironing; the hydraulic or direct-drive pumps cannot be cold-ironed. In 2006, there were two diesel-electric product tankers visiting California ports.

Product tankers are different than crude-oil tankers in one important fashion: products are not only pumped off but also pumped onto the ships while docked. On-shore pumps load the material into the product tankers. Even if the product pumps on the tanker were driven by electric motors, they would be shut down while receiving a product, which is about 40 percent of the time. As with crude-oil tankers, pumping the cargo from the ship uses significantly more power than general power consumption for lights and ballast pumps. Pumping requires 1 MW to 1.5 MW of power, while general power consumption ranges between 50 MW to 600 kW.

The hotelling times for product tankers range from 20 hours to 130 hours per visit. While the hotelling times appear long, a single visit by a product tanker to POLA/POLB may include stops at one to three different berths. Consequently, the average berthing time for a product tanker more likely varies from 25 hours to 50 hours.

<u>Bulk and General Cargo Ships</u>

Bulk and general cargo ships carry material that is not easily placed into containers. Examples of material a bulk or general cargo ship could transport include rolls of steel, large machines, gypsum, and wood products. Similar to reefer ships, most of these types of ships are equipped with cranes or other equipment to load or unload the cargo.

Similar to other ocean-going ships, bulk ships are propelled by a large low-speed diesel engine, and electrical several auxiliary diesel engines provide electrical power. Electrical power is needed for lights and ballast pumps, and possibly for cargo loading/unloading equipment, such as cranes or conveyer belts. More than any other vessel category, bulk and general cargo ships have very few frequent visitors to California ports. In 2006, bulk ships making only one visit to a California port accounted for half of all the total visits made by this ship category.

B. California Ports

Each of the California ports is unique, not only in its physical size, but also in the types and amounts of cargo that is handled at the port. Each port can have one to several terminals. Each terminal can have one to several berths. Each terminal is usually dedicated to a certain type of ship, such as a container ship or passenger ship, although some terminals are multi-use. Table III-1 shows the number of ship visits by port based on 2006 State Lands Commission data. The Ports of Los Angeles and Long Beach make up the largest port complex in the State. The majority of ship calls in California are made to these two ports. The Port of Oakland has the third most ship visits in the State. All other ports account for 30 percent of remaining California ship visits.

Table III-1: Port Ranking by Ship Visits in 2006

Port	Number of Ship Visits	Percentage of Total Visits to State
Los Angeles/Long Beach	5,469	52%
Oakland	1,939	18%
Carquinez	745	7%
Richmond	549	5%
San Diego	551	5%
San Francisco	272	3%
Hueneme	371	4%
El Segundo	211	2%
Stockton	173	2%
All Other	232	2%
Total	10,512	100%

The number of terminals and berths is different for each California port. The larger ports have a number of terminals, each with several berths. Table III-2 shows the number of terminals and berths by ship category at each port. It should be noted that not all berths included in the numbers would be utilized on a regular bases. For example, some terminals receive only larger ships that can span several berths when docked. These blocked berths can not routinely service other ships. In addition, there are other terminals and berths at California ports that are used primarily for cargo storage and port services, or may not currently be in use. These terminals and berths were not included in Table III-2.

Table III-2: Number of Terminals and Berths per Ship Category for Each California Port														
Port	**Container**		**Reefer**		**Vehicle Carrier**		**Bulk**		**Tanker**		**Passenger**		**Total**	
	T	**B**	**T**	**B**	**T**	**B**	**T**	**B**	**T**	**B**	**T**	**B**	**T**	**B**
Avalon-Catalina	**no wharf**													
Benicia					**1**	**3**							**1**	**3**
Carquinez					1	1	1	3	1	2			3	6
Crockett							1	1					1	1
El Segundo									1	2			1	2
Hueneme			1	3	1	2							2	5
Humboldt							3	5			1	1	4	6
Long Beach/ Los Angeles	18	98	2	4	3	9	19	44	15	37	2	4	59	196
Monterey	**no wharf**													
Oakland	10	25											10	25
Pittsburg	**bulk ships at port already cold-ironed**													
Redwood City							3	5					3	5
Richmond					1	2	3	4	1	4			5	10
Sacramento							6	6					6	6
San Diego			1	4	1	7					2	4	3	15
San Francisco							7	11	1	1	2	3	10	15
Stockton							9	19	1	1			10	20
Totals	28	123	4	11	8	24	52	98	20	47	7	12	119	315

As can be seen in Table III-2, there are 119 terminals at California ports providing services to over 300 berths. Some terminals receive ships from more than one category. For example, at Richmond, vehicle carrier ships and bulk cargo ships visit the same berths. For these cases, staff assigned the terminals and berths to the type of ships that utilizes them the most. POLA/POLB combined handle ships from all categories and have the greatest number of terminals and berths, 59 and 196, respectively. There are very specialized ports, such as El Segundo which receives only tankers, and Crockett, Humboldt, Redwood City, Stockton, and Sacramento which receives predominately bulk deliveries. The Ports of Avalon-Catalina and Monterey do not have terminals because they have no wharfs. Passenger ships at these ports anchor offshore, and smaller boats ferry passengers to and from shore. There is only one facility using the port at Pittsburg, USS POSCO, and all four bulk ships that deliver to this facility are cold-ironed.

From a ship perspective, container ships visit three ports: Long Beach, Los Angeles, and Oakland. Reefers also visit only four ports: Hueneme, Los Angeles, Long Beach, and San Diego. Vehicle carriers visit six ports: Carquinez, Hueneme, Long Beach, Los Angeles, Richmond, and San Diego. Passenger ships visit six ports: Hueneme, Humboldt, Long Beach, Los Angeles, San Diego, and San Francisco. Tankers visit seven ports: Carquinez, El Segundo, Long Beach, Los Angeles, Richmond, San Francisco, and Stockton. Bulk ships visit nearly all of the ports.

According to the 2006 Lands Commission data, there were just over 2,000 ships making a total of just over 10,500 visits to California ports. Table III-3 summarizes these ship visits by ship category.

Table III-3: Ship Visits to California Ports in 2006, by Ship Category

Category	Total Ships Visiting California	Total Ship Visits
Container	585	4,783
Passenger	52	752
Reefer	65	298
Tanker	451	2,111
Vehicle Carrier	235	1,039
Bulk	629	1,402
Other	33	127
Total	2,050	10,512

While container ships comprise less than a third of the total ships visiting in 2006 (585 of 2,050), they made nearly 50 percent of the total ship visits (4,783 of 10,512). Tankers, vehicle carriers, and bulk ships make up almost two-thirds of the total ships visiting in 2006 (1,315 of 2,050); however, combined they only made roughly 40 percent of the total ship visits (4,552 of 10,512). Reefers, passenger ships, and ships categorized as other made the least ship visits in 2006.

REFERENCES:

California Air Resources Board. *Evaluation of Cold-Ironing Ocean-Going Vessels at California Ports*; March 2006. http://www.arb.ca.gov/ports/shorepower/report.pdf

California Lands Commission. 2006 Port Call Database.

Marine Exchange of the San Francisco Bay Region. *Golden Gate Ports Handbook 2004-2005*. Seattle: Northwest Publishing Center, 2004. 32-53.

Port of Hueneme Wharfinger Data. 2006 Port Call Database.

Port of Oakland Wharfinger Data. 2006 Port Call Database.

Port of Oakland. *Maritime: Terminal Specifications*; September 2007. http://www.portofoakland.com/maritime/terminal.asp

Port of Long Beach Wharfinger Data. 2006 Port Call Database.

Port of Long Beach. *Trade/Commerce: Cargo/Tenants – Containerized, Dry Bulk, Liquid Bulk, Break Bulk & Ro Ro*; September 2007. http://www.polb.com/economics/cargotenant/default.asp

Port of Los Angeles Wharfinger Data. 2006 Port Call Database.

Port of Los Angeles. *Facilities: Passenger Terminal, Automobile Terminal, Breakbulk Terminals, Container Terminals, Dry Bulk Terminals, and Liquid Bulk Terminals*; September 2007. http://www.portoflosangeles.org/facilities.htm

Port of San Diego Wharfinger Data. 2006 Port Call Database.

Port of San Francisco Wharfinger Data. 2006 Port Call Database.

IV. CURRENT SHORE POWER ACTIVITIES AT WEST COAST PORTS

This chapter will discuss current and future shore power actions that have been taken on by California ports, other West Coast ports, and the shipping industry to help decrease emissions from onboard auxiliary engines. This chapter will also discuss the fact that shore power activities are proven and technically feasible. A few ports in California have integrated shore power at some berths. A limited number of ships are currently or will soon be using shore power at California ports. Some ports have established very specific goals for installing shore power while others are researching or revising plans to determine the most efficient and cost-effective method to do this. There have also been several ships that have been retrofitted for connecting to an electrified berth, but without the shore-side power supply, those ships cannot shut down their auxiliary engines. Despite the current lack of shore-side power, some shipping companies continue to move forward with retrofitting additional ships or incorporating shore power equipment on new builds in anticipation of future infrastructure at the port.

A. Shore Power Plans at California Ports

The process of initiating shore power plans can take two years or more due to the amount of time necessary to approve the Environmental Impact Report/Environmental Impact Statement (EIR/EIS) and to obtain the required permits. Many of the plans listed in this chapter require at least a three-year time span for a project to become operational. Once this timetable is overcome and a power supply is available to visiting ships, the flow of shore power can lead to significant emission reductions.

<u>The San Pedro Bay Clean Air Action Plan (CAAP)</u>

The Port of Long Beach (POLB) and the Port of Los Angeles (POLA) are working jointly to reduce emissions by setting project goals in the San Pedro Bay Clean Air Action Plan (CAAP). Strategies to improve air quality for ocean-going vessels include implementing a Vessel Speed Reduction Program, using 0.2 percent sulfur (or lower) marine gas oil fuel in auxiliary engines, requiring diesel particulate and NOx control devices where practicable, and installing shore power capabilities. Both ports have shore-power goals for 2011, and POLB has additional goals for 2016. The CAAP states that all major container terminals, certain liquefied bulk terminals, and passenger ship terminals will be subject to shore power implementation.

POLA will incorporate Alternative Maritime Power (AMP), which is the Port’s term for shore power, at 15 berths at a total approximate cost of $49.1 million. The AMP infrastructure at the China Shipping Terminal (berth 100), installed in 2004, also satisfies part of the CAAP’s requirement for this terminal. Yusen Terminal also completed an AMP installation at berth 214 to service the shore power-equipped ship, the *NYK Atlas*.

The CAAP requires installation of shore power infrastructure for two berths at the Cruise Terminal (berths 91 and 93) in 2008. In addition to this plan, Princess Cruises signed a shore power agreement to begin using shore power when docking. The Norwegian Cruise Line also signed a multi-year contract that includes the use of shore power technology for its ship, the *Norwegian Star*.

The CAAP sets a series of goals for a number of container berths to reach an operational shore power status by 2009. The Evergreen Terminal (berths 224-236) should have AMP installed at one berth by 2008 to power the newly retrofitted S-class Evergreen ships. In addition to the China Shipping settlement requirements, electrification is planned for one more berth at the China Shipping Terminal by 2009. By 2009, two berths at the Trans Pacific Container Service Corp. (TraPac) Terminal (berths 136-147) should have shore power infrastructure. A Draft Environmental Impact Statement/ Draft Environmental Impact Report (DEIS/DEIR) for the TraPac Terminal is currently under public review.

The ultimate goal at POLA is to have all planned shore-side infrastructure completely operational by 2011. To achieve this goal, two berths at the West Basin Container Terminal (berths 121-131), one berth at the Pasha Terminal (berths 175-181), and one berth at the Port of Los Angeles Container Terminal (berths 206-209) will be equipped with shore power. Also, one berth each at the APL Terminal (Pier 300) and the APM Terminal (Pier 400) will be electrified. At the APM Terminal, a liquid bulk ship berth will have a 2011 goal to reach completion as well.

In addition to the CAAP, POLA has indicated that all new shore-side power infrastructures for container ships will include a 6.6-kV plug at the wharf. Transformers, connection cables, cable reels, and plugs will be expected to be included on the ships, not at the wharf. However, POLA is considering an innovative approach of housing a portable power-transfer system, which includes a transformer, cables, and cable reels in a container stored at the dock. When the ship is ready to be cold-ironed and the appropriate space onboard has been made, a crane lifts the container onto the ship, and electricians make the appropriate connections. In this manner, the transformer is not located on the ship or the wharf, but is managed as a container and put into service when needed.

On the other side of San Pedro Bay, POLB will potentially incorporate shore power at 16 berths at a total approximate cost of $130 million. In the Fourth Quarter of 2007, the crude oil Berth T121 at the BP Terminal should be electrified. British Petroleum (BP) is equipping two of its new Alaskan-class tankers, the *Alaskan Frontier* and the *Alaskan Navigator*, with shore-power capabilities. The two ships are expected to be completed around the First Quarter of 2008.

A total of nine berths at POLB are set to be operational in 2011. This includes two berths at Pier C, one berth at the Middle Harbor Terminal (Piers E), three berths at the International Transportation Service, Inc. (ITS) container terminal (Pier G), and three berths at Pier S. Preparation of the electrical infrastructure EIR/ EIS is currently underway for Piers E and S.

Prior to the CAAP, ITS (a K-Line subsidiary) signed a lease agreement with POLB to phase in shore power and other technologies to reduce NOx emissions by ninety percent at Piers G and J. The construction plans at Pier G were recently approved and completion of the project is set for spring of 2008. Matson Navigation Co. and SSA Marine (at Pier C) also signed a lease agreement requiring the same reduction in emissions as the ITS agreement. Construction of the shore power infrastructure is in progress for Piers C and G.

Between 2011 and 2016, POLB hopes to coordinate with the City of Long Beach and terminal leaseholders to mandate shore power. The terminal leases are not up for renewal for another five years; therefore, this goal has been extended to a later date. The additional six berths include one berth at the Carnival Cruise Terminal, two berths at the Sea-Launch and at the Navy Mole, one berth at the Total Terminals International (TTI) Terminal (Pier T), and one berth each for the SSA Terminals at Pier A and Pier J.

Another delay for the latter set of goals is the lack of electrical service to power the berths at POLB. While the Los Angeles Department of Water and Power (LADWP) has the existing electrical infrastructure to supply adequate power to POLA, Southern California Edison (Edison) will need to extend their infrastructure from Interstate 405 to meet shore power needs of POLB. Extending these trunk lines will account for approximately 50 percent ($69.3 million of $130 million) of the total cost for the shore power infrastructure at POLB.

If POLA/POLB meet the 2011 goals of the CAAP, 25 berths between the two ports will be electrified and operational. According to the CAAP, POLA and POLB should be able to accommodate a total of 1,052 vessel calls (671 at POLA and 381 at POLB) in 2011. The 2016 goals for POLB are based upon renewal lease agreements and power supply and the progress of the 2011 goals. POLA and POLB intend to review the progress each year and revise areas that need attention. The CAAP currently lists plans for 2016 as potential additions; however, the cost to electrify those berths is included in the overall plan cost. The overall estimated cost for 2011 and 2016 goals comes to $179.1 million ($4.1 million for POLA and $130 million for POLB).

Port of Oakland

The Port of Oakland has been exploring the option of using portable distributed generation equipment to provide power to a docked vessel. The objective of this system is to eliminate emissions from onboard diesel-powered auxiliary engines by operating a natural-gas-fired engine to provide power to the ship. Currently, the system has been tested by Wittmar Engineering and Construction, Inc. at the Port of Oakland on the container ship the *APL China*.

Port of San Diego

San Diego Gas and Electric (SDG&E) conducted a draft shore power feasibility study, as requested by the San Diego Unified Ports District (SDUPD). SDUPD assessed the Tenth Avenue Marine Terminal (TAMT) and the Cruise Ship Terminal (CST) for shore power through five different options. The main goal is to provide the appropriate amount of power to supply the shore power needs of reefers at the TAMT and cruise ships at the CST.

Currently, SDUPD and SDG&E are holding discussions to make this shore power project even more efficient and less costly. SDUPD is looking into possibly using construction improvements in San Diego's downtown area to help supply power needs to the TAMT and the CST.

Port of San Francisco

The Port of San Francisco approved a shore power project at Pier 27 in March of 2007. The Bay Area Air Quality Management District is currently considering contributing Carl Moyer Memorial Air Quality Standards Attainment Program funds to the Port of San Francisco for this project. These funds will help cover most of the cost of getting the power from the street to the dockside. The power will be supplied by either Pacific Gas & Electric (PG&E) or from Hetch Hetchy by way of a PG&E substation. Since a generic range was given for the cost of trenching a pathway for the power supply, the utility infrastructure cost is still unknown. Pier 27 is planned to service Princess passenger ships. The pier is estimated to be operational prior to ship arrivals in 2009.

B. Installed Shore Power Infrastructures

Currently, there are just a handful of shore power applications operating in California. In addition to these few ports in California, other ports outside of California have installed shore power infrastructure in an effort to reduce auxiliary engine emissions. This section will discuss shore-side infrastructures that can be utilized on a regular basis. It was stated earlier in this chapter that the Yusen Terminal, Inc. (berth 214) at the Port of Los Angeles was complete; however, it is not currently functional. System testing is necessary to ensure functionality and safety of the infrastructure before ships can regularly connect to onshore power.

China Shipping Terminal at Port of Los Angeles

The Port of Los Angeles retrofitted the China Shipping Terminal to include a shore power infrastructure as part of a lawsuit settlement with the Natural Resources Defense Council (NRDC), the Coalition for Clean Air, and local community groups. The settlement requires a minimum of 70 percent of ship calls to this berth, on an annual average, to utilize shore power.

At this site, a substation at the edge of the property supplies 14.5 kV of electricity, which is stepped down by a nearby transformer to 6.6 kV. Underground cables transport the electricity hundreds of yards to the edge of the wharf. A transformer that is housed on a barge next to the ship reduces the power further to 440 volts (V). The barge also contains a crane, cable reels, switching gear, and nine cables. Figure IV-1 shows the barge supported shore power application at the China Shipping Terminal.

When a ship is ready to connect to shore power, a crane lifts the cables from the barge to the ship, where personnel plug them into a panel at the stern of the ship. Figure IV-2 shows the cable connections on a China Shipping vessel. The Port has indicated that the barge configuration will no longer be used in future shore power applications because of the cost and size of the barge.

Figure IV-1: Shore Power Provided via a Barge at China Shipping

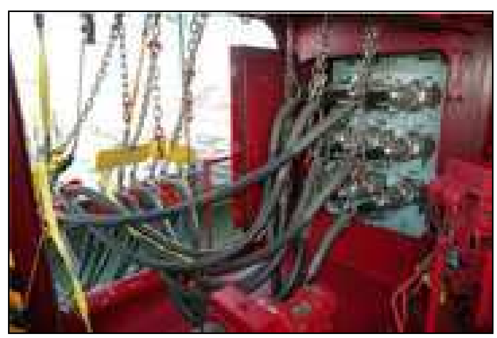


Figure IV-2: Cable Connections on a China Shipping Vessel

South Franklin St. Dock in Juneau, Alaska

Princess Cruises began cold-ironing some of its ships berthed at the South Franklin St. dock in Juneau in 2001. The shore power operations were installed in response to community concerns over the smoke emissions from passenger ships visiting in the summer. During the summer cruise season, the air is stagnant over Juneau and the emissions from the ships' auxiliary engines significantly reduce visibility.

At this site, a dual-voltage transformer supplies power from the utility company. The transformer can step down the voltage to either 11 kV or 6.6 kV. Underground cables carry the power from the transformer to the dock switch, where four 3 ½-inch diameter flexible electrical cables direct the power to the ship. The cables hang in a festooning pattern on a steel gantry located on the dock next to the ship as illustrated in Figure IV-3. The gantry system allows the cables to accommodate Juneau's 20-foot tidal range as well as withstand the 100-mph winds during the winter.

Figure IV-3: Steel Gantry Festooning System at Juneau, Alaska

When connecting to shore power, personnel use the festooning system to lower the cables to a side shell door on the ship, where the cables are pulled through the doorway and the 70-pound custom-made plugs are connected to the electrical connection cabinet on the ship. The cable connection is a male/female plug-and-socket system similar to what is used in the American mining industry. Figure IV-4 shows cables entering a ship, and Figure IV-5 shows the cable connection on a ship. Onboard software allows the shore power and the ship generator power to automatically synchronize, combine, and transfer. Synchronizing the ship and shore power is mandatory for passenger ships, where any disruption to passenger services is unacceptable.

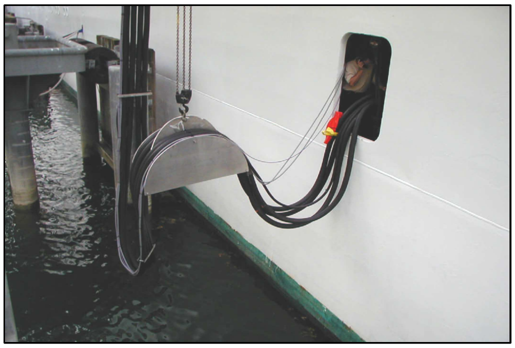


Figure IV-4: Cables Entering a Princess Cruises Ship

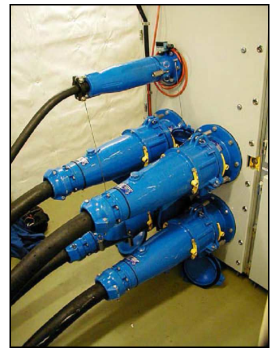


Figure IV-5: Cables Connected to an Electrical Cabinet on a Princess Cruises Ship

Port of Seattle, Washington

Princess Cruises began cold-ironing some of its shore power-equipped vessels at the Port of Seattle in the summer of 2005. Likewise, the Holland America Line has retrofitted three ships since 2006 to take advantage of the shore power infrastructure. This project was a collaborative effort among Princess Cruises, the Port of Seattle, Seattle City Light (the local utility), and the United States Environmental Protection Agency (U.S. EPA) to reduce emissions from ships at the Port's new Terminal 30 Cruise Facility, which Princess Cruises shares with the Holland America Line. The Port has two passenger ship terminals serving five passenger ship lines.

At this site, existing utility power is brought to a custom-made step-down transformer, which can deliver either 11 kV or 6.6 kV, similar to the Juneau site. The specialized transformer provides flexibility to the Princess Cruises fleet to accommodate not only the larger *Princess Diamond* and *Princess Sapphire* ships but also the smaller Princess vessels that were originally retrofitted for Juneau. Similar to Juneau, four cables carry power to the ships' electrical connection cabinet via a side shell door. The cables are lowered to the ship by a winch connected to a metal support structure located at the edge of the wharf. The structure can be pivoted away from the ship when not in use. Figure IV-6 shows the cable management system for a Princess ship at the Port of Seattle.

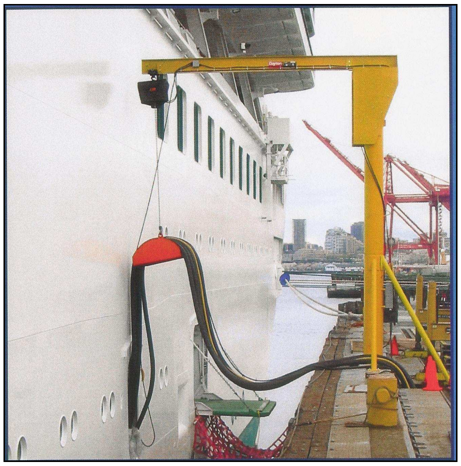


Figure IV-6: Power cables at the Princess Cruises Terminal at the Port of Seattle

USS POSCO Industries in Pittsburg, California

Four dry-bulk ships cold-iron while docked at USS POSCO Industries' steel mill in Pittsburg, California. The ships, which are owned by Hyundai, Hanjin, and Korea Line shipping companies, were built between 1989 and 1992 and are equipped with Selective Catalytic Reduction (SCR) technology. Connection to shore power began in 1991 as a means to mitigate emissions from a facility expansion. At this site, two 480-volt cables are stored at the side of the dock. When shore power is provided, the cables are connected to a power box located at the edge of the dock and then pulled up the side of the ship and bolted to an electrical panel in an exterior room on the ship. Figure IV-7 shows the cables connected to the dock, and Figure IV-8 shows the cables bolted to the shore power connection panel on the ship.

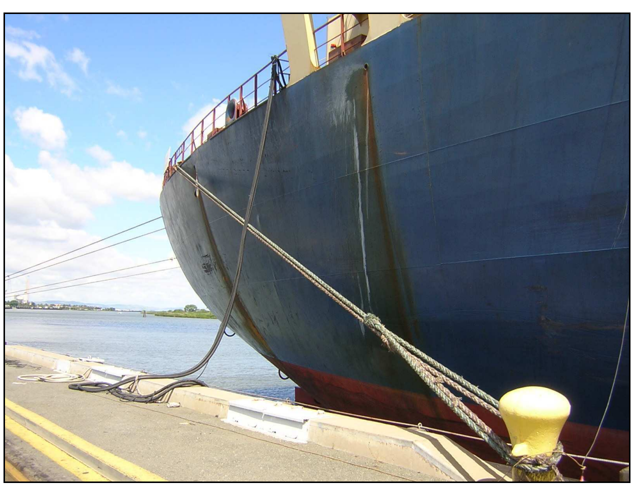


Figure IV-7: Shore-side power connection at the USS POSCO facility in Pittsburg, CA

Figure IV-8: Shore power connection on the *Pacific Success* at the USS POSCO facility

United States Naval Station in San Diego, California

The Navy cold-irons ships while in port at bases all over the world. The Navy connects to shore power as a matter of routine and has done so for several decades. The ships are also hooked up to shoreside water, sewer, communication, and steam while docked.

The Navy has developed a unique electrical cable connection system in order to avoid compatibility issues with different ports of call. Figure IV-9 shows a schematic of the Navy's shore-power connection system.

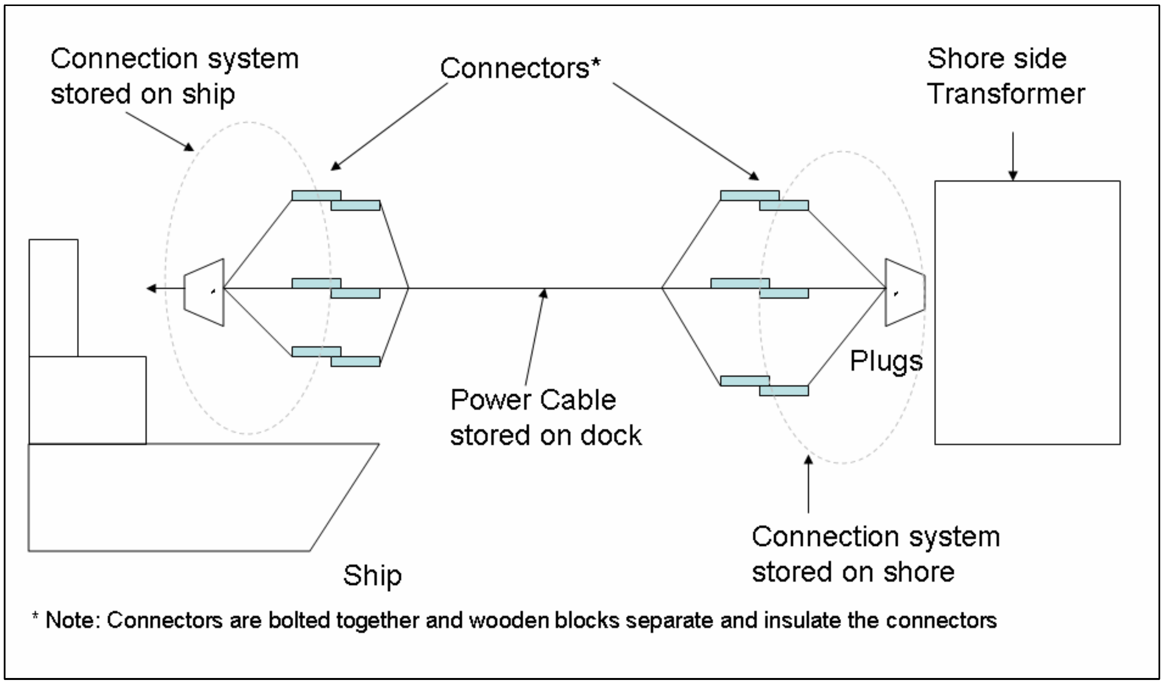


Figure IV-9: Navy ships' shore-power connection system

This system consists of power cables that are stored on the docks at the naval stations around the world. On either end of the power cables are "pigtails" of three separate cables that end in metal connection plates. Plugs with similar pigtails of cables and metal connectors are carried on the Navy ship as well as stored near the transformer/substations on the docks at the naval stations. When a ship docks at the Naval Station in San Diego, a crane lifts a cluster of power cables onto the ship. Navy personnel on the ship bolt the power cable pigtails to the plug pigtails stored onboard. Similarly, Navy personnel on the dock bolt the power cable pigtails to the plug pigtails stored near the substation. Then the plugs are connected to the receptacles on the substation and on the ship. Figure IV-10 shows the plugs stored adjacent to a substation at the San Diego Naval Station. Figure IV-11 shows cables connected to the receptacles on a Navy ship.

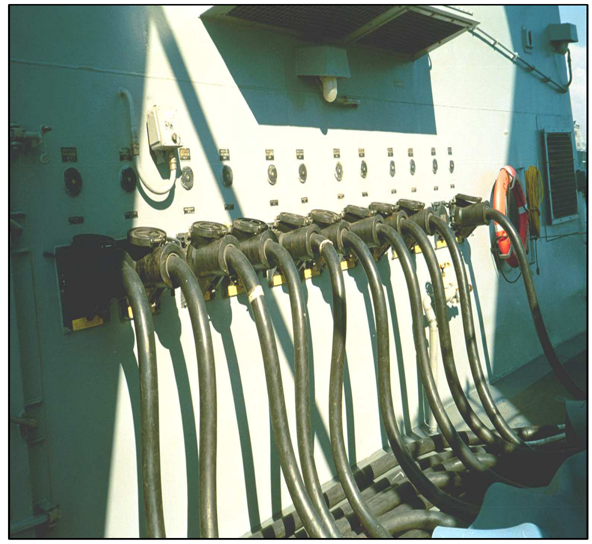


Figure IV-10: Plugs stored at a substation at the San Diego Naval Station

Figure IV-11: Shore-Power connection on a Navy ship

Each cable can deliver 480 volts at 400 amps to the ship once the connection is complete. Having to attach plugs to power cables every time a ship cold-irons makes the Navy procedure more labor-intensive; however, since the Navy cold-irons across the globe and has its own plugs aboard the ships and on the docks, there are no compatibility issues with the different ports of call.

The transfer of power from the ships' auxiliary generators to shore power is synchronized to avoid blackouts. For example, a destroyer-class ship has two auxiliary gas-turbine generators running in parallel when entering the port. One of the generators is turned off when the ship is docked and the second generator is ramped down during the transfer of power. It takes about 60 to 90 minutes after the ship is docked for personnel to connect the ship to electrical and other utility needs.

C. Shore Power Equipped Ships

Staff is aware of 42 ships that are currently visit American ports that are equipped with shore power capabilities. These include container ships, passenger ships, and dry bulk ships. The ships are listed below in Table IV-1.

Table IV-1: Ships with Shore Power Capability

Operator	Ship Type	Number of Ships
China Shipping	Container	17
Evergreen America	Container	7
Holland America	Passenger	3
MSC	Container	1
NYK Line	Container	1
POSCO	Dry Bulk	4
Princess Cruises	Passenger	9
Total Number of Ships		42

China Shipping

The China Shipping settlement requires a minimum of 70 percent of ship calls to Berth 100, on an annual average, to utilize shore power. There are now at least 17 China Shipping vessels that are equipped with shore power capability. In 2006, shore power was used for 88 out of 125 ship calls to berth 100, or an average shore power use of 70 percent. Although an impressive start, these 88 cold-ironed ship calls still represent a small fraction of overall container ship visits to the Port. In 2006, the China Shipping fleet made 125 calls (seven percent) of the 1,705 container-ship visits to POLA.

Evergreen S-Class Vessels

In March 2005, Evergreen Marine Corporation announced that its new S-class 7,024-TEU container vessels will be equipped with cold-ironing capability. Since 2005, the *Hatsu Sigma*, the *Hatsu Smart*, the *Ever Superb*, and the *Ever Steady* have made their maiden calls to POLA. Figure IV-12 shows the cable reel aboard the *Ever Steady* while it was docked in 2007 at the Port of Oakland. Figure IV-13 shows the plugs ready to be lowered for shore-side connection.

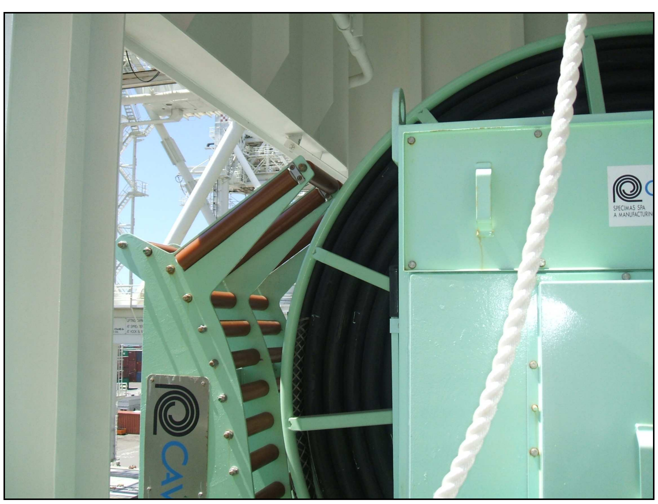


Figure IV-12: Cable Reel Onboard the *Ever Steady*

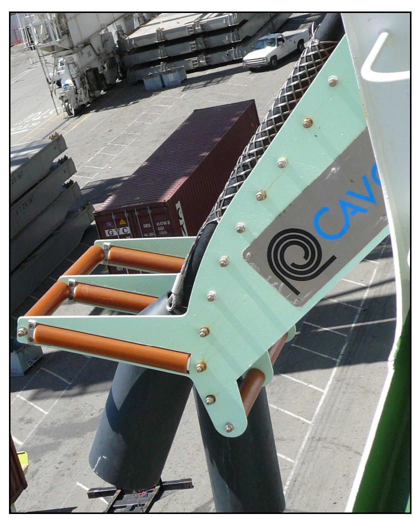


Figure IV-13: Plugs Extended from the *Ever Steady*

In 2006, Evergreen's entire fleet made 253 visits out of a total of 1,705 container ship visits to POLA, with the S-class fleet making 11 percent (28 out of 253 visits) of Evergreen's total visits. Similarly, Evergreen's fleet made 114 visits out of a total of 1,938 container ship visits to the Port of Oakland in 2006, with the S-class fleet making seven percent (8 out of 114 visits) of Evergreen's total visits.

Holland America

In 2006, the Holland America Line retrofitted two passenger ships, the *MS Oosterdam* and *MS Westerdam*, to accommodate the shore power infrastructure at the Port of Seattle. In 2007, the *MS Noordam* was retrofitted with similar shore power capability. According to the 2007 Sailing Schedule for the Port of Seattle, 189 ship visits by 16 vessels are scheduled for 2007. Forty-three of these ship visits (or 23 percent) were made by two Holland America Line vessels equipped with shore power capability, the *Oosterdam* and the *Noordam*.

NYK Atlas at Port of Los Angeles

Figure IV-14: The NYK Atlas docked at POLA

POLA built a shore-side infrastructure at the Yusen Terminal (berth 214) to provide power to a container ship (*NYK Atlas*) when in port. The *NYK Atlas*, as shown in Figure IV-14, was equipped with shore-power capabilities when built and first arrived at POLA in August 2004. The ship is one of 19 NYK ships that visited POLA in 2006, accounting for nine of the 89 total NYK ship visits.

At the Yusen Terminal, 6.6 kV will be provided at a plug on the wharf (a "wharf box"). Two cables that are housed on a cable reel on the *NYK Atlas* will be lowered down the side of the ship via a roller guide and connected to the wharf box. Because the *NYK Atlas* uses 6.6 kV, no transformer is needed for this shore power application. At the moment, the *NYK Atlas* is going through a testing program for its shore power set up.

Princess Cruises Ships

According to Princess Cruises, there are currently nine ships that are equipped to cold-iron when at the Port of Seattle and the port in Juneau. According to the 2007 Sailing Schedule for the Port of Seattle, 189 ship visits by 16 vessels are scheduled for 2007. Forty-two of these ship visits (or 22 percent) were made by two Princess Cruise Line vessels equipped with shore power capability, the *Golden Princess* and the *Sun Princess*. According to Juneau's 2007 Cruise Ship Roster, 40 passenger ships should visit Juneau, including seven of Princess's shore-power equipped ships. The Princess ships that will be able to use shore power represent 125 out of 646 total ship visits to Juneau in 2007 (or 19 percent).

As can be seen in this section, one NYK container ship, one MSC container ship, three Holland America passenger ships, four POSCO dry bulk ships, nine Princess Cruises passenger ships, 17 China Shipping container ships, and seven new S-class Evergreen container ships have been equipped with shore-power capabilities. It should be noted that perhaps not all of these ships will call on California ports in the future.

D. Future Ship Retrofits and New Builds

Shipping companies are continuing efforts to increase the number of shore powered vessels in anticipation that the ports will establish and carry out plans to provide shore side infrastructure.

British Petroleum

Two BP tankers, the *Alaskan Frontier* and the *Alaskan Navigator*, are currently undergoing retrofits to accommodate the ship side infrastructure. As previously stated, these two ships are expected to be fully equipped with shore power capabilities around the First Quarter of 2008.

Evergreen America

In addition to the seven S-class ships that presently have shore power capability, Evergreen plans to build another two ships, bringing the S-class fleet total to nine ships. The additional ships are the *Ever Safety* and *Ever Salute*.

K-Line

K-Line is upgrading some of their fleet to accommodate shore power at the ITS terminal. Presently, K-Line is retrofitting five vessels for shore power. The five ships are the *Chicago Bridge*, *Rotterdam Bridge*, *Genoa Bridge*, *Shanghai Bridge*, and *Long Beach Bridge*. All five ships may be completed by 2008 or shortly thereafter.

NYK Line

The NYK Line has committed to retrofitting 17 ships, starting with the *NYK Apollo*, that will use a container to house the ship-side infrastructure for shore power. As shown in Figure IV-15, an onboard container will house the infrastructure necessary to plug into the AMP outlet dockside. The power provided will supply the ship with 6.6 kV, which will not require a transformer. In addition to these retrofits, the NYK Line plans to build about 20 new ships that are equipped to connect to shore power.

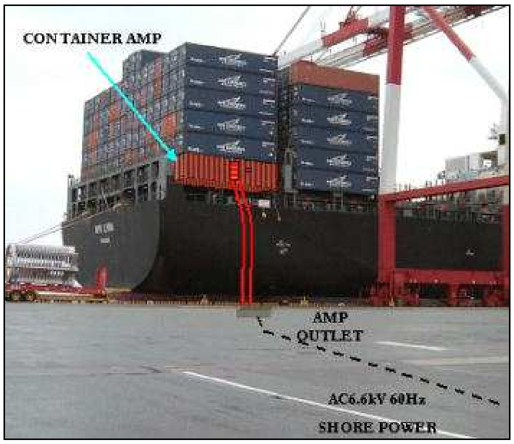


Figure IV-15: Shore Power Connection Using a Container Box

Norwegian Cruise Line

As stated previously, the Norwegian Cruise Line signed a multi-year lease agreement with POLA to retrofit the *Norwegian Star* to utilize AMP when docked. The terms of this contract are to take effect in 2008.

Conclusion

As can be seen in this chapter, cold-ironing is proven and technologically feasible. Shore power is currently being used or planned for passenger ships, container ships, bulk ships, and oil tankers, as well as having been practiced routinely for decades at U.S. Navy ports all over the world. Cold-ironing strategies are currently part of some ports' efforts to reduce public health impacts to the surrounding communities. The Port of Los Angeles has an active Alternative Maritime Power program and is installing or planning to install several shore power sites. Based on the CAAP, the Port of Long Beach has committed to adding shore power requirements to future lease conditions and already has a shore power berth at its BP terminal. Other ports are evaluating adding shore power to their terminals. The Port of San Francisco is planning to add shore power to its new passenger ship terminal and the Port of San Diego is planning to add shore power to its passenger ship terminal and refrigerated cargo terminal. Additionally, some container-ship, passenger-ship, and tanker companies are now voluntarily adding shore-power-equipped ships to their fleets.

REFERENCES:

Appy, Ph.D., Ralph G. *NRDC VS. City of Los Angeles Amended Stipulated Judgment Quarterly Report – 4th Quarter 2006*; March 9, 2007.

British Petroleum. Personal communication. June 29, 2007.

California Air Resources Board. *Evaluation of Cold-Ironing Ocean-Going Vessels at California Ports*; March 2006. http://www.arb.ca.gov/ports/shorepower/report.pdf

Cruise Line Agencies of Alaska. *Cruise Ship Calendar for 2007*; February 23, 2007. http://www.claalaska.com/pdf/2007/2007_Juneau.pdf

Eric Caris, Port of Los Angeles. Personal communication. June 28, 2007.

Evergreen Line. *News Archive*; Press Releases about S-Type Green Ships; October 2007. http://www.evergreen-line.com/tbn1/jsp/TBN1_GreenShip_Introduction.jsp#6

Holland America Line. *Holland America Line Seagoing Environmental Innovation*; Environmental Commitment; January 2007. http://www.hollandamerica.com/about/environmental.do?env=standards

Hollman, Michael (MPH). "Cold ironing gathers momentum." *Germanischer Lloyd nonstop*. Edition 2: 26-27. June 2006. http://www.gl-group.com/images/glgroup/nonstop_2006-02_E.pdf

Jay Ach, Port of San Francisco. Personal communication. August 21, 2007.

Joe Calavita, California Air Resources Board. Personal communication. October 1, 2007.

Michelle White, Port of San Diego. Personal communication. September 25, 2007.

NYK Line. "NYK Successfully Tests Connection to New Shoreside Electric Power Unit." Press Release. September 3, 2007. http://www.nyk.com/english/news/2007/0903/index.htm

NYK Line. "NYK to Deploy Thirty Eight Containerships with Alternative Maritime Power Capability." Press Release. April 26, 2007. http://www.nykline.co.jp/english/news/2007/0426_1/index.htm

Port of Long Beach. “Port Seeks Public Comment on Pier S Development Project.” Press Release. January 26, 2007. http://www.polb.com/civica/filebank/blobdload.asp?BlobID=3622

Port of Long Beach. “Port, ITS and ‘K’ Line Commit to ‘Green Policy’.” Press Release. July 31, 2006. http://www.polb.com/civica/filebank/blobdload.asp?BlobID=3057

Port of Long Beach. “Port Approves First ‘Green Lease’ Construction Contract.” Press Release. September 19, 2006. http://www.polb.com/civica/filebank/blobdload.asp?BlobID=3281

Port of Long Beach. “Port Signs Landmark Historic Agreements to Cut Pollution by 90%.” *RE: Port*. Press Release. August 21, 2006. http://www.polb.com/civica/filebank/blobdload.asp?BlobID=3186

Port of Long Beach. “Ships ‘Plug In’ to Cut Pollution.” *RE: Port*. Press Release. September 2007. http://www.polb.com/news/displaynews.asp?NewsID=284&targetid=18

Port of Long Beach. “’K Line’ Retrofitting Five Ships for Shore-side Power.” Press Release. June 11, 2007. http://www.polb.com/civica/filebank/blobdload.asp?BlobID=3954

Port of Los Angeles and Port of Long Beach. *San Pedro Bay Ports Clean Air Action Plan*; November 2006. http://www.portoflosangeles.org/DOC/CAAP_Tech_Report_Final.pdf and/or http://www.polb.com/civica/filebank/blobdload.asp?BlobID=3451

Port of Los Angeles. “Princess ships will connect to shore power at the Port of Los Angeles in 2008.” Press Release. January 22, 2007. http://www.portoflosangeles.org/News/news_012207pc.htm

Port of Los Angeles. “Port of Los Angeles signs agreement with Norwegian Cruise Line that includes multiple environmental initiatives.” Press Release. January 30, 2007. http://www.portoflosangeles.org/News/news_013007ncl.htm

Port of Los Angeles. “Port extends public comment period on TraPac Container Terminal environmental document.” Press Release. August 6, 2007. http://www.portoflosangeles.org/News/news_080607trapac.htm

Port of Los Angeles. “Two of Evergreen Group’s ‘Green’ Mega Ships Call at the Port of Los Angeles Simultaneously.” Press Release. August 7, 2006. http://www.portoflosangeles.org/Press/REL_Hatsu_Smart_Sigma.pdf

Port of Los Angeles. “Evergreen Group’s First ‘Green’ Mega Ship, Ever Superb, Makes Her Maiden Call at the Port of Los Angeles.” Press Release. August 7, 2006. http://www.portoflosangeles.org/Press/REL_Ever_Superb_First_Call.pdf

Port of Los Angeles. “Evergreen Group’s ‘Green’ Mega Ship, Ever Steady, Makes Her Maiden Call at the Port of Los Angeles.” Press Release. January 18, 2007. http://www.portoflosangeles.org/News/news_011807es.htm

Port of Los Angeles Wharfinger Data. 2006 Port Call Database.

Port of Oakland Wharfinger Data. 2006 Port Call Database.

Port of Seattle. *Preliminary Sailing Schedule*; Cruise Seattle 2007; March 2007. http://www.portseattle.org/downloads/seaport/CruiseSched200704.pdf

San Diego Gas and Electric. *Cold Ironing Feasibility Study for Electrical Services at Cruise Ship & 10th Avenue Marine Terminals*; January 2007.

Stefan/George Associates. Personal communication. May 23, 2007.

Stefan/George Associates. Personal communication. May 16, 2007.

Wittmar Engineering & Construction, Inc. *American President Line; DFMV Cold Ironing™ Presentation.* September 6, 2006.

V. EMISSIONS, POTENTIAL EXPOSURES, AND RISK

This chapter presents estimated hotelling emissions from ocean-going vessels visiting California ports. As stated in Chapter II, ARB staff is proposing requirements for three of the six major categories of ocean-going vessels that visit California ports—container ships, passenger ships, and refrigerated cargo ships (reefers). The other ship categories will be addressed in a future rulemaking that is expected to be completed by late 2008.

In this chapter, ARB staff first presents statewide 2006 hotelling emissions for all ship categories, then discusses in detail the three ship categories affected by the proposed regulation. This chapter also includes a discussion on the potential cancer and non-cancer health impacts due to current hotelling emissions from all ocean-going vessels.

A. Estimated Hotelling Emissions from Ocean-Going Vessels

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 reefers visiting the Ports of Los Angeles, Long Beach, Oakland, San Diego, San Francisco, and Hueneme.

The inventory integrates information from multiple sources. From the 2006 Lloyd's Fairplay Ship Registry, staff gleaned information about the characteristics of individual ships, such as engine size, net registered tonnage, and other data. Staff used data about port calls and hotelling times from databases developed by the California State Lands Commission and from management organizations at many ports in California. We received information on engine loads from previous ARB surveys and inventories developed for the Ports of Los Angeles, Long Beach, and Oakland. Finally, staff used emission factors taken from available studies of ship emissions tests.

We calculated emissions 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. Base year emissions were 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, which would be used in place of auxiliary engines.

A description of the methodology for developing the engine inventory and associated emissions and the projection for future years is provided in Appendix B.

Current 2006 Hotelling Emission from Ocean-Going Vessels

The hotelling emission estimates are associated with the use of diesel-fueled auxiliary engines on ocean-going ships to power the vessel's electrical systems while docked. These emissions are a function of how often the ship visits a California port, how long the ship is at-berth, the emissions rate of the engines, and the typical operating load of the auxiliary engines while the ship is at-berth.

Data used for estimating hotelling 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

ARB staff estimates that in 2006, there were approximately 2000 ocean-going vessels calling at California ports, emitting about 1.8 tons per day (TPD) of diesel PM and 21.1 TPD of NOx from diesel-fueled auxiliary engines while at-berth.

In addition, based on a range of statewide NOx-to-PM conversion factors of 0.3 - 0.5 g NH_4NO_3/g NOx, ARB staff estimates a secondary formation of $PM_{2.5}$ nitrate from NOx hotelling emissions ranges from 6.3 to 10.6 tons per day.[1]

[1] The conversion factor for the transformation of NOx to NH_4NO_3 was based on an analysis of annual-average conversion factors for secondary formation of PM_{10} nitrate from NOx emissions at a number of urban sites in California. A more detailed description of the methodology used to evaluate the conversion of NOx to NH_4NO_3 is found in Appendix D.

Estimates of 2006 NOx, and diesel PM hotelling emissions per ship category are presented in Table V-1.

Table V-1: Estimated 2006 Hotelling Emissions by Ship Category

Ship Category	2006 Emissions, Tons/Day	
	NOx	PM
Container	13.8	1.1
Passenger	2.8	0.2
Reefers	0.9	0.1
Tanker	2.0	0.2
Bulk/General	1.0	0.1
Vehicle Carriers	0.6	0.1
Totals	21.1	1.8

Figures V-1, and V-2 show the relative share of NOx and diesel PM emitted by each ship category. As can be seen in these figures, the hotelling emissions from the three affected ship categories—container ships, passenger ships, and reefer ships—represent over 80 percent of total statewide hotelling emissions.

Figure V-1: 2006 NOx Emissions Distributions for All Ship Categories

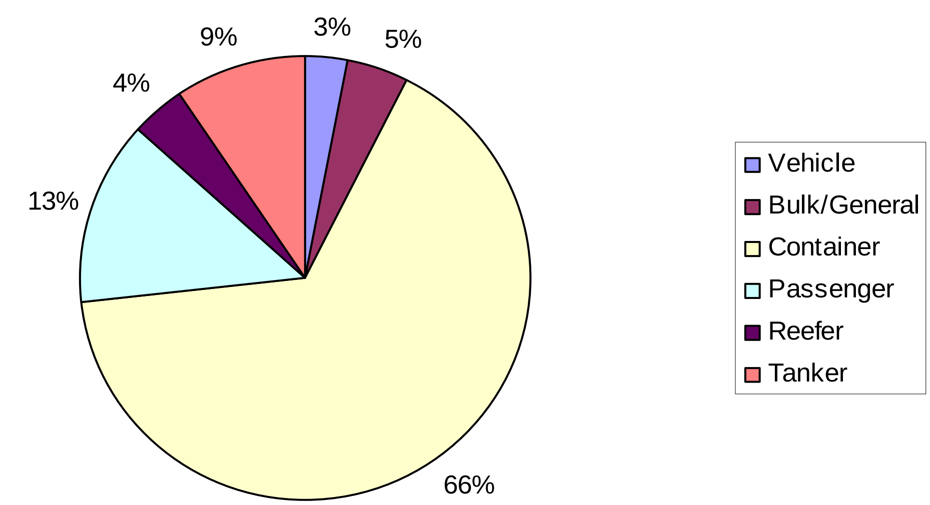
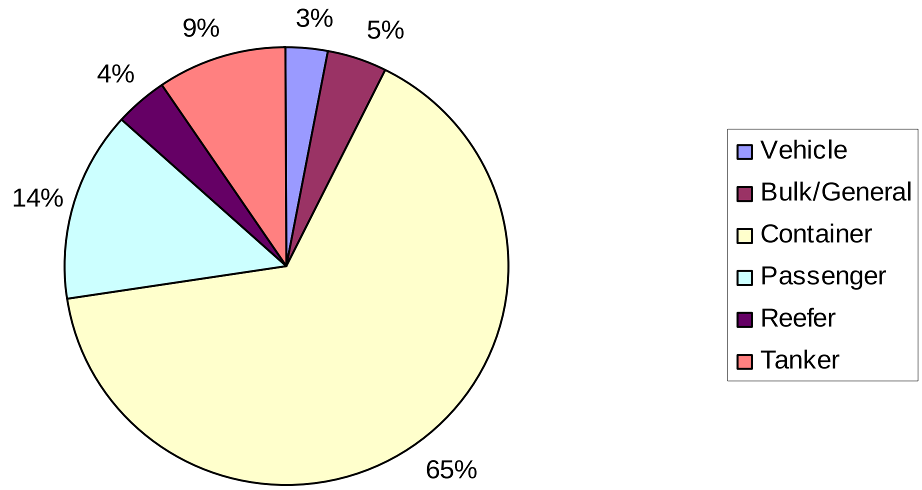


Figure V-2: 2006 Diesel PM Emission Distributions for All Ship Categories



The proposed regulation would affect ships visiting the Ports of Los Angeles and Long Beach (which, for the proposed regulation, is considered one port), Oakland, San Diego, Hueneme, and San Francisco. To provide a perspective of the shipping activities at these ports compared to all other ports in California, staff presents total hotelling emission by California port in Table V-2.

Table V- 2: Estimated 2006 Hotelling Emissions for All Ship Categories by Port (Tons per Day

Port	NOx	PM
Los Angeles/Long Beach	14.3	1.2
Oakland	2.6	0.2
San Diego	1.1	0.1
Hueneme	0.7	0.1
San Francisco	0.5	0.1
Other Ports	1.2	0.2
Total	21.1	1.8

As can be seen in this table, most of the shipping activities and hotelling emissions occur at the largest ports in California: Los Angeles and Long Beach followed by Oakland. The six ports affected by the proposed regulation account for over 90 percent of total hotelling emissions at California ports.

Projected 2014 and 2020 Hotelling Emission Estimates for Container Ships, Passenger Ships, and Reefer Ships

Staff developed growth factors for each ship category to project future hotelling emissions. In general, the growth in vessel hotelling emissions is directly proportional to the growth in vessel visits, ship size, berthing times, and, in the case of container ships, the number of refrigerated containers aboard. Details on the growth assumptions are provided in Appendix B.

Hotelling emissions from ocean-going ships are predicted to increase from 2006. Container ship and passenger ship emissions are expected to double by 2020. Reefer ship emissions are expected to decline at the Ports of Long Beach and Los Angeles, slightly increase at the Port of Hueneme, and triple at the Port of San Diego by 2020.

The projected hotelling emission estimates for container ships, passenger ships, and reefer ships for 2014 and 2020 are presented in Table V-3. In December 2005, the Board adopted an auxiliary engine fuel regulation that would limit the sulfur content of fuel used with auxiliary engines starting in 2007. At the time this technical support document was published, the regulation had been challenged in federal district court and is undergoing appeal at the Ninth Circuit Court of Appeals. The future emission projections were based on the assumption that the auxiliary engine regulation would ultimately be upheld and the auxiliary engines would be operating on low-sulfur fuel.

Table V-3: Projected 2014 and 2020 Hotelling Emission Estimates for Container Ships, Passenger Ships, and Reefer Ships

Ship Category	Projected 2014 Emissions Tons per Day		Projected 2020 Emissions Tons per Day	
	NOx	PM	NOx	PM
Container	21.4	0.38	30.8	0.55
Passenger	3.6	0.07	5.2	0.09
Reefer	1.0	0.02	1.3	0.02
Totals	26	0.47	37.3	0.67

B. Potential Health Impacts of Hotelling Emissions

This section discusses the potential cancer and non-cancer health impacts due to current hotelling emissions from ocean-going vessels. For the analysis of potential cancer impacts, we used earlier analyses conducted as part of the Port of Los Angeles/Long Beach Health Risk Assessment (ARB, 2006a). A copy of the Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach is included in Appendix C. For non-cancer impacts, we updated work done as part of the Goods Movement Emission Reduction Plan (ARB, 2006b). A discussion of the non-cancer health assessment is included in Appendix D.

Particulate matter (PM) and NOx are the emissions of the greatest health concern from hotelling emissions from ocean-going vessels. Particulate matter emitted from diesel-fueled engines (diesel PM) is used as the measure of the toxicity of diesel exhaust, which includes over 40 identified toxic air contaminants. The annual average concentration of diesel PM due to hotelling emissions is used to estimate the potential cancer risk near port communities.

Non-cancer impacts are estimated based on the annual average concentration of PM. There are two sources of PM emissions from diesel-fueled auxiliary engines. The first source of PM is the PM directly emitted in the exhaust from diesel auxiliary engines. This is referred to as directly emitted diesel PM. The second source of PM is the PM that is formed in the atmosphere when gases emitted in the exhaust from diesel engines, primarily NOx and SOx, react to form PM. This is referred to as secondary diesel PM.

Non-cancer impacts can also occur from exposures to NOx and hydrocarbon emissions from diesel-fueled engines. NOx and hydrocarbon emissions contribute to the formation of ozone, which also has associated non-cancer health impacts.

In 1998, the Board identified PM emissions from diesel-fueled engines as a toxic air contaminant (TAC). The Board concluded that long-term occupational exposures to diesel exhaust increases the risk of developing lung cancer. The Board also concluded that a number of adverse long-term non-cancer effects have been associated with exposure, including a greater incidence of respiratory irritation and chronic bronchitis.

Over the last several years, a substantial number of epidemiologic studies have found a strong association between exposure to elevated PM levels (of which diesel PM is a subset) and adverse non-cancer health effects. (ARB, 2002; ARB, 2006b). These non-cancer health effects include premature death, increased hospitalizations for respiratory and cardiovascular causes, asthma and lower respiratory symptoms, acute bronchitis, work loss days, and minor restricted activity days. Non-cancer health effects linked to exposure to elevated levels of ozone include: premature deaths, hospital admissions for respiratory diseases, minor restricted activity days, and school absence days.

C. Estimating Potential Cancer Impacts near California Ports

The increased exposure to diesel PM from hotelling emissions from diesel-fueled ocean-going vessel auxiliary engines may result in elevated cancer risks to people who live and work near California ports.

To provide a perspective on the potential cancer risk from hotelling emissions, staff used an existing analysis from 2004 of diesel PM emissions from port related activities (including hotelling emissions) at the Port of Los Angeles and the Port of Long Beach and adjusted the results of that study to reflect 2006 estimated hotelling emissions. (2006a) Estimates of potential cancer risks from hotelling emissions at the Ports of Los Angeles and Long Beach would represent the upper range of cancer risks, given the magnitude of hotelling emissions in the San Pedro Bay area and the proximity of the emissions to highly urbanized areas. Semi-quantitative estimates of the relative impact of hotelling emissions from ocean-going vessels for other areas can be estimated based on a comparison of the relative magnitude of emissions and the proximity of the emissions to urbanized areas. For example, using the port-specific hotelling emission estimates in Table V-2, one would expect that the potential cancer risk estimate for the Port of Oakland would be about 20 percent of the estimate for the Ports of Los Angeles and Long Beach, while the cancer risk estimates for the Port of San Diego would be about 90 percent lower.

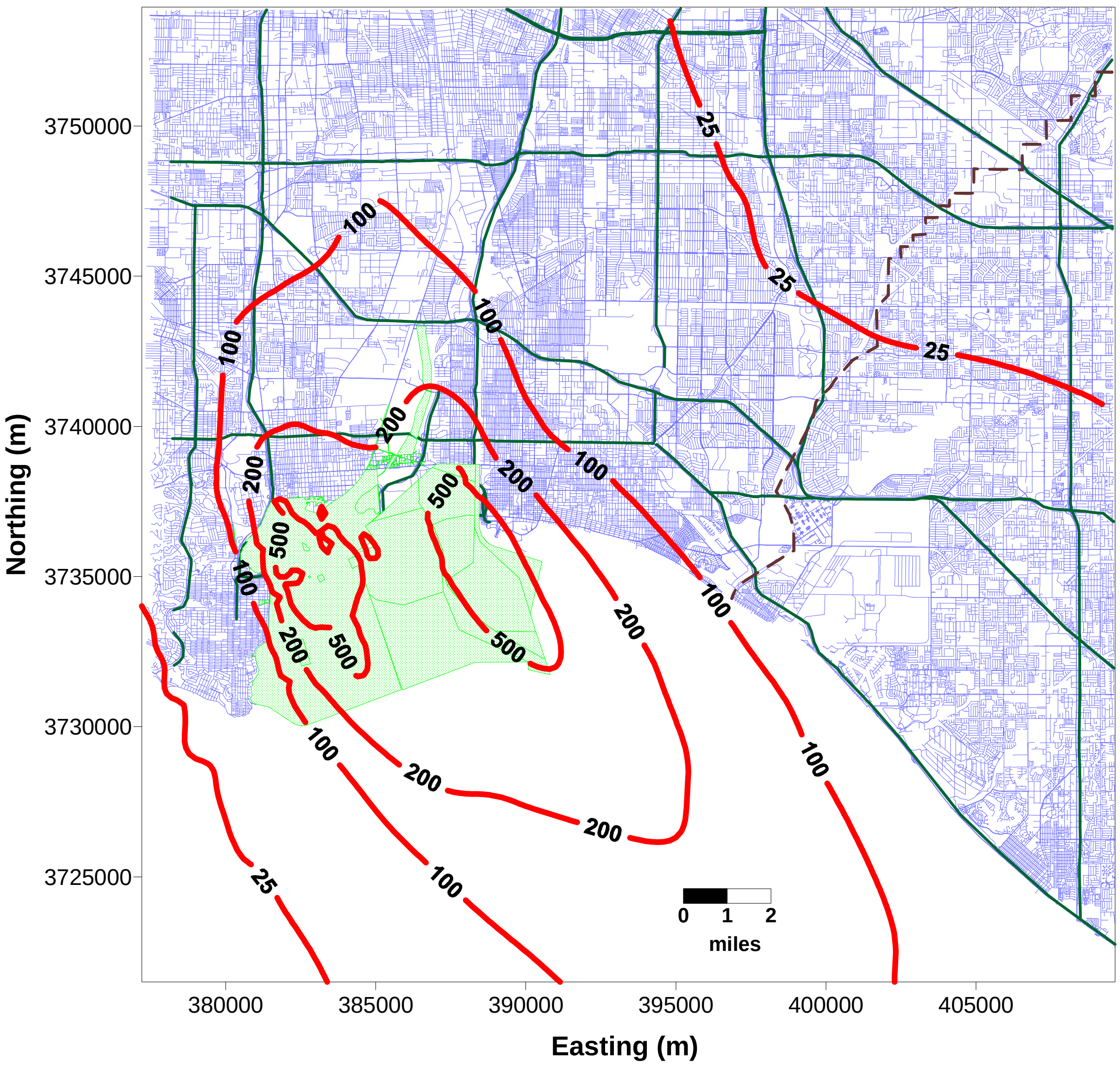
In addition to the risk assessment conducted for the Ports of Los Angeles and Long Beach, ARB staff is currently conducting a diesel PM exposure assessment study for the West Oakland community which includes the Port of Oakland. This assessment will be similar in scope as the study completed for the Ports of Los Angeles and Long Beach. Staff expects a draft report on the West Oakland study to be released in late November.

The following section first discusses the cancer risks estimates for hotelling emissions in and around the ports of Los Angeles and Long Beach. This discussion is followed by a discussion of the methodology used to develop the cancer risk estimates.

Cancer Risk Estimates

ARB staff has estimated that the hotelling emissions may result in risk impacts in the nearby residential areas surrounding the Ports of Los Angeles and Long Beach. Figure V-3 shows the risk isopleths for 2006 diesel PM hotelling emissions at the Ports of Los Angeles and Long Beach superimposed on a map that covers the ports and the nearby communities. As can be seen in this figure, the area in which the risks are predicted to exceed 100 in a million has been estimated to be about 21,000 acres. For the higher risk level of over 200 in a million, the impacted areas have been estimated to be about 4,100 acres. Overall, about 100 percent of the effective modeling receptor domain of 255 square miles (excluding the port property and the surrounding ocean area) has an estimated risk level of over 10 in a million due to hotelling emissions from ocean-going vessels.

Figure V-3: Estimated Diesel PM Cancer Risk from 2006 Hotelling Emissions at the POLA and POLB (Wilmington Met Data, Urban Dispersion Coefficients, 80th Percentile Breathing Rate, Emission = 430 TPY, Modeling Domain = 20 mi x 20 mi, Resolution = 200 m x 200 m)



Using the U.S. Census Bureau's year 2000 census data, we estimated the population within the isopleth boundaries. Table V-4 presents a summary of the area impacted and the population affected for the risk ranges of greater than 10 in a million, greater than 100 in a million, greater than 200 in a million, and greater than 500 in a million. Over two million people live in the area around the ports that has predicted cancer risks of greater than 10 in a million due to hotelling emissions from ocean-going vessels. In other words, almost everyone living within the domain is exposed to a risk level of equal or greater than

10 in a million. Note that the size of the modeling domain was limited by the technical capabilities of the model. However, it is clear that a significant number of people outside the modeling domain are exposed to potential cancer risks greater than 10 in a million.

Table V-4: Summary of Area Impacted and Population Affected by Risk Levels from Hotelling Emissions from Ocean-Going Vessel Auxiliary Engines (Emission Inventory Based on 2006 Port Calls)

Risk Level	Acres Impacted	Population Affected
Risk > 500	30	750
Risk > 200	4,100	87,500
Risk > 100	21,000	341,000
Risk > 10	163,435	1,978,000

Note: The effective modeling receptor domain is about 255 square miles or 163,435 acres, and the total population within the domain is about 2 million. The area with predicted risks greater than 10 in a million extends beyond the modeling domain. As such, the actual acres impacted and population exposed to levels greater than 10 in a million are larger than those presented in Table V-4.

Health Risk Assessment Methodology for Cancer

Because analytical tools to distinguish between ambient diesel PM emissions from hotelling emissions and that from other sources of diesel PM do not exist, we cannot measure the actual concentration of diesel PM from ocean-going vessels at-berth. In place of direct measurements of diesel PM, we rely on a health risk assessment process to estimate the potential cancer risks from hotelling emissions form ocean-going vessels. A health risk assessment, as defined under the Air Toxics "Hot Spots" Act, includes a comprehensive analysis of the dispersion of hazardous substances into the environment, the potential for human exposure, and a quantitative assessment of both individual and population-wide health risks associated with those levels of exposure.

To investigate the potential risks from exposures to hotelling emissions, ARB staff used dispersion modeling to estimate the ambient concentration of diesel PM from hotelling vessels at the Ports of Los Angeles and Long Beach. The key variables that can impact the results of a health risk assessment for ocean-going vessel auxiliary engines at-berth include the diesel PM emission rate and release characteristics (magnitude, location, and time of day of the emissions), the local meteorological conditions, and the length of time a person is exposed to the emissions.

Diesel PM emissions are a function of the age and horsepower of the auxiliary engine, the average load the engine is operated at when the vessel is at-berth, the emissions rate of the engine, and the annual hours the ships is at-berth.

Older engines tend to have higher pollutant emission rates than newer engines, and the longer an engine operates, the greater the total pollutant emissions. Meteorological conditions can have a large impact on the modeled concentration of diesel PM, with higher concentrations found along the predominant wind direction and under lower or calm wind conditions. How close a person is to the emissions plume and how long they breathe the emissions (exposure duration) are key factors in determining potential cancer risk, with longer exposure times typically resulting in higher risk.

To examine the potential cancer risks from hotelling emissions, staff used an existing analysis of 2002 diesel PM emissions from port related activities (including hotelling emissions) at the Port of Los Angles and the Port of Long Beach with updated 2006 estimated hotelling emissions.

Meteorological data from Wilmington was used for this study. The Wilmington site is about one mile away from the ports, and the measurements were collected in 2001. The U.S. EPA's Industrial Source Complex Dispersion Model (ISCST3) air dispersion model was used to estimate the annual average offsite concentration of diesel PM in the area surrounding the two ports.[2] The modeling domain (study area) spans a 20 by 20 mile area, which includes both the ports, the ocean surrounding the ports, and nearby residential areas in which about two million people live. The land-based portion of the modeling domain, excluding the property of the ports, comprises about 65 percent of the modeling domain. A Cartesian grid receptor network (160 by 160 grids) with 200-by-200-meter resolution was used in this study. While grids within the ports were included in the receptor network, the risks within these grids were excluded from the final risk analyses. The elevation of each receptor within the modeling domain was determined from the United States Geological Service topographic data.

The potential cancer risks were estimated using standard risk assessment procedures based on the annual average concentration of diesel PM predicted by the model and a health risk factor (referred to as a cancer potency factor) that correlates cancer risk to the amount of diesel PM inhaled. The methodology used to estimate the potential cancer risks is consistent with the Tier-1 analysis presented in the Office of Environmental Health Hazard Assessment (OEHHA) Air Toxics Hot Spots Program Risk Assessment Guidelines. (OEHHA, 2002) (OEHHA, 2003) Consistent with the OEHHA guidelines, we assumed that the most impacted individual would be exposed to modeled diesel PM concentrations for 70 years. This exposure duration represents an "upper-bound" of the possible exposure duration. The potential cancer risk was estimated by multiplying the inhalation dose by the cancer potency factor (CPF) of diesel PM (1.1 milligrams per kilogram body weight-days $(mg/kg\text{-}d)^{-1}$).

[2] The U.S. EPA has promulgated the AERMOD model as the preferred air dispersion model and ISCST3 had been phased out of use by November 2006. The ARB's estimates of potential health risk associated with emissions of diesel PM at the ports of Los Angeles and Long Beach was completed in 2005.

D. Estimating Potential Non-Cancer Impact of Emissions from At-Berth Ocean-Going Vessel Auxiliary Engines

To estimate the statewide potential non-cancer health impacts from auxiliary engines on hotelling ships, ARB staff used the same methodology used in Appendix A of the Ports and Goods Movement Emission Reduction Plan (ARB, 2006b) with an updated PM-mortality relationship based on new published data (Pope 2002). The following section first discusses the statewide non-cancer risks estimates for auxiliary engines on hotelling ships. This is followed by a discussion of the methodology used to develop the non-cancer risk estimates.

Non-Cancer Risk Estimates

Staff estimates that current exposure to direct and secondary diesel PM emissions from at-berth ocean-going vessel auxiliary engines can be associated with about 61 premature deaths per year. Due to the location of the ocean-going vessels' operations, their emissions were assumed to affect the population only within the county in which the vessels are docked.

Using the 2006 statewide estimate of directly emitted diesel PM hotelling emissions and the relationship of diesel PM to PM-mortality derived from Pope's work, we estimate approximately 39 premature deaths (11 – 68, 95 percent confidence interval (95% CI)) per year statewide due to uncontrolled, directly emitted diesel PM from auxiliary engines on hotelling ships.

Using the 2006 statewide estimate of NOx hotelling emissions and the relationship of NOx/nitrate to PM-mortality discussed below, we estimated approximately 22 (6 – 36, 95% CI) premature deaths per year statewide due to uncontrolled, secondary diesel PM from auxiliary engines on hotelling ships.

In addition to PM-mortality, we estimate that the 2006 estimated emissions (directly emitted and secondary sources) from at-berth ocean-going vessel auxiliary engines will result in the following non-cancer health impacts:

- 13 hospital admissions due to respiratory causes (8 – 18, 95% CI)
- 24 hospital admissions due to cardiovascular causes (15 – 37, 95% CI)
- 1,800 cases of asthma-related and other lower respiratory symptoms (700 – 2,800, 95% CI)
- 150 cases of acute bronchitis (0 – 320, 95% CI)
- 11,000 work loss days (9,000 – 12,000, 95% CI)
- 61,000 minor restricted activity days (50,000 – 72,000, 95% CI)

Non-Cancer Health Effects Methodology

Primary Diesel PM

Consistent with U.S. EPA (EPA, 2004), ARB has been using the PM-premature death relationship from Pope et al. (2002) since the approval of the Ports and Goods Movement Emission Reduction Plan by the Board (ARB, 2006). In 1998, the ARB estimated a statewide population-weighted average diesel $PM_{2.5}$ exposure of 1.8 $\mu g/m^3$ (ARB, 1998). Using this population-weighted exposure estimate and the study by Pope et al. (2002), staff estimated that diesel PM exposure can be associated with a mean estimate of 2,200 premature deaths per year in California, about 10% higher than previous estimates (Lloyd and Cackette, 2001). The diesel $PM_{2.5}$ emissions corresponding to the diesel $PM_{2.5}$ concentration of 1.8 $\mu g/m^3$ is 36,000 tons for the year 2000 based on the emission inventory developed for this rule.

Using this information, we estimate that reducing 17 tons per year of diesel $PM_{2.5}$ emissions would result in one fewer premature death. This factor is derived by dividing 36,000 tons of diesel PM by 2,168 deaths (unrounded number of deaths described above). Although a single statewide factor (tons per death) is discussed in this example, staff actually developed basin-specific factors for the health impacts assessment of emissions from the operation of auxiliary engines on hotelling ships. These basin-specific factors were developed using basin-specific diesel PM concentrations and emissions for the year 2000. The basin-specific factors were applied to the county where each port is located to estimate health impacts.

Using these basin-specific factors and after adjusting for population changes between 2000 and 2006, staff estimates that 580 tons of emissions from the operation of auxiliary engines on hotelling ships for the year 2006 are associated with approximately 39 annual deaths (11 – 68, 95% CI). Estimates of other health impacts, such as hospitalizations and asthma symptoms, were calculated using basin-specific factors developed from other health studies. Details on the methodology used to calculate these estimates can be found in Appendix A of the Emission Reduction Plan for Ports and Goods Movement in California (ARB, 2006).

Secondary Diesel PM

In addition to directly emitted PM, diesel exhaust contains NOx, which is a precursor to nitrates, a secondary diesel-related PM formed in the atmosphere. Lloyd and Cackette (2001) estimated that secondary diesel $PM_{2.5}$ exposures from NOx emissions can lead to additional health impacts beyond those associated with directly emitted diesel $PM_{2.5}$. To quantify such impacts, staff developed population-weighted nitrate concentrations for each air basin using data not only from the statewide routine monitoring network, which was used in Lloyd and

Cackette (2001), but also from special monitoring programs such as IMPROVE and Children's Health Study (CHS) in the year 1998. The IMPROVE network provided additional information in the rural areas, while the CHS added more data to southern California. Staff calculated the health impacts resulting from exposure to these concentrations and then associated the impacts with the basin-specific NOx emissions to develop basin-specific factors (tons per death). The basin-specific factors were applied to the county where each port is located to estimate health impacts. Using a similar approach as that for primary diesel PM and adjusting for population changes between 2006 and 1998, staff estimates that approximately 7,000 tons of emissions from the operation of auxiliary engines on hotelling ships in year 2006 are associated with an estimated 22 annual premature deaths (6 – 36, 95% CI). Other health effects were also estimated as outlined above.

E. Assumptions and Limitations of Health Impacts Assessment

Several assumptions were used in quantifying the health effects of PM exposure. They include the selection and applicability of the concentration-response functions, the exposure assessment, and the baseline incidence rates. These are briefly described below.

- For premature death, calculations were based on the concentration-response function of Pope et al. (2002). ARB staff assumed that the concentration-response function for premature death in California is comparable to that developed by Pope and colleagues. This is supported by other studies (Dominici et al. 2005, Franklin et al. 2007) in California showing an association between $PM_{2.5}$ exposure and premature death similar to that reported by Pope et al. (2002). In addition, the Pope et al. (2002) study included subjects in several metropolitan areas of California. The U.S. EPA has been using the Pope et al. (2002) study for its regulatory impact analyses since 2004. For other health endpoints, the selection of the concentration-response functions was based on the most recent and relevant scientific literature. Details are in the Emission Reduction Plan for Ports and Goods Movement in California (ARB, 2006).

- ARB staff assumed the model-predicted diesel PM exposure estimates published in the report titled "Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant" (ARB, 1998) could be applied to the entire population within each basin. That is, the entire population within the basin was assumed to be exposed uniformly to modeled concentration, an assumption typical of this type of assessment.

- Due to the location of the ocean-going vessels' operations, their emissions were assumed to affect the population only within the county in which the vessels are docked.

- The basin-specific factors relating emissions to health effects were applied to the county where each port is located to estimate health benefits. That is, ARB staff assumed that the basin-specific factors applied to each county within a basin.

- ARB staff assumed the baseline incidence rate for each health endpoint was uniform across each county. This assumption is consistent with methods used by the U.S. EPA for its regulatory impact assessment, and the incidence rates match those used by U.S. EPA.

- Although the analysis illustrates that reduction in diesel PM exposure would confer health benefits to people living in California, we did not provide estimates for all endpoints for which there are C-R functions available. Health effects such as myocardial infarction (heart attack), chronic bronchitis, and onset of asthma were unquantified due to the potential overlap with the quantified effects such as lower respiratory symptoms and hospitalizations. In addition, estimates of the effects of PM on low birth weight and reduced lung function growth in children are not presented. While these endpoints are significant in an assessment of the public health impacts of diesel exhaust emissions, there are currently few published investigations on these topics, and the results of the available studies are not entirely consistent (ARB, 2006). In summary, because only a subset of the total number of health outcomes is considered here, the estimates should be considered an underestimate of the total public health impact of diesel PM exposure.

REFERENCES:

California Air Resources Board. *Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach*, April 2006. (ARB, 2006a)

California Air Resources Board. *Emission Reduction Plan for Ports and Goods Movement in California*; April 2006.
http://www.arb.ca.gov/planning/gmerp/march21plan/march22_plan.pdf
(ARB, 2006b)

California Air Resources Board. *Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant*, Appendix III, Part A, Exposure Assessment, April 1998. (ARB, 1998)

California Air Resources Board and Office of Environmental Health Hazard Assessment. *Staff Report: Public Hearing to Consider Amendments to the Ambient Air Quality Standards for Particulate Matter and Sulfates*, 2002.
http://www.arb.ca.gov/research/aaqs/std-rs/pm-final/pm-final.htm; (ARB, 2002)

Dominici et al. 2005. Revised analyses of the National Morbidity, Mortality, and Air Pollution Study: mortality among residents of 90 cities. J Toxicol Environ Health A. Vol. 68(13-14):1071-92.

Franklin et al. Association between PM2.5 and all-cause and specific-cause mortality in 27 US communities. J Expo Sci Environ Epidemiol. Vol. 17: 279-287, 2007.

Lloyd, A.C.; Cackette, T.A.; *Diesel Engines: Environmental Impact and Control*; J Air Waste Manage. Assoc. 2001, 51: 809-847, 2001.
http://www.arb.ca.gov/research/seminars/lloyd/AWMA2001/JAWMADieselCriticalReview.pdf (Lloyd /Cackette, 2001)

Office of Environmental Health Hazard Assessment. *The Air Toxics Hot Spot Program Risk Assessment Guidelines: Part II-Technical Support Document for Describing Available Cancer Potency Factors*; 2002. (OEHHA, 2002)

Office of Environmental Health Hazard Assessment. *Air Toxics Hot Spots Program Risk Assessment Guidelines: The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*; 2003. (OEHHA, 2003)

Pope et al. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. Journal of the American Medical Association. Vol. 287 (9): 1132-41, 2002.
(Pope, et. al., 2002)

U.S. Environmental Protection Agency (EPA), Assessment and Standards Division, Office of Transportation and Air Quality. *Final Regulatory Analysis: Control of Emissions from Nonroad Diesel Engines Chapter 4*. EPA420-R-04-007. May 2004. http://www.epa.gov/nonroad-diesel/2004fr/420r04007j.pdf (EPA, 2004)

VI. SUMMARY OF THE PROPOSED REGULATION

In this chapter, we provide a plain English discussion of the key requirements of the proposed regulation for reducing emissions from ocean-going vessels while they are docked (or “hotelling”). This chapter begins with a general overview of the regulation. The remainder of the chapter follows the structure of the proposed regulation and provides an explanation of each major requirement of the proposal. This chapter is intended to satisfy the requirements of Government Code section 11346.2, which requires that a noncontrolling “plain English” summary of the regulation be made available to the public.

A. Overview of the Proposed Regulation

The proposed regulation requires that the operators of container ships, refrigerated cargo ships (“reefers”), and passenger ships visiting specific California ports either shut down their auxiliary engines for most of their visit to a port or reduce the emissions from those auxiliary engines by some specified percentages while docked. The specific California ports identified in the proposed regulation where these requirements would apply are the Ports of Los Angeles, Long Beach, Oakland, San Diego, San Francisco, and Hueneme. The Ports of Los Angeles and Long Beach are considered one port for purposes of this regulation.

The “limited engine use” option requires operators of container ships, passenger ships, and reefers that visit California ports to shut down their auxiliary engines for most of their stay while hotelling. Auxiliary engines would be allowed to run for three or five hours per visit. Specifically, these auxiliary engines must be shut down for at least 50 percent of a fleet’s total visits to a California port in 2014 and at least 80 percent of the fleet’s total visits to a port in 2020. While auxiliary engines are shut down, the ship’s onboard electrical requirements would need to be satisfied by some other source of power. The source of electrical power used instead of the auxiliary engines must be provided either by the grid or by another power source that meets specific emissions standards.

The “emissions reduction” option requires vessel operators to reduce their fleet hotelling emissions by specific amounts by specific dates, depending on the types of emission reduction techniques that are applied to the fleet. The emission reduction techniques that could be applied to a fleet include: 1) using selected vessels for grid-based power based on potential auxiliary engine emission reductions rather than fleet visit percentages; 2) using distributed generation equipment to provide power to a vessel; 3) using alternative emission controls onboard a vessel or adjacent to the vessel; and 4) using a combination of these techniques.

B. Purpose

The purpose of this proposed regulation is to reduce emissions of diesel PM and NOx, with a co-benefit of reducing CO_2, a significant greenhouse gas (GHG). If adopted, the proposed regulation will achieve significant emission reductions. Specifically, the proposed regulation will have the following benefits:

- diesel PM emission reductions will reduce the potential cancer risk, premature mortality, and other adverse health impacts from PM exposure to people who live in the vicinity of California's major ports;

- diesel PM emission reductions will reduce regional exposure to PM, and help continue progress toward State and federal ambient air quality standards for PM_{10} and $PM_{2.5}$;

- NOx emission reductions will reduce the formation of regional ozone and secondary nitrate PM; and

- CO_2 emission reductions will reduce overall GHG emissions and help mitigate the effect of GHGs on global climate change.

C. Applicability

The regulation would apply to any person who owns, operates, charters, rents, or leases any container ship, passenger ship, or refrigerated cargo ship that visits a California port, or any person who owns or operates a port or terminal located at a port where container, passenger, or refrigerated cargo (also known as "reefer") ships visit. These ports include Los Angeles, Long Beach, Oakland, San Diego, San Francisco, and Hueneme. For purposes of complying with the proposed regulation, the ports of Los Angeles and Long Beach are considered as one port.

The regulations apply to both U.S.-flagged vessels and foreign-flagged vessels. Foreign-flagged vessels are vessels registered under the flag of a country other than the United States.

D. Exemptions

The proposed regulation contains general and specific exemptions. Under the general exemptions, vessels in "innocent passage"; vessels owned or operated by local, state, federal or foreign governments in government non-commercial service; steamships; and auxiliary engines using natural gas are exempt from the regulation.

"Innocent passage" generally means travel within the 24 nautical miles boundary off California's coastline without stopping or anchoring, except in limited situations such as when the vessel is in distress or must stop to comply with U.S. Coast Guard regulations.

Military ships used for purposes of national defense and safety would not be affected by the proposed regulation. The military operates numerous vessels and the Navy has a long tradition of using shore-side services, including electricity, when vessels are in port. ARB staff is unaware of any local or state entity that operates an ocean-going vessel.

A steamship is an ocean-going vessel whose primary propulsion and electrical power are provided by steam boilers. Unlike engines, boilers must be shutdown and started up over many hours making it infeasible to shutdown these boilers for the typical port visit. Additionally, there are less then ten steamships currently visiting California ports. These ships are all container vessels that are 40 years old and represent only two percent of the total container vessels that visited California ports during 2006.

Although staff is not aware of any vessels using natural gas in their auxiliary engines, we provided an exemption for vessel operators who may choose to switch fuels to natural gas. As with shore-based engines used in distributed generation applications, switching to natural gas reduces NOx emissions by 85 percent and eliminates diesel PM emissions.

There are also particular exemptions from specified portions of the regulation for emergency events and delays caused by federal agency inspections and a de minimus exemption for small fleets, which will be discussed later in this chapter.

As noted earlier in this report, vessel categories that are not attractive candidates for shore power—bulk and general cargo ships, tankers, and vehicle carriers—are excluded from the proposed regulation; however, staff proposes to address the auxiliary engine emissions from these vessels in a subsequent rulemaking.

E. Limited Auxiliary Engine Operation

General Requirements

The proposed regulation allows for two options for reducing a fleet's hotelling emissions: 1) ship operators can either shut down their auxiliary engines during most of their stay while in port; or 2) ship operators can reduce the emissions from those auxiliary engines while in port by applying one or several emission-reduction techniques to their fleet's vessels. Each option would have different compliance dates.

The "limited engine use" option in the proposed regulation requires that the operators of container ships, passenger ships, and reefers that visit California ports shut down their auxiliary engines during most of their stay while hotelling. Specifically, these auxiliary engines must be shut down for at least 50 percent of a fleet's total visits to a California port in 2014 and at least 80 percent of the fleet's total visits to a port in 2020. While auxiliary engines are shut down, the ship's onboard electrical needs must be satisfied by some other source of power. The source of electrical power used instead of the auxiliary engines must be provided either by the grid or by another power source that meets specified emission standards.

Staff recognizes that sufficient time must be allowed to connect and disconnect electrical lines for shore power, so the proposed regulation allows the auxiliary engines to operate for up to three hours total during a visit on vessels using synchronous power transfer, or five hours total during a visit for vessel that lose power during the process of switching power from the vessel's auxiliary engines to shore power. This time period may be extended due to circumstances beyond the control of the vessel operators, such as emergency events or delays resulting from obligations imposed by federal agencies (for example, the U.S. Coast Guard or some other branch of the Department of Homeland Security).

The regulation defines "fleet" as vessels operated under the direct control of a person or a company. Direct control includes the operation of vessels that are under a contract, lease agreement, or other arrangement with a third-party to operate the vessels. Under of the proposed regulation, a company or person will have a different fleet for each California port visited.

A "visit" is defined in the regulation as the time period between when a vessel initially ties its mooring lines upon arrival at a berth and when it casts off its mooring lines prior to departure. When a vessel visits two different berths and the time interval between when the mooring line is cast off at the first berth visited and when the mooring line is initially tied to the next berth is less than two hours, then those two berth visits are still considered one "visit." This provision was added to ensure that ships visiting more than one berth at the ports of Los Angeles and Long Beach (which are treated as one port in the regulation) within a short amount of time would be treated as one visit. Port wharfinger data indicated that some container and reefer vessels do visit more than one berth in the POLA/POLB complex during a visit.

Compliance Dates for Grid-Based Shore Power

While the final requirements of the proposed regulation are consistent with the proposal in the Goods Movement Emission Reduction Plan (80 percent of vessel visits to California ports using shore power by 2020), the interim compliance dates and vessel visit percentage requirements in the proposed regulation are different. As discussed in Chapter I, the strategy for shore power contained in the Goods Movement Emission Reduction Plan required 20 percent of the vessel visits to California ports use shore power by 2010 and 60 percent of the vessel visits use shore power by 2015.

Staff did not propose a 2010 compliance requirement for grid-based shore power. Grid-based shore power implementation will require extensive modification to port and terminal electrical infrastructures. In some cases, a significant upgrade to the utility grid may be needed to bring the additional electrical power to the port. Such modifications are likely to require environmental review, permits, and complex construction—construction activity that needs to be coordinated with an operating terminal—which is likely to take up to five years to complete. Assuming the proposed regulation is effective in late 2008, the proposed regulation's initial milestone of 2014 for shore power allows for five years for initial implementation.

Although 2014 is the first compliance date for grid-based shore power in the proposed regulation, staff expects earlier reductions to occur from shore power projects already planned at some California ports. Emissions reductions from vessels using shore power at Long Beach and Los Angeles will occur well before 2014 because of commitments made in the Clean Air Action Plan. If the plan is fully implemented, staff anticipates reductions of 1,300 tons of NOx emissions and 37 tons of PM emissions by 2011, which represents a reduction in emissions of 15 percent for NOx and 20 percent for PM of emissions in 2011 at the ports. The ports are continuing to update the Clean Air Action Plan, and it is likely both ports will identity additional reductions for shore power prior to 2014. In addition, to satisfy the 2014 milestone, staff anticipates that emission reductions as a result of the regulation will begin in 2011 and significant reductions will occur in 2012 and 2013.

Finally, the proposed regulation requires that 50 percent of the vessel visits connect to shore power in 2014 as opposed to the Goods Movement Emission Reduction Plan's strategy for a shore power that requires 60 percent of the vessel visits use shore power by 2015. Staff proposed a compliance date one year earlier to allow the NOx emission reductions from the proposed regulation to be used to satisfy the South Coast air basin SIP for attaining the $PM_{2.5}$ ambient air quality standard. By moving the date up one year, staff proportionally reduced the percentage of vessel visits from 60 percent to 50 percent.

De Minimus Fleet Visit Levels

Since the emission reduction requirements of the proposed regulation are based on fleet averages, ARB staff recognized that infrequent visitors belonging to small fleets should be exempt from the regulation. Those vessels are simply not cost-effective for shore power. Consequently, ARB staff added a de minimus limit to the proposed regulation for each ship category.

For example, at the Port of San Diego in 2006, 18 vessels from 18 different passenger ship companies visited just once. Without a de minimus exemption, each of those vessels would have to retrofit to use shore power. (The regulation does require that if any of these ships were already equipped for shore power, it would have to plug into a berth that is likewise equipped with shore power capabilities.) There are similar cases in the container ship and reefer ship categories.

Staff chose 25 visits as the de minimus number of fleet visits for the container ships and reefers because the 2006 data revealed that, below that level, shore power was not cost-effective due to infrequent visitation of those vessels to a California port. Nevertheless, the capture of ship visits to California ports is extremely high, as seen in Table VI-1.

Table VI-1: Percentage of Vessel Fleets Subject to the Proposed Regulation (2006 Wharfinger Data)

Category	Total / Affected Fleets	Total / Affected Visits	Percentage of Visits Captured
Container Ships	66 / 44	4,928 / 4,737	96 %
Passenger Ships	51 / 15	686 / 632	92 %
Reefers	11 / 3	300 / 203	68%
Total	128 / 62	5,914 / 5,572	94%

Most of the reefer fleets are exempt from the proposed regulation; however, these fleets make too few visits and are seasonal in nature to be cost-effective for shore power. By affecting the three largest reefer fleets in California, the proposed regulation will capture two-thirds of the total visits by reefers.

F. Emissions Reduction Option

General Requirements

An alternative to the “limited engine use” approach is the “emissions reduction” option, in which the ship operators reduce their fleet hotelling emissions by applying one or several emission-reduction techniques to their fleet’s vessels. The compliance dates for this approach are different than those for the limited engine use option. Grid-based power involves a significant lead time to install at a terminal. Alternative emission controls, such as distributed generation (DG) power and emission controls onboard a vessel or at the berth, could provide reductions in hotelling emissions much earlier than grid-based shore power. Consequently, staff is requiring earlier compliance dates for the “emission reduction option” than what is required for the “limited engine use.”

The emission reduction techniques that could be applied to a fleet include: 1) ship operators selecting vessels for grid-based power based on potential auxiliary engine emission reductions rather than fleet visit percentages; 2) using distributed generation equipment to provide power to a vessel; 3) using alternative emission controls onboard a vessel or adjacent to the vessel; and 4) a combination of these techniques.

Compliance Dates for Emission Reduction Option

For ship operators satisfying the emission reduction option by selecting vessels for grid-based power based on potential auxiliary engine emission reductions rather than fleet visit percentages, the NOx and PM emissions from the fleet's auxiliary engines at a port must be reduced by 50 percent from the baseline fleet emissions by 2014 and by 80 percent by 2020.

For ships satisfying the emission reduction option by using distributed generation equipment to provide power to a vessel or by using onboard or shore-side alternative emission controls, the NOx and PM emissions from the fleet's auxiliary engines at a port must be reduced by 20 percent from the baseline fleet emissions by 2010, 40 percent by 2012, 60 percent by 2014, and 80 percent by 2016.

For ships satisfying the emission reduction option by using a combination of grid power, distributed electrical generation, or alternative emission controls, the NOx and PM emissions from the fleet's auxiliary engines at a port must be reduced by 20 percent from the baseline fleet emissions by 2012, 50 percent by 2014, and 80 percent by 2020.

Percent Emission Reduction Calculations

Percent emission reductions are calculated as a ratio between the emissions reduced and the baseline emissions, which are defined as the emissions that would have otherwise occurred if no controls had been applied. Baseline fleet emissions are calculated by multiplying the emission rate, average berthing time, average at-berth power load, and number of visits of each ship and summing the results for each ship in the fleet. Post-baseline fleet emissions are calculated in a similar fashion with the addition of multiplying a control factor, where applicable, for each ship's emission rates.

The proposed regulation provides default values for making the percent emission reductions calculation, including default values for emission factors and power requirements. In addition, the proposed regulation provides procedures for determining control factors and applicable emission testing procedures.

Requirements for Distributed Generation (DG) Power

Sources of electrical power, other than the grid, that are used to comply with the emission reduction option would be required to satisfy additional requirements. Before January 1, 2014, distributed generation equipment must satisfy the emission standards applicable to a newly manufactured spark-ignited off-road engine. These engines are typically 85 percent cleaner than the NOx emissions from the vessel's auxiliary engines and do not emit any diesel PM. However, after factoring in the time the vessel is actually using the power from another source, the overall efficiency for NOx reduction will be 70 to 80 percent and diesel PM reduction will be 85 to 95 percent.

As of January 1, 2014, all distributed generation would be subject to a more stringent emission standard that is equivalent to a spark-ignited engine using Best Available Control Technology (BACT). The application of BACT will reduce emissions of NOx from distributed generation by another order of magnitude (from two grams per kilowatt-hour to 0.2 grams per kilowatt-hour). Finally, the source of electrical power must emit no more CO_2 (a greenhouse gas) emissions than a combined-cycle gas turbine—the emissions level that the California Public Utilities Commission recommended for unspecified sources of power.

G. Test Methods

The proposed regulation includes test methods to determine the emissions from the auxiliary engines when alternative emissions controls are applied in lieu of shutting off the engines while hotelling, or from engines used for distributed generation of electricity. Specifically, the proposed regulation requires using ARB Method 100 testing for NOx and CO_2; ISO 8178 test procedures for diesel PM; Bay Area Air Quality Management District Source Test Procedure ST-1B for ammonia slip from SCR systems; and ISO 8754 for the sulfur content of fuel.

H. Recordkeeping and Reporting Requirements

The proposed regulation has reporting and recordkeeping requirements affecting the vessel operators, terminals and ports.

Vessel Operators

The reporting and recordkeeping requirements for vessel operators depend upon the compliance option selected by the vessel operator. The proposed regulation requires a vessel fleet plan to be submitted to the Executive Officer of the ARB in the year prior to the year of the fleet's regulatory compliance dates. The regulatory compliance dates and the fleet plan due dates are listed in Table VI-2 below, according to each compliance option available to vessel operators.

Table VI-2: Schedule of Compliance Dates and Fleet Plans for Vessel Operators for Each Regulatory Compliance Option

Date	Limited Engine Operation (Grid)	Reduced Emission Operation (Grid)	Reduced Emission Operation (Non-Grid)	Reduced Emission Operation (Both)
July 1, 2009	-	-	Fleet plan	-
January 1, 2010	-	-	Compliance date	-
July 1, 2011	-	-	Fleet plan	Fleet plan
January 1, 2012	-	-	Compliance date	Compliance date
July 1, 2013	Fleet plan	Fleet plan	Fleet plan	Fleet plan
January 1, 2014	Compliance date	Compliance date	Compliance date	Compliance date
July 1, 2015	-	-	Fleet plan	-
July 1, 2016	-	-	Compliance date	-
July 1, 2019	Fleet plan	Fleet plan	-	Fleet plan
January 1, 2020	Compliance date	Compliance date	-	Compliance date

In addition to the vessel fleet plans, the proposed regulation requires an annual statement of compliance to be submitted to the Executive Officer of the ARB certifying compliance with the regulatory requirements for the previous calendar year. As with the fleet plans, the dates for the initial submittals depend upon the compliance option selected by the vessel operator. The initial submittal dates for the annual statements of compliance are listed below in Table VI-3 according to each compliance option available to vessel operators.

Table VI-3: Schedule for Initial Submittal of Annual Statements of Compliance for Each Compliance Option

Compliance Option	First Regulatory Compliance Date	Initial Submittal of Annual Statement of Compliance
Limited Engine Operation (Grid)	January 1, 2014	March 1, 2015
Reduced Emission Operation (Grid)	January 1, 2014	March 1, 2015
Reduced Emission Operation (Non-Grid)	January 1, 2010	March 1, 2011
Reduced Emission Operation (Both)	January 1, 2012	March 1, 2013

The recordkeeping and reporting requirements are simpler for the limited engine use option because they focus on only those vessels that will comply with the 2014 and 2020 shore power requirements. The recordkeeping and reporting requirements for the emission reduction option are more significant because the vessel operator must track the emissions of each vessel in the fleet.

<u>Terminal Operators</u>

A terminal that receives more than 50 vessel visits in 2008 is required to submit a plan to the Executive Officer of the Air Resources Board by July 1, 2009. This plan is required to identify how the terminal will be upgraded to allow affected vessels to satisfy either the limited engine use option or the emissions reduction option. The terminal is also required to submit plan updates at a frequency dependant upon the control strategy selected by the vessel and terminal operators. The plan updates must include contingency measures, should the planned infrastructure modifications identified in the original plan prove to be infeasible by the specified target dates.

In addition, the terminal operator is required to keep records of equipment breakdowns that affect a vessel’s ability to comply with the limited engine use option or the emission reduction option, and records of electricity usage for shore power.

<u>Ports</u>

The port is required to submit wharfinger data annually to ARB’s Executive Officer. The port’s report must document when each vessel visits the port, the berth that the vessel visited, and the dates and times that the vessel was initially tied to the berth and subsequently released from the berth.

I. Violations

The proposal specifies a violations provision that provides, among other things, that any violation of any part of the regulation would constitute a single, separate violation for each hour that the violation occurs. The exception to this would be for violations of the recordkeeping and reporting requirements; a violation of those provisions would constitute a single, separate violation for each day that the violation occurs.

J. Regulatory Alternatives

Staff considered two regulatory alternatives: 1) targeting the highest-emitting ships to obtain the necessary reductions, or 2) using best available control technology (BACT) on auxiliary engines while the ship is hotelling.

Alternative 1 would target the ships that make the most visits to specific ports and make them use shore power or an equivalent control technology to reduce hotelling emissions. For example, a requirement under this regulatory alternative might state "container ships making more than four visits to a California port in 2014 must turn off their engines or use an alternative control technology."

Staff estimated that this regulatory alternative would be as effective as the proposed regulation; however, staff did not pursue this alternative because of the complexity and difficulty of tracking the ships that were required to reduce emissions. Many of these ships would be repositioned elsewhere, while other ships would replace them in California service, creating excessive recordkeeping requirements and practical enforcement challenges.

Alternative 2 requires vessel operators to install BACT on their auxiliary engines. Currently, few emission-control technologies that have been used successfully on land-based engine applications have been demonstrated on marine engines. Nevertheless, for the purpose of determining a potential cost-effectiveness of this alternative, staff selected selective catalytic reduction (SCR) for NOx emissions reductions and diesel oxidation catalyst (DOC) for diesel PM emissions reductions.

Installing this equipment on the same ships affected by the proposed regulation would cost less than the overall cost of the proposed regulation. However, the reduction of PM emissions would be considerably less with this BACT alternative because DOCs achieve only about 25 percent PM emission reductions. Furthermore, the varying load of the auxiliary engines during transiting, maneuvering, and hotelling would compromise the performance of the SCR, achieving less than 80 percent emissions reduction.

Considering the unproven application of these technologies for marine engines, fewer total emissions reductions, and much higher cost-effective values for diesel PM emissions reductions, staff did not pursue this alternative regulatory alternative.

VII. FEASIBILITY OF PROPOSED REGULATORY REQUIREMENTS

The proposed regulation allows for two options to reduce hotelling emissions; ship operators can either shut down their auxiliary engines during most of their visit to a port ("limited engine use" option), or reduce the emissions from those auxiliary engines by some specified percentages while docked ("emissions reduction option").

Staff expects most ship operators to comply with the limited engine use option in the regulation. While the proposed regulation's shutdown requirement does not require vessels, ports, or terminals to install or modify any equipment, staff anticipates that vessel owners, ports, and terminals will elect to install equipment that will allow vessels to use shore power while the auxiliary engines are shut down at berth. The source of the shore power is expected to be the utility grid. However, some ship operators may decide to reduce their fleet hotelling emissions by applying a number of other techniques to their fleet, including using alternative sources of power at the berth (e.g. distributed generation equipment), and using onboard or shore-based engine emission control technologies.

This chapter will discuss the feasibility of grid-based shore power, modifications that would be needed to ships and terminals to make shore power a viable hotelling emission reduction measure, and port power demands for meeting the shore power requirements. Staff will also discuss possible distributed generation technologies that operators could use as alternative sources of shore power, NOx and PM emission reduction control strategies that could be used to reduce fleet emissions, and emission reduction demonstration projects that have been conducted on marine vessel engines.

A. Shutting Off Engines and Connecting to Grid-Supplied Shore Power

The regulation requires ship operators to shut off auxiliary engines except for three or five hours of total operation, during 50 percent and 80 percent of port visits by 2014 and 2020, respectively. To achieve this, power that would otherwise be supplied by the ships' auxiliary engines must be available at the berth, and the ships must be able to connect to the shoreside power.

As was demonstrated in Chapter IV, grid-supplied shore power has been proven and is technologically feasible. Shore power is already being used or will soon be used for passenger ships, container ships, bulk ships and oil tankers at California ports. Shore power is currently used at the China Shipping Terminal at the Port of Los Angeles (POLA) and at the USS POSCO facility at Pittsburg. Ships will soon be utilizing shore power at two other container terminals at POLA and at a tanker terminal at the Port of Long Beach (POLB). In addition, POLA and POLB have committed to adding shore power to their passenger-ship terminals and to several of their container-ship terminals. Several passenger ships that visit California ports have been retrofitted to connect to shore power, and some container ship owners have committed to adding shore power equipment to their newbuilds and retrofitting some of their existing fleet with shore-power capabilities.

As was illustrated in Chapter IV, modifications are needed for both terminals and ships to utilize grid-based shore power as a method for reducing hotelling emissions. The following sections discuss these modifications.

Terminal Modifications

Terminal operators will have to design shore-power installations based on the types of ships visiting the terminal. Container-ship, passenger-ship, and reefer-ship terminals may have different shore-power designs because the ships have different voltage and power loads. Most ocean-going vessels, including reefers, are configured for 440 - 480 volts (V). Larger container ships and passenger ships are configured for 6.6 kilovolts (kV), although the larger, newer, passenger ships are configured for 11 kV. The future trend in container-ship design is to build larger ships that use 6.6 kV; however, some manufacturers are still building vessels to operate on 440 - 480 V. Since all ships do not have the same voltage requirements, a transformer will be needed to increase or decrease the voltage to a ship. The terminal operator must decide if the transformer will be provided at the berth or expected to be onboard visiting ships. For example, the Ports of Los Angeles (POLA) and Long Beach (POLB) will provide 6.6 kV power at their container terminals when they install future shore power projects. Ships using lower voltage will be expected to use an onboard transformer during shore power connection. However, the cruise ship terminal at the Port of Los Angeles will have a dual voltage transformer at the wharf to accommodate the various-sized passenger ships that visit the port.

Terminal operators must also decide if power connection cables will be placed at the berth or onboard the visiting ships. As with transformers, POLA and POLB will expect visiting ships to carry the necessary connecting cables and reels onboard, but the passenger ship terminal at POLA will have cables and reels stored on-site.

Transformers, cables, and other necessary power connection equipment can also be placed in a container that is permanently stored on a ship. Some container ship companies have indicated that they will use this configuration with the ships they choose to retrofit with shore power capability.

To accommodate ships that carry cables onboard, receptacles must be provided at the berth into which the ships can plug and receive the power. More than one power receptacle may be needed at the berth to accommodate various-sized ships and to allow ships to tie-down to the berth on the port or starboard side.

Ship Modifications

Shipping companies that visit shore-power equipped terminals will have to modify existing ships that visit the terminals or build new ships with shore power capabilities. As was mentioned in Chapter IV, some passenger ships have been retrofitted with shore power capabilities and some were built with shore power equipment. The same will be true with container ships. Currently no reefer ships have been modified or built with shore power capabilities. Typically, shipping companies frequently change their ships' route of service. To reduce the number of ships needing to be retrofitted, ship companies may need to commit their shore-power equipped ships to specific routes for several years.

Synchronization of Power Transfer

Ship owners will also have to consider the synchronization of power transfer when retrofitting existing ships or for new-builds. Some vessels will lose power for a period of time during the process of switching power from the vessel's auxiliary engines to shore power because the power transfer is not synchronized. However, ship side shore power equipment can be designed to synchronize power transfer so that the power from the shore is ramped up while the power from the auxiliary engines is ramped down. In this manner, there is no interruption to the ship's power load demands during transfer. Passenger ships use synchronized power transfer when connecting to shore power because any interruption to power on these types of ships is unacceptable.

Standardization of Power Connection

With six ports and over 1,400 ships potentially affected over the life of the proposed regulation, standardization of power connections will be a concern to ship and terminal operators. Generally, the number of cables needed to connect ships to shore power is based on the voltage and power load of the ship. Ships with lower-power voltage would require more cables for power connection. For example, nine cables are used to supply 440 V of power to the ships at POLA's China Shipping Terminal. The container ship, *NYK Atlas*, which operators at 6.6 kV, uses two cables to connect to shore power. Four power cables are used to supply passenger ships (which generally have higher power loads than container ships) with 6.6 kV or 11 kV of power in Juneau and Seattle.

Recognizing the importance of standardizing shore power connection at ports throughout the world, the International Organization of Standardization (ISO) formed a working group under its Technical Committee 8, Ships and Marine Technology, to develop a standardized shore-to-ship power system. The Port of Los Angeles is a member of this working group. Subcommittees have been formed to explore a number of issues related to developing a shore-to-ship power standard, including power demand, voltage, reliability, power transfer, equipment location, power outlets, and cable management systems. The objective is to establish Publicly Available Specifications (PAS), which will allow ports and carriers to refer to an official document that provides shore-to-ship power specifications.

Additional Power Supply for Shore Power

Power demand will increase at the ports as shore power installations are added to the terminals. ARB staff estimated the total power demand for satisfying the shore power requirements by 2020. Table VII–1 presents peak load in megawatts (MW) and annual power consumption in megawatt-hours (MW-hr) by 2020 for each affected ship category and port.

Table VII-1: Estimated Peak Load and Annual Power Consumption by 2020 for Shore Power

Port	**Ship Category**	**Peak Load (MW)**	**Annual power consumption (MW-hr) by 2020**
Los Angeles	Container	40	215,000
Long Beach	Container	40	168,000
Oakland	Container	20	94,000
Los Angeles	Passenger	30	40,000
San Diego	Passenger	30	53,000
Long Beach	Passenger	15	24,000
San Francisco	Passenger	15	9,000
San Diego	Reefer	10	24,000
Hueneme	Reefer	5	16,000
Statewide totals		**205**	**643,000**

By 2020, the peak load for shore power will be approximately 205 megawatts, and the annual power consumption for all ship categories will be over 640 gigawatt-hours. Not surprisingly, container ships, having the most ship visits to Californian ports, will have the greatest annual power consumption (about 75 percent of the statewide total). Although there are far fewer passenger ships visiting California ports than container ships, passenger ships have the highest at-berth power loads of all three ship categories, resulting in significant annual power consumption. The number of reefer ships affected by the proposed regulation will be the fewest of the three ship categories. Considering that reefer ships have lower power loads, reefers are expected to make up the smallest portion of annual power consumption from shore power by 2020.

Based on projected power consumption information in the most recent Integrated Energy Policy Report from the California Energy Commission, the power demand for shore power in 2020 will represent less than one-quarter of one percent of the State's overall annual power consumption.

To meet this additional power demand, the ports must work with their local utility companies to ensure that the power can be delivered to the port. Some ports will be able to use the utility's existing circuits to access the additional power, and others will have to rely on new substations for the power. For example, the utility companies for the Ports of Los Angeles and Hueneme have indicated that they can provide the additional power demands with their existing system. However, the utility for the Port of Long Beach will have to install new substations to satisfy the additional power demand for shore power.

Public utilities are required, either through city charters for municipal-owned utilities or the Public Utilities Code for investor-owned utilities, to provide service to their customers upon request, although the timing and infrastructure costs are negotiable.

B. Reducing Fleet Hotelling Emissions Using Alternative Sources of Power and Engine Emission Control Technologies

An alternative to the limited auxiliary engine compliance approach is the "emissions reduction option," in which the fleets reduce their auxiliary engine emissions at a port by specific percentages and by specific dates. The emission reduction techniques that could be applied to a fleet include: 1) using select vessels for grid-supplied power based on potential auxiliary engine emission reductions rather than fleet visit percentages; 2) using alternative sources of power (distributed generation equipment) to provide power to a vessel; 3) using alternative emission controls onboard a vessel or adjacent to the vessel; and 4) using a combination of these techniques.

Alternative Sources of Shore Power

Alternative sources of power at the berth could be supplied by distributed electrical generation (DG) technologies, such as fuel cells, engines, and turbines. The proposed regulation would only allow the use of DG technologies that meet specific emission limits.

Terminal operators would need to consider space constraints at the berth when considering using a DG technology. The size of the DG equipment would depend on the ship's auxiliary engine load that it would be replacing. For example, if a ship generally has a one-megawatt auxiliary engine load while at berth, the DG technology must be able to supply an equivalent amount of power to the ship during its visit. Sufficient space must be available for a DG technology if it is installed permanently at a terminal. A more attractive option to operators may be portable DG that could be moved from berth to berth at the terminal. As with connecting to grid-supplied shore power, ships would need to be equipped with shore power capabilities to connect to DG shore power.

Alternative Emission Control Technologies

Alternative emission control technologies for auxiliary engines could include alternative fuels and post-combustion control measures. Emission control equipment for auxiliary engines could be placed at the berth or onboard the ships. While many control technologies have been proven to reduce emissions of PM and NOx from land-based diesel-fueled engines, there is limited experience in applying these technologies to marine vessel engines. In addition, there are currently no emission control strategies verified by the ARB for marine applications. Some of these technologies have been applied to harbor craft engines, but those applications were on much smaller engines than the auxiliary engines on ocean-going vessels.

A few demonstration projects have been conducted on auxiliary ocean-going vessel engines. These involved the use of portable distributed generation, a seawater scrubber, biodiesel fuel, an on-demand water/fuel emulsion system, and selective catalytic reduction. However, because these technology demonstrations are still at an early stage, ARB staff cannot predict at this time the future deployment or feasibility of these alternative technologies as effective emission control measures for auxiliary engines on ships at berth.

Several factors would impact the selection of an alternative emission control strategy, including the engines' duty cycles, the varying hotelling power load requirements of different ship types and sizes, the exhaust system configuration, available space for control equipment, the size and weight of the proposed emission control strategy, and age of the engines. In addition, any design modification must be approved by the U.S. Coast Guard prior to changes being made to a U.S.-flagged ship.

Table VII-2 provides general descriptions of diesel NOx and PM emission reduction control strategies that have been used in diesel engine applications and includes a brief description of demonstration projects that have been applied in the marine environment. Most of these projects are primarily with harbor craft engines, but a few have been conducted on ocean-going vessels. More details on the various control technologies and demonstration projects are provided in Appendix F.

Table VII-2: Emission Control Strategies for Diesel Marine Engines

Control Technology	Brief Description	Potential Emission Reductions		Demonstration Projects
		Diesel PM	NO_x	
Diesel Particulate Filters (DPF)/Catalyzed Diesel Particulate Filters (CDPF)	DPF-Removes PM through physical filtration usually through a ceramic filter. CDPF- ceramic diesel particulate filter along with a platinum catalyst to catalyze the oxidation of carbon-containing emissions	85%	0%	One project to date, a DPF was installed on an auxiliary engine of a ferry. Emission testing results have not been provided.
Diesel Oxidation Catalysts (DOC)	After-treatment with catalytic surfaces that enhance the combustion of carbonaceous pollutants	25%	0%	DOCs have been installed on vessels in Europe with some success. One known installation on a large container ship in CA. No specific data available.
Flow-through Filters (FTF)	Densely packed material that either traps PM or causes turbulent exhaust flow to enhance combustion of unburned hydrocarbons	50–75%	0%	One installation on a work boat with 400 hp Detroit Diesel propulsion engines. Emission testing results available.
Selective Catalytic Reduction (SCR)	Injects ammonia or urea into the exhaust, in the presence of a catalyst, to reduce NO_x to nitrogen and water	0%	50–85%	SCR has been used on a variety of European marine vessel main and auxiliary engines for a number of years. Here in California, SCR was installed on a catamaran ferry and a few large container ships. Recent information indicates this application has issues that need to be addressed.
Water/Fuel Mixture	Water absorbs heat in the combustion chamber. This reduces the peak combustion temperature and, in turn, reduces NO_x formation	0%	One-to-one water to NO_x up to 20% water	One installation on a ferry with 1,000 hp Detroit Diesel propulsion engines. Emission testing results available. One demonstration project to date on the main engine of a 5,100-TEU container ship is incomplete.
Humidify Intake Air/ Water Injection at Air Intake	Water absorbs heat in the combustion chamber, reducing the peak combustion temperature which reduces NO_x formation	0%	15–25%	Humid Air system tested on high speed hydrofoil ferry – 1050 hp engines. Water injection tested on Tier 0, 360 hp, ferry engine.

Table VII-2: (cont.). Emission Control Strategies for Diesel Engines

Control Technology	Brief Description	Potential Emission Reductions		Demonstration Projects
		Diesel PM	NO_x	
Alternative Fuels	Impacts on emissions depend on the fuel type	Fuel Dependent	Fuel Dependent	One demonstration of the potential of biodiesel in the marine sector. Biodiesel, B20 and B100, was used. A report of the results available. One major cruise line uses biodiesel in its main engines which are gas turbines.
Exhaust Gas Recirculation (EGR)	Reduces NO_x formation by diluting the fuel mixture in the chamber with exhaust gas and reducing the combustion temperatures	PM disbenefit 50-300%	15-50%	To date, there have been no demonstrations of this technology with a marine application.
Sea Water Scrubber	Sea water is pumped to a scrubber where calcium carbonate in the water absorbs all the SOx from the exhaust gas to produce harmless calcium sulphate. The majority of particulates as well as some NOx are also removed and stripped from the water prior to discharge.	Up to 80%	5%	One installation in Europe on a 1 MW auxiliary engine of a ferry. Demonstration project on one of the diesel generator of a large cruise ship is currently undergoing evaluation and testing.
Portable Distributed Generation	Uses alternative fuels such as liquefied natural gas (LNG) to power a generator mounted on a trailer which supplies electricity to the ship.	Fuel Dependent	Fuel Dependent	Demonstration project in the proof of concept phase at the Port of Oakland supplied partial power to 5,100-TEU container ship. Port of Richmond demonstration project scheduled.
Shore-based After-Treatment System	Captures exhaust gases from a ship's stack and channels them to a chamber scrubber and a SCR	Fuel Dependent	Fuel Dependent	System tested on a locomotive at Roseville, CA rail yard. Fall 2007 testing scheduled for a bulk ship at the Port of Long Beach
Fuel Cells	Converts chemical energy to electricity by combining oxygen from the air with fuel	100%	100%	No fuel cells are currently in-use in marine applications. The WTA plans to include fuel cell technology as the auxiliary engine in a future vessel.

C. In-Use Experience with Marine Engine Emission Control Strategies

Demonstration Projects

This section provides a more detained discussion of emission control demonstration projects that were conducted or will be conducted on marine engines including harbor craft and ocean-going vessels. Although there have been only a limited number of demonstration projects for emission control techniques used on ocean-going vessel engines, there has been more testing of emission-control techniques on harbor craft engines, specifically on ferries. These engines, however, are generally much smaller than those used on ocean-going ships.

1. Diesel Particulate Filter on U.S. Navy Workboat

In 2006, one of two DDC 12V-71 400 horsepower engines on a U.S. Navy workboat operating in the Suisun Bay was rebuilt with Clean Cam Technology (CCT) system, including combustion chamber and injector modifications and the addition of a turbocharger. Based on preliminary emissions tests results, the rebuilt engine reduced PM emissions by over 30 percent and NO_x emissions by approximately 70 percent. A Rypos active flow-through DPF was tested on the engine before it was rebuilt with CCT. This filter achieved a PM reduction of approximately 70 percent and a small NO_x reduction. Used together, the CCT and Rypos active DPF achieved over 80 percent PM reduction and over 70 percent NO_x reduction. Durability testing of the system was completed in late 2006.

This project is a prime example of the uniqueness associated with the installation of marine-related after-treatment controls. The DPF was engineered specifically for the space available below deck, the average engine load, and the size of the engines powering the vessel. In addition, modifications were made to the vessel's exhaust system to ensure that there would be no intrusion by salt water into the system.

This demonstration shows that DPFs are a technology that has the potential for wider marine applications if steps are taken to ensure that the control device is sized appropriately and any unique feature of the vessel design or operation is addressed in the system's design.

2. Selective Catalytic Reduction

SCR systems have been used on European marine vessels to reduce NOx emissions since the early 1990's. European SCR designer and manufacturer Munters estimates that it has delivered and installed over 200 SCR systems for both main and auxiliary marine engines on close to 60 vessels throughout

Europe. (Munters, 2007) Here in the United States, marine applications of SCR systems are relatively new and less widespread.

a. *Sophie Maersk* Container Ship

In 2005, a urea-based SCR was installed on auxiliary engine #5 of the container ship *Sophie Maersk*. The University of California, Riverside, CE-CERT in association with Maersk and CARB, conducted the testing using a partial dilution system conforming to ISO 8178. NOx and PM were measured at engine loads of 25 percent, 50 percent and 75 percent on three separate dates using both heavy fuel oil (HFO) and marine diesel oil (MDO).

The NOx reductions averaged 90 percent at the three test loads using HFO and there were no PM reductions. The NOx reductions averaged nearly 100 percent at the three test loads using MDO, but the ammonia slip was high at 10 to 70 parts-per-million (ppm). The PM reductions averaged approximately 60 percent when using MDO. (Maersk, 2007)

b. Vallejo Baylink Ferry

In 2004, the Vallejo Baylink Ferry launched *M/V Solano*, a low-emissions ferry utilizing a urea-based SCR system made by Steuler GmBH. The SCR system was used with the two MTU/DDC 16V-4000 propulsion engines with rated power of 3100 hp each. The SCR system was designed to reduce NO_x by 57 percent. (Baylink, 2006; MARAD, 2003)

In July of 2007, engine alarms indicating high cylinder temperature activated in the *M/V Solano*'s propulsion engines. Baylink staff inspected the engine and the SCR unit. They found that a number of the starboard engine cylinders showed excessive wear as well as ring damage. Upon opening up the starboard SCR unit, they found extensive damage to the catalyst blocks. The catalyst block damage included what appeared to be salt water corrosion and excessive heat and mechanical impacts. The Baylink staff has published a report and continues to look into the potential reasons for the damage to the engine and the SCR unit. (Baylink, 2007)

c. Staten Island Ferry

The two Caterpillar 3516 1,550-horsepower propulsion engines of the *M/V Alice Austen* were retrofitted with SCR and diesel oxidation catalyst in 2004. The system was designed to reduce NO_x by 50 percent as well as PM by 25 percent. (Bradley, 2006)

The *M/V Alice Austen* has been operating with SCR since 2005. The vessel is in service during the night runs of the Staten Island Ferry system (9 p.m. to 5 a.m.). The route that the vessel is assigned includes two 20-minute runs and idling periods during passenger loading and unloading. There have been no problems with the SCR system.

d. San Francisco Bay Area Water Transit Authority Ferry

The San Francisco Bay Area Water Transit Authority (WTA) is planning on building two new 149-passenger ferries to be put into service in late 2008, which will include exhaust after-treatment to reduce NOx emissions by at least 85 percent beyond Tier 2 standards. The ferries are being designed to incorporate a compact SCR system coupled with an oxidation catalyst with the 1410-hp Detroit Diesel propulsion engines. The inclusion of the after-treatment system will require about six feet to be added to the vessel's overall length. The ferries' design includes a dry exhaust with a high exhaust stack. (WTA, 2006)

3. Water/Fuel Mixture

a. San Francisco Bay Area Water Transit Authority Ferry

In 2003, the San Francisco Bay Area WTA partnered with the Golden Gate Bridge, Highway and Transit District, to test PuriNOx™, a water and diesel emulsion, on the ferry *M/V Golden Gate*. The 28-year-old ferry is powered by two 671-hp Caterpillar 3412C turbocharged and after-cooled diesel engines. Its fuel tanks were cleaned, and for 11 weeks it ran on PuriNOx™ fuel instead of conventional diesel fuel. No filter fouling was observed. The fuel emulsion remained stable in the fuel tanks. Because emissions testing was conducted during periods of passenger service, test points were limited to full cruising power, idle in-gear, and idle in-neutral. PM was reduced by approximately 60 percent at high power, but increased somewhat at idle. NOx was only slightly reduced at high power. There were no operational implications resulting from lower maximum power. (MARAD, 2003a)

b. Container Ship *APL Singapore*

In spring 2007, an on-demand water/fuel emulsion system was installed on the *APL Singapore* container ship using funding from the Carl Moyer Program administered by Santa Barbara County Air Pollution Control District (SBCAPCD), the Port of Los Angeles, Port of Long Beach, Ventura County APCD, and the San Luis Obispo APCD. (APL, 2007a)

In September 2007, the water/fuel emulsification of 10 percent water was used in the main engine on a voyage from Hong Kong to Los Angeles with no adverse effects to the engine. The mixture was increased to 22 percent water on the subsequent trip from Los Angeles to Oakland. University of California Riverside, CE-CERT was responsible for baseline emissions testing and will perform post-retrofit emissions testing in October 2007. (APL, 2007b)

4. Humid Air Injection

SCX Ferries, Inc and MARAD tested the emission reduction potential of an air humidification system on a hydrofoil ferry in San Diego, California. The ferry is powered by four high-speed Detroit Diesel 12V92 diesel-fueled engines, each rated at 1050 hp driving two water jets. The water injection (fumigation) system reduces NO_x by reducing peak combustion temperatures. The system was able to reduce NO_x by about 16 percent. (MARAD, 2003)

5. Alternative Fuels

a. Blue and Gold Fleet Ferry

In 2002, Blue and Gold Fleet and the San Francisco Bay Area WTA released the results of emission testing conducted on the 400-passenger ferry *M/V OSKI*. The *OSKI* is powered by twin two-stroke, 12V-71, Detroit Diesel engines. The testing established NOx and PM emissions for baseline operation with low-sulfur diesel fuel, for a 20-percent blend of biodiesel, for 100-percent biodiesel, and for a continuous water injection system with both low-sulfur diesel and 100-percent biodiesel fuel.

The biodiesel fuel was a soy-based methyl-ester type. Biodiesel is a renewable energy source that reduces greenhouse gases and particulate matter. However, biodiesel often increases NOx emissions. In order to reduce NOx, a continuous water injection system was installed to inject finely atomized water droplets in the engine's intake air system. Water injection reduces maximum combustion temperatures and, consequently, reduces NOx emissions.

At the data points tested, B20 produced a NOx increase ranging from 2 to 11 percent, and the B100 increase ranged from 5 to 20 percent. The water injection system, which was only operated at higher powers, reduced NOx by averages greater than 20 percent. B100 generally reduced PM emissions by over 50 percent.

Formal fuel performance tests were not conducted, but the operator stated there was no noticeable change in consumption when the continuous water injection system was applied.

Blue and Gold, a ferry operator in San Francisco Bay, managed the project with MARAD as a co-sponsor. The water injection equipment was purchased from MA Turbo/Engine Ltd. of Vancouver, British Columbia. The biodiesel fuel was purchased from World Energy, Inc. Testing and test reports were by Walther Engineering. (MARAD, 2003b)

b. Royal Caribbean Cruise Lines

In 2007 Royal Caribbean Cruises, Ltd. began to use biodiesel in its ships equipped with gas turbines, (Royal, 2006) and in August 2007 entered into a 5-year contract with a biodiesel producer to purchase a minimum of 15 million gallons of B100 fuel in 2007 and a minimum of 18 million gallons each year thereafter. (GreenCar, 2007)

6. Sea Water Scrubber

Holland America Line is conducting a seawater scrubber feasibility project aboard the MS Zaandam in 2007-08 with the assistance of EPA/West Coast Collaborative and Puget Sound Clean Air Agency grants.

The sea water scrubber system was scheduled to be installed in April 2007 with operation and testing of the system from May 2007 to October 2008. Results are scheduled to be reported in October 2008. (Holland, 2007a)

The same company that manufactured the sea water scrubber system for the *MS Zaandam* also installed a similar system on the ferry *M/V Pride of Kent* in the United Kingdom in 2005. (Holland, 2007)

7. Shore-Based After-Treatment System

The Advanced Cleanup Technologies, Inc. (ACTI) system was tested on a locomotive engine at the Roseville, CA rail yard in the summer of 2006. Emissions testing data is available. The same system is scheduled to be fitted to a dock-side crane for testing on at a bulk ship terminal at the Port of Long Beach in the late fall 2007. (ACTI, 2006)

8. Combined Technologies

In 2006, Cleaire worked with Blue and Gold Ferries in San Francisco to install an after-treatment control system on a ferry. The system installed consisted of a DPF and a lean NO_x catalyst element. The lean NO_x catalyst element was a diesel fuel injector located down-stream of the DPF. The diesel fuel served as a catalyst to reduce NO_x.

The after-treatment control system was sized and installed on the ferry based on a successful demonstration in on-road bus Detroit Diesel 4 stroke engines. The engines on the ferry were identical to those on the bus. During the course of emission testing the system on simulated ferry runs, the diesel fuel injector in the lean NO_x catalyst element was thermally destroyed. After several attempts to resolve that issue, the demonstration and emission testing was discontinued. It is assumed that the failure was due to the difference in a ferries engine load and cycle when compared to that of an on-road bus.

9. Foss Tugboat with Hybrid System

The Foss Tug Company of Seattle, Washington recently “laid keel” on a Dolphin-class hybrid tug boat. The tug boat will be a stern-drive vessel used primarily for harbor assist services. The tug boat’s electric drive units will be powered by two 670-horsepower battery packs coupled with two 335-horsepower diesel-fueled generators. Although the main engines will have lower horsepower than those found in the existing Dolphin-class tug boats, the total horsepower of the hybrid tug boat will be equal to that of the existing Dolphin-class tug boats—about 5,000 hp.

Foss anticipates a number of benefits from the use of hybrid technology. These benefits include over a 40-percent reduction in emissions of PM and NO_x, lower fuel consumption, and a reduction in the noise associated with the operation of the vessel. It is anticipated that the vessel will begin operations in 2008. (Foss, 2007)

10. Portable Distributed Generation

In July 2007, Wittmar Engineering and Construction, Inc. (Wittmar), with financial support from the Port of Oakland, the Bay Area Air Quality Management District (BAAQMD) and Pacific Gas & Electric (PG&E), conducted a proof-of-concept test of its portable distributed generation system on the 5,100-TEU *APL China* container ship at the Port of Oakland. The liquefied natural gas (LNG) powered generator supplemented one of the ship’s auxiliary engines and provided partial power to the ship for an 18-hour test period. Another proof-of-concept test is planned at the Port of Richmond. (APL, 2007)

REFERENCES:

Advanced Cleanup Technologies, Inc. *ACTI When Experience Counts*; Informational Brochure 2006.

Alimchandani, Jai K.; A.P. Moeller – Maersk Group; Regulatory Affairs Technical Organization. “Maersk Pilot Fuel Switch Initiative”. July 26, 2007. http://www.arb.ca.gov/ports/marinevess/presentations/072407/072407maepres.pdf

American Presidents Line Maritime Ltd. “APL announces breakthrough plan to reduce emissions.” Press Release. June 13, 2007.

American Presidents Line Maritime Ltd. *Draft Emissions Testing Protocol: In-use Emissions Testing of an Ocean-going Vessel Retrofitted with Emissions Control Technologies (2006/2007) APL-Singapore Container Ship*; May 01, 2007.

Baylink Ferry. SCR Project-M/V Solano. June 30, 2007.

California Air Resources Board. *Evaluation of Cold-Ironing Ocean-Going Vessels at California Ports*; March 2006. http://www.arb.ca.gov/ports/shorepower/report.pdf

California Energy Commission. *Integrated Energy Policy Report*; November 2005. http://www.energy.ca.gov/2005publications/CEC-100-2005-007/CEC-100-2005-007-CMF.PDF

DieselNet. http://dieselnet.com/tech/engine_adv.html (DieselNet, 2002a)

Foss Maritime Company. “World’s First True Hybrid Tug to be Built by Foss Maritime.” Press Release. March 7, 2007. http://www.foss.com/press/Press_Release_030207.html

Frank Angelacci, American Presidents Line Maritime Ltd. Personal communication. September 10, 2007.

Green Car Congress, “Royal Caribbean Cruises Signs Long-Term Biodiesel Contract with Imperium Renewables.” August 7, 2007. http://www.greencarcongress.com/2007/08/royal-caribbean.html

Holland America Line. *Holland America Line - MS Zaandam Sea Water Scrubber Technology Demonstration Project Environmental Impact Assessment (EIA) Plan*; August 10, 2007.

Joseph Calavita, California Air Resources Board. Personal communication. October 5-6, 2006.

Los Angeles Department of Water and Power. Personal communication. September 14, 2007.

M.J. Bradley and Associates. *Staten Island Ferry: Alice Austen Vessel SCR Demonstration Project Final Report.* August 2006.

Martin Robbins, Baylink Ferry. Personal communication. October 24, 2006.

Munters Europe AB. *DEC SCR Converter System*. April 26, 2007.

Port of Los Angeles and Port of Long Beach. *San Pedro Bay Ports Clean Air Action Plan*; November 2006.
http://www.portoflosangeles.org/DOC/CAAP_Tech_Report_Final.pdf and/or
http://www.polb.com/civica/filebank/blobdload.asp?BlobID=3451

Public Utilities Commission (PUC). Chapter 3, Article 1, Section 451-467; Public Utilities Code. Date accessed: October 9, 2007. http://www.leginfo.ca.gov/cgi-bin/displaycode?section=puc&group=00001-01000&file=451-467

Royal Caribbean Cruises Ltd. "Royal Caribbean Reports Second Quarter 2006 Earnings." Press Release. July 27, 2006.

San Francisco Bay Area Water Transit Authority. "The SF Bay Area Water Transit Authority is Building Boats." Press Release. May 9, 2006.
http://www.watertransit.org/pressreleases/pressRelease050906.pdf

Sea to Sky Pollution Solutions. *WiFE on Demand*; September 5, 2007.
http://www.seatoskypollutionsolutions.com/solution-wife.php

Tina Stotz, Holland America Line, Inc. Personal communication. September 14, 2007.

U.S. Department of Transportation Maritime Administration Office of Shipbuilding and Marine Technology. *Energy Technologies. Newsletter No. 04*; Winter 2003-2004.
http://www.marad.dot.gov/nmrec/energy_technologies/images/ETNo4Winter0304.htm Date accessed: August 9, 2006.

U.S. Department of Transportation Maritime Administration Office of Shipbuilding and Marine Technology. *Energy Technologies. Newsletter No. 3*; Spring 2003.
http://marad.dot.gov/NMREC/energy_technologies/images/ETNo3Spring03.htm
Date accessed: August 12, 2007.

U.S. Department of Transportation Maritime Administration Office of Shipbuilding and Marine Technology. *Energy Technologies. Newsletter No. 2*; Fall 2002. http://marad.dot.gov/NMREC/energy_technologies/images/ETNo2Fall2002.htm Date accessed: August 12, 2007.

VIII. ENVIRONMENTAL IMPACTS

The proposed regulation is intended to protect the health of California's citizens by reducing auxiliary diesel engine emissions from ocean-going vessels while at-berth in a California port. This chapter describes the potential environmental impacts of the proposed regulation, including potential impacts on air quality, wastewater treatment, and hazardous waste disposal. Based upon available information, the ARB staff has determined that no significant adverse environmental impacts should occur as the result of adopting the proposed regulation.

A. Legal Requirements

The California Environmental Quality Act (CEQA) and ARB policy require an analysis to determine the potential environmental impacts of proposed regulations. Because the ARB's program involving the adoption of regulations has been certified by the Secretary of Resources pursuant to Public Resources Code section 21080.5, the CEQA environmental analysis requirements may be included in the Initial Statement of Reasons (ISOR) for this rulemaking. In the ISOR, ARB must include a "functionally equivalent" document, rather than adhering to the format described in CEQA of an Initial Study, a Negative Declaration, and an Environmental Impact Report. In addition, staff will respond, in the Final Statement of Reasons for the regulation, to all significant environmental issues raised by the public during the public review period or at the Board public hearing.

Public Resources Code section 21159 requires that the environmental impact analysis conducted by ARB include the following:

- An analysis of reasonably foreseeable environmental impacts of the methods of compliance;
- An analysis of reasonably foreseeable feasible mitigation measures; and
- An analysis of reasonably foreseeable alternative means of compliance with the regulation.

Compliance with the proposed regulation is expected to directly affect air quality and potentially affect other environmental media as well. Our analysis of the reasonable foreseeable environmental impacts of the methods of compliance is presented in the next section.

Regarding mitigation measures, CEQA requires an agency to identify and adopt feasible mitigation measures that would minimize any significant adverse environmental impacts described in the environmental analysis. As mentioned earlier, based upon available information, the ARB staff has determined that no significant adverse environmental impacts should occur as the result of adopting the proposed regulation.

The proposed regulation is needed to reduce the risk from exposures to diesel PM as required by Health and Safety Code (HSC) section 39666 and 39667, to help fulfill the goals of the October 2000 Diesel Risk Reduction Plan (ARB, 2000), and to help meet the goals of the Goods Movement Emission Reduction Plan (ARB, 2006). The regulation is also necessary to fulfill ARB's obligations under HSC 43013 and 43018 to achieve the maximum feasible and cost effective emission reductions from all mobile source categories, including marine engines. The emission reductions from the proposed regulation in ambient levels of PM, and NO_x will help make progress in meeting the State and Federal ambient air quality standards for ozone and PM in non-attainment areas of the State.

Regarding alternative mean of compliance with the regulation, alternatives to the proposed regulation were discussed in the Chapter VI. ARB staff has concluded that there are no feasible alternative mitigation methods that would achieve similar diesel PM and NOx emission reductions at a lower cost.

B. Effects on Air Quality

The proposed regulation will provide diesel PM and $NO_{x,}$ emission reductions throughout California, especially in communities surrounding California's major ports, areas which, in most cases, are non-attainment for federal ambient air quality standards for ozone, PM10, and PM2.5. The regulation would also have a co-benefit of reducing CO_2 emissions. A more detailed discussion of the CO_2 emission reduction benefits expected from the proposed regulation is included in Chapter IX.

The projected controlled hotelling emissions from ocean-going vessels from the three ship categories affected by the proposed regulation are presented in Table VIII-1.

Table VIII-1: Projected 2014 and 2020 Hotelling Emissions with Proposed Regulation Implementation (Tons per Day)

Category	Current 2006 Emissions		2014 Controlled Emissions		2020 Controlled Emissions	
	PM	NO_x	PM	NO_x	PM	NO_x
Container ships	1.12	13.8	0.19	10.6	0.13	7.4
Passenger ships	0.24	2.5	0.03	1.7	0.03	1.6
Refrigerated cargo ships	0.07	0.9	0.01	0.5	0.01	0.5
Totals	1.42	17.2	0.23	12.8	0.17	9.5

Note: Sums may not be exact due to rounding.

The reductions due specifically to the regulation are summarized in **Table VIII-2**, and Table VIII-3. As can be determined from the information provided in the tables, PM and NOx emissions will be 50 percent lower in 2014 and 75 percent lower in 2020 than they would be without the regulation.

Table VIII-2: Projected Statewide Diesel PM Emissions Benefits of the Proposed Regulation

Year	PM Emissions without Regulation (tons/day)	PM Emissions with Regulation (tons/day)	Emission Reductions (tons/day)	% Emission Reductions
2014	**0.47**	**0.23**	**0.24**	**51**
2020	**0.67**	**0.17**	**0.50**	**75**

Table VIII-3: Projected Statewide NOx Emissions Benefits of the Proposed Regulation

Year	NOx Emissions without Regulation (tons/day)	NOx Emissions with Regulation (tons/day)	Emission Reductions (tons/day)	% Emission Reductions
2014	**26.1**	**12.8**	**13.3**	**51**
2020	**37.3**	**9.5**	**27.8**	**74**

Figures VIII-1 and III-2 show the projected diesel PM and NOx hotelling emissions for container ships, passenger ships, and reefer ships, with and without implementation of the proposed regulation. The uncontrolled projections assume emissions from implementation of ARB's auxiliary engine fuel regulation.[3]

Figure VIII-1: Projected Diesel PM Emissions With and Without the Proposed Regulation

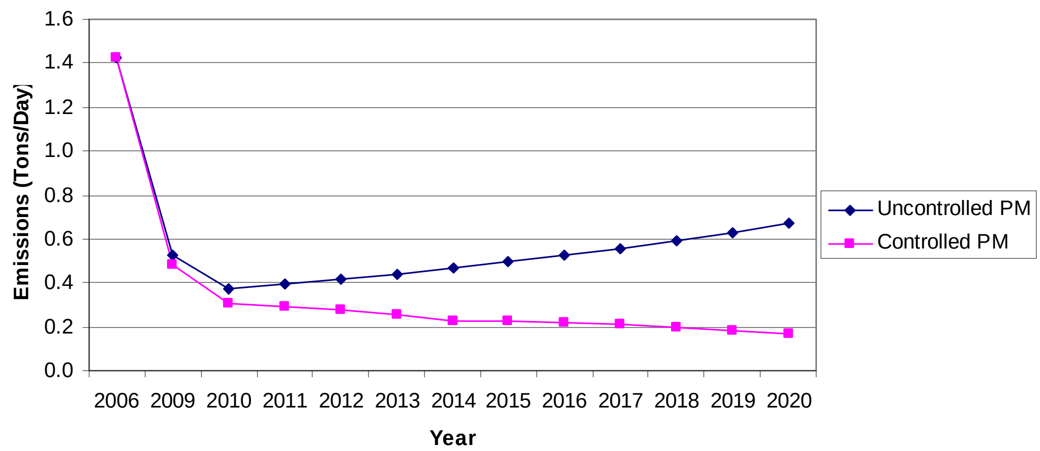
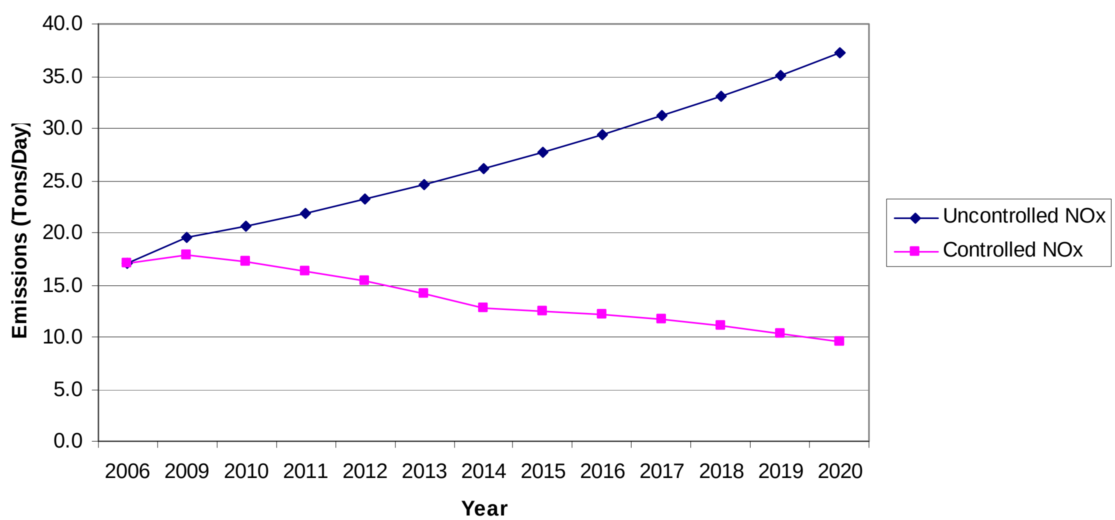


Figure VIII-2: Projected NOx Emissions With and Without the Proposed Regulation



[3] See title 13 CCR § 2299.1 and title 17 CCR § 93118. At the time this Technical Support Document (TSD) was published, those regulations had been challenged in federal district court and undergoing appeal at the Ninth Circuit Court of Appeals. Pacific Merchant Shipping Ass'n v. Cackette, (E.D.Cal. Oct 05, 2007) 2007 WL 2914961 (No. Civ. S-06-2791-WBS-KJM). The analysis presented in this portion of the TSD assumes those auxiliary engine regulations will ultimately be upheld on appeal.

As summarized in Table VIII-4 below, staff estimates that approximately 1,100 tons of diesel PM and 61,700 tons of NO_x will be removed from California's air between 2006 and 2020 due to the implementation of the proposed regulation.

Table VIII-4: Emission Benefits from Implementation of the Proposed Regulation

	PM	**NO_x**
Total Emission Reductions 2006 to 2020 (Tons)	1,100*	61,700*
Annual Average Reductions (Tons per Year)	85	4,700

* For the container-ship category, the regulatory period is 2009 – 2030 to account for ship turnover. Total emissions reductions to 2030 are 2,600 tons of diesel PM and 140,000 tons of NOx.

C. Health Benefits Analysis

Reduced Ambient Particulate Matter Levels

A substantial number of epidemiologic studies have found a strong association between exposure to ambient particulate matter (PM) and adverse health effects. (ARB, 2002) For this report, ARB staff evaluated the impacts the proposed regulation would have on potential cancer risks and conducted a quantitative analysis of seven potential non-cancer health impacts associated with exposures to ambient levels of directly emitted diesel PM.

1. Reduction in Potential Cancer Risks

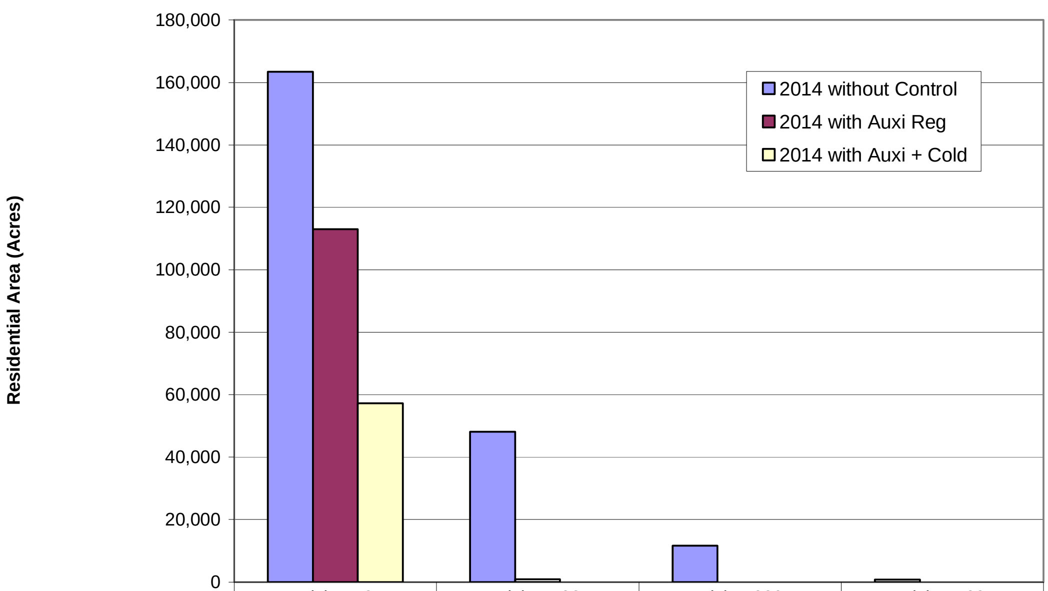
The reductions in diesel PM emissions that will result from implementation of the proposed regulation will reduce the public's exposures to diesel PM emissions and the potential cancer risks associated with those exposures. The ARB staff used the air dispersion model and model inputs developed for the Port of Los Angeles (POLA) and Port of Long Beach (POLB) health risk assessment to estimate the reductions in potential cancer risk that would result from implementation of the proposed regulation in the area surrounding the two ports. Staff believes that the results from this analysis provide quantitative results for exposures around POLA/POLB and are generally applicable to other ports in California, providing a semi-quantitative estimate for those areas.

To investigate the reductions in potential risks commensurate with the reductions in hotelling emissions from container ships, passenger ships, and reefer ships, ARB staff used dispersion modeling and the projected emissions inventories for 2014 and 2020. Staff estimated the ambient concentrations of diesel PM from hotelling emissions at POLA/POLB in those two years.

The auxiliary engine fuel regulation, adopted by the Board in December 2005, reduces diesel PM from hotelling ships by about 70 percent. Because of the expected growth in ship visits to California ports, however, the potential exposure of diesel PM to nearby residents will increase from 2007 to 2020 without further control. Staff estimates that the proposed regulation will reduce diesel PM by 75 percent in 2020. These emission reductions will more than offset the emissions increases from the growth in ship activity, thereby reducing the potential exposure to nearby residents.

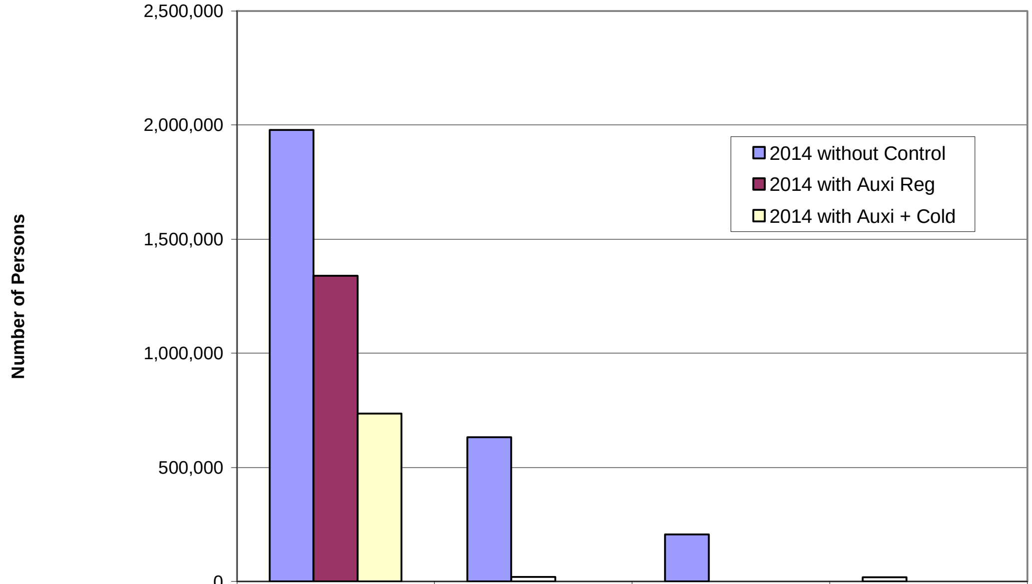
As shown in Figures VIII-3 through VIII-6, we expect a significant decline in the number of people exposed to elevated risk levels from hotelling emissions and the acres impacted as the auxiliary engine regulation is implemented. In addition to this reduction, the proposed at-berth ocean-going vessel regulation will reduce the number of residential acres and population exposed to diesel PM concentrations greater than 10 per million an additional 50 percent by 2014 and 70 percent by 2020. More importantly, all higher risk levels of greater than 100 in a million are eliminated due to implementation of the proposed regulation.

Figure VIII-3: Projected Residential Areas Impacted by Hotelling Emissions at POLA/POLB by 2014



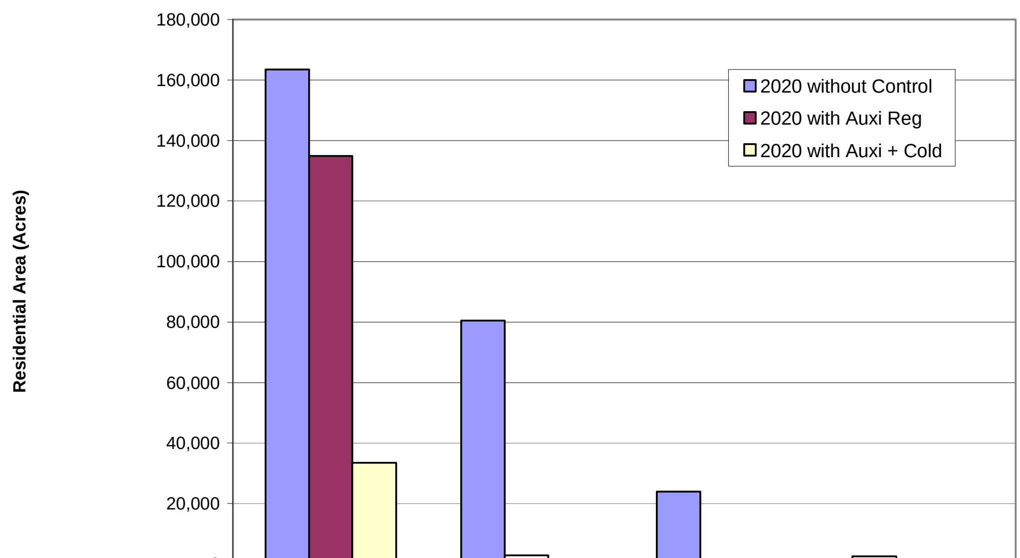
	Risk > 10	Risk > 100	Risk > 200	Risk > 500
2014 without Control	163,435	48,146	11,653	761
2014 with Auxi Reg	113,016	939	0	0
2014 with Auxi + Cold	57,269	0	0	0

Figure VIII-4: Projected Numbers of Population Affected by Hotelling Emissions at POLA/POLB by 2014



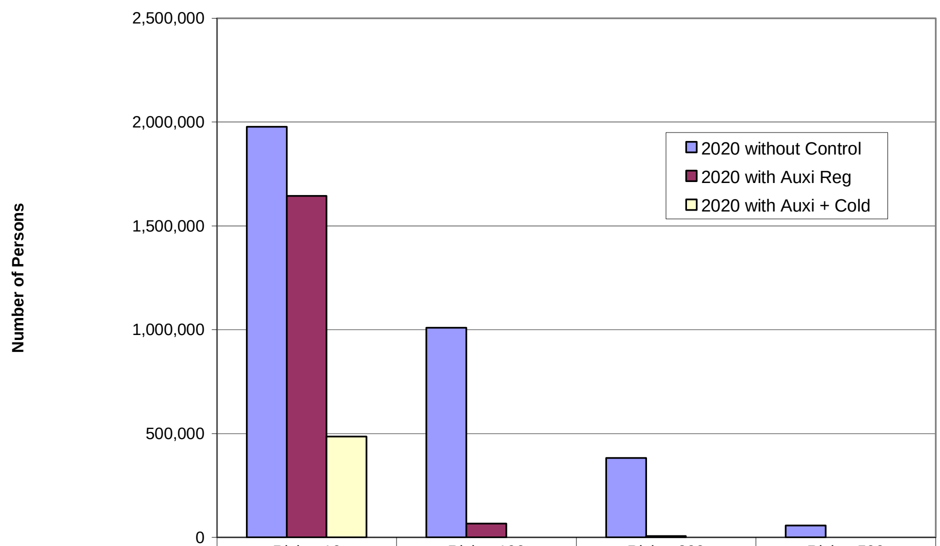
	Risk > 10	Risk > 100	Risk > 200	Risk > 500
2014 without Control	1,977,764	631,799	206,577	17,917
2014 with Auxi Reg	1,339,600	20,800	0	0
2014 with Auxi + Cold	736,000	0	0	0

Figure VIII-5: Projected Residential Areas Impacted by Hotelling Emissions at POLA/POLB by 2020



	Risk > 10	Risk > 100	Risk > 200	Risk > 500
2020 without Control	163,435	80,457	23,979	2,540
2020 with Auxi Reg	134,820	2,955	119	0
2020 with Auxi + Cold	33,517	0	0	0

Figure VIII-6: Projected Numbers of Population Affected by Hotelling Emissions at POLA/POLB by 2020



	Risk > 10	Risk > 100	Risk > 200	Risk > 500
2020 without Control	1,977,765	1,009,250	381,870	57,600
2020 with Auxi Reg	1,644,856	65,856	6,180	0
2020 with Auxi + Cold	485,000	0	0	0

2. Non-Cancer Health Impacts and Valuations

To determine the impacts from the proposed regulation on non-cancer health endpoints, ARB staff used the methodology described previously in Chapter V to evaluate the change in ambient PM levels that are expected due to implementation of the proposed regulation. A discussion of the non–cancer health impacts assessment is included in Appendix D.

This analysis shows that the statewide cumulative impacts of the emissions reduced through this regulation from year 2009 through 2020 are approximately:

- 280 premature deaths (78 to 480, 95% confidence interval (CI))
- 60 hospital admissions due to respiratory causes (38 to 83, 95% CI)
- 110 hospital admissions due to cardiovascular causes (70 to 170, 95% CI)
- 8,200 cases of asthma-related and other lower respiratory symptoms (3,200 to 13,000, 95% CI)
- 680 cases of acute bronchitis (0 to 1,400, 95% CI)
- 49,000 work loss days (42,000 to 57,000, 95% CI)
- 280,000 minor restricted activity days (230,000 to 330,000, 95% CI)

Table VIII-5 lists the impacts associated with primary and secondary diesel emissions separately. The methodology for estimating these health impacts is outlined below and details can be found in Appendix A of the Emission Reduction Plan for Ports and Goods Movement in California (ARB, 2006) [4].

Table VIII-5: Estimated Total Health Benefits Associated with Reductions in Hotelling Emissions from Container Ships, Passenger Ships, and Reefer Ships (2009-2020)[*]

Endpoint	Pollutant	# of Cases 95% C.I. (Low)	# of Cases (Mean)	# of Cases 95% C.I. (High)
Premature Death	PM	22	80	140
	NOx	56	200	340
	Total	*78*	*280*	*480*
Hospital admissions (Respiratory)	PM	11	17	24
	NOx	27	43	59
	Total	*38*	*60*	*80*
Hospital admissions (Cardiovascular)	PM	20	31	49
	NOx	50	79	120
	Total	*70*	*110*	*170*
Asthma & Lower Respiratory Symptoms	PM	910	2,400	3,800
	NOx	2,300	5,900	9,300
	Total	*3,200*	*8,200*	*13,000*
Acute Bronchitis	PM	0	200	430
	NOx	0	480	1,000
	Total	*0*	*680*	*1,400*
Work Loss Days	PM	12,000	14,000	16,000
	NOx	30,000	35,000	41,000
	Total	*42,000*	*49,000*	*57,000*
Minor Restricted Activity Days	PM	66,000	81,000	96,000
	NOx	160,000	200,000	240,000
	Total	*230,000*	*280,000*	*330,000*

[*] Health effects from primary and secondary PM are labeled PM and NOx, respectively. The sum of PM and NOx impacts may not equal the total given due to rounding.

3. Economic Valuation of Non-Cancer Health Effects

This section describes the methodology for monetizing the value of avoiding adverse health impacts.

The U.S. EPA has established $4.8 million in 1990 dollars at the 1990 income level as the mean value of avoiding one premature death (U.S. EPA, 1999). This value is the mean estimate from five contingent valuation studies and 17 wage-risk studies. Contingent valuation and wage-risk studies examine the willingness to pay (or accept payment) for a minor decrease (or increase) in the risk of

[4] http://www.arb.ca.gov/planning/gmerp/march21plan/appendix_a.pdf

premature death. For example, if individuals are willing to pay $800 to reduce their risk of mortality by 1/10,000, then collectively they are willing to pay $8 million to avoid one death. This is also known as the “value of a statistical life” or VSL.[5]

As real income increases, people are willing to pay more to prevent premature death. U.S. EPA adjusts the 1990 value of avoiding a premature death by a factor of 1.201[6] to account for real income growth from 1990 through 2020, (U.S. EPA, 2004). Assuming that real income grows at a constant rate from 1990 until 2020, we adjusted VSL for real income growth, increasing it at a rate of approximately 0.6% per year. We also updated the value to 2006 dollars. After these adjustments, the value of avoiding one premature death is $8.2 million in 2007, $8.3 million in 2009 and $8.9 million in 2020, all expressed in 2006 dollars.

The U.S. EPA also uses the willingness-to-pay (WTP) methodology for some non-fatal health endpoints, including lower respiratory symptoms, acute bronchitis and minor restricted activity days. WTP values for these minor illnesses are also adjusted for anticipated income growth through 2020, although at a lower rate (about 0.2% per year in lieu of 0.6% per year).

For work-loss days, the U.S. EPA uses an estimate of an individual’s lost wages, (U.S. EPA, 2004), which CARB adjusts for projected real income growth, at a rate of approximately 1.5% per year.

“The Economic Value of Respiratory and Cardiovascular Hospitalizations,” (ARB, 2003), calculated the cost of both respiratory and cardiovascular hospital admissions in California as the cost of illness (COI) plus associated costs such as loss of time for work, recreation and household production. When adjusting these COI values for inflation, CARB uses the Consumer Price Index (CPI) for medical care rather than the CPI for all items.

Table VII-6 lists the valuation of avoiding various health effects, compiled from ARB and U.S. EPA publications—updated to 2006 dollars. The valuations based on WTP, as well as those based on wages, are adjusted for anticipated growth in real income.

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[5] U.S. EPA’s most recent regulatory impact analyses, (U.S. EPA 2004, 2005), apply a different VSL estimate ($5.5 million in 1999 dollars, with a 95 percent confidence interval between $1 million and $10 million). This revised value is based on more recent meta-analytical literature, and has not been endorsed by the Environmental Economics Advisory Committee (EEAC) of U.S. EPA’s Science Advisory Board (SAB). Until U.S. EPA’s SAB endorses a revised estimate, ARB staff continues to use the last VSL estimate endorsed by the SAB, i.e., $4.8 million in 1990 dollars.

[6] U.S. EPA’s real income growth adjustment factor for premature death incorporates an elasticity estimate of 0.4.

Table VIII-6: Undiscounted Unit Values for Health Effects (at various income levels in 2006 dollars) [A]

Health Endpoint	2006	2015	2025	References
Mortality				
Premature death ($ million)	8.2	8.6	9.2	U.S. EPA (1999, p. 70-72, 2000, (2004, p. 9-121)
Hospital Admissions				
Cardiovascular ($ thousands)	43	48	54	ARB (2003), p. 63
Respiratory ($ thousands)	35	39	44	ARB (2003), p. 63
Minor Illnesses				
Acute Bronchitis	451	459	469	U.S. EPA (2004), 9-158
Lower Respiratory Symptoms	20	20	21	U.S. EPA (2004), 9-158
Work loss day	189	217	252	2002 California wage data, U.S. Department of Labor
Minor restricted activity day (MRAD)	64	65	66	U.S. EPA (2004), 9-159

[A] The value for premature death is adjusted for projected real income growth, net of 0.4 elasticity. Wage-based values (Work Loss Days) are adjusted for projected real income growth, as are WTP-derived values (Lower Respiratory Symptoms, Acute Bronchitis, and MRADs). Health endpoint values based on cost-of-illness (Cardiovascular and Respiratory Hospitalizations) are adjusted for the amount by which projected CPI for Medical Care (hospitalization) exceeds all-item CPI.

Benefits from the proposed rule on the operation of auxiliary engines on at-berth ocean-going vessels are substantial. ARB staff estimates cumulative benefits over the period from 2009 to 2020 to be nearly $1.9 billion using a 3% discount rate or $1.3 billion using a 7% discount rate[7]. A large proportion of the monetized benefits results from avoiding premature death. The estimated benefits from avoided morbidity are approximately $28 million with a 3% discount rate and nearly $20 million with a 7% discount rate. Approximately 72% of the benefits are associated with reduced PM from NOx emissions, and the remaining 28% from direct PM emissions.

Reduced Ambient Ozone Levels

Emissions of NOx and ROG are precursors to the formation of ozone in the lower atmosphere. Exhaust from diesel engines contributes a substantial fraction of ozone precursors in any metropolitan area. Therefore, reductions in NOx and ROG from diesel engines would make a considerable contribution to reducing

[7] ARB follows U.S. EPA practice in reporting results using both 3% and 7% discount rates.

exposures to ambient ozone. Controlling emissions of ozone precursors would reduce the prevalence of the types of respiratory problems associated with ozone exposure and would reduce hospital admissions and emergency visits for respiratory problems.

D. Reasonably Foreseeable Environmental Impacts as a Result of Potential Compliance Methods

The primary compliance strategy proposed in the regulation is turning off the auxiliary engines and plugging in to shore power. ARB staff anticipates that the majority of affected ship companies will choose to comply with the requirements of the proposed regulation by using shore power. ARB staff does not foresee any negative environmental impacts associated with the use of shore power as a primary strategy.

ARB staff recognizes that there are emissions associated with the generation of electricity used for shore power (i.e., emissions from power plants that supply electricity to the grid). When calculating the emission reduction benefits of the proposed regulation, ARB staff considered the *net* benefits, subtracting the emissions associated with the grid.

One compliance option with potential adverse environmental impacts is the use of diesel emission control strategies. To date, there are no ARB verified after-treatment controls for marine engines. As such, the ARB is encouraging the use of non-verified after-treatment control devices in the hopes of achieving some reductions of diesel PM associated with ocean going vessels due to the installation of after-treatment controls. The ARB staff does not anticipate significant reductions of diesel PM from ocean going vessels attributable to after-treatment controls until such time as those technologies are proven to be effective and durable when used in the marine environment. The ARB continues to support projects that utilize after-treatment controls in the hopes that those technologies will become verified in the future.

The ARB has identified potential adverse environmental impacts from the use of diesel oxidation catalysts (DOCs), diesel particulate filters (DPFs), selective catalytic reduction (SCR), alternative fuels, exhaust gas recirculation (EGR), seawater scrubbers, and shore-based after-treatment systems. These include a potential increase in sulfate PM, a potential increase in NO_2 from some DPFs, and the potential for creating hazardous wastes. As described below, options are available to mitigate these potential adverse impacts.

<u>Diesel Oxidation Catalyst (DOC)</u>

Two potential adverse environmental impacts of the use of diesel oxidation catalysts have been identified. First, as is the case with most processes that incorporate catalytic oxidation, the formation of sulfates increases at higher temperatures. Depending on the exhaust temperature and sulfur content of the fuel, the increase in sulfate particles may offset the reductions in soluble organic fraction emissions.

Second, a DOC could be considered a "hazardous waste" at the end of its useful life depending on the materials used in the catalytic coating. Because catalytic converters have been used on gasoline powered on-road vehicles for many years, there is a very well-established market for these items (see, for example, http://pacific.recycle.net – an Internet posting of buyers and sellers of various scrap materials). In the recycling process, the converters are broken down, and the metal is added to the scrap-metal stream for recycling, while the catalysts (one or a combination of the platinum group metals) are extracted and reused.

Because of platinum's high activity as an oxidation catalyst, it is the predominant platinum group metal used in the production of diesel oxidation catalysts. There is a very active market for reclaimed platinum for use in new catalytic converters, jewelry, fuel cells, cathode ray tube screens, catalysts used during petroleum refining operations, dental alloys, oxygen sensors, platinum electrode spark plugs, medical equipment, and platinum-based drugs for cancer treatment, to name a few. (Kendall, 2002) (Kendall, 2003)

Catalyzed Diesel Particulate Filters

These devices are composed of a ceramic diesel particulate filter along with a platinum catalyst to catalyze the oxidation of carbon-containing emissions and significantly reduce diesel PM emissions. This is an obvious positive environmental impact.

However, there are also inorganic solid particles present in diesel exhaust, which are captured by diesel particulate filters. These inorganic materials are metals derived from engine oil, diesel fuel, or engine wear and tear. While the PM filter is capable of capturing inorganic materials, these materials are not oxidized into a gaseous form and expelled.

Because these materials would otherwise be released into the air, the filters are benefiting the environment by capturing these metallic particles, known as "ash." However, the ash that is collected in the PM filter must be removed from the filter periodically to maintain the filter's effectiveness.

Ash collected from a diesel engine using a typical lubrication oil and no fuel additives has been analyzed and is primarily composed of oxides of the following elements: calcium, zinc, phosphorus, silicon, sulfur, and iron. Zinc is the element of primary concern because, if present in high enough concentration, it can make a waste a hazardous waste. Title 22, CCR, section 66261.24 establishes two limits for zinc in a waste: 250 milligrams per liter for the Soluble Threshold Limit Concentration and 5,000 milligrams per kilogram for the Total Threshold Limit

Concentration. The presence of zinc at or above these levels would cause a sample of ash to be characterized as a hazardous waste.

Under California law, it is the generator's responsibility to determine whether their waste is hazardous or not. Applicable hazardous waste laws are found in the HSC, division 20; title 22, CCR, division 4.5; and title 40 of the Code of Federal Regulations. Staff recommends owners that install a diesel particulate filter on an engine to contact both the manufacturer of the diesel emission control system and the California Department of Toxic Substances Control (DTSC) for advice on proper waste management.

Additionally, the technology exists to reclaim zinc from waste. For example, the Swedish company MEAB has developed processes for extracting zinc and cadmium from various effluents and industrial waste streams. Whether reclamation for reuse will be economically beneficial remains to be seen. (MEAB, 2003)

Because of the time and costs associated with filter maintenance, there are also efforts by industry to reduce the amount of ash formed. Most of the ash is formed from the inorganic materials in engine oil, particularly from zinc-containing additives necessary to control acidification of engine oil – due in part to sulfuric acid derived from sulfur in diesel fuel. As the sulfur content of diesel fuel is decreased, the need for acid neutralizing additives in engine oil should also decrease. A number of technical programs are ongoing to determine the impact of changes in oil ash content and other characteristics of engine oil on exhaust emission control technologies and engine wear and performance.

It may also be possible to reduce the ash level in diesel exhaust by reducing oil consumption from diesel engines. Diesel engine manufacturers over the years have reduced engine oil consumption in order to reduce PM emissions and to reduce operating costs for engine owners. Further improvements in oil consumption may be possible in order to reduce ash accumulation rates in diesel particulate filters.

In addition, measurements of NO_x emissions for heavy-duty diesel vehicles equipped with passive catalyzed filters have shown an increase in the NO_2 portion of total NO_x emissions, although the total NO_x emissions remain approximately the same. In some applications, passive catalyzed filters can promote the conversion of nitrogen oxide (NO) emissions to NO_2 during filter regeneration. More NO_2 is created than is actually being used in the regeneration process; and the excess is emitted. The NO_2 to NO_x ratios could range from 20 to 70 percent, depending on factors such as the diesel particulate filter systems, the sulfur level in the diesel fuel, and the duty cycle. (DaMassa, 2002)

Formation of NO_2 is a concern because it irritates the lungs and lowers resistance to respiratory infections. Individuals with respiratory problems, such as asthma, are more susceptible to the effects. In young children, nitrogen dioxide may also impair lung development. In addition, a higher NO_2/NO_x ratio in the exhaust could potentially result in higher initial NO_2 concentrations in the atmosphere, which, in turn, could result in higher ozone concentrations.

Model simulations have shown that a NO_2 to NO_X emission ratio of approximately 20 percent would nearly eliminate any impact of increased NO_2 emissions. (DaMassa, 2002). According to the model, at the NO_2 to NO_x ratio of 20 percent, there will be a decrease of the 24-hour ozone exposure (greater than 90 parts per billion) by two percent while an increase of the peak 1-hour NO_2 by six percent (which is still within the NO_2 standard).

The health benefits derived from the use of PM filters are immediate and offset the possible adverse effects of increases in NO_2 emissions. For this reason, a cap of 20 percent NO_2 to NO_x emission ratio was established for all diesel emission control systems through ARB's Verification Procedure.

Selective Catalytic Reduction (SCR)

The heart of the SRC system is the catalyst. The reaction converting NOx to nitrogen and water occurs on the surface of the catalyst. NOx compounds must come into contact with the catalyst in order to be converted. Modern catalysts are usually made in the form of honeycomb structures.

Many catalysts materials contain heavy metal oxides that are hazardous to human health. Vanadium pentoxide, for example, is on the U.S. EPA's Extremely Hazardous Substances. In California, spent catalyst from SCR is considered to be hazardous waste and the volume of waste from SCR is large. The disposal of catalyst is expensive, but some catalyst manufacturers provide for disposal and/or recycling of the catalyst. In Japan, for example, titanium from titanium dioxide spent catalyst is used for paint pigment. An advantage of precious metal catalysts is that they do not produce as much hazardous waste, and they have a salvage value at the end of their useful life, but the initial cost is higher.

Ammonia or urea is necessary for the chemical reactions in SCR to work. Urea is less expensive and less hazardous than ammonia, so almost all systems use urea. Urea comes in the form of powder that is dissolved with water and then injected into the exhaust stream. The urea breaks down to form nitrogen and hydrogen compounds that will react with nitrogen oxide. The temperature range for efficient NOx reduction with urea is higher than the exhaust temperature of some engines (minimum of approximately 270℃), so u rea injection is limited to systems where there is either ample exhaust temperature or supplemental firing applied to the exhaust stream. (Munters, 2007)

In the unlikely event ammonia is used in place of urea, there could be some environmental impacts. Ammonia (in lieu of urea) is necessary for the chemical reactions in SCR to work. Unfortunately, ammonia is also a hazardous substance. Ammonia is on the U.S. EPA's list of extremely hazardous substances under Title III, Section 302 of the Superfund Amendments and Reauthorization Act of 1986 (SARA). Ammonia is immediately dangerous to life and health (IDLH) at only 500 ppm. It has a time weighted average (TWA) exposure limit (the maximum allowable exposure limit in a 10 hour day in a 40 hour week) of 25 ppm. Ammonia has a pungent, suffocating odor. Exposure to ammonia causes eye, nose, and throat irritation, and it will burn the skin.

If used, ammonia is released from an SCR system because excess ammonia is required for efficient conversion of NOx to nitrogen. Excess ammonia is required because of imperfect distribution of the chemical. In theory, if the ammonia could be perfectly distributed so that the reactants could come into contact, no ammonia would be released, but under real world conditions this is not possible. This is also analogous to the necessity for excess air required for combustion. Excess air is required since all the oxygen molecules can't find all the fuel molecules to react with during the short period of time of combustion due to imperfect mixing of fuel and air.

The molar ratio of nitrogen oxide (NO) to ammonia in the SCR reaction is 1.0 (i.e., 1 ft^3 of ammonia is required to convert 1 ft^3 of NOx), and the molar ratio of ammonia to nitrogen dioxide (NO_2) is 2.0. Over 80 percent of the NOx compounds in the exhaust are nitrogen oxide, so the SCR system is usually run with a ratio of ammonia to NOx around 1.0. Further increases of this ratio will reduce NOx emissions, but emissions of ammonia will also increase.

In an SCR unit, it is critical that the ammonia is injected and thoroughly distributed throughout the flue gas stream. This is done with the ammonia injected grid located upstream of the catalyst. Ammonia is drawn out of a storage tank and evaporated with an electrically- or steam-heated vaporizer. The vapor is then mixed with a carrier gas, which is usually compressed air or steam. The carrier gas provides the momentum to deliver the gas into the exhaust stream.

The storage of ammonia is usually considered to be a greater potential hazard than the ammonia slip from the exhaust stack. Emitted levels of ammonia slip are far below the odor and health hazard thresholds of the chemical. Because ammonia is water soluble, it doesn't remain very long in the atmosphere.

Ammonia for an SCR unit is stored in a tank, and a relatively large volume of storage is required. Accidental release from storage could pose problems to communities surrounding a vessel or facility equipped with SCR. Aqueous and anhydrous ammonia are the two types of ammonia used for ammonia injection. The aqueous form is favored in that the stored ammonia concentration can be limited and the volatilization rate is reduced, so it is generally safer. The aqueous form is used in more heavily populated areas.

In summary, we do not believe the use of SCR, to the extent that it is used, will result in significant adverse environmental impacts because: (1) urea is safer and cheaper than ammonia, so urea is much more likely to be used, (2) ammonia is water soluble, so its persistence in the atmosphere is relatively short, and (3) use of the aqueous ammonia is generally safer and is the preferred form in heavily populated areas, such as the areas surrounding the ports where the regulated vessels will visit. In addition, to the extent SCR is used on land-based engines that will provide alternative means of shore power to affected vessels, such land-based engines will be subject to already stringent local air district permitting and emissions control requirements, as well as the applicable requirements specified in the proposed regulation. Thus, we believe the use of SCR, if any, will result in no significant adverse environmental impacts.

Alternative Fuels

As discussed in Appendix F, a number of alternative fuels and alternative diesel fuels show great promise in their potential to reduce diesel PM emissions. These include alternative diesel fuels such as biodiesel, emulsified diesel fuel, and Fischer-Tropsch fuels, and alternative fuels such as natural gas. No significant negative environmental impacts have been determined from the use of alternative fuels. With respect to alternative diesel fuels, there may be an increase in NO_x emissions as a result of biodiesel use. (Hofman/Solseng, 2002)

Exhaust Gas Recirculation (EGR)

Exhaust gas recirculation (EGR) lowers combustion temperatures thereby reducing NOx formation. By reducing combustion temperatures and available air for combustion, EGR may cause incomplete combustion, increases in HC, CO, and PM emissions, and decreased fuel economy. (DieselNet, 2006).

Sea Water Scrubber (SWS)

Seawater scrubbing utilizes the water surrounding the ship, whether it is seawater, coastal water or harbor water, as an exhaust gas-washing medium. The scrubbing equipment uses this water to scrub out and neutralize the sulfur oxides (SOx) from the exhaust of marine main and auxiliary engines. Calcium carbonate in the seawater absorbs the SOx from the exhaust gas and produces calcium sulphate. SOx are also readily soluble in seawater where they form sulfuric acid. The natural alkalinity of the seawater then neutralizes this and other acids formed during scrubbing. In addition SWS also removes up to 80 percent of the PM and up to five percent of the NOx as well as other unburned/partially burned hydrocarbon derived from fuel and lubricants, ash, and other incombustible materials, such as metals, in the exhaust gas. SWS systems should be designed to ensure that the contaminants removed from exhaust gas stream are subsequently removed from the wash water prior to the wash water being discharged. (Holland, 2007)

Although concentrations of these compounds within the wash water are generally extremely low, even in the absence of any wash water treatment system, the accumulation of these compounds over time in the marine ecosystem must be considered. The removal and storage or proper disposal of wash water contaminants as a neutralized sludge ensures that the accumulation affect in the marine environment does not occur.

E. Reasonably Foreseeable Mitigation Measures

ARB staff has concluded that no significant adverse environmental impacts should occur from the adoption of and compliance with the proposed regulation. Therefore, no mitigation measures would be necessary.

F. Reasonably Foreseeable Alternative Means of Compliance with the Proposed Regulation

Alternative means to comply with the proposed regulation are provided through the use of emission control strategies to achieve the same fleet-wide emission reductions that would be achieved through utilizing shore power. Alternatives to the proposed regulation are discussed in Chapter VI of this report. ARB staff has concluded that the proposed regulation provides the most effective and least burdensome approach to reducing children's and the general public's exposure to diesel PM and other air pollutants emitted from the diesel auxiliary engines on ocean-going vessels while at berth.

Although there are issues associated with the use of alternative diesel emission control strategies to achieve reductions of emissions of NO_x and diesel PM from ocean going vessels, the ARB staff believes that there are ways to address and mitigate any adverse environmental impacts associated with a specific emission control strategy.

The alternative compliance strategies described above and in Chapter VI provide benefits associated with the reduction of NO_x and diesel PM from ocean-going vessels. In addition to providing flexibility to the regulated community, these compliance options also promote the development of cleaner retrofit and emission control technologies for ocean-going vessels.

REFERENCES:

California Air Resources Board. *Emission Reduction Plan for Ports and Goods Movement in California*; April 2006. (ARB, 2006)

California Air Resources Board. *Final Research Report: The Economic Value of Respiratory and Cardiovascular Hospitalizations*; May 2003. ftp://ftp.arb.ca.gov/carbis/research/apr/past/99-329.pdf (ARB, 2003)

California Air Resources Board. *Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles*; October 2000. http://www.arb.ca.gov/diesel/documents/rrpapp.htm (ARB, 2000)

California Air Resources Board and Office of Environmental Health Hazard Assessment. *Public Hearing to Consider Amendments to the Ambient Air Quality Standards for Particulate Matter and Sulfates, Staff Report*; May 2002. http://www.arb.ca.gov/research/aaqs/std-rs/pm-final/pm-final.htm (ARB, 2002)

DaMassa, John*.* California Air Resources Board. *Presentation: Air Quality Effects of Trap-Related Emissions (Updated)*; February 6, 2002. (DaMassa, 2002)

DieselNet. *Engine Design for Low Emissions: Water in Diesel* Combustion; DieselNet Technology Guide. September 29, 2006. http://www.dieselnet.com/tech/engine_water.html (DieselNet, 2006)

Holland America Line. *Holland America Line - MS Zaandam Sea Water Scrubber Technology Demonstration Project Environmental Impact Assessment (EIA) Plan*; August 10, 2007. (Holland, 2007)

Kendall, Tom; Johnson Matthey. *Platinum 2002*; May 2002. http://www.platinum.matthey.com/publications/1051543656.html (Kendall, 2002)

Kendall, Tom; Johnson Matthey. *Platinum 2003*; May 2003. http://www.platinum.matthey.com/publications/1059138410.html (Kendall, 2003)

Metallextraktion AB (MEAB). August 2003. *http://www.meab-mx.se/en/index.htm* (MEAB, 2003)

Munters Europe AB. *DEC SCR Converter System*. April 26, 2007. (Munters, 2007)

United States Environmental Protection Agency. *Clean Air Interstate Rule: Regulatory Impact Analysis*; March 2005. http://www.epa.gov/interstateairquality/pdfs/finaltech08.pdf (EPA, 2005)

United States Environmental Protection Agency, *Guidelines for Preparing Economic Analyses.* EPA240-R-00-003. September 2000. http://www.epa.gov/opei/pubsinfo.htm (EPA, 2000)

United States Environmental Protection Agency. *The Benefits and Costs of the Clean Air Act 1990 to 2010*. EPA-410-R-99-001. November 1999. http://www.epa.gov/air/sect812/copy99.html (EPA, 1999)

United States Environmental Protection Agency, Assessment and Standards Division, Office of Transportation and Air Quality. *Draft Regulatory Impact Analysis: Control of Emissions of Air Pollution from Nonroad Diesel Engines and Fuel*. EPA420-R-03-008. CD-ROM. Research Triangle Park, North Carolina. April 2003http://www.epa.gov/otaq/cleaner-nonroad/r03008.pdf (EPA, 2003)

U.S. Environmental Protection Agency (EPA), Assessment and Standards Division, Office of Transportation and Air Quality. *Final Regulatory Analysis: Control of Emissions from Nonroad Diesel Engines Chapter 4*. EPA420-R-04-007. May 2004.
http://www.epa.gov/otaq/regs/nonroad/equip-hd/2004fr.htm#ria (EPA, 2004)

IX. SHORE POWER AS A GREENHOUSE GAS EMISSION REDUCTION MEASURE

The focus of the proposed regulation is to require reductions in oxides of nitrogen and diesel particulate matter from ocean-going vessels while hotelling. However, as a co-benefit, it is also expected to result in a significant reduction in the emissions of carbon dioxide (CO_2), a greenhouse gas (GHG). This chapter discusses the proposed regulation as a measure to reduce GHG emissions.

A. Climate Change and California

Climate change poses a serious threat to the economic well-being, public health, natural resources, and the environment of California. California is vulnerable to the impacts of climate change through the reduction in the quality and supply of water to the state from the Sierra snow pack; the exacerbation of California's air quality problems; the adverse impact on human health by increasing heat stress and related deaths, incidence of infectious disease, and risk of asthma, respiratory and other health problems; the rise in sea level along the 1,100 miles of coastline; and detrimental impacts to agriculture due to increased temperatures, diminished water supply and changes in the abundance and distribution of pests.

National and international actions are necessary to fully address the issue of global warming; however, action taken by California to reduce emissions of greenhouse gases will have far-reaching effects by encouraging other states, the federal government, and other countries to act. Taking a leadership role, Governor Arnold Schwarzenegger signed Executive Order S-3-05 in June 2005, which established targets for reducing GHG emissions in California: roll back GHG emissions to 2000 levels by 2010, to 1990 levels by 2020, and finally to 80 percent below 1990 levels by 2050.

In 2006, the Governor signed Assembly Bill 32 (AB 32) (Stats. 2006, ch.488), which established the 2020 GHG emission reduction goal in State law (HSC § 38500 et seq.) and made the ARB responsible for monitoring and reducing GHG emissions. AB 32 requires the Board, by January 1, 2009, to design and adopt an overall plan to reduce GHG emissions to 1990 levels by 2020. The Board has until January 1, 2011, to adopt the necessary regulations to implement that plan. Implementation begins no later than January 1, 2012, and the emission reduction target must be fully achieved by January 1, 2020. AB 32 also required the Board to identify a list of discrete early action GHG reduction measures by June 30, 2007. AB 32 defines discrete early action measure as regulations adopted by the Board and enforceable by January 1, 2010.

In April 2007, ARB staff released a report identifying 37 proposed early action items the Board could undertake to mitigate GHG emissions in California. Port electrification was identified as a GHG emission reduction measure in this report. In September 2007, ARB staff, for the purpose of GHG emission reductions, renamed the shore electrification measure “Green Ports” and recommended reclassifying it from an early action measure to a discrete early action measure. Staff’s recommended reclassifications will be considered by the Board at its October 2007 hearing.

AB 32 requires that all GHG reduction regulations adopted and implemented by the Board be technologically feasible and cost-effective. As mentioned earlier, ARB staff has developed the proposed regulation to reduce NOx and diesel PM, and has identified GHG emissions reductions as a co-benefit of the regulation; therefore, there are no additional costs for the reduction of CO2 associated with the proposed regulation.

B. Carbon Dioxide Emission Factors

Staff estimated the CO_2 emissions reductions to be achieved under the proposed regulation. Since we expect both main compliance options under the regulation to be associated with the use of shore-based electricity, we calculated the CO_2 emission reductions by multiplying the CO_2 emissions rate associated with each of the sources of power (in pounds per megawatt-hour) by the total amount of power to be transferred from the shore to the ships (in megawatt-hours).

Auxiliary Engines

For the onboard auxiliary engines burning marine gas oil, ARB staff used a CO_2 emission factor of 690 grams per kilowatt-hour (1520 pounds per megawatt-hour). This figure is based on work done by Entec using *Lloyd’s of London* and *IVL Swedish Environmental Institute* data that related emissions to engine speed and the type of fuel used (Entec 2002).

The Electrical Grid

The utility companies generate or purchase electricity from a variety of sources: hydroelectric dams, gas-fired power plants, coal-fired power plants, wind turbines, photoelectric cells, nuclear plants, and distributed generation sources using landfill and digester biogas or biomass, such as wood chips or agricultural wastes. Each of these sources has its own CO_2 emissions profile. The utility companies typically generate and distribute their electricity in a manner called economic dispatch. That is, they generate electricity that is the least expensive to produce first, then the next least expensive next, and so on. A notable exception to this concept of economic dispatch includes producing electricity from renewable sources as required by State law, which may be among the most expensive generated.

ARB staff took three different approaches to estimate the CO_2 emissions from grid electricity. The first two are based on the generation of marginal power, while the third is based on current power-supply portfolios of the utility companies that would provide power to the six affected ports.

By presenting several options, staff recognizes the current work by others to quantify CO_2 emissions associated with California's electrical grid and provides a range of CO_2 emissions reductions possible through the adoption and implementation of the proposed regulation. Under any of these options, ARB staff expects the GHG benefits from using grid-based shore power will increase with time, as AB 32 and other energy programs produce cleaner sources of electricity.

1. Marginal Electricity

Electricity used for shore power will be a new load for California utilities—it will be additional power generated over and above baseline electrical needs and marginal loads. ARB staff believes that the best approach for estimating the emissions from shore power is to use the emission profile for marginal power. The utility companies providing the power to the six ports affected by the proposed regulation indicated that marginal electricity production is typically generated at a natural gas-fired power plant utilizing a combined-cycle gas turbine (CCGT).

A CCGT generates electricity by combusting the natural gas in a large turbine, which drives a generator, then taking the exhaust heat from that turbine to produce steam, which drives another turbine attached to another generator for additional electricity. The overall efficiency of a CCGT can be about 55 percent, which is higher than large simple-cycle turbines (40 percent) and internal-combustion engines (30 to 38 percent), although their overall efficiency can be improved by utilizing their waste heat in other processes. This is called combined-heat-and-power (CHP). The exhaust heat can be used to heat water, make steam, heat or cool buildings, or supplement industrial processes.

When considering CO_2 emissions from marginal power, staff considered two sources: 1) the CO_2 emissions value that the California Energy Commission (CEC) and the California Public Utilities Commission (CPUC) recommended for unspecified sources of electricity; and 2) an emissions estimate that the Climate Action Team (CAT) Economics Subgroup developed.

a. California Energy Commission and the California Public Utilities Commission Values for CCGT Emissions

The estimated CO_2 emissions from a CCGT vary, and staff used values based on work being conducted to satisfy the requirements of SB 1368 (Stats. 2006, ch. 598) and AB 32. SB 1368 requires the California Energy Commission (CEC), in consultation with the California Public Utilities Commission (CPUC) and the ARB, to establish a greenhouse gases emission performance standard for all baseload generation of local publicly owned electric utilities that is no higher than the rate of emissions of greenhouse gases for combined-cycle natural gas baseload generation. SB 1368 also requires that the greenhouse gases emission performance standard established by the CEC be consistent with the standard adopted by the CPUC.

In the second quarter of 2007, the CPUC and the CEC adopted an emission performance standard of 1,100 pounds of CO_2 per megawatt hour of electricity (lbs CO_2/MW-hr). Although this standard of performance is higher than that of a new CCGT using best available control technology (BACT), the CPUC and CEC set the standard so that new, clean units in adverse conditions such as high altitude or hot temperatures would not be crowded out by a standard that was too restrictive (CEC, March 2007).

In another joint effort between the CPUC and the CEC, the commissions recommended in September 2007 that ARB, as part of its AB 32 obligations, adopt a reporting and verification regulation for GHG emissions from the electricity sector based upon the commissions' proposed model rule (CEC/CPUC, September 2007). Of particular interest is the recommendation that, when the source of a power purchase is not identified, ARB use a regional default emission factor of 1,100 lbs CO_2/MW-hr. The commissions recommended that this value be used for purchases from both in-state and out-of-state unspecified sources, and should be in effect until a regional tracking system for GHG emissions from electricity is implemented.

b. Climate Action Team Economics Subgroup Macroeconomic Analysis

When Governor Schwarzenegger signed Executive Order S-3-05 in June 2005, he created a Climate Action Team (CAT) to implement global warming emission reduction programs and report on the progress made toward meeting the statewide greenhouse gas targets that were established in the Executive Order (Schwarzenegger, 2005). The CAT, under the guidance of the California Environmental Protection Agency (Cal/EPA), was comprised of representatives from the ARB, the Business, Transportation and Housing Agency, the Department of Food and Agriculture, the Resources Agency, the CPUC, and the CEC.

The CAT created an Economics Subgroup to examine the economic impacts of achieving the State's climate goals. The subgroup presented preliminary findings to the Governor in March 2006 as part of an overall CAT Report. As described in the 2006 CAT Report, the macroeconomic impact assessment available at that time was preliminary, and would benefit from updated cost and savings estimates for the strategies as well as a refined analysis. Consequently, the Economics Subgroup committed to providing an updated analysis.

In September 2007, the Economics Subgroup presented a draft updated macroeconomic analysis (CAT Economics Subgroup, 2007). The goals of the updated analysis were to ensure consistent methods for estimating emissions, costs, and savings for the GHG emissions reductions measures identified by the CAT; identify and address potential double counting, identify and address co-benefits; and provide documentation and transparency.

One key element of the economic analysis was to determine the GHG impact of generating electricity. For that analysis, the subgroup estimated the GHG emissions related to electricity production, examining both “avoided fossil-fuel generation” and “avoided renewable generation.”

The subgroup defined “avoided fossil-fuel generation” as electricity from a combined-cycle gas turbine with a heat rate of 7,000 Btus per kilowatt-hour. It considered this level of performance as a reasonable representation of a new power plant whose construction may be avoided due to reduced electricity demand, and the subgroup estimated the emissions from this representative plant to be 815 lbs CO_2/MW-hr.

By 2020, renewable generation is expected to be at least 20 percent of electric supply. The investor-owned utilities are committed to achieving this level of renewables by 2010, and the municipal utilities are expected to achieve this level prior to 2020. Therefore, reductions in electricity demand in 2020 will reduce generation from the entire mix of generating assets, including renewable generation. While some renewable electric supply has zero direct GHG emissions (e.g., wind), data provided by the CPUC indicate that geothermal sources may have emissions on the order of 50 lbs CO_2/MW-hr. Based on recent CEC staff scenario analysis showing that geothermal sources may account for about one-third of renewable energy production, the subgroup estimated emissions from the renewable portion of electric power generation to be 17 lbs CO_2/MW-hr.

The subgroup also considered transmission losses. Based on CPUC data, it estimated that losses from in-state generation are about 4.5% and losses from out-of-state generation are about 7.5%. Furthermore, the subgroup assumed that 80 percent of the new generation would come from in-state sources, with the remainder coming from out-of-state sources (similar to the current supply ratio).

Using these assumptions about marginal electricity production, renewables, transmission losses, and sources of the electricity, the subgroup estimated the emission factor for avoided electricity to be 690 lbs CO_2/MW-hr.

2. Average Utility Portfolio Values

As mentioned above, the utility companies generate or purchase electricity from a variety of sources: hydroelectric dams, gas-fired power plants, coal-fired power plants, wind turbines, photoelectric cells, nuclear plants, and distributed generation sources. Because the utility companies have different portfolios of generated and purchased power, the CO_2 emissions associated with those portfolios varies.

Table IX-1 shows the emission factor that staff estimated for the utility companies that would provide power to the ports affected by the proposed regulation using the 2005 CEC power mix and power content labels (CEC, 2006).

Table IX-1: Carbon Dioxide Emission Factors for Electrical Generation by Utility Company (Pounds per Megawatt-Hour)

Port(s)	Utility	Estimated Average Emission Factor
Los Angeles	Los Angeles Department of Water and Power	1,300
Long Beach, Hueneme	Southern California Edison	700
Oakland, San Francisco	Pacific Gas & Electric*	450
San Diego	San Diego Gas & Electric	750

* The Port of Oakland receives its power from the Western Area Power Administration (WAPA), and the Port of San Francisco receives its power from Hetch Hetchy Water & Power. PG&E is used as a surrogate here. The actual emission factor may be lower due to the hydroelectric sources of electricity from these two utilities.

The portfolio of the Los Angeles Department of Water and Power (LADWP) contains electricity generated by out-of-state coal-fired power plants, so its average GHG emission factor is considerably higher than the other utility companies. The requirements of SB 1368 and AB 32, and the requirements for achieving specified targets of renewables within portfolios, will reduce this emission factor and probably all of the emission factors, as the grid gets “cleaner” between now and 2020.

Based upon the discussion above, the emissions factors for calculating GHG emissions reduction are presented in Table IX-2.

Table IX-2: Carbon Dioxide Emission Factors for Electrical Generation (Pounds per Megawatt-Hour)

Onboard Auxiliary Engines	Marginal Electricity from the Grid	Average Utility Portfolios
1,518	690 – 1,100	450 – 1,300

C. Emission Reduction Calculations

The estimated electricity shifted from the auxiliary engines to the grid is presented in Table IX-3. (See Chapter VII for discussion on California grid impacts of proposed regulation.)

Table IX-3: Estimated Electricity Demand in 2020 for Shore Power

PORT	PEAK LOAD (MW)	ANNUAL USAGE (GW-HRS)
Hueneme	5	16
Long Beach	55	192
Los Angeles	70	255
Oakland	20	94
San Diego	40	77
San Francisco	15	9
TOTAL	**205**	**643**

To estimate the CO_2 emissions reductions achieved by the proposed regulation, staff multiplied the difference between the auxiliary engine emission factor and the electrical grid factor(s) by the shift in total load from the ships to the grid.

For example:

(1,518 – 690) lbs/MW-hr x 643,000 MW-hr in 2020 ÷ 2,200 lbs/metric ton =

242,000 metric tons of CO_2 reduced in 2020

This example assumes that the marginal electricity supplied by the grid for shore power resembles that estimated by the CAT Economics Subgroup. If the CPUC/CEC figure of 1,100 lbs CO_2/MW-hr is used, the estimated statewide CO_2 emissions reductions drops to 122,000 metric tons of CO_2 reduced in 2020.

Using the current portfolios of the specific utility companies, the estimated statewide CO_2 emissions reductions are shown in Table IX-4.

Table IX-4: Estimated Statewide Carbon Dioxide Emissions Reductions Using Average Portfolio Emission Factors

Port	Annual Usage (GW-hrs)	Estimated CO_2 Emission Reductions (Metric Tons)
Hueneme	16	5,500
Long Beach	192	71,000
Los Angeles	255	25,000
Oakland	94	46,000
San Diego	77	27,000
San Francisco	9	4,000
TOTAL	**715**	**179,000***

* If 100 percent hydroelectric generation is assumed for the Bay Area ports, the total reductions would be 197,000 metric tons of CO_2.

Therefore, the estimated statewide CO_2 emissions reductions achieved by the proposed regulation in 2020 are 122,000 – 242,000 metric tons.

These reductions are less than the 500,000 metric tons of CO_2 originally estimated for the CAT for two significant reasons:

- ARB staff revised downward the growth factors for the ocean-going vessels, especially the passenger ships, since the original estimate; and

- Based on wharfinger data supplied by the ports for the development of the proposed regulation, the average berthing times of the ships are shorter than what staff used in the original estimate in 2006.

D. Conclusions

ARB staff considered the co-benefit of the proposed regulation on CO_2 emission reductions and reached the following conclusions:

1. In all scenarios—whether considering the generation of marginal power or using the emissions associated with specific utility portfolios—shore power will achieve CO_2 reduction benefits.

2. ARB staff believes that the most likely source of electricity for shore power will be a mix of marginal sources of power with an mid-range emission factor of about 900 lbs/MW-hr.

3. With the above assumption, the proposed regulation would reduce GHG emissions in 2020 by 181,000 metric tons, a 40 percent reduction for the affected ships.

4. The GHG benefits of using grid-based shore power will increase with time, as AB 32 and other energy programs produce cleaner sources of electricity.

E. Impact of Alternative Technologies on Carbon Dioxide Emissions Reductions

The proposed regulation will allow the use of alternative technologies to achieve required emission reductions. These alternatives may include ship-side technologies, such as post-combustion devices, alternative fuels, or cleaner engines; or shore-side technologies, including distributed generation or emission-capture-and-treatment devices (so-called “bonnet” systems). These technologies—although attractive for early deployment for NOx and diesel PM reductions—will most likely be less effective in reducing GHG emissions when compared to grid-based shore power, but they are permitted as specified in the proposal.

For example, one of the alternative technologies being considered is providing power to the ship via a portable generator driven by an engine fueled with liquid natural gas (LNG). Assuming an engine efficiency of 36 percent, which is not unusual for a large spark-ignited engine, this alternative technology would emit about 1,090 lbs CO_2/MW-hr, which is essentially the same as the recommended CPUC/CEC value for combined-cycle gas turbines, although it is certainly higher than a CCGT using BACT or many of the average values associated with the individual utility company portfolios.

For sources of electricity other than the grid for providing shore power to the ships, the proposed regulation limits the CO_2 emissions to 500 grams per kilowatt-hour (1,100 lbs CO_2/MW-hr). This emission standard will prohibit the use of electrical generation technologies that emit much higher levels of CO_2, such as diesel engines and less efficient spark-ignited engines.

The post-combustion technologies—selective catalytic reduction (SCR), diesel particulate filters (DPFs), and diesel oxidation catalysts (DOCs)—tend to increase CO_2 emissions due to increased fuel use. However, the DPFs and DOCs remove black carbon, a component of diesel PM and a likely contributor to global warming.

For the emission-capture-and-treatment devices (e.g., Advanced Cleanup Technologies’ “bonnet” system), there would be a much larger CO_2 penalty because there is an auxiliary burner on the treatment unit for reheating the stack gases so that the SCR operates effectively. In addition, a vessel would use a bonnet system to allow the continued operation of the onboard auxiliary engines.

Thus, the auxiliary engines aboard the ships would still be operating, along with the treatment unit's burner. On the other hand, this alternative technology would capture and treat the NOx and PM emissions from the boilers on the ships—something that shore power would not do—so the increase in CO_2 emissions would need to be balanced against the additional NOx and PM emission reductions.

Most of these technologies are at the proof-of-concept stage, and ARB staff cannot at this time predict with certainty the extent of their deployment in the future. Therefore, we are unable to project the impact of such alternatives on overall CO_2 emission reductions under this program.

REFERENCES:

California Air Resources Board. *Proposed Early Actions to Mitigate Climate Change in California*, April 2007.

California Air Resources Board. *Expanded List of Early Action Measures to Reduce Greenhouse Gas Emissions in California Recommended for Board Consideration*, October 2007.

California Energy Commission. *Initial Study/Proposed Negative Declaration for Regulations Establishing and Implementing a Greenhouse Gases Emission Performance Standard for Local Publicly Owned Electric Utilities, CEC-700-2007-006*, March 2007.

California Energy Commission. *Net System Power: A Small Share of California's Power Mix in 2005*, CEC-300-2006-009-F, April 2006.

California Energy Commission. *Reporting and Verification of Greenhouse Gas Emissions in the Electricity Sector," California Public Utilities Commission, CPUC Rulemaking 06-04-009, Decision # 07-09-017, September 6, 2007, California Energy Commission, Docket 07-OIIP-1*, September 12, 2007.

California Environmental Protection Agency. *Climate Action Team Report to Governor Schwarzenegger and the Legislature*, March 2006.

Climate Action Team Economics Subgroup. *Updated Macroeconomic Analysis of Climate Strategies Presented in the March 2006 Climate Action Team Report, Public Review Draft*, September 7, 2007.

Entec UK Limited. *Quantification of Emissions from Ships Associated with Ship Movements between Ports in the European Community*, July 2002.

Los Angeles Department of Water and Power. " Power Content Label, Annual Report of Actual Electricity Purchases for LADWP, Calendar Year 2006." May 2007. http://www.ladwp.com/ladwp/cms/ladwp006643.pdf

Pacific Gas and Electric Company. "July 2006 Bill Inserts." 2006 http://www.pge.com/customer_service/bill_inserts/2006/july.html

San Diego Gas and Electric. "Power Content Label." http://www.sdge.com/tariff/inserts/FINAL0730070_PowerLabel_3.pdf

Southern California Edison. "Power Content Label." 2006. http://www.sce.com/NR/rdonlyres/145E4E27-36CF-43FE-8E84-38D7FFE84A30/0/Insert_PCL_Q3_0606.pdf

Schwarzenegger, Arnold, “Executive Order S-3-05.” June 1, 2005.

X. ECONOMIC IMPACTS

In this chapter, we present the estimated costs and economic impacts associated with the implementation of the proposed regulation. The estimated capital and recurring costs are presented, as well as an analysis of the cost-effectiveness. The economic impacts associated with the costs of the proposed regulation are presented for private companies, as well as for governmental agencies.

A. Legal Requirements

In this chapter, we will also address certain legal requirements that must be satisfied in analyzing the economic impacts of the proposal.

Section 11346.3 of the Government Code requires State agencies to assess the potential for adverse economic impacts on California business enterprises and individuals when proposing to adopt or amend any administrative regulation. The assessment shall include a consideration of the impact of the proposed regulation on California jobs, business expansion, elimination or creation, and the ability of California businesses to compete with businesses in other states.

In addition, the ARB is required under section 43013(b) of the Health and Safety Code (H&SC) to adopt standards and regulations, consistent with H&SC section 43013(a), for marine vessels to the extent permitted by federal law. Health and Safety Code section 43013(a) authorizes ARB to adopt and implement “motor vehicle emission standards, in-use performance standards, and motor vehicle fuel specifications…which the State board has found to be necessary, cost-effective, and technologically feasible…”

A literal reading of H&SC section 43013(a) would lead one to conclude that the criteria “necessary, cost-effective, and technologically feasible” do not apply to a marine vessel regulation because marine vessels are non-vehicular by definition. (See H&SC section 39039.) However, because the Legislature placed the authorization to regulate marine vessels in H&SC section 43013(b), we will infer a legislative intent to require ARB to determine that its proposed regulations on marine vessels are “necessary, cost-effective, and technologically feasible.”

Also, State agencies are required to estimate the cost or savings to any State or local agency and school district in accordance with instructions adopted by the Department of Finance (DOF). The estimate shall include any non-discretionary cost or savings to local agencies and the cost or savings in federal funding to the State.

Finally, H&SC section 57005 requires the Air Resources Board to perform an economic impact analysis of submitted alternative regulatory approaches to a proposed regulation before adopting any major regulation. A major regulation is defined as a regulation that will have a potential cost to California business enterprises in an amount exceeding ten million dollars in any single year. The estimated cost of the proposed regulation does exceed ten million dollars in a single year, although much of the cost will be borne by businesses based outside of California. Nevertheless, we have conducted an economic impact analysis of submitted alternative regulatory approaches to the proposal.

The following is a description of the methodology used to estimate costs as well as ARB staff's analysis of the economic impacts on California businesses and State and local agencies.

B. Summary of the Economic Impacts

Although not required, staff assumes that the most widely deployed technique for meeting the requirements of the proposed regulation will be grid-based shore power. This approach satisfies the "limited engine use" option and will probably be the technique of choice for the emissions reduction option. Consequently, staff's economic analysis addressed the use of grid-based shore power only.

Staff estimates the statewide total regulatory costs for affected businesses and port authorities to comply with the proposed regulation to be approximately $1.8 billion, discounted to 2006 dollars. Annually, the costs are expected to vary from $30 million to $137 million. The low end of the range represents a year when the only major capital expenditures are for retrofitting container ships due to repositioning, and the high end of the range represents a year when capital expenditures are being made for shoreside infrastructure and for retrofitting a considerable number of ships to meet the 2020 milestone. The total statewide annual costs to private business include recovery of capital expenditures, both aboard the ships and at the ports, and operating costs, which are labor costs and net energy costs, if any.

Since 25 of the 35 vessel fleets affected by the proposed regulation are container-ship fleets, for the purposes of this proposed regulation, the typical ship company refers to a company operating container ships. The total costs to a typical ship company complying with the proposed regulation, including capital and ongoing costs, are estimated to be about $34 million. This cost would be distributed over the years 2009 to 2030. Annual costs would vary between $600,000 and $3 million per year, with the average cost of $1.5 million per year over this time period. The low end of the range represents a year when no major capital expenditures are made, and the high end of the range represents a year where capital expenditures are made for both new ships as well as replacement ships that are rerouted.

For the other ship categories, the total costs for a typical ship company to comply with the proposed regulation, including capital and ongoing costs, are estimated to be about $3.2 million. This cost would be distributed over a 12-year period, from 2009 to 2020. Annual costs would vary between $150,000 and

$500,000 per year, with the average cost of $260,000 per year over this time period

Similarly, the total costs to a typical terminal operator complying with the proposed regulation, including capital and ongoing costs, are estimated to be about $11 million. About 20 percent of the cost is attributed to labor costs and the other 80 percent for capital costs. This cost would be distributed over a 12-year period, from 2009 to 2020. Annual costs would vary between $500,000 and $1.1 million per year, with the average cost of $1 million per year over this time period. The low end of the range represents a year where no major capital expenditures are made, and the high end of the range represents a year where capital expenditures are made for shore-side improvements. With 31 terminals and 35 vessel fleets affected by the proposed regulation, the cost to a typical business would be $26 million.

Ship companies, terminals, and ports would have additional recurring costs associated with recordkeeping and reporting. For a ship company, the costs associated with reporting and recordkeeping will vary between $600 and $12,000 annually. The higher cost for reporting and recordkeeping is based upon the ship company complying with the emission reduction option of the proposed regulation, and the lower end of the range is the costs for ship companies complying with the limited engine use option. Similarly, for the terminal operator, the costs associated with reporting and recordkeeping is about $800 annually.

Staff estimated that the overall cost effectiveness of the proposed regulation is about $12,800 per ton of NOx emissions reduced, assuming all costs are allocated to NOx reduction. For diesel PM, staff estimated an overall cost-effectiveness of $690,000 per ton, assuming all costs are allocated to PM reduction.

ARB staff considers the CO_2 emissions reductions achieved by this proposed regulation to be a co-benefit; therefore, there are no costs associated with CO_2.

C. Methodology for Estimating Costs Associated with Implementation

This section provides the general methodology and assumptions used to estimate the costs associated with the proposed regulation.

1. Compliance Options

The proposed regulation has two basic approaches for achieving emissions reductions: 1) the limited engine use option, and 2) the emissions reduction option. (See Chapter VI for a complete description of the requirements of the proposed regulation.)

The limited engine use option requires certain container ships, passenger ships, and refrigerated cargo ships (reefers) to turn off their auxiliary engines when they dock, or "hotel," at a California port. For 2014, at least 50 percent of the ship visits from these three categories of ships must turn off their auxiliary engines. In 2020, at least 80 percent of the ship visits must do this. The assumption is that these ships will receive their electrical needs from on-shore through electrical cables.

The alternative regulatory approach—the emissions reduction option—would require these ships to reduce their auxiliary engine hotelling emissions by specific amounts by certain dates, depending on the control technologies chosen. For example, if the vessel fleet operator chooses shore power, that fleet must reduce its hotelling emissions by at least 50 percent by 2014 and 80 percent by 2020. If the vessel fleet operator chooses to use an alternative control technology, that fleet must reduce its hotelling emissions by 20 percent in 2010, increasing another 20 percent every two years until the fleet has reduced its emissions by at least 80 percent by 2016. Finally, someone choosing a combination of these two approaches has emission-reduction targets of 20 percent in 2012, 40 percent in 2014, and 80 percent in 2020.

Staff believes that the most widely deployed technique for meeting the requirements of the proposed regulation will be grid-based shore power. This approach satisfies the limited engine use requirement and will probably be the technique of choice for the emissions reduction option. Consequently, the economic analysis below will address the use of grid-based shore power. Staff will provide a general discussion of alternative control technologies, citing costs where available.

2. Capital Cost Assumptions

The sections below discuss the capital cost assumptions used in the cost-effectiveness analysis. Appendix E contains additional information regarding the information used to establish the assumptions and also contains an example cost-effectiveness calculation.

Ships

For shore power to be implemented, ships need to be equipped to receive power from an outside source. Existing ships usually need to be retrofitted with specific electrical equipment—wiring, connectors, transformers, and switch gear—while many new ships are being built with this equipment as part of their naval architecture.

Based on previous shore-power projects, the cost to modify a ship to receive shore power ranges from $500,000 to $2 million. The less expensive ship retrofits have occurred with passenger ships, the more expensive retrofits with container ships. To date, no reefers have been retrofitted for shore power. (See Chapter IV for a complete discussion of current shore power activities, including specific ship retrofit costs.)

For the purpose of estimating total costs and calculating cost effectiveness, staff used $1.5 million per ship. This represents a conservative estimate, as it is toward the higher end of the cost spectrum, and staff expects the cost per ship to decrease as new ships are built with shore-power capability instead of retrofitting existing ships. Staff estimates that as many as 1,450 ships will need to be equipped for shore power over the lifetime of this proposed regulation.

Terminals

Just as the ships need to be equipped to receive shore power, the berths at the terminals must be capable of providing that power. The necessary shoreside infrastructure may include cables, plugs, underground wiring, substations, transformers, and switch gear. Based upon information provided by various ports, staff estimates that the cost to modify each berth at a terminal will be about $5 million. Staff estimates that 78 berths will have to provide shore power to visiting ships in 2020.

Electrical Infrastructure Outside Ports

Electrical infrastructure, such as distribution lines and substations, may be required on the part of the local utility company to supply the ports with sufficient electricity for shore power projects. The Ports of Los Angeles and Hueneme are not expected to need significant additional outside electrical infrastructure; however, several other ports will require upgraded electrical service. For example, the Port of Long Beach has estimated that to bring sufficient power to the port, an additional $15 million needs to be invested. The Port of San Diego may require as much as $32 million of additional investment, although recent reconfigurations should lower that estimate considerably. (SDG&E 2007)

For the purpose of estimating total capital costs and the cost effectiveness of the proposed regulation, staff used $15 million for the Ports of Long Beach, Oakland, and San Francisco, $30 million for the San Diego, and no additional significant costs for Los Angeles and Hueneme. Some of these capital costs may be borne by the local utility, since the customers (the terminals) will be paying higher utility bills for increased electricity usage; however, the ports, terminals, and utility companies ultimately negotiate these arrangements.

3. Operating Cost Assumptions

Energy Costs

Shore power shifts electrical generation from a ship's onboard generators, driven by auxiliary engines, to a source on shore, usually the electrical grid. Consequently, the ship must purchase electricity, but it saves fuel by shutting down its auxiliary engines.

Electrical tariff schedules vary among utilities, but they all typically include monthly fees, demand charges, time-of-use charges, and seasonal adjustments. Overall, the cost of electricity from the grid depends upon how much capacity is needed (i.e., the "demand," the maximum number of megawatts needed at any one time) and how much electricity is used annually.

The most expensive average electrical rates occur if the electrical demand is high (a lot of megawatts are needed, as with passenger ships), but the actual usage is low (few ships using shore power infrequently). In this case, the demand charges, which can be substantial and are paid whether one is using electricity or not, dominate the total electricity costs. Conversely, for most tariff schedules, the more continually the electricity is used, the lower the average electrical rate. In this case, the monthly fees and the demand charges are diluted by the energy costs, which can be relatively low (8 cents per kilowatt-hour).

Staff used actual utility tariff schedules to estimate electrical costs for shore power with one exception. The Los Angeles Department of Water and Power (LADWP), which serves the Port of Los Angeles, is proposing a special AMP (Alternative Maritime Power) tariff schedule that will be based on an interruptible schedule and will cost about 13 cents per kilowatt-hour ($0.13/kW-hr). Southern California Edison (SCE), who serves the Port of Long Beach, is discussing a similar approach. For container ships, which are expected to consume three-quarters of the electricity required for shore power, staff assumed that the cost of electricity would be $0.13/kW-hr.

Passenger ships use a considerable amount of electricity while hotelling—up to 12 megawatts—and they normally hotel during the day when rates are the highest, so their cost for electricity is considerably greater than that for container ships. (ARB, 2005a) Therefore, for passenger ships, staff used actual utility tariff schedules to estimate electrical costs for shore power. (PG&E, 2005) (SDG&E, 2005) (SCE, 2005) These electricity costs ranged from $0.13/kW-hr to $0.29/kW-hr.

Staff also used tariff schedules for the reefers. (SDG&E, 2005) (SCE, 2005) Although their overall usage is low, their rates are more affected by demand charges, raising their average cost for electricity per kilowatt-hour. The electricity rate for reefers at San Diego remained near $0.13/kW-hr, but the Hueneme rates were $0.23 – 0.26/kW-hr.

For fuel costs, staff assumed that the ships were burning distillate fuel in their auxiliary engines, pursuant to the requirements of the auxiliary engine fuel regulation adopted by the Board in December 2005. Although there has been a legal challenge to that regulation, staff assumes that distillate will continue to be used at dockside. Based on published costs for fuels in the spot-fuel market in the summer of 2007, staff estimated distillate fuel to cost $550 per metric ton. Using the energy content of these fuels, and an average internal-combustion-engine efficiency of 35 percent, these market values correspond to about $0.13/kW-hr. Therefore, staff assumed for the container ships the cost of distillate fuel used in the auxiliary engines would offset each other, thereby resulting in no net cost to the ships that use shore power. For the other two ship categories, staff compared actual electricity rates from the tariff schedules to the price of fuel, resulting in a net energy cost to the ships for shore power.

Labor

For all ship categories, staff included the cost of using union electricians to both connect and disconnect electrical power for these ships. Staff assumes that three electricians are necessary to perform this function at a compensation rate of $100/hour, or $600 per ship visit. However, if electricians are not already on duty, costs could be much higher, as labor contracts require that workers, once called, be paid for an entire shift. Assuming that electricians were paid an entire shift to connect a ship and again to disconnect a ship, the labor costs for a ship visit could be as high as $4800. For the purpose of calculating total operating costs and overall cost-effectiveness, staff used $4800 per visit. In the case of passenger ships, staff assumed that two electricians would connect and disconnect electrical power. All other assumptions regarding labor costs are the same.

Maintenance

ARB staff assumed that additional maintenance costs incurred with shore-power—mostly associated with shore-side electrical equipment—would be offset by reduced maintenance costs for the ship’s auxiliary engines, which would accrue fewer hours of operation. Therefore, maintenance was not included in the cost-effectiveness analysis.

Recordkeeping and Reporting Requirements

The proposed regulation has reporting and recordkeeping requirements affecting the ship companies, terminals, and ports.

The reporting and recordkeeping requirements for ship companies depend upon the compliance option selected by the vessel owner or operator and terminal. The proposed regulation requires a vessel fleet plan to be submitted to the Executive Officer of the ARB in the years prior to the fleet's regulatory compliance dates. In addition to the vessel fleet plans, the proposal requires an annual statement of compliance to be submitted to the Executive Officer of the ARB certifying compliance with the regulatory requirements for the previous calendar year.

The recordkeeping and reporting requirements are simpler for the limited engine use option because the vessel owner or operator choosing that option must track only those vessels that will comply with the 2014 and 2020 shore power requirements. The recordkeeping and reporting requirements for the emission reduction option are more significant because the vessel owner or operator choosing that option must track the emissions of each vessel in the fleet.

Staff estimates that, for the ship companies that choose the limited engine use option, eight hours would be expended to complete the vessel fleet plan, and 16 hours would be used to complete the annual compliance report. Based upon these estimates, the cost to prepare the vessel fleet plan is about $300, and each ship company is expected to expend about $600 annually to prepare the compliance report. Finally, staff anticipates that the ship companies would use existing resources to satisfy the proposed regulation's reporting requirements.

Similarly, for a ship company using the emission reduction option, the reporting and recordkeeping costs associated with these requirements are about $800 for the vessel fleet plan and about $8,000 annually to prepare the compliance report. Finally, staff estimates that the recordkeeping for this option would cost about $4,000 annually.

A terminal that receives more than 50 vessel visits in 2008 is required to submit a plan to the Executive Officer of the Air Resources Board by July 1, 2009. This plan is required to identify how the terminal will be upgraded to allow vessels to satisfy either the limited engine use option or the emissions reduction option. The terminal is also required to submit plan updates at a frequency that depends on the control strategy selected by the vessel fleet owner or operator and the terminal.

Staff estimates that a company will use one person-month to develop the plan and use three days to prepare each of the plan updates required by the proposed regulation. Furthermore, staff anticipates that existing resources would be used to satisfy the proposed regulation's reporting requirements. Overall, the cost to develop the plan is estimated to be about $7,000 with another $1,000 to be expended by terminal staff for each update to the plan.

The port is required to submit wharfinger data annually to ARB's Executive Officer. The port's written submittal must document when each vessel visits the port, the berth that the vessel visited, and the dates and times that the vessel was initially tied to the berth and subsequently released from the berth. In addition, the terminal operator is required to keep records of electricity usage for shore power and equipment breakdowns that affect a vessel's ability to comply with the limited engine use option or the emission reduction option.

Staff anticipates that each port will use eight hours of staff time to prepare the wharfinger data and one hour a month for recordkeeping. Overall, the annual cost for the ports is expected to cost about $800 annually.

4. Ship Assumptions

Number of Ships Affected

ARB staff developed a 2006 baseline for the number of ships potentially affected by this proposed regulation, then applied the growth factors in Table X-1 to estimate activity levels in 2014 and 2020. The 2006 baseline is based upon wharfinger information provided by the ports. For all ships that visited a specific port, the wharfinger information provides the berth that the ship visited and its date and time of arrival and departure.

Table X-1: Growth Factors Used in Cost-Effectiveness Analysis

Category	Growth Factors
Container Ships	Container ship growth: • **2014**: ships are 45 percent larger than in 2004 • **2020:** ships are 55 percent larger than in 2004 Ship visits: • **2014:** 40 percent increase in ship traffic from 2004 • **2020:** 75 percent increase in ship traffic from 2004
Passenger Ships	Ship visits: • **2014:** 36 to 95 percent increase in ship traffic from 2006, depending upon specific port • **2020:** 72 to 323 percent increase in ship traffic from 2006, depending upon specific port
Reefers Ships	Ship visits: • **2014:** 15 to 205 percent increase in ship traffic from 2006, depending upon specific port • **2020:** 27 to 350 percent increase in ship traffic from 2006, depending upon specific port

To account for growth in activity for the passenger ships and reefers, staff developed growth factors and increased the number of ship visits accordingly. (See Appendix B for a discussion on the development of the ARB emissions inventory.) For container ships, the growth in activity (i.e., total containers imported and exported) will be accomplished by both larger ships and more visits. For this reason, staff used the growth estimates for container ships in the report *Forecast of Container Vessel Specifications and Port Calls within San Pedro Bay* (Mercator, 2005), which considered these two phenomena.

Hotelling Times

Staff used port wharfinger data from 2004 – 2006 to determine hotelling times for the three ship categories, excluding the data for container ships visiting the Ports of Los Angeles or Long Beach during the second half of 2004. There was a labor shortage during that period, extending the hotelling times to levels that are considered unrepresentative.

Hotelling times for the passenger and reefer ships are generally consistent with each visit. For container ships, the hotelling times are more variable, depending on the port visited, the carrier, and the size of the container ship. This variation in hotelling times was considered in the cost-effectiveness analysis.

Power Usage

Staff estimated ship hotelling electrical requirements based upon the results of the 2005 ARB Ocean-Going Vessel Survey and subsequent discussions with ship operators. For container ships, the electrical demand includes two elements: 1) a basic hotelling requirement for water-pumping and general household requirements, and 2) the electrical load from refrigerated containers (reefer boxes). The 2005 survey results provided estimates of the basic hotelling load and some information on the load from reefer containers. Staff requested additional information on reefer boxes carried by container ships in the 2007 ARB Ocean-Going Vessel Survey and also attempted to estimate the reefer load by compiling U.S. Department of Commerce (DOC) data on goods imported and exported in California that are likely to be refrigerated.

Table X-2 presents a summation of assumptions that staff used in its estimation of the total cost and cost-effectiveness of the proposed regulation.

Table X-2: Major Assumptions Used In Cost-Effectiveness Analysis

Category	Assumptions
All	• An annual five percent real interest rate is basis of all economic impacts, assuming seven percent nominal interest and two percent inflation • All costs reported in 2006 dollars • Ship capital costs amortized over 10 years • Terminal capital costs amortized over 20 years • Cost-effectiveness analysis period covers period beginning with year with first expenses and ends with year with the final expenses - 2009 through 2020 for passenger and reefer ships - 2009 through 2030 for container ships
Container Ships	• Average power requirements for this category vary from 1 to 2 MW, depending upon the size of the ship • Hotelling times average between 8 hours to over 100 hours—the average is about 50 hours in the POLA/POLB and 22 hours in Oakland. The hotelling time varies depending upon the ship size and the carrier—the smaller ships average 40 hours or less per visit and the largest ships average 60 to 70 hours per visit. • Capital cost for retrofitting ship is assumed to be $1.5 million dollars • To address the ship re-deployment issue, staff assumed that twice as many ships would be equipped with shore power capability over the economic life of the regulation • Labor used to connect cables and power switchover from ship power to shore power will be a combination of longshoremen and electrical union. Cost will be based upon using three personnel for 8 hours each—at a cost of $100/hr • Electrical cost are assumed to offset cost savings from not using distillate fuel in auxiliary engines
Passenger Ships	• Power requirements for this category vary from 7 to 15 MW • Hotelling times average 10-11 hours per visit • Capital cost for retrofitting ship is assumed to be $1.5 million dollars • Labor used to connect cables and power switchover from ship power to shore power will be a combination of longshoremen and electrical union. Cost will be based upon using two personnel for 8 hours each—at a cost of $100/hr • Staff used actual tariff schedules. Electrical rates were $0.13 - $0.29 per kW-hr.

Category	Assumptions
Reefer Ships	• Average power requirements: 3.3 MW for fully containerized reefer ships, 1.3 MW for break-bulk reefer ships • Hotelling times average between 25 hours to over100 hours. The average is dependent upon the product being shipped. For example, ships carrying bananas stay in port for about 60 hours per visit and ships carrying melons stay in port for about 30 hours per visit • Capital cost for retrofitting ship is assumed to be $1.5 million dollars • Labor used to connect cables and power switchover from ship power to shore power will be a combination of longshoremen and electrical union. Cost will be based upon using three personnel for 8 hours each—at a cost of $100/hr. • Staff used actual tariff schedules. Electrical rates were $0.13 - $0.26 per kW-hr.
Terminals	• Capital cost for retrofitting each berth is assumed to be $5 million • Number of berths considered for shore power equipment based upon: 1) berths with more than 30 visits in 2006; 2) historical traffic at berth; and 3) if growth exceeds historical traffic at the berth, staff assumed new berths are added
Utilities	• San Diego ($30 million); Long Beach, Oakland, and San Francisco ($15 million); Los Angeles and Hueneme (None)

D. Potential Costs and Impacts to Businesses

In this section, we estimate the costs and impacts on private companies from complying with the proposed regulation. The analysis estimates the overall total statewide cost to private businesses, as well as the cost to a typical business, and the total costs to different sections of the industry.

We do not believe that the ship companies or terminal operator subject to this proposed regulation would qualify as small businesses due to the large capital and operating costs associated with vessel operation. Typical container ships are estimated to cost $50 to $100 million (Mercator, 2005). In addition, Government Code section 11342.610 excludes businesses in transportation and warehousing with annual gross receipts exceeding one and a half million dollars from its definition of “small business.” We believe that the annual gross receipts for a profitable vessel owner or operator would far exceed this level in order to be profitable. For example, a single Asia-to-U.S. West Coast voyage for a typical container ship costs about $2 to $3 million. (*Ibid*) Similarly, the terminal operators are generally related to the ship companies (e.g., Evergreen ships visiting an Evergreen terminal). The few terminal operators not directly related to ship companies are also large companies. Therefore, we do not believe there are any small businesses directly affected by the proposed regulation. As such, we have only included costs in this analysis for typical businesses.

Total Costs

Staff estimates that as many as 1,450 ships will need to be equipped for shore power over the lifetime of this proposed regulation (2009 -2030). This estimate includes approximately 15 reefers, 85 passenger ships, and 1,350 container ships. Staff estimated that the number of container ships operating at California ports that need to be fitted for shore power in 2020 would be 675. However, since the container ship fleet serving California changes with time and ships are redeployed to other routes worldwide, staff doubled the number of retrofits/new installations needed to account for repositioning of ships from California service. Although historically some carriers have redeployed container ships at a higher rate, staff believes that this method is reasonable: the ships that will call on California ports and be subject to this proposed regulation will require capital investments that may result in longer use of these ships in California ports. Furthermore, staff believes that using $1.5 million per ship is likely overestimates the average cost; staff expects that new builds and later retrofits will be less expensive.

Staff estimates that 78 berths will have to be equipped provide shore power to visiting ships in 2020, including five reefer berths, six passenger berths, and 67 container berths. The additional capital costs identified above for bringing power to several of the ports add $75 million to total shoreside infrastructure costs.

Staff estimates the statewide total regulatory costs for affected businesses and port authorities to comply with the proposed regulation to be approximately $1.8 billion, discounted to 2006 dollars. Annually, the costs are expected to vary from $30 million to $137 million. The low end of the range represents a year when the only major capital expenditures are for retrofitting container ships due to repositioning, and the high end of the range represents a year when capital expenditures are being made for shoreside infrastructure and for retrofitting a considerable number of ships to meet the 2020 milestone. The total statewide annual costs to private business include recovery of capital expenditures, both aboard the ships and at the ports, and operating costs, which are labor costs and net energy costs, if any.

Costs to Ship Companies and Terminal Operators

Staff prepared costs for a typical ship company and a typical terminal operator complying with the proposed regulation. For this example, both the ship company and terminal operator are in the container shipping business. For the ship company, the costs are distributed over a 22-year period (2009 - 2030), and for the terminal operator, the costs are distributed over an 11-year period (2009 - 2020). The longer analysis period for the ship company is required for the full recovery of the capital expenditures related to the second round of retrofits due to the repositioning of ships as discussed above.

The total costs to a typical ship company complying with the proposed regulation, including capital and ongoing costs, are estimated to be about $34 million, assuming an average fleet size of 20 ships. This cost would be distributed over a 22-year period, from 2009 to 2030. About 40 percent of the cost is associated with modifying additional ships to replace ships that have been re-deployed away from California ports. Annual costs would vary between $600,000 and $3 million per year, with the average cost of $1.5 million per year over this time period. The low end of the range represents a year when no major capital expenditures are made, and the high end of the range represents a year where capital expenditures are made for both new ships as well as replacement ships that are rerouted.

For the other ship categories, the total costs for a typical ship company to comply with the proposed regulation, including capital and ongoing costs, are estimated to be about $3.2 million. This cost would be distributed over a 12-year period, from 2009 to 2020. Annual costs would vary between $150,000 and $500,000 per year, with the average cost of $260,000 per year over this time period.

Similarly, the total costs to a typical terminal operator complying with the proposed regulation, including capital and ongoing costs, are estimated to be about $11 million. About 20 percent of the cost is attributed to labor costs and the other 80 percent for capital costs. This cost would be distributed over an 11-year period, from 2009 to 2020. Annual costs would vary between $500,000 and $1.1 million per year, with the average cost of $1 million per year over this time period. The low end of the range represents a year where no major capital expenditures are made and the high end of the range represents a year where capital expenditures are made for shore-side improvements.

Both companies would have additional recurring costs associated with recordkeeping and reporting. For the ship company, the costs associated with reporting and recordkeeping will vary between $600 and $12,000 annually. The higher cost for reporting and recordkeeping is based upon the ship company complying with the emission reduction option of the proposed regulation, and the lower end of the range is the costs for ship companies complying with the limited engine use option. Similarly, for the terminal operator, the costs associated with reporting and recordkeeping is about $800 annually.

Costs and Impacts to Various Industry Sectors

ARB staff categorized the private businesses into three groups: ship companies, terminal operators, and utilities. The costs by industry sector are given in Table X-3. The total costs to private businesses are expected to be about $1.8 billion over the life of the regulation. Sixty-seven percent of the total costs of complying with the proposed regulation will be in the ship company category. As discussed above, about half the cost attributed to the ship company category is for replacement ships as ships are re-routed to other shipping routes. This cost can be substantially reduced if the ship companies elect to dedicate ships equipped with shore-power equipment to visiting California ports.

Table X-3: Distribution of Total Costs for Private Companies

Business Category	Estimated Total Statewide Costs
Ship companies	$1.2 billion
Terminal Operators	$540 million
Utility Companies	$60 million

The methodology used to estimate the costs in Table X-3 is the same used to estimate the total statewide costs of the proposed regulation, except that the individual industry sectors are analyzed separately. The total statewide costs for ship companies include costs for capital and electricity, and the total statewide costs for the terminal operators include costs for capital and additional labor. Staff assumes that the costs to the local utilities will be fully recovered through the additional sale of electricity and possibly tariff rate modifications.

Potential Business Impact

In this section, we analyze the potential impacts of the estimated costs of the proposed regulation on business enterprises. Section 11346.3 of the Government Code requires that, in proposing to adopt or amend any administrative regulation, State agencies shall assess the potential for adverse economic impact on California businesses to compete with businesses in other states, the impact on California jobs, and the impact on California business expansion, elimination, or creation.

The companies likely affected by the proposed regulation are not California-based businesses. Nearly all the affected businesses are foreign owned enterprises, sometimes involving complicated ownership arrangements involving consortiums of investors. Additionally, these businesses subject to this proposed regulation are large companies generating billions of dollars in annual sales and employing thousands of people. A list of some of the affected companies is given in Table X-4. Consequently, the proposed regulation is not expected to impose a significant cost burden on these companies.

Table X-4: Some Companies Affected by the Proposed Regulation

Company
American President Lines
Carnival Cruise Lines
China Shipping Container Lines
Dole
Hanjin Shipping
Maersk Line
Nippon Yusen Kaisha (NYK) Line
SSA Marine

Comparison of the Costs of the Proposed Regulation

Staff compared the costs based upon the commodity being affected. For container ships, the costs ranges from $25 to $40 per container moved. This estimated is based upon the containers moved through the ports of Long Beach, Los Angeles, and Oakland for 2006 and assuming that by 2020 the amount of containers moved through these ports will either double (high end of range) or triple (low end of range). This cost represents less than five percent of the typical costs to ship a container. For the passenger ship category, the cost for complying with the proposed regulation represents about 15 percent of the cost of a cabin for a typical three-day or seven-day cruise. Overall, this proposed regulation is not expected to have a major impact on the cost for operating these vessels

Potential Impact on Business Competitiveness

The businesses affected by the proposed regulation are primarily based in foreign countries. Therefore, the proposed regulation is not expected to affect the ability of California businesses to complete with businesses located outside the state.

The proposed regulation could potentially affect the ability of California ports and California based vessel operators to compete with ports and vessel operators outside California due to the slight increase in operating costs. However, we do not believe that the added costs of the proposed regulation are high enough for vessel operators to consider alternative ports outside California.

There are several reasons for this. First, many vessel operators utilize California ports because there is already a local market for their goods within California, or because California exporters choose to utilize California ports to transport their goods overseas. Second, other vessel operators find that the overall cost of transporting goods to their final destination beyond California is lowest by using

California ports because of the ports' existing and well established infrastructure, including road and rail access. Third, in some cases, vessel operators would have to factor in the added costs of fuel and other costs of traveling greater distances to non-California ports. Finally, as stated previously, the added costs resulting from the proposed regulation are a small fraction of the costs to move these commodities, and as discussed above, these costs are not expected to result in a significant adverse impact on the profitability of typical companies.

Most of the affected businesses that operate vessels are large businesses and can either absorb or pass-through the increased costs associated with the proposed regulation with no significant impact on their ability to compete with non-California businesses. Based on these reasons, we do not believe the relatively low costs of this proposed regulation are high enough to significantly affect the competitiveness of those businesses that are integrally linked to the movement of goods through California ports.

Potential Impact on Employment, Business Creation, Elimination or Expansion

As noted, we do not expect the proposal to have a significant adverse economic impact on businesses. Therefore, the proposed regulation is not expected to have a noticeable impact on employment, or business creation, elimination, or expansion. The proposed regulation may lead to an increase or modification of job duties, leading to no net change in the number of jobs. For example, existing longshoreman or electrical labor may be used to connect the vessel to shore power. To the extent that electrical equipment, emission control equipment or distributed generation equipment are manufactured in California, some jobs may also be created to make, install, repair or operate these systems.

E. Potential Costs to Local and State Agencies

Local Agencies

In this section, we estimate the total costs to governmental agencies. The governmental agencies affected by the proposed regulation are the port authorities, which are departments under the applicable cities. The ports affected by the proposed regulation are the Ports of Hueneme, Long Beach, Los Angeles, Oakland, San Diego, and San Francisco. Additionally, the cruise terminal at the Port of Long Beach is owned by the City of Long Beach.

The Ports of Long Beach, Los Angeles, and Oakland are landlord ports that have long-term agreements with their tenants. Staff assumes that the landlord ports will work with their tenants, the terminal lessees, to provide the shoreside infrastructure necessary to meet the requirements of the proposed regulation. Furthermore, staff assumes that the landlord ports will eventually recover their capital costs through modifications to terminal leases, while the non-landlord ports will recover their capital costs through fees collected from the carriers.

Table X-4 provides the costs associated with satisfying the requirements of the proposed regulation, both the fiscal impact—defined as the costs incurred to the local agencies in the three fiscal years starting with the 2007/2008 fiscal year—and the total capital costs. Staff anticipates that there would be no fiscal impact until the second year. At this time, staff anticipates that the port authorities would begin to make payments during fiscal year 2008/2009 and 2009/2010 for the necessary shore-power equipment to satisfy the 2014 milestone. For this analysis, the capital costs were amortized over a 20-year period at a five percent real interest rate. The fiscal costs range from $600,000 to $7.4 million for the fiscal years 2007/2008 and 2009/2010.

In addition, Table X-5 shows the total costs to be expended by the port authorities to add shore-power equipment to their facilities. This cost ranges between $4 million to $86 million for the affected ports.

Table X-5: Summary of Annualized Costs for Public Agencies' Compliance with the Proposed Regulation

Port	Total Fiscal Impact	Total Costs
Long Beach	$7 million	$79 million
Los Angeles	$7 million	$86 million
Oakland	$7 million	$80 million
Hueneme	$2 million	$12 million
San Diego	$2 million	$12 million
San Francisco	$620,000	$4 million

<u>State Agencies</u>

We do not expect any significant fiscal impacts on State agencies. The ARB will need to expend resources to enforce the proposed regulation. However, these enforcement activities can be conducted with existing resources in the short term. Eventually, additional resources will be needed as the implementation of this and other port-related measures occur.

<u>Federal Agencies</u>

We are not aware of any impacts on federal agencies. Military and other government owned or operated vessels in government , non-commercial service are exempted from the requirements of the proposed regulation.

F. Summary of Total Costs for Compliance with the Proposed Regulation

Under this section, the total cost of the proposed regulation to both private and governmental agencies is estimated. As shown in Table X-6, nearly all of the cost is expected to be borne by private companies, including costs for shore-side infrastructure at Los Angeles, Long Beach, and Oakland. Staff assumes that these ports are likely to pass the cost of any shore-power project to the terminal operator. The other affected ports, including Hueneme, San Diego, and San Francisco, are not likely to be able to pass the costs to their tenants. Since these ports operate as a unit under the jurisdiction of the city where port is located, the anticipated costs for these ports are included in the city category for Table X-6.

Table X-6: Total Capital Costs for Compliance with the Proposed Regulation

Category	Total Costs
Private	$1.8 billion
City	$27 million
Total	$1.8 billion

G. Cost-Effectiveness

This section discusses the cost-effectiveness of the proposed regulation. Cost effectiveness is expressed in terms of control costs (dollars) per unit of air emissions reduced (ton). As described below, the cost-effectiveness for the proposed regulation is determined by dividing the total cost of the proposed regulation by the total tons of air pollutants reduced from 2009 to 2020. (As mentioned previously, for the container-ship category, the regulatory period is 2009 - 2030 to allow for the full recovery of the capital expenditures related to the second round of retrofits due to the repositioning of ships.)

Staff calculated cost-effectiveness values for each terminal affected by the proposed regulation. For each terminal, staff considered the shoreside infrastructure costs (including any additional utility infrastructure costs that may apply outside the port); the infrastructure costs aboard the ships that visited the terminal; the net energy costs, if any, while the ship hotelled; and the labor costs to connect and disconnect the power to the ships.

<u>Allocation of Capital Costs for Ships</u>

A ship may visit multiple ports in California—for example, a container ship visiting the Port of Long Beach and the Port of Oakland. To avoid counting the capital costs of retrofitting that ship for shore power multiple times, ARB staff assigned the capital costs to the port that the ship visited most frequently during 2006. In the rare case where the ship visited two or more ports the same number of times, staff used total berthing hours at each port as a tie-breaker.

Phase-In of Capital Costs

For grid-based shore power, for which staff conducted these cost-effectiveness analyses, the first regulatory milestone is 2014. At that time, a vessel fleet calling on a port must shut off on-board auxiliary engines for at least 50 percent of its total port calls and presumably connect to shore power. Staff assumed that the ship companies, in order to minimize the number of affected ships, would initially modify the ships that make the most frequent visits to California ports. Based upon this approach, most ship companies would typically need to modify about 25 - 35 percent of their ships with shore-power equipment to satisfy the 50 percent requirement. This would represent about 300 ships.

Similarly, the terminal operator will also need to update one to two berths at their terminals by 2014, as required by the proposed regulation, to handle the ships equipped with shore-power equipment. Overall, statewide, 44 berths would need to be equipped with shore-power infrastructure to satisfy the 2014 milestone.

For the 2020 regulatory milestone—80 percent of port calls by a vessel fleet using shore power—again staff assumed that ship companies would modify the ships that make the most frequent visits to California ports. Most ship companies would typically need to modify 50 - 60 percent of the ships, or an additional 20 - 25 percent, in order to satisfy the 80 percent criteria. Coupled with the expected increase in goods movement, which results in additional container ship activity, ship companies will need to equip more ships with shore-power equipment than was done to satisfy the 2014 milestone. Overall, satisfying the 2020 milestone would result in 450 additional ships equipped with shore-power capability.

As mentioned earlier, because of the historical repositioning of container ships to different shipping lanes, staff assumed in the cost-effectiveness analyses that over a 15-year period, beginning in 2016, operators of container-ship fleets would need to replace the entire fleet with other ships equipped with shore-power equipment, or another 700 container ships.

The terminal operators will need to modify additional berths at their terminals to handle the additional ships now equipped with shore-power equipment. Staff estimates an additional 31 berths would be modified to satisfy the 2020 milestone.

Cost-Effectiveness Results

Using the assumptions described above, staff estimated that the overall cost effectiveness of the proposed regulation is about $12,800 per ton of NOx emissions reduced, assuming all costs are allocated to NOx reduction. For diesel PM, staff estimated an overall cost-effectiveness of $690,000 per ton, assuming all costs are allocated to PM reduction.

Since the proposed regulation reduces both pollutants, Table X-7 presents the cost-effectiveness values in several formats: 1) the total costs are borne by NOx emissions reduction only; 2) the total costs are borne by diesel PM emissions reduction only; and 3) the total costs are split between NOx emissions reductions and diesel PM emissions reductions. The range of values represents the variation in cost-effectiveness among all the terminals analyzed.

Table X-7: Summary of Cost-Effectiveness for Shore-Power Based on Full Regulatory Compliance in 2020

	All Costs for NOx Only	All Costs for PM Only	Half Costs for NOx	Half Costs for PM
(Dollars per Ton of Pollutant Reduced)				
Container Ships—POLA/POLB	$11,000 to $32,000	$400,000 to $1.1 million	$5,500 to $16,000	$200,000 to $550,000
Container Ships--Oakland	$11,500 to $71,000	$400,000 to $2.5 million	$5,800 to $36,000	$200,000 to $1.2 million
Passenger Ships	$13,000 to $47,000	$440,000 to $1.6 million	$6,400 to $23,000	$220,000 to $810,000
Reefer Ships	$16,000 to $30,000	$600,000 to $1 million	$7,900 to $15,000	$300,000 to $510,000

The cost-effectiveness values for PM emissions reductions are elevated because a previously adopted ARB regulation (*Regulation for Auxiliary Diesel Engines and Diesel-Electric Engines Operated on Ocean-Going Vessels within California Waters and 24 Nautical Miles off the California Coastline*) reduced diesel PM emissions from hotelling ships by 70 percent, leaving 30 percent available to be further reduced by the proposed regulation.

Typically, the longer a ship stays in berth, the more cost-effective shore power is for that ship: more emissions are reduced for the same capital investment and labor costs. Yet despite shorter hotelling times for container ships visiting Oakland—an average of 21 hours, as compared to 50 hours for POLA/POLB—the cost-effectiveness values for Oakland are reduced because the capital costs associated with the ships visiting Oakland have been allocated to POLA/POLB. In other words, many of the container ships visiting Oakland would not incur additional capital costs. The cost of a shore power project at Oakland will largely be the cost of providing the shoreside infrastructure only.

The better cost-effective values represent terminals that receive numerous ship calls—again more emissions reductions for the investment. Conversely, the higher values represent terminals who must invest in shoreside infrastructure with fewer ship calls to achieve emissions reductions.

For perspective, the cost-effectiveness values of the proposed regulation are compared to that for other regulations recently adopted by the Board. For example, the *Heavy Duty Urban Bus Engines and Fleet Rule for Transit Agencies*, approved by the Board in September 2005, estimated a cost-effectiveness of nearly $68,000 per ton of NOx reduced, assuming all of the costs go toward NOx emissions reductions. The average cost-effectiveness of the proposed regulation is below this value, as are the calculations for the individual terminals, with the exception of one terminal at Oakland, which is slightly above this cost-effectiveness level.

The highest cost-effective values for regulations adopted by the Board to reduce PM emissions was about $320,000 per ton of PM reduced for the *Diesel Particulate Control Measure for On-Road Heavy-Duty Diesel-Fueled Vehicles Owned or Operated by Public Agencies and Utilities*. If the total costs of the proposed regulation are split between NOx emissions reductions and diesel PM reductions, then about half of the terminals are below this cost-effectiveness threshold. Again, the auxiliary engine fuel regulation already has reduced hotelling diesel PM emissions by 70 percent.

Table X-8 provides cost-effectiveness values for 2014, when the interim milestone becomes effective. The calculation method is different than that used to determine the overall cost-effectiveness of a proposed regulation. To determine cost-effectiveness for an interim date within the regulatory period, staff must add the annualized capital recovery costs to the operating costs for that year and divide by the emissions reductions for that year. In general, the cost-effectiveness values for 2014 are consistent with the overall cost-effectiveness values for the proposed regulation. In the few cases where the 2014 values were significantly higher than the overall cost-effectiveness values, the terminals in question either had a disproportionately greater number of ships affected by the 2014 milestone than the other terminals, or had fewer ships visiting the terminal.

Table X-8: Summary of Cost-Effectiveness for Shore-Power for Complying With 2014 Requirement

	All Costs for NOx Only	All Costs for PM Only	Half Costs for NOx	Half Costs for PC
(Dollars per Ton of Pollutant Reduced)				
Container Ships—POLA/POLB	$10,000 to $49,000	$360,000 to $1.7 million	$5,000 to $25,000	$180,000 to $850,000
Container Ships--Oakland	$18,000 to $63,000	$620,000 to $2.2 million	$9,000 to $32,000	$310,000 to $1.1 million
Passenger Ships	$10,000 to $30,000	$350,000 to $1 million	$5,000 to $15,000	$170,000 to $500,000
Reefer Ships	$9,900 to $29,000	$170,000 to $500,000	$5,000 to $14,000	$86,000 to $250,000

In conclusion, staff considers the proposed regulation to be cost-effective for NOx emissions reductions and marginally cost effective for diesel PM emissions reductions. In its cost-effectiveness calculations, staff used conservative estimates. For example, staff assumed an overall cost of $1.5 million per ship to add shore-power equipment. One carrier, NYK, has announced that it will deploy 38 container ships with shore power capability at a total cost of $22 million, or a cost of $600,000 per ship. This cost is based upon placing the necessary shore-power equipment (transformer, switchgear, and associated controls) in a container at the berth that can be placed on each ship equipped to use this shore-power container. With this approach, the necessary equipment can be moved from ship to ship on an as-needed basis instead of fully retrofitting each ship with the necessary electrical equipment. Since the cost to modify the ships represents about 80 percent of the capital costs for shore power, reducing the ship-side costs can significantly improve the cost effectiveness of the regulation.

Finally, as was discussed in Chapter IX, staff allocated no costs to the reduction of CO_2, a greenhouse gas (GHG). Staff considers these reductions to be a co-benefit of the proposed regulation; however, if staff allocated costs to these GHG emission reductions, the cost-effective values for the proposed regulation would be even less.

H. Availability of Incentive Funding

The Proposition 1B: Goods Movement Emission Reduction Program (Prop 1B Bond) and the Carl Moyer Air Quality Standards Attainment Program (Carl Moyer Program) are two distinct state incentive programs that could potentially help fund shore power projects. The Prop 1B Bond, approved by voters in 2006, will provide $1 billion in funding over four years beginning in 2008 to reduce emissions and health risk from activities associated with freight movement in

California's trade corridors. ARB was appropriated $250 for this program in fiscal year 2007/2008. The Carl Moyer Program provides up to $140 million annually for projects that reduce emissions from diesel engines, vehicles, and equipment. Both state programs seek to leverage non-state funds, and are required by statute to reduce emissions beyond what would otherwise occur though regulation or other legal mandate.

The Prop 1B Bond program is a new incentive program. Implementing legislation was passed in August 2007 that requires ARB to adopt program guidelines by the end of 2007. ARB is now holding public workshops regarding minimum requirements of shore power projects and other Prop 1B Bond projects. Staff believes project criteria for shore power projects funded through the $1B Bond Program and the Carl Moyer Program should be complementary to ensure the programs aren't competing for the same group of applicants.

While no shore power projects have been funded through the Carl Moyer Program to date, interest in program funding for this source category is increasing. Staff intends to include specific criteria for Carl Moyer Program funding of shore power projects in its updated program guidelines, scheduled to be considered by the Board in February 2008. Shore power projects will have to meet all Carl Moyer Program requirements to receive program funding. For example, projects must be operational at least three years before required by regulation, and project life used for evaluating project cost-effectiveness may not extend beyond an applicable rule compliance date. All Carl Moyer program projects must also achieve real, surplus, quantifiable, and enforceable emission reductions, and cost no more than $14,300 per weighted ton of emissions reduced.[8] ARB shall hold a workshop on preliminary draft Carl Moyer Program criteria for all project categories in November 2007 and release draft guideline revisions for public comment in early 2008.

I. Analysis of Alternative Regulatory Approaches

In this section, staff compares the cost-effectiveness of the proposed regulation to two alternative regulatory approaches: 1) targeting the highest-emitting ships to obtain the necessary reductions, or 2) using best available control technology (BACT) on auxiliary engines while the ship is hotelling.

Staff originally considered approach 1 before choosing the "visits or emissions reduction" approach contained in the proposed regulation. Approach 1 would "tag" the ships that make the most visits to specific ports and make them use shore power or an equivalent control technology to reduce hotelling emissions. For example, a requirement under this regulatory approach might state

[8] Cost effectiveness is calculated as cost per ton of NOx + ROG + 20*PM emissions reduced. The $14,300 per weighted ton cost-effectiveness cap will likely rise to reflect an increase in the Consumer Price Index when the Guidelines are revised.

"container ships making more than four visits to a California port in 2014 must turn off their engines or use an alternative control technology."

Staff estimated that this regulatory approach would be as effective as the proposed regulation. An advantage to this approach is that it would identify the most cost-effective ships from which to reduce emissions; however, staff abandoned this approach because of the complexity and difficulty of tracking the ships that were required to reduce emissions. Many of these ships would be repositioned elsewhere, while other ships would replace them in California service, creating excessive recordkeeping requirements and practical enforcement challenges.

The second alternative that ARB staff considered is requiring ship companies to install BACT on their auxiliary engines. Currently, few emission-control technologies that have been used successfully on land-based engine applications have been demonstrated on marine engines. Nevertheless, for the purpose of determining a potential cost-effectiveness of this approach, staff selected selective catalytic reduction (SCR) for NOx emissions reductions and diesel oxidation catalyst (DOC) for diesel PM emissions reductions.

Staff estimated that the cost to install SCR and DOC on auxiliary engines would be $155 per horsepower per engine ($130 for SCR and $25 for DOC). Installing this equipment on the same ships affected by the proposed regulation would cost $1.2 billion dollars, which is less than the overall cost of the proposed regulation.

The PM emission reductions would be considerably less with this BACT approach because DOCs achieve only about 25 percent PM emission reductions. Furthermore, the NOx emissions reductions typically achieved by SCR systems on land (80 percent or higher) would more than likely be less because of the varying load of the auxiliary engines during transiting, maneuvering, and hotelling. SCR systems work more effectively under constant load conditions.

Staff estimated the average cost-effectiveness for NOx reductions using SCR to range from $11,000 to $21,000 per ton reduced, which may be considered comparable to the $12,800 per ton achieved by the proposed regulation. The cost-effectiveness for diesel PM reductions using this approach, estimated at $1.7 million per ton, is more than twice as high as the $690,000 per ton of diesel PM emissions achieved with the proposed regulation.

Considering the unproven application of these technologies for marine engines, fewer total emissions reductions, and much higher cost-effective values for diesel PM emissions reductions, staff did not pursue this alternative regulatory approach.

REFERENCES:

California Air Resources Board. *2005 Oceangoing Vessel Survey of Results*; 2005. http://www.arb.ca.gov/regact/marine2005/appc.pdf.

California Air Resources Board. *Emission Reduction Plan for Ports and Goods Movement in California*; April 2006. http://www.arb.ca.gov/planning/gmerp/march21plan/march22_plan.pdf

California Air Resources Board. *Proposed Amendments to the Exhaust Emission Standards for 2007-2009 Model-Year Heavy Duty Urban Bus Engines and the Fleet Rule for Transit Agencies*; September 2005. (ARB, 2005c)

California Air Resources Board. *Proposed Diesel Particulate Matter Control Measure for On-Road Heavy-Duty Diesel-Fueled Vehicles Owned or Operated by Public Agencies and Utilities*; October 2005. (ARB, 2005b)

California Air Resources Board. *Proposed Diesel Particulate Matter Control Measure for On-Road Heavy-Duty Residential and Commercial Solid Waste Collection Vehicles*; September 2003.

California Air Resources Board. *Proposed Regulation for In-Use Off-Road Diesel Vehicles*; April 2007.

Mercator Transport Group. *Forecast of Container Vessel Specifications and Port Calls Within San Pedro Bay*; February 2005.

Pacific Gas and Electric Company. “Tariff Book.” Pacific Gas and Electric Company. July 2005. http://www.pge.com/tariffs/ERS.SHTML#ERS (PG&E, 2005)

San Diego Gas and Electric. *Cold Ironing Feasibility Study for Electrical Services at Cruise Ship & 10th Avenue Marine Terminals*; January 2007. (SDG&E, 2007)

San Diego Gas and Electric. “Electric Tariff Book - Commercial/Industrial Rates.” San Diego Gas and Electric. July 2005. http://www.sdge.com/regulatory/tariff/elec_commercial.shtml (SDG&E, 2005)

Southern California Edison. “Regulatory – SCE Tariff Books, General Service – Industrial Rate Schedules.” Southern California Edison. July 2005. http://www.sce.com/AboutSCE/Regulatory/tariffbooks/ratespricing/businessrates.htm (SCE, 2005)