



## **STAFF REPORT: INITIAL STATEMENT OF REASONS FOR PROPOSED RULEMAKING**



## **PROPOSED REGULATION FOR AUXILIARY DIESEL ENGINES AND DIESEL-ELECTRIC ENGINES OPERATED ON OCEAN-GOING VESSELS WITHIN CALIFORNIA WATERS AND 24 NAUTICAL MILES OF THE CALIFORNIA BASELINE**

**Stationary Source Division  
Emissions Assessment Branch  
October 2005**

**State of California  
AIR RESOURCES BOARD**

**STAFF REPORT: INITIAL STATEMENT OF REASONS  
FOR PROPOSED RULEMAKING**

**Public Hearing to Consider**

**PROPOSED REGULATION FOR AUXILIARY DIESEL ENGINES AND DIESEL-  
ELECTRIC ENGINES OPERATED ON OCEAN-GOING VESSELS WITHIN  
CALIFORNIA WATERS AND 24 NAUTICAL MILES OF THE CALIFORNIA  
BASELINE**

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Headquarters Building  
1001 "I" Street  
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Sacramento, California

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**State of California  
AIR RESOURCES BOARD**

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CALIFORNIA WATERS AND 24 NAUTICAL MILES OF THE CALIFORNIA  
BASELINE**

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**Staff Report: Initial Statement of Reasons for Proposed Rulemaking  
Proposed Regulation for Auxiliary Diesel Engines and Diesel-Electric Engines  
Operated on Ocean-going Vessels within California Waters and  
24 Nautical Miles of the California Baseline**

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## EXECUTIVE SUMMARY

Air pollution from maritime port activities is a significant and growing concern in California. Diesel-powered vehicles and engines at the ports emit soot, or diesel particulate matter (PM), and other air pollutants than can increase health risks to nearby residents. Port operations are also a significant source of oxides of nitrogen (NOx) which can contribute to the formation of regional smog, or ozone, and fine particulate matter.

Living in any area impacted by air pollution is harmful, particularly for children, the elderly, and those with compromised health. The communities closest to port operations face even greater impacts and have a greater localized risk due to exposures to high levels of diesel PM. This pollutant poses a lung cancer hazard for humans, and causes non-cancer respiratory and cardiovascular effects that increase the risk of premature death. In addition, in many cases, the populations nearby ports are economically disadvantaged and less able to obtain quality health care to address air pollution-related illnesses.

Unless substantial additional control measures are implemented, port-related emissions are expected to significantly increase as trade grows over the next 15 to 20 years. While the movement of goods through California ports is a vital component of the State's overall economy and provides a key link to international trade, it is essential that aggressive steps be taken to counter the projected emissions increases and ensure that the port-related emissions are reduced to health protective levels.

As one of several steps being taken to reduce emissions from port activities, the Air Resources Board (ARB) staff is proposing a regulation to reduce emissions from ocean-going vessel auxiliary engines. Implementation of this regulation will be an important and necessary step in the effort to improve the public health in communities near ports. A recent ARB study has shown that diesel PM emissions from hotelling (auxiliary engine emissions while vessels are moored) are the largest contributor of toxic pollutants to neighboring communities. The proposed regulation would reduce the emissions of diesel PM, NOx, sulfur oxides (SOx), and "secondarily" formed PM (PM formed in the atmosphere from NOx and SOx). The proposed regulation will reduce emissions from ocean-going vessel auxiliary engines through the use of cleaner marine distillate fuels, or equally effective alternative controls. This would result in immediate, substantial reductions in emissions upon implementation in 2007. Specifically, for the nearly 80 percent of vessels currently using heavy fuel oil in their auxiliary engines, compliance with the proposed regulation will result in an estimated 75 percent reduction in diesel PM, 80 percent reduction in SOx, and 6 percent reduction in NOx.

This proposed regulation is one of several measures currently under consideration that will continue progress in meeting the air quality goals defined in the Diesel Risk Reduction Plan and the State Implementation Plan and that will help offset the projected emissions increases in port-related emissions. Other regulations being proposed include measures to reduce emissions from cargo handling equipment, commercial

harbor craft, and off-road diesel engines. ARB staff is also pursuing additional air pollution control strategies for ocean-going vessels in the coming years, including addressing the main engines on ocean-going vessels, and exploring emission reduction options for vessels that make frequent port visits.

Presented below is an overview which briefly discusses the information presented in this document. For simplicity, the discussion is presented in question-and-answer format. It should be noted that this summary provides only brief discussions of the topics. The reader is directed to subsequent chapters in the main body of the report for more detailed information.

## **1. What is ARB proposing?**

The proposed regulation requires that auxiliary engines on vessels operating within 24 nautical miles (nm) of the California coastline significantly reduce their diesel PM, NO<sub>x</sub>, and SO<sub>x</sub> emissions. Emission reductions can be achieved by using cleaner-burning marine distillate fuels, or implementing equally effective alternative emission control strategies under an “Alternative Compliance Plan (ACP).” For vessels complying with the fuel requirement, vessel operators will need to switch from the use of heavy fuel oil to marine distillate fuel while they are in port and while they are operating within 24 nm of the California coastline, unless they already use complying distillate fuels or choose to use distillate fuels on a permanent basis. If operators choose to comply with the proposed regulation under an ACP, they must demonstrate that the alternative emission control strategies will result in no greater emissions relative to the emissions that would have occurred by complying with the fuel requirements. The proposed regulation will apply to both U.S.-flagged and foreign-flagged vessels.

## **2. Does ARB have the authority to regulate the emissions from ocean-going vessels as specified in the proposal?**

Yes, under State and federal law, ARB can regulate both criteria pollutants and toxic diesel PM emissions from marine vessels. Health and Safety Code (H&SC) sections 43013 and 43018 authorize ARB to regulate marine vessels to the extent such regulation is not preempted by federal law. Also, H&SC § 39666 requires ARB to regulate emissions of toxic air contaminants (TAC) from nonvehicular sources, which include ocean-going vessels. The proposed regulation reduces or limits emissions of diesel PM, which is both a TAC and criteria pollutant, and NO<sub>x</sub> and SO<sub>x</sub>, which are both criteria pollutants.

The proposed regulation is neither preempted under federal law, nor does it violate the Commerce Clause. Federal authorization under section 209(e) of the Clean Air Act (CAA) is required for regulating new nonroad engines and for requiring retrofits on existing engines. Ocean-going vessel engines, by definition, fall within the category of nonroad engines. However, no federal authorization is required for implementing in-use operational requirements on existing marine vessels and their engines. The proposed regulation is an in-use operational requirement because it does not apply to the

manufacturing process for an engine (i.e., new engine certifications), but only to the emissions of engines installed on ocean-going vessels that operate in California waters.

Further, the proposed regulation does not conflict with the Ports and Waterways Safety Act (PWSA) and U.S. Coast Guard regulations. As an even-handed regulation with substantial benefits, the proposed regulation does not violate the Commerce Clause. And federal and state cases support our authority to regulate both U.S. and foreign-flag vessels within California waters. Therefore, federal law neither preempts the proposed regulation, nor does the regulation violate the requirements of the Commerce Clause.

### **3. Why is ARB proposing statewide implementation of this regulation rather than having the districts adopt regulations?**

We are proposing statewide, uniform implementation of this regulation, rather than encouraging district-by-district adoption of different regulations, for practical reasons as well as ensuring that California speaks with “one voice” with regard to regulating foreign-flag vessels. Under H&SC § 43013 and 43018, ARB and the districts share concurrent jurisdiction over marine vessels, which are considered to be nonvehicular sources. In addition, H&SC § 39666(d) requires the districts to implement and enforce an ARB airborne toxic control measure (ATCM) or adopt and enforce an equally effective or more stringent ATCM. Thus, the districts are authorized to regulate the auxiliary diesel engines on vessels, and each district can do so provided its regulations are equally effective or more stringent.

The districts’ authority notwithstanding, we believe it is prudent for the districts to coordinate their efforts with those of ARB and have ARB to take the lead role in implementing the ATCM. We believe this for several reasons. First, it is impractical for many districts to enforce an ATCM against ocean-going vessels, many of which make multiple visits to ports throughout California. Second, ARB has gained technical expertise over several years of developing this regulation, which would require a significant expenditure of district resources to replicate. Third, the districts are permitted but not required to adopt and enforce an equally effective or more stringent ATCM. By coordinating their efforts with ARB and having ARB take the primary lead in implementing the ATCM statewide, the districts will have met their statutory obligations under H&SC § 39666(d).

Equally important to the practical concerns are the international foreign commerce concerns. Under the dormant Foreign Commerce Clause, regulations that interfere with a nation’s ability to “speak with one voice when regulating commercial relations with foreign governments,” may be held invalid. Having a patchwork of district regulations different from ARB’s proposal, may frustrate the efficient execution of the nation’s foreign policy to speak with one voice. Thus, it would be in California’s best interests to coordinate statewide efforts so that foreign-flag and U.S.-flag vessels visiting California ports only need to understand and meet one set of statewide regulations.

#### **4. What is an ocean-going vessel?**

Ocean-going vessels are generally very large vessels designed for deep water navigation. Ocean-going vessels include large cargo vessels such as container vessels, tankers, bulk carriers, and car carriers, as well as passenger cruise vessels. These vessels transport containerized cargo; bulk items such as vehicles, cement, and coke; liquids such as oil and petrochemicals; and passengers.

Ocean-going vessels travel internationally and may be registered by the U.S. Coast Guard (U.S.-flagged), or under the flag of another country (foreign-flagged). The majority of vessels that visit California ports are foreign-flagged vessels.

#### **5. What is an auxiliary engine?**

Auxiliary engines are diesel engines on ocean-going vessels that provide power for uses other than propulsion (except as noted below for diesel-electric vessels). Auxiliary engines are usually coupled to generators used to produce electrical power. On cargo vessels, most auxiliary engines are used to provide ship-board electricity for lighting, navigation equipment, refrigeration of cargo, and other equipment. Typically, a cargo vessel will have a single, very large main engine used for propulsion, and several smaller auxiliary “generator-set” engines.

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

#### **6. What fuels do ocean-going vessel operators use in auxiliary engines?**

Most vessel operators use either heavy fuel oil (HFO or residual fuel) or marine distillate fuels in their auxiliary engines. HFO is a very viscous fuel that must be heated to allow it to flow through piping and be combusted in auxiliary engines. HFO is often referred to as residual fuel or bunker fuel. This fuel has high levels of sulfur, ash, and nitrogen containing compounds, and results in much higher emissions than the use of marine distillate fuels. Marine distillate fuels include marine gas oil (MGO) and marine diesel oil (MDO). These distillate fuels are similar to the diesel fuel used by landside sources. According to an ARB survey of vessels visiting California ports, about 75 percent of auxiliary engines use HFO and about 25 percent use marine distillate fuels.

#### **7. What emissions result from the auxiliary engines used on ocean-going vessels?**

Estimates of the statewide 2004 emissions of diesel PM, NO<sub>x</sub>, hydrocarbons (HC), and SO<sub>x</sub>, from ocean-going vessel auxiliary engines are presented in Table ES-1 below.

These emissions estimates include emissions that occur within 100 nm or less off California’s coast, emissions that occur in California inland waters such as emissions from vessels transiting to the ports of Stockton and Sacramento, and emissions that occur while vessels are in-port. The “boundary” of 100 nm was selected because it can be distinguished with relative ease and it is inclusive of the major areas of activity of the sources of interest.

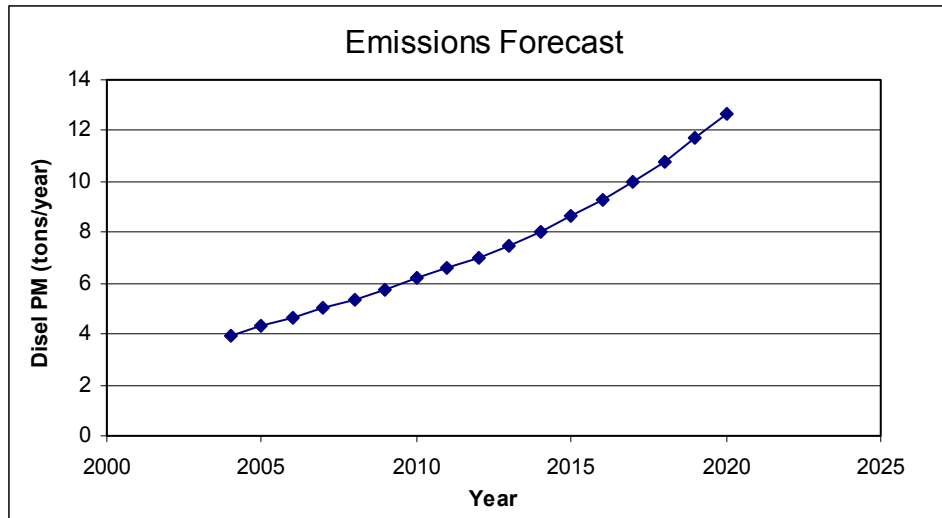
**Table ES-1: 2004 Emissions from Ocean-going Vessel Auxiliary Engines in California**

Vessel Types	Number of Vessels	Numbers of Vessel Visits	2004 Pollutant Emissions, Tons/Day				
			NOx	HC	CO	PM	SOx
Auto	225	750	1.11	0.03	0.08	0.10	0.71
Bulk	475	946	4.02	0.11	0.30	0.35	2.55
Container	594	4744	18.11	0.50	1.37	1.57	11.48
General	196	721	1.75	0.05	0.13	0.15	1.11
Passenger	44	687	14.44	0.39	1.09	1.39	10.24
Reefer	19	52	0.60	0.02	0.05	0.05	0.38
RoRo	13	34	0.40	0.01	0.03	0.03	0.25
Tanker	372	1941	3.16	0.09	0.24	0.27	2.00
Totals	1938	9875	43.6	1.20	3.29	3.91	28.7

As shown in Table ES-1, there are approximately 1,900 ocean-going vessels that visited California’s ports in 2004, and these vessels made nearly 10,000 port calls. Of those 1,900 vessels that visited California’s ports, 30 percent were container vessels, and these vessels represented more than 45 percent of the vessel visits to California’s ports.

The emissions from ocean-going vessels are projected to grow significantly over time as trade continues to increase. The projected diesel PM emission estimates up to 2020 are presented in Figure ES-1.

**Figure ES-1: Ocean-going Vessel Auxiliary Engine Diesel PM Emissions Estimates Projected to Year 2020**



**8. What are the exposures and potential health risks from ocean-going vessel auxiliary engine emissions?**

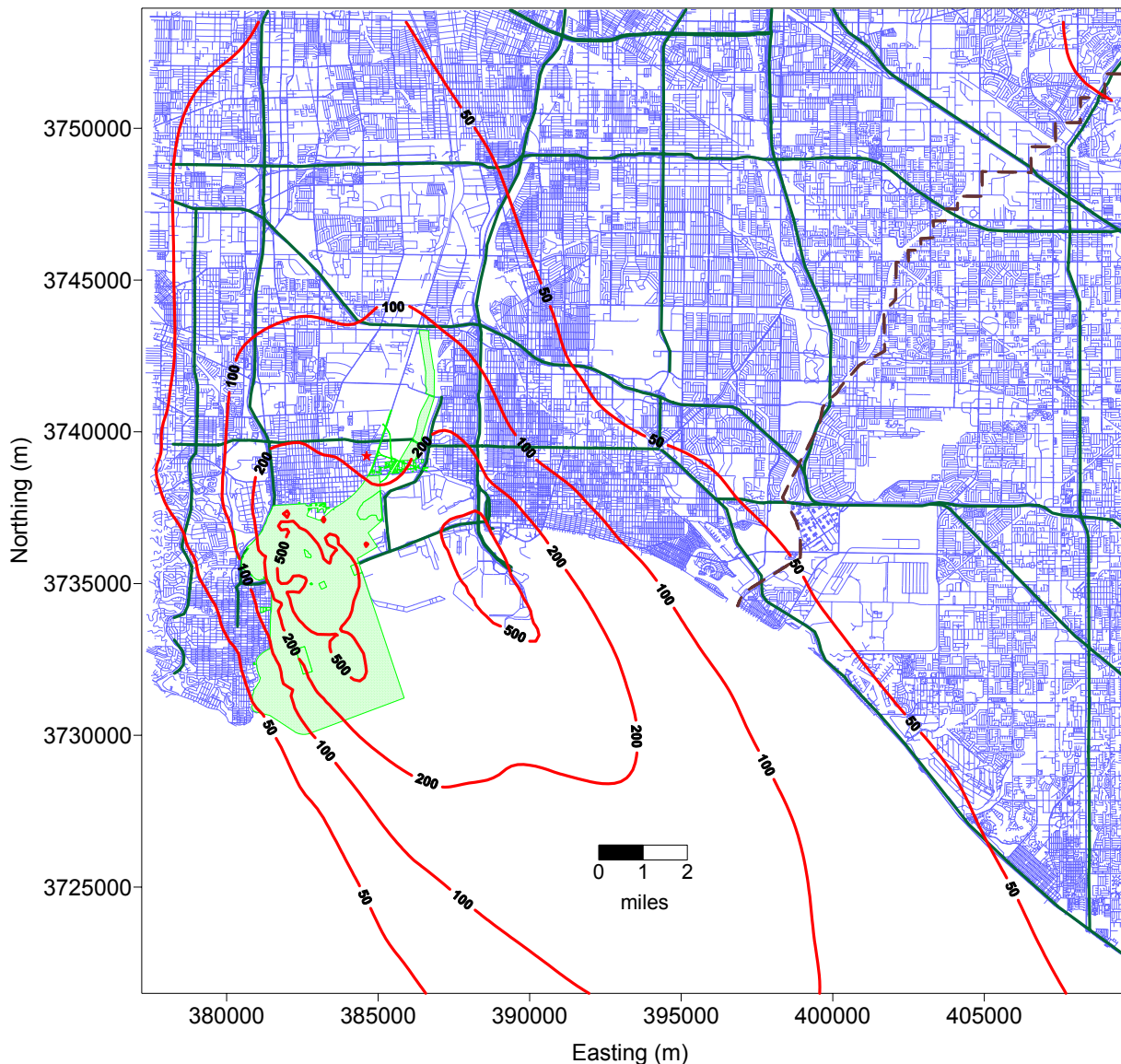
The majority of California's ports are in urban areas and, in most cases, are located near where people live, work, and go to school. This results in substantial exposures to diesel PM emissions from the operation of vessel auxiliary engines California. Exposures to these emissions can result in increased cancer risk and non-cancer health impacts, such as premature death, irritation to the eyes and lungs, allergic reactions in the lungs, and asthma exacerbation.

Because analytical tools to distinguish between ambient diesel PM emissions from vessel auxiliary engines and that from other sources of diesel PM do not exist, we cannot measure the actual exposures to emissions from auxiliary engines. However, modeling tools can be used to estimate potential exposures. To investigate the potential risks from exposures to the emissions from auxiliary engines, ARB staff used dispersion modeling to estimate the ambient concentration of diesel PM that results from the operation of ocean-going vessel auxiliary engines that visit the Port of Los Angeles (POLA) and the Port of Long Beach (POLB). The study area was a 20-mile by 20-mile grid centered on POLA and POLB.

The activities of vessel auxiliary engines resulted in significant cancer risk and other PM related health impacts on the nearby residential areas. Figure ES-2 shows the estimated cancer risk isopleths for diesel PM emissions from vessel auxiliary engines (during transiting, maneuvering, and hotelling) at the Ports of Los Angeles and Long Beach superimposed on a map that covers the ports and the nearby communities.

ARB estimated the area in which the cancer risks are predicted to exceed 100 in a million to be about 13,500 acres with an exposed population of about 225,000. For the cancer risk level over 200 in a million, the impacted area is estimated to be about 2,260 acres, with an exposed population of about 48,000 people. Overall, about 99.5 percent of the study area (excluding port property and the surrounding ocean area) has an estimated cancer risk level of over 10 in a million due to auxiliary engine emissions. We estimate that about 2 million people live in the study area. ARB staff believes that the results from this analysis provide quantitative results for exposures around the Ports of Los Angeles and Long Beach and indicate that elevated risks also occur at other ports in California.

**Figure ES-2: Estimated Diesel PM Cancer Risk from Vessel Auxiliary Engine Activity at POLA and POLB (Wilmington Met Data, Urban Dispersion Coefficients, 80<sup>th</sup> Percentile Breathing Rate, Emission = 405 TPY, Modeling Receptor Domain = 20 mi x 20 mi, Resolution = 200 m x 200 m)**





ARB staff also estimated the potential non-cancer impacts associated with exposure to diesel PM from ocean-going vessel auxiliary engines. The non-cancer health effects evaluated include premature death, asthma attacks, work loss days, and minor restricted activity days due to diesel PM emissions from auxiliary engines. Based on the analysis, staff estimates that the average number of cases statewide per year that would be expected from exposure to the 2004 ocean-going vessel diesel PM emission levels are as follows:

- 31 premature deaths (for ages 30 and older), 16 to 48 deaths as 95% confidence interval (CI);
- 830 asthma attacks, 202 to 1,457 as 95% CI;
- 7,258 days of work loss (for ages 18-65), 6,143 to 8,370 as 95% CI;
- 38,526 minor restricted activity days (for ages 18-65), 31,403 to 45,642 as 95% CI.

## **9. What does the proposed regulation require?**

Under the proposed regulation, vessel operators are required to reduce diesel PM, NO<sub>x</sub> and SO<sub>x</sub> emissions to levels equivalent to the emissions levels that would occur if cleaner-burning distillate fuels were used. To meet this requirement, we expect that most vessel operators will elect to use the distillate fuels specified in the proposal. However, some may decide to implement an alternative emission control strategy that would achieve equivalent or greater emission reductions. Specifically, under the proposal, starting on January 1, 2007, vessel operators can comply by using one of the following distillate fuels when operating their auxiliary engines within 24 nm of the California Coastline: (1) marine gas oil (MGO); or (2) marine diesel oil (MDO) with less than or equal to 0.5 percent by weight sulfur. A 0.5 percent sulfur limit is specified for MDO because it tends to have a higher sulfur level than MGO. MGO is expected to average at or below 0.5 percent sulfur in California based on the results of a survey sent to vessel operators in 2005.

Starting on January 1, 2010, marine gas oil meeting a 0.1 percent sulfur limit is specified under the proposed regulation. This lower sulfur fuel will result in additional emission reductions of PM and SO<sub>x</sub>, compared to the January 1, 2007 requirement. This standard is consistent with a recently adopted European Union regulation. However, a feasibility analysis is required under the proposed regulation prior to implementation of this fuel requirement to investigate the supply, cost, and technical feasibility of using this fuel. Based on the results of this evaluation, modifications to this requirement could be proposed to the Board.

While ARB has the authority to regulate ocean-going vessel emissions, we recognize that uniform national or international regulation of vessel emissions would be preferable to most vessel operators. As such, we have included a provision in the staff's proposal that requires the Executive Officer to propose terminating or modifying the requirements of this proposal to the Board if the United States Environmental Protection Agency

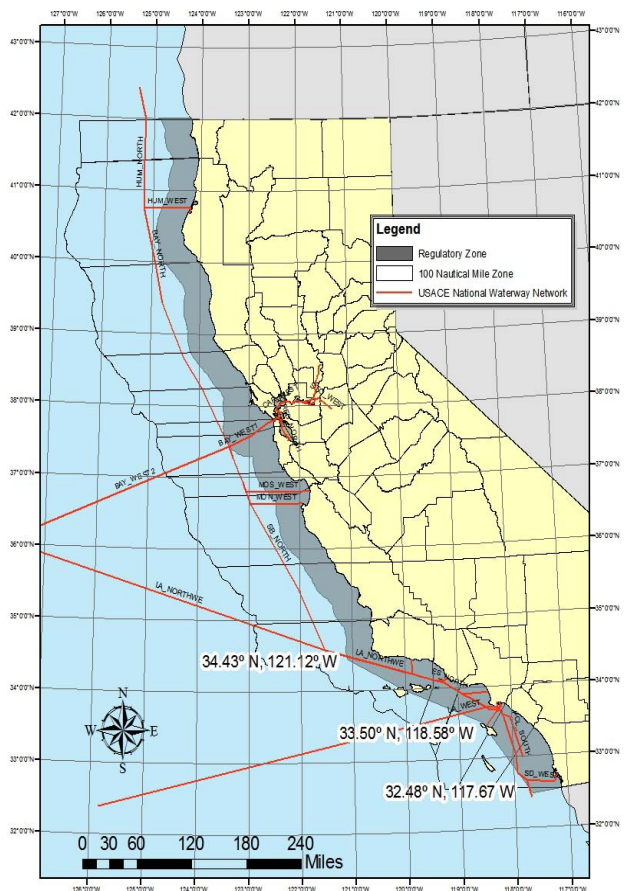
(U.S. EPA) or the International Maritime Organization adopts regulations that will achieve equivalent or greater emission reductions from vessels.

The proposed regulation does not address emissions from main engines (except for diesel-electric vessels), boilers, gas or steam turbine engines, or auxiliary engines on military vessels, which are exempted from the requirements of the proposed regulation. ARB staff plan to address main engines and other sources not regulated in this proposed rulemaking in the next couple of years.

### 10. How far offshore are ocean-going vessels required to comply with the proposed regulation?

Under the proposed regulation, vessel emissions would be regulated up to 24 nm off the California coastline. ARB has the authority to require emission reductions out to the California Coastal Water (CCW) boundary. This is the region within which emissions are likely to be transported onshore, and it extends beyond the 24 nm boundary. However, the 24 nm boundary which is shown as the gray area in Figure ES-3 was proposed because it significantly lowers the cost of the regulation while still providing the vast majority of the potential on-shore benefits in terms of reduced exposure to diesel PM. Specifically, about 75 percent of the auxiliary engine diesel PM emissions within 100 nm of the California coastline is emitted within the 24 nm boundary. The 24 nm boundary is also easily defined for vessel operators. The boundary is aligned in Central and Northern California with the outer boundary of the Contiguous Zone, an internationally recognized boundary which extends 24 nm offshore and is noted on most nautical charts. In Southern California, the boundary consists of straight line segments approximately 24 nm offshore of the coastline. This approximation is used because the outer edge of the Contiguous Zone extends around the Channel Islands, bringing the boundary well beyond 24 nm, and in some cases beyond the California Coastal Waters boundary.

**Figure ES-3: Offshore 24 Nautical Mile Boundary for Proposed Regulation**



## **11. Are the fuels specified in the proposed regulation available?**

Yes. It is important that these fuels be available at ports worldwide because vessel operators seeking to comply with the proposed regulation through the use of these fuels will need to use them upon entering the 24 nm boundary off California's coastline. The fuels specified for January 1, 2007, are MGO, and MDO at or below 0.5 percent sulfur. MGO is widely available at ports worldwide since it is already used by harbor craft and many auxiliary engines on ocean-going vessels. We are not proposing a sulfur limit for MGO at this time because some ports only have higher sulfur MGO available. Because the proposed regulation has an initial compliance date of January 1, 2007, ARB staff had concerns that there would not be sufficient time or incentive for fuel refiners and suppliers worldwide to make fuel meeting a specified sulfur limit available at all bunkering ports. However, we expect the sulfur content of the MGO used by vessels visiting California ports to average at or below 0.5 percent sulfur, based on the results of an ARB survey and data on historical trends in sulfur content for these fuels. To provide additional flexibility to vessel operators, we are also allowing the use of MDO. This fuel tends to have a higher sulfur content than MGO, so we are limiting this fuel to 0.5 percent sulfur. Vessel owners can choose between using MDO that meets the sulfur limits or MGO.

Beginning January 1, 2010, MGO meeting a 0.1 percent sulfur limit is specified under the proposed regulation. While this fuel is not currently available at all ports worldwide, we believe it will become much more widely available by 2010, when a European Union directive requires the use of MGO meeting a 0.1 percent sulfur limit. In addition, to ensure this requirement of the proposed regulation can be implemented, ARB staff is proposing that an evaluation be conducted prior to 2010 to investigate the availability of 0.1 percent sulfur MGO at bunkering ports worldwide.

## **12. Will ocean-going vessels need to make modifications to the use the specified fuels?**

According to a survey conducted by ARB staff, we expect that about 10 percent of the ocean-going vessels visiting California ports will require some type of modification to use the fuels specified in the proposed regulation. The modifications needed are vessel-specific, and may include:

- expanding fuel storage capacity for distillate fuel;
- adding piping, instrumentation, valves, and vents;
- adding fuel processing equipment (settling tanks, filters, etc.); and/or
- modifying fuel pumps and fuel injectors.

The proposed regulation has provisions to provide additional time (up to five years to make vessel modifications) and flexibility to operators of these vessels (see item 14 below).

**13. Is the proposal technically feasible?**

Yes. Based upon ARB staff's analysis and discussions with numerous stakeholders, including the engine manufacturers, staff believes that the requirements of the proposed regulation are technically feasible. Under the proposal, vessel operators may comply by using cleaner-burning marine distillate fuels in their auxiliary engines instead of heavy fuel oils, or implementing alternative emission control strategies. For vessel operators that comply through the use of cleaner-burning fuels, they will need to ensure that they are using marine distillate fuels prior to entering the 24 nm boundary. ARB staff found that vessel operators already switch to marine distillate fuels prior to certain scheduled maintenance operations, and many also routinely switch to these fuels for air quality reasons in California. Discussions with the manufacturers also indicated that these engines can operate on marine distillate fuels provided certain precautions are followed, such as performing fuel switches according to recommended procedures. Beginning January 1, 2010, the proposal specifies a lower 0.1 percent sulfur marine distillate fuel. This standard will be subject to a feasibility evaluation prior to implementation to fully investigate the availability of this fuel and if any technical issues exist.

**14. What key provisions are included in the proposed regulation to provide flexibility?**

The proposed regulation includes two provisions providing compliance flexibility. These provisions are summarized below.

Alternative Control Plan

The alternative compliance plan (ACP) was included in the proposed regulation to provide vessel owner/operators with the flexibility to implement alternative emission control strategies that result in no greater emissions compared to the use of the fuels specified in the proposal. Alternative emission control strategies may include the use of shore-side electrical power, engine modifications, exhaust treatment devices such as diesel oxidation catalysts, and the use of alternative fuels or fuel additives. ACP plans may apply to a single vessel, or a fleet of vessels under the direct control of the applicant for an ACP.

There is also a specific provision that applies to vessels that shut off their diesel auxiliary engines and connect to shore-side power. Under this provision, emissions from auxiliary engines will be considered to meet the emission reduction requirements of the proposed regulation: (1) during travel from a previous port to a California port where shore-side power is used; (2) while docked and utilizing shore power; and (3) during travel to a subsequent port. This provision is designed to encourage the expanded use of shoreside power, which achieves greater emission reductions closest to nearby communities.

### Noncompliance Fee Provision

This provision provides vessel operators with the flexibility to pay a fee in lieu of compliance in certain limited circumstances. The funds collected under this provision would be used to substantially reduce emissions from: (1) port sources; (2) sources within 2 miles of port boundaries; or (3) oceangoing vessels within "Regulated California Waters." Under this program, the fee is designed to ensure that participants will not be provided an economic advantage compared to vessel operators complying with the regulation. The fee schedule is graduated such that subsequent visits would result in increasing fees.

This option could only be used in the following circumstances:

- vessel is unexpectedly redirected to a California port;
- vessel was not able to acquire a sufficient quantity of compliant fuel at the last fueling port;
- fuel was found to be out of compliance after leaving the last bunkering port;
- modifications are required and the vessel operator is not able to complete the modifications in time to meet the January 1, 2007 requirements; and
- modifications are required and the vessel will visit a California port a maximum of two times per calendar year, and a four times over the life of the vessel after January 1, 2007.

#### **15. How does the regulation affect diesel-electric vessels?**

Diesel-electric vessels use large diesel generator sets to provide power for both propulsion and ship-board electricity. Passenger cruise vessels, and a few tankers, use this engine configuration. For the purposes of the proposed regulation, these large diesel generator sets are considered "auxiliary engines," and are covered by the proposed regulation. We are proposing to regulate these engines the same as other auxiliary engines because they are mechanically similar to the smaller auxiliary engines used on other vessels. Specifically, they are four-stroke, medium speed engines used in generator set applications. As such, these engines can meet the requirements of the proposed regulation. In fact, some diesel-electric cruise vessels currently use the distillate fuels specified in the proposed regulation near California ports.

#### **16. How will ARB staff verify compliance with the proposed regulation?**

Enforcement of the proposed regulation will be achieved through random inspections of records, and fuel sampling/testing. ARB staff will coordinate vessel inspections with inspections conducted by other State agencies such as the California State Lands Commission to the extent feasible. During vessel inspections, records will be reviewed to determine when vessels traveled within "Regulated California Waters" and the fuels used during this time. Records on the quantity of fuel purchased, the fuel type, and the sulfur content of the fuel will be reviewed to determine compliance. Fuel samples will

be analyzed to ensure that they meet the ISO specifications for the fuel type and do not exceed the sulfur content limits under ISO or the proposed regulation.

As a long term goal, ARB staff wants to transition from compliance data being recorded in logs maintained on the vessel, to automated electronic data devices that can store and transmit data needed to assess compliance. ARB staff plans to work with vessel owners and equipment suppliers to develop and field test data recording and submittal systems that can provide compliance data on a real-time basis.

**17. What businesses and public agencies will be affected by the proposed regulation?**

The proposed regulation would impact foreign and domestic businesses that own or operate large ocean-going vessels. This would include ocean shipping companies and passenger cruise vessel operators.

We do not expect significant impacts on “downstream” companies such as importers or exporters of goods, since the added costs imposed by the proposal are not expected to result in significant adverse impacts to vessel owners or operators. Similarly, we do not expect adverse impacts on California ports because we do not believe the added cost of the proposed regulation is great enough to induce vessel operators to divert cargos to ports outside California.

We do not predict any significant impact on public agencies. With the exception of military vessels, which are exempted from the requirements of the proposed regulation, public agencies in California generally do not operate ocean going vessels as defined in the proposal.

**18. What are the health and environmental impacts of the proposed regulation?**

Upon implementation in 2007, the proposed regulation will result in immediate and significant reductions in emissions of diesel PM, NO<sub>x</sub>, SO<sub>x</sub>, and “secondarily” formed particulate matter. Specifically, considering only the directly emitted emissions (not secondarily formed PM), the proposed regulation will result in estimated statewide emission reductions of 2.7 TPD of diesel PM, 1.9 TPD of NO<sub>x</sub>, and 22 TPD of SO<sub>x</sub> in 2007. For perspective, the proposal would result in an estimated 75 percent reduction in diesel PM, 80 percent reduction in SO<sub>x</sub>, and a 6 percent reduction NO<sub>x</sub> from an engine that previously used typical heavy fuel oil. Beginning in 2010, the 0.1 percent sulfur limit will result in an additional 10 percent reduction in diesel PM. The estimated reductions for diesel PM, NO<sub>x</sub> and SO<sub>x</sub>, as shown in Table ES-2, reflect the use of the cleaner marine distillate fuels specified in the proposed regulation, although alternative control technologies could also be used to achieve equivalent reductions. The estimates do not reflect participation in the “noncompliance fee provision” in the proposal that allow shippers to pay a fee in lieu of compliance because we cannot predict the rate of participation. However, we would expect that the use of

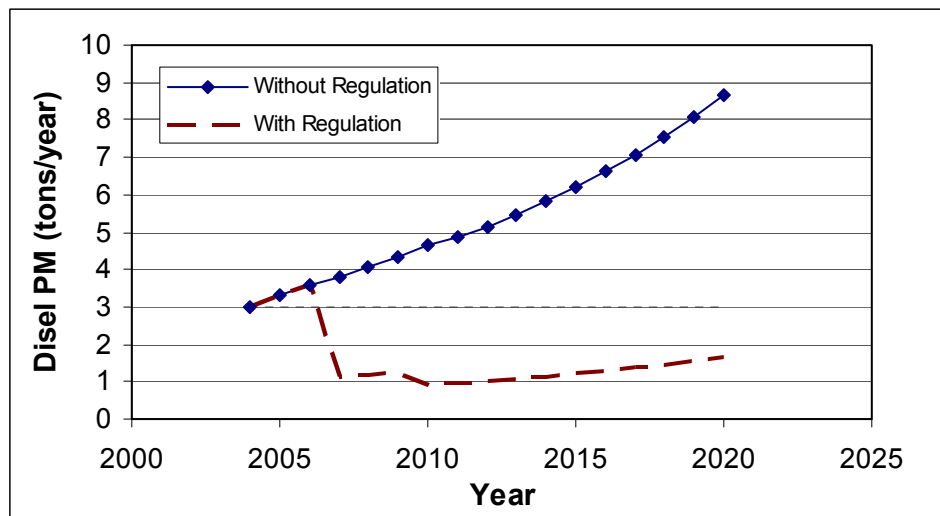
noncompliance fees would be very limited, and whatever fees that are generated would be used to achieve emission reduction around the ports.

**Table ES-2: Estimated Emission Reductions from Implementation of the Proposed Regulation**

Year	Auxiliary Engine Emission Reductions (Tons per Day)		
	PM	NOx	SOx
2007	2.7	1.9	22
2010	3.7	2.3	32
2015	5.0	3.2	43
2020	7.0	4.4	61

The emission reductions shown for 2007 reflect the initial implementation of the fuel specifications in the proposal, assuming that the average sulfur content of the fuel will be 0.5 percent. The 2010 and later reductions reflect the use of 0.1 percent sulfur marine gas oil, which is scheduled to be implemented in 2010 subject to the results of a feasibility evaluation required under the proposed regulation. Figure ES-4 provides a graphical depiction of the change in diesel PM emissions expected with implementation of the regulation.

**Figure ES-4: Estimated Diesel PM Emissions in 24 nm Zone With and Without the Implementation of the Proposed Regulation**



Significant air quality benefits are expected from the proposed regulation. The reductions in diesel PM, NOx and SOx will help improve regional ambient air quality levels of PM and ozone. We also anticipate significant health benefits due to reduced

mortality, incidences of cancer, PM related cardiovascular effects, chronic bronchitis, asthma, and hospital admissions for pneumonia and asthma-related conditions. These directly emitted diesel PM reductions are expected to reduce the number of premature deaths and other non-cancer health effects from air pollution in California. Staff estimates that the implementation of this regulation will avoid between 2007 and 2020 years approximately:

- 520 premature deaths (260 to 810, 95% CI)
- 14,000 asthma attacks (3,400 to 24,000, 95% CI)
- 120,000 work loss days (103,000 to 140,000, 95% CI)
- 650,000 minor restricted activity days (530,000 to 770,000, 95% CI)

With respect to potential cancer risk, ARB staff believes there will be significant reductions in exposures and potential cancer risks to residents that live near ports in California. For example, based on an analysis of the predicted 2008 and 2015 ambient diesel PM levels near the POLA and POLB, we estimate that in 2008 there will be a 70 percent reduction in the population-weighted average risk relative to the predicted risk levels in 2008 from ocean-going vessel auxiliary engine diesel PM emissions and a 78 percent reduction in 2015.

ARB staff has concluded that no significant adverse environmental impacts will occur from implementation of the proposed regulation. There will be no increase in emissions at any of the locations due to this proposed regulation. The locations experiencing the greatest emission reductions will be those areas nearest to the ports.

## **19. What are the economic impacts of the proposed regulation?**

The proposed regulation would directly impact businesses that operate large ocean-going vessels. These businesses would be required to reduce their emissions through the use of marine distillate fuels, or other equally effective emission control strategies. To estimate the costs of the proposed regulation, we assume compliance will occur through the use of marine distillate fuels. We also estimate that about ten percent of vessels will need to make some modifications to be able to use the specified fuels. For example, some vessels would add an additional fuel tank dedicated for the use of marine distillate fuels.

We estimate the total added fuel cost of the proposed regulation to be about \$34 million annually, and about \$38 million in 2010 when the lower sulfur fuel standard is scheduled to be implemented. We also estimate total capital costs of about \$11 to \$18 million for vessel modifications.

The total annual cost and cost-effectiveness of the proposed regulation is estimated in table ES-3 below by assigning all of the cost of the proposed regulation to each pollutant individually. Using this approach, the diesel PM cost-effectiveness would be about \$26-27 per pound of diesel PM reduced. This estimate does not account for the fact that the proposed regulation would also reduce emissions of NOx and SOx. If half



of the compliance costs are attributed to diesel PM reductions, and half to NOx and SOx reductions, the diesel PM cost-effectiveness would be about \$13-14 per pound. Using either approach, these results compare favorably with the cost-effectiveness of other diesel PM regulations adopted by the Board.

**Table ES-3: Cost-Effectiveness of the Proposed Regulation\***

Year	Total Annual Cost (dollars)	Emission Reductions (tons per year)			Cost-Effectiveness \$/Ton and (\$/pound)		
		NOx	PM	SOx	NOx	PM	SOx
2007 - 2009	38 million	575	730	5,800	66,000 (\$33)	52,000 (\$26)	6,600 (\$3.20)
2010 - 2011	42 million	575	800	7,200	73,000 (\$37)	53,000 (\$27)	5,800 (\$2.90)

\*The proposed regulation becomes effective on January 1, 2007. A lower sulfur 0.1 percent marine gas oil is scheduled for implementation on January 1, 2010, subject to review. The emission reductions and costs shown are based on the 2004 emissions inventory to be consistent with other 2004 data used. The emission reductions in 2007 and 2010 will be greater than the emission reduction figures shown.

The cost to individual businesses will vary widely based on factors such as the following:

- number of vessels visiting California ports;
- number of California port visits per vessel;
- power generated by the auxiliary engines;
- whether the vessel is a “diesel-electric” vessel; and
- number of vessels requiring retrofits.

For example, a business that owns a single small cargo vessel that makes a single annual visit to a California port visit may incur an added cost of a couple thousand dollars. On the other hand, a large vessel operator with several vessels making frequent California port visits may incur added fuel costs approaching a million dollars annually.

Table ES-4 below provides a summary of the added costs to a typical company. The added costs are higher for operators of diesel-electric vessels because their engines use more fuel than the auxiliary engines on other vessels, and because they are primarily large cruise vessel companies that make more frequent visits to California ports.

**Table ES-4: Estimated Added Fuel Cost to Typical Vessel Operators\***

Type of Company	Capital Cost*	Average Added Annual Fuel Cost
Cargo Vessel	\$100,000 per vessel	\$20,000 per company
Passenger Cruise Vessel/Diesel-electric	\$100,000 to \$500,000 per vessel	\$2,000,000 per company

\* Most companies will not need to modify their vessels. Average added annual fuel costs are rounded.

We estimate that affected businesses will be able to absorb the costs of the proposed regulation with no significant adverse impacts on their profitability. This finding is based on the staff’s analysis of the estimated change in “return on owner’s equity” (ROE). The analysis found that the overall change in ROE for typical businesses was less than one percent. Generally, a decline of more than ten percent in ROE suggests a significant impact on profitability. In addition, the added costs of the proposed regulation are a small fraction of the overall operating costs of these large vessels.

Another way to analyze the costs of the proposed regulation is to assume all of the added costs are passed on to the customer. Using this type of analysis, we do not expect significant impacts on the customers of oceangoing vessel operators. For example, we estimate that the added costs of the proposed regulation would add about a dollar per container for importers or exporters shipping containerized goods overseas. We estimate that this represents less than one percent of the shipping cost. For passenger cruise ships, we estimate the added cost of the proposed regulation for a typical Los Angeles to Mexico cruise would be about \$8 per passenger, representing about a 2 percent fare increase.

Since the proposal would not significantly alter the profitability of most businesses, we do not expect a noticeable change in employment, business creation, elimination, or expansion, and business competitiveness in California. We also found no significant adverse economic impacts on any local or State agencies.

**20. How does the proposed regulation compare to other air quality regulations affecting ocean-going vessel auxiliary engines?**

The U.S. EPA and the International Maritime Organization (IMO) have adopted regulations designed to reduce the emissions from these engines. However, these existing regulations will achieve relatively modest diesel PM reductions compared to the proposed regulation. The U.S. EPA and IMO regulations are summarized below in Table ES-5.

**Table ES-5: Summary of U.S. EPA and IMO Regulations**

<b>Regulation</b>	<b>Description of Regulation</b>	<b>Comparison to the ARB Staff Proposal</b>
IMO Annex VI New Engine Standards	Establishes NOx exhaust standards for new marine engines. Engine manufacturers have complied since 2000.	•Standards do not reduce PM and achieve modest NOx benefits
U.S. EPA 1999 Category 1&2 Engine Rule	Establishes NOx+HC, PM, and CO exhaust standards for new marine engines. Implementation starts in 2007 for most vessel auxiliary engines.	<ul style="list-style-type: none"> <li>▪ Standards only apply to U.S.-flagged vessels.</li> <li>▪ Foreign trade exemption is provided that exempts most vessel auxiliary engines</li> <li>▪ Benefits phase in slowly with vessel turnover</li> </ul>
U.S. EPA 2003 Category 3 Engine Rule	Establishes NOx exhaust standards for new marine propulsion engines equivalent to IMO standards. Would apply large “auxiliary” engines on diesel-electric vessels	<ul style="list-style-type: none"> <li>▪ Standards only apply to U.S. flagged vessels</li> <li>▪ Eliminates the foreign trade exemption for category 1 &amp; 2 vessels (see above)</li> </ul>
Annex VI IMO marine fuel sulfur limit	Establishes a fuel sulfur cap of 4.5 percent.	Very little fuel is available with a sulfur content this high.
EPA Nonroad diesel Rule	Establishes sulfur limits for diesel fuel used in marine applications	Exempts heavy fuel oil, and marine diesel oil.

In addition to the regulations summarized above (which apply to engines operated in the United States), the European Union countries have developed measures that will reduce emissions from oceangoing vessels. In November, 2002, the European Commission adopted a European Union Strategy to reduce atmospheric emissions from seagoing ships. A step toward implementing this strategy is *Directive 2005/33/EC of the European Parliament and Council Modifying Directive 1999/32 as Regards the Sulfur Content of Marine Fuels* (Directive 2005/33/EC). Directive 2005/33/EC enters into force on August 11, 2005, and includes the following provisions:

- A 1.5 percent sulfur limit for marine fuels used by all seagoing vessels in the Baltic Sea starting May 19, 2006, and in the North Sea and English Channel starting in Autumn 2007;
- A 1.5 percent sulfur limit for marine fuels used by passenger vessels on regular services between EU ports, starting May 19, 2006; and
- A 0.1 percent sulfur limit on fuel used by inland vessels and by seagoing ships at berth in EU ports, starting January 1, 2010.

The provision regarding the use 0.1 percent sulfur fuel by seagoing ships at berth is very similar to the staff’s proposal. Like the staff’s proposal, the EU control measure specifies a 0.1 percent sulfur limit in 2010. However, the staff’s proposal extends out 24 nm, while the EU proposal only applies at berth.

## **21. How was this proposal developed?**

Staff began the development of the proposal with the creation of the Maritime Air Quality Technical Working Group (MWG) in late 2001. During MWG meetings, staff discussed different approaches to reduce marine vessel emissions at the conceptual stage. In late 2004, staff began a series of public workshops focused on the proposed regulation for auxiliary engines. Extensive efforts were made to ensure that the public and affected parties were aware of and had the opportunity to participate in the development of this proposal. For example, meetings to discuss the proposal were held at times and locations that encouraged public participation, including meetings at California ports and evening sessions. Attendees included representatives from environmental organizations, community groups, port administration, vessel operators, engine manufacturers, fuel producers, the U.S. Coast Guard, local and federal air quality agencies, and other parties interested in marine emissions. These stakeholders participated both by providing data and reviewing draft regulations, and by participating in open forum workshops, in which staff directly addressed their concerns. During these meetings, ARB staff discussed a number of regulatory strategies at the concept stage, including the current proposal. Nearly 400 individuals and/or companies were notified for each workshop through a series of mailings. Notices were posted to ARB's marine and public workshops web sites and e-mailed to subscribers of the marine electronic list server.

As a way of inviting public participation and enhancing the information flow between ARB and interested parties, staff created a commercial marine Internet website (<http://www.arb.ca.gov/msprog/offroad/marinevess/marinevess.htm>) in 2001. Since that time, staff has consistently made available on the website all related documents, including meeting presentations and draft versions of the proposed regulatory language. The website has also provided workshop and meeting notices and materials, other marine related information, and has served as a portal to other websites with related information.

Recognizing that other states also have concerns about marine emissions, and that uniformity of requirements should be promoted, ARB set up a States Marine Emission Reduction Group. ARB staff schedules periodic meetings with this group, which includes regulatory agencies in other states and Canada.

## **22. How does the proposed regulation relate to the State Implementation Plan for Ozone and PM?**

On October 23, 2003, ARB adopted the *Proposed 2003 State and Federal Strategy for the California State Implementation Plan* (State and Federal Strategy). The State and Federal Strategy identifies the Board's regulatory agenda to reduce ozone and PM by establishing targets to develop and adopt new measures for each year from 2003 to 2006. In addition to meeting federal requirements, the Statewide Strategy ensures continued progress towards California's own health-based standards. The State and

Federal Strategy includes a commitment to reduce emissions from the existing fleet of ocean-going vessels. The proposed regulation will help to fulfill this commitment.

**23. How does the proposed regulation relate to ARB's goals for Environmental Justice?**

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. ARB's Environmental Justice Policies are intended to promote the fair treatment of all Californians and cover the full spectrum of ARB's activities.

The proposed regulation is consistent with the environmental justice policy to reduce health risks from toxic air contaminants in all communities, including those with low-income and minority populations, regardless of location. The proposal will reduce diesel PM, NOx and SOx emissions from ocean-going vessels for all communities near California ports and shipping lanes, particularly for communities near the ports of Los Angeles, Long Beach and Oakland.

**24. What future activities are planned?**

In addition to activities associated with monitoring and compliance with the proposed regulation, staff recognizes the need to conduct a number of other activities. These activities include:

- outreach to the vessel operators that only visit California ports occasionally to ensure that they are aware of the requirements of the proposal;
- develop procedures to implement the Noncompliance Fee Provision, and ensure funds are used effectively to reduce port and marine emissions; and
- continue to encourage the U.S. EPA and the IMO to take a more active role in reducing emissions from ocean-going vessels.

In addition, staff recognizes the need to achieve additional emission reductions from ocean-going vessels. Reducing emissions from the main propulsion engines on ocean-going vessels will be the next priority. While the emissions from these engines are mostly emitted outside the ports, they contribute far more emissions than those affected by the current proposal. Another area for investigation is the potential for emission reductions from vessels that make frequent calls at California ports. One such option for these vessels may be the use of shore-side power. ARB staff is developing a study of the feasibility of implementing shore-side power hookups that will investigate the technical and economic issues. These and other potential emission reduction strategies will be evaluated as part of an effort to develop a port and intermodal goods movement Comprehensive Emission Reduction Plan that will define the strategies needed to reduce public health impacts from ports and related activities. This effort, which is part of the Governor's Phase II Goods Movement Action Plan, is currently underway and it is expected to be completed by the end of 2005.

## **25. What is staff's recommendation?**

We recommend that the Board approve the proposed regulation presented in this report (Appendix A). The proposal will reduce emissions of diesel PM, NO<sub>x</sub>, and SO<sub>x</sub>, resulting in significant health benefits to the public. In particular, communities near California's major ports and shipping lanes benefit from reduced exposure to the potential cancer risk from diesel PM. Staff believes that the proposal is technologically and economically feasible and necessary to carry out the Board's responsibilities under State law.

## **REFERENCES**

(Directive 2005/33/EC) European Union Official Journal, Directive 2005/33/EC of the European Parliament and of the Council of 6 July 2005 amending Directive 1999/32/EC

## **I. INTRODUCTION**

In this chapter, the Air Resources Board (ARB or Board) staff provides an overview of the Staff Report, discusses the purpose of the proposed regulation (“proposal”), and discusses the regulatory authority ARB has to adopt the proposed regulation. We also discuss the process used to include all interested stakeholders in the development of the proposal, including providing opportunities for meaningful public participation.

### **A. Overview**

This report presents the proposed regulation to reduce emissions of diesel particulate matter (PM), nitrogen oxides (NO<sub>x</sub>), and sulfur oxides (SO<sub>x</sub>) from diesel auxiliary engines used on ocean-going vessels within 24 nautical miles of the California Coastline. A detailed summary of the requirements of the proposal are included in Chapter V. The report also shares the information that ARB staff used in developing the proposal. This information includes:

- the health effects associated with exposure to diesel PM, NO<sub>x</sub>, and SO<sub>x</sub> emissions (Chapter II);
- a description of the affected industry and the existing regulations designed to reduce emissions from auxiliary engines used on ocean-going vessels (Chapter III);
- the diesel PM, NO<sub>x</sub>, and SO<sub>x</sub> emission inventory and health risks posed by auxiliary engines used on ocean-going vessels (Chapter IV);
- a summary of the provisions in the proposal, and a discussion of the regulatory alternatives to the proposal that were considered (Chapter V);
- a discussion of the technical feasibility of using the fuels specified in the proposal, and other control technology options (Chapter VI);
- the environmental impacts of implementing the proposal (Chapter VII); and
- the estimated costs to industry and the fiscal impacts of these costs (Chapter VIII).

In developing the proposal, there were a number of technical and policy issues that had to be addressed. These included the impacts of the proposal on diesel-electric vessels, vessels requiring modifications to use distillate fuel, and the scope of the Alternative Compliance Plan provision. These and other key issues are discussed in Chapter IX, Additional Considerations.

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

## **B. Purpose**

The purpose of this proposal is to reduce emissions of diesel PM, NO<sub>x</sub>, SO<sub>x</sub>, and “secondarily” formed PM (PM formed in the atmosphere from NO<sub>x</sub> and SO<sub>x</sub> emissions). Diesel PM emission reductions are needed to reduce the potential cancer risk, premature mortality and other adverse impacts from PM exposures to people who live in the vicinity of California’s major ports and shipping lanes. Reductions in diesel PM and SO<sub>x</sub> (which forms “secondary” sulfate PM in the atmosphere) will also contribute to regional PM reductions that will assist in California’s progress toward achieving State and federal air quality standards. Reductions in NO<sub>x</sub>, an ingredient in the formation of ozone pollution, will help reduce regional ozone levels and secondary nitrate PM. The health impacts of these pollutants are described in Chapter II.

## **C. Regulatory Authority**

Under State and federal law, ARB can regulate both criteria pollutant and toxic diesel PM emissions from marine vessels. Health and Safety Code (H&SC) sections 43013 and 43018 authorize ARB to regulate marine vessels to the extent such regulation is not preempted by federal law. Also, H&SC § 39666 requires ARB to regulate emissions of toxic air contaminants (TAC) from nonvehicular sources, which include ocean-going vessels. The proposed regulation reduces or limits diesel PM, which is both a TAC and criteria pollutant, and NO<sub>x</sub> and SO<sub>x</sub>, which are both criteria pollutants.

The proposed regulation is neither preempted under federal law, nor does it violate the Commerce Clause. Federal authorization under section 209(e) of the Clean Air Act (CAA) is required for regulating new nonroad engines and for requiring retrofits on existing engines. Ocean-going vessel engines, by definition, fall within the category of nonroad engines. However, no federal authorization is required for implementing in-use operational requirements on existing marine vessels and their engines.

Further, the proposed regulation does not conflict with the Ports and Waterways Safety Act (PWSA) and U.S. Coast Guard regulations. As a non-discriminatory regulation with substantial benefits, the proposed regulation does not violate the Commerce Clause. And federal and state cases support our authority to regulate both U.S. and foreign-flag vessels within California Coastal Waters. Therefore, federal law does not preempt the proposed regulation, nor does the regulation violate the requirements of the Commerce Clause.

The ARB’s legal authority to promulgate the proposed regulation is discussed in more detail in Appendix B.



## **D. 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 "Policies and Actions for Environmental Justice," which formally established a framework for incorporating Environmental Justice into ARB's programs, consistent with the directive 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. These 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 (Policies) are intended to promote the fair treatment of all Californians and cover the full spectrum of ARB's activities. Underlying these Policies is a recognition that the agency needs to engage community members in a meaningful way as it carries out its activities. People should have the best possible information about the air they breathe and what is being done to reduce unhealthy air pollution in their communities. The ARB recognizes its obligation to work closely with all communities, environmental and public health organizations, industry, business owners, other agencies, and all other interested parties to successfully implement these Policies.

During the development process, ARB staff searched for opportunities to present information about the proposed regulation at places and times convenient to stakeholders. For example, the meetings were held at times and locations that encouraged public participation, including meetings at California ports, and evening sessions. Attendees included representatives from environmental organizations, community groups, port administration, vessel operators, engine manufacturers, fuel producers, the U.S. Coast Guard, local and federal air quality agencies, and other parties interested in marine emissions. These individuals participated both by providing data and reviewing draft regulations, and by participating in open forum workshops, in which staff directly addressed their concerns. Table I-1 below provides meeting dates that were made to apprise the public about the development of the proposed regulation.

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

<b>Date</b>	<b>Meeting</b>	<b>Location</b>	<b>Time</b>
December 6, 2001	Maritime Working Group	Port of Long Beach	10:30 a.m.
April 9, 2002	Maritime Working Group	Port of Long Beach	9:30 a.m.
May 23, 2002	Maritime Working Group/Incentives Subgroup	Phillip Burton Federal Building, San Francisco	10:00 a.m.
July 26, 2002	Maritime Working Group	Port of Oakland	9:00 a.m.
December 3, 2003	Maritime Working Group	Port of Los Angeles	10:30 a.m.
April 8, 2004	Maritime Working Group	Cal/EPA Building, Sacramento	10:00 a.m.
Sept. 9-10, 2004	Conference on Air Quality, Int'l Trade and Transportation	Marina Hotel, San Pedro	10:00 a.m.
October 27, 2004	No Net Increase Air Quality Task Force	Sheraton LA Harbor Hotel, San Pedro	1:00 p.m.
November 10, 2004	Public Workshop	Cal/EPA Building, Sacramento	1:30 p.m.
January 19, 2005	Port Community Advisory Committee	Port of Los Angeles	4:30 p.m.
February 24, 2005	California Air Resources Board: Board Meeting	Cal/EPA Building, Sacramento	9:00 a.m.
April 7, 2005	Environmental Law Super Symposium	Omni Hotel, Los Angeles	1:00 p.m.
May 18, 2005	Public Workshop	Cal/EPA Building, Sacramento	1:00 p.m.
August 15, 2005	Workgroup Meeting	Teleconference	9:00 a.m.
August 24, 2005	Public Workshop	Port of Long Beach	1:00 p.m.
August 24, 2005	Community Workshop	Long Beach Senior Center	6:00 p.m.
October 4, 2005	Workgroup Meeting	Teleconference	1:30 p.m.
October 7, 2005	Bunkerworld Forum: Marine Fuel Sustainability	Hyatt Regency, San Francisco	11:00 a.m.

The proposal is consistent with the environmental justice policy to reduce health risks in all communities, including those with low-income and minority populations, regardless of location. The proposal will achieve the most significant reductions in emissions in the

communities adjacent to the ports of Los Angeles, Long Beach, and Oakland, where the greatest shipping activity occurs. The proposal will also provide air quality benefits to other coastal regions, particularly near shipping lanes and the other ports.

### Outreach Efforts

Since the identification of diesel PM as a toxic air contaminant (TAC) in 1998, the public has been more aware of the health risks posed by the emissions of this TAC. At many of ARB's community outreach meetings over the past few years, the public has raised questions regarding our efforts to reduce exposure to diesel PM. At these meetings, ARB staff told the public about the Diesel Risk Reduction Plan adopted in 2000 and described some of the measures in that plan, including those for marine vessels.

To create a forum for the discussion of marine and port air quality issues, ARB formed the Maritime Air Quality Technical Working Group (Maritime Working Group or "MWG") in late 2001. The MWG provided an opportunity for ARB staff to include the public in the early stages of developing strategies to reduce emissions from marine sources, including the emissions from the existing fleet of ocean-going vessels. From late 2001 to early 2004, ARB held five such meetings. During these meetings, ARB staff discussed a number of regulatory strategies at the concept stage, including the current proposal. Five public workshops or workgroup meetings have also been held since late 2004 to discuss draft language for the proposed regulation. During this process, staff has modified the proposal based on the comments received.

Nearly 400 individuals and/or companies were notified for each workshop through a series of mailings. Notices were posted to ARB's marine and public workshops web sites and e-mailed to subscribers of the marine electronic list server.

Recognizing that other states also have concerns about marine emissions, and that uniformity of requirements should be promoted, ARB set up a States Marine Emission Reduction Group. The ARB staff schedules periodic meetings with this group, which includes regulatory agencies in other states and Canada, including the following: Environment Canada, the Northeast States for Coordinated Air Use Management, the New York State Department of Environmental Conservation, the Puget Sound Clean Air Agency, the Alaska Department of Environmental Conservation, Northeast States Clean Air Foundation, Texas Commission on Environmental Quality, Washington State Department of Ecology, and the Oregon Department of Environmental Equality. During these meetings, status reports are given on the progress of marine air quality projects, including the proposed regulation.

In addition to the public meetings presented in Table I-1, ARB staff and management participated in numerous meetings with industry, government agencies, and environmental groups over the past three years. During these meetings, staff presented information on ARB's plans to regulate emissions from marine vessels, and incorporated the feedback from stakeholders. Some of the groups participating were the Pacific Merchant Shipping Association, International Council of Cruise Lines,

Western States Petroleum Association, Ports of Los Angeles, Long Beach, Oakland, and San Francisco, the U.S. Maritime Administration, U.S. Environmental Protection Agency, U.S. Coast Guard, U.S. Navy, California Maritime Academy, California State Lands Commission, South Coast Air Quality Management District, Santa Barbara County Air Quality Management District, Coalition for Clean Air, Environmental Defense, Natural Resources Defense Council, Union of Concerned Scientists, Citizens for a Better Environment, Wilmington Coalition for a Safe Environment, and San Pedro Homeowners Association.

As a way of inviting public participation and enhancing the information flow between ARB and interested parties, staff created a commercial marine Internet web site (<http://www.arb.ca.gov/msprog/offroad/marinevess/marinevess.htm>) in 2001. Since that time, staff has consistently made available on the web site all related documents, including meeting presentations and draft versions of the proposed regulatory language. The web site has also provided workshop, meeting notices and materials, and other marine related information, along with serving as a portal to other web sites with related information.

Outreach efforts have also included hundreds of personal contacts via telephone, electronic mail, regular mail, surveys, facility visits, and individual meetings with interested parties. These contacts have included interactions with engine manufacturers and operators, emission control system manufacturers, local, national, and international trade association representatives, environmental, State agencies, military officials and representatives, and other federal agencies.

## **II. NEED FOR CONTROL OF DIESEL PARTICULATE MATTER**

In 1998, the Air Resources Board identified diesel PM as a toxic air contaminant (TAC). Diesel PM is by far the most important TAC and contributes over 70 percent of the estimated risk from air toxic contaminants today. In September 2000, ARB approved the "Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles" (Diesel Risk Reduction Plan). The goal of the Diesel Risk Reduction Plan is to reduce diesel PM emissions and the associated cancer risk by 85 percent in 2020. In addition, the Office of Environmental Health Hazard Assessment (OEHHA) identified diesel PM in 2001 as one of the TACs that may cause children or infants to be more susceptible to illness, pursuant to the requirements of Senate Bill 25 (Stats. 1999, ch. 731). Senate Bill 25 also requires ARB to adopt control measures, as appropriate, to reduce the public's exposure to these special TACs (H&SC section 39669.5). In the following sections, we describe the physical and chemical characteristics of diesel PM and discuss the adverse health and environmental impacts from the suite of pollutants emitted by diesel-fueled engines.

### **A. Physical and Chemical Characteristics of Diesel PM**

Diesel engines emit a complex mixture of inorganic and organic compounds that exist in gaseous, liquid, and solid phases. The composition of this mixture will vary depending on engine type, engine age and horsepower, operating conditions, fuel, lubricating oil, and whether or not an emission control system is present. The primary gas or vapor phase components include typical combustion gases and vapors such as carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), sulfur dioxide (SO<sub>2</sub>), oxides of nitrogen (NO<sub>x</sub>), reactive organic gases (ROG), water vapor, and excess air (nitrogen and oxygen).

Many of the diesel particles exist in the atmosphere as a carbon core with a coating of organic carbon compounds, or as sulfuric acid and ash, sulfuric acid aerosols, or sulfate particles associated with organic carbon. (Beeson, 1998) The organic fraction of the diesel particle contains compounds such as aldehydes, alkanes and alkenes, and high-molecular weight polycyclic aromatic hydrocarbons (PAH) and PAH-derivatives. Many of these PAHs and PAH-derivatives, especially nitro-PAHs, have been found to be potent mutagens and carcinogens. Nitro-PAH compounds can also be formed during transport through the atmosphere by reactions of adsorbed PAH with nitric acid and by gas-phase radical-initiated reactions in the presence of oxides of nitrogen. Fine particles may also be formed secondarily from gaseous precursors such as SO<sub>2</sub>, NO<sub>x</sub>, or organic compounds. Fine particles can remain in the atmosphere for days to weeks and travel through the atmosphere for hundreds to thousands of kilometers, while coarse particles deposit to the earth within minutes to hours and within tens of kilometers from the emission source.

Almost the entire diesel particle mass is in the fine particle range of 10 microns or less in diameter (PM<sub>10</sub>). Approximately 94 percent of the mass of these particles are less than 2.5 microns (PM<sub>2.5</sub>) in diameter. Diesel PM can be distinguished from noncombustion sources of PM<sub>2.5</sub> by the high content of elemental carbon with the

adsorbed organic compounds and the high number of ultrafine particles (organic carbon and sulfate).

The soluble organic fraction (SOF) consists of unburned organic compounds in the small fraction of the fuel and atomized and evaporated lube oil that escape oxidation. These compounds condense into liquid droplets or are adsorbed onto the surfaces of the elemental carbon particles. Several components of the SOF have been identified as individual TACs.

## **B. Health Impacts of Exposure to Diesel PM, Ambient Particulate Matter, Ozone, and Sulfur Dioxide**

The proposed regulation will reduce the public's exposure to diesel PM as well as reduce ambient particulate matter. In addition, the proposed regulation is expected to result in reductions in NO<sub>x</sub> and SO<sub>x</sub>. NO<sub>x</sub> is a precursor to the formation of ozone, and both NO<sub>x</sub> and SO<sub>x</sub> also contribute to secondarily formed PM in the lower atmosphere. The primary health impacts of these air pollutants are discussed below.

### Diesel Particulate Matter

Diesel PM is of specific concern because it poses a lung cancer hazard for humans as well as a hazard from noncancer respiratory effects such as pulmonary inflammation. (ARB, 1998a) Because of their small size, the particles are readily respirable and can effectively reach the lowest airways of the lung along with the adsorbed compounds, many of which are known or suspected mutagens and carcinogens. (ARB, 2002) More than 30 human epidemiological studies have investigated the potential carcinogenicity of diesel PM. On average, these studies found that long-term occupational exposures to diesel exhaust were associated with a 40 percent increase in the relative risk of lung cancer. (ARB, 1998b) However, there is limited specific information that addresses the variable susceptibilities to the carcinogenicity of diesel exhaust within the general human population and vulnerable subgroups, such as infants and children and people with preexisting health conditions. The carcinogenic potential of diesel exhaust was also demonstrated in numerous genotoxic and mutagenic studies on some of the organic compounds typically detected in diesel exhaust. (ARB, 1998b)

Diesel PM was listed as a TAC by ARB in 1998 after an extensive review and evaluation of the scientific literature by OEHHA. (ARB 1998c) Using the cancer unit risk factor developed by OEHHA for the TAC program, it was estimated that for the year 2000, exposure to statewide average population-weighted ambient concentrations of diesel (1.8 µg/m<sup>3</sup>) could be associated with a health risk of 540 potential cancer cases per million people exposed over a 70 year lifetime.

Another highly significant health effect of diesel exhaust exposure is its apparent ability to act as an adjuvant in allergic responses and possibly asthma. (Dab, 2000; Diaz-Sanchez, 1996; Kittelson, 1999) However, additional research is needed at diesel

exhaust concentrations that more closely approximate current ambient levels before the role of diesel PM exposure in the increasing allergy and asthma rates is established.

### Ambient Particulate Matter

The key health effects categories associated with ambient particulate matter, of which diesel PM is an important component, include premature mortality; aggravation of respiratory and cardiovascular disease (as indicated by increased hospital admissions and emergency room visits, school absences, work loss days, and restricted activity days); aggravated asthma; acute respiratory symptoms, including aggravated coughing and difficult or painful breathing, chronic bronchitis, and decreased lung function that can be experienced as shortness of breath. (U.S. EPA, 2000; U.S. EPA, 2003)

Health impacts from exposure to the fine particulate matter (PM<sub>2.5</sub>) component of diesel exhaust have been calculated for California, using concentration-response equations from several epidemiological studies. Both mortality and morbidity effects could be associated with exposure to either direct diesel PM<sub>2.5</sub> or indirect diesel PM<sub>2.5</sub>, the latter of which arises from the conversion of diesel NO<sub>x</sub> emissions to PM<sub>2.5</sub> nitrates. It was estimated that 2000 and 900 premature deaths resulted from long-term exposure to either 1.8 µg/m<sup>3</sup> of direct PM<sub>2.5</sub> or 0.81 µg/m<sup>3</sup> of indirect PM<sub>2.5</sub>, respectively, for the year 2000. (Lloyd, 2001) The mortality estimates are likely to exclude cancer cases, but may include some premature deaths due to cancer, because the epidemiological studies did not identify the cause of death. Exposure to fine particulate matter, including diesel PM<sub>2.5</sub>, can also be linked to a number of heart and lung diseases.

### Ozone

Diesel exhaust consists of hundreds of gas-phase, particle-phase, and semi-volatile organic compounds, including typical combustion products, such as CO<sub>2</sub>, hydrogen, oxygen, and water vapor. Diesel exhaust also includes compounds resulting from incomplete combustion, such as CO, ROG, carbonyls, alkenes, aromatic hydrocarbons, PAHs, PAH derivatives, and SO<sub>x</sub>. Ozone is formed by the reaction of ROG and NO<sub>x</sub> in the atmosphere in the presence of heat and sunlight. The highest levels of ozone are produced when both ROG and NO<sub>x</sub> emissions are present in significant quantities on hot, clear summer days. This pollutant is a powerful oxidant that can damage the respiratory tract, causing inflammation and irritation, which can result in breathing difficulties.

Studies have shown that there are impacts on public health and welfare from ozone at moderate levels. Short-term exposure to high ambient ozone concentrations have been linked to increased hospital admissions and emergency visits for respiratory problems. (Peters, 2001) Repeated exposure to ozone can make people more susceptible to respiratory infection and lung inflammation and can aggravate preexisting respiratory diseases, such as asthma. Prolonged (six to eight hours), repeated exposure to ozone can cause inflammation of the lung, impairment of lung defense mechanisms, and possibly irreversible changes in lung structure, which over time could lead to premature

aging of the lungs and/or chronic respiratory illnesses such as emphysema and chronic bronchitis.

The population subgroups most susceptible to ozone health effects include individuals exercising outdoors, children and people with preexisting lung disease such as asthma, and chronic pulmonary lung disease. Children are more at risk from ozone exposure because they typically are active outside, during the summer when ozone levels are highest. Also, children are more at risk than adults from ozone exposure because their respiratory systems are still developing. Adults who are outdoors and moderately active during the summer months, such as construction workers and other outdoor workers, also are among those most at risk. These individuals, as well as people with respiratory illnesses such as asthma, especially asthmatic children, can experience reduced lung function and increased respiratory symptoms, such as chest pain and cough, when exposed to relatively low ozone levels during prolonged periods of moderate exertion.

### Sulfur Dioxide and Sulfates

Sulfur dioxide (SO<sub>2</sub>) is a gaseous compound of sulfur and oxygen. SO<sub>2</sub> is formed when sulfur-containing fuel is burned by mobile sources, such as locomotives, vessels, and off-road diesel equipment. SO<sub>2</sub> is also emitted from several industrial processes, such as petroleum refining and metal processing.

SO<sub>2</sub> causes a wide variety of health and environmental impacts because of the way it reacts with other substances in the air. Particularly sensitive groups include people with asthma who are active outdoors and children, the elderly, and people with heart or lung disease. Effects from SO<sub>2</sub> exposures at levels near the one-hour standard include bronchoconstriction accompanied by symptoms, which may include wheezing, shortness of breath and chest tightness, especially during exercise or physical activity. Children, the elderly, and people with asthma, cardiovascular disease or chronic lung disease (such as bronchitis or emphysema) are most susceptible to these symptoms. Continued exposure at elevated levels of SO<sub>2</sub> results in increased incidence of pulmonary symptoms and disease, decreased pulmonary function, and increased risk of mortality.

Sulfates (SO<sub>4</sub><sup>2-</sup>) are the fully oxidized ionic form of sulfur. Sulfates occur in combination with metal and / or hydrogen ions. In California, emissions of sulfur compounds occur primarily from the combustion of petroleum-derived fuels (e.g., gasoline and diesel fuel) that contain sulfur. This sulfur is oxidized to sulfur dioxide (SO<sub>2</sub>) during the combustion process and subsequently converted to sulfate compounds in the atmosphere. The conversion of SO<sub>2</sub> to sulfates takes place comparatively rapidly and completely in urban areas of California due to regional meteorological features. When these are breathed, they gather in the lungs and are associated with increased respiratory symptoms and disease, difficulty in breathing, and premature death. (ARB 1991a,b; ARB 1994a,b; EPA, 2000a)



### **C. Applicability of the Cancer Potency Factor for Diesel PM to Engines Using Marine Gas Oil, Marine Diesel Oil, or Marine Heavy Fuel Oil**

ARB staff, in consultation with OEHHA, has concluded that particulate matter emissions from ocean-going vessel diesel (compression ignition) engines operating on marine gas oil (MGO), marine diesel oil (MDO), or marine heavy fuel oil (HFO) constitute “diesel particulate matter” emissions. As such, the cancer potency factor and chronic reference exposure level for exhaust emissions from diesel-fueled engines, approved by the Scientific Review Panel and adopted by the ARB in 1998, are applicable to exhaust emissions from ocean-going vessel diesel engines using MGO, MDO, or HFO. The basis for staff’s conclusion is presented below.

#### Marine Gas Oil and Marine Diesel Oil

For the following reasons, ARB staff believes the health values developed for diesel PM are appropriate for emissions from diesel engines using MGO and MDO:

- MGO and MDO are distillate fuels with most fuel properties nearly identical to diesel fuel.

Marine gas oil is generally the heavier middle fraction product from the atmospheric distillation of crude oil. Conventional diesel is the lighter middle fraction product from the atmospheric distillation of crude oil. The key fuel properties for marine distillate fuel (MGO and MDO) are very similar to conventional diesel fuel that is used for on-road and off-road diesel engines. The density, heating value, and hydrogen and carbon content for MGO, MDO and conventional diesel fuel are essentially the same. The viscosity of MGO and conventional diesel are very close to the same; while the viscosity of MDO is somewhat higher than MGO or conventional diesel fuel.

The main difference among these fuels is the sulfur content. Since diesel used in on-road and off-road applications are required to meet ARB and U.S. EPA sulfur content limits, conventional diesel fuel generally has lower sulfur content than MGO or MDO. As discussed earlier, the current average sulfur content for MGO used by vessels visiting California ports is about 0.5 percent (5000 ppm). Diesel fuel meeting ARB specification averages about 0.014 percent (140 ppm) and is scheduled to be reduced to 0.0015 percent (15 ppm) in 2006. Generally, MGO will be sold as MDO if it has come in contact with HFO.

- The fuel specifications for MGO and MDO are very similar to the diesel fuel specification that existed prior to 1993.

MGO and MDO fuel specifications are very similar to pre-1993 diesel fuel. Pre-1993 diesel fuels, compared to post-1993 diesel fuel in California, generally had higher aromatic content (33 vs. 20-25 vol. percent), higher sulfur (<5000 vs. 100-150 ppm Wt.), lower cetane number (>40 vs. 50-55), higher PAHs (8 vs. 2-5 Wt. percent) and higher nitrogen (300-600 vs. 40-500 ppm Wt.) (ARB, 1998). This is important in that one of

the key health studies linking increases cancer risk with exposure to diesel exhaust emissions was based on railroad workers exposed to diesel exhaust emissions in the 1950s through 1970s.

### Heavy Fuel Oil

The health values developed for diesel PM are also appropriate for emissions from diesel engines using HFO since the basic fuel properties of HFO are similar to diesel fuel, and since emission characteristics from diesel engines using HFO are similar to diesel engines using diesel fuel.

- HFO is a blended petroleum product containing the same classes of hydrocarbons as diesel fuel

Heavy fuel oil, like diesel fuel, is comprised of a complex mixture of aliphatic, naphthenic, and aromatic hydrocarbons. With both types of fuel, the final product will contain varying amounts of these classes of hydrocarbons based on the crude oil used and the refinery process. Heavy fuel oil simply contains a higher proportion of heavier (higher molecular weight - typically having a carbon number from C<sub>20</sub> to C<sub>50</sub>) versions of the same hydrocarbon types, and higher levels of sulfur, metals, and other contaminants.

- Heavy fuel oil contains some diesel fuel

Marine fuels may be separated into two basic types of fuels: distillate and residual (EPA, 1999). Distillate fuel (e.g., diesel fuel and marine gas oil) is composed of the fractions of crude oil that are separated in a refinery by a boiling process, while the remaining fraction that did not boil is referred to as residual. To produce fuels that can be conveniently handled and stored in industrial and marine installations, and to meet marketing specifications limits, the high viscosity residual components are normally blended with MGO or similar lower viscosity fractions. (CONCAWE, 1998) For example, the most common grades of marine heavy fuel oil (IFO-380 and IFO-180) are composed of a mixture of residual compounds and distillate components (EPA, 1999; FAMM, 2001). Specifically, typical heavy fuel oil has been estimated to contain as much as 12 percent distillate (EPA, 1999).

- The emission characteristics of a marine diesel engine using HFO are similar to those of a diesel engine using diesel fuel

The diesel engines covered by the proposed regulation are larger versions of typical land-based diesel engines. They operate on a compression-ignition “diesel” cycle similar to land-based diesel engines. Marine diesel engines are designed to burn HFO, MGO, or MDO. The combustion process is nearly identical for any of these fuels. The liquid petroleum based fuel is injected into the engine where it is compressed to the point of auto-ignition. The peak combustion temperatures are similar for all of the fuels. While the relative magnitude of the combustion products may vary with fuel; the relative

percentage of organic material, elemental carbon, and ash are similar among the various fuels. The percent of sulfates and sulfate bound water is higher as the sulfur content of the fuel increases. As a result of the nearly identical combustion process, we would expect that the major combustion products of an engine burning HFO will be similar in chemical nature to an engine using diesel fuel.

- The general classes of PM exhaust components from a marine diesel engine using HFO are similar to a diesel engine using diesel fuel

The PM components emitted from vessel auxiliary engines using heavy fuel oil are the same as those emitted from a typical diesel engine: elemental carbon, ash, soluble organic compounds, and a sulfate fraction (Man B&W, 2004). However, the overall levels of PM will be significantly higher, and a greater proportion of the PM will be from sulfate. Specifically, as discussed in Chapter IV, we estimate that a typical vessel auxiliary engine running on 2.5 percent sulfur heavy fuel oil will emit about 1.5 g of PM per kW-hr. This compares to an emission factor of about 0.3 g/kw-hr for the same engine running on marine gas oil with a sulfur content of about 0.25 percent. Much of this difference is due to the sulfur content of the fuel, since sulfate PM is estimated to be directly related to fuel sulfur. The higher ash content and density of heavy fuel oil is also expected to play a role in the higher emissions from engines using heavy fuel oil (EPA 2002).

- The particle size distribution of the exhaust emissions from a marine diesel engine using HFO is similar to the particle size distribution from a diesel engine using diesel fuel

Preliminary results from testing performed in 2005 by the University of California, Riverside, CE-CERT, in association with Maersk and CARB, indicate that over 85 percent of the particulate matter emissions from a marine diesel engines burning HFO are less than 2.5 microns in size. These results are similar to results for diesel engines using diesel fuel where 95 percent of the particulate were found to be less than 2.5 microns in size. (ARB, 1998) These very small particles are more likely to be inhaled deep into the lung and, as a result, may pose more of a health issue than larger particles.

#### **D. Health and Environmental Benefits from the Proposed Regulation**

Reducing diesel PM emissions from vessel auxiliary engines will have both public health and environmental benefits. The proposed regulation will reduce localized health risks associated with the operation of vessel auxiliary engines that are near receptors and will contribute to the reduction of the general exposure to diesel PM that occurs on a region-wide basis due to collective emissions from diesel-fueled engines. Additional benefits associated with the proposed regulation include further progress in meeting the ambient air quality standards for PM<sub>10</sub>, PM<sub>2.5</sub>, and ozone, and enhancing visibility.

### Reduced Diesel PM Emissions

The estimated reductions in diesel PM emissions and the associated benefits from reduced exposure and risk are discussed in detail in Chapter VIII.

### Reduced Ambient Particulate Matter Levels

Reducing diesel PM will also help efforts to achieve the ambient air quality standards for particulate matter. Both the State of California and the U.S. EPA have established standards for the amount of PM<sub>10</sub> and PM<sub>2.5</sub> in the ambient air. These standards define the maximum amount of PM that can be present in outdoor air. California's PM<sub>10</sub> standards were first established in 1982 and updated June 20, 2002. It is more protective of human health than the corresponding national standard. Additional California and federal standards were established for PM<sub>2.5</sub> to further protect public health (Table II-1).

**Table II-1: State and National PM Standards**

California Standard		National Standard	
<b>PM<sub>10</sub></b>			
Annual Arithmetic Mean	20 µg/m <sup>3</sup>	Annual Arithmetic Mean	50 µg/m <sup>3</sup>
24-Hour Average	50 µg/m <sup>3</sup>	24-Hour Average	150 µg/m <sup>3</sup>
<b>PM<sub>2.5</sub></b>			
Annual Arithmetic Mean	12 µg/m <sup>3</sup>	Annual Arithmetic Mean	15 µg/m <sup>3</sup>
24-Hour Average	No separate State standard	24-Hour Average	65 µg/m <sup>3</sup>

Particulate matter levels in most areas of California exceed one or more of current State PM standards. The majority of California is designated as non-attainment for the State PM<sub>10</sub> standard (ARB 2002). Diesel PM emission reductions from diesel-fueled engines will help protect public health and assist in furthering progress in meeting the ambient air quality standards for both PM<sub>10</sub> and PM<sub>2.5</sub>.

The emission reductions obtained from this proposal will result in lower ambient particulate matter levels and significant reductions of exposure to primary diesel and secondary PM resulting from NO<sub>x</sub> and SO<sub>x</sub> emissions from auxiliary engines. Lower ambient particulate matter levels and reduced exposure mean reduction of the prevalence of the diseases attributed to diesel PM, reduced incidences of hospitalizations, and prevention of premature deaths.

### Reduced Ambient Ozone Levels

Emissions of NO<sub>x</sub>, a precursor to the formation of ozone in the lower atmosphere, will also be reduced by the proposed regulation. In California, most major urban areas and many rural areas are non-attainment for the State and federal 8-hour ambient air quality

standard for 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. Ozone can also have adverse health impacts at concentrations that do not exceed the 8-hour NAAQS. Reducing NOx emissions will also reduce secondarily formed PM (nitrates).

**Table II-2: State and National Ozone Standards**

	<b>California Standard</b>	<b>National Standard</b>
1 hour	0.09 ppm (180 $\mu\text{g}/\text{m}^3$ )	
8 hour	0.07 ppm (137 $\mu\text{g}/\text{m}^3$ )	0.08 ppm (157 $\mu\text{g}/\text{m}^3$ )

Improved Visibility

In addition to the public health effects of fine particulate pollution, inhalable particulates including sulfates, nitrates, organics, soot, and soil dust contribute to regional haze that impairs visibility.

In 1999, the U.S. EPA promulgated a regional haze regulation that calls for states to establish goals and emission reduction strategies for improving visibility in 156 mandatory Class I national parks and wilderness. California has 29 of these national parks and wilderness areas, including Yosemite, Redwood, and Joshua Tree National Parks. Reducing diesel PM from stationary diesel-fueled engines will help improve visibility in these Class I areas.

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### **III. INDUSTRY CHARACTERIZATION**

Ocean-going vessels (or “vessels”) that operate within 24 nautical miles of the California coastline (“regulated waters”) would be subject to the requirements of the proposed regulation. The requirements of the proposal would apply to both foreign-flagged and domestic vessels. However, exemptions are provided for military vessels and vessels passing through regulated waters without stopping at a California port (“innocent passage”).

For the purposes of the proposed regulation, an ocean-going vessel is defined as a commercial or military vessel that meets any one of the following criteria:

- a U.S.-registered vessel that is used in foreign trade, and has the appropriate U.S. Coast Guard endorsement;
- a foreign-registered vessel;
- a vessel greater than 400 feet in overall length;
- a vessel greater than or equal to 10,000 gross tons; or
- a vessel propelled by a marine compression ignition engine with a per cylinder displacement of greater than or equal to 30 liters.

Vessels meeting none of these criteria are classified as harbor craft (including pleasure craft), and are subject to more stringent fuel requirements than those specified in this proposal.<sup>1</sup>

In this chapter, we identify the types of vessels that are defined as ocean-going vessels, and also describe the types of engines and fuels currently being used by these vessels. Additional information on this industry can also be found in the U.S. EPA’s Final Regulatory Support Document: Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder. (U.S. EPA, 2003).

This section also identifies and summarizes the requirements of existing air pollution regulations that affect ocean-going vessels.

#### **A. Vessel Descriptions**

Examples of the types of oceangoing vessels subject to the proposed regulation include container vessels, passenger cruise vessels, general cargo, reefers, RORO vessels, tanker vessels, and bulk carriers. Brief descriptions of these vessel types are provided below.

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<sup>1</sup> Specifically, only diesel fuel meeting CARB vehicular diesel fuel standards will be sold to harbor craft in California in 2007 (2006 in the South Coast Air Quality Management District).



## Container Vessels

Container vessels are cargo vessels that carry standardized truck-sized containers. These containers have capacities measured in TEUs (Twenty-foot Equivalent Units). One TEU refers to a container with external dimensions of 8'x8'x20'. Capacity is sometimes also measured by FEU's, forty-foot equivalents, 8'x8'x40', since the majority of containers used today are 40 feet in length. Many vessels also have a number of container slots that will accept refrigerated containers.



Container vessel capacity is often described in terms of the number of TEU's the vessel can hold. Due to economies of scale, container vessel capacity has increased over the years. Currently, some large vessels are able to transport between 5,000 and 8,000 TEUs. This compares to older vessels built prior to 1970, which typically held less than 1,000 TEUs.

Most container vessels, like most ocean-going vessels, are propelled by large slow-speed two-stroke direct drive diesel engines (see figure 2). In addition, most container vessels have installed a number of smaller medium speed four-stroke auxiliary engines. The auxiliary engines, which are subject to the proposed regulation, provide electrical power for lighting, navigation equipment, and other ship-board uses.

## Passenger Cruise Vessels



Passenger cruise vessels are passenger vessels used for pleasure voyages. These vessels typically stop at ports, where they coordinate activities for their passengers. Passenger cruise vessels also provide a number of entertainment options for their passengers while on the vessel. These vessels typically include swimming pools, exercise and recreation facilities, movie theaters, dance halls, casinos, and restaurants. As with other types of vessels, the size and capacity of these vessels has increased steadily over the years.

**Table III-1: Typical Size of Passenger Cruise Vessels Over the Years**

<b>Year Built</b>	<b>Tonnage</b>	<b>Number of Passengers</b>
1970	18,420	377 passengers
1980	37,600	707 passengers
1990	74,140	975 passengers
2000	137,300	1557 passengers

(Solentwaters, 2005)

Cruise ship propulsion is typically provided by several diesel engines coupled to generators. 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.

Some vessels have the electric motor outside the ships hull in an azipod. This method eliminates the need for a rudder as the pod can be rotated to provide thrust in any direction. Some vessels also have a combination of a fixed propeller and azipods.

### Reefer Vessels

A Reefer vessel is a type of vessel typically used to transport perishable commodities which require temperature-controlled transportation, mostly fruits, meat, fish, vegetables, dairy products, and other foods. Reefer vessels are effectively large refrigerators, heavily insulated with glass fiber or similarly efficient insulation. They are vessels that tend to be divided into many more spaces than conventional dry cargo vessel, so that different commodities can be separated and carried, if required, at different temperatures. Below deck, a reefer vessel resembles a large modern warehouse, and cargo is usually carried and handled in palletized form, moved about on conveyors or by electric fork lift trucks.

### RORO Vessels

A RORO vessel carries wheeled cargo such as automobiles, trailers or railway carriages. RORO is an acronym for "roll on/roll off". RORO vessels have built-in ramps, which allow the cargo to be "rolled on" and "rolled off" the vessel when in port. While smaller ferries that operate across rivers and other short distances often have these facilities, the term RORO is generally reserved for ocean-going vessels.



Typically new automobiles that are transported by vessel around the world are moved on ROROs. These large new-car carriers are commonly called Pure Car Carriers (PCCs) or Pure Car Truck Carriers (PCTCs). The largest PCC currently in service can carry over 7000 cars.

### Bulk Carriers



Bulk carriers are vessels used to transport bulk items such as mineral ore, fertilizer, wood chips, or grain. They have large box-like hatches on their deck, designed to slide outboard for loading.

The bulk carriers primarily carry dry cargoes, which are shipped in large quantities and do not need to be carried in packaged form. The principal bulk cargoes are coal, iron ore, bauxite, phosphate, nitrate and grains such as wheat. The advantage of carrying such cargoes in bulk is that packaging costs can be greatly reduced and loading and unloading operations can be speeded up.

### Tanker Vessel

Tanker vessels are vessels designed to transport liquids in bulk. Tankers can range in size from several hundred tons, designed for coastal service, to several hundred thousand tons, for transoceanic voyages. A wide range of products are carried by tankers, including:



- hydrocarbon products such as crude oil, LPG, and LNG
- chemicals, such as ammonia, chlorine, and styrene monomer; or
- fresh water

Different products require different handling and transport, thus special types of tankers have been built, such as "chemical tankers," "oil tankers," and "LNG carriers."

## **B. Vessels That Visit California Ports**

California is a key player in international shipping. All of the vessel types described previously visit California ports delivering and receiving products used in California, the United States, and the rest of the world. As shown in Table III-2 below, container vessels accounted for nearly half of the California port visits in 2004, followed by tankers at 19 percent of port visits. The remaining categories of vessels each account for less than ten percent of vessel visits.

**Table III-2: 2004 California Port Calls by Vessel Type**

<b>Vessel Type</b>	<b>Number of Calls</b>	<b>Percentage of Total Calls</b>
Container Vessels	4,545	48%
Tankers	1,811	19%
Bulk Carriers	885	9%
Auto Carriers (RORO)	713	8%
General Cargo/Reefers	685	7%
Passenger Cruise Vessel	652	7%
Barge	106	1%
Other	44	<1%
Total	9,441	100%

( California State Lands Commission, 2004)

Table III-3 ranks California’s ports by the number of vessel visits. As shown in the table, over 50 percent of port calls occurred at the Ports of Los Angeles and Long Beach (which are adjacent to each other). The Port of Oakland accounted for about 19 percent of the port calls, and the remaining ports individually received 5 percent or less of the vessel calls.

**Table III-3: 2004 Port Ranking by Vessel Visits**

<b>Port</b>	<b>Number of Calls</b>	<b>Percentage of Total Calls</b>
Los Angeles/Long Beach	5,083	54%
Oakland	1,797	19%
Richmond	491	5%
Carquinez	463	5%
San Diego	447	5%
Hueneme	318	3%
San Francisco	300	3%
El Segundo	205	2%
Stockton	133	2%
All Other	203	2%
Total	9,441	100%

(California State Lands Commission, 2004)

### **C. Auxiliary Engines and Fuels**

The following sections describe the types of engines currently being used by ocean-going vessels. The information presented below was reported by vessel owners and operators in response to ARB’s *Oceangoing Ship Survey* or “Survey” (January 2005). The Survey requested information only for oceangoing vessels that visited California ports in 2004. Data was provided on approximately 327 vessels and over 1,400 engines. For more detailed Oceangoing Ship Survey data, see Appendix C.

Most of the ocean-going vessels subject to the proposed regulation have both main propulsion (main engines) and auxiliary diesel engines. The main engine for most vessels is a diesel-mechanical propulsion system, where the diesel engine is directly coupled to the propeller through a transmission. The exception is passenger cruise vessels and a few tankers, where the main engines are coupled to electric generators which provide electric power to electric motors which are directly coupled to the propellers. These are referred to as diesel-electric systems.

In most cases, the auxiliary engines provide power for uses other than propulsion. Most auxiliary engines are part of a diesel-electric system that is used to provide power for a variety of on-board systems including lighting systems, onboard cargo handling equipment, heating and air conditioning systems, and emergency power. Many passenger cruise vessels that have diesel-electric propulsion systems use the main engines to power electric motors that perform the same functions as auxiliary engines. Because of the relatively high electrical energy draw aboard a passenger cruise vessel, some also have gas turbine-electric systems aboard. Below we provide summaries of selected data collected from the Survey with an emphasis on auxiliary engine information.

### Auxiliary Engines

All vessel owners responding to the Survey reported at least one auxiliary engine. Table III-4 summarizes the quantity of auxiliary engines the Survey reported. The majority of the auxiliary engines are diesel compression ignition engines and all of the auxiliary engines reported are four-stroke engines. A four-stroke engine completes one power cycle for every two revolutions of the crankshaft. Therefore, there is one power stroke for every two revolutions of the crankshaft. The four-strokes include: intake, compression, power, and exhaust. The tables listed below provide more information on auxiliary engines on oceangoing vessels.

**Table III-4: Number of Auxiliary Engines**

<b>Vessel Type</b>	<b>Minimum Number of Auxiliary Engines</b>	<b>Maximum Number of Auxiliary Engines</b>	<b>Average Number of Auxiliary Engines</b>
Passenger/Cruise	3	6	4.7
Reefer	4	4	4
Auto Carrier	2	4	2.9
Container	2	6	3.6
Tanker	1	6	2.7
Other	2	4	2.9

Tables III-5 and III-6 provide information on the type of fuel used to power the auxiliary engines and the average sulfur content of that fuel. According to the Survey, 25 percent of the auxiliary engines already use distillate fuel. The sulfur content of the distillate ranges from 0.03 – 1.5 percent with an average sulfur content of 0.5 percent.

**Table III-5: Auxiliary Engine Fuels**

<b>Fuel Used in Auxiliary Engine</b>	<b>Number of Engines Reporting in Survey</b>	<b>Percent of Total Engines</b>
Heavy Fuel Oil	877	75%
Distillate Fuel	294	25%

**Table III-6: Average Sulfur Content of Fuel Used in Ocean-going Auxiliary Engines**

<b>Fuel</b>	<b>Minimum Sulfur Content (%)</b>	<b>Maximum Sulfur Content (%)</b>	<b>Average Sulfur Content (%)</b>
Heavy Fuel Oil	0.15%	4.0%	2.5%
Distillate	0.03%	1.5%	0.5%*

\* 0.5 for compression-ignition engines only (excludes turbines which use low sulfur fuel).

The manufacturers of the auxiliary engines were numerous, but five manufacturers accounted for almost 90 percent of the engines reported. These manufacturers are shown below in Table III-7.

**Table III-7: Ocean-going Vessel Auxiliary Engine Manufacturers**

<b>Engine Maker</b>	<b>Number of Engines</b>	<b>Percent of Total Engines</b>
Man B&W	324	29%
Daihatsu	251	22%
Wartsila/Sulzer	249	22%
Yanmar	118	10%
MAK	44	4%
Other	151	13%

Figure III-1 shows the distribution in age of the auxiliary engines. It is interesting to note that a large percentage of the auxiliary engines are less than 10 years old. Typically, the auxiliary engines last the life of the vessel, so the age distribution of these engines is similar to the age distribution of vessels visiting California ports.

**Figure III-1: Ocean-going Vessel Auxiliary Engine Age Distribution**

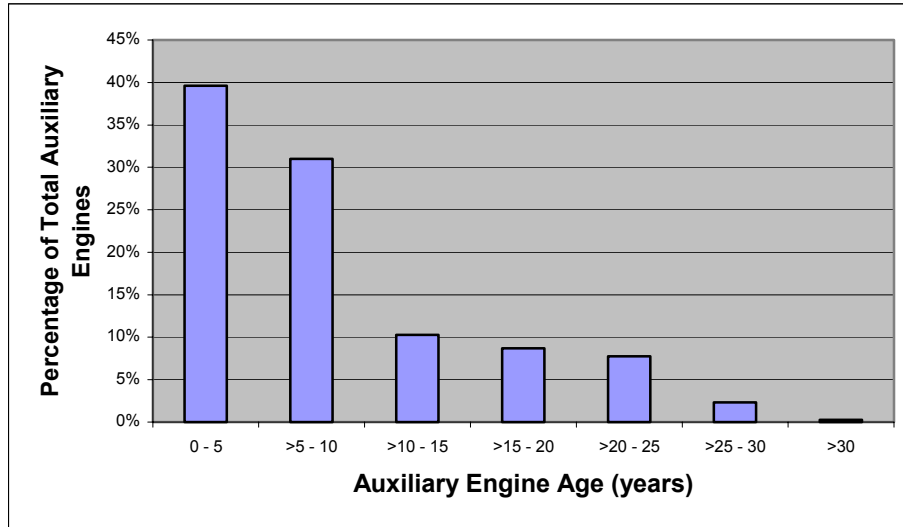


Table III-10 provides information on the average power generated by the auxiliary engines when vessels are hotelling (dockside), maneuvering at ports, and transiting at sea. The diesel generator set engines on passenger cruise vessels are defined as “auxiliary engines” for the purposes of the proposed regulation. The power generated by these engines is much higher than for other vessels because these engines produce electrical power for both propulsion and ship-board electricity.

**Table III-8: Average Power Generated**

Type of Vessel	Power Generated While Hotelling (kw)	Power Generated While Maneuvering (kw)	Power Generated While At Sea (kw)
Passenger/Cruise	7,500	13,800	34,000
Container	1,600	3,300	3,800
Other	1,450	1,700	4,200
Auto Carrier	600	1,300	580
Tanker	500	660	480
Reefer	1,200	1,200	2,000
Average All Vessels	2,000	3,420	6,600

## Main Engines

According to the Survey, as reported in Table III-9, main engines are dominated by diesel engines, with only a small fraction being either gas or steam turbine. The diesel piston engines used on vessels are reciprocating internal combustion engines that operate on the same basic principles as land-based diesel engines. The main engine type results are shown below.

**Table III-9: Main Engine Types**

<b>Engine Type</b>	<b>Number of Engines</b>	<b>Percent of Total Main Engines</b>
Diesel Compression-Ignition	289	96%
Steam Turbine	9	3%
Gas Turbine	2	1%

Additional information was gathered regarding whether the diesel engines were either two or four-stroke. As shown in Table III-10 below, 95 percent of the main engines on oceangoing vessels were reported to be two-stroke engines. Reciprocating internal combustion engines may operate in a two or four-stroke cycle, where a stroke is one complete movement of the piston from one end of the cylinder to the other. Two stroke engines have higher horsepower to weight ratio than four-stroke engines, but two-stroke engines tend to have higher NOx emissions. According to the survey, main engines use primarily heavy fuel oil.

**Table III-10: Diesel Main Engine Types**

<b>Diesel Engine Type</b>	<b>Number of Engines</b>	<b>Percent of Total Diesel Engines</b>
2-stroke	271	95%
4-stroke	15	5%

## **D. Vessel Fuels and Fuel Systems**

As explained in Section B, most oceangoing vessels are propelled by a single large slow-speed two-stroke direct drive diesel engine, with smaller medium speed four-stroke auxiliary engines providing electrical power for lighting, navigation equipment, and other ship-board uses. For these vessels, the large main engine almost always operates on heavy fuel oil (HFO), while the smaller auxiliary engines may run on either HFO or marine distillate fuels such as marine gas oil or marine diesel oil. Vessels that use HFO in both their main and auxiliary engines are referred to as mono-fueled (or uni-fueled) vessels, while vessels that use distillate fuels in their auxiliary engines are referred to as dual-fueled.

Diesel-electric vessels such as passenger cruise vessels use very large four-stroke medium speed engines coupled to generators to provide electrical power for both



propulsion and ship-board electrical power. These vessels generally use HFO, although some have reported using marine distillate fuels close to shore to reduce their emissions.

### Fuel Types

The two basic types of marine fuels are distillate and residual. Distillate fuel is composed of the lighter fractions of crude oil that are separated in a refinery by a boiling process, while the remaining fraction that did not boil is referred to as residual.

#### *Distillate Marine Fuels*

The two most common types of marine distillate fuels are marine gas oil (MGO) and marine diesel oil (MDO). MGO is also referred to as DMA using official fuel specification terminology, where the “D” denotes a distillate fuel, the “M” indicates a marine fuel, and the “A” is the grade of fuel. MDO is similar to MGO, but may have a somewhat higher viscosity and sulfur content. This fuel is also referred to as DMB using official terminology, with the same nomenclature as for DMA fuel. MDO is generally MGO that contains a limited amount of residual fuel from storage in tanks or piping that previously held residual fuel. Other types of distillate marine fuels include DMX and DMC fuels. DMX fuel is special grade of fuel generally used only in emergency backup generators, while DMC is a distillate fuel like DMB, except that it is intentionally manufactured from heavier boiling fractions from a distillation process, or is blended from DMA and residual fuels. (U.S. EPA, 1999).

#### *Residual Fuels*

Marine residual fuel (also called “heavy fuel oil”) is generally a mixture of residual and distillate fuels referred to as intermediate fuel oil (IFO). While there are numerous grades of marine residual fuels, the most common types are IFO-180 and IFO-380. Using this informal terminology, the numbers used in naming these fuels refers to the viscosity limits at the common fuel handling temperature of 50°C. Similar to the distillate fuels, there is also a parallel official terminology. For example, IFO-380 fuel is referred to as either RMG-35 or RMH-35. Using this terminology the “R” denotes a residual fuel, the “M” denotes a marine fuel, and the “35” is the maximum viscosity at 100°C. (U.S. EPA, 1999)

Listed below in Table III-11 are the common marine fuels discussed above, and the range in their allowable properties.

**Table III-11: Selected ASTM Specifications for Marine Fuels**

Specification	Distillate Fuels		HFO/Residual Fuels	
	MGO (DMA)	MDO (DMB)	IFO 180 (RME/F-25)	IFO 380 RMG/H-35
Min. Flash Pt. (°C)	60	60	60	60
Kinematic Viscosity (cSt@40°C)	1.5-6	11 max	25 *	35*
Max % Sulfur (wt.)	1.5	2.0	5.0**	5.0**
Max. % Ash (wt.)	0.01	0.01	0.10-0.15	0.15-0.2
% Distillate	100	99+	12	2

\* Viscosity in centistokes at 100°C, \*\* IMO Annex VI limits sulfur to 4.5%.

### Fuel Handling

Ocean-going vessels have complex fuel handling and processing systems that vary with the individual vessel. Most have multiple fuel storage tanks that can hold various grades of fuel, both distillate and HFO. Marine fuels undergo several processes before they are combusted in the engine. Typically, fuel from the storage tank is: (1) pumped to a settling tank; (2) pumped to a centrifuge for removal of water and sludge; (3) pumped to service (day) tank; and (4) pumped to the engine for consumption. Depending on the vessel, there are different ways these processes are handled, some with complete segregation of fuel processes for different grades of fuel, and some utilizing the same fuel processing components for different grades of fuel (Marintek, 2003). In addition, the complete fuel handling system will include additional filtration, venting, drainage, and other components.

The fuel processing steps mentioned above apply to both HFO and distillate fuels. However, heavy fuel oil must also be heated to 100 to 200 degrees Celsius to reduce its viscosity to a point where it can be pumped and combusted in the engine. Because HFO is so viscous, vessel operators switch to distillate marine fuels prior to vessel dry-dock maintenance operations so that this fuel does not solidify in pipes and components when the engine is stopped.

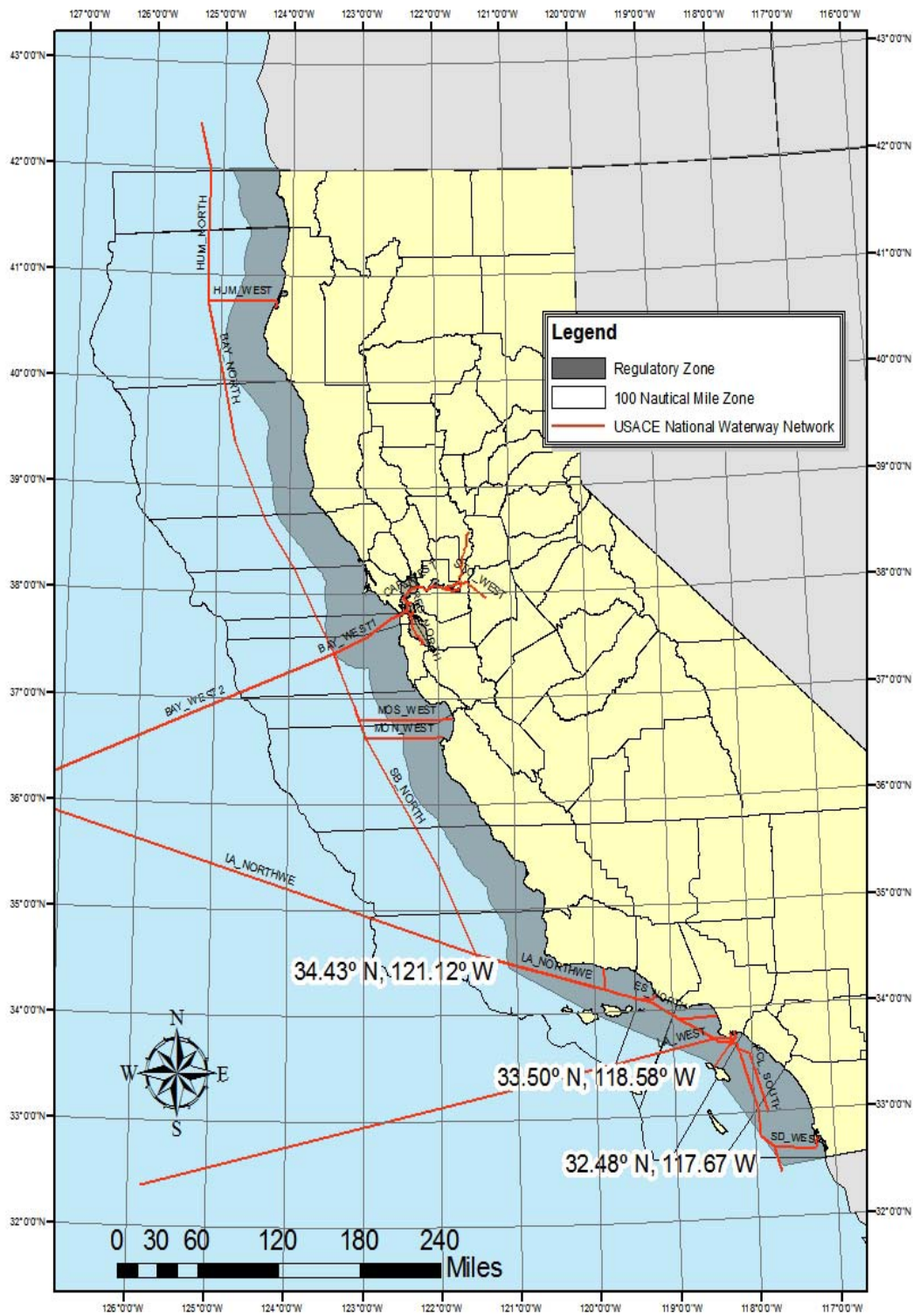
### **E. The Shipping Lanes and Ocean-going Vessel Activity Off the Coast of California**

The coastline of California stretches more than 800 miles, from Mexico in the south to Oregon in the north. In 2004, California's ports were visited by more than 1,900 ocean-going vessels. These vessels made approximately 10,000 visits to one or more of California's deep-water ports.

Ships typically travel in designated shipping lanes in high traffic areas near California's ports. For example, there are designated shipping lanes that oceangoing vessels use within the Santa Barbara Channel and approximately 25 nautical miles south of the

Ports of Los Angeles and Long Beach. (Marine Exchange of Southern California). Similarly, there are designated shipping lanes within the San Francisco Bay and surrounding areas north to approximately Point Reyes, west to the Farallon Islands, and south to Half Moon Bay. (Marine Exchange of San Francisco). Outside of the port areas, vessels are generally free to choose their routes, although certain vessel-specific requirements may apply. For these low traffic areas, approximations must be made of the most likely routes. To approximate the routes used by oceangoing vessels off California's coastline, including both designated shipping lanes and other areas, ARB staff used the "United States Army Corps of Engineers (USACE) Shipping Lanes," as shown in Figure III-2.

**Figure III-2: USACE Shipping Lanes Off the Coast of California and the 24 nm Contiguous Zone**



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#### **IV. EMISSIONS, POTENTIAL EXPOSURES, AND RISK**

This chapter presents the most recent emissions inventory for diesel-fueled ocean-going vessel auxiliary engines operating offshore of California as well as at California's ports. A discussion on the potential cancer and non-cancer health risks that may occur due to the operation of auxiliary engines is also provided.

##### **A. Estimated Emissions from Ocean-going Vessel Auxiliary Engines**

To develop an emissions estimate of the emissions from diesel-fueled ocean-going vessel auxiliary engines operating offshore of California as well as at California's ports, ARB staff developed a methodology that integrated information from three main sources of information:

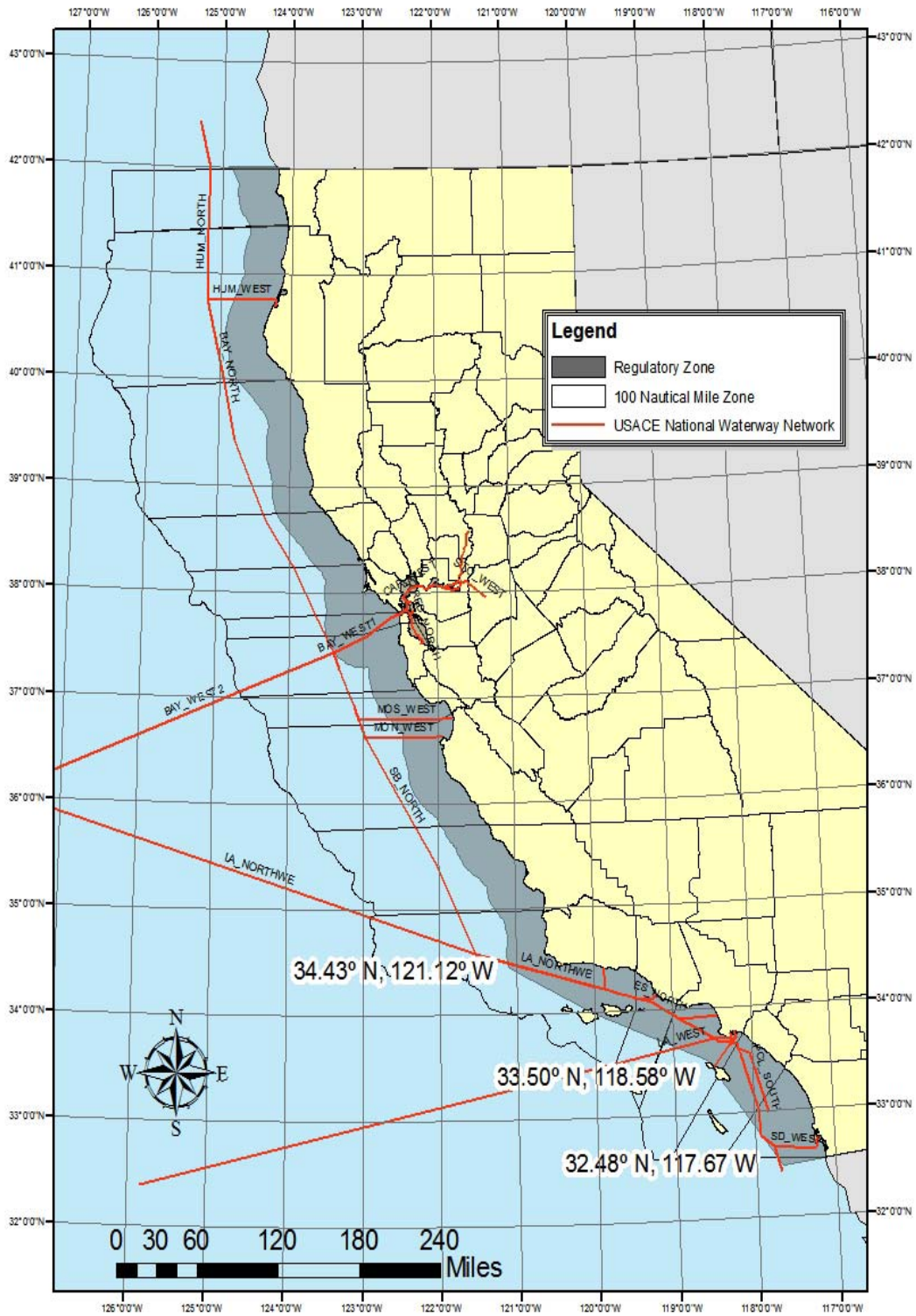
- ARB's 2005 Ocean-going Vessel Survey;
- 2004 California State Lands Commission ocean-going vessel visit data; and
- the ocean-going vessel element of the 2001 Port of Los Angeles emission inventory.

Baseline emission estimates for the year 2004 were developed and emission projections to 2010 and 2020 were also developed using estimates of expected growth. Details of the methodology are found in Appendix D. Based on the information available to date, we believe the methodology has resulted in a reasonable estimate of the emissions from ocean-going vessel auxiliary engines. However, there are continuing efforts by ARB and the major California ports to update and improve the ocean-going vessel emission inventories. As new information becomes available from these efforts, the ocean-going vessel auxiliary engine emission inventory will be updated.

##### Current 2004 Emission Estimates for Diesel-fueled Ocean-going Auxiliary Engines

ARB staff estimate that the statewide operation of diesel-fueled ocean-going vessel auxiliary engines operating 100 nm or less off of California's coast, in California's ports, and inland waters results in approximately 4 tons per day or approximately 1,430 tons per year of diesel PM emissions. These emission estimates are associated with the use of an ocean-going vessel's auxiliary engines to assist the propulsion engines during the maneuvering of the vessel or to power the vessels electrical systems while at dockside (hotelling). The estimates also include emissions from ocean-going vessels powered by diesel-electric engines. The emission estimation "boundary" of 100 nm was selected because it can be distinguished with relative ease and it is inclusive of the major areas of activity of the sources of interest. Figure IV-1 provides a graphical representation of the 100 nm emission inventory boundary. On the figure, the outer black line, which mirrors the California coastline, represents the inventory boundary while the shaded gray area is the region in which the proposed regulation would be applicable.

**Figure IV-1: Ocean-going Vessel Emission Inventory Boundary**



In addition, based on a range of statewide NOx to PM conversion factors of 0.3 – 0.5 g NH<sub>4</sub>NO<sub>3</sub>/g NOx, ARB staff estimate a secondary formation of PM<sub>10</sub> nitrate from NOx emissions from ocean-going vessel diesel-fueled auxiliary engines to be between 13.1 and 21.8 tons per day.<sup>2</sup> This estimate only reflects the potential conversion of the ocean-going vessel auxiliary engine NOx emissions associated with maneuvering and hotelling activities. The ARB staff is unable at this time to adequately evaluate the potential for the formation of secondary PM<sub>10</sub> nitrate at sea due to a lack of documentation concerning the impacts of higher humidity at sea, less available ammonia at sea, and the overall deposition of PM in transport along the coast of California. Because of this we believe these values are an underestimate of the quantities of secondary PM<sub>10</sub> nitrate formed from ocean-going vessel diesel-fueled auxiliary engines.

Estimates of statewide 2004 diesel PM, NOx, SOx, carbon monoxide, and hydrocarbons from ocean-going vessel auxiliary engines are presented in Table IV-1.

**Table IV-1: Estimated Statewide 2004 Ocean-going Vessel Auxiliary Engine Emissions**

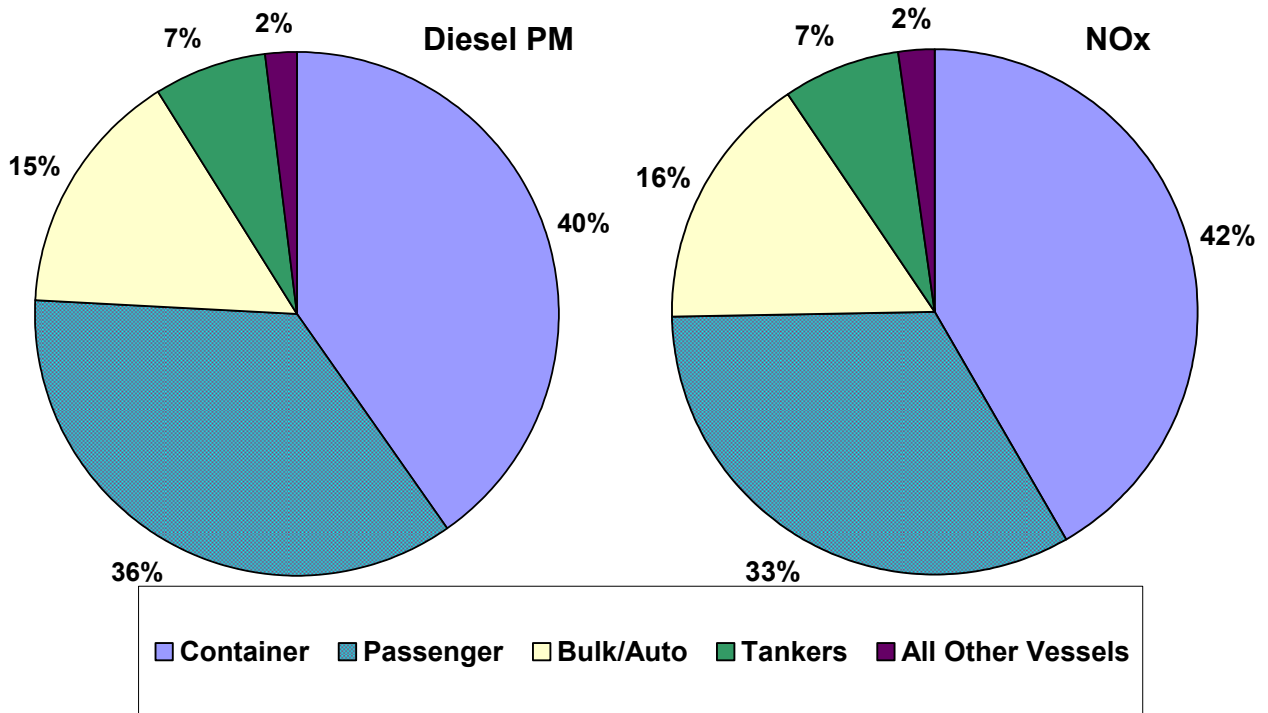
Vessel Types	Numbers of Vessels	Numbers of Vessel Visits	2004 Pollutant Emissions, Tons/Day				
			NOx	HC	CO	PM	SOx
Auto	225	750	1.11	0.03	0.08	0.10	0.71
Bulk	475	946	4.02	0.11	0.30	0.35	2.55
Container	594	4744	18.11	0.50	1.37	1.57	11.48
General	196	721	1.75	0.05	0.13	0.15	1.11
Passenger	44	687	14.44	0.39	1.09	1.39	10.24
Reefer	19	52	0.60	0.02	0.05	0.05	0.38
RoRo	13	34	0.40	0.01	0.03	0.03	0.25
Tanker	372	1941	3.16	0.09	0.24	0.27	2.00
Totals	1938	9875	43.6	1.20	3.29	3.91	28.7

As shown in Table IV-1, there are approximately 1,900 ocean-going vessels that visited California's ports in 2004. Of those 1,900 vessels that visited California's ports, 30 percent were container vessels. Those container vessels represented more than 45 percent of the vessel visits to California's ports. As shown in Figure IV-2, container vessels represent approximately 50 percent of all the pollutants emitted by ocean-going vessel auxiliary engines; followed by passenger vessels, tankers, and bulk cargo and auto carriers.

<sup>2</sup> The conversion factor for the transformation of NOx to NH<sub>4</sub>NO<sub>3</sub> was based on an analysis of annual-average conversion factors for secondary formation of PM<sub>10</sub> 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<sub>4</sub>NO<sub>3</sub> is found in Appendix E.



**Figure IV-2: 2004 NOx and Diesel PM Emission Distributions for Ocean-going Vessel Auxiliary Engines**



The ARB staff also estimated district-specific emissions associated with ocean-going vessel auxiliary engines. The allocation of these estimates is based on the length(s) of United States Army Corps of Engineers shipping lanes associated with a specific district. Table IV-2 presents a district-by-district estimate of emissions from ocean-going vessel auxiliary engines.

**Table IV- 2: Estimated 2004 Ocean-going Vessel Auxiliary Engine Emissions By District (tpd)<sup>3</sup>**

<b>District</b>	<b>NOx</b>	<b>HC</b>	<b>CO</b>	<b>PM</b>	<b>SOx</b>
Bay Area	7.37	0.21	0.55	0.66	4.81
Mendocino	0.85	0.02	0.06	0.08	0.58
Monterey Bay	1.40	0.04	0.10	0.13	0.95
North Coast	1.47	0.04	0.11	0.13	1.00
Northern Sonoma	0.39	0.01	0.03	0.04	0.27
San Diego	5.50	0.16	0.42	0.53	3.83
San Joaquin Valley	0.39	0.01	0.03	0.03	0.23
San Luis Obispo	0.78	0.02	0.06	0.07	0.53
Santa Barbara	2.96	0.08	0.22	0.27	1.96
South Coast	21.32	0.59	1.62	1.89	13.78
Ventura	0.98	0.03	0.07	0.09	0.64
Yolo-Solano	0.18	<0.01	0.01	0.01	0.11
<b>Total</b>	<b>43.59</b>	<b>1.21</b>	<b>3.28</b>	<b>3.93</b>	<b>28.69</b>

Note: The following districts had no ocean-going auxiliary engine emissions allocated to them; Amador, Antelope Valley, Butte, Calaveras, Colusa, El Dorado, Feather River, Glenn, Great Basin Unified, Imperial, Kern, Lake, Lassen, Mariposa, Modoc, Mojave Desert, Northern Sierra, Placer, Sacramento, Shasta, Siskiyou, Tehama, and Tuolumne.

Table IV-3 provides estimates of emissions from ocean-going auxiliary engines operating in the proposed regulated waters, which includes all of California's inland waters, estuarine waters, and all waters within 24 nautical miles (nm) of the California coastline. The 24 nm proposed regulatory waters has been designated by ARB staff as the area where the proposed regulation would be enforced. This area is shown in Figure IV-1 as the dark grey area adjoining the California coastline.

<sup>3</sup> The total emissions may vary slightly from the values shown in Table IV-1 due to rounding.

**Table IV-3: Estimated 2004 Ocean-going Vessel Auxiliary Engine Emissions Occurring Within the Proposed Regulatory Waters**

Vessel Types	2004 Pollutant Emissions, Tons/Day				
	NOx	PM	HC	CO	SOx
Auto	0.90	0.08	0.02	0.07	0.57
Bulk	3.76	0.33	0.10	0.28	2.38
Container	15.71	1.37	0.43	1.19	9.95
General	1.62	0.14	0.04	0.12	1.03
Passenger	8.31	0.80	0.23	0.62	5.89
Reefer	0.59	0.05	0.02	0.04	0.37
RoRo	0.34	0.03	0.01	0.03	0.21
Tanker	2.24	0.19	0.06	0.17	1.42
Totals	33.47	2.99	0.91	2.52	21.82

Projected 2010 and 2020 Emission Estimates for Ocean-going Vessel Auxiliary Engines

The projected emission estimates for the years 2010 and 2020 are presented in Table IV-4. As discussed in the methodology included in Appendix D, the vessel type-specific ocean-going vessel growth estimates were developed based upon historical data of the installed power of the propulsion engines of ocean-going vessels from 1997 to 2003. The vessel type-specific growth rates developed were the midpoint between the best fit compounded growth rate for the seven data points and the best fit linear (arithmetic) growth rate for the same data.

The port specific growth rates were applied to in-port emissions: hotelling and maneuvering and in-transit emissions within 3 nm of the coast of the California mainland. In-transit emissions that occur in the outer continental shelf (beyond the 3 nm limit) cannot be tied directly to a single port; as a result, vessel type-specific growth factors are used. The vessel type specific growth factors are also used where port specific factors are not available, such as passenger vessels calling on Monterey. Details on the growth assumptions are provided in Appendix D.

Expected emission reductions and the impact on the ocean-going vessel auxiliary engine emission estimates are discussed in Chapter VII, Environmental Impacts.

**Table IV-4: Ocean-going Vessel Auxiliary Engine  
Projected Year 2010 and 2020 Emission Estimates**

Vessel Types	2010 Emission, Tons per Day					2020 Emission, Tons per Day				
	NOx	HC	CO	PM	Sox	NOx	HC	CO	PM	SOx
<b>Auto</b>	1.35	0.04	0.10	0.12	0.86	2.63	0.07	0.20	0.23	1.67
<b>Bulk</b>	5.40	0.15	0.41	0.47	3.42	8.34	0.23	0.63	0.73	5.28
<b>Container</b>	23.22	0.64	1.76	2.02	14.72	33.71	0.93	2.55	2.93	21.37
<b>General</b>	2.36	0.07	0.18	0.21	1.50	4.42	0.12	0.33	0.38	2.80
<b>Passenger</b>	14.99	0.41	1.13	1.44	10.63	40.26	1.10	3.03	3.88	28.55
<b>Reefer</b>	0.86	0.02	0.07	0.08	0.55	1.27	0.03	0.10	0.11	0.81
<b>RoRo</b>	0.49	0.01	0.04	0.05	0.31	0.71	0.02	0.05	0.06	0.45
<b>Tanker</b>	2.99	0.08	0.23	0.26	1.89	4.09	0.11	0.31	0.36	2.59
<b>Totals</b>	51.66	1.42	3.92	4.65	33.88	95.43	2.61	7.20	8.68	63.52

**B. Transport of Offshore Ocean-going Vessel Emissions to Onshore**

The transport of air pollution over long distances and between air basins has been well established. The emissions from ocean-going vessels can travel great distances and numerous studies have shown local, regional, and global impacts on air quality. (Endresen, 2003; Jonson, 2000; Corbett and Fishbeck, 1997; Streets, 2000; Saxe and Larsen, 2004) Tracer studies, air quality modeling, and meteorological data analysis are typical approaches used to determine the extent to which emissions released offshore can impact onshore areas. Several studies support ARB staffs conclusion that emissions from ocean-going vessels released offshore the California Coast can impact onshore air quality. These studies are briefly described below and provided in additional detail in Appendix F.

A tracer study involves the release of a known amount of a non-toxic, inert gas such as sulfur hexafluoride and perfluorocarbon, from either a moving or fixed point offshore and the subsequent sampling of the atmosphere for concentrations of that gas at sites onshore. In California, there have been three tracer studies conducted to investigate the effect of offshore vessel emissions on onshore air quality (Chen, 2005; ARB, 1982; ARB, 1983; ARB, 1984). The tracer gases were released from 8 to over 20 miles offshore. All three studies resulted in tracer gases being detected at onshore sampling

stations spanning over wide distances. From these studies we can infer that pollutants emitted from offshore vessels can be transported to onshore areas and be available to participate in onshore atmospheric processes, influencing onshore air quality.

The onshore impacts of offshore emissions have also been investigated using air quality modeling. A modeling study conducted by the Department of Defense has concluded that the emissions released within 60 nautical miles offshore in the southern California coastal region could transport to the coast (ARB, 2000). Another modeling study conducted by the U. S. Navy using 10 years of hourly surface wind data to estimate the probability that offshore emissions would impact land from specified distances has shown that for California, the probabilities of offshore emissions being transported to the coast within 96 hours were greater than 80 percent from 50 nautical miles offshore (Eddington, 1997).

The U.S. EPA has set a 175 nautical mile boundary off from the United States coasts for development of vessel NO<sub>x</sub> emission inventory (Eddington, 2003; EPA, 2003). The 175-mile area is based on the estimate of the distance a NO<sub>x</sub> molecule could travel in one day (assuming a 10 mile per hour wind traveling toward a coast, NO<sub>x</sub> molecules emitted 12 miles from the coast could reach the coast in just over one hour. NO<sub>x</sub> molecules emitted 175 nautical miles (200 miles) could reach the coast in less than a day). ARB has also conducted studies on the onshore impact of offshore emissions. ARB's studies have demonstrated that pollutants released off California's coast can be transported to inland areas due to the meteorological conditions off the coast (Chen, 2005; ARB, 1982; ARB, 1983; ARB, 1984).

There has been very little actual in-transit measurement of the pollutant emissions from ships to better understand various aspects of vessel plume chemistry and reconcile differences between measurements and model predictions. However, a recent study conducted by Chen et al (Chen, 2005), in which measurements of chemical species in vessel plumes were taken from aircraft transecting a vessel plume, indicates that the NO<sub>x</sub> half-life within a vessel's plume may be much shorter than predicted by photochemical models. The study demonstrated a NO<sub>x</sub> lifetime of about 1.8 hours inside the vessel plume at noontime as compared to about 6.5 hours in the background marine boundary layer of the experiment. Additional studies investigating vessel plume chemistry will help us better understand vessel plume chemistry and improve the photochemical models used to investigate the impacts of vessels on air quality.

The analysis of meteorological data can also be used to demonstrate that emissions released offshore can reach onshore airsheds. In 1983, the ARB established the California Coastal Waters (CCW) boundary, based on coastal meteorology, within which pollutants released offshore would be transported onshore. The development of the boundary was based on over 500,000 island, ship-board, and coastal observations from a variety of records, including those from the U.S. Weather Bureau, U.S. Coast Guard, Navy, Air Force, Marine Corps, and Army Air Force (ARB, 1982). The CCW boundary ranges from about 25 miles off the coast at the narrowest to just over 100 miles at the widest.

### **C. Potential Exposures and Health Risks from Ocean-going Vessel Auxiliary Engine Diesel PM Emissions**

This section examines the exposures and potential health risks associated with particulate matter (PM) emissions from auxiliary engines on ocean-going vessels. A brief qualitative discussion is provided on the potential exposures of Californians to the diesel PM emissions from ocean-going vessel auxiliary engine operations. In addition, a summary is presented of a health risk assessment conducted to determine the 70-year potential cancer risk associated with exposures to diesel PM emissions from ocean-going vessel auxiliary engines associated with operations at the Ports of Los Angeles and Long Beach. The ARB staff believes that the results from this analysis provide quantitative results for exposures around the Ports of Los Angeles and Long Beach and are generally applicable to other ports in California, providing a qualitative estimate for those areas.

#### Exposures to Diesel PM

As discussed previously, ocean-going vessels visit California ports and travel in waters along the coastline of California and within certain inland waterways. The diesel PM emissions from auxiliary engines contribute to ambient levels of diesel PM emissions. Based on the most recent emissions inventory, there are about 10,000 visits to California ports by ocean-going vessels that have auxiliary engines. The majority of ports are in urban areas and, in most cases, are located near where people live, work, and go to school. This results in substantial exposures to diesel PM emissions from the operation of vessel auxiliary engines. Because analytical tools to distinguish between ambient diesel PM emissions from vessel auxiliary engines and that from other sources of diesel PM do not exist, we cannot measure the actual exposures to emissions from diesel-fueled vessel auxiliary engines. However, modeling tools can be used to estimate potential exposures.

To investigate the potential risks from exposures to the emissions from auxiliary engines, ARB staff used dispersion modeling to estimate the ambient concentration of diesel PM emissions that result from the operation of ocean-going vessel auxiliary engines that visit the Ports of Los Angeles and Long Beach. The potential cancer risks from exposures to these estimated ambient concentrations of diesel PM were then determined. The results from this study are presented below, and additional details on the methodology used to estimate the health risks are presented in Appendix G.

#### Health Risk Assessment

Risk assessment is a complex process that requires the analysis of many variables to simulate real-world situations. There are three key types of variables that can impact the results of a health risk assessment for cargo handling equipment: the magnitude of diesel PM emissions, local meteorological conditions, and the length of time of exposure. Diesel PM emissions are a function of the age and horsepower of the

engine, the emissions rate of the engine, and the annual hours of operation. 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 resultant ambient concentration of diesel PM, with higher concentrations found along the predominant wind direction and under calm wind conditions. How close a person is to the emissions plume and how long he or she breathes the emissions (exposure duration) are key factors in determining potential risk, with longer exposures times typically resulting in higher risk.

To examine the potential health risks for ocean-going vessel auxiliary engines, ARB staff conducted a risk assessment for operations at the Ports of Los Angeles and Long Beach. We evaluated the impacts from the 2002 estimated emissions for all sources of emissions at the two ports including ocean-going vessel auxiliary engines. Meteorological data from Wilmington was used for the study. The Wilmington site is about one mile away from the ports, and the measurements were collected in 2001. The U.S. EPA's ISCST3 air dispersion model was used to estimate the annual average offsite concentration of diesel PM in the area surrounding the two ports. The modeling domain (study area) spans a 20 x 20 mile area, which includes both the ports, the ocean surrounding the ports, and nearby residential areas in which about 2 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 x 160 grids) with 200-meter x 200-meter resolution was used in this study. While grids within the ports were included in the 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, 2002a; OEHHA, 2002b). Following 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 ( $1.1 \text{ (mg/kg-d)}^{-1}$ ).

#### Cancer Risk Characterization

Emissions from vessel auxiliary engines resulted in significant health risk impacts on the nearby residential areas. Figure IV-3 shows the risk isopleths for diesel PM emissions from vessel auxiliary engines (transiting and hotelling) at the Ports of Los Angeles and Long Beach superimposed on a map that covers the ports and the nearby communities.

As shown in Figure IV-3, the area in which the risks are predicted to exceed 100 in a million has been estimated to be about 13,500 acres with a population of 225,100. For the risk level of over 200 in a million, the impacted areas have been estimated to be about 2,260 acres and about 48,000 people living around the ports who are exposed to the risk level. Overall, about 99.5 percent of the effective modeling domain (excluding the port property and the surrounding ocean area) has an estimated risk level of over 10 in a million and about 99.6 percent of 2 million people who are living in the domain are exposed to the risk level (see Table IV-5).

Using the U.S. Census Bureau's year 2000 census data, we estimated the population within the isopleth boundaries. The acres impacted and population affected for the risk ranges of 10-100, 100-200, 200-500, and over 500 are presented in Table IV-5. As shown in Table IV-5, nearly 2 million people living in the area around the ports have a predicted cancer risk of greater than 10 in a million due to emissions from auxiliary engines. 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 area are exposed to risks greater than 10 in a million.

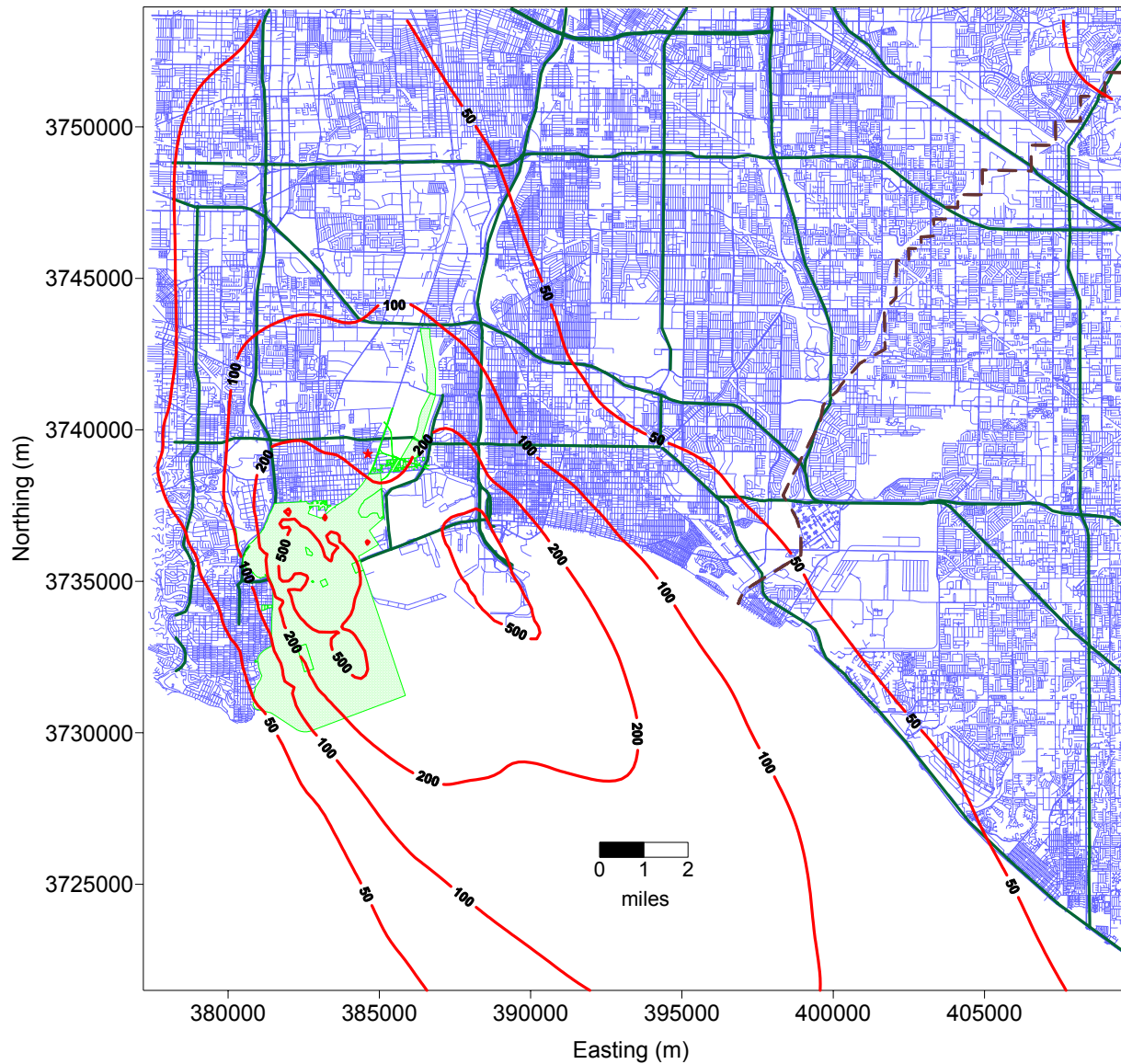
**Table IV-5: Summary of Area Impacted and Population Affected by Risk Levels**

<b>Risk Level</b>	<b>Acres Impacted</b>	<b>Population Affected</b>
Risk > 500	0	0
Risk > 200	2,263	47,941
Risk > 100	13,492	225,162
Risk > 10	162,565	1,969,397

Note: The effective modeling domain is the land area outside of port property, and is about 255 square miles or 163,435 acres. The total population within the domain is about 2 million.



**Figure IV-3: Estimated Diesel PM Cancer Risk from Ocean-going Vessel Auxiliary Engine Activity at POLA and POLB**



Parameters: Wilmington Met Data  
Urban Dispersion Coefficients  
80<sup>th</sup> Percentile Breathing Rate  
Emission = 405 TPY  
Modeling Receptor Domain = 20 mi x 20 mi  
Resolution = 200 m x 200 m

## Non-Cancer Health Risks

A substantial number of epidemiologic studies have found a strong association between exposure to ambient particulate matter and adverse health effects. (CARB, 2002) As part of this study, ARB staff conducted an analysis of the potential non-cancer health impacts associated with exposures to the model-predicted ambient levels of directly emitted diesel PM (primary diesel PM) discussed above and extrapolated them to the rest of the state. The non-cancer health effects evaluated include premature death, asthma attacks, work loss days, and minor restricted activity days.

Based on our analysis, we estimate that the average number of cases statewide in 2004 due to emissions from auxiliary engines would be as follows:

- 31 premature deaths (for ages 30 and older), 16 to 48 deaths as 95% confidence interval (CI);
- 830 asthma attacks, 202 to 1, 457 as 95% CI;
- 7,258 days of work loss (for ages 18-65), 6,143 to 8,370 as 95% CI;
- 38,526 minor restricted activity days (for ages 18-65), 31,403 to 45,642 as 95% CI.

As stated previously, to estimate these statewide potential non-cancer health impacts from auxiliary engine emissions, ARB staff estimated the non-cancer health impacts from ocean-going vessel auxiliary engine emissions in the area surrounding the ports of Los Angeles and Long Beach and extrapolated these results to predict statewide values based on the ratio of the mass emissions at the POLB and POLA to those in the rest of the State. A brief discussion on the methodology used to generate these estimates is provided below.

### Non-Cancer Health Effects Methodology

ARB staff assessed the potential non-cancer health impacts associated with exposures to the model-predicted ambient levels of directly emitted diesel PM (primary diesel PM) within each 200 meter by 200 meter grid cell within the modeling domain used for the POLA-POLB exposure assessment study. Because the study used the 2002 emissions estimates for auxiliary engine emissions at the ports, the ambient concentrations were adjusted to reflect the updated 2004 emissions inventory developed by ARB staff. The populations within each grid cell were determined from U.S. Census Bureau year 2000 census data. Using the methodology peer-reviewed and published in the Staff Report: Public Hearing to Consider Amendments to the Ambient Air Quality Standards for Particulate Matter and Sulfates (PM Staff Report; CARB, 2002), we calculated the number of annual cases of death and other health effects associated with exposure to the ambient PM concentrations modeled for each of the grid cells. For each grid cell, each health effect was estimated based on concentration-response functions derived from published epidemiological studies relating changes in ambient concentrations to changes in health endpoints, the population affected, and the baseline incidence rates. The total affected population was obtained by summing the results from each grid cell.

The selection of the concentration-response functions was based on the latest epidemiologic literature, as described in the PM Staff Report (ARB, 2002) and in Lloyd and Cackette (Lloyd and Cackette, 2001). Staff estimated that the ports of Los Angeles and Long Beach account for approximately 48% of total statewide emissions related to auxiliary engine activities. Hence, the statewide impact of the auxiliary engine emissions was estimated by dividing the estimated impacts in the modeling domain around the ports of Los Angeles and Long Beach by 0.48.

Several assumptions were used in quantifying the health effects of PM exposure. They include the selection and applicability of the concentration-response functions, exposure estimation, subpopulation estimation, baseline incidence rates, and the extrapolation from results in the modeling domain to the statewide results. These are briefly described below.

- Premature death calculations were based on the concentration-response function of Krewski et al. (Krewski et al, 2000) The ARB staff assumed that concentration-response function for premature mortality in the model domain is comparable to that in the Krewski study. It is known that the composition of PM can vary by region, and not all constituents of PM have the same health effects. However, numerous studies have shown that the mortality effects of PM in California are comparable to those found in other locations in the United States, justifying our use of Krewski et al's results. Also, the U.S. EPA has been using Krewski's study for its regulatory impact analyses since 2000. For other health endpoints, the selection of the concentration-response functions was based on the most recent and relevant scientific literature. Details are ARB's PM Staff Report (ARB, 2002).
- The ARB staff assumed the model-predicted exposure estimates could be applied to the entire population within each modeling grid. That is, the entire population within each modeling grid of 200 meter x 200 meter was assumed to be exposed uniformly to modeled concentration. This assumption is typical of this type of estimation.
- The ARB staff assumed the grid cell population had similar age distributions as the county in which it was located. The subpopulation used for each health endpoint was calculated by multiplying the all-age population for each grid cell by the county-specific ratio of the subpopulation used for the endpoint over the all-age population. For example, mortality estimates were based on subpopulations age 30 or more estimated from ratios of people over 30 over the entire population, specific for each county. For Los Angeles County, this value was 54 percent. These estimates were needed because information on the particular subpopulation in each modeling grid was not available.
- The ARB staff assumed the baseline incidence rates were uniform across each modeling grid, and, in many cases, across each county. This assumption is

consistent with methods used by the U.S. EPA for its regulatory impact assessment. The incidence rates match those used by U.S. EPA.

- Because only impacts from directly emitted diesel PM are estimated and a subset of health outcomes is considered here, the estimates should be considered an underestimate of the total public health impact. In addition, the model domain for the study was 20 miles by 20 miles and did not capture all of impacts on the surrounding communities from the POLA and POLB emissions.
- Without readily available modeled concentrations at other ports in California, staff extrapolated the results based on the modeling domain around ports of Los Angeles and Long Beach to infer statewide effects. In doing so, we assumed that the population density and the change in concentrations due to the regulation would be similar to those in the ports of Los Angeles and Long Beach.

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## **V. SUMMARY OF THE PROPOSED REGULATION**

In this chapter, we provide a plain English discussion of the key requirements of the proposed regulation for auxiliary diesel engines operated on ocean-going vessels (or “vessels”). This chapter begins with a general overview of the regulation and the approach taken in developing the requirements in the proposal. 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 non-controlling “plain English” summary of the regulation be made available to the public.

### **A. Overview of the Proposed Regulation**

The proposed regulation requires that auxiliary engines operating within 24 nautical miles (nm) of the California coastline significantly reduce their diesel particulate matter (PM), nitrogen oxide (NO<sub>x</sub>), and sulfur oxide (SO<sub>x</sub>) emissions. Emission reductions can be achieved by using cleaner burning distillate marine fuels, or implementing alternative emission control strategies under an “Alternative Compliance Plan (ACP).” For vessels electing to comply with the fuel requirement, vessel operators will need to switch from the use of heavy fuel oil to marine distillate fuel within 24 nm of the California coastline, unless they already use complying distillate fuels or choose to use distillate fuels on a permanent basis. If operators choose to comply with the proposed regulation under an ACP, they must demonstrate that the alternative emission control strategies will achieve equivalent or greater emission reductions compared to the fuel requirements.

Our approach in developing the fuel and ACP requirements in the proposal was to apply the best available emission control strategy that could be applied to the variety of vessels visiting California ports. Factors considered when establishing these requirements included the potential for near-source risk reduction in port communities, the cost and technical feasibility of using the fuels specified in the proposal, and sufficient availability of the specified fuels at ports worldwide.

### **B. Purpose**

The purpose of this proposed regulation is to reduce emissions of diesel PM, NO<sub>x</sub>, SO<sub>x</sub>, and “secondarily” formed PM (PM formed in the atmosphere from NO<sub>x</sub> and SO<sub>x</sub>). If adopted, the proposed regulation will achieve immediate, significant emission reductions upon implementation in 2007. 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 and shipping lanes;

- diesel PM emission reductions will reduce regional exposure to PM, and help continue progress toward State and federal ambient air quality standards for PM<sub>10</sub> and PM<sub>2.5</sub>;
- NOx emission reductions will reduce the formation of regional ozone and secondary nitrate PM; and
- reductions in SOx emissions will reduce the formation of secondary sulfate PM.

### **C. Applicability**

This subsection explains who must comply with the proposed regulation. Except for the exemptions described below, the proposal applies to any person who owns or operates an ocean-going vessel within 24 nm of the California coastline. The definition of ocean-going vessel is key to this section. In general, ocean-going vessels include large cargo vessels and passenger cruise vessels (see section on “Definitions” below). The regulation applies 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.

The proposed regulation includes language clarifying that the proposal does not change any applicable U.S. Coast Guard regulations and that vessel owners and operators are responsible for ensuring that they meet all applicable U.S. Coast Guard regulations.

### **D. Exemptions**

The proposed regulation includes three exemptions. First, the proposal does not apply to vessels while in “innocent passage.” As defined in subsection (d) of the proposal, “innocent passage” generally means travel within the 24 nm 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.

An exemption is included for two-stroke slow-speed diesel engines as defined in subsection (d) of the proposal. The design of these engines differs significantly from the four-stroke, medium speed engines used in virtually all auxiliary engine applications. While distillate fuels can be used in two-stroke slow-speed engines in some situations, the additional technical challenges associated with using distillate fuels in these engines make it impractical to subject these engines to the same performance standards as four-stroke medium speed engines.

An exemption is also included for military vessels. Military vessels primarily use military specification distillate fuels that must be used on a consistent basis for military equipment globally.



## **E. Definitions**

The proposed regulation provides definitions for a number of terms that are not self-explanatory, or have specific meaning within the context of the proposed regulation. In this subchapter, we discuss some of the key definitions.

### *Auxiliary Engine*

Auxiliary engines are defined as engines designed primarily to provide power for uses other than for direct, mechanical propulsion. Auxiliary engines include diesel generator set engines on diesel-electric vessels, which are used as a source of electricity for any use. Generally, auxiliary diesel engines on cargo vessels are connected to generators and are used to produce electrical power primarily for ship-board uses such as lighting and navigation equipment. These engines are generally four-stroke, medium speed engines. In contrast, the main propulsion engines on cargo vessels are generally very large two-stroke slow-speed engines of a significantly different design than auxiliary engines. Passenger cruise vessels are generally diesel-electric vessels, where several large diesel generator sets provide power for both propulsion and on-board electrical needs. These large generator sets are included in the proposed regulation as “auxiliary engines” because they are similar in design to the smaller auxiliary engines on cargo vessels. Specifically, they are four-stroke, medium-speed generator set engines.

### *Baseline*

The California “baseline” is the boundary line that divides the land and internal waters from the ocean. This boundary line is determined by the United States Baseline Committee and shown on the official United States nautical charts published by the National Oceanic and Atmospheric Administration (NOAA). Because the waterline rises and falls with the tide, the baseline is defined with respect to the tides. For this regulation, we have defined the baseline as the mean lower low water line along the California coast, as shown on the applicable NOAA Nautical Charts authored by the NOAA Office of Coast Survey. The NOAA routinely updates its nautical charts to update hazards to navigation and other information considered essential for safe navigation and any changes made to the baseline by the U.S. Baseline Committee. It is our understanding that NOAA will be updating the charts for the California coast in the near future. The California baseline is used in the definitions of “Territorial Sea” (which extends to 12 nautical miles from the California Baseline) and “Contiguous Zone” (which extends to 24 miles from the California baseline).

### *Marine Gas Oil*

Marine Gas Oil (MGO) is a marine grade distillate fuel very similar to on-road diesel fuel except that it has a higher flash point requirement and often a much higher sulfur content. The International Organization for Standardization (ISO) sets standards for marine fuels under International Standard ISO 8217, including fuels designated DMX

and DMA, which correspond to marine gas oil. For example, the maximum sulfur content for grade DMA fuel is 1.5 percent by weight, and the minimum flash point is 60 degrees Celsius. If a fuel meets all of the standards for DMA or DMX fuels in the applicable ISO standard, then it qualifies in the proposed regulation as “marine gas oil.” In practice, on-road diesel fuel in California often meets the specifications for DMA fuel and is sold for marine use. In most cases, DMX grade fuel is primarily used only for emergency generators, so marine gas oil is generally DMA grade fuel.

### Marine Diesel Oil

Marine Diesel Oil (MDO) is a marine grade distillate fuel very similar to marine gas oil except that it generally contains a small amount of marine residual fuel (heavy fuel oil) due to storage or transportation in tanks or piping that previously held marine residual fuels. The International Organization for Standardization (ISO) sets somewhat less stringent standards for MDO fuel, which corresponds to DMB grade fuel in ISO terminology. The sulfur content limit for DMB grade fuel is 2 percent, compared to 1.5 percent for DMA grade fuel (marine gas oil).

### Ocean-going Vessel

An ocean-going vessel is defined as a vessel meeting any of the following criteria:

- a vessel with a “registry” (foreign trade) endorsement on its U.S. Coast Guard certificate of documentation, or a vessel that is registered under the flag of a country other than the United States;
- a vessel greater than or equal to 400 feet in length overall (LOA) as defined in the Code of Federal Regulations (50 CFR § 679.2, as adopted June 19, 1996);
- a vessel greater than or equal to 10,000 gross tons (GT ITC) per the convention measurement (international system) as defined in 46 CFR 69.51-.61, as adopted September 12, 1989; or
- a vessel propelled by a marine compression ignition engine with a per-cylinder displacement of greater than or equal to 30 liters.

The criteria in the definition of ocean-going vessel are designed to include vessels that travel internationally, such as container vessels, auto carriers, tankers, and passenger cruise vessels. The definition is also designed to exclude harbor craft such as tug boats, fishing boats and ferries, which will be subject to more stringent fuel requirements in 2007. Specifically, diesel fuel sold to harbor craft in California will be required to meet California on-road “vehicular” standards.

### Territorial Sea and Contiguous Zone

Both the Territorial Sea and the Contiguous Zone represent internationally recognized over-water boundaries. The Territorial Sea extends 12 nm offshore of the California coastline (or “baseline”), while the Contiguous Zone extends from the Territorial Sea to 24 nm offshore of the California coastline. Together, these zones represent the region

subject to the proposed regulation approximately north of Point Concepción. South of this point, a boundary approximately 24 nm off the shoreline is defined by straight line segments. We selected this linear boundary south of Point Concepción because the Territorial Sea and Contiguous zone around the Channel Islands would bring the effective zone of the proposed regulation beyond the intended boundary of approximately 24 nm offshore of the California mainland coastline.

## **F. Cleaner Fuel Option**

This section explains the types of fuels that may be used by operators of ocean-going vessels to comply with the requirements of the proposed regulation. Under the proposed regulation, starting on January 1, 2007, vessel operators can comply with the proposal by using one of the following fuels when operating their auxiliary engines within 24 nm of the California coastline: (1) marine gas oil; or (2) marine diesel oil with less than or equal to 0.5 percent by weight sulfur. A 0.5 percent sulfur limit is specified for marine diesel oil because it tends to have a higher sulfur level than marine gas oil. Marine gas oil used by vessels that visit California ports is expected to average at or below 0.5 percent sulfur based on the results of a survey sent to vessel operators in 2005. Specifically, the average sulfur content of distillate marine fuels used by vessel auxiliary engines was reported to be 0.5 percent, and we do not anticipate that this will increase in the future.

Starting on January 1, 2010, marine gas oil meeting a 0.1 percent sulfur limit is specified under the proposed regulation. This lower sulfur fuel will result in additional emission reductions of PM and SO<sub>x</sub>, compared to the January 1, 2010 requirement. This standard is also consistent with a recently adopted European Union regulation. However, a feasibility analysis is required under the proposed regulation prior to implementation of this fuel requirement to investigate the supply, cost, and technical feasibility of using this fuel. Based on the results of this evaluation, modifications to this requirement may be proposed to the Board.

Under the proposed regulation, vessel emissions would be regulated up to 24 nm off the California coastline. The ARB has the authority to require emission reductions out to the California Coastal Water (CCW) boundary. This is the region within which emissions are likely to be transported onshore, and it extends beyond the 24 nm boundary. However, the 24 nm boundary was proposed because it significantly lowers the cost of the regulation while still providing the vast majority of the potential on-shore benefits in terms of reduced exposure to diesel PM. Specifically, about 75 percent of the auxiliary engine diesel PM emissions within 100 nm of the California coastline is emitted within the 24 nm boundary. The 24 nm boundary is also easily defined for vessel operators. The boundary is aligned in Central and Northern California with the outer boundary of the Contiguous Zone, an internationally recognized boundary which extends 24 nm offshore and is noted on most nautical charts. In Southern California, the boundary consists of straight line segments approximately 24 nm offshore of the coastline. This approximation is used because the Contiguous zone extends around

the Channel Islands, bringing the boundary well beyond 24 nm, and in some cases beyond the California Coastal Waters boundary

## **G. Recordkeeping and Reporting Requirements**

### Recordkeeping

Recordkeeping, in addition to ship-board inspections and fuel testing, is necessary for ARB enforcement staff to verify that a vessel operator is complying with the requirements of the proposed regulation. This section explains the recordkeeping requirements.

Beginning with the implementation of the fuel requirement on January 1, 2007, any person who owns or operates an ocean-going vessel within 24 nm of the California coastline will be required to maintain certain records (in English) for a minimum of three years. These requirements do not apply to vessels that travel along California's coastline in "innocent passage," meaning traveling without stopping or anchoring, except in limited situations. The records that must be maintained are as follows:

- the date, time, and position (longitude and latitude) of the vessel for each entry into and departure from the region covered by the proposed regulation;
- the date, time, and position (longitude and latitude) of the vessel at the initiation and completion of any fuel switching procedures used to comply with the fuel requirements in the proposed regulation. Completion of fuel switching procedures means the moment at which auxiliary engines have completely switched from one fuel to another fuel;
- the date, time, and position (longitude and latitude) of the vessel at the initiation and completion of any fuel switching procedures within the region covered by the proposed regulation;
- the type of each fuel used (e.g. marine gas oil) in each auxiliary engine operated within the region covered by the proposed regulation; and
- the types and amounts of fuels purchased for use on the vessel, and the actual percent by weight sulfur content of such fuels as reported by the fuel supplier or a fuel testing firm.

### Reporting and Monitoring Provisions

These provisions explain when the records described above will be provided (reported) to ARB. The provisions also explain that access to vessels shall be provided to allow enforcement staff to verify compliance with the proposed regulation. For example, enforcement staff may need to access the vessel to inspect records instead of requesting that they be mailed, or they may need to obtain a sample of fuel used by the vessels auxiliary engines.

Under these provisions, the recordkeeping information specified in the proposed regulation must be supplied in writing to the Executive Officer upon request. Some of

the recordkeeping required by the proposed regulation may already be recorded to comply with other regulations or standardized practices. In these cases, the information may be provided to ARB in a format consistent with these regulations or practices, as long as the required information is provided.

Vessel owners or operations may be requested to provide additional information needed to determine compliance with the proposed regulation. For example, information about the auxiliary engines, fuel tanks, and fuel delivery system may be needed on a case-by-case basis.

To monitor compliance with the requirements of the proposed regulation, these provisions require that vessel owners or operators provide access to the vessel to employees or officers of the Air Resources Board. This is to include access to records necessary to establish compliance with the requirements of the proposal and access to fuel tanks or pipes for the purpose of collecting fuel samples for testing and analysis.

## **H. Noncompliance Fee Option**

The proposal contains this provision to address the limited situations where a vessel operator may not be able to comply with the proposed regulation for reasons beyond their reasonable control, or it may be impractical to comply. Instead of providing exemptions for these situations, staff is proposing a provision that would allow a vessel owner or operator, under special circumstances, to pay a fee in lieu of complying with the proposed regulation. The funds collected under this provision would be used for marine or port emission reduction projects, with the goal of achieving equivalent or greater emission reductions near affected communities. Under this program, the vessel owners or operators would need to notify the Executive Officer that they will not meet the requirements of the regulation prior to entering the 24 nautical mile boundary (California Regulatory Waters). The fees under this program are designed to ensure that participants will not receive an economic advantage over vessel operators that directly comply with the proposed regulation. The fee schedule is graduated such that subsequent visits would result in increasing fee amounts.

This option could only be used in the following circumstances:

- the vessel owner is unexpectedly redirected to a California port and the vessel does not have a sufficient quantity of fuel complying with the requirements of the proposed regulation;
- due to reasons beyond the vessel operator's control, the vessel was not able to acquire a sufficient quantity of fuel complying with the requirements of the proposed regulation;
- due to reasons beyond the vessel operator's control, fuel necessary to comply with the requirements of the proposed regulation was found to be contaminated or otherwise out of compliance after the vessel left the last bunkering port prior to a California port call;

- modifications to a vessel are required to comply with the proposed regulation and the vessel operator is not able to complete the modifications in time to meet the January 1, 2007 requirements in the proposal. The vessel operator must submit a Compliance Retrofit Report that identifies the modifications necessary and the date by which modifications will be completed; and
- modifications to a vessel are required to comply with the proposed regulation and the vessel will visit a California port a maximum of two times per calendar year, and four times over the life of the vessel after January 1, 2007 (the effective date of the requirements in the proposal).

The non-compliance fees funds would be deposited into the port's Noncompliance Fee Settlement and Air Quality Mitigation Fund prior to leaving the port. The fee increases with each port visited while complying with this provision. The port visits are cumulative over the life of the vessel. For example, if a diesel-electric vessel visits a California port and uses the noncompliance fee option for the first time, the vessels owner would pay a fee of \$32,500. If that same vessel visits another California port sometime later and again uses the noncompliance fee option, the vessel owner would pay a fee of \$65,000; since this was the second port visited under this provision. The basis of the fees is discussed in Appendix H, Basis for the Noncompliance Fees. The fee schedule is shown in Table V-1, Noncompliance Fee Schedule, Per Vessel.

**Table V-1: Noncompliance Fee Schedule, Per Vessel**

<b>Noncompliance Fee Schedule</b>		
<b>Visit</b>	<b>Fee (per vessel)</b>	
	<b>Diesel-Electric Vessels</b>	<b>Other Vessels</b>
1 <sup>st</sup> Port Visited	\$32,500	\$13,000
2 <sup>nd</sup> Port Visited	\$65,000	\$26,000
3 <sup>rd</sup> Port Visited	\$97,500	\$39,000
4 <sup>th</sup> Port Visited	\$130,000	\$52,000
5 <sup>th</sup> or more Port Visited	\$162,500	\$65,000

**I. Alternative Compliance Plan**

The alternative compliance plan (ACP) is included in the proposed regulation to provide vessel owner/operators with the flexibility to implement alternative emission control strategies that achieve equivalent or greater emission reductions than the distillate fuel compliance option. Alternative emission control strategies may include the use of shore-side electrical power, engine modifications, exhaust treatment devices such as diesel oxidation catalysts, the use of alternative fuels or fuel additives, and operational controls such as limits on idling time.

## Application Process

To comply with the proposed regulation under the ACP, a vessel owner or operator must submit an application to ARB. The application must demonstrate that the alternative emission control strategy employed will achieve equivalent or greater emission reductions in PM, NO<sub>x</sub>, and SO<sub>x</sub> from auxiliary engines, relative to the emission reductions that would have occurred by using the distillate fuel compliance option. The proposed regulation specifies basic information that must be included in the application, such as emissions test data, and other information that demonstrates the emissions level to be achieved with the proposed alternative emission control strategy. ARB staff will develop a guidance document to assist applicants in making a demonstration of equivalent emission reductions.

The scope of the ACP is limited to auxiliary engines. In other words, emission reductions from main engines or other sources may not be included in the ACP. In addition, compliance with the ACP can be demonstrated on an individual vessel basis, or across a fleet of vessels with the same owner or lessor.

After an application for an ACP is submitted, ARB has 90 days to accept or deny the application. If ARB staff finds that additional information is necessary, the applicant will be provided an opportunity to submit the necessary information. It should be noted that submittal of an ACP application does not mean that the applicant is complying with the regulation. The applicant must comply with the fuel requirements and other provisions of the regulation until an ACP application is granted. For this reason, applicants may want to submit applications at least 90 days prior to the implementation date of the fuel requirement on January 1, 2007.

ARB may revoke or modify an ACP if it believes that an ACP has been granted to an owner or operator that is not complying with the provision or no longer meets the criteria of an ACP. In addition, ACP applications may be inadequate if the 0.1 percent sulfur MGO requirement effective on January 1, 2010, is implemented. As such, applicants may want to consider pursuing alternative emission control strategies that will also comply with this more stringent emission level.

## Additional provision for applicants using shore-side power

There is an additional provision in the ACP that applies to vessels that connect to shore-side power, subject to certain conditions. Specifically, the vessel must connect to power supplied by a utility company (or another source with equivalent or lower emissions per unit of delivered energy) and shut down all auxiliary engines subject to the proposed regulation. The vessel must also connect to shore power within one hour after the vessel is secured at the port terminal, and continuously use this power until no more than one hour prior to when the vessel leaves the terminal.



If these conditions are met, the vessel would not be subject to the fuel-based emission limitation during travel from a previous port to a California port where shore-side power is to be used, while docked prior to utilizing shore-side power, and during travel to a subsequent port. For example, a vessel operator could run their auxiliary engines on heavy fuel oil while traveling to a California port where shore-side power is to be used. After docking at this port, the vessel would have one hour to shut off all its auxiliary engines and begin using shore-side electrical power. When preparing to depart, the vessel could disconnect from shore-side power and run their auxiliary engines on heavy fuel oil for up to one hour prior to departing. While departing port, the vessel operator could continue to run the auxiliary engines on heavy fuel oil.

If two California ports are visited in succession, and a vessel utilizes shore-side power only at the second port, the vessel would be considered to meet the emission reduction requirements of the ACP: (1) while traveling from the first port to the second port; (2) while dockside at the second port; and (3) while departing the second port. While traveling to the first port, and during mooring at the first port, the vessel must comply with the requirements of the regulation through the use of distillate fuels or other emission control strategies (See Figure V-1). For example, while traveling to the first port, a vessel operator may switch from heavy fuel oil to distillate fuels in the auxiliary engines prior to entering the 24 nautical mile boundary off California's coastline. The distillate fuel would continue to be used while at dockside. However, as soon as the vessel operator left the first port, the operator could switch to heavy fuel oil, which could be used thereafter except when the auxiliary engines are shut down while the vessel is connected to shore-side power at the second port.

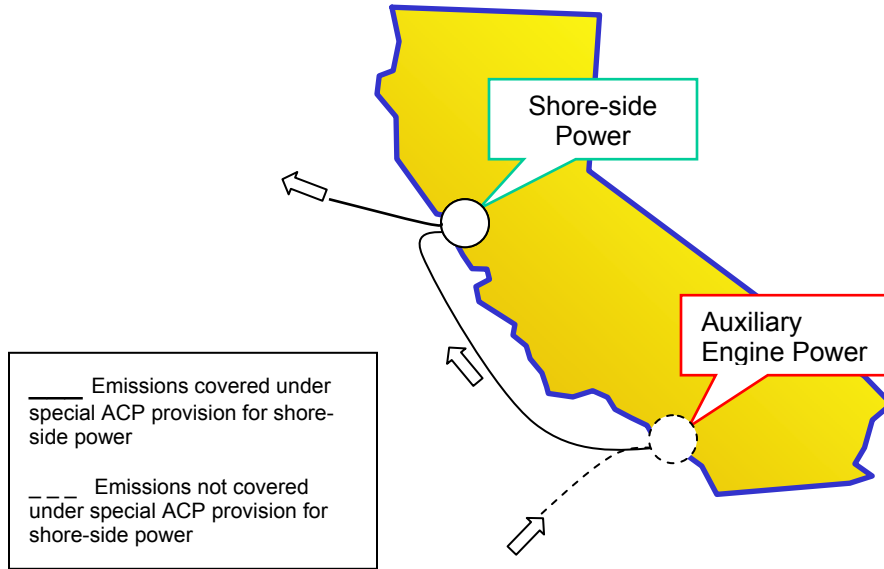
If two California ports are visited in succession and a vessel utilizes shore-side power at the first port visited, the vessel would meet the requirements of the ACP during travel to this first port, during the time the vessel is dockside at the first port, and while traveling from the first to second port. While dockside at the second port, and during the departure from the second port, the vessel must comply with the requirements of the regulation through the use of distillate fuels or other emission control strategies (See Figure V-2 below). For example, while traveling to the first port, a vessel operator may use heavy fuel oil. The heavy fuel oil could continue to be used while at dockside for up to one hour, after which the auxiliary engines must be shut off while shore-side power is connected. While preparing to depart, the vessel could disconnect from shore-side power and begin operating the auxiliary engines on heavy fuel oil. Heavy fuel could also be used in transit to the second port. However, at some point prior to docking at the second port, the vessel operator would need to switch to distillate fuel or implement an alternative emission control strategy, which would be used at dockside and while the vessel departs the second port.

The additional provisions for applicants using shore-side power are included in the proposed regulation to encourage the use of shore-side power in recognition of its ability to greatly reduce diesel PM emissions released close to portside communities. In addition, the use of shore-side power results in significant reductions in carbon dioxide (a global warming gas).

Applicants do not have to utilize this provision of the ACP in all cases when their emission control strategies utilize shore-side power. They may choose to comply with the proposal using shore-side power under the general ACP provisions. For example, if they cannot connect within one hour of mooring at the terminal, they can utilize the general provisions of the ACP. However, the special provisions for shore-side power provide some advantages. First, the application process would be simplified because less information would be needed to demonstrate compliance. In addition, there may be instances where the emissions from a vessel would be greater overall while utilizing this provision compared to compliance with the fuel requirements in the proposed regulation. However, we believe the benefits of reducing the risk resulting from near-shore PM emission reductions will generally offset any potential increases in overall emissions.

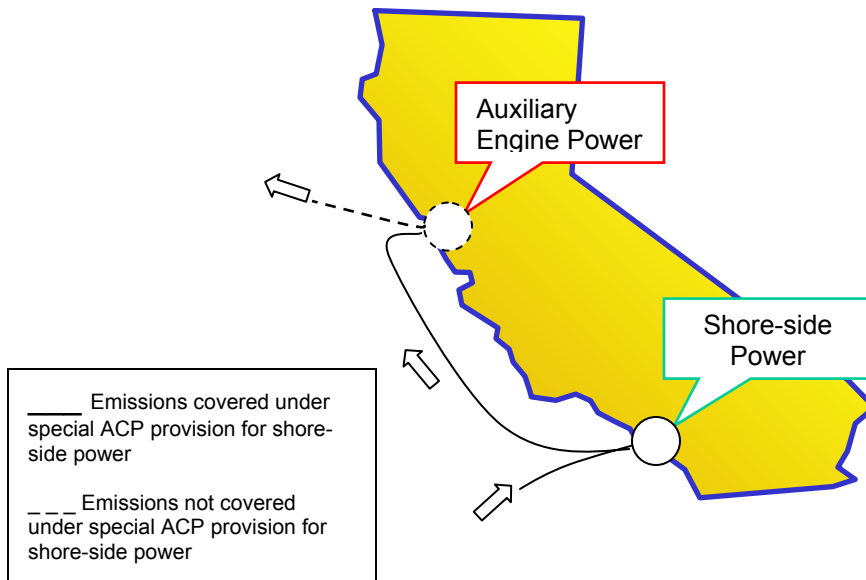
**Figure V-1**

**Vessel Uses Auxiliary Engine Power at First Port Call and Shore-side Power at Second Port Call**



**Figure V-2**

**Vessel Uses Shore-side Power at First Port Call and Auxiliary Engine Power at Second Port Call**



## **J. Test Methods**

The proposed regulation includes test methods to determine whether fuels meet the requirements of the proposed regulation. Specifically, the proposed regulation references International Standard 8217 as adopted by the International Organization for Standardization in 1996. ISO 8217 includes the properties necessary for a fuel to qualify as DMX or DMA grade fuel (marine gas oil), or DMB grade fuel (marine diesel oil), and specifies the test methods to be used to determine compliance with each of these properties. The proposal also includes the test method to be used to determine the sulfur level of these fuels.

The proposed regulation allows the use of alternative test methods demonstrated to be equally accurate, as approved by the Executive Officer of ARB. For example, ASTM equivalent methods are available for many or all of the ISO test methods specified in ISO 8217.

## **K. Sunset and Technology Review Provisions**

### Sunset Provision

If the Executive Officer of the ARB determines that the IMO or the U.S. EPA adopts regulations that will achieve equivalent or greater emission reductions from ocean-going vessels in California, compared to the emission reductions achieved by the proposed regulation, then the Executive officer will propose to the Board for its consideration terminating or modifying the requirements of the proposed regulation. This provision recognizes that it would be preferable to adopt regulations for ocean-going vessels on a national or international basis.

### Feasibility Review

This section describes the feasibility evaluation that will be conducted relative to the January 1, 2010, fuel requirement to use 0.1 percent sulfur marine gas oil. Under these provisions, an evaluation of the feasibility of this fuel requirement will be conducted by ARB staff no later than July 1, 2008. The evaluation will consider, at a minimum, the following:

- the current availability of 0.1 percent sulfur MGO at bunkering ports worldwide;
- the ability of petroleum refiners and marine fuel marketers to supply this fuel by 2010;
- technical considerations such as whether fuel at this lower sulfur level will be compatible with all marine engines; and
- the cost of this fuel.

If, based on the evaluation, modifications to the regulation are necessary, staff will propose changes to the Board prior to January 1, 2009, (a year prior to the implementation date of the 0.1 percent sulfur fuel standard).

## **L. Severability**

This provision states that if a particular section of the proposed regulation is held to be invalid, the remainder of the proposal shall continue to be effective.

## **M. Regulatory Alternatives**

The Government Code section 11346.2 requires ARB to consider and evaluate reasonable alternatives to the proposed regulation and provide the reasons for rejecting those alternatives. ARB staff evaluated five alternative strategies to the current proposal. Based on the analysis, none of the alternative control strategies were considered more effective than the proposed regulation. Full implementation of the proposed regulation is necessary to make progress toward ARB's goals of: (1) reducing diesel PM by 85 percent in 2020, as described in the Diesel Risk Reduction Plan; and (2) achieving State and federal air quality standards for PM and ozone. The proposed regulation provides vessel operators with the flexibility to pursue alternative emission control strategies if they choose not comply with the fuel requirements in the proposal.

This section discusses each of the five alternatives and provides reasons for rejecting those alternatives.

### Alternative 1: Do Nothing

As discussed in Chapter VII, the proposed regulation will result in significant reductions in diesel PM, NO<sub>x</sub>, and SO<sub>x</sub> emissions. The diesel PM reductions are an important element of the Diesel Risk Reduction Plan, and along with other regulations to be adopted by ARB, will contribute to reducing cancer and noncancer health risks to the public associated with inhalation exposure to emissions of diesel PM.

The emission reductions from the proposal are also necessary to make progress toward compliance with State and federal air quality standards for ozone and PM in nonattainment areas throughout the State. As discussed in Chapter IV, NO<sub>x</sub> and SO<sub>x</sub> emissions form "secondary" nitrate and sulfate PM, respectively, in the atmosphere, while NO<sub>x</sub> emissions contribute to the formation of ozone.

In addition, ARB is required by H&SC Section 39658 to establish regulations for toxic air contaminants (TACs) such as diesel PM. Further, H&SC Sections 39666 and 39667 require the ARB to adopt measures to reduce emissions of TACs from nonvehicular and vehicular sources. In consideration of ARB's statutory requirements and the recognized potential for adverse health impacts to the public resulting from exposure to diesel PM and ozone, this alternative is not a reasonable option.

## Alternative 2: Rely on U.S. Environmental Protection Agency (EPA) and International Maritime Organization (IMO) Regulations

As discussed in subsection K above, the proposed regulation includes a “sunset” provision which requires the Executive Officer of ARB to consider terminating the requirements of the proposed regulation if it is determined that the U.S. EPA or IMO adopts regulations that will achieve equivalent or greater emission reductions from vessel auxiliary engines compared to the emission reductions achieved by the proposed regulation. This provision recognizes that it would be preferable to adopt regulations for ocean-going vessels on a national or international basis. However, existing IMO and U.S. EPA regulations will not achieve the needed emission reductions from the proposal in the near term (prior to 2010), and it appears unlikely that the U.S. EPA or IMO will adopt equally effective regulations in the next foreseeable future. The following is a brief summary of the status of IMO and U.S. EPA activities supporting our position that we cannot wait for IMO or U.S. EPA to act.

### IMO Annex VI NOx Standards

These standards apply to marine diesel engines greater than 130 kilowatts, which would include the auxiliary engines covered by the ARB staff proposal. However, these standards only apply to NOx emissions, and therefore would not achieve the significant PM benefits of the proposed regulation.

### U.S. EPA 1999 Category 1&2 Engine Rule

The standards in this rule apply to new “category 1 & 2” engines (engines with a displacement less than 30 liters per cylinder), which would apply to most auxiliary engines covered by the ARB staff proposal (except the engines on diesel-electric vessels such as cruise vessels). This rule specifies standards for NOx plus hydrocarbons, PM, and carbon monoxide. However, this rule only applies to new engines in U.S.-flagged vessels, which make up a very small proportion (less than 10 percent) of the vessels that visit California ports. In addition, there is a foreign-trade exemption for U.S.-flagged vessels.

### U.S. EPA 2003 Category 3 Engine Rule

The U.S. EPA recently adopted standards for new “category 3” engines (the large engines used for propulsion of ocean-going vessels). These NOx standards would apply to the large generator set engines used on diesel-electric vessels such as cruise vessels. However, the standards are identical to the IMO NOx standards and would only achieve modest NOx emission reductions and no diesel PM reductions. In addition, they only apply to new engines on U.S.-flagged vessels, which represent a very small proportion of the vessels visiting California ports. In this rulemaking, U.S. EPA also addresses “category 1” and “category 2” engines, with a displacement at or above 2.5 liters per cylinders but less than 30 liters per cylinder (typical of auxiliary engines used on ocean-going vessels). On U.S.-flagged vessels, these engines would

be required to meet NOx standards equivalent to the IMO standards. In addition, beginning in 2007, these engines would be subject to the U.S. EPA's standards for category 1 and 2 engines adopted in 1999. In this rulemaking, U.S. EPA also eliminated the foreign trade exemption included in U.S. EPA's 1999 rule. However, all these requirements would only apply to U.S. flagged vessels, which represent a small proportion of the vessels that visit California ports.

#### EPA Nonroad Diesel Rule

Among other requirements, this rule would limit the sulfur content of diesel fuels for non-road applications. For marine use, the rule would limit the sulfur content in diesel fuel to 0.05 percent (500 ppm) in 2007, and 0.0015 percent (15 ppm) in 2012 (EPA, 2004). However, this rule does not apply to marine diesel oil or heavy fuel oil. Since most ocean-going vessel auxiliary engines use heavy fuel oil, this would have little impact in reducing emissions from this source.

#### Potential Tier II EPA Category 3 New Engine Standards

The U.S. EPA reportedly intends to adopt more stringent technology-forcing Tier 2 standards for category 3 engines in April, 2007. (EPA, 2003). However, these standards may again only apply to U.S.-flagged vessels, and may not address PM emissions. In addition, we estimate that such standards would become effective for new engines in the 2010 timeframe and the emission reductions achieved by such a measure would phase in gradually as new vessels enter into service. As such, the measure would not be expected to achieve significant reductions until well after 2010.

#### Sulfur Emission Control Area (SECA)

The U.S. EPA, in association with ARB and other air quality agencies, is currently investigating the creation of SECA's under a process provided by the IMO. Specifically, the IMO's Annex VI ("Regulations for the Prevention of Air Pollution from Ships") of the MARPOL Convention provides a mechanism to require the use of marine fuel with a sulfur content limit of 1.5 percent in designated areas. The formation of a SECA may provide significant and necessary PM and SOx emission reductions to California if a West Coast SECA is established. However, the benefits of such a program would not be comparable to the ARB staff proposal. The percent PM and SOx emission reductions achieved from the use of 1.5 percent sulfur heavy fuel oil are far less than the reductions that would be achieved by the use of the distillate fuels specified in the proposed regulation. Specifically, the U.S. EPA estimates an 18 percent PM reduction and a 44 percent SOx reduction from the use of 1.5 percent heavy fuel oil (EPA, 2002). We estimate the use of the distillate fuel will result in a 75 percent PM reduction, an 80 percent SOx reduction, and a 6 percent NOx reduction. It should be noted that the use of 1.5 percent heavy fuel oil may result in larger emission reductions overall because it would apply to the main and auxiliary engines of vessels, whereas the ARB staff proposal would only apply to auxiliary engines. However, the ARB staff proposal would achieve far greater emission reductions at dockside where diesel PM reductions are

most critical. In addition, ARB staff plans to develop strategies to reduce the emissions from main engines on marine vessels in the next year or two.

A comparison between the ARB staff proposal and the potential regulations discussed in Alternative 2 are summarized in Table V-2. As shown, none of the potential regulations are expected to achieve the same benefits as the measure proposed by ARB staff.

**Table V-2: Comparison between Potential IMO/U.S. EPA Proposals and the ARB Staff Proposal**

<b>Regulation</b>	<b>Comparison to the ARB Staff Proposal</b>
IMO Annex VI NOx Standards	<ul style="list-style-type: none"> <li>▪Standards do not reduce PM</li> </ul>
U.S. EPA 1999 Category 1&2 Engine Rule	<ul style="list-style-type: none"> <li>▪ Standards only apply to U.S. flagged vessels</li> <li>▪ Benefits phase in slowly starting in 2007 for most engines</li> <li>▪ Foreign-trade exemption for U.S. flagged vessels</li> </ul>
U.S. EPA 2003 Category 3 Engine Rule	<ul style="list-style-type: none"> <li>▪ Standards only apply to U.S. flagged vessels</li> <li>▪ Standards same as IMO and do not reduce PM for category 3 engines</li> <li>▪ Rulemaking eliminates foreign trade exemption for certain category 1 &amp; 2 engines on U.S.-flagged vessels</li> </ul>
U.S. EPA Nonroad Diesel Rule	<ul style="list-style-type: none"> <li>▪ Specifies sulfur limits for diesel fuel used in marine applications, but exempts marine diesel oil &amp; heavy fuel oil</li> </ul>
Potential Tier II EPA Category 3 New Engine Standards (2007 adoption expected)	<ul style="list-style-type: none"> <li>▪ Standards may only apply to U.S.-flagged vessels</li> <li>▪ Standards may not reduce PM</li> <li>▪ Standards not expected to be effective until circa 2010</li> <li>▪ Benefits phase in slowly beginning in 2010 with vessel turnover</li> </ul>
Potential IMO SECA off California Coast	<ul style="list-style-type: none"> <li>▪ Significantly less reductions in diesel PM and SOx at dockside</li> <li>▪ Standards expected to be effective later than the ARB staff proposal if implemented</li> <li>▪No NOx benefit</li> </ul>

**Alternative 3: Use Marine Distillate Fuels Only at Dockside**

Under this alternative, ocean-going vessels visiting California ports would only be required to use marine distillate fuels at dockside. The emission reductions under this proposed alternative would be reduced by a minimum of 40 percent compared to the proposed regulation because the emissions from auxiliary engines on vessels at sea within the 24 nm boundary during transit would no longer be controlled. Fewer health benefits would result from this approach, and the loss in emission reductions would be greater if auxiliary engines are allowed to transition from one fuel to another at dockside, since such transitions can take an hour or more.

The recurring fuel costs associated with the proposed regulation would be lower under this alternative. There could also be a reduction in the cost impacts associated with modifying vessels to use distillate fuel, particularly with the diesel-electric vessels. For



example, we anticipate that some vessels may not need an additional tank for storing distillate fuel if the fuel will only be used at dockside. However, given the variability involved, we cannot quantify the reduction in retrofit costs under this alternative. Nevertheless, looking at the overall industry costs, the retrofit costs are relatively small compared to the recurring added fuel costs. Therefore, the overall cost-effectiveness, in terms of dollars per pound of emissions reduced, of the alternative is expected to be similar to the proposed regulation. In summary, this alternative has similar cost-effectiveness to the ARB staff proposal, due to both reduced cost and reduced emission reductions. However, given the feasibility, cost-effectiveness, and health benefits of requiring reductions both at dockside and within the specified 24 nautical mile zone, Alternative 3 was judged inferior to the proposed regulation.

#### Alternative 4: Special Provisions for Diesel-Electric Vessels

Under this alternative, diesel electric-vessels would have three compliance options: (1) use distillate fuels only at dockside as in Alternative 3 above; (2) use 1.5 percent sulfur heavy fuel oil within the 24 nm boundary and at dockside; or (3) retrofit vessels to use shoreside electrical power and connect at California terminals where the facilities are available.

Under the first option, the same situation applies as in Alternative 3, except that the option only applies to diesel electric-vessels (primarily cruise vessels). This option would achieve significantly less emission reductions and the cost would be reduced proportionately. The cost-effectiveness is expected to be similar to the staff's proposal.

For the option to use 1.5 percent sulfur heavy fuel oil, the estimated PM emission reductions are expected to be significantly less (about 18 percent versus 75 percent for staff's proposal relative to an engine burning standard high sulfur heavy fuel oil). SO<sub>x</sub> emissions would be reduced by about 44 percent versus 80 percent for staff's proposal, and there would be no NO<sub>x</sub> reductions. On the other hand, the cost of the 1.5 percent sulfur heavy fuel is currently much less than marine gas oil. As a result, the cost of this option would be considerably less than the cost associated with staff's proposal. Overall, we expect that the PM cost effectiveness of this option would be in the same range as the proposed regulation.

The third option, utilizing cold ironing where available is difficult to analyze because vessels retrofitted for cold ironing would only plug into shoreside power if it is available. To date, only a few California port terminals have shoreside power facilities installed. Additional facilities are anticipated at the Ports of Los Angeles, Long Beach and Oakland. However, it will be several years before new additional shoreside power facilities are operational. As a result, we cannot quantify the emissions reductions for this option at this time.

Overall, the emission reductions from any of these options under this alternative would be significantly less than the ARB staff proposal, although the cost-effectiveness would be similar. As with Alternative 3, we judged this option to be inferior.

## Alternative 5: Exemption of Power used for Propulsion in Diesel-Electric Vessels

Diesel-electric vessels have large diesel engines coupled to generators that supply electrical power for both propulsion and shipboard electrical uses. Under this alternative, only the power generated for shipboard electrical uses would be subject to the proposed regulation. The power generated for propulsion would not be subject to regulation.

Industry sources have suggested this alternative because the engines used for propulsion in other vessel types are not controlled under the staff proposal. Specifically, most other (non-diesel-electric) vessels have separate main engines mechanically connected to a propeller used for propulsion, and auxiliary engines used for shipboard power. The main engines would not be subject to control, while the auxiliary engines would be covered. For diesel-electric vessels, which have generator set engines that supply electrical power for both propulsion and shipboard electricity, all of the power and emissions generated by these engines would be subject to control. As such, the costs are higher for operators of these vessels.

However, we feel it is appropriate to control all of the emissions from the engines on diesel-electric vessels, whether generated for shipboard electrical power or propulsion, because it is technically feasible and cost-effective to do so. The engines used in diesel-electric vessels are very similar to the auxiliary engines used in other vessels, except that they are larger. Specifically, they are four-stroke, medium speed engines used in generator set applications. The main engines in other vessels are generally two-stroke slow-speed engines. These engines have a significantly different design that is less amenable to the use of distillate fuels.

Alternative 5 would achieve less emission reductions than the staff proposal because the amount of power (and thus emissions) generated by diesel-electric vessels for propulsion is significant, and would not be controlled under this alternative. The cost to ship operators would also be reduced proportionally because they would not need to use the more expensive distillate fuels (or other emission control strategies) for the power generated for propulsion. However, the overall, the cost-effectiveness is expected to be similar to the staff's proposal.

Another consideration is the difficulty in separating out the power generated for propulsion and shipboard electricity. For example, a typical diesel-electric cruise ship will have varying shipboard electrical power needs based on factors such as the effect of temperature on space heating or cooling for passenger cabins. Propulsion power needs will also vary based on the speed of the vessel and ocean currents. Even if the power used only for shipboard electrical uses could be clearly distinguished, it may be difficult for ship operators to limit the emissions only from the amount of power for shipboard use separately from the power used for propulsion. Extensive recordkeeping would be necessary to ensure compliance under this alternative.

In summary, this alternative has similar cost-effectiveness to the ARB staff proposal, due to both reduced cost and reduced emission reductions. This alternative would also require burdensome recordkeeping. Given the cost-effectiveness, technical feasibility, and health benefits of controlling emissions from all power generated by these engines, Alternative 5 was judged inferior to the proposed regulation.

## REFERENCES

(EPA, 2002) United States Environmental Protection Agency, *Control of Emissions of Air Pollution from New Marine Compression-Ignition Engines at or Above 30 Liters/Cylinder*, Notice of Proposed Rulemaking, April 30, 2002, Table VI.F-1.

(EPA, 2003) United States Environmental Protection Agency Regulatory Announcement, *Emission Standards Adopted for New Marine Diesel Engines*, EPA420-F-03-001, January 2003.

(EPA, 2004) United States Environmental Protection Agency Fact Sheet, *Clean Air Nonroad Diesel Rule*, EPA420-F-04-032, May 2004.

## **VI. TECHNOLOGICAL FEASIBILITY OF THE PROPOSED REGULATION**

In this chapter, we discuss the technological feasibility of the proposed regulation. In particular, we focus on the availability of the fuel that we expect most vessel operators will use to comply with the emission limits, and the ability of ocean-going vessels to use that fuel. In addition, we discuss possible alternative emission reduction strategies that vessel operators may use.

It should be noted at the outset that the proposed regulation does not require the use of any specific fuels. Rather, the proposed regulation requires vessel operators in regulated California waters to limit the emissions from their auxiliary engines to the levels of specified pollutants (diesel PM, NO<sub>x</sub>, SO<sub>x</sub>) equivalent to or lower than the levels that would have resulted had those engines used (1) marine gas oil (MGO), or (2) marine diesel oil (MDO) with a sulfur content of 0.5 percent or less. In 2010, the proposed regulation further reduces these limits to the level of emissions from an engine operating on MGO with 0.1 percent sulfur to maximize the regulation's emissions benefits.

Vessel operators can meet these limits in one of several ways. First, they can use MGO, or MDO with 0.5 percent sulfur or less, starting January 1, 2007. For the second tier (2010) limits, they can use MGO with 0.1 percent sulfur or less. As we stated above, vessel operators are not required to use these fuels, but there is an automatic presumption created that the operator has met the emission limits if he uses these fuels in the regulated engines.

Another way vessel operators can meet the emission limits is through the use of an approved Alternative Compliance Plan (ACP). The ACP provides a high degree of flexibility by allowing vessel operators to implement alternative emission control strategies, provided such measures achieve equivalent or greater reductions relative to the emission reductions that would have occurred by using the marine distillate fuels described above. Thus, if a vessel operator determines that there are overriding concerns justifying the use of other emission control strategies (e.g., safety during fuel switching, costs), the operator can seek, prior to entering California waters, ARB approval of an ACP, under which the operator would achieve equivalent or greater reductions using measures that the operator chooses. In this way, the vessel operator maintains full control in determining which emission reduction strategy is best suited for each particular vessel, with due consideration for safety, costs, and other factors important to the operator.

### **A. Availability of Marine Distillate Fuels**

The term "marine distillate" refers to specific grades of marine distillate fuels. The proposed regulation allows the use of MGO that meets the specifications for DMX or DMA<sup>4</sup> grades as defined in Table I of the International Standard ISO 8217 (as revised in 1996). The proposed regulation also allows the use of MDO (limited to 0.5 percent

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<sup>4</sup> "D" means distillate, "M" means marine, and "A" is the grade of the fuel.

sulfur), which is fuel that meets all the specifications for DMB grades as defined in Table I of the International Standard ISO 8217 (as revised in 1996). DMA is the most prominent marine distillate, and is available in the largest quantities. DMX, which is similar in specification to CARB diesel, is used in smaller amounts and is required for use in emergency back-up engines on vessels. DMB is basically DMA containing a limited amount of residual fuel (heavy fuel oil), typically due to storage or transfer of DMA in tanks or piping that previously held residual fuel.

In this section, we present information on the international fuel specifications for marine distillates, data on the current fuel sulfur levels found in fuels supplied to ocean-going vessels, and information on where vessels that come to California ports normally fuel. In addition, we discuss our findings with respect to the volume of fuels needed to comply with the proposed regulation and the impact the proposed regulation could have on the availability of marine distillate fuel worldwide. We also provide our preliminary findings on the availability of lower 0.1% sulfur distillate fuels we expect most vessels will use to comply with the proposed 2010 emissions limits.

### Fuel Sulfur Specifications for Marine Distillates

The majority of marine distillates produced and sold worldwide conform to fuel quality standards categorized under ISO 8217. These standards place limits on the fuels' chemical and physical properties, including sulfur content. Table VI-1, Fuel Specifications, lists the sulfur content and flashpoint of land and marine based fuels that can be used to fuel compression-ignition ("diesel") engines. The sulfur content of a fuel is important because the lower the sulfur content of the fuel, the lower the PM and SO<sub>x</sub> emissions. Flashpoint is important for safety reasons; the minimum flashpoint for marine fuels is 60 degrees Celsius. (ISO 8217, 1996).

In general, land-based fuels are required to meet more stringent State and federal sulfur specifications than marine distillates. As shown in Table VI-1, the lowest sulfur content specifications are for land-based distillates – with the exception of U.S. EPA off-road diesel. However, this exception will not be long-lived since the U.S. EPA off-road diesel specifications will in 2010 be harmonized with the on-road diesel specifications effective in 2007. The marine fuels also differ from land-based distillates in the minimum flashpoint specification. The lowest sulfur content specifications for fuels that meet the flashpoint specification for marine applications are found in the specifications for marine distillates. In contrast the highest sulfur content specifications are found in residual marine fuels (heavy fuel oil).

**Table VI-1: Fuel Specifications**

<b>Primary Use</b>	<b>Fuel Type</b>	<b>Fuel Grades</b>	<b>Fuel Specifications</b>	<b>Maximum Sulfur (%)</b>	<b>Maximum Sulfur (ppm)</b>	<b>Minimum Flashpoint (Centigrade)</b>
<b>Land</b>	<b>Distillate</b>	CARB Diesel (2006) Ultra Low Sulfur Diesel (ULSD)	No. 2-D	0.0015	15	52
<b>Land</b>	<b>Distillate</b>	CARB Diesel (current)	No. 2-D	0.05	500	52
<b>Land</b>	<b>Distillate</b>	U.S. EPA Diesel	No. 2-D	0.05	500	52
<b>Land</b>	<b>Distillate</b>	Off-Road U.S. EPA Diesel	No. 2-D	0.5	5,000	52
<b>Marine</b>	<b>Distillate</b>	Marine Gas Oil (MGO)	DMA	1.5	1,500	60
<b>Marine</b>	<b>Distillate</b>	Marine Diesel Oil (MDO)	DMB	2.0	2,000	60
<b>Marine</b>	<b>Residual</b>	Intermediate Fuel Oil (IFO) 180	RME/F-25	5.0 <sup>1</sup>	50,000	60
<b>Marine</b>	<b>Residual</b>	Intermediate Fuel Oil (IFO) 380	RMG/H-35	5.0 <sup>1</sup>	50,000	60
<b>Marine</b>	<b>Residual</b>	Bunker fuel	RML-55	5.0 <sup>1</sup>	50,000	60

1. The International Maritime Organization (IMO) MARPOL 73/78 Annex VI, Regulations for the Prevention of Air Pollution from Ships, entered into force in May 2005, lowers the sulfur cap on residual fuel from 5.0% to 4.5% in 2007.

Fuel Sulfur Properties of Currently Available Marine Distillates

The fuel specifications discussed above essentially establish limits that cannot be exceeded for sulfur content and flashpoint. As shown, marine distillates meet the most stringent sulfur specification for marine fuels. In order to assess the impact on emissions from the use of marine distillates, staff evaluated the actual fuel sulfur properties of marine distillate fuel currently available. The two sources of fuel property information staff reviewed were the ARB Oceangoing Ship Survey and the Det Norske Veritas Petroleum Services fuel sample data. (DNV, 2005). The results are summarized in Table VI-2 and discussed below.

**Table VI-2: Current Sulfur Properties of Marine Fuel**

Fuel Specification	Average Fuel Sulfur Content (wt. %)	
	ARB Survey (CA Vessels)	DNV (Worldwide)
<b>DMA</b>	0.5%	0.38%
<b>DMB</b>	(survey asked for marine distillate sulfur content)	0.65%
<b>Residual</b>	2.5%	-

The ARB Oceangoing Ship Survey (ARB Survey) was sent out in January 2005 to 158 vessel operators and agents. The survey requested information about ocean-going vessels that visited California ports in 2004. To date, we have received information on 327 vessels that visit California ports. This represents about 17 percent of the total number of vessels that visited California in 2004 (ARB Survey, 2004).

From the survey responses, staff estimates that the average sulfur content of marine distillate fuels used in auxiliary engines is about 0.5 percent. (Note: Separate sulfur content estimates for DMA and DMB were not requested in the survey). The average sulfur content of residual fuel was reported to be about 2.5 percent. Both are well below the maximum specifications listed in Table VI-1, which are 1.5 to 2.0 percent for marine distillates and 5.0 percent for residual fuel.

DNV performs a service to the marine industry by sampling and testing marine fuels from many suppliers in ports throughout the world and claims to be responsible for testing 70 percent of the marine fuel tested worldwide. DNV collected samples of marine distillates from ocean-going vessels in 2003. (DNV, 2003) The average sulfur content of samples of DMA taken worldwide was 0.38 percent sulfur by weight – well below the 1.5 percent standard. For DMB, the average sulfur content from the samples was 0.65 percent sulfur by weight – well below the 2.0 percent standard. Among the different areas of the world, averages are calculated from the samples taken at each port. The minimum and maximum average sulfur content samples of DMA taken from any one area of the world were 0.05 percent (Mexico) to 0.97 percent sulfur (Saudi Arabia). The minimum and maximum average sulfur content samples of DMB taken from any one location in the world were 0.05 percent (Mexico) to 1.30 percent sulfur (Germany).

Table VI-3 lists the average marine distillate sulfur contents for those areas of the world where ocean-going vessels that operate in the Pacific Rim have historically refueled. As shown in Table 3, the sulfur content of marine distillates varies widely. Figure VI-1



shows the historical average sulfur content of all samples taken in these areas of the world over the last ten years. As shown, the average sulfur content has ranged from a high of about 0.50 percent to a low of about 0.35 percent. Although historical trends are no guarantee of future sulfur levels, staff believes current and future regulatory efforts to lower sulfur levels in all types diesel fuels will result in the average sulfur levels continuing to decline over the coming years; specifically, regulatory efforts to reduce emissions from diesel engines in California, the United States, Japan, and Europe.

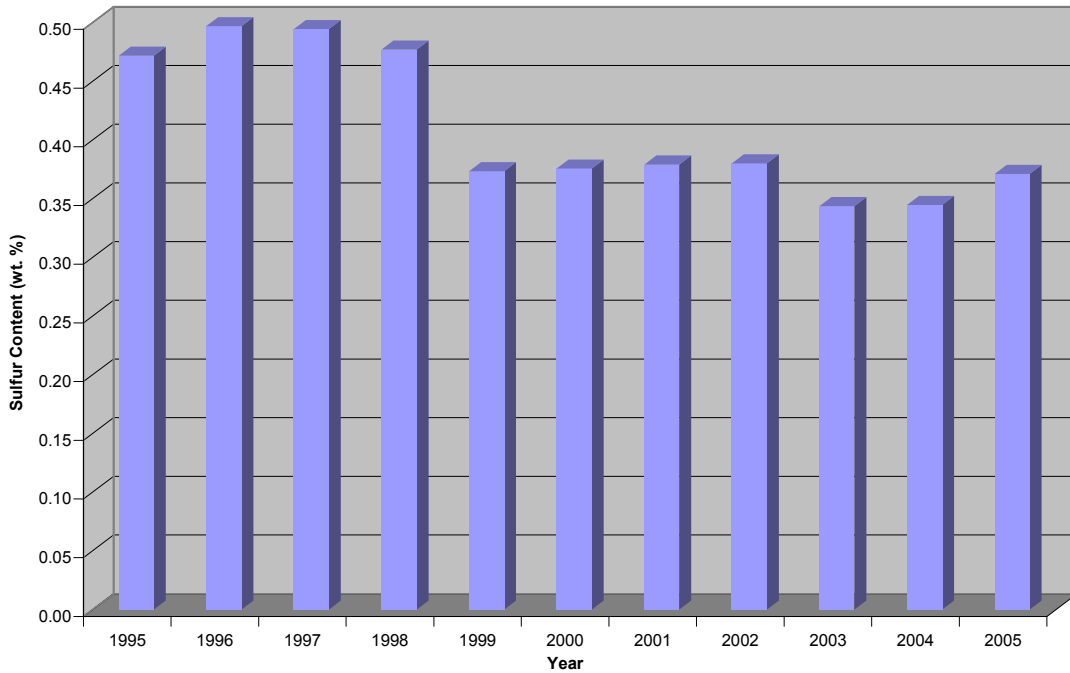
**Table VI-3: Marine Distillate Average Sulfur Content (weight % Sulfur)**

Area of World	<b>MGO</b>	<b>MDO</b>
	<b>DMA</b>	<b>DMB</b>
Netherlands	0.30	1.02
Malaysia	0.40	0.36
Mexico	0.05	0.05
Panama	0.42	0.42
Canada	0.21	0.24
Singapore	0.53	0.53
Japan	0.12	0.77
Hong Kong	0.39	0.42
Korea	0.81	0.87
China	0.29	0.32
United States	0.23	0.68
<b>Average</b>	<b>0.34</b>	<b>0.52</b>

(Source: DNVPS, 2003)

**Figure VI-1: Sulfur Content of MGO at Pacific Rim Refueling Ports from 1995 to 2005**

**Average Sulfur Content of MGO at Major Ports**



(Source: DNV, 2005)

**Availability of Marine Distillate Fuel**

Marine distillate fuel is currently available in most areas throughout the world. (Beicip-Franlab, 2003). Vessels typically obtain marine distillate via fuel barges, where the fuel is loaded on the barge either directly from a refinery terminal or from a storage tank at that is dedicated to marine distillate fuels. Based on discussions with vessel operators, a key factor in determining where to refuel is finding a fueling location within a vessel’s current route, where it is available at the lowest cost.

Table VI- 4 provides a listing of ports where ocean-going vessels that operate in California waters have historically refueled either before or after operating in California waters.

**Table VI-4: Common Refueling Ports for Vessels that Visit California**

<b>Vessels that Visit California Ports May Refuel at the Following U.S. or International Ports</b>	
<b>U.S. Port Locations</b>	<b>International Locations</b>

Los Angeles (POLB, POLA) Santa Barbara (Hueneme) Puget Sound Oakland San Diego San Francisco Savannah Honolulu Norfolk New York/New Jersey Charleston	Netherlands (Rotterdam) Singapore Japan (Shimzu, Tokyo, Osaka, Nagoya, Moji, Hakata, Yokohama, Kobe) China (Hong Kong, Ningbo, Chiwan, Quigdao, Xiamen) South Korea (Busan, Kwangyand) Mexico (Lazaro Cardenas) Malaysia Panama (Balboa, Manzanillo) Canada (Vancouver, B.C.)
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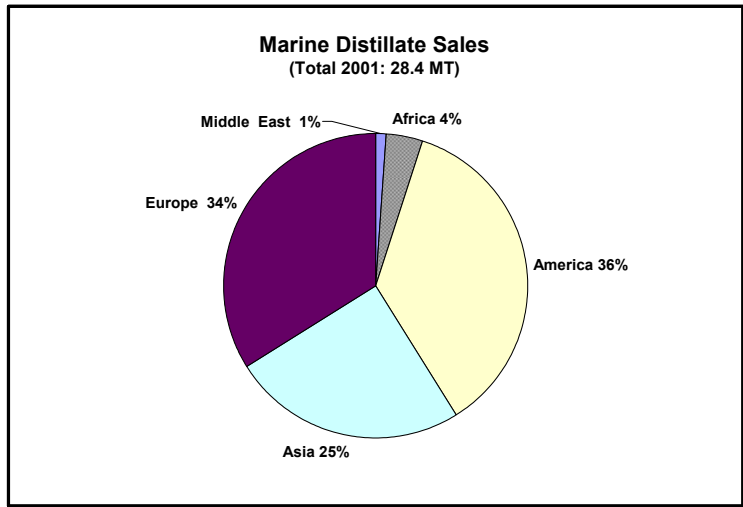
(ARB Bunker Survey, 2005; Correspondence, 2005; Starcrest Report, 2005)

### Impact on Volume of Marine Distillate Required by Proposed Regulation

Currently, ocean-going vessels use either heavy fuel oils or marine distillates in their auxiliary engines. Based on the ARB Survey responses, about 75 percent of the oceangoing vessels use heavy fuel oil in their auxiliary engines and 25 percent use marine distillate. As stated earlier, we expect most vessel operators will use marine distillates while within 24 nm of the California coastline to comply with the proposed regulation's emission limits.

Assuming all vessels elected to comply with the proposed regulation by using marine distillate, staff estimates that approximately 46 million gallons (150,000 metric tons) of low-sulfur marine distillate would be needed in 2007 and 61 million gallons (200,000 metric tons) would be needed in 2010. This equates to less than 1 percent of the current total sales, 28.4 million metric tones (MT), for marine distillate worldwide. The distribution of marine distillate sales throughout the world is shown in figure VI-2. Marine distillate sales are highest in areas where Pacific Rim vessels have historically refueled -- Asia, Europe, and America. (Beicip-Franlab, 2003; Marine Distillate Volume Calculation, 2005).

**Figure VI-2: Worldwide Marine Distillate Sales**



Based on the reasons discussed above, staff believes that the relatively small additional demand for marine distillate likely to be created by this rule will be met by existing refineries without significant modifications to existing infrastructure. However, operators who choose to replace all residual fuel used in their auxiliary engines with marine distillate may experience some scheduling conflicts and logistics issues when loading large amounts from local suppliers (e.g. 1,400 MT or more). We cannot predict the extent to which these delays may occur, if at all, but the primary limiting factor in these situations is the capacity of barges dedicated to carrying marine distillate fuels. (Barge Capacity, 2005)

Some commenters have suggested during the informal phase of this rulemaking that the proposal’s emission limits based on the use of MGO be based instead on MGO that is capped at 0.5 percent sulfur. We do not agree with this suggestion. At this time, we believe that establishing an emissions limit based on a 0.5 percent sulfur cap for MGO is likely to result in a supply issue at some port locations. This would be especially true for ports in areas of the world that import marine distillate from refineries that use crude oil with a high sulfur content.

For example, South Korea imports all of their crude oil, and most of it comes from the Persian Gulf region. Persian Gulf crude oil is typically “sour” crude, meaning that it has a relatively high sulfur content that typically ranges from 0.8 to 2.3 percent. This high sulfur content is reflected in the DMA sample data summarized in Table VI-3, which lists Korea as having the highest average sulfur content of those countries listed at 0.81 percent. (Starcrest, 2005; Blumberg, 2003).

Availability of Low-Sulfur Marine Distillate Fuel

As noted previously, the proposed regulation limits emissions, starting in 2010, to levels based on the use of 0.1 percent sulfur marine distillate. It is important to note that this requirement is consistent with the recently adopted European Union Directive 2005/33/EC, which establishes a 0.1 percent sulfur standard for marine fuels used by

seagoing vessels at berth in European Union ports starting January 1, 2010. (EU, 2005).

In an earlier version of the staff's proposal, we explored the feasibility of an emissions limit based on 0.2 percent sulfur marine distillate beginning in 2006. We evaluated the availability of low-sulfur marine distillates and determined that low-sulfur marine distillate with a sulfur content of 0.2 percent or less cannot be reliably supplied in most port locations and there are many unanswered questions regarding the ability of the worldwide fuel market to make adjustments that would enable them to reliably supply the fuel in the near-term. These findings are presented in Appendix I.

Based on the findings discussed in Appendix I, staff concluded it was not feasible to implement a requirement to use 0.1 or 0.2 percent marine distillate fuel in the near term (i.e., before 2010) without having additional information about world-wide fuel supplies and refining capacities. As such, staff revised the proposal to its current version, which retains the majority of the emissions benefits and ensures that fuel will be available to comply with the proposed regulation in the near-term.

While the proposal retains an emissions limit based on the use of 0.1 percent low-sulfur fuel in 2010, many of the same concerns associated with the availability of less than 0.2 percent sulfur by weight marine distillate also apply to 0.1 percent sulfur marine distillate. To address these concerns, the proposed regulation contains a feasibility review provision to ensure the fuel supply issues are thoroughly evaluated prior to implementation.

Under the review provision, the Executive Officer would evaluate by 2008 the feasibility of the 0.1 percent sulfur limit. This evaluation would take into consideration the availability of the low-sulfur fuel at bunkering ports worldwide; the ability of petroleum refiners and marine fuel suppliers to deliver the fuel by the January 1, 2010 implementation date; the fuel lubricity and compatibility with heavy fuel oil during fuel transitions; and the costs of the fuel compared to marine gas oil with a sulfur content of greater than 0.1 percent. If the Executive Officer determines that modifications are necessary, the Executive Officer would propose changes to the Board prior to January 1, 2009.

By harmonizing with the 2010 EU requirements for low sulfur marine distillates, the staff's proposal promotes international consistency and increases the availability of cleaner marine distillates at ports that refuel Pacific Rim vessels.

## **B. Feasibility of Using Distillate Marine Fuels in Ocean-going Vessel Auxiliary Engines**

Currently, most ocean-going vessels use either heavy fuel oils or marine distillate fuels in their auxiliary engines. According to ARB's 2005 Ship Survey ("Survey"), approximately 75 percent of the engines subject to the proposed rule currently use heavy fuel oil, while the other 25 percent use distillate fuels such as marine gas oil or marine diesel oil. For the 75 percent of the engines that currently use residual fuel, the

proposed regulation would likely result in ship operators switching to distillate fuel prior to entering within 24 nm of the California coastline, assuming the operator selected this compliance option.

Because heavy fuel oil is virtually a solid at room temperature, it is heated to reduce its viscosity to the point where it can be pumped and injected into marine engines. Once liquefied, heavy fuel oil behaves much like ordinary diesel in the engine. By contrast, marine distillate fuels are liquids at room temperature, with properties already similar to typical on-road diesel fuel.

When an engine switches from one fuel to another, a transition period is generally needed to minimize rapid temperature changes; reduce fuel gassing; and ensure smooth, steady-state operation of the engine, as discussed in more detail below. To accomplish this transition period, vessel operators typically use a mixing tank. The operator steadily increases the ratio of distillate fuel to heavy fuel oil in the mixing tank, which eventually results in only distillate fuel being fed into the engine.

Considering the available information as discussed below, we believe that vessel operators can safely make this fuel switch and continue to operate their auxiliary engines with distillate fuels while operating off California's coastline. We also note these engines are certified by the manufacturer to International Maritime Organization nitrogen oxide emission standards through engine testing while the engine is operating on a distillate fuel, since heavy fuel oil properties are too variable. (IMO Annex VI) In addition, the European Union adopted a rule that will require the use of 0.1 percent sulfur fuel at dockside in 2010, which will also require these engines to switch to distillate fuel since heavy fuel oil is not available at this low sulfur level. (EU). Finally, we note that the ACP provisions in the proposed regulation allow a vessel operator to achieve equivalent emission reductions by other means if the operator chooses not to use distillate fuel.

### Existing Practice

Marine vessels currently perform the same type of fuel switches that are likely to occur under this regulation. Vessel operators perform many of these fuel switches prior to dry-dock maintenance operations to prevent heavy fuel oil from solidifying in fuel lines and engine components after engine shut down.

More importantly, there are also some vessels that routinely switch from heavy fuel oil to distillate fuels during California port visits. Specifically, NYK Line, a major container ship operator, reported that they are using low (0.2 percent) sulfur marine diesel oil in their auxiliary engines on 9 to 12 vessels while hotelling at the Port of Los Angeles. (NYK Line, 2004; NYK Line, 2005) These vessels use auxiliary engines made by three different engine manufacturers, and NYK Line reported no operational problems with their use of low-sulfur MDO.

Another example involves four steel coil carrier vessels operated by USS-POSCO Industries. In these vessels, the operators switch from heavy fuel oil to ultra-low (less than 0.05 percent) sulfur diesel two to three hours prior to entering the Bay Area Air Quality Management District boundary on their regular routes between South Korea and Pittsburg, California. (McMahon) These fuel switches have been performed since the early 1990's to facilitate the use of on-board selective catalytic reduction emission control systems used to reduce emissions of nitrogen oxides.

Further, some passenger liners regularly switch fuels for air quality reasons. For example, Carnival Cruise Lines, a major passenger cruise line, reported that it is company policy to switch to distillate MDO fuel when their vessels are within 3 miles of the California shore. (Carnival, 2005a; Carnival 2005b) Another cruise line, Crystal Cruises, also reported that it switches to MDO near California ports to reduce smoke, and that cruise line has not had any operational problems with this practice. (Crystal Cruises, 2005) Further, Marine Transport Lines, which operates under contract with the United States Maritime Administration, also reported that it switches to distillate fuel in its vessels prior to entering the Bay Area. (MTL, 2005)

Finally, we should note that switching to distillate fuels upon entry to port was a standard practice for most diesel powered vessels in the past, when it was difficult for main engines to operate reliably on heavy fuel oil during maneuvering and low load operation. The use of less expensive heavy fuel oil in auxiliary engines, and main engines during maneuvering, is a relatively recent development made possible by improvements in fuel heating technology. (BMT, 2000)

#### Vessel Fuel Infrastructure Needs

Most vessels are equipped to run their auxiliary engines on either distillate fuel or heavy fuel oil. Less than 10 percent of the vessels that participated in the ARB Ship Survey reported the need for vessel modifications to use marine gas oil in their auxiliary engines. Specifically, 32 out of 358 vessels were reported to need modifications. These changes may or may not require that the vessel be dry-docked. Dry-dock maintenance typically occurs every five years, and many other maintenance operations are performed while the vessel is at dockside.

For vessel operators that reported the need to modify their vessels, the following types of changes were reportedly required:

- segregate an existing fuel tank for MGO;
- convert an existing heavy fuel oil tank to use MGO;
- add a fuel cooler;
- modify fuel pumps and injectors; and/or
- add a mixing tank and separate fuel treatment system.

Although most vessels have multiple fuel tanks, they may not have adequate capacity in their distillate fuel tanks to operate in the waters covered by the proposed regulation.



This is particularly true for diesel-electric vessels, and “mono-fueled” vessels (i.e., vessels that normally operate both their main and auxiliary engines on heavy fuel oil). In these cases, vessel owners may need to add a new tank, convert an existing heavy fuel oil tank to use MGO, or segregate an existing tank by installing a barrier inside the tank.

If a new or segregated tank is required, ancillary equipment such as pumps, piping, vents, filling pipes, gauges, and manhole access would be required, as well as tank testing. (Entec, 2002) In addition, fuel processing systems include settling tanks, filters, and centrifuges. While some vessel operators may be able to use their existing processing systems, other operators have reported that they will need to add to these systems, along with increased fuel capacity or other modifications.

As noted previously, mixing tanks are used to assist in a gradual transition from one fuel to another. (Wartsila, 2005a) As discussed below, sudden changes in fuel temperature or viscosity may cause damage to fuel pumps and injectors. One Survey participant reported that a mixing tank would be necessary. Fuel coolers may also assist in controlling fuel temperatures and viscosity during fuel transitions. One Survey participant reported the need for a fuel cooler.

Some Survey participants also reported the need to modify engine components such as fuel pumps, injectors, and nozzles. However, engine manufacturers have stated that, with certain caveats, the engines they designed for heavy fuel can also operate on MGO. (Wärtsilä, 2004; Caterpillar, 2005; MAN B&W, 2005; Pielstick, 2004; Yanmar, 2005)

#### Fuel Switching Procedures and Safety

As discussed above, marine engines can operate continuously during transitions between heavy fuel oil and distillate fuels. Procedures for conducting these transitions are well known since vessel operators perform these transitions prior to dry-dock maintenance. Engine manufacturers and marine equipment suppliers publish guidance for vessel operators that explain the recommended procedures. (MAN B&W, 2001; Aalborg) These procedures are designed to ensure a transition period from one fuel to another that controls temperature changes and ensures minimum fuel viscosity levels are maintained.

Engine manufacturers have commented that problems can occur if the transition is conducted too quickly, including fuel pump or injector scuffing, seizure, or cavitation, and fuel gassing. However, based on the fact that many vessels routinely transition from heavy fuel oil to distillate fuel, and virtually all vessels do this prior to dry-dock maintenance, we believe that vessel operators are well equipped to safely handle these transitions. We also note that equipment is available to vessel owners to automatically handle these fuel transitions.

As noted previously, we believe the safety of fuel transitions is amply demonstrated by the many vessels that routinely perform them. There are no problems reported for the vast majority of these fuel switches. However, there is a slight risk that temporary engine failure may occur if the vessel operator does not correctly follow procedures, possibly resulting in some loss of electrical power to the vessel. In these cases, a vessels' emergency backup generators, which run solely on marine distillate fuel, would become operational.

For diesel-electric vessels, which generally have several large diesel generator sets that provide power for both propulsion and onboard electrical power, a temporary failure in one or more engines could compromise vessel maneuverability to some degree. However, we do not believe fuel switching on diesel-electric vessels raises a significant problem for a number of reasons. First, the proposed regulation permits, but does not require, vessel operators to switch to the lower-sulfur distillate fuels. As we discussed previously, vessel operators can choose to comply with the regulation's emission limits with one of several options, only one of which is switching to the low sulfur fuels. Those vessel operators who believe fuel switching may cause problems that raise safety concerns have other options with which to comply. Second, as mentioned above under "existing practice," many diesel-electric cruise vessels currently switch to cleaner distillate fuels near California ports on a routine basis. Third, because there are generally several engines on diesel-electric vessels, it is likely that some engines would remain operational, providing the necessary power to the ship's systems. Fourth, the U.S. Coast Guard and shipping associations have recommended in some cases that fuel transitions in propulsion engines be performed away from confined areas. (PSSOA, 1999) The proposed regulation is entirely consistent with these recommendations because the 24 nautical mile boundary in the regulation would generally result in fuel transitions being performed in open water, for those operators that choose to switch fuels. Arguably, switching fuels at or prior to entering the 24 nm, should provide a greater margin for safety than conducting the switch much closer to the ports, which is the practice for some vessels.

### Technical and Safety Considerations

ARB staff contacted the major manufacturers of auxiliary engines used on ocean-going vessels to determine whether these engines could operate on marine distillate fuel (marine gas oil or marine diesel oil). Based on our requests for information, engine manufacturers uniformly reported that their auxiliary engines designed for use with heavy fuel oil can also use distillate fuels. (Wartsila, 2004; Caterpillar, 2005; MAN B&W, 2005; Yanmar, 2005; Pielstick, 2004) However, they noted that certain technical and safety considerations need to be observed with the use of distillate fuels and during the transition from one fuel to another.

Given this, we believe that vessel operators already can and do safely use distillate fuels when they follow the engine manufacturers' recommendations. In some cases, modifications may need to be made to the fuel supply and processing equipment on the vessel. Each of these technical considerations is discussed below.

*Fuel Compatibility:* Engine manufacturers have commented that there is always a risk of fuel incompatibility when blending two fuels, particularly between heavy fuel oil and distillate fuels (especially very low sulfur distillate fuels which tend to be low in aromatic hydrocarbons). The main concern is that aromatic hydrocarbons in heavy fuel oil keep asphaltene compounds in solution, and the introduction of lower sulfur (often low aromatic) fuels may cause some asphaltene compounds to precipitate out of solution and clog fuel filters.

Much of the available information on this subject is focused on continuous blending of low sulfur distillate fuels with high sulfur heavy fuel oils to produce 1.5 percent sulfur fuel for Sulfur Emission Control Areas in Europe. In these situations, there may be a greater potential for filter plugging to occur than during the temporary mixing of fuels that occurs during the switchover from one fuel to another. Nevertheless, manufacturers have stated that incompatibility problems are a concern during fuel transitions as well. However, as noted above, many vessels routinely transition from heavy fuel oil to existing marine distillate fuel without incident, and virtually all vessels do this prior to dry-dock maintenance.

We also note that some manufacturers have stated that the potential for incompatibility problems is more of a concern with the very low sulfur on-road fuels which tend to have the lowest aromatic levels. (CIMAC, 2004; MAN B&W, 2005) The proposed regulation limits emissions based on the use of regular MGO, or MDO at or below 0.5 percent sulfur, starting January 1, 2007. As such, the distillate fuels used under the proposed regulation would be essentially the same fuels vessel operators now use when performing fuel transitions.

The proposed regulation also specifies a 0.1 percent sulfur level for 2010, consistent with a European Union Directive for vessels at dockside. (EU) However, as specified in the proposed regulation, ARB staff will conduct a feasibility study prior to 2010 to investigate fuel compatibility as well as other issues, prior to implementing this fuel.

*Compatibility of Lubricants with Low Sulfur Fuels:* Marine engine lubricants are matched to the expected sulfur content of fuel. Specifically, sulfur in fuel results in acidic compounds in the engine that are neutralized by alkaline calcium compounds in the engine lubricant. Higher “base number (BN)” lubricants are able to neutralize higher sulfur fuels. When a relatively high BN lubricant is used with a low sulfur fuel, calcium deposits can form in the combustion chamber.

These problems are primarily associated with slow speed two-stroke engines, rather than the four-stroke engines covered by this proposed regulation. (DNV, 2005) One manufacturer stated that the effect of using low sulfur fuel with a relatively high BN lubricant is a long-term issue for four-stroke engines, whereas the impact is more immediate for two-stroke engines. (Wartsila, 2005b)

For four-stroke engines that temporarily use lower sulfur fuels with a relatively high BN lubricant, problems are generally not expected unless low sulfur fuel is used for extended periods of time. One engine manufacturer recommends that their four-stroke engines can continue to use the same high BN lubricant when a heavy fuel oil engine alternates between heavy fuel oil and distillate fuel. (*Ibid*) Another manufacturer reported that their heavy fuel oil engines are expected to be able to operate for up to 300 hours on marine gas oil with high BN lubricants. (Yanmar, 5/1/05) We do not expect vessels to spend close to 300 hours of operation while traveling within 24 nautical miles (nm) of the California coastline. This is because a vessel would only need 40 hours to travel at 20 knots along the entire 800 nm California coastline.

*Lubricity:* Several sources reported that lower sulfur fuels have lower lubricity, which could potentially cause fuel pump damage. (DNV, 2005, App I; CIMAC, 10/04; MAN B&W, 5/05) Some of these sources noted that low sulfur automotive diesel fuels have a minimum lubricity requirement, unlike marine fuels. However, the concern appears to be related to the use of very low sulfur levels associated with landside diesel fuels, which have a lower sulfur content than what the proposed regulation specifies. For example, one source states that sulfur levels below 0.05 percent, in conjunction with a viscosity below 2 centistokes, could lead to fuel pump problems. (DNV, 2005, App. I) Another source reported that lubricity is not considered a problem for their four-stroke engine fuel injectors as long as the sulfur content is above 0.01 percent. This source mentioned that insufficient information was available to determine if fuel below this level would be problematic, but noted that lubricity additives could be added by the fuel manufacturer or marketer. (Wartsila, 2005b) As noted previously, ship operators can comply with the proposed regulation through the use of marine gas oil with no sulfur limit, or through the use of marine diesel oil with a relatively high sulfur limit of 0.5 percent in 2007. For 2010, there is a lower 0.1 percent sulfur limit. However, this limit will be subject to a feasibility review that will consider this and other technical concerns prior to implementation.

*Low Viscosity:* One manufacturer noted that the low viscosity of distillate marine fuels could potentially be a concern with some of their engines. One of the potential impacts of low fuel viscosity is greater internal leakage in fuel pumps and injectors, resulting in lower fuel pressures, and less fuel delivered. (DNV, 2005) According to one manufacturer, the minimum viscosity of fuel supplied to their engines is in the range of 1.8 to 3 centistokes, and noted that minimum viscosity for marine gas oil (DMA) is 1.5 centistokes. However, this manufacturer also noted that for their four-stroke engines low fuel viscosity is generally not a severe problem. The manufacturer suggested that a minimum viscosity could be specified when ordering distillate fuels, or modifications could be made to address this issue. (Wartsila, 2005b) One possible modification would be a fuel cooler since lowering the fuel temperature will increase its viscosity.

*Fuel Energy Content Differences:* Marine distillate fuels have less energy than heavy fuel oils on a volume basis. Some manufacturers have commented that this will reduce the output of a four-stroke engine by approximately 6-15 percent depending on the

engine model. (Wartsila, 2005b; Yanmar, 2005; Pielstick, 2004) Depending on the engine, governor adjustments or a change in the fuel “rack” position may address this issue.

*Pipe Leakage:* Use of less viscous marine distillate fuels, and temperature changes that occur during transitions between heated heavy fuel oil and non-heated distillate fuel have been reported to increase the likelihood of fuel leaks. However, such leaks would also be expected to occur during fuel transitions performed prior to dry-dock operations. Such leaks can be prevented through maintenance, such as replacement of deteriorated gasket materials or o-rings, and tightening connections.

### **C. Potential Options for Alternative Control Plans**

Below, we provide descriptions of diesel PM and NO<sub>x</sub> emission reduction control strategies that potentially could be used as compliance options under an alternative control plan. These technologies are currently available or projected to be available in the near future. In many cases, similar technologies have been used on stationary diesel engines, which are operated similarly to vessel auxiliary engines. Each technology may not be by itself an alternative emission control strategy, but used in combination with other technologies may equal or exceed the required emission levels of the proposed regulation. Additional information on the wide variety of emission reduction options for diesel fueled engines is provided in the Diesel Risk Reduction Plan. (ARB, 2000)

#### Cold Ironing or Alternative Marine Power

This option would allow vessels to use dockside electrical power (cold ironing) during hotelling, instead of operating ship-board auxiliary diesel engines to provide electric power. Although there are technical challenges associated with providing cold ironing for vessels, this process is currently being used by several West Coast ports. For example, the Princess Cruise vessels that dock in Juneau, Alaska and Seattle, Washington use shore-side power for hotelling.

USS-POSCO industries has four vessels that have been cold ironing at a Pittsburg, California terminal since the early 1990s. The Port of Los Angeles retrofitted the China Shipping terminal to include shoreline power infrastructure. Two China Shipping vessels began connecting to shore power in June 2004, with the goal of 70 percent of the vessels visiting the terminal using shore power. Also at the Port of Los Angeles, shore-side infrastructure is currently being constructed to allow an NYK Atlas container vessel already built with cold ironing capabilities to use shore-side power. The Port of Long Beach will also provide cold ironing capabilities for two British Petroleum tankers that regularly visit the port. Finally, the U.S. Navy has been cold ironing in port at bases all over the world for several decades.

#### Selective Catalytic Reduction (SCR)

Selective catalytic reduction (SCR) is an exhaust after-treatment method for controlling NOx emissions up to 90 percent or more. The SCR process basically works by using ammonia (NH<sub>3</sub>) as a reagent, injecting it into the exhaust gas of the engine, in the presence of a catalyst. The ammonia and NOx emissions react in the presence of the catalyst to form nitrogen (N<sub>2</sub>) and water. Atmospheric nitrogen is usually in its diatomic form of N<sub>2</sub> and the water is non-polluting. The ammonia is injected into the process with air or steam.

SCR systems have been installed on new marine engines for many years. For example the four USS-POSCO vessels mentioned above are equipped with SCR on their main engines. However, retrofitting SCR systems on existing vessels is challenging. Some SCR retrofit challenges are urea and ammonia storage and safety requirements. Also, SCR systems require a large amount of space near the engine.

### Diesel Oxidation Catalysts

Diesel oxidation catalysts (DOCs) have been used on many land-based engines. DOCs are generally referred to as “catalytic converters.” DOCs are devices attached to the engine exhaust system similar to a muffler. They have chemical catalysts dispersed on a substrate within their interior which assist in the oxidation of carbonaceous pollutants – some of the soot emissions and a significant portion of the soluble organic fraction of diesel PM. These carbon-containing pollutants are oxidized to CO<sub>2</sub> and water. The catalysts that are used are known as the platinum group metals. These consist of platinum, iridium, osmium, palladium, rhodium, and ruthenium. Platinum is best suited as the catalyst for diesel engine control devices; therefore, it appears that it will be the main catalyst used in diesel catalytic converters. (Kendall, 2002/2003)

### Flow Through Filters

Flow through filter (FTF) technology is a relatively new technology for reducing diesel PM emissions. Unlike diesel particulate filters (DPF), in which only gases can pass through the substrate, the FTF does not physically “trap” and accumulate PM. Instead, exhaust flows through a medium (such as wire mesh) that has a high density of torturous flow channels, thus giving rise to turbulent flow conditions. The medium is typically treated with an oxidizing catalyst that is able to reduce emissions of PM, HC, and CO, or used in conjunction with a fuel-borne catalyst. Any particles that are not oxidized with the FTF flow out with the rest of the exhaust and do not accumulate. Also, limiting the sulfur fuel content to <350 ppm or less will limit clogging and reduce backpressure problems.

The filtration efficiency of an FTF is lower than that of a DPF, but the FTF is much less likely to plug under unfavorable conditions, such as high PM emissions, low exhaust temperatures, and emergency circumstances. The FTF, therefore, is a candidate for use in applications that are unsuitable for DPFs.

### Advanced Control Technology Inc. Technology

Advanced Control Technology Inc. (ACTI) has developed an emission reduction technology that they claim has the potential to remove 95 percent of NO<sub>x</sub> emissions and 90 percent of PM emissions. The system would reduce emissions from marine engine auxiliary engines while at port by placing a flexible hood over the exhaust stack. The flexible hood would be placed over the exhaust stack by a robotic arm, diverting the exhaust into a two stage “wet scrubbing” process where the pollutants would be removed. The system would be placed on a mobile barge. (ENN, 2005) Currently, ACTI is installing this technology at the J.R. Davis Roseville, California rail yard. Testing will follow with the goal of U.S. EPA certification. (ARB, 2005)

### Slide Valve Technology

Replacing stock fuel injectors with slide valve fuel injector technology can result in a PM reduction of up to 50 percent, depending on the engine load. Standard fuel injectors leave a residual volume of fuel that remains in the injector after the fuel is injected into the cylinder. The remaining fuel drips into the cylinder during the non-combustion portion of the stroke, causing soot and PM. The new slide valve technology reduces the residual fuel volume to a minimum, thereby reducing soot and PM emissions. Most engine companies are installing slide valve technology on their new engines as standard equipment and also offering slide valves during normal injector maintenance replacement. (Man B&W)

### Common Rail

Fuel pressure is distributed evenly to the injectors by an accumulator or rail. The high pressure is supplied by a pump. The rail pressure, at the start and the end of the injection is controlled electronically. The common rail system offers the following advantages: high fuel pressure at all engine speeds, ability to offer pilot injection and post injection at all engine speeds, and most conventional injection systems can be replaced with a common rail system without major engine modifications. (DieselNet, 2002a)

### Water Injection

Adding water to the combustion chamber absorbs heat when the water vaporizes, lowering the peak combustion temperatures and reducing NO<sub>x</sub> emissions. Water can be introduced in a variety of ways: direct water injection, fumigation into the intake air, or with the fuel in an emulsion. Unmodified engines can use emulsified fuel, if the injection systems can handle the extra volume. Other systems require major redesign to include separate water supply tanks, injection lines, fuel pumps, injectors, etc. Generally, a 1 percent increase of water equates to a 1 percent decrease in NO<sub>x</sub> emissions. However, hydrocarbon and carbon monoxide emissions may increase using water injection strategies. (DieselNet, 2003)

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## **VII. ENVIRONMENTAL IMPACTS**

This chapter describes the potential environmental impacts of the proposed regulation. The proposed regulation is intended to protect the health of California's citizens by reducing the exposure to the emissions from ocean-going vessel auxiliary engines. An additional consideration is the impact that implementation of the proposed regulation may have on the environment. Based upon available information, ARB staff has determined that no significant adverse environmental impacts should occur as the result of the proposed regulation. This chapter describes the potential impacts that the proposed regulation may have on air quality, water quality, and hazardous waste disposal.

### **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 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 below.

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.

The proposed regulation is needed to reduce the risk from exposures to diesel PM as required by Health and Safety Code (H&SC) sections 39666 and to fulfill the goals of the Diesel Risk Reduction Plan. Alternatives to the proposed regulation have been

discussed earlier in Chapter V of this report. ARB staff has concluded that there are no alternative means of compliance with the requirements of H&SC sections 39666 that would achieve similar diesel PM emission reductions at a lower cost.

## **B. Effects on Air Quality**

The proposed regulation will provide diesel PM, NO<sub>x</sub>, and SO<sub>x</sub> emissions reductions throughout California, especially in coastal urban areas many of which are non-attainment for the State and federal ambient air quality standards for PM<sub>10</sub>, PM<sub>2.5 a</sub> and ozone.

### Emission Reduction Estimates

For 2007 through 2009, the emission reductions resulting from the proposed regulation were estimated based on the proportion of auxiliary engines using heavy fuel oil, and the differences in the emissions between auxiliary engines using 2.5 percent heavy fuel oil and 0.5 percent marine gas oil. The sulfur levels for heavy fuel oil and marine gas oil represent the average sulfur contents for these fuels based on vessels visiting California ports based on the ARB's 2005 Ship Survey. (ARB, 2005). Auxiliary engines using distillate fuels would generally be unaffected by the proposed regulation until 2010.

For 2010 and later, when the emission limit based on the anticipated use of 0.1 percent sulfur marine gas oil is implemented, we estimated the emission reductions based on: (1) the proportion of auxiliary engines using heavy fuel oil, and the differences in the emissions between auxiliary engines using 2.5 percent heavy fuel oil and 0.1 percent marine gas oil; and (2) the proportion of auxiliary engines using distillate fuel, and the differences in the emissions between auxiliary engines using 0.5 percent marine gas oil and 0.1 percent marine gas oil.

The estimated reductions in PM emissions that would occur when switching from heavy fuel oil to distillate fuels result, in large part, from the lower sulfur content of distillate fuel, which reduces the formation of sulfate PM. In addition, the lower ash content and lower density of distillate fuel also contributes to lower PM emissions (EPA, 2002). The lower sulfur content of distillate fuel also directly contributes to lower SO<sub>x</sub> emissions. For example, lowering the sulfur content from 2.5 percent to 0.5 percent represents an 80 percent reduction in the sulfur content of these fuels, and results in an 80 percent reduction in SO<sub>x</sub> emissions. The lower nitrogen content of distillate fuels also results in a reduction in NO<sub>x</sub> emissions (EPA, 2002).

The emission factors used to estimate the emissions and emission reductions from auxiliary engines are discussed in detail in Appendix D. These emission factors are shown in Table VII-1 below. The estimated percent emission reductions from auxiliary engines that switch fuels are shown in Table VII-2 below. While these percent emission reductions represent our best estimates, we recognize that emissions test results for PM vary widely depending on the source of information.

**Table VII-1: Estimated Emission Factors (g/kw-hr)**

<b>Pollutant</b>	<b>HFO @ 2.5% sulfur</b>	<b>MGO @ 0.5% sulfur</b>	<b>MGO @ 0.1% sulfur</b>
NOx	14.7	13.9	13.9
SOx	11.1	2.1	0.4
PM	1.5	0.38	0.25

**Table VII-2: Estimated Emission Reductions for Auxiliary Engines Switching from Heavy Fuel Oil to the Specified Distillate Fuels**

<b>Pollutant</b>	<b>Percent Reduction: HFO to MGO @ 0.5% Sulfur</b>	<b>Percent Reduction: HFO to MGO @ 0.1% Sulfur</b>
NOx	6%	6%
SOx	80%	96%
PM	75%	83%

Table VII-3 below shows the auxiliary engine emissions within the 24 nautical mile boundary, which are subject to the proposed regulation. The emissions are grown uncontrolled from 2004 to 2020 based on the growth assumptions discussed in Appendix D.

**Table VII-3: Projected Emissions from Auxiliary Engines within 24 Nautical Miles of California's Coastline**

<b>Year</b>	<b>Auxiliary Engine Emissions (Tons per Day)</b>		
	<b>PM</b>	<b>NOx</b>	<b>SOx</b>
2004	3.0	34	22
2007	3.8	43	28
2010	4.6	52	34
2015	6.2	69	45
2020	8.7	95	64

The ARB staff estimates that implementation of the proposed regulation will result in immediate and substantial reductions in diesel PM, NOx, and SOx emissions, as shown in Table VII-4 below. Upon implementation in 2007, this represents about a 70 percent reduction in PM emissions from the baseline emissions subject to the regulation (emissions within the 24 nautical mile boundary). In addition, the proposed regulation will result in reductions in carbon dioxide (CO<sub>2</sub>), a global warming gas. Specifically, the use of use of distillate marine fuels will result in about a 5 percent reduction in CO<sub>2</sub>

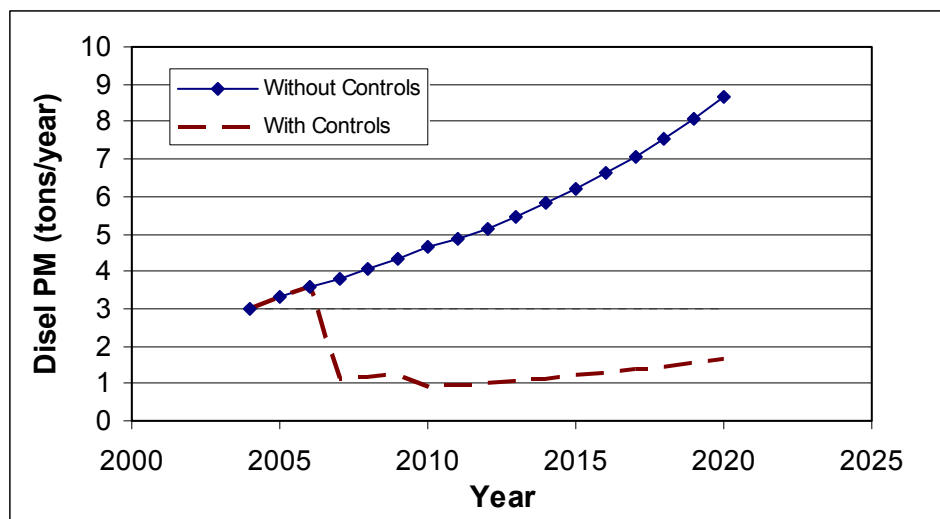
emissions compared with heavy fuel oil, and use of shore-side power would result in much greater percent reductions compared to the use of diesel auxiliary engines.

**Table VII-4: Emission Reductions from Implementation of the Proposed Regulation**

Year	Auxiliary Engine Emission Reductions (Tons per Day)		
	PM	NOx	SOx
2007	2.7	1.9	22
2010	3.7	2.3	32
2015	5.0	3.2	43
2020	7.0	4.4	61

Figure VII-1 illustrates how the diesel PM emissions from ship auxiliary engines within the 24 nautical mile boundary will grow with and without the proposed regulation. As shown, the growth in emissions would eventually negate the emissions reductions associated with the implementation of the proposed regulation.

**Figure VII-1: Estimated Diesel PM Emissions in 24 nm Zone With and Without the Implementation of the Proposed Regulation**



## **C. Estimating the Health Benefits Associated with the Reductions of Diesel PM Emissions**

### 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 four potential non-cancer health impacts associated with exposures to ambient levels of directly emitted diesel PM.

### Reduction in Potential Cancer Risks

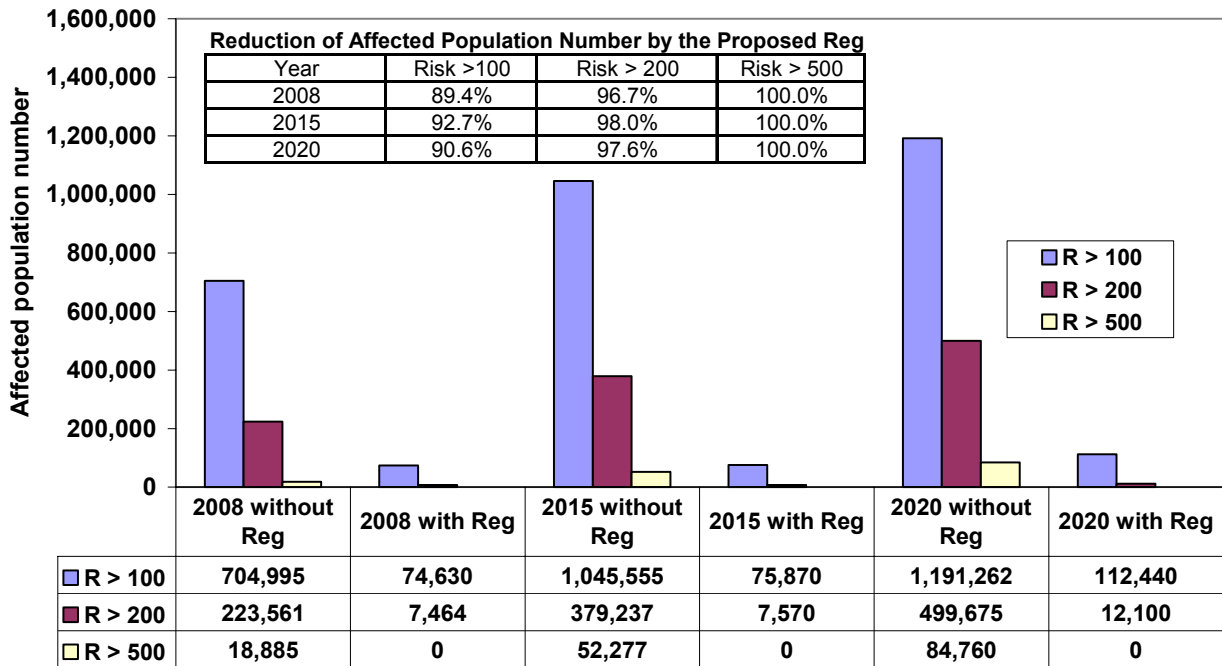
The reductions in diesel PM emissions that will result from implementation of the proposed regulation will reduce the public's exposures to diesel PM emissions and the potential cancer risks associated with those exposures. The ARB staff used the air dispersion model and model inputs developed for the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

To investigate the reductions in potential risks that will result as emissions from ocean-going vessel auxiliary engines decline, ARB staff used dispersion modeling and the projected 2008 and 2015 controlled and uncontrolled emissions inventories to estimate the ambient concentration of diesel PM emissions that result from the operation of cargo handling equipment at the Ports of Los Angeles and Long Beach in 2008 and 2015. The potential cancer risks from exposures to the projected controlled and uncontrolled 2008 and 2015 emissions were then estimated to determine how the potential risks will change. As shown in Figures VII-2 and VII-3, we expect a significant decline in the number of people exposed to high risk levels from cargo handling equipment emissions and the acres impacted as the proposed regulation is implemented.<sup>5</sup> Based on our analysis, which is summarized in Appendix K, we estimate that, in 2008, there will be a 70 percent reduction in the population-weighted average risk relative to uncontrolled risk levels in from ocean-going vessel auxiliary engine emissions and approximately a 78 percent reduction in 2015.

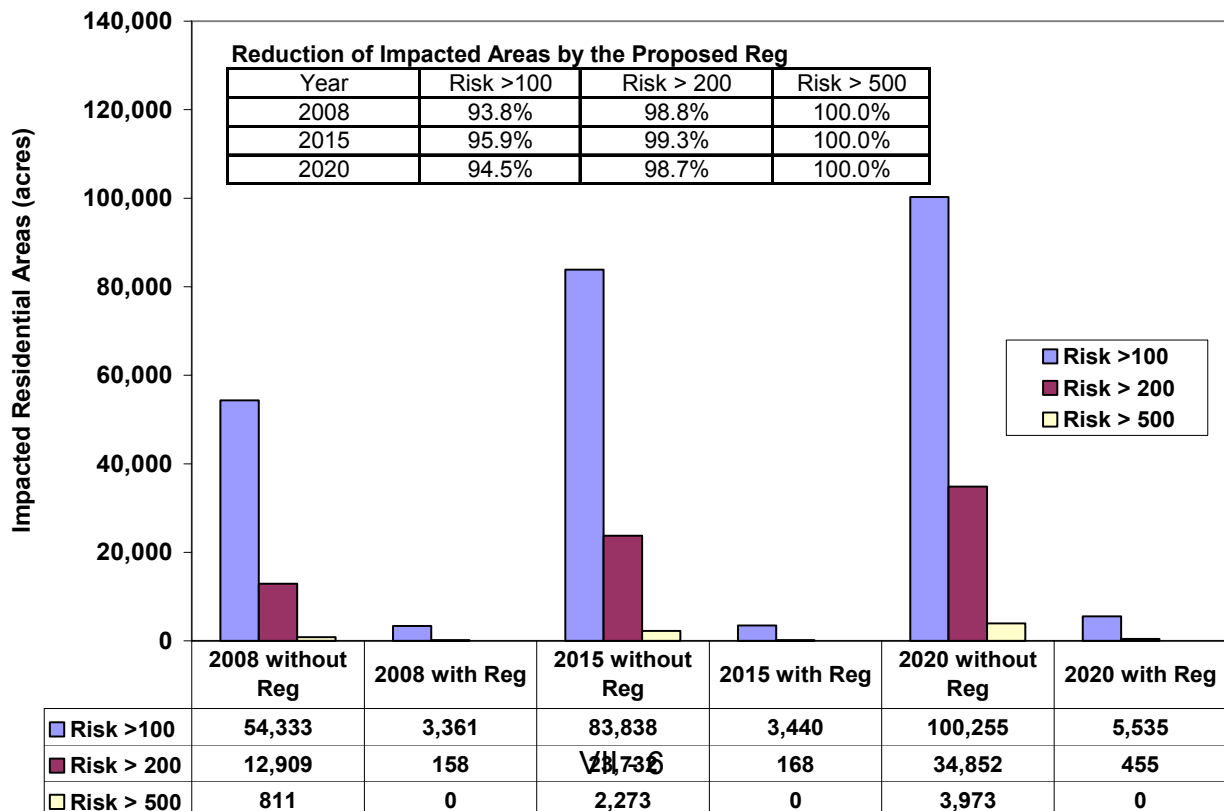
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<sup>5</sup> Because the isopleths for risk levels at 10 in a million were outside the modeling domain, we are not able to quantify the expected regulatory impact on this risk level. However, we believe that the risk levels greater than 10 in a million are also significantly reduced.

**Figure VII-2: Comparison of Affected Population Numbers With and Without the Proposed Ship Auxiliary Engine Fuel Regulation for the Years 2008 and 2015**



**Figure VII-3: Comparison of Impacted Residential Areas With and Without the Proposed Ship Auxiliary Engine Fuel Regulation for the Years 2008 and 2015**





## 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 IV but evaluated the change in ambient PM levels that are expected due to implementation of the proposed regulation. This analysis shows that the statewide cumulative impacts of the emissions reduced through this regulation from year 2007 through 2020 are approximately:

- 520 premature deaths (260 to 810, 95% CI)
- 14,000 asthma attacks (3,400 to 24,000, 95% CI)
- 120,000 work loss days (103,000 to 140,000, 95% CI)
- 650,000 minor restricted activity days (530,000 to 770,000, 95% CI)

### Value of Non-Cancer Effects

*Premature Death:* The U. S. EPA has established \$6.3 million (in 2000 \$) for a 1990 income level as the mean value of avoiding one death. (EPA, 2003) As real income increases, people may be willing to pay more to prevent premature death. The U.S. EPA further adjusted the \$6.3 million value to \$8 million (in 2000 \$) for a 2020 income level. Assuming that real income grew at a constant rate from 1990 and will continue at the same rate until 2020, we adjusted the value of avoiding one death for income growth. We then updated the value to 2005 dollars and discounted values of avoiding a premature death in the future back to the year 2005. The U.S. EPA's guidance of social discounting recommends using both three and seven percent discount rates. (EPA, 2000)

Based on these rates, the total valuation of the avoided premature deaths is about \$3 billion at seven percent discount rate, and \$4 billion at three percent discount rate. Based on using the annual avoided deaths as weights, the weighted average value of reducing a future premature death, discounted back to the year 2005, is around \$5 million at seven percent discount rate, and \$7 million at three percent. These are point estimates. The uncertainty in the mortality estimates is on the order of 50 percent, so the valuation estimates are likewise uncertain, by plus-or-minus about 2 billion dollars.

*Non-Mortality Health Effects:* To estimate the values of certain non-mortality health effects, we use U.S. EPA valuations, updated to 2005 dollars, for avoiding non-fatal health effects (EPA, 2003):

- \$49 for acute asthma attack
- \$180 for work loss day
- \$58 for minor restricted activity day (MRAD)

The expected reduction in acute asthma attack is about 14,000 cases. The total valuation is about \$0.4 million using a seven percent discount rate, and \$0.6 million using a three percent discount rate.

For the 120,000 avoided work loss days, their valuation is about \$14 million using a seven percent discount rate, and \$18 million using a three percent discount rate. For the 650,000 avoided MRAD, their valuation is about \$24 million using a seven percent discount rate, and \$31 million using a three percent discount rate.

### Reduced Ambient Ozone Levels

Emissions of NO<sub>x</sub> 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 NO<sub>x</sub> and ROG from diesel engines would make a considerable contribution to reducing 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 proposed regulation has two possible compliance routes, the fuels option, and the alternative compliance plan (ACP). Both options have potential environmental impacts.

The fuels option is expected to be the most common compliance method. A vessel complying with the regulation through this option may need to increase its storage capacity for distillate fuel by adding a tank or segregating an existing tank. Adding a fuel tank could potentially displace some cargo space, increasing the amount of fuel burned and emissions per a given amount of cargo transported. However, ARB staff does not expect a significant impact from the potential loss of cargo space. Most vessels already have multiple fuel tanks and are thereby able to accept multiple fuels. Specifically, according to the Survey, only about 10 percent of vessels would require modifications to use distillate fuels to comply with the proposed regulations (such as increasing their storage capacity for distillate fuels). Since some vessels reported the need for modifications not related to fuel storage, less than 10 percent of vessels would need to increase their storage capacity for cleaner burning fuels. For the minority of vessels that need to increase their fuel storage capacity, many may be able to segregate an existing tank as an alternative to adding a new tank. Finally, others will be able to add a new tank without impacting cargo capacity.

The use of a different fuel for California may also require increased fuel deliveries to the ship. This could potentially increase the possibility of fuel spills. However, refueling personnel can lower the possibility of fuel spills with training, and by following standard refueling operating procedures.

The ACP provides for a range of technologies that could be used to comply with the proposed regulation. Listed below are some potential technologies that could be used to comply with the proposed regulation. The ACP provisions are described in more detail in Chapter V.

### Selective Catalytic Reduction (SCR)

The heart of the SRC system is the catalyst. The reaction converting NO<sub>x</sub> to nitrogen and water occurs on the surface of the catalyst. NO<sub>x</sub> 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 which 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 from 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 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.

Ammonia is released from an SRC system because excess ammonia is required for efficient conversion of NO<sub>x</sub> 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 in the real world 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<sup>3</sup> of ammonia is required to convert 1 ft<sup>3</sup> of NO<sub>x</sub>), and the molar ration of ammonia to nitrogen dioxide (NO<sub>2</sub>) is two. Over 80% of the NO<sub>x</sub> compounds in the exhaust are nitrogen oxide, so the SCR system is usually run with a ratio of ammonia to NO<sub>x</sub> around 1.0. Further increase of the ratio will reduce NO<sub>x</sub> emissions, but emissions of ammonia will 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 the electrical heated 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 stack. Emitted levels of ammonia slip are far below the odor and health hazard thresholds of the chemical. Since ammonia is water soluble, it doesn't remain very long in the atmosphere.

Ammonia from SCR is stored in a tank and a relatively large amount of storage is required. Accidental release from storage could pose problems to communities surrounding the ship. 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 safer. The aqueous form is used in more heavily populated areas.

Urea is a chemical that comes in the form of powder that can also be used in place of ammonia for SCR. The urea 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 most engines, so urea injection is limited to systems where there is supplemental firing applied to the exhaust stream.

#### Shoreside Port Electrification ("Cold Ironing")

Supplying shore power to a vessel while at port is an option to reduce hotelling emissions. While shore power is supplied to the ship, the auxiliary engines are turned off. This option does not completely eliminate emissions because most vessels continue to operate boilers. However the emissions from boilers is a small fraction of the hotelling emissions from most vessels, so overall emissions are reduced dramatically. Table VII-5 below compares the emissions per unit of energy for a marine auxiliary engine operating on residual fuel (heavy fuel oil) and distillate fuel (marine diesel oil), and for a power plant.

**Table VII-5: Auxiliary Engine and Powerplant Emission Comparison**

<b>Pollutant</b>	<b>Residual (g/kw-hr)</b>	<b>MDO (g/kw-hr)</b>	<b>Powerplant (g/kw-hr)</b>
NOx	14.7	13.9	0.0908
PM	1.5	0.3	0.012
SOx	12.3	1.1	0.006

Source: ARB, 2004

As stated previously, shoreside power eliminates the emissions from vessel auxiliary engines, but the power is produced by powerplants. Powerplants get their power from a variety of sources each with a variety of air emissions. Natural gas plays a dominant role in California's fuel-fired generating system and is the preferred fuel for powerplants because of its cleaner combustion characteristics compared to other fuels. Natural gas has negligible sulfur, which limits sulfur compound emissions; negligible ash, which limits particulate matter emissions; and NO<sub>x</sub> emission rates that are generally lower than from other fuel types. Natural gas provides 91 percent of the fuel – fired electrical generation in California. (ARB, 2004)

### Diesel Oxidation Catalyst (DOC)

Two potential adverse environmental impacts from the use of DOCs 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. Using low sulfur diesel fuel can minimize this effect. 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://www.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 DOC. 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 H&SC, 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.

The ARB staff has consulted with personnel of the DTSC regarding management of the ash from diesel particulate filters. DTSC personnel have advised ARB that it has a list of facilities that accept waste from businesses that qualify as a conditionally exempt small quantity generator. Such a business can dispose of a specific quantity of hazardous waste at certain Household Hazardous Waste events, usually for a small fee. An owner who does not know whether or not he qualifies or who needs specific information regarding the identification and acceptable disposal methods for this waste should contact the DTSC.<sup>6</sup>

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

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<sup>6</sup> Information can be obtained from local duty officers and from the DTSC web site at <http://www.dtsc.ca.gov>.

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<sub>x</sub> emissions for heavy-duty diesel vehicles equipped with passive catalyzed filters have shown an increase in the NO<sub>2</sub> portion of total NO<sub>x</sub> emissions, although the total NO<sub>x</sub> emissions remain approximately the same. In some applications, passive catalyzed filters can promote the conversion of NO emissions to NO<sub>2</sub> during filter regeneration. More NO<sub>2</sub> is created than is actually being used in the regeneration process; and the excess is emitted. The NO<sub>2</sub> to NO<sub>x</sub> 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<sub>2</sub> 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<sub>2</sub>/NO<sub>x</sub> ratio in the exhaust could potentially result in higher initial NO<sub>2</sub> concentrations in the atmosphere which, in turn, could result in higher ozone concentrations.

Model simulations have shown that a NO<sub>2</sub> to NO<sub>x</sub> emission ratio of approximately 20 percent would nearly eliminate any impact of increased NO<sub>2</sub> emissions. (DaMassa, 2002). According to the model, at the NO<sub>2</sub> to NO<sub>x</sub> 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<sub>2</sub> by six percent (which is still within the NO<sub>2</sub> standard).

The health benefits derived from the use of PM filters are immediate and offset the possible adverse effects of increases in NO<sub>2</sub> emissions. For this reason, a cap of 20 percent NO<sub>2</sub> to NO<sub>x</sub> emission ratio was established for all diesel emission control systems through ARB's Verification Procedure.

**E. Reasonably Foreseeable Mitigation Measures**

The ARB staff has concluded that no significant adverse environmental impacts should occur from 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**

Alternatives to the proposed regulation are discussed in Chapter V 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 oceangoing auxiliary diesel-fueled engines.



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## VIII. 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 governmental agencies.

### 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 business 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 alternatives 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 alternatives 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.

#### **A. Summary of the Economic Impacts**

Under the proposed regulation, ocean-going vessel (or "vessel") operators can comply through the use of distillate marine fuel or equally effective emission control strategies. This requirement would apply when ships are within 24 nautical miles (nm) of the California coastline.

To estimate the costs of compliance with the proposed regulation, the use of distillate marine fuel will be assumed because the costs can be predicted more accurately compared with the wide range in potential costs from the multitude of potential alternative control strategies. In addition, it is unlikely that alternative control strategies would be pursued unless they are less expensive than the use of distillate marine fuels.

To estimate the costs for 2007 through 2009, we assume that vessel operators will use marine gas oil (MGO) to comply with the proposed regulation. For 2010 and later, we assume that vessel operators will use of 0.1 percent sulfur MGO. However, it should be noted that the 2010 emission limit will be subject to a feasibility evaluation that will consider the supply of this fuel in 2010, as well as technical issues. Therefore, it is possible that this standard could be modified. In addition, throughout the analysis, the costs to passenger cruise vessels (diesel-electric vessels) and cargo vessels (generally direct drive motor-ships) will be analyzed separately due to the differences in these vessel types.

Since the majority of vessels currently use heavy fuel oil in their auxiliary engines, most vessel operators will need to switch to more expensive marine distillate fuel in California upon entering the 24 nm boundary. This fuel is roughly twice as expensive by weight as heavy fuel oil. The added cost to businesses due to the higher cost of using distillate fuel will vary widely based on the amount of heavy fuel oil they use in California. For example, a business that owns a single small cargo vessel that makes a single annual visit to a California port may incur an added cost of a couple thousand dollars, while an operator of a large fleet of vessels that make frequent California port visits may incur costs exceeding a million dollars annually. On average, we estimate the added annual fuel cost for a typical cargo vessel operator at about \$20,000 per company (\$17,000 for years 2007 to 2009, and \$19,000 for 2010 and later). For passenger cruise vessel operators, we estimate the added annual fuel cost at about \$2 million per company (\$1.7 million for years 2007 to 2009, and \$1.9 million for 2010 and later). For the entire oceangoing shipping fleet that visits California, we estimate an added annual fuel cost of about \$34 million (2007-2009), and \$38 million (2010 and later). These estimates are based on current fuel consumption and do not account for growth.

In addition, we estimate that about five percent of non-diesel-electric (cargo) vessels, and about forty percent of diesel-electric (passenger cruise) vessels will need some modifications such as adding a new fuel tank and piping. These costs will vary widely with the type of modifications, but we estimate the average cost to be on the order of \$100,000 per vessel for cargo vessels, and \$100,000 to \$500,000 for diesel-electric vessels. We estimate the total retrofit cost to the industry at about \$11 million to \$18 million dollars.

We do not expect significant economic impacts to the industry based on the added costs of the proposed regulation. The added costs of the regulation are relatively minor compared to the overall operating expenses of these vessels. In addition, based on an analysis of the change in “return on owners equity” (ROE) for typical businesses, the added costs of the proposed regulation would result in less than a one percent change in ROE. Generally, a decline of more than ten percent in ROE suggests a significant impact on profitability. Because the proposed regulation would not alter significantly the profitability of most businesses, we do not expect a noticeable change in employment, business creation, elimination, or expansion, and business competitiveness in California. We also do not expect significant economic impacts on governmental agencies on the local, state, or federal level. Military vessels are exempt from the proposed regulation.

We also do not expect significant impacts on the customers served by ocean-going vessel operators, even assuming that all of the added costs are passed on to customers. For example, we estimate that the added cost of the proposed regulation would add about a dollar per container for importers or exporters shipping containerized goods overseas. We estimate that this represents less than one percent of the shipping cost. For passenger cruise ships, we estimate the added cost of the proposed regulation for a typical Los Angeles to Mexico cruise would be about \$8 per passenger, representing about a 2 percent fare increase.

The overall cost-effectiveness of the proposed regulation, considering only reductions in diesel PM, is estimated to be about \$52,000 per ton of diesel PM reduced (\$26 per pound of diesel PM) from 2007 to 2009, and about \$53,000 per ton of diesel PM reduced (\$27 per pound of diesel PM) in 2010 and later, when the 0.1 percent sulfur marine gas oil limit is scheduled to be implemented. This is similar to the cost-effectiveness of other regulations adopted by the Board to reduce diesel PM. However, the proposed regulation would also reduce emissions of nitrogen oxides (NOx) and sulfur oxides (SOx). Attributing half the cost of the proposed regulation to diesel PM, and half to NOx plus SOx, the cost-effectiveness for 2007 to 2009 would be about \$26,000/ton (\$13/pound) of diesel PM reduced, and about \$3,000/ton (\$1.50/pound) of NOx+SOx reduced. For 2010 and later, the cost-effectiveness would be about \$27,000/ton (\$14/pound) of diesel PM reduced, and about \$2,700/ton (\$1.40/pound) of NOx+SOx reduced.

The health benefits of implementing the proposed regulation are substantial. The estimated statewide benefit of reduced premature mortality is about \$3 billion at a seven percent discount rate, and \$4 billion at a three percent discount rate.

## **B. Capital Costs**

In order to use marine distillate fuels in their auxiliary engines, some vessel owners will need to add additional tanks and piping, or make other modifications to their vessels. This will result in capital costs to the vessel owner. To estimate the number of vessels requiring modifications, we conducted the ARB 2005 Ship Survey (“Survey”). The Survey requested that respondents identify whether their vessels will require modifications to use distillate fuel and the nature of the changes if needed. (ARB, 2005). Eleven companies reported 32 vessels that would require modifications out of 358 total vessels reported in the Survey (i.e., less than 10 percent would require retrofits). More specifically, 8 cargo vessel operators reported 15 vessels requiring modifications, and 3 cruise vessel operators reported 17 vessels requiring modifications. The types of retrofits reported by vessel operators included the addition of fuel tanks, segregation of existing fuel tanks for distillate fuels, addition of a mixing tank and fuel treatment equipment, and fuel pump and fuel injector modifications.

### Estimated Average Retrofit Cost per Vessel

The average cost to modify a vessel to use distillate fuel is difficult to estimate because the cost will vary widely based on the particular vessel and the type of modifications. One common modification would be the addition of a tank for distillate fuel, or the partitioning of an existing tank. To estimate the potential cost to add a tank, ARB staff reviewed the available literature, contacted marine engineering firms, and requested information from respondents to the Survey. Our findings and recommendations are summarized below.

The U.S. EPA estimated the cost to add a fuel tank and associated piping to allow a vessel to use cleaner fuel (either distillate or 1.5% sulfur heavy fuel oil) at \$50,000. (U.S. EPA, 2002). Relatively little information was provided in the U.S. EPA report detailing how the estimate was derived, so marine engineering firms were contacted to estimate the cost of installing an additional tank that would allow a typical cargo vessel to comply with the proposal. They responded that the \$50,000 estimate in the U.S. EPA report was reasonable assuming the vessel is in dry-dock for other maintenance (Herbert Engineering, 2005; Sweeney, 2005).

Others have reported higher costs. For example, a report prepared for the European Union estimated the cost to install a tank, as well as pumps, gauges, and ancillary equipment at 25,000 € (~\$30,000) for a 30 meter vessel, and 80,000 € (~\$96,000) for a 100 meter vessel. (Entec, 2002). However, the vessels mentioned in the report are smaller than those subject to the proposed control, and it is unclear whether or not the fuel tanks would provide capacity only for auxiliary engine use. ARB staff also

contacted respondents to the Survey that indicated that some of their vessels would require retrofits. Only one company responded with an estimate of \$350,000 to \$500,000 for a passenger cruise vessel. However, as discussed later in this chapter, cruise vessels and other diesel-electric vessels may have higher retrofit costs than other types of vessels. For this reason, a separate business impacts analysis was performed for these vessels, which account for less than three percent of the vessels that visit California annually. Considering the information available and the uncertainty in estimating the retrofit costs, ARB staff proposes to double the U.S. EPA estimate for cargo vessels and use \$100,000 per vessel retrofit (except for diesel-electric vessels) to avoid underestimating the cost. For diesel-electric vessels (cruise vessels and some tankers), ARB staff proposes a range from \$100,000 to \$500,000.

Total Capital Cost of the Proposed Regulation

The capital cost was estimated based on the estimated number of vessels requiring modifications and the cost per vessel. These costs were analyzed separately for non-diesel-electric (cargo) vessels, and diesel-electric (cruise vessels) as shown in Table VIII-1 below.

For cargo vessels, 15 of the 317 cargo vessels reported in the Survey (about 5 percent) were reported to require modifications. According to the California State Lands Commission (CSLC), 1,945 unique vessels (excluding barges) visited California in 2004 (CSLC, 2005). Excluding the 44 cruise vessels from the data, there are about 1,900 cargo vessels. Applying the 5 percent modification rate to the CSLC data (less barges and cruise vessels), we estimate that about 95 cargo vessels would require modifications. Assuming the cost of these retrofits averages \$100,000 per vessel, we estimate the total capital cost for cargo vessels would be about \$9.5 million.

For cruise vessels, the Survey can be used to directly estimate the number of vessels to be modified because the Survey coverage was nearly complete. Forty-one vessels were reported out of 44 reported by the CSLC data, and 17 of these were indicated to require modifications. Using the 17 vessels and a range in cost from \$100,000 (the average for other vessel types) to \$500,000 (the highest estimate received as discussed above), the estimated total capital cost to the cruise vessel industry is \$1.7 to \$8.5 million.

**TableVIII-1: Capital Cost Summary**

<b>Industry Sector</b>	<b>Estimated Retrofit Cost (\$/Vessel)</b>	<b>Estimated Number of Retrofitted Vessels</b>	<b>Total Industry Capital Cost (\$/year)</b>
Cargo Vessels	\$100,000	95	\$9.5 million
Passenger Cruise Vessels	\$100,000 to \$500,000	17	\$1.7 to \$8.5 million
Total	N/A	197	\$11 to \$18 million

There are a number of reasons why the actual capital costs may be different than our estimate. First, the number of vessels requiring retrofits (and the associated total capital costs) may be lower or higher than the above estimate. This is because we modified the proposed regulation after the Survey was conducted to remove the sulfur limit cap on marine gas oil (MGO) for the initial fuel requirement, whereas MGO with a sulfur cap of 0.2% sulfur was the proposed requirement at the time of the Survey. As such, some vessels may not need to add tankage and associated piping to comply with the proposal because they may already carry complying marine distillate fuels.

The current proposal still includes a provision requiring the use of 0.1% sulfur marine gas oil in 2010 subject to a feasibility review. However, this proposal is designed to align with the European Union's Directive which requires the use of 0.1% sulfur MGO for vessels at dockside and in inland waterways. (EU, 2005). It is likely many vessels may already be planning vessel retrofits to meet the EU requirement.

Moreover, the inclusion of a noncompliance fee option to the proposal will also reduce the number of vessels that will need to perform retrofits. Under this option, which was not included in the proposal at the time of the Ship Survey, an infrequent visitor that would otherwise need to perform vessel modifications to use distillate fuel could pay a fee in lieu of compliance with the proposal's fuel requirements.

Another factor that may affect the actual capital costs is the number of new visitors to California ports. As stated above, we based the total capital cost on the estimated total number of vessels that may require modifications to visit California ports in 2004. However, in subsequent years, there will be some new vessels visiting California ports. These could be vessels that did not visit California ports previously, or new vessels that have been added to the worldwide fleet. Some of these vessels may be required to perform modifications to use distillate fuel under the proposed regulation.

The actual number of these new vessels is difficult to estimate due to a variety of variables, including growth in the various shipping sectors, vessel turnover, and route changes initiated by individual businesses due to normal fluctuations in demand. The number of new vessels also could change as vessel owners try to minimize the number of vessels that would require modifications. Nevertheless, to determine an upper end cost estimate, we compared vessel visits over a two-year period. Based on our analysis of State Lands Commission data for 2003 and 2004, we estimate that roughly 50 percent of the vessels in 2004 did not visit in 2003. (CSLC, 2005). Assuming capital costs are proportional to the number vessels, we estimate the capital costs at about half the initial year total capital cost of \$11 to \$18 million, or \$5.5 to \$9 million annually, increasing the total present value cost of the regulation from \$165 to \$171 million, to \$184 to \$200 million (over a five year lifetime). Under this scenario, the 2007-2009 cost-effectiveness for PM would increase from about \$52,000 per ton PM reduced, to \$58,000 - \$63,000 per ton PM reduced (see Appendix J-Part II).

## C. Recurring Costs

The recurring costs associated with the purchase of distillate fuel were determined and accounted for in the cost analysis. We calculated the recurring costs based on the current estimated fuel consumption and the price differential between existing fuels and the cleaner fuels required by the proposal for the years 2007-2011. For years 2007-2009, we calculated the cost based on the consumption of heavy fuel oil in auxiliary engines and the differential in price between the most widely used type of heavy fuel oil (HFO-380) and standard marine gas oil (MGO). For 2010 and 2011, we based the cost on the sum of: (1) the estimated current consumption of heavy fuel oil and the differential in price between HFO-380 and MGO with a 0.1 percent sulfur cap; and (2) the estimated current consumption of standard MGO and the differential in price between standard MGO, and MGO with a 0.1% sulfur cap. Growth in the industry was not projected for this analysis, nor did we attempt to factor in expected price increases due to inflation, given the highly volatile and unpredictable nature of petroleum prices. However, we believe that growth and inflation are likely to have similar effects on both fuels, such that the differential will remain relatively constant. Our assumptions for fuel consumption rates and the price differential between MGO and HFO-380 are described below.

### Fuel Consumption Estimates

As shown in detail in Appendix B, we estimated fuel consumption within the 24 nautical mile boundary based on: (1) the estimated NOx emissions from auxiliary engines operating within this zone; (2) the energy specific NOx emission factor for medium speed four-stroke auxiliary engines using heavy fuel oil (Entec, 2002), which allowed emissions to be converted to associated energy in kilowatt-hours; and (3) the brake specific fuel consumption for these engines (*Ibid*), which allowed energy to be converted to estimated fuel consumption. Based on this information, we estimate that about 172,000 metric tons of fuel is currently consumed by auxiliary engines statewide within the 24 nm boundary.

Based on the Survey, we estimate about 92 percent of the fuel used by diesel-electric engines, and 72 percent of the fuel used by auxiliary engines on all other vessels was heavy fuel oil. Overall, about 78 percent of the fuel (by weight) used by all auxiliary engines was heavy fuel oil, and the remaining 22 percent was distillate fuel. Applying this breakdown to the total fuel consumption of 172,000 metric tons, we estimate that about 134,000 metric tons of heavy fuel oil and 38,000 metric tons of distillate fuel are used by the vessels traveling within 24 nm of California's coastline.

### Price Premium for Cleaner Fuels

To determine the estimated price differential between heavy fuel oil and distillate fuels complying with the proposed regulation, we estimated an average cost differential using current prices for HFO-380, the most common grade of heavy fuel oil, and marine gas oil. (Bunkerworld, 2005). As shown in Table VIII-2 below, prices were averaged over



the time period from March, 2005 through September, 2005 using three major bunkering ports: Singapore, Rotterdam, and Fujairah. Fuel prices tend to be volatile and may change significantly in the future. However, we believe that the price differential between HFO and MGO will be fairly constant.

Table VIII-2: Marine Fuel Prices (\$/tonne)\*

<b>Fuel</b>	<b>Fujairah</b>	<b>Singapore</b>	<b>Rotterdam</b>	<b>Average</b>
MGO	512	504	523	513
HFO-380	261	264	243	256
Difference	251	240	280	257

\* Bunkerworld, 2005. Prices averaged from March to September, 2005. A “tonne” equals a metric ton, or 2200 pounds.

To determine the cost differential between standard marine gas oil and 0.1 percent marine gas oil, we used a report prepared for the European Union. The report estimated the price premium for 0.1 percent sulfur marine gas oil compared to standard marine gas oil with no sulfur limit at 14-21 €/metric ton, or about \$21/metric ton using the median cost from the range and a conversion of 0.83 Euro per dollar. (Beicip-Franlab, 2002). Table VIII-3 summarizes the estimated price differential for the cleaner fuels specified in the proposed regulation.

Table VIII-3: Fuel Price Differential Due to Proposed Regulation

<b>Year</b>	<b>Fuel Change</b>	<b>Price Premium* (\$/tonne)</b>
2007-2009	HFO-380 to Standard MGO	257
2010 and later	HFO-380 to 0.1% S MGO	278
2010 and later	Standard MGO to 0.1% S MGO	21

\*Reflects data from Table VIII-2 above and “Advice on the Costs to Fuel Producers and Price Premium Likely to Result from a Reduction in the Level of Sulphur in Marine Fuels Marketed in the EU,” Beicip-Franlab, April 2002. A “tonne” equals a metric ton, or 2200 pounds.

### Total Recurring Costs

The total annual recurring costs for years 2007-2009, and 2010 and later, for each industry sector and for the total marine industry are shown below in Tables VIII-4 and VIII-5. These estimates are based on the estimated fuel consumption by sector and price differentials shown in Table VIII-3 above.

Table VIII-4: Total Industry Annual Fuel Costs for Years 2007-2009

<b>Marine Industry Sector</b>	<b>Estimated HFO Consumed (tonne)*</b>	<b>Price Differential (\$ per tonne)</b>	<b>Total Sector Cost (millions)</b>
Auto Carrier	3,500	\$257	\$0.90
Bulk	14,000	\$257	\$3.60
Container	58,000	\$257	\$14.9
General	6,000	\$257	\$1.50
Passenger	40,000	\$257	\$10.3
Reefer	2,200	\$257	\$0.60
RORO	1,300	\$257	\$0.30
Tanker	9,000	\$257	\$2.3
<b>Total</b>	<b>134,000</b>	<b>\$257</b>	<b>~\$34</b>

\* Estimated annual fuel consumption based on methodology used above for total industry fuel consumption.

The total annual recurring fuel cost estimates for 2010 and later reflect the use of somewhat higher cost 0.1 percent sulfur marine gas oil, as shown in Table VIII-5 below. Specifically, the current estimated fuel consumption of heavy fuel oil is multiplied by the higher incremental cost (\$278) between heavy fuel oil and 0.1 percent sulfur marine gas oil. The current estimated fuel consumption of marine distillate fuels is multiplied by the higher incremental cost (\$21) between standard marine gas oil and 0.1 percent marine gas oil. These costs were added to obtain the total recurring fuel cost by industry sector.

We do not expect significant additional recurring costs to the industry due to recordkeeping and reporting requirements, crew time, or other factors, which are discussed in section E of this Chapter.

Table VIII-5: Total Industry Annual Fuel Costs for 2010 and Later

<b>Marine Industry Sector</b>	<b>Estimated HFO Consumed (tonne)*</b>	<b>Estimated MGO Consumed (tonne)*</b>	<b>Price Differential (HFO to 0.1% S MGO)</b>	<b>Price Differential (Std. MGO to 0.1% S MGO)</b>	<b>Total Sector Cost (millions)</b>
Auto Carrier	3,500	1,100	\$278	\$21	\$1.0
Bulk	14,000	5,300	\$278	\$21	\$4.0
Container	58,000	22,600	\$278	\$21	\$16.6
General	6,000	2,300	\$278	\$21	\$1.7
Passenger	40,000	2,600	\$278	\$21	\$11.2
Reefer	2,200	850	\$278	\$21	\$0.63
RORO	1,300	500	\$278	\$21	\$0.37
Tanker	9,000	3,200	\$278	\$21	\$2.6
<b>Total</b>	<b>134,000</b>	<b>~38,000</b>	<b>\$278</b>	<b>\$21</b>	<b>~\$38</b>

\* Estimated fuel consumption based on methodology used above for total industry fuel consumption.

#### **D. Total Industry Cost and Total Annual Cost**

##### Total Industry Cost

We estimate the total statewide cost of the proposed regulation over a 5 year period to be about \$165-171 million dollars. This estimated cost was derived from the present value of the capital costs shown in Table VIII-1 combined with the present value of the recurring costs shown in Tables VIII-4 and VIII-5, over a 5 year period (see Appendix B).

##### Total Annual Cost

The total annual cost, including the total capital costs from Table VIII-1, and the recurring costs from Tables VIII-4 and VIII-5, is estimated to be about \$38 million for years 2007-2009, and about \$42 million for 2010 and 2011 (See Appendix B). The majority of the estimated total annual cost is contributed by the recurring fuel costs.

#### **E. Potential Additional Costs or Savings**

There may be some other costs and potential cost savings that could be incurred under the proposed regulation, but data were not available to enable quantification of these possible impacts. Nevertheless, the net impact of these costs and savings is not expected to be significant. These are briefly described below.

##### Distillate fuel may result in lower or higher maintenance costs

Marine distillate fuel has a lower sulfur and ash content than heavy fuel oil and may result in a permanent, ongoing reduction in engine maintenance in some engines due to

a reduction in deposit formation (Croner, 2002). On the other hand, the use of lower viscosity distillate fuel may make leaks at weak pipe joints more likely than the use of heavier fuels, requiring additional maintenance. Because these effects, to the extent they may occur, are very engine and vessel-specific, we cannot quantify the overall potential savings or added costs from changes in maintenance costs.

#### Crew time/training

The fuel switching operations necessary under the proposed regulation may be automated or performed manually, depending on the specific vessel. Depending on the fuel system, training of the vessel crew may be required. Vessel crew time would also be required to perform the fuel transition upon entering and leaving the 24 nautical mile boundary. Because of the uncertainty in the extent additional crew time and training may be needed, we are not able to estimate these costs. However, to the extent crew training is required, we expect such crew training to be minimal because vessels must already switch to marine gas oil prior to dry dock maintenance, and fuel transitions may be handled with the existing crews.

#### Dry-dock costs

The proposed regulation provides up to a one year extension for a small minority of vessels requiring significant modifications to comply with the proposed regulation (i.e., a fraction of the 10 percent of vessels requiring some modification). In addition, a noncompliance fee provision provides an option that allows vessel operators to pay a fee in lieu of compliance for up to five port visits per vessel, if their vessel requires modifications to comply with the proposal. However, even with these provisions, there may still be a small number of vessels that need to make modifications in response to the proposed regulation prior to a regularly scheduled dry-dock date. This would result in lost business opportunities while the vessel is out of service for modifications. We are not able to predict the extent this would occur and therefore cannot accurately quantify these costs.

#### Fueling costs

Some manufacturers have reported that the proposed regulation may result in more frequent fueling because they may use a smaller tank for the more expensive fuel that can be used to comply with the proposed regulation. However, we cannot predict the extent to which this would occur and the industry has not supplied estimates of these costs.

#### Loss of Cargo Capacity

For the minority of vessels that will need to add a fuel tank to comply with the proposed regulation, there is a possibility that the addition of the tank will reduce the cargo carrying capacity of the vessel. However, vessel owners can in many cases opt to

segregate a volume of an existing tank to avoid this impact. We are unable to estimate the extent of these potential impacts.

### Recordkeeping

We do not expect significant added costs to the industry due to the recordkeeping and reporting requirements in the proposed regulation. The proposed regulation would require records be kept of: (1) the date, time, and position of the vessel upon entry to and exit from the 24 nm boundary, and upon initiation and completion of fuel transitions; and (2) fuel purchases, and the types of fuels used within the 24 nm boundary. The recording of fuel purchases and fuel use is already required in accordance with standard practices as well as other regulations and Vessel Classification Society requirements. Recording the date, time, and position of the vessel as required by the proposed regulation would be an added requirement, but we do not expect these activities to require significant time or costs to comply as these can easily be logged either manually or automatically. We expect that existing vessel crews can readily record these data. Finally, the proposed regulation does not require periodic reporting of records. Reporting is only required upon request.

### **F. Estimated Cost to Businesses**

The proposed regulation would primarily impact businesses that operate large ocean-going vessels. These costs are estimated below for typical (average) businesses. However, the cost to individual businesses will vary widely based on factors such as the following:

- number of vessels visiting California ports;
- number of California port visits per vessel;
- power generated, and thus fuel consumed, by the auxiliary engines;
- whether the vessel is a “diesel-electric” vessel; and
- number of vessels requiring retrofits.

For example, a business that owns a single small cargo vessel that makes a single annual visit to a California port visit may incur an added fuel cost of a couple thousand dollars. On the other hand, a large vessel operator with several vessels making frequent California port visits may incur added fuel costs approaching a million dollars annually.

Table VIII-6 below provides a summary of the range of added fuel costs that could be incurred by shipping companies. As shown, most companies make relatively few visits and would incur proportionally lower costs, while a small number of large operators would incur costs up to about \$1 million. The average added fuel costs for travel in the 24 nm boundary associated with a California port visit (\$3,400/visit) was approximated by dividing the total annual industry recurring cost for years 2007 to 2009, \$34 million dollars (see Table VIII-4), by the roughly 10,000 port visits to California ports. In

addition, as described below, operators of diesel-electric vessels such as passenger cruise vessels are expected to incur greater costs.

**Table VIII-6: Estimated Average Added Fuel Cost to Vessel Operators\***

<b>Number of Companies</b>	<b>Number of California Port Visits</b>	<b>Added Fuel Cost @\$3,400 per Visit</b>
3	200-300	\$680,000-\$1 million
6	100-199	\$340,000-\$677,600
20	50-99	\$170,000-\$336,600
210	10-49	\$34,000-\$166,600
221	5-9	\$17,000 - \$30,600
83	4	\$13,600
124	3	\$10,200
265	2	\$6,800
500	1	\$3,400
1432 Total	~10,000 Total	N/A

\* Company and port visit information based on the California State Lands Commission data. Added costs assume no diesel-electric vessels, which represent less than 3% of the fleet visiting California.

We do not believe that the vessel operators subject to this proposed vessel would qualify as small businesses due to the large capital and operating costs associated with vessel operation. Typical container vessels are estimated to cost on the order of \$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 vessel costs about \$2 to \$3 million. (*Ibid*) 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.

The capital and recurring costs to typical businesses are discussed below. Separate analyses are performed for operators of non-diesel-electric vessels (mainly cargo vessels) and diesel-electric vessels (passenger cruise vessels and some tankers), which are expected to incur greater costs. Diesel-electric vessels make up less than three percent of the fleet that visits California.

Capital Costs to Typical Businesses (except diesel-electric vessels)

As discussed previously, capital costs due to the proposed regulation would include vessel modifications, such as adding fuel tanks and piping, or engine modifications. These costs are vessel-specific and are expected to vary widely, with most vessels requiring no retrofits and a few incurring significant costs. According to ARB’s Survey,

only about 5 percent of non-diesel-electric (cargo) vessels are expected to require modifications. For those companies with vessels that require modifications, the Survey reported a range of one to four vessels requiring modifications per company. Overall, 8 companies reported a total of 15 vessels requiring modifications, or an average of roughly 2 per company. Based on an estimated cost of \$100,000 per vessel (section B above), the total cost for a typical company with vessels requiring modifications would be about \$200,000, with a range from \$100,000 to \$400,000.

Recurring Costs to Typical Businesses (Except Diesel Electric Vessels)

The recurring cost for typical businesses is based on the ongoing higher cost of marine distillate fuels that would be required by the proposed regulation. The total cost to a particular company will vary directly with the amount of fuel consumed by the company’s vessels operated in California. To determine the average annual ongoing cost for a typical business, we divided the total estimated fuel cost of the regulation for non-diesel-electric vessels by the number of shipping companies that operated ocean-going vessels in California in 2004, as reported by the California State Lands Commission. Specifically, we divided the total recurring cost of \$24 million for years 2006-2009 as shown in Table VIII-4 (excludes diesel-electric cruise vessels), and \$27 million in 2010 and subsequent years as shown in Table VIII-5, by the approximately 1,400 companies reported by the California State Lands Commission to be responsible for vessel visits to California. (SLC, *supra*) This resulted in an average added fuel cost per company of about \$17,000 per year (2006-2009) and \$19,000 per year (2010 and later).

Summary of Costs to Typical Businesses (except passenger cruise vessels)

Table VIII-7 below summarizes the costs to a typical business with and without vessels requiring retrofits. As noted previously, only about 5 percent of non-diesel-electric vessels are expected to require modifications, so the cost to most affected businesses would be represented by the recurring higher cost of fuel only. The capital costs are annualized over a five year period, after which only the recurring costs would remain.

**Table VIII-7: Summary of Costs to Typical Businesses**

<b>Affected Business</b>	<b>Capital Cost</b>	<b>Annualized Capital Cost*</b>	<b>Recurring Cost</b>	<b>Total Annual Cost</b>
Modifications on 2 vessels	\$200,000	\$46,200	\$17,000 - \$19,000 (2010)	\$63,200 - \$65,200 (2010)
No Modifications	0	0	\$17,000 - \$19,000 (2010)	\$17,000 - \$19,000 (2010)

\*Capital costs annualized over 5 years, 5% interest rate. Recurring cost based on use of marine gas oil meeting ISO sulfur standards (pre 2010).

## Costs to Businesses Operating Diesel-Electric Vessels

In this section, we analyze the costs to businesses operating diesel-electric vessels. These businesses are analyzed separately because we expect the proposed regulation to result in greater impacts on diesel-electric vessels, compared to other types of vessels.

The cost impacts of the proposed regulation are greater for diesel-electric vessels because the large diesel generator sets on these vessels are used for both propulsion and ship-board electricity. Therefore, the amount of fuel used by these engines is greater than for auxiliary engines on other types of vessels, and the cost impacts are larger by a commensurate amount.

To determine the impacts on diesel-electric vessels, we focused solely on passenger cruise vessels. Based on the Survey, all passenger cruise vessels serving California were reported to be diesel-electric. With the exception of a couple of tankers that are diesel-electric (but exempt from the proposed regulation because they use slow-speed two-stroke engines), the Survey results did not report any other diesel-electric vessels. However, ARB staff is aware of at least one diesel-electric tanker that recently entered into California that uses an engine that would be subject to the proposed regulation. (Seafarers, 2005)

To put the cost impacts of diesel-electric vessels into perspective, we estimated the average fuel cost associated with a single port visit. To estimate this cost, we divided the total estimated added cost to the cruise vessel industry, \$10.3 million (2007-2009), by the 687 port calls to California per the CSLC, yielding about \$15,000 per port visit, compared with about \$3,400 per port visit for non-diesel-electric vessels as discussed above.

To determine the recurring fuel cost on a typical cruise vessel business, we divided the total estimated added fuel cost of \$10.3 million (2007-2009) to \$11.2 million (2010 and later) annually by the six companies that reported to the survey. This resulted in an added annual fuel cost of nearly \$2 million per company (\$1.7 for 2007-2009, and \$1.9 million per company for 2010 and later). However, it should be noted that this cost is relatively high compared to businesses operating other types of vessels because cruise vessels make more trips to California ports on average than other types of vessels, and because the passenger cruise industry has undergone mergers in the last few years that have consolidated more vessels under fewer companies.

In addition to higher fuel costs, it appears that these vessels are more likely to require modifications. According to the Survey, 17 of the 41 cruise vessels were reported to require vessel modifications. We also note that the California State Lands Commission reported 44 passenger cruise ships visiting California in 2004. (SLC, *supra*) Therefore, the industry participation in the Survey was nearly complete and the cost of modifying the 17 vessels reported should be a fairly accurate indication of the overall cruise vessel industry cost.



For those cruise vessel operators with vessels that require modifications, the Ship Survey reported a range of 1 to 12 vessels requiring modifications per company. Specifically, 3 companies reported a total of 17 vessels requiring modifications, or an average of roughly 6 vessels per company. Based on an estimated retrofit cost of \$100,000 per vessel, the total capital cost for a typical company with 6 vessels requiring modifications would be about \$600,000, or about \$140,000 annualized over 5 years using a 5 percent discount rate. However, there is a possibility that the average cost of modifications per vessel is higher for cruise vessels than for other types of vessels. This is due to the greater amounts of distillate fuels that would be needed to comply with the proposed regulation, and associated fuel tank capacity, piping, and fuel processing equipment. Only one diesel-electric vessel operator (a cruise vessel operator) provided an estimate of the cost of modifying a vessel to comply with the proposed regulation. This estimate, at \$350,000 to \$500,000 per cruise vessel, was higher than the other sources of information cited previously. Nevertheless, based on the \$500,000 figure as an upper bound, the estimated cost to a typical company with 6 vessels requiring retrofits would be about \$3 million, or about \$700,000 annualized over five years with a 5 percent discount rate.

Table VIII-8 provides a summary of the estimated costs to the cruise vessel industry. As mentioned previously, about 17 of the 41 cruise vessels reported in the Ship Survey were reported to require retrofits. However, the annual cost of fuel is much higher than the annualized retrofit costs, even when using the upper end retrofit cost estimate of \$500,000 per vessel.

**Table VIII-8: Summary of Costs\* to Typical Cruise Vessel Business**

<b>Affected Business</b>	<b>Capital Cost</b>	<b>Annualized Capital Cost*</b>	<b>Recurring Cost</b>	<b>Total Annual Cost</b>
Retrofits on 6 vessels	\$600,000 to \$3.0 million	\$140,000 to \$700,000	\$1.7-1.9 million	\$1.8-2.6 million
No Retrofits	0	0	\$1.7-1.9 million	\$1.7-1.9 million

\*Capital costs annualized over 5 years at a 5% discount rate. Recurring cost based on the use of marine gas oil meeting ISO sulfur standards (pre 2010).

## **G. Potential Business Impacts**

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 business enterprises and individuals. The assessment shall include a consideration of the impact of the proposed or amended regulation on the ability of California businesses to compete with businesses in other states, the impact on California jobs, and the impact on California business expansion, elimination, or creation.

This analysis is based on a comparison of the annual return on owner's equity (ROE) for affected businesses before and after the inclusion of the capital and recurring costs associated with the proposed regulation. The analysis also compares the estimated added costs of the proposed regulation to the overall operating costs of these vessels

ARB staff does not have access to financial records for many of these companies. However, it should be noted that many of these businesses are not California-based businesses. Many are foreign owned enterprises, sometimes involving complicated ownership arrangements involving consortiums of investors.

As stated in Section E above, we do not believe that the businesses subject to this proposed regulation would qualify as small businesses due to the large capital and operating costs associated with vessel operation.

#### Analysis of Return on Owner's Equity (ROE)

In this section, we evaluate the potential economic impact of the proposed regulation on California businesses as follows:

- (1) Typical businesses affected by the proposed regulation are identified from port visit data from the California State Lands Commission. The Standard Industrial Classification (SIC) codes associated with these businesses are listed in Table VIII-9 below;
- (2) The annual costs of the proposed regulation are estimated for each of these businesses based on the SIC code. For ranges in cost estimates, the high end of the range was used;
- (3) The total annual cost for each business is adjusted for both federal and state taxes; and
- (4) The adjusted costs are subtracted from net profit data and the results used to calculate the ROE. The resulting ROE is then compared with the ROE before the subtraction of the adjusted costs to determine the impact on the profitability of the businesses. A reduction of more than 10 percent in profitability is considered to indicate a potential for significant adverse economic impacts. This threshold is consistent with the thresholds used by the U.S. EPA and others.

Using publicly available financial data from 2002 to 2004 for the representative businesses, staff calculated the ROEs, both before and after the subtraction of the adjusted annual costs, for the typical businesses from each industry category. These calculations were based on the following assumptions:

- (1) All affected businesses are subject to federal and state tax rates of 35 percent and 9.3 percent, respectively; and

(2) Affected businesses neither increase the cost to their customers, nor lower their cost of doing business through cost-cutting measures due to the proposed regulation.

These assumptions, though reasonable, might not be applicable to all affected businesses.

The results of the analysis are shown in Table VIII-9 below. Using the ROE to measure profitability, we found that the ROE range for typical businesses from all industry categories would have declined by less than one percent due to the proposed regulation. This represents a small decline in the average profitability of the affected businesses. Overall, most affected businesses will be able to absorb the costs of the proposed regulation with no significant impacts on their profitability.

**Table VIII-9: ROE Analysis of Businesses**

<b>SIC Code</b>	<b>Description of SIC Code</b>	<b>Percent Change in ROE</b>
4412	Deep Sea Foreign Transportation of Freight	-0.01
4424	Deep Sea Domestic Transportation of Freight	-0.05
4481	Deep Sea Passenger Transportation	-0.60

Comparison of the Costs of the Proposed Regulation with Vessel Operating Costs

This analysis compares the added costs of the proposed regulation with the normal operating costs of large ocean-going vessels. While the costs of the proposed regulation are substantial, they are a small fraction of the overall operating costs for these businesses. For example, based on a typical scenario, a container vessel would pay an extra \$5,000 for fuel during visits to two California ports (see Appendix J-Part IV). We do not expect this cost to have a significant impact on vessel operators, or businesses that rely on the goods transported by these businesses, because the added fuel cost represents a minor percentage of the overall transportation cost. To put this in perspective, the total operating cost of a single Asia to U.S. West Coast voyage for a typical container vessel is estimated to be about 2 to 3 million dollars. Therefore, the \$5,000 added cost represents less than one percent of the total transportation cost for the voyage, or about a dollar per shipping container for a 5,000 TEU (transport equivalent unit) vessel, out of total costs on the order of \$500 per TEU. (Mercator, *supra*)

As compared to typical cargo vessels, the proposed regulation will have a larger impact on diesel electric-vessels (primarily cruise lines and some tankers). Nevertheless, we do not think the added costs will significantly impact these vessel operators. The added cost of the proposal for a typical cruise vessel visit to Mexico from the Los Angeles area would be about \$16,000 (see Appendix J-Part III). Because a typical cruise vessel for this voyage carries about 2,000 passengers (Carnival, 2005a), the added cost would be

about \$8 per passenger. For a relatively low cost 3 or 4 day Mexico cruise, about \$350 (Carnival, 2005b), a 2 percent increase in fare would be needed to offset the increased fuel cost.

Because the added costs of the proposed regulation are such a small percentage of the overall operating costs for both cargo and cruise vessels, we do not expect a significant impact on these businesses. There is also a possibility the proposed regulation will result in a positive impact on business creation due to additional sales of marine fuels in California beginning in 2010, when the 0.1 percent sulfur fuel requirement becomes effective (subject to a feasibility review). This is because California is expected to have 0.1 percent sulfur fuel available, whereas it is uncertain whether other ports worldwide will have this fuel available.

#### **H. Potential Impact on Business Competitiveness**

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 vessel 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, which may negate the cost savings in not purchasing the lower sulfur fuel. Finally, as stated previously, the added costs resulting from the proposed regulation are a small fraction of the overall operating costs of these vessels, and 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.

#### **I. Potential Impact on Employment, Business Creation, Elimination or Expansion**

The proposed regulation is not expected to have a noticeable impact on employment, or business creation, elimination, or expansion. As stated above, the added costs of the

proposed regulation are a small percentage of the overall operating costs for both cargo and cruise vessels. In addition, an analysis of the impact of the proposed regulation on the profitability of typical businesses indicated no significant adverse impacts.

There is also a possibility the proposed regulation will result in a positive impact on business creation due to additional sales of marine fuels in California beginning in 2010, when the 0.1 percent sulfur fuel requirement becomes effective (subject to a feasibility review). This is because California is expected to have 0.1 percent sulfur fuel available, whereas it is uncertain whether other ports worldwide will have this fuel available.

## **J. Potential Costs to Local, State, and Federal Agencies**

### Local Agencies

We do not expect any significant fiscal impacts on local agencies. We are not aware of any local government agency that operates an ocean-going vessel as defined in the proposed regulation. However, some minor impacts are possible on ports, which in California are established by state government and are operated by entities such as port authorities and departments of municipal governments.

The proposed regulation will increase costs for vessels visiting California ports. As such, some vessel operators could potentially choose to utilize alternative ports outside of California. However, as discussed in detail in section G above, we do not believe that this will occur to any significant degree.

We do not expect significant fiscal impacts on local air pollution control agencies due to the proposed regulation because ARB intends to enforce the provisions of the proposal statewide.

### State Agencies

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.

The only other State agency identified by ARB staff that could potentially be impacted is the California Maritime Academy (CMA) in Vallejo. The CMA operates the "Golden Bear" training vessel on an annual overseas voyage. This vessel already uses only distillate marine fuel, so it probably already complies with the proposed regulation. However, when the 0.1 percent sulfur marine gas oil requirement becomes effective in 2010 (subject the required feasibility review), there may be an added cost to operate the vessel.

## Federal Agencies

We are not aware of any impacts on federal agencies. Military vessels are exempted from the requirements of the proposed regulation.

### **K. Cost-Effectiveness**

For the purposes of this section, cost-effectiveness is defined as the ratio of the cost of compliance per ton of pollution reduced. Cost-effectiveness figures allow different regulations to be compared to determine the most economic way to reduce a given amount of emissions.

In this section, we calculate the cost-effectiveness in two ways. First, we attribute the total annual cost of the proposed regulation to each pollutant individually. This results in the highest cost-effectiveness values, and may overestimate the overall cost-effectiveness of the proposed regulation. For example, a regulation that resulted in the same costs and diesel PM emission reductions, but no reductions in other pollutants, would have the same cost-effectiveness in terms of diesel PM as the proposed regulation. Therefore, as an alternative, we also calculate the cost-effectiveness by attributing half of the costs of the proposed regulation to diesel PM reductions, and the other half to reductions in nitrogen oxides (NO<sub>x</sub>) and sulfur oxides (SO<sub>x</sub>).

We also discuss the cost-effectiveness for diesel-electric vessels, which will generally incur greater costs. Finally, we will analyze the cost-effectiveness of some alternative proposals to the proposed regulation recommended by ARB staff.

#### Cost-Effectiveness of the Proposed Regulation for All Vessels: Attributes All Costs to Each Pollutant Individually

The estimate of the cost-effectiveness of the proposed regulation for all vessels is shown in Table VIII-10 below, expressed in 2005 dollars. The cost-effectiveness is expressed in terms of dollars per ton of NO<sub>x</sub>, diesel PM, and SO<sub>x</sub> removed, with the total annual cost attributed to each pollutant individually.

The cost-effectiveness estimates for 2010 and later assumes that the 0.1 percent sulfur marine gas oil requirement becomes effective in 2010. However, this requirement will be subject to the results of a feasibility analysis as required by the proposed regulation that will analyze the available supply of this fuel, cost, and technical feasibility.

**Table VIII-10: Cost-Effectiveness of the Proposed Regulation for All Vessels: Attributes All Costs to Each Pollutant Individually**

Year	Total Annual Cost (\$ millions)	Emission Reductions* (tons per year)			Cost-Effectiveness \$/ton and (\$/pound)		
		NOx	PM	SOx	NOx	PM	SOx
2007-2009	38	575	730	5,800	66,000 (\$33)	52,000 (\$26)	6,600 (\$3.20)
2010 - 2011	42	575	800	7,200	73,000 (\$37)	53,000 (\$27)	5,800 (\$2.90)

\* The emission reductions and costs shown are based on the 2004 emissions inventory to be consistent with other 2004 data used. The emission reductions in 2007 and 2010 will be greater than the emission reduction figures shown.

The cost-effectiveness of the proposed regulation for diesel PM (as calculated in Table VIII-10) is similar to other regulations recently adopted by the Board (see Table VIII-11 below). For example, the diesel PM cost-effectiveness of the solid waste collection vehicle rule was estimated at \$56,000 per ton, excluding the benefits of NOx and hydrocarbon reductions. (ARB, 2003a) The cost-effectiveness of the stationary diesel engine airborne toxic control measure (ATCM) was estimated to range from \$8,000 to \$51,000 per ton of diesel PM reduced. (ARB,2003b) Finally, the transport refrigeration unit ATCM was estimated to have a cost-effectiveness of \$20,000 to \$40,000 per ton of diesel PM reduced. (ARB, 2003c)

**Table VIII-11: Diesel PM Cost-Effectiveness of the Proposal and Other Regulations/Measures (Attributes All Costs to Each Pollutant Individually)**

Regulation or Airborne Toxic Control Measure	Diesel PM Cost-Effectiveness	
	Dollars/Ton PM	Dollars/ Pound PM
Ship Auxiliary Engine Proposal	\$52,000 - \$53,000	\$26 – 27
Solid Waste Collection Vehicle Rule	\$56,000	\$28
Stationary Diesel Engine ATCM	\$8,000 - \$51,000	\$4 - \$26
Transport Refrigeration Unit ATCM	\$20,000 - \$40,000	\$10 - \$20

Cost-Effectiveness of the Proposed Regulation for All Vessels: Attributes Half the Costs to Diesel PM and Half to NOx plus SOx

In Table VIII-12 below, we calculate the cost-effectiveness by attributing half of the costs of the proposed regulation to diesel PM reductions, and the other half to reductions in nitrogen oxides (NOx) and sulfur oxides (SOx). This may reflect the overall cost-effectiveness more accurately in that it accounts for the multiple benefits of the proposed regulation.

**Table VIII-12: Cost-Effectiveness of the Proposed Regulation for All Vessels: Attributes Half of the Costs to Diesel PM and Half to NOx+SOx**

Year	Half of Total Annual Cost (\$ millions)	Emission Reductions (tons per year)		Cost-Effectiveness \$/ton and (\$/pound)	
		PM	NOx+SOx	PM	NOx+SOx
2007-2009	19	730	6,300	\$26,000 (\$13.00)	\$3,000 (\$1.50)
2010 - 2011	21	800	7,800	\$27,000 (\$14.00)	\$2,700 (\$1.40)

Cost-Effectiveness for Diesel-Electric Vessels

As explained in section F, the costs of the proposed regulation are greater for diesel-electric vessels because the large diesel generator sets these vessels use for both propulsion and ship-board electrical uses are covered as “auxiliary engines” under the proposed regulation. However, the emission reductions resulting from the use of distillate fuels will increase proportionally with the cost, so the overall cost-effectiveness of the proposed regulation for these vessels is similar to the other types of vessels. This is shown by comparing the cost-effectiveness results of Table VIII-10, for all vessels, to the results in Table VIII-13 below for diesel-electric vessels only. Similarly, the cost-effectiveness for diesel electric vessels would also be comparable to all vessels using the alternative calculation where half of the proposed regulation costs are attributed to diesel PM and half to NOx plus SOx (as calculated in Table VIII-12).

**Table VIII-13: Cost-Effectiveness of Proposal on Diesel-Electric Vessels**

Year	Total Annual Cost (\$ millions)	Emission Reductions (tons per year)			Cost-Effectiveness \$/ton and (\$/pound)		
		NOx	PM	SOx	NOx	PM	SOx
2006-2009	10.7 to 12.3	150	215	1,700	\$71,000- \$82,000 (\$36 - \$41)	\$50,000- \$57,000 (\$25- \$29)	\$6,300- \$7,200 (\$3.20- \$3.60)
2010 - 2011	11.6 to 13.2	150	240	2,000	\$77,000- \$88,000 (\$39- \$44)	\$48,000- \$55,000 (\$24- \$28)	\$5,800- \$6,600 (\$2.90- \$3.30)

\* Total industry fuel cost of \$10.3 million (\$11.2 in 2010), and annualized capital cost of 0.4 to 2 million. Annualized capital costs based on a range in retrofit costs per vessel of \$100,000-\$500,000 for 17 vessels reported in the ARB Ship Survey, a five year life, and 5% discount rate. Emission reductions estimated using the proportion of heavy fuel oil consumption by cruise ships compared to all vessels (~37%) and applying this ratio to total emission reductions from the proposed regulation.



## **L. Analysis of Alternatives**

In this section, we compare the cost-effectiveness of the proposed regulation to two of the four alternative control options discussed in Chapter V. We do not discuss the cost-effectiveness of two additional alternatives discussed in Chapter V because (“Do Nothing” and “Rely on U.S. EPA and IMO Regulations”) because there are no added costs associated with them.

As described below, the two alternatives analyzed would achieve significantly less emission reductions and associated health benefits. However, the cost of these alternatives would also be lower, resulting in similar cost-effectiveness to the proposal.

### Alternative 1: Use Marine Gas Oil at Dockside Only

Under this alternative, ocean-going vessels visiting California ports would only be required to use marine distillate fuels at dockside. The emission reductions under this proposed alternative would be reduced by a minimum of 40 percent compared to the proposed regulation because the emissions from auxiliary engines on vessels at sea within the 24 nm boundary during transit would no longer be controlled. The actual reduction in emission reductions would be greater if auxiliary engines are allowed to transition from one fuel to another at dockside, since such transitions can take an hour or more. The recurring fuel costs associated with the proposed regulation would be reduced proportionally with the reduction in emissions.

The impact of this alternative on modification costs is difficult to estimate. There will probably be some reduction in retrofit costs, particularly with the diesel-electric vessels that would benefit most from this alternative. For example, such vessels may not need an additional tank for storing higher quantities of distillate fuel if the fuel will only be used at dockside. However, given the variabilities involved, we cannot quantify with certainty the reduction in retrofit costs under this alternative. Nevertheless, looking at the overall industry costs, the retrofit costs are relatively small compared to the recurring added fuel costs. Therefore, the overall cost-effectiveness of the alternative is expected to be similar to the proposed regulation.

### Alternative 2: Diesel-Electric Vessels

Under this alternative, diesel electric vessels would have three compliance options: (1) use distillate fuels only at dockside as in Alternative 3 above; (2) use 1.5% sulfur heavy fuel oil within the 24 nautical mile boundary and at dockside; or (3) retrofit vessels to use shoreside electrical power and connect at California terminals where the facilities are available.

Under the first option, the same situation applies as in Alternative 3, except that the option only applies to diesel-electric vessels (primarily cruise vessels). This option

would achieve significantly less emission reductions and the cost would be reduced proportionately. The cost-effectiveness is expected to be similar to the staff's proposal.

For the option to use 1.5 percent sulfur heavy fuel oil, the estimated PM emission reductions are expected to be significantly less (about 18 percent versus 75 percent for staff's proposal). SO<sub>x</sub> emissions would be reduced by about 44 percent versus 80 percent for staff's proposal, and there would be no NO<sub>x</sub> reductions. On the other hand, the cost of the 1.5 percent sulfur heavy fuel is currently much less than marine gas oil. As a result, the cost of this option would be considerably less than the cost associated with staff's proposal. Overall, we expect that the PM cost-effectiveness of this option would be in the same range as the proposed regulation.

The third option, utilizing cold ironing where available is difficult to analyze because vessels modified for cold ironing would only plug into shoreside power if it is available. To date, only a few California port terminals have shoreside power facilities installed. Additional facilities are anticipated at the Ports of Los Angeles, Long Beach and Oakland. However, it will be several years before new additional shoreside power facilities are operational. As a result, we cannot quantify the emissions reductions for this option at this time.

Overall, the emission reductions from any of these options under this alternative would be significantly less than the ARB staff proposal, although the cost-effectiveness would be similar.

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## **IX. ADDITIONAL CONSIDERATIONS**

In this chapter, we discuss additional technical and policy issues that were addressed in developing the proposed regulation for auxiliary engines on ocean-going vessels. These include the impacts on infrequent visitors to California ports, diesel-electric vessels, the over-water boundary covered by the proposal, and the scope of the Alternative Compliance Plan (ACP) provision.

### **A. Ocean-going Vessels that Require Modifications to Comply**

We estimate that a small percentage of vessels will require modifications to comply with the proposed regulation. For example, we estimate that about 5 percent of non-diesel-electric vessels (which make up nearly 98 percent of the vessels visiting California ports) will require retrofits. However, for the minority of vessels that require modifications, the proposed regulation may pose additional challenges. For example, industry representatives have stated that there are a limited number of shipyards available to perform vessel modifications, and it may be difficult to perform the required changes by the January 1, 2007 effective date of the proposed regulation.

In addition, industry representatives have stated that it may be impractical and burdensome to perform vessel modifications on vessels that only occasionally visit California ports. In fact, based on California State Lands Commission data, roughly half of the nearly 2,000 unique vessels that visited California in 2004 only visited once or twice. Although only about 5 percent of these vessels may need modifications, these infrequent visitors that require modifications would still constitute a significant percentage of the overall visits to California ports. Therefore, it is important that these emissions be controlled under the proposed regulation.

To address the above concerns, two options have been included in the Noncompliance Fee Provision as discussed below. Under the Noncompliance Fee Provision, vessel operators can pay a fee in lieu of complying with the emission standard in the proposed regulation. The funds collected would be deposited in an account that would provide resources for port and marine related emission reduction projects. The objective is to reduce equivalent or greater emissions in the same general area more cost-effectively. The fee will be designed to encourage direct compliance with the proposed regulation by ensuring that the use of the provision does not provide an economic advantage relative to the cost of direct compliance with the proposal.

#### Vessels that Cannot Complete Modifications by January 1, 2007

Under this option, vessel operators may pay a noncompliance fee if they can demonstrate that they cannot complete the necessary modifications prior to the January 1, 2007 effective date of the emission limits in the proposed regulation. To utilize this option, vessel operators must submit a "Compliance Retrofit Report," signed by the Chief Engineer of the vessel which identifies the modifications needed to comply

with the proposed regulation, demonstrates that the modifications will be made at the earliest possible date, and provides the date when modifications will be completed.

### Infrequent Visitors that Require Modifications

Under this option, a vessel operator could pay the noncompliance fee in lieu of compliance for a vessel requiring modifications up to a maximum of two California port visits per calendar year, and four California port visits over the life of the vessel (starting on January 1, 2007). The vessel operator must demonstrate that vessel modifications are necessary to comply with the proposed regulation and commit to the visitation limits.

#### **B. Vessel Noncompliance for Reasons Beyond the Reasonable Control of the Vessel Owner/Operator**

In certain limited situations, vessel owners or operators may not be able to comply with the proposed regulation for reasons beyond their reasonable control. Instead of providing an exemption for these situations, staff is proposing to allow use of the “noncompliance fee” provision. The situations where this provision could be utilized include the following:

- the vessel was redirected to a California port and the vessel does not have sufficient quantity of fuel that meets the requirements of the proposal;
- the vessel operator was not able to acquire a sufficient quantity of complying fuel; or
- the fuel was found to be noncompliant in route to a California port.

To utilize this option, vessel operators must demonstrate through adequate documentation that noncompliance resulted from circumstances beyond their reasonable control.

We believe it is important to retain the fee schedule for vessels that do not comply under these circumstances, as opposed to an exemption or variance, to prevent the creation of a loophole in the proposal. In addition, vessel visits occur too quickly to allow for a detailed review of the information necessary to determine whether a variance or exemption is justified.

#### **C. Diesel-Electric Vessels**

Diesel-electric vessels are vessels that use large diesel engines coupled to generators (“gen-sets”) to produce electrical power which propels the vessel and provides ship-board electricity. This is in contrast to typical cargo vessels where a large main engine provides propulsion, and separate smaller diesel gen-sets (“auxiliary engines”) provide electrical power for ship-board uses. The large gen-sets on diesel-electric vessels are defined as “auxiliary engines” in the proposed regulation and thus are subject to the requirements of the proposed regulation the same as the smaller gen-sets on cargo vessels.

Industry representatives have stated that it is inappropriate to regulate the large gen-sets on diesel-electric vessels as “auxiliary engines” because they are used for propulsion as well as ship-board electricity and the costs of the proposal are disproportionately high for diesel-electric vessels. They have also stated that we may inadvertently drive the industry away from cleaner diesel-electric vessels to higher polluting two-stroke direct drive configurations common in most other types of vessels.

Industry representatives have suggested a number of alternative regulatory approaches to address these diesel-electric vessels including the following: (1) limiting the control of these vessels to the portion of power used for ship-board electrical uses (i.e. exempt the portion of power generated for propulsion); (2) limit the requirements of the proposal to dockside operation; and (3) require the use of 1.5 percent sulfur heavy fuel oil instead of the distillate fuels specified in the proposed rulemaking.

Staff believes it is appropriate to control all of the emissions from the large gen-set engines on diesel-electric vessels because the proposal represents a technically feasible and cost-effective means of controlling their emissions. These large gen-set engines are mechanically similar to the smaller auxiliary engines. Specifically, both engines are four-stroke, medium speed engines, and both are used in generator set applications. We are not addressing the main engines in other types of vessels because they are predominantly two-stroke engines that are mechanically very different, and because the use of marine distillate fuels in these engines introduces additional challenges compared to four-stroke medium speed engines. We plan to address main propulsion engines in future efforts.

We agree that the added cost on the operators of diesel-electric vessels will be significantly higher than for operators of other vessel types. Specifically, because the gen-sets on diesel-electric vessels are used for propulsion as well as ship-board electrical uses, the amount of fuel used in these engines is much greater and the impact of using the distillate fuels specified in the proposal would be proportionately higher. However, as explained in Chapter VIII, Economic Impacts, the impacts on operators of these vessels are not expected to result significant adverse impacts on their profitability, and the control of these vessels is equally cost-effective compared to other vessels because the emission reductions increase commensurately with the cost.

We do not believe that the proposal will lead the industry away from diesel-electric vessels. As mentioned above, we plan to address the emissions from the main engines not covered by the proposed regulation at a later date. In addition, as discussed in Chapter VIII, the added cost resulting from the proposed regulation is generally a small percentage of vessels’ overall operating costs. Finally, diesel-electric vessels have advantages that were considered in the design of vessel and its intended function. For example, cruise vessels sometimes operate at less than maximum speed and can run more efficiently by operating some (but not all) of their gen-sets at relatively high loads where they are more fuel-efficient, as opposed to running a single large engine at a less

fuel efficient load. In addition, diesel-electric vessels generally have several gen-sets which provide for redundancy in the case of an engine failure.

#### **D. Scope of the Alternative Compliance Plan**

The Alternative Compliance Plan (ACP) was included in the proposed regulation to allow vessel owner/operators with the flexibility to implement alternative emission control strategies that achieve equivalent or greater emission reductions than the fuel requirements specified in the proposal. Alternative emission control strategies may include the use of shore-side electrical power, engine modifications, exhaust treatment devices such as diesel oxidation catalysts, the use of alternative fuels or fuel additives, and operational controls such as limits on idling time.

As proposed, the ACP allows a company with a fleet of vessels to average its auxiliary engine emissions over all the vessels in the fleet such that the total emission reduction achieved is equivalent to or greater than the emission reductions that would have occurred if all these vessels complied with the fuel provisions in the proposal. For example, a company with a vessel that frequently visits California ports could achieve greater emission reductions than required on that vessel to offset higher emissions from one or more other vessels. However, the ACP does not allow inter-fleet averaging (i.e. averaging among the fleets of two different companies). The ACP provision also does not allow emission reductions from main engines, or other sources not classified as vessel auxiliary engines. We believe this limitation is necessary to ensure that the complexity of the program will not adversely affect the ability of ARB staff to ensure ongoing compliance under an ACP. In addition, limiting the provision to auxiliary engines will ensure that emission reductions achieved farther offshore are not traded for fewer reductions close to shore, where diesel PM emission reductions are most critical to reducing the potential cancer risk.

#### **E. Enforcement of the Proposed Regulation**

Enforcement of this regulation will be achieved through random inspections of records and fuel sampling/testing. Specifically, records will be inspected to determine when vessels were traveling within “Regulated California Waters” and what fuel was used during this time. Records on quantity of fuel purchased, the fuel type, and the sulfur content of the fuel will be reviewed to determine compliance. As appropriate, fuel sampling will be conducted during the vessel inspection. Fuel samples will be analyzed to ensure that they meet the ISO specifications for the fuel type and do not exceed the sulfur content limits under ISO or the regulation.

Given the large number of vessels and relatively lengthy inspection time per vessel, we envision using vessel visit data to prioritize inspection resources. One approach will be to focus on the vessels that are the most frequent visitors to California ports. Inspection priority could also be directed to vessels that are complying using an alternative compliance plan.

As a long term goal, ARB staff would like to transition from compliance data being recorded in logs maintained on the vessel, to automated electronic data devices that can store and transmit data needed to assess compliance. We are aware of technology that potentially would allow continuous monitoring of key parameters such as fuel flow and vessel positions. This information could be recorded in a data logger. Such information could be accessed during an inspection or transmitted to a shore-based receptor.

ARB staff plans to work with vessel owners and equipment suppliers to develop and field test data recording and submittal systems that can provide compliance data on a real-time basis.