California Environmental Protection Agency

AIR RESOURCES BOARD

INITIAL STATEMENT OF REASONS FOR PROPOSED RULEMAKING

FUEL SULFUR AND OTHER OPERATIONAL REQUIREMENTS FOR OCEAN-GOING VESSELS WITHIN CALIFORNIA WATERS AND 24 NAUTICAL MILES OF THE CALIFORNIA BASELINE

Stationary Source Division
Emissions Assessment Branch

June 2008

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State of California
AIR RESOURCES BOARD

STAFF REPORT: INITIAL STATEMENT OF REASONS FOR PROPOSED RULEMAKING

Public Hearing to Consider

ADOPTION OF THE PROPOSED REGULATION FOR FUEL SULFUR AND OTHER OPERATIONAL REQUIREMENTS FOR OCEAN-GOING VESSELS WITHIN CALIFORNIA WATERS AND 24 NAUTICAL MILES OF THE CALIFORNIA BASELINE

To be considered by the Air Resources Board on July 24-25, 2008, at:

California Environmental Protection Agency
Headquarters Building
1001 “I” Street
Byron Sher Auditorium
Sacramento, California

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State of California
AIR RESOURCES BOARD

PROPOSED REGULATION FOR FUEL SULFUR AND OTHER OPERATIONAL REQUIREMENTS FOR OCEAN-GOING VESSELS WITHIN CALIFORNIA WATERS AND 24 NAUTICAL MILES OF THE CALIFORNIA BASELINE

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EXECUTIVE SUMMARY

Air pollution from international trade and goods movement activities in California is a major public health concern at both regional and community levels. The diesel-powered vehicles and engines used to transport goods emit soot, or diesel particulate matter (PM), and other air pollutants that can increase health risks to nearby residents. Goods movement activities are also a significant source of sulfur oxides (SOx) and oxides of nitrogen (NOx) which can contribute to the formation of regional smog and fine particulate matter.

As one of many steps being taken to reduce emissions from goods movement activities, the Air Resources Board (ARB) staff is proposing a fuel quality regulation[1] to reduce emissions from ocean-going vessel auxiliary diesel and diesel-electric engines, main propulsion engines, and auxiliary boilers (OGV engines and auxiliary boilers). This proposed regulation is a key element of ARB's Diesel Risk Reduction Plan and Goods Movement Emission Reduction Plan (GMERP) and is essential to reducing exposures to PM emissions both regionally and in communities near maritime ports. (ARB, 2000; ARB, 2006a). Two recent health risk assessments by ARB staff have shown that diesel PM emissions from ocean-going vessels are one of the largest contributors of toxic pollutants and diesel PM in neighboring communities. (ARB, 2006b; ARB, 2008) The proposed regulation would reduce the emissions of diesel PM, PM, NOx, SOx, and "secondarily" formed PM (PM formed in the atmosphere from NOx and SOx) by requiring the use of cleaner marine distillate fuels in OGV engines and auxiliary boilers.

The proposed regulation would require both domestic and foreign flagged ocean-going vessels to use less polluting marine distillate fuel instead of heavy fuel oil when visiting California ports. The fuel requirement would be implemented in two phases with progressively more stringent fuel sulfur levels. Upon implementation of the Phase I requirement in 2009, there would be an immediate and substantial reductions in emissions. Specifically, for vessels currently using heavy fuel oil in their OGV engines and auxiliary boilers, we estimate a 74 percent reduction in PM (diesel PM and directly emitted PM from auxiliary boilers), 81 percent reduction in SOx, and 5 percent reduction in NOx. Compliance with Phase 2 in 2012 will result in an additional 9 percent reduction in PM and an additional 14 percent reduction in SOx. Overall, this translates into emission reductions of about 13 tons per day of PM statewide in 2010 and 15 tons per day in 2012.

This action will significantly reduce potential cancer risks in communities near ports. It will also reduce statewide premature deaths due to exposure to directly emitted particulate matter air pollution from OGV by 75 percent in 2010 and by 80 percent in 2012. Reductions in directly emitted PM alone would result in an estimated 2,000 fewer premature deaths in California between 2009 and 2015. In addition, the reductions in

[1] Two essentially identical regulations are being proposed to reflect the authorities granted to the ARB in the California Health and Safety Code to regulate sources of toxic air contaminants and to regulate marine vessel emissions. Throughout this report the regulations are collectively referred to as "the regulation."

diesel PM, PM, SOx and NOx will help ensure further progress towards achieving California's PM and ozone air quality goals.

In 2005, the ARB approved the Auxiliary Engine Regulation that, beginning on January 1, 2007, effectively required cleaner marine distillate fuels to be used in OGV auxiliary engines visiting California. Due to a successful legal challenge of that regulation as a preempted emissions standard, enforcement of the Auxiliary Engine Regulation was suspended in May 2008, and cannot resume until ARB obtains approval, called an authorization, from the United States Environmental Protection Agency (U.S. EPA) to implement state level emission standards under the Clean Air Act. Given the generally lengthy time and uncertainty involved in obtaining U.S. EPA approval of waiver and authorization requests, staff is proposing to incorporate requirements for the fuel used in auxiliary engines into this proposed regulation. Because California can implement fuel-only requirements without an authorization, this approach will address the courts' findings and allow implementation of the cleaner fuel-use requirements for auxiliary engines once again.[2]

Prior to the court ruling that an authorization was required, the Auxiliary Engine Regulation was successfully implemented for over 14 months demonstrating that the use of cleaner marine distillate fuels is feasible and that it does not impose undue burdens on the shipping industry. In fact, there are vessel operators who have said that they will continue to voluntarily comply with the suspended regulation. The proposed regulation for OGV main engines and auxiliary boilers builds on the auxiliary engine experience by requiring all OGV engines and auxiliary boilers to use the same low sulfur marine distillate fuel. Incorporating requirements for auxiliary engines, main engines, and auxiliary boilers into one rule will ensure that there are consistent requirements for all OGV engines and auxiliary boilers. This will help provide vessel operators, fuel producers, and fuel providers with certainty in what fuel needs to be provided and by when. Staff believes that this certainty will assist in implementation and enforcement, maximize the emission reduction benefits, and minimize the burden on OGV vessel operators.

While ARB has the authority to regulate ocean-going vessel emissions, we recognize that uniform national or international regulation of vessel emissions at an appropriate stringency level would be preferable, both to the ARB and to most vessel operators. This past year there has been positive movement at the International Maritime Organization (IMO) to strengthen international standards that would greatly reduce emissions from ships. While the final fuel sulfur limits being considered at IMO for

[2] On its face, the Auxiliary Engine Regulation was held to constitute an emissions standard that was preempted under section 209(e) of the Clean Air Act (CAA). ARB legal staff is therefore drafting a request for authorization for the suspended regulation under CAA section 209(e). The Auxiliary Engine Regulation can be found at title 13, California Code of Regulations (CCR), section 2299.1 "Emission Limits and Requirements for Auxiliary Diesel Engines and Diesel-Electric Engines Operated on Ocean-Going Vessels within California Waters and 24 Nautical Miles of the California Baseline" and the identical section title 17, CCR, section 93118 "Airborne Toxic Control Measure for Auxiliary Diesel Engines and Diesel-Electric Engines Operated on Ocean-Going Vessels within California Waters and 24 Nautical Miles of the California Baseline."

emission control areas (ECAs) mirror our proposed fuel sulfur levels, under the current proposal they could not be implemented until 2015 at the earliest. Given the large health impacts attributable to ship emissions, California cannot wait until 2015 to reduce emissions from OGV and we are proposing to act much sooner. However, to help California transition to national or international controls once they are established, the proposed regulation includes a provision that requires the Executive Officer to propose terminating or modifying the requirements of this proposal to the Board if the U.S. EPA or the IMO adopts regulations that will achieve equivalent benefits.

Presented below is an overview that 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?

ARB staff is proposing a regulation to require operators of OGVs to use cleaner-burning marine distillate fuels in auxiliary diesel and diesel-electric engines, main propulsion engines and auxiliary boilers (OGV engines and auxiliary boilers) on vessels operating within a 24 nautical miles (nm) zone of the California coastline (Regulated California Waters). Unless vessel operators already use complying distillate fuels or choose to use distillate fuels on a permanent basis, they will need to switch from the use of heavy fuel oil to compliant marine distillate fuel prior to entering Regulated California Waters (RCW). The proposed regulation will apply to both U.S.-flagged and foreign-flagged vessels. The proposed regulation is implemented in two steps beginning in 2009 and requiring progressively more stringent fuel sulfur levels again in 2012. The proposed regulation would establish the most comprehensive and stringent marine fuel-use requirements for OGVs in the world.

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&S) sections 43013 and 43018 authorize ARB to regulate marine vessels to the extent such regulation is not preempted by federal law. Also, H&S section 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 PM, NOx and SOx, which are criteria pollutants.

The proposed regulation is neither preempted under federal law, nor does it violate the dormant Commerce Clause of the U.S. Constitution. 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, rather than an emissions standard, because it does not apply a numerical emissions limit to be met (e.g., 10 grams NOx per brake horsepower-hour), does not require retrofits, or mandate design changes to the vessel. Rather, the regulation only requires that specified fuels be used on OGV engines and auxiliary boilers operating in Regulated California Waters.

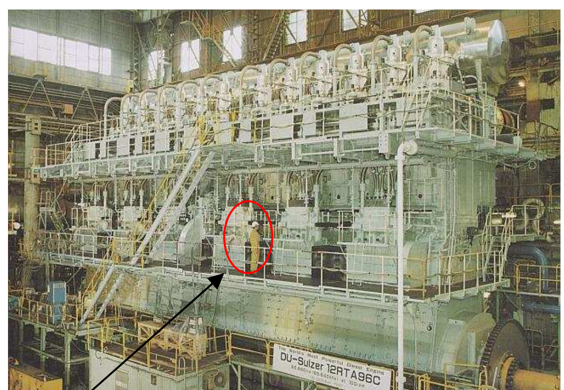
Further, the proposed regulation does not conflict with the Ports and Waterways Safety Act (PWSA) and U.S. Coast Guard regulations. As a nondiscriminatory[3] regulation with substantial benefits, the proposed regulation does not violate the dormant Commerce Clause. And, federal and state cases support our assertion of authority to regulate both U.S. and foreign-flag vessels within the regulated California waters. Therefore, federal law does not preempt or otherwise prohibit the proposed regulation and its application in the waters off California's coast.

3. What is an ocean-going vessel?

Ocean-going vessels are 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.

4. What is a main propulsion engine?



Marine Engineer

Main propulsion engines are diesel engines on ocean-going vessels that provide power for propulsion (except as noted below for diesel-electric vessels). Typically, a cargo vessel will have a single, very large, two-stroke main engine used for propulsion, and several smaller auxiliary "generator-set" engines. Passenger cruise vessels, and some tankers, use a different engine configuration that is referred to as "diesel-electric." These vessels use large four-stroke diesel generator sets to provide electrical power for both propulsion and ship-board electricity.

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[3] The proposal treats regulated vessels equally, irrespective of whether they are based in California or not and whether they are U.S.-flagged or foreign-flagged.

Main engines on OGVs are designed to propel very large vessels. Not surprisingly, the engines themselves are also very large. For example, a nine cylinder K98MC-C MAN engine produces about 40 megawatts (MW), enough energy to power 30,000 houses for a year. The 65 feet long by 60 feet high engine is as tall as a 5-story building, weighs about 1,500 tons, and costs about 15 million dollars.

5. What are auxiliary engines?

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). They are generally four-stroke diesel engines that are smaller than the main engines. Most OGVs have more than one auxiliary engine. 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.

Passenger cruise vessels, and some tankers, use a different engine configuration that 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” because they are physically similar to auxiliary engines.

6. What is an auxiliary boiler?

Auxiliary boilers are fuel-fired combustion equipment designed primarily to produce steam for uses other than propulsion, such as heating of residual fuel and liquid cargo, heating of water for crew and passengers, powering steam turbine discharge pumps, freshwater generation, and space heating of cabins. Boilers used to provide propulsion (steam ships) are not included in the proposed regulation because there are very few steamships still in service.

7. What fuels do ocean-going vessel operators use in OGV engines and boilers?

Most vessel operators use heavy fuel oil (HFO or residual fuel) in their main propulsion engines and auxiliary boilers. 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 of PM and SOx 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, the majority of vessels calling California use HFO in their main engines and auxiliary boilers.

Prior to implementation of the Auxiliary Engine Regulation in 2007, 75 percent of vessels used HFO in their auxiliary engines. The remaining 25 percent used marine distillate fuels in their auxiliary engines. (ARB, 2005) During the 14 months that the Auxiliary Engine Regulation was in effect, vessels using HFO when visiting California switched to using marine distillate fuels in their auxiliary engines. Since the Auxiliary Engine Regulation was suspended in May 2008, we believe many vessel operators have switched back to using HFO in their auxiliary engines, but we are unsure of the exact number. However, two major vessel operators, Maersk and APL, have publically stated that they will continue to use marine distillate fuel in their auxiliary engines.

8. What emissions result from the main engines and auxiliary boilers used on ocean-going vessels?

The 2006 estimates of the statewide emissions of PM, NOx, SOx, carbon monoxide (CO), carbon dioxide (CO_2) and reactive organic gases (ROG) from OGV are presented in Table ES-1 below. These estimates include emissions that occur within the 24 nm zone of the California coast. Emissions that occur in California inland waters such as emissions from ocean-going vessels transiting to the ports of Stockton and Sacramento are also included in the estimate.

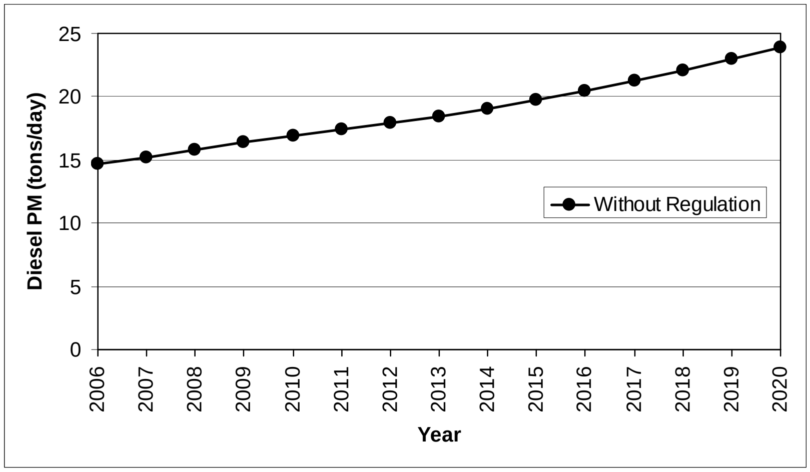
Table ES-1: 2006 Ocean-Going Vessel Emissions (tons/day) in California (24 nm zone)

Vessel Type	Vessels	Port Calls	PM_{10}	$PM_{2.5}$	SO_x	NO_x	CO	CO_2	ROG
Auto	234	1006	0.6	0.6	4.6	7.3	0.6	288	0.3
Bulk	475	983	0.7	0.7	5.1	7.9	0.6	323	0.3
Container	593	5038	8.4	8.1	60.1	94.2	7.7	3818	3.7
Cruise	52	770	1.2	1.1	9.0	12.0	0.9	616	0.4
General	147	371	0.3	0.3	2.1	3.3	0.3	133	0.1
Reefer	68	315	0.2	0.2	1.7	2.2	0.2	111	0.1
Ro-ro	28	112	0.1	0.1	0.5	0.7	0.1	31	0.0
Tanker	458	2391	3.2	3.1	34.1	29.5	2.4	2082	1.2
Total	**2055**	**10986**	**15**	**14**	**117**	**157**	**13**	**7402**	**6**

As shown in Table ES-1, there are over 2,000 ocean-going vessels that visited California's ports in 2006, and these vessels made nearly 11,000 port calls. Of those 2,000 vessels that visited California's ports, 30 percent were container vessels, and these vessels were responsible for more than 45 percent of the total port calls at 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. As shown, OGV emissions will increase by about 60 percent in 2020 if left uncontrolled, relative to 2006 levels.

Figure ES-1: Ocean-Going Vessel Emissions Estimates Projected to Year 2020 (24 nm zone)

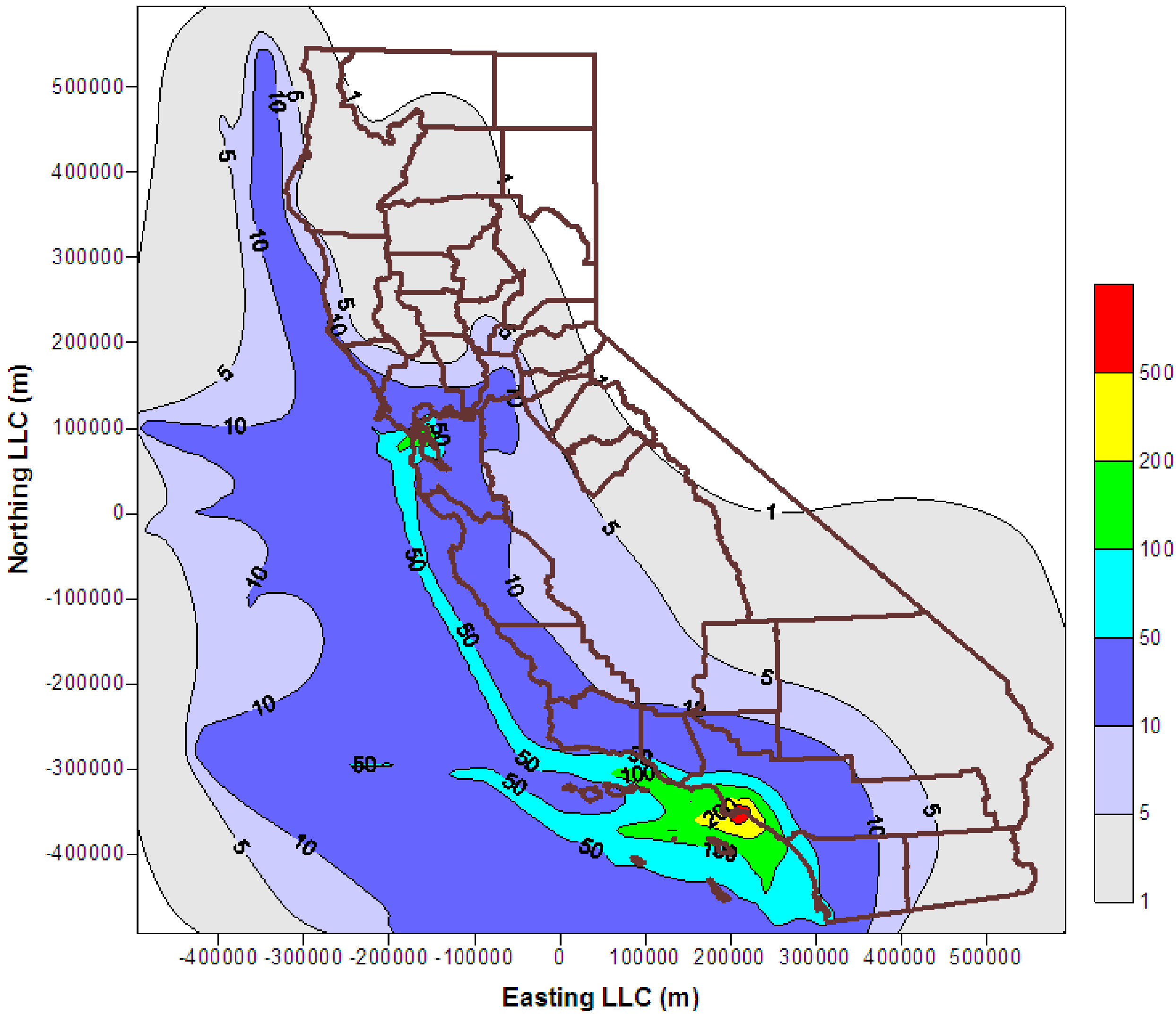


9. What are the exposures and potential health risks from ocean-going vessel emissions?

Most California ports and major shipping lanes are in or near urban areas and are located near where people live, work, and go to school. The operation of OGV results in substantial public exposures to PM and diesel PM emissions. Exposure to these emissions can result in increased cancer risk and non-cancer health impacts, such as premature mortality, PM-related cardiovascular effects, chronic bronchitis, asthma, and hospital admissions for pneumonia and asthma-related conditions. Staff generally uses potential cancer risk as an indicator of the severity of the impacts of diesel PM emissions on people living near the emission source. Estimates of premature deaths are generally used as an indicator of the severity of noncancer impacts due to PM emissions on a regional or statewide basis.

At the community level, OGV emissions also result in significant localized potential cancer risks. Using the recent health risk assessment work done in the West Oakland community, staff estimates that the potential cancer risk in the West Oakland community from OGVs operating in the San Francisco Bay is about 150 chances per million. This is about 12 percent of the estimated potential cancer risk in the West Oakland community due to all sources of diesel PM. At the statewide level, OGV emissions impact most Californians. Based on a modeling analysis done as part of this regulation development, staff determined that about 27 million people are exposed to OGV diesel PM emissions resulting in potential cancer risk levels of 10 chances in a million or greater. And, about 2.4 million people are exposed to potential cancer risk levels greater than 200 chances in a million due to diesel PM emissions from OGV (Figure ES-2).

Figure ES-2: Statewide Potential Cancer Risk Resulting from OGV Diesel PM (2005 Baseyear)



Direct PM emissions from OGV also result in significant contributions to noncancer health effects, including premature death. Statewide, staff estimates that in 2005, directly emitted PM from OGV results in:

- 300 premature deaths (80 – 510, 95% confidence interval (CI))
- 7,700 cases of asthma-related and other lower respiratory symptoms (3,000 – 12,500, 95% CI)
- 50,000 work loss days (43,000 – 58,000, 95% CI)
- 300,000 minor restricted activity days (241,000 – 351,000, 95% CI)

These are annual values and, as the emissions in OGV continue to grow unabated, each year the noncancer health impacts due to OGV emissions are expected to increase. If left uncontrolled, we estimate that in 2015, the number of premature deaths statewide due to OGV directly emitted PM emissions would be greater than 400. As mentioned, these are the noncancer health impacts due only to directly emitted PM. Impacts from secondary PM formed from SOx and NOx emissions have been quantified for the South Coast Air Basin and are discussed later in this report.

10. What are the key compliance requirements and dates in the proposed regulation?

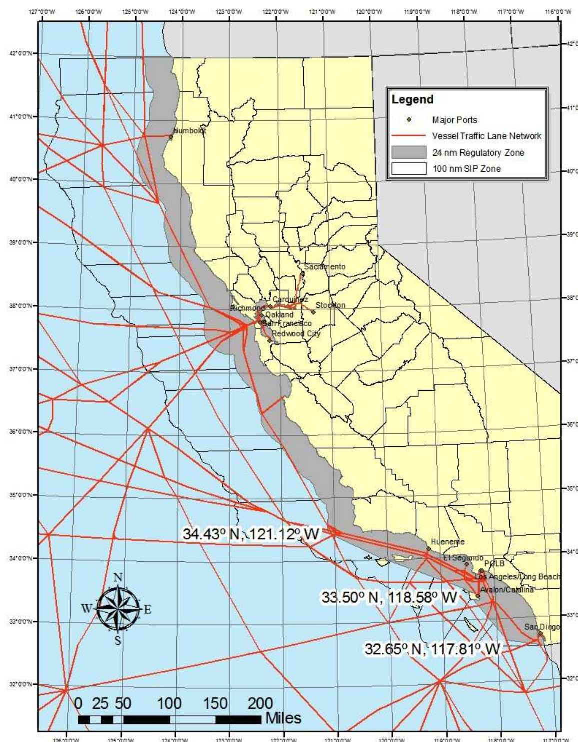
Under the proposed regulation, vessel operators would be required to use cleaner-burning marine distillate fuels in their auxiliary and main engines and in their auxiliary boilers when operating within the California 24 nautical mile (nm) zone. Phase 1 would require vessel operators to use either marine gas oil (MGO), which typically averages 0.3% sulfur and is capped at 1.5% or marine diesel oil (MDO) with a sulfur limit of 0.5% or less when operating their engines and boilers within the 24 nm zone. For auxiliary engines, Phase 1 would begin on the effective date of the regulation (normally 30 days after approval by the Office of Administrative Law). For main propulsion engines and auxiliary boilers, Phase 1 would begin July 1, 2009.

Phase 2 would require OGV operators to use either MGO meeting a 0.1% sulfur limit or MDO meeting a 0.1% sulfur limit in their auxiliary and main engines and auxiliary boilers when operating within the 24 nm zone. Phase 2 would begin January 1, 2012 for auxiliary and main engines and auxiliary boilers.

We recognize that most vessel operators would prefer uniform national or international regulation of vessel emission. So, we have included a provision in the proposed regulation that requires the Executive Officer to propose terminating or modifying the regulation if the U.S. EPA or the IMO implements regulations that will provide equivalent benefits to California citizens.

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

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



Under the proposed regulation, vessel operators would be required to use cleaner marine distillate fuels when operating in the 24 nm zone off the California baseline. The 24 nm zone boundary is shown as the gray area in Figure ES-3. Staff has proposed this 24 nm zone because it captures a large majority of the vessel emissions affecting the most heavily populated portions of California, it is consistent with the regulatory boundary selected for the previously adopted Auxiliary Engine Regulation, it minimizes the need for on-board tankage modifications to comply with the in-use fuel requirement, and it reduces fuel availability concerns. This boundary also reduces the cost of the regulation while still providing significant on-shore benefits in terms of reduced exposure to diesel PM. Approximately 68 percent of the PM emissions from OGV engines and auxiliary boilers occurring within 100 nm of the California coastline are emitted within the 24 nm boundary. The 24 nm boundary is also easily defined for vessel operators and is noted on most nautical charts. The boundary is aligned in Central and Northern California with the outer boundary of the Contiguous Zone, an internationally recognized boundary which extends approximately 24 nm out from the California coastline with a “bubble” that extends about 45 nm beyond the Golden Gate Bridge around the Farallon Islands. But, in Southern California, the boundary consists of straight line segments approximately 24 nm offshore of the mainland coastline. This approximation is used because the outer edge of the Contiguous Zone extends around the Channel Islands, up to 90 nm offshore the California coastline.

12. Are there potential benefits to extending the regulatory boundary farther offshore?

ARB staff has conducted detailed modeling and health risk assessments at California’s major ports demonstrating the impacts of OGV emissions that occur within 100 nm on onshore air quality and public health. Based on the current emissions inventory, which estimates that approximately 68 percent of the emissions that occur within 100 nm are released within the 24 nm zone, ARB staff believes that this boundary will achieve a large portion of the heath and environmental benefits that can be realized from a fuel sulfur control program. Setting the boundary at 24 nm also improves the ability of the shipping industry to procure and store the needed fuel supplies and comply in the timeframes required, and reduces the cost of the proposal. However, ARB staff believes that additional modeling and analysis may support setting boundaries farther offshore to realize additional health and environmental benefits. Analysis of other pollutants may also support a larger control area. Most of ARB's modeling efforts have focused primarily on directly emitted PM. However, other pollutants, such as NOx, SOx, and hydrocarbons, are involved in complex atmospheric reactions and can have impacts far from where they were released. For example, NOx and SOx can be converted to sulfate and nitrate-based PM. We believe that further study and modeling will help to determine whether boundaries farther offshore are appropriate considering these effects. We believe that these analyses are best conducted in conjunction with U.S. EPA as part of the application process for a Sulfur Emission Control Area (SECA) under current IMO MARPOL Annex VI protocols, or pending amendments that would create a similar process for Emission Control Areas (ECA).

13. Are the fuels specified in the proposed regulation available?

Yes. It is important that these fuels are or will be available at ports where California-bound vessels refuel. This is because vessel operators will need to use the marine distillate upon entering the 24 nm zone off California's coastline. The fuels specified for Phase 1, are MDO meeting a 0.5% sulfur limit or MGO.

MGO is widely available at ports worldwide. We are not proposing a sulfur limit for MGO, below the maximum allowed by specification (1.5% sulfur), because some foreign ports only have higher sulfur MGO available (i.e. higher than 0.5%). And with the proposals initial compliance date in 2009, ARB staff has concerns that there would not be sufficient time or incentive for fuel refiners and suppliers worldwide to provide very low sulfur MGO at all bunkering ports. However, we expect the average sulfur content of the MGO used in vessels visiting California ports to average at or below 0.3% sulfur, based on the results of the worldwide fuel sample data for 2007.

To provide additional flexibility to vessel operators, we are also allowing the use of MDO. This fuel tends to have slightly higher sulfur content than MGO, so we are limiting the use of this fuel to 0.5% sulfur. Vessel owners can choose between using MDO that meets the 0.5% sulfur limits or MGO that meets the allowable IMO specification limit.

Beginning January 1, 2012, Phase 2 would require the use of MGO or MDO, both meeting a 0.1% sulfur limit. While neither fuel with this sulfur content is currently available at all ports where California-bound vessels refuel, we believe they will become more readily available after 2010. As, the global trend toward lower sulfur fuels continues to expand, fuel suppliers will have more fueling infrastructures that will be capable of delivering the lower sulfur fuels.

14. What provisions are included in the proposed regulation if the specified fuels are not available at key fueling ports?

In the unlikely event a vessel operator cannot obtain the required fuel prior to coming to California, the proposed regulation includes a provision that allows the operator to pay a noncompliance fee subject to specified conditions. This is discussed in more detail in Question 15. Despite this provision, we do not anticipate extensive use of this fee, particularly during Phase I of the regulation. This is because MGO, and MDO with no more than 0.5% sulfur, are widely available at fueling ports throughout the world.

Our experience with implementing the Auxiliary Engine Regulation during 2007 and 2008 showed that very few vessel operators needed to use the noncompliance fee provision. Over the 14 months that the Auxiliary Engine Regulation was implemented, vessel operators paid a noncompliance fee only six times out of the estimated 13,000 vessel visits in California. Based on this experience we believe it is reasonable to expect the same outcome for Phase 1 of this proposal.

In contrast to Phase I, there is greater uncertainty of the worldwide availability of 0.1% sulfur MGO and MDO, either of which vessel operators will be required to use in California waters under Phase 2 starting on January 1, 2012. Because of this, we are proposing to include a provision to address the situation where 0.1% sulfur MGO or MDO is not available for an individual vessel on a specific voyage to California. Under this provision, the noncompliance fee will be waived for one vessel visit each calendar year until December 31, 2014. To use this provision, the vessel operator must acquire compliant fuel at the first California port visited on a voyage and use that fuel for the remainder of the voyage within the 24 nm zone. In addition, the vessel must be operated on either MGO or MDO (MDO has a sulfur limit of 0.5%) during the noncompliant, incoming portion of the voyage. This provision provides the vessel operator the option of purchasing compliant fuel in California if it was not available at other ports outside California.

15. What other provisions are included in the proposed regulation to accommodate special circumstances?

The proposed regulation exempts the master of the vessel from complying with the fuel sulfur and other specified requirements if the master determines that compliance would endanger the safety of the vessel, its crew, its cargo or its passengers because of severe weather conditions, equipment failure, fuel contamination, or other reasons beyond the master's reasonable control. It is important to note that, over the 14 months that the Auxiliary Engine Regulation was enforced, only 1 vessel operator requested the safety exemption. In this case, the vessel operator purchased fuel that when tested, did not meet the flashpoint specification for marine distillate fuels.

As noted, the proposed regulation also contains a Noncompliance Fee Provision that provides vessel operators with the flexibility to pay a fee in lieu of direct compliance with the fuel-use requirement in certain limited circumstances. We have designed the fees such that they do not confer an economic advantage to participants relative to vessel operators who use the specified low sulfur fuels. This was achieved by graduating the fee schedule so that subsequent visits necessitating payment of the fees would result in substantially increasing fees.

This option can only be used when the vessel:

- is unexpectedly redirected to a California port;
- was not able to acquire a sufficient quantity of compliant fuel at the last fueling port;
- acquired fuel that was later found to be out of compliance after leaving the last bunkering port; or
- needs modifications and the modifications cannot be made prior to the effective date of the regulation or the vessel will make no more than four California port visits over the life of the vessel (after the regulation goes into effect).

The proposal also includes a provision for those relatively rare instances when a vessel, for unusual reasons, cannot use the specified low sulfur distillate fuels without essential modifications to the vessel. This provision provides an exemption from the fuel use requirement provided certain criteria are met. This provision will sunset December 31, 2014.

16. Will ocean-going vessels need to make modifications to comply with the proposed regulation?

We do not believe many vessels will need to make modifications to use the distillate fuels. OGV engines and boilers are designed to be able to use marine distillate and all vessels have some fuel storage dedicated to marine distillate. However, some vessel operators may choose to make modifications to provide for a more convenient fuel-switching operation since fuel-switching will occur more frequently than what is traditionally done. There may also be a small number of vessels, due to longer routes within the regulated zone or nonstandard tankage or fuel system designs, that may need to make modifications to comply with the proposal.

For the following reasons, we think in most cases modifications will not be necessary in most cases to comply with the in-use fuel requirement:

- All ocean going vessels already have the capability to store and use marine distillate fuels in their main engines and auxiliary engines. Current standard practice for vessel operators is to use marine distillate fuels to operate the main engine and auxiliary engines prior to going into dry-dock, prior to other large scale engine work, to assist with engine emergencies, and to comply with environmental regulations and programs such as port-lease requirements, California’s Auxiliary Engine Regulation (suspended), and company voluntary environmental initiatives.

- Maersk, the world's largest shipping line, has reported that no capital investments were necessary to implement their voluntary program to use low-sulfur marine distillate fuel in the main engines of their vessels that visit California. Over a period from April 2006 to early 2008, Maersk vessels made over 517 fuel switches on over 105 different vessels with a variety of main engine makes, models and ages, and did not make any capital investments for ship modifications.
- For the Auxiliary Engine Regulation, the Pacific Merchant Shipping Association has stated in legal filings documents that none of their members' vessels needed modifications to comply with that regulation.
- In responding to an ARB survey conducted in 2007, some vessel operators reported that vessel modifications would be needed if marine distillate was required to be used in the main engine. However, based on additional evaluation of the responses and follow-up contacts, staff concluded that most vessels would not have to make modifications to use of the cleaner marine distillate fuels within the 24 nm regulated zone.
- Many shipping companies charter vessels from the world-wide fleet of over 40,000 vessels and can minimize the need for modifications by chartering vessels or rerouting vessels to California that do not need modifications to use the cleaner marine distillate fuel.

17. Is the proposal technically feasible?

Yes. Based upon ARB staff's analysis and discussions with numerous stakeholders, including the engine and auxiliary boiler manufacturers, staff believes that the requirements of the proposed regulation are technically feasible and achievable in the timeframes provided. Under the proposal, vessel operators will comply by using cleaner-burning marine distillate fuels in their OGV engines and auxiliary boilers instead of heavy fuel oils.

To meet the fuel requirements, vessel operators will need to ensure that they are using compliant marine distillate fuels prior to entering the 24 nm zone. In Phase 1, MGO or MDO at 0.5% sulfur or less would be required beginning in 2009. Staff found that fuel meeting the Phase 1 requirements is readily available at ports serving vessels coming to California. Staff found that technical issues including fuel viscosity/lubricity, lube oil compatibility, fuel switching, and fuel system leaks are manageable if attention is paid to fuel specification, engine and fuel system maintenance, and crew training. Furthermore, the 14 months of experience implementing the Auxiliary Engine Regulation provides additional evidence that the Phase 1 requirements are technically feasible.

In Phase 2, MGO or MDO (both having to meet a 0.1% sulfur limit) is required beginning in 2012. While fuel meeting the Phase 2 requirements is not currently available at the all the key ports serving vessels coming to California, we see this situation as improving over the next few years. We believe that by 2012, 0.1% sulfur MGO or MDO will be more readily available at ports serving vessels traveling to California. Staff believes that the technical issues associated with 0.1% sulfur distillate are somewhat more pronounced than with Phase 1 distillate fuel. However, it is not clear if the technical issues are a result of lack of experience using the low sulfur fuel, the result of very low sulfur on-road diesel being used in marine applications, or the result of the sulfur content of the marine distillate being further reduced. We believe that the three year lead time before implementing Phase 2 requirements will provide sufficient time to identify and find solutions to the technical challenges associated with using 0.1% sulfur distillate.

18. Why is it important to have a two-phase implementation process?

We are proposing a two-step phase in of the fuel requirements to address a number of potential technical and safety issues. The requirement to use cleaner marine distillate in engines that have been designed to operate on heavy fuel oil present a number of significant challenges to the shipping industry. These challenges fall primarily into two areas: fuel management challenges to maintain the sulfur limits of the fuel and operational challenges.

Fuel management challenges come from procuring and maintaining fuel cleanliness with respect to the lower fuel sulfur limits. Cross contamination can occur both in the fuel delivery system and vessel fueling system. The bunkering industry has been providing heavy fuel oil, with sulfur levels in the 3 to 4% range. This proposal would require distillates in the 0.1 to 1.5% range. The challenges in both the procurement and on-board fuel management are significant for the vessel operators. Since OGV are not likely to be operated entirely on distillate fuel due to the significant cost differential between HFO and marine distillates, the on-board fuel management challenge is compounded by the potential for cross-contamination associated with storing and operating on two different fuels.

Operational challenges stem from running engines, designed to operate primarily on HFO, on a cleaner marine distillate that has very different physical properties than HFO. These differences include much lower viscosity and potentially lower lubricity. Because of the significant operational challenges, a number of stakeholders, including some shipping companies and the United States Coast Guard, recommended phasing in the fuel sulfur levels to reach the 0.1% sulfur marine distillate. During Phase 1, either MGO, typically below 0.5% sulfur and capped at 1.5% sulfur, or MDO, at or below 0.5%, is required. Maintaining the Phase 1 sulfur levels in both the delivery and on-board fuel delivery system will be somewhat easier to manage than the lower Phase 2 level, thus allowing the operators to focus on the operational challenges of using the distillate fuel in engines designed for heavy fuel oil. Because the sulfur levels are not as restrictive, the operators will have more flexibility in specifying viscosity levels when purchasing the fuel and may not have the possible lower lubricity issues that have been observed, to a very limited extent, in the very low sulfur distillate fuels.

Staff evaluated the trade-off between allowing the phase-in approach compared to requiring 0.1% sulfur level fuel in the first phase. Because the worldwide average sulfur content of marine distillate is about 0.3%, the distillate fuels used in Phase 1 are expected to have much less sulfur than the 1.5% sulfur specification for MGO. Inspection results from the Auxiliary Engine Regulation have substantiated this finding showing that marine distillate fuels used to comply with similar fuel requirements were 0.3% sulfur, on average. Finally, staff believes that the small differences in reductions by having a phase-in requirement will be mitigated by providing the flexibility to the operators to successfully address the technical challenges presented by this proposed regulation.

19. 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 and testing. To the extent feasible, ARB staff will coordinate vessel inspections with inspections conducted by other State agencies such as the California State Lands Commission. 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, whichever is lower.

Based on our experience in enforcing the Auxiliary Engine Regulation, we expect to have a very active enforcement program for the proposed regulation. Over the 14 months of implementation for the Auxiliary Engine Regulation, ARB enforcement staff conducted over 200 vessel inspections.

20. 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 do not operate ocean-going vessels as defined in the proposal.

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

Upon implementation in 2009, the proposed regulation will result in immediate and significant reductions in emissions of diesel PM, PM, SOx, NOx, 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 approximately 13 tons per day (TPD) of diesel PM, 10 TPD of NOx, and 109 TPD of SOx in 2010. For perspective, the proposal would immediately upon implementation result in an estimated 74 percent reduction in diesel PM, 81 percent reduction in SOx, and a 5 percent reduction NOx from an engine that previously used heavy fuel oil.

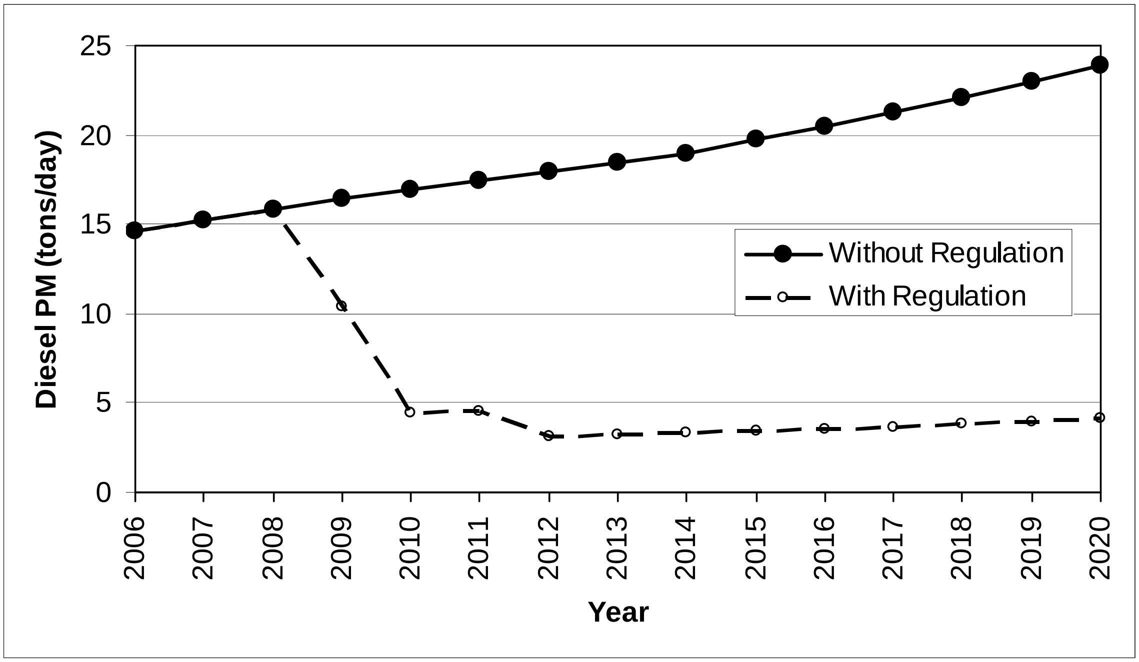
Beginning in 2012, the 0.1% sulfur limit will result in an additional 9 percent reduction in diesel PM and SOx. The estimated reductions for PM (which includes diesel PM), SOx and NOx, as shown in Table ES-2, reflect the use of the cleaner marine distillate fuels specified in the proposed regulation. The estimates do not reflect participation in the “noncompliance fee provision” in the proposal that allow shippers to pay a fee in lieu of using the low sulfur distillates because we cannot predict the rate of participation. However, from our experience implementing the Auxiliary Engine Regulation over 14 months, we would expect a very limited use of noncompliance fees under this proposal.

Table ES-2: Estimated Statewide Emission Reductions from Implementation of the Proposed Regulation (24 nm)

Year	Main Engine and Auxiliary Engine Emission Reductions (Tons per Day)		
	PM	**NOx**	**SOx**
2010	13	10	109
2012	15	11	135
2015	16	12	148
2020	20	15	178

The emission reductions shown for 2010 reflect the initial implementation, Phase 1, of the fuel sulfur requirements in the proposal, assuming that the average sulfur content of the fuel will be 0.5%. The 2012 and later reductions reflect the use of 0.1% sulfur MGO or MDO, as required under Phase 2 of the proposed regulation. Figure ES-4 shows 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

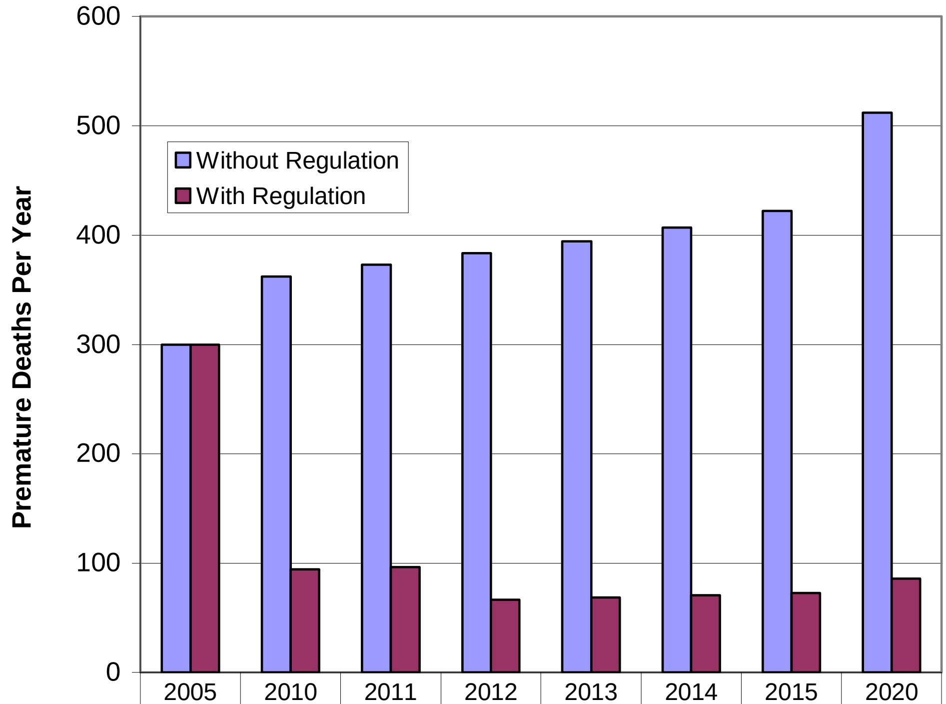


Significant air quality benefits are expected from the proposed regulation. The reductions in diesel PM, PM, NOx and SOx will help improve regional ambient air quality levels of PM and ozone. We also anticipate significant health benefits due to reduced incidences of cancer, premature mortality, PM-related cardiovascular effects, chronic bronchitis, asthma, and hospital admissions for pneumonia and asthma-related conditions. The 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 about 2,000 premature deaths between 2009 and 2015 due to reduction in diesel PM alone. (Figure ES-5).

With respect to potential cancer risk, 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 2010 and 2015 ambient diesel PM levels statewide, we estimate that in 2010 there will be a 75 percent reduction in the population-weighted average risk relative to the predicted risk levels in 2010 from OGV diesel PM emissions and an 83 percent reduction in 2015.

ARB staff has concluded that, with the exception of CO_2 emissions, no significant adverse environmental impacts will occur from implementation of the proposed regulation. There will be no increase in emissions of diesel PM, PM, NOx, or SOx 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.

Figure ES-5: Estimated Statewide Premature Deaths from OGV Diesel PM Emissions With and Without the Proposed Regulation (# per year)



	2005	2010	2011	2012	2013	2014	2015	2020
Without Regulation	300	362	373	384	394	407	422	512
With Regulation	300	94	96	66	69	71	73	86

22. What are the impacts on greenhouse gas emissions?

Emissions of diesel PM, PM, NOx, SOx, and "secondarily" formed PM would be reduced by burning cleaner marine distillate fuels while globally, greenhouse gas (CO_2) emissions could increase slightly. Based on a total fuel cycle analysis of the CO_2 emissions associated with a switch to marine distillate fuels, ARB staff estimates that there potentially could be a slight one to two percent increase in global CO_2 emissions. (Corbett and Winebrake, 2008) This net change in fuel-cycle CO_2 emissions is primarily a function of the increased energy required at the refining stage to produce compliant distillate fuels. This offsets the decreased CO_2 emissions from ship operations. The decrease in CO_2 emissions from ship operations results primarily from the higher energy to carbon content of the distillate fuel, as compared to heavy fuel oil. But these results do not assume that refineries may be able to improve energy efficiency while maintaining, upgrading, or expanding their capacity to produce distillate fuels. Therefore, the referenced potential fuel-cycle increase in CO_2 emissions due to greater use of more highly refined fuels may be overestimated.

If CO_2 emissions associated with the fuel used by California-visiting ships do increase by one to two percent under this proposal, we project such an increase would result in up to 50,000 tons per year of additional CO_2. While this is a very small increase relative to the overall CO_2 emissions from shipping, we nevertheless believe this may represent a significant adverse environmental impact. However, the very substantial health and environmental benefits from the proposal clearly constitute overriding considerations that amply justify the proposal. This is discussed in more detail later in the Environmental Impacts section of the Staff Report.

23. What are the economic impacts of the proposed regulation?

Under the proposed regulation, OGV (or "vessel") operators would comply through the use of distillate marine fuels. This requirement would apply when ships are within "Regulated California Waters," a zone that extends to approximately 24 nm off the California coastline.

Since the majority of vessels currently use heavy fuel oil in their engines and boilers, most vessel operators will need to switch to the more expensive marine distillate fuel in California. The costs resulting from the proposed regulation are estimated over a six year lifetime, from implementation in 2009 through 2014. Beginning in 2015, there is a possibility that an Emission Control Area (ECA) may be established under the International Maritime Organization that would require the use of 0.1% sulfur fuel off the California coastline (see Chapter V). If an ECA is established that achieves substantially equivalent benefits, then Air Resources Board staff will propose to the Board the termination of this regulation.

The added cost to businesses due to the higher cost of using distillate fuel can vary widely based on the amount of fuel they use in California. For example, a business that owns a single vessel which makes a single annual visit to a California port may incur an added cost of about $30,000. By contrast, an operator of a large fleet of vessels that make frequent California port visits may incur costs in the millions of dollars annually. On average, we estimate the annual additional fuel cost for a typical vessel operator at about $300,000 to $700,000 per company. For the entire ocean-going shipping fleet that visits California, we estimate an added annual fuel cost of about $140 to $360 million, or about $1.5 billion between 2009 and 2015. This added cost of the regulation represents less than one percent of the total costs of a typical trans-Pacific voyage. We also do not expect that the proposed regulation will result in significant capital costs to ship operators, since most vessel are unlikely to need to make modifications to use distillate fuel.

We do not expect significant economic impacts to the industry based on the added costs of the proposed regulation. As noted, the added costs of the regulation are relatively small compared to the overall operating expenses of these vessels. In addition, based on an analysis of the change in "return on owner's equity" (ROE) for typical businesses, the added costs of the proposed regulation would result in about a 1.5 percent decline in ROE. At this level, we would not anticipate 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. As noted, local and State government agencies typically do not operate ocean-going vessels and military vessels are exempt from the proposed regulation.

We 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. Under a typical scenario we estimate that the added cost of the proposed regulation would add about six dollars per shipping container for importers or exporters shipping containerized goods overseas on a typical Asia to U.S, West Coast voyage. We estimate that this represents roughly 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 $15 per passenger, representing about a 3 to 4 percent fare increase.

The overall cost-effectiveness of the proposed regulation, considering only reductions in diesel PM, is estimated to be about $63,000 per ton of diesel PM reduced ($32 per pound of diesel PM). However, the proposed regulation would also reduce emissions of NOx and SOx. Attributing half the cost of the proposed regulation to diesel PM, and half to NOx plus SOx, the cost-effectiveness would be about $31,000/ton ($16/pound) of diesel PM reduced. We estimate the cost-effectiveness of the combined NOx+SOx control at about $3,200/ton ($1.60/pound). The PM cost-effectiveness of the proposed regulation is similar to that of other regulations adopted by the Board to reduce diesel particulate matter.

Implementing the proposed regulation will achieve substantial health benefits. The diesel PM reductions between 2009 and 2015 will result in an estimated $15.4 billion (present value) cost savings due to estimated decreases in premature mortality. This would mean a benefits to cost ratio of 10 to 1.

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

The U.S. EPA and IMO have adopted regulations designed to reduce the emissions from these engines. However, these regulations will achieve relatively modest diesel PM reductions compared to the proposed regulation. The U.S. EPA and IMO regulations and a comparison to the ARB proposed regulation are summarized below in Table ES-3.

Table ES-3: Summary of U.S. EPA and IMO Regulations

Regulation	Description of Regulation	Comparison to the ARB Staff Proposal
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.	▪ Standards only apply to U.S.-flagged vessels which are a small percentage of the vessels that visit California ▪ Foreign trade exemption is provided that exempts most vessel auxiliary engines ▪ Benefits phase in slowly with vessel turnover
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. Implementation begins in 2004	▪ Standards only apply to U.S. flagged vessels ▪ Eliminates the foreign trade exemption for category 1 & 2 vessels (see above)
Annex VI IMO marine fuel sulfur limit	Establishes a fuel sulfur cap of 4.5%.	No reductions achieved by allowing fuel 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 entered into force on August 11, 2005, and includes the following provisions:

- A 1.5% 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% sulfur limit for marine fuels used by passenger vessels on regular services between EU ports, starting May 19, 2006; and
- A 0.1% 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% sulfur fuel by inland vessels and seagoing ships at berth affects only the operation of OGV auxiliary engines and auxiliary boilers at berth – not main engines. This is because inland vessels are considered to be harborcraft such as ferries and fishing vessels. Like the staff's proposal, the EU control measure specifies a 0.1% sulfur limit. However, the staff's proposal extends out 24 nm, and will reduce emissions from the operation of the main engine. Based on our emissions inventory, these emissions are about 70 percent of the total emissions from OGV in the 24 nm zone. In addition, because the EU control measure only applies at berth and the measure allows vessels to purchase the necessary fuel once in port, it is not necessary for vessels to obtain the fuel prior to coming to the EU.

25. How does the proposed regulation compare to the recently proposed amendments to International Maritime Organization's Annex VI of MARPOL and why doesn't California rely on an ECA to be implemented to reduce OGV emissions?

In spring 2008, the IMO's Marine Environmental Protection Committee (MEPC 57) agreed on amendments and revisions to MARPOL Annex VI (Prevention of Air Pollution from Ships) to reduce air emissions from ships. The amendments still have to be formally adopted at the next meeting of the MEPC in October 2008. If approved, the amendments will enter into force in February 2010.[4] The proposed amendments would establish new fuel sulfur limits for OGV fuels. Specifically, the proposal would require the following for fuel sulfur levels at open sea:

- 4.50% Prior to Jan 1, 2012
- 3.50% Jan 1, 2012
- 0.50% Jan 1, 2020

The proposal also includes a review process for the 0.50% standard in 2020 that will be conducted by group of experts by 2018 to determine the availability of such fuel. If that standard is determined as not possible or feasible, then the date becomes January 1, 2025.

The proposed amendments to Annex VI also allow for the creation of Emission Control Areas (ECA) which can be designated for any individual or combination of the three pollutants from ships - SOx, PM, and NOx. For ECAs, parties to the Annex can submit documentation that demonstrates the need for controls that would then be subject to approval by IMO. The sulfur limits applicable to an ECA are:

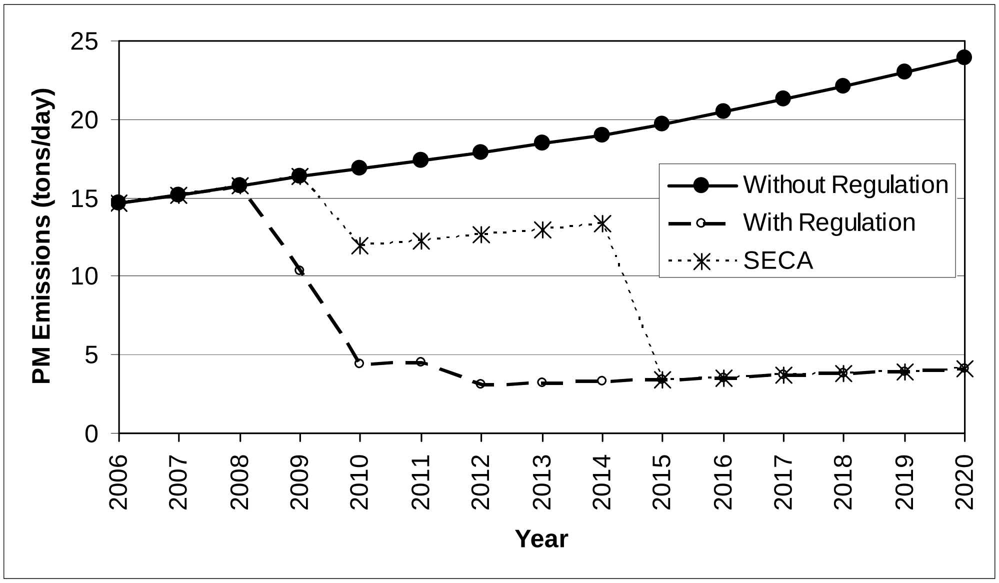
- 1.50% Prior to Mar 1, 2010
- 1.00% Jan 1, 2012
- 0.10% Jan 1, 2015

Although the regulations do not stipulate which fuels must be use to achieve these levels, distillates will be the most plausible way to achieve fuel sulfur levels below 1.0%. While this new proposal at IMO is very promising and we are hopeful that it will be adopted in October, ARB's proposed regulation differs from the recent IMO amendments in two aspects and will achieve significantly more emission reductions in the 2009-2015 timeframe. First, ARB's proposed regulation requires the use of distillate in all phases. Although Phase 1 of ARB's proposed regulation allows marine gas oil

[4] As with the existing MARPOL Annex VI, enabling legislation would likely need to be enacted before the amendments can enter into force in the U.S. This is expected to require additional time before the amendments, if passed, enter into force in the U.S.

with an upper sulfur limit of 1.5%, the average sulfur content is 0.3%, which is much lower than would be achievable with a heavy fuel oil with an upper limit of 1.5%. Second, ARB's proposed regulation contains a Phase 2 fuel requirement of 0.1% sulfur by January 1, 2012. As shown in Figure ES-6, the ARB proposed regulation will achieve significantly greater benefits in the 2009 through 2015 timeframe. For this reason, ARB cannot wait for an ECA to reduce emissions from OGVs.

Figure ES-6: Comparison of Diesel PM Emission Reductions Between the Proposed ARB Regulation and an ECA Provided for in the April 2008 Proposed Amendments to Annex VI



It is also important to acknowledge that, at this point in time, there is much uncertainty with respect to the possibility of implementing an ECA in the U.S. First, the U.S. is not yet a Party to MARPOL Annex VI and until that happens, cannot even vote on the current amendments to Annex VI. In the event the U.S. does become a Party to the treaty and the recent proposed amendments are approved by IMO, then the U.S. must develop documentation supporting the need to prevent, reduce, and control emissions in the ECA and obtain IMO approval. Nevertheless, ARB staff is optimistic that ultimately there will be progress at IMO and that the U.S. will become a Party to Annex VI. With that expectation in mind, ARB staff has been working closely with U.S. EPA staff on building the technical underpinnings for an ECA request. As mentioned earlier, the proposed California regulation includes a provision that would allow the ARB to sunset the rule in the event an international (or national) program is in place that will achieve equivalent benefits.

26. How is this proposed regulation affected by the Pacific Merchant Shipping Association (PMSA) lawsuit contending that ARB enforcement of the Auxiliary Engine Rule without US Environmental Protection Agency (EPA) approval violates the Clean Air Act?

The results of the PMSA lawsuit do not prohibit ARB from directly requiring the use of low sulfur distillate fuels in main and auxiliary ship engines, as set forth in the proposal. In December 2006, PMSA filed suit in federal district court challenging the Auxiliary Engine Regulation as preempted emission standards under Clean Air Act (CAA) section 209(e). PMSA also claimed that the Submerged Lands Act preempted the regulation to the extent the regulation was applied beyond 3 nm off the California coast. In May 2008, the 9th Circuit Court of Appeals upheld the lower court's granting of summary judgment against ARB and reinstated the lower court's injunction against ARB's enforcement of that regulation. The Court held that, on its face, the regulation constituted an emissions standard, which is preempted under CAA section 209(e) unless California obtains an authorization from U.S. EPA under the same section. In finding preemption under section 209(e), the Court did not reach the Submerged Lands Act issue.

The Court held that the Auxiliary Engine Regulation was an emissions standard because it allowed vessel operators to comply by showing equivalence to using the specified low sulfur distillates. To address this holding, we have incorporated into the proposal direct fuel-use requirements for main and auxiliary engines.[5] Under U.S. EPA implementing regulations for CAA section 209(e), direct fuel-sulfur limits do not constitute emission standards; instead, fuel sulfur limits are non-preempted in-use operational requirements, like limits on hours of operation and speed limits. Thus, we believe the proposed regulation's operational fuel-use requirements will survive another preemption challenge based on section 209(e).

27. Why is ARB proposing statewide implementation of this regulation?

We are proposing a statewide and uniform implementation of this regulation for practical reasons as well as ensuring that California employs state level consistent requirements with regard to regulating foreign-flag vessels. Under H&SC sections 43013 and 43018, ARB and the districts share concurrent jurisdiction over marine vessels, which are considered to be nonvehicular sources. In addition, H&SC section 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 under State law to regulate the main engines and auxiliary boilers 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

[5] Auxiliary boilers are not affected by the PMSA lawsuit because boilers are not engines under CAA section 209(e).

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&S section 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 operators of foreign-flagged and U.S.-flagged vessels visiting California ports only need to understand and meet one set of statewide regulations.

28. How was this proposal developed?

In March, 2007, staff began a series of public workshops focused on the proposed regulation. 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. 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.

In July 2007, a Maritime Air Quality Technical Working Group (MWG) meeting was held to provide a forum for the presentation and discussion of the technical feasibility of using cleaner distillate fuel in the main engines and auxiliary boilers. Topics included the technical feasibility of fuel switching, greenhouse gas impacts, in-use experience with using distillate fuels in the main engines and worldwide availability of low sulfur marine distillates. Speakers included representatives from the two largest engine makers, MAN and Wärtsila, Herbert Engineering Corp., a naval architecture, and engineering firm, University of Delaware Marine and Earth Studies, the A.P. Moller-Maersk Group, BP Shipping, and DNV Petroleum Services, Inc.

More than 1,700 individuals and companies were notified for each workshop and the Maritime Working Group meeting 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/marine) 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.

29. How does the proposed regulation relate to the State Implementation Plan for Ozone and PM and the Goods Movement Emission Reduction Plan?

The federal Clean Air Act (CAA) requires the U.S. EPA to establish National Ambient Air Quality Standards (national standards) for pollutants considered harmful to public health, including fine particulate matter (PM2.5) and ozone. Areas in the State that exceed the national standards are required by federal law to develop State Implementation Plans (SIPs) describing how they will attain the standards by certain deadlines. Diesel PM and PM emission reductions are needed because they contribute to ambient concentrations of PM2.5; NOx emission reductions are needed because NOx leads to formation in the atmosphere of both ozone and PM2.5; and SOx emission reductions are needed because SOx leads to the formation in the atmosphere of PM2.5.

In particular, the proposed regulation is critical to assist the South Coast Air Quality Management District (SCAQMD) in attaining the national ambient air quality standard (NAAQS) for PM2.5 and to fulfill obligations in the State Implementation Plan (SIP). The South Coast Air Basin is required to attain the national standard for PM2.5 by April 5, 2015. Because the compliance with the standard is based on calendar annual averages, this effectively means that all reductions needed to meet the standard must be in place in 2014. The ARB has adopted revisions to the South Coast ozone and PM2.5 SIPs and has submitted the SIPs to the U.S. EPA. Air quality modeling indicates that significant reductions in diesel PM, PM, NOx and SOx are needed to meet the PM2.5 standards. The strategy to achieve attainment of the PM2.5 standards in the South Coast Air Basin includes a 68 percent reduction in SOx emissions, a 55 percent reduction in NOx emissions, and a 15 percent reduction in direct PM2.5 emissions from 2006 baseline levels. However, the modeling also indicates that reducing SOx emissions is the most effective strategy for attaining the standard. Preliminary modeling indicated that reducing one ton of SOx emissions was 10 times as effective in reducing ambient PM2.5 as reducing one ton of ROG, and over three times as effective as reducing one ton of NOx emissions. (Cassmassi, 2008) The diesel PM, PM, NOx, and SOx, emission reductions from the proposed regulation would play an essential role in assisting the South Coast Air Basin with meeting its 2014 PM2.5 deadline as well as its future ozone deadlines. The PM and SOx emission reductions from the proposal would meet the SIP reduction targets for ships, while the NOx emission reductions would assist other measures in making progress toward the NOx reduction targets.

The federal CAA permits states to adopt more protective air quality standards if needed, and California has set standards for particulate matter and ozone that are more protective of public health than respective federal standards. The Bay Area, South

Coast, and San Diego areas are nonattainment for the State standards for ozone and PM2.5. Health and Safety Code section 40911 requires the local air districts to submit plans to the Board for attaining the State ambient air quality standards, and H&S section 40924 requires triennial updates of those plans. The NOx, SOx, and PM2.5 emission reductions from the proposed regulation will assist the districts in achieving attainment of the State ambient air quality standards.

The proposed regulation is also an important element of the Goods Movement Emission Reduction Plan (GMERP) which outlines the measures necessary to achieve an 85 percent statewide diesel PM risk reduction. The PM and SOx emission reductions from the proposal would meet the GMERP targets for ships, while the NOx emission reductions would assist other measures in making progress toward the plan's targets.

30. 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, 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, San Diego, and Oakland. For example, in the West Oakland community ARB staff estimates about an 80 percent reduction in potential cancer risk due to exposures to diesel PM from OGV in 2015 from implementation of the proposed regulation.

31. What future activities are planned?

In addition to activities associated with monitoring and enforcement of 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; and to continue to encourage the U.S. EPA and the IMO to take an active role in reducing emissions from ocean-going vessels. As discussed below, ARB staff intend to work closely with U.S. EPA on pursuing an ECA, continue to monitor fuel availability for marine distillate fuels specified in the proposed regulation, and undertake additional studies that will investigate the impacts of fuel-switching on marine engines and associated components.

IMO

ARB staff will continue to work with the U.S. EPA to establish a Sulfur Emission Control Area (SECA) or an Emission control Area (ECA) in the event the most recent amendments under consideration at IMO are approved and the U.S. enacts legislation to implement the treaty provisions.

Fuel Availability

While ARB staff believes the fuels specified in the proposed regulation will be available for OGV operators, we intend to monitor fuel availability as the regulation is implemented to ensure that vessel operators are able to obtain the necessary fuel in Pacific Rim fueling ports. Staff will determine if it is appropriate to propose amendments to the regulation under certain circumstances: (1) in the event we notice a significant increase in the number of noncompliance fees paid due to the inability to obtain the necessary fuel or, (2) if after 2012, a significant portion of the fleet finds it necessary to purchase fuel in California because it was not available at the prior fueling port.

Studies Evaluating Impacts of Marine Distillate Fuels

During the development of the proposed regulation, ARB staff determined that operating OGV engines and auxiliary boilers on marine distillate fuels is feasible. However, concerns were raised by engine manufacturers and vessel operators regarding impacts on fuel pumps and long-term engine maintenance when routinely switching from HFO to MGO or MDO. To provide further knowledge in these areas, ARB staff intends to undertake two additional studies to investigate the impacts of fuel switching in OGV main engines.

The first study will investigate the acceptable lower limits of fuel viscosity and lubricity in the fuel pumps. Some ship operators have expressed concern that use of low sulfur fuels (especially below 0.05% sulfur) would be damaging to fuel injection pumps because these fuels are low in viscosity and may be low in lubricity. In this study, ARB is partnering with the major marine engine manufactures to bench test low sulfur distillate fuels in a simulated “pump rig test”. For this program, a fuel injection pump, typical of a large two-stroke, slow-speed engine, would be operated on a test stand. The pump will be operated with the designated fuel for a specified period of time and then disassembled and inspected for wear. The goal of this testing is to determine the lower limits of fuel lubricity and viscosity for marine fuel injection pumps used on large two-stroke, slow-speed OGV main engines.

The second study will investigate the long term impacts of fuel switching on main engine performance, component wear and failure rates. In this study, fuel switching between heavy fuel oil (HFO) and low sulfur, cleaner-burning distillate would be done on a select number of ocean-going vessel main engines. Currently, there have been no documented long term studies or demonstrations on the effect of low sulfur marine fuels on the long term performance and operation of modern two-stroke engines on ocean-going vessels which routinely fuel switch between HFO and distillate fuels. In this program, the long term operation, such as engine performance, component failure rate, and component wear would be evaluated to determine the long term effects of fuel switching. Shipping companies and engine makers would provide in-kind services to partner with the ARB. In addition, emission testing for diesel PM, criteria pollutants and greenhouse gasses would be performed to determine emission benefits of fuel switching.

In addition, staff recognizes the need to achieve additional emission reductions from ocean-going vessels. ARB staff is currently studying the feasibility of implementing vessel speed reduction (VSR) including an evaluation of the technical and economic issues associated with VSR. Further, a clean ship measure is being developed to target strategies to reduce emissions in new ship builds. These and other potential emission reduction strategies are part of the SIP and GMERP.

32. 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, PM, NOx, and SOx, 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.

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I. INTRODUCTION

The California Air Resources Board's (ARB) mission is to promote and protect public health, welfare, and ecological resources through the effective and efficient reduction of air pollutants while recognizing and considering the effects on the economy of the state. Ocean-going vessel (OGV) auxiliary diesel and diesel electric engines, main propulsion engines, and auxiliary boiler (engines and auxiliary boilers) exhaust is a source of unhealthful air pollutants including particulate matter (PM), diesel PM, nitrogen oxides (NOx), and sulfur oxides (SOx). Emissions from OGV are a significant concern in communities near California ports. In this chapter, the Air Resources Board (ARB or Board) staff provides an overview of this 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 public outreach process used to include all interested stakeholders in the development of the proposal.

A. Overview

This report presents the proposed regulation to reduce emissions of diesel PM, PM, NOx, and SOx from OGV engines and auxiliary boilers used on ocean-going vessels within a 24 nautical mile zone 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, PM, NOx, and SOx emissions (Chapter II);
- a description of the affected industry (Chapter III);
- the emissions inventory and health risks posed by exhaust from OGV engines and boilers (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, (Chapter VI);
- the environmental impacts of implementing the proposal, including greenhouse gases, (Chapter VII); and
- the estimated costs to industry and the fiscal impacts of these costs (Chapter VIII).

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

B. Purpose

The purposed regulation is designed to reduce emissions of diesel PM, PM, NOx, SOx, and "secondarily" formed PM (PM formed in the atmosphere from NOx and SOx emissions). Diesel PM emission reductions are needed to reduce the potential cancer risk. Diesel PM, PM from boilers, and secondarily formed PM reductions are needed to reduce premature mortality and other noncancer health impacts from PM exposures to people who live in the vicinity of California's major ports and shipping lanes. Reductions in diesel PM, PM and secondary PM from SOx and NOx will also contribute to regional PM reductions that will assist in California's progress toward achieving State and federal air quality standards. Reductions in NOx, 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 requires the use of lower sulfur marine distillate fuels that will result in reductions of diesel PM, which is both a TAC and criteria pollutant, and NOx, SOx, and PM which are 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

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 unhealthful 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.

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

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 locations that encouraged public participation, including meetings at California ports. Attendees included representatives from environmental organizations, community groups, port administration, vessel operators, engine manufacturers, fuel producers and suppliers, 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. Over 1,700 individuals and/or companies were notified for each workshop through a series of mailings to the subscribers of the maritime electronic list server. In addition, all notices and meeting materials were posted to ARB's marine and public workshops web sites.

Table I-1: Public Workshops *

Date	Meeting	Location
March 20, 2007	Public Workshop	Port of Long Beach
June 13, 2007	Public Workshop	Cal/EPA Building, Sacramento
July 24, 2007	Maritime Working Group	Cal/EPA Building, Sacramento
September 24, 2007	Public Workshop	Cal/EPA Building, Sacramento
March 5, 2008	Public Workshop	Cal/EPA Building, Sacramento
May 13, 2008	Public Workshop	Cal/EPA Building, Sacramento

*All workshops and public meetings held at the Cal/EPA headquarters building were web-cast.

In addition to the public meetings presented in Table I-1, ARB staff and management participated in numerous meetings with industry, government agencies, community groups and environmental groups over the past two 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, 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 Office of Spill Prevention and Response, San Francisco Harbor Safety Committee, 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 and San Francisco Bar Pilots. Some of the shipping companies participating were the A.P. Moller-Maersk Group, Chevron Shipping Company, BP Shipping, APL, and Matson.

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/marine) 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 EMISSIONS FROM OCEAN-GOING VESSELS

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. Since that time, there have been several initiatives undertaken to reduce exposures diesel PM. In September 2000, ARB approved the "Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles" (DRRP or Diesel Risk Reduction Plan). The DRRP established a goal of reducing diesel PM by 75 percent in 2010 and by 85 percent in 2020. In April 2006, the ARB approved the Emission Reduction Plan for Ports and Goods Movement in California (ARB, 2006) which outlines a comprehensive strategy to meet an 85 percent diesel PM risk reduction target from goods movement activities. 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&S 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, age and horsepower, operating conditions, fuel, lubricating oil, and the presence of an emission control system. The primary gas or vapor phase components include typical combustion gases and vapors such as carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), oxides of nitrogen (NOx), 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 et al., 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_2, NOx, 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. Conversely, coarse particles deposit to the earth within minutes to hours and within tens of kilometers from the emission source.

The total diesel particle mass consists almost entirely of inhalable particles in the range of 10 microns or less in diameter (PM_{10}). Approximately 94 percent of the mass of these particles are less than 2.5 microns ($PM_{2.5}$) in diameter. Diesel PM can be distinguished from noncombustion sources of $PM_{2.5}$ 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 toxic air contaminants.

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, which is a component of ambient particulate matter. In addition, the proposed regulation is expected to result in reductions in PM, NOx, and SOx. NOx is a precursor to the formation of ozone, and both NOx and SOx contribute to secondarily formed PM in the lower atmosphere. The primary health impacts of these air pollutants are discussed below.

Diesel Particulate Matter

Since most diesel exhaust particle mass consists of particles 2.5 microns or less in diameter, they can be inhaled deep into the lung. The majority of epidemiologic studies that have investigated the health effects of exposure to diesel exhaust are occupational studies, primarily railroad workers, truck drivers, or workers in mines, and the results generally support the view of an association between long-term exposure to diesel exhaust and lung cancer (Garshick et al., 2004; Garshick et al., 2006; Laden et al., 2006; Ris, 2007). Also other researchers (Hart et al., 2006) have reported that diesel exhaust exposure was associated with death from chronic obstructive pulmonary disease in railroad workers. There are no direct monitoring methods for diesel PM, and so exposure assessments have been typically based on job classification. 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, 1998a) .

A potentially significant health effect of diesel exhaust exposure is its apparent ability to act as an adjuvant in allergic responses and possibly asthma (Diaz-Sanchez et al., 1996; Diaz-Sanchez et al., 1999; Riedl & Diaz-Sanchez, 2005). 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.

Diesel PM was listed as a TAC by ARB in 1998 after an extensive review and evaluation of the scientific literature by OEHHA (ARB, 1998b). 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 $\mu g/m^3$) could be associated with a health risk of 540 potential cancer cases per million people exposed over a 70 year lifetime.

Ambient Particulate Matter

Ambient PM is a complex mixture of tiny particles that may consist of dry solid fragments, solid cores with liquid coatings, and small droplets of liquid. These particles vary greatly in shape, size, and chemical composition, and can consist of many different materials such as metals, soot, soil, and dust. As described above, PM can be directly emitted from sources, such as diesel PM, or can be produced indirectly from sources which emit precursors that are converted to PM by atmospheric processes. Particles 10 micrometers or less in diameter are defined as "respirable particulate matter" or "PM_{10}." PM_{10} and particles 2.5 micrometers or less in diameter ($PM_{2.5}$) can be inhaled deep into the lungs. $PM_{2.5}$ contributes significantly to regional haze and reduction of visibility in California. Besides reducing visibility, the acidic portion of PM (nitrates, sulfates) can harm crops, forests, aquatic and other ecosystems (ARB, 2002a). Ambient particulate matter includes diesel PM as an important component.

Considerable epidemiologic research over the past 15 years has investigated the responses of humans to PM. The principal health effects of ambient PM exposure are summarized below:

- Many studies have consistently found statistical associations between $PM_{2.5}$ and premature death with both long-term (Pope et al. 2004; Krewski et al., 2001; Pope et al., 2002; Laden et al., 2006) and daily exposures (Dominici, 2003, Dominici et al., 2005; Laden et al., 2000; Schwartz et al., 2003). The association with premature mortality is considerably stronger for annual average $PM_{2.5}$ exposure than for daily average $PM_{2.5}$. That is, long-term exposure appears to pose a greater risk of death than short-term exposure.

- A recent study suggests that long-term exposure to $PM_{2.5}$ may influence the risk of adverse cardiovascular events in women (Miller et al., 2007), including death from heart attack or stroke, and hospitalization for heart attack, stroke, or coronary artery angioplasty.

- Daily exposure to $PM_{2.5}$ has been associated with hospitalization for heart and lung related causes (Moolgavkar, 2003; Schwartz et al., 2003; Zanobetti et al., 2003). Others have found that exposure to $PM_{2.5}$ resulted in increased emergency room visits, exacerbation of asthma, and other respiratory diseases (Sheppard, 2003; Peel et al., 2005). Other research indicates that exposure to $PM_{2.5}$ leads to increased asthma medication usage (Gent et al., 2003) and increased asthma symptoms (Whittemore & Korn, 1980; Delfino et al., 2002).

Exposure to $PM_{2.5}$ has also been associated with increased work loss days (Ostro & Rothschild, 1989; Ostro et al., 1993).

- Older adults with preexisting chronic heart or lung disease are at greatest risk of experiencing adverse effects related to $PM_{2.5}$ exposure (Moolgavkar, 2003; Dominici et al., 2006; Symons et al., 2006).

- In May 2008, ARB released a draft report *Methodology for Estimating Premature Deaths Associated with Long-term Exposure to Fine Airborne Particulate Matter in California*. In this draft report, the relative risk of premature death due to PM2.5 exposure was reevaluated based on all relevant scientific literature, and a ne relative risk factor was developed. This new relative risk factor is a 10 percent increase in premature deaths per 10 $\mu g/m^3$ increase in PM2.5 exposures. (ARB, 2008)

There is some evidence suggesting that air pollution may have greater effects in children than in adults. This may be because they inhale more $PM_{2.5}$ per pound of body weight than do adults, and because they breathe more rapidly than adults. Adverse effects reported in children include reduced lung function growth in higher pollution areas (Gauderman et al., 2000; Gauderman et al., 2002; Gauderman et al., 2004) that may at least partially reverse if the child moves to an area with cleaner air (Avol et al., 2001); and increased asthma and bronchitis symptoms (McConnell et al., 1999; Gauderman et al., 2005).

Ozone

Diesel exhaust consists of hundreds of gas-phase, particle-phase, and semi-volatile organic compounds, including typical combustion products, such as CO_2, 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 SOx. Ozone (O_3) is formed by the reaction of ROG and NOx in the atmosphere in the presence of heat and sunlight. The highest levels of ozone are produced when both ROG and NOx emissions are present in significant quantities on hot, clear summer days.

Outdoor air often contains a sufficiently high concentration of O_3 to induce adverse responses in large segments of the population. Studies of human subjects exposed to controlled concentrations of O_3 have consistently shown that exposures at concentrations above 0.08 ppm for 6 to 8-hours or 0.12 ppm for one-hour consistently induce adverse responses in some individuals. The magnitude of effects depends on the inhaled dose of O_3, which is the product of ambient O_3 concentration, the volume of air breathed, and the duration of exposure (Silverman et al., 1976; Folinsbee et al., 1978; Adams et al., 1981; Drechsler-Parks et al., 1990). Acute effects of O_3 exposure include:

- Reductions in various measures of lung function (Folinsbee et al., 1977a; Folinsbee et al., 1977b; McDonnell et al., 1983; Kulle et al., 1985; Schelegle & Adams, 1986; Seal et al., 1993).
- Increased respiratory symptoms, such as cough, pain on deep breath, and difficulty taking a deep breath (Folinsbee et al., 1977a; Kulle et al., 1985; Schelegle & Adams, 1986; Seal et al., 1993; McConnell et al., 1999).

- Cellular and biochemical changes indicative of lung inflammation (Devlin et al., 1991; Aris et al., 1993; Balmes et al., 1996; Devlin et al., 1996).

The people most at risk for experiencing adverse acute responses to O_3 are those who inhale the most O_3, namely those who are active outdoors during the period of the day when the O_3 concentration is highest, particularly children, outdoor workers, and athletes (EPA 1996). Responsiveness to O_3 varies considerably between individuals (Adams et al., 1981; McDonnell et al., 1983; McDonnell et al., 1985; Aris et al., 1995; McDonnell et al., 1995), although the specific factor(s) that determine degree of responsiveness is (are) unknown (McDonnell et al., 1993; Frampton et al., 1997; Torres et al., 1997).

Some studies suggest that mild to moderate asthmatics have lung function and symptoms responses similar to those of nonasthmatics (Horstman et al., 1986; Koenig et al., 1987; Koenig et al., 1988), while others suggest that asthmatics may be more sensitive to O_3 than nonasthmatics (Scannell et al., 1996; Peden et al., 1997). Some asthmatics also have increased lung inflammatory responses to O_3 compared to healthy people (McBride et al., 1994; Peden et al., 1997), and enhanced allergic responses after O_3 exposure (Molfino et al., 1991; Peden et al., 1995; Kehrl et al., 1999), although the literature is inconsistent on this point (Ball et al., 1996; Hanania et al., 1998).

Epidemiological studies have reported statistically significant associations between outdoor O_3 concentrations and:

- Increased asthma and respiratory symptoms (Whittemore & Korn, 1980; Brunekreef et al., 1994; Devlin et al., 1996; Thurston et al., 1997; Mortimer et al., 2002; Gent et al., 2003; Millstein et al., 2004; Mudway et al., 2006; Romieu et al., 2006).

- Hospital admissions and emergency room visits, primarily for asthma or other respiratory causes including COPD and bronchitis (Schwartz, 1995; Anderson et al., 1997; Burnett et al., 1997; Delfino et al., 1997; Delfino et al., 1998; Sheppard et al., 1999; Peel et al., 2005; von Klot et al., 2005; Yang et al., 2005; Medina-Ramon et al., 2006).

- Increased school absenteeism for respiratory illnesses (Gilliland et al., 2001)

- Reduced lung function growth in children (Frischer et al., 1999; Rojas-Martinez et al., 2007; Oftedal et al., 2008).

- Increased risk of acquiring asthma for children who engage in three or more outdoor sports and live in high ozone areas (McConnell et al., 2002).

- Premature mortality (Ito & Thurston, 1996; Thurston & Ito, 2001; Bell et al., 2004; Gryparis et al., 2004; Bell et al., 2005; Levy et al., 2005).

Not only does ozone adversely affect human and animal health, but it also affects vegetation throughout most of California. These effects include reduced yield and quality in agricultural crops, disfiguration or unsatisfactory growth in ornamental vegetation, and damage to native plants. During the summer, ozone levels are often highest in the urban centers in Southern California, the San Joaquin Valley, and Sacramento Valley, which are adjacent to the principal production areas in the State's multibillion-dollar agricultural industry (USDA, 2006). ARB studies indicate that ozone pollution damage to crops is estimated to cost agriculture over $500 million dollars annually (ARB, 1987; 2006).

Sulfur Dioxide and Sulfates

Sulfur dioxide (SO_2) is a gaseous compound of sulfur and oxygen. SO_2 is formed when sulfur-containing fuel is burned by mobile sources, such as locomotives, marine vessels, and off-road diesel equipment. SO_2 is also emitted from several industrial processes, such as petroleum refining and metal processing.

Human exposure studies provide the most consistent data as to adverse health effects of SO_2. These studies have found that the population subgroups most likely to experience adverse responses to SO_2 at low levels include primarily asthmatics and some individuals with allergies and airway hyperresponsiveness (Sheppard et al., 1980; Koenig et al., 1981; Sheppard et al., 1981; Horstman et al., 1986; Linn et al., 1987; Nowak et al., 1997; Koenig, 1998). Even among asthmatics, there is wide variability in SO_2 susceptibility: one investigation of adult asthmatics suggests a seven-fold range of lung function responses to fixed levels of SO_2 exposures (Horstman et al., 1986). Low humidity and exercise (or voluntary hyperventilation) augment the responses observed in asthmatics (Sheppard et al., 1981; Linn et al., 1983; Bethel et al., 1984; Sheppard et al., 1984; Linn et al., 1985).

Some epidemiologic studies have suggested associations between ambient SO_2 levels and more serious categories of adverse health outcomes including mortality and various acute morbidities; however, the results are not consistent between studies. U.S. EPA (EPA, 2007) reviewed the existing literature on health effects related to SO_2, and concluded that there is a likely causal relationship between short-term SO_2 exposures (up to several hours) and acute respiratory effects such as symptoms, bronchoconstriction, and emergency department visits for respiratory causes, but that evidence for longer-term or more serious effects was inconclusive. Because ambient

SO_2 concentration is generally strongly correlated with other air pollutants originating from the same sources, such as $PM_{2.5}$, CO, and NO_2, it is difficult to determine whether observed effects are related to SO_2, or to one or more of these co-pollutants.

Sulfates (SO_4^{2-}) 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_2) during the combustion process and subsequently converted to sulfate compounds in the atmosphere. Conversion of SO_2 to sulfates takes place comparatively rapidly and completely in urban areas of California due to regional meteorological features. Ambient sulfates comprise a sub-fraction of ambient particulate matter, primarily in the $PM_{2.5}$ size category. Few studies have investigated health effects related specifically to sulfates exposure, although the consensus view is that the effects are comparable in nature and severity to those associated with $PM_{2.5}$ (ARB, 2002a).

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.

Diesel Engines Using 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 the 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% (5000 ppm). Diesel fuel meeting ARB specification averages about 0.014% (140 ppm) and is scheduled to be reduced to 0.0015% (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. %), higher sulfur (<5000 vs. 100-150 ppm Wt.), lower cetane number (>40 vs. 50-55), higher PAHs (8 vs. 2-5 Wt. %) 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.

<u>Diesel Engines Using Heavy Fuel Oil</u>

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_{20} to C_{50}) 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 OGV 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, 2005). 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 or main engine running on 2.5% 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%. 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

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.

Boilers Using MGO, MDO, or HFO

ARB staff does not believe that the health values developed for diesel PM are appropriate for emissions from boilers using MGO, MDO, or HFO. Boilers are not internal combustions engines. The health studies for diesel PM were based on exposure to exhaust emissions from internal combustion, compression ignition engines. Boiler design, combustion characteristics, operating temperatures and pressure, residence time, and exhaust parameters are sufficiently different to questions the applicability of the diesel PM risk factor to boiler PM.

D. Health and Environmental Benefits from the Proposed Regulation

Reducing emissions from OGV engines and auxiliary boilers will have both public health and environmental benefits. The proposed regulation will reduce localized health risks associated with the operation of OGV engines and auxiliary boilers that are near receptors and will contribute to the reduction of the general exposures to PM that occurs on a region-wide basis due to collective emissions from OGV engines and auxiliary boilers. Additional benefits associated with the proposed regulation include further progress in meeting the ambient air quality standards for PM_{10}, $PM_{2.5}$, 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 and PM from OGV 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_{10} and $PM_{2.5}$ in the ambient air. These standards define the maximum amount of PM that can be present in outdoor air. California's PM_{10} 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 $PM_{2.5}$ to further protect public health (Table II-1).

Table II-1: State and National PM Standards

California Standard		National Standard	
PM_{10}			
Annual Arithmetic Mean	20 $\mu g/m^3$	Annual Arithmetic Mean	50 $\mu g/m^3$
24-Hour Average	50 $\mu g/m^3$	24-Hour Average	150 $\mu g/m^3$
$PM_{2.5}$			
Annual Arithmetic Mean	12 $\mu g/m^3$	Annual Arithmetic Mean	15 $\mu g/m^3$
24-Hour Average	No separate State standard	24-Hour Average	65 $\mu g/m^3$

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_{10} standard (ARB, 2002b). Diesel PM and PM emission reductions from OGV engines and auxiliary boilers will help protect public health and assist in furthering progress in meeting the ambient air quality standards for both PM_{10} and $PM_{2.5}$.

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 NOx and SOx emissions from OGV engines and auxiliary boilers. 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 NOx, 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

	California Standard	National Standard
1 hour	0.09 ppm (180 $\mu g/m^3$)	
8 hour	0.070 ppm (137 $\mu g/m^3$)	0.075 ppm (147 $\mu g/m^3$)

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 the 24 nautical miles zone 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, governmental, or military vessel that meets any one of the following criteria:

- 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.

In this chapter, we provide examples of the types of ocean-going vessels, and also describe the 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. (EPA, 2003).

A. Vessel Descriptions

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

<u>Container Vessels</u>

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. In addition, most container vessels have several 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

Year Built	Tonnage	Number of Passengers
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.

RO-RO Vessels

A RO-RO vessel carries wheeled cargo such as automobiles, trailers or railway carriages. RO-RO is an acronym for "roll on/roll off". RO-RO 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 RO-RO is generally reserved for ocean-going vessels.

Typically new automobiles that are transported by vessel around the world are moved on RO-ROs. 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 2006, followed by tankers at 22 percent of port visits. The remaining six categories of vessels each account for less than ten percent of vessel visits.

Table III-2: 2006 California Port Calls by Vessel Type

Vessel Type	Number of Calls	Percentage of Total Calls
Auto Carriers	1,006	9%
Bulk Carriers	983	9%
Container	5,038	46%
Passenger Cruise Vessels	770	7%
General Cargo	371	3%
Reefer	315	3%
Ro-Ro	112	1%
Tanker	2,391	22%
Total	10,986	100%

(CSLC, 2006)

Table III-3 ranks California's ports by the number of vessel visits. As shown in the table, 50 percent of port calls occurred at the combined Ports of Los Angeles and Long Beach (which are adjacent to each other). The Port of Oakland accounted for about 18 percent of the port calls, and the remaining ports individually received 7 percent or less of the vessel calls.

Table III-3: 2006 Port Ranking by Vessel Visits

Port	Number of Calls	Percentage of Total Calls
Los Angeles/Long Beach	5,494	50%
Oakland	1,955	18%
Richmond	598	5%
Carquinez	794	7%
San Diego	550	5%
Hueneme	417	4%
San Francisco	306	3%
El Segundo	268	2%
Stockton	189	2%
All Other	415	4%
Total	10,986	100%

(CSLC, 2006)

C. Ocean-Going Vessel 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 *Ocean-Going Ship Survey* or "Survey." The Survey requested information only for ocean-going vessels that visited California ports in 2006. The respondents provided Information on 761 vessels, their main engines, and approximately 2,500 auxiliary engines. For more detailed Ocean-Going Ship Survey data or information, see Appendix C. In addition, most vessels have auxiliary boilers used to produce steam. Information on boilers is provided later in this chapter.

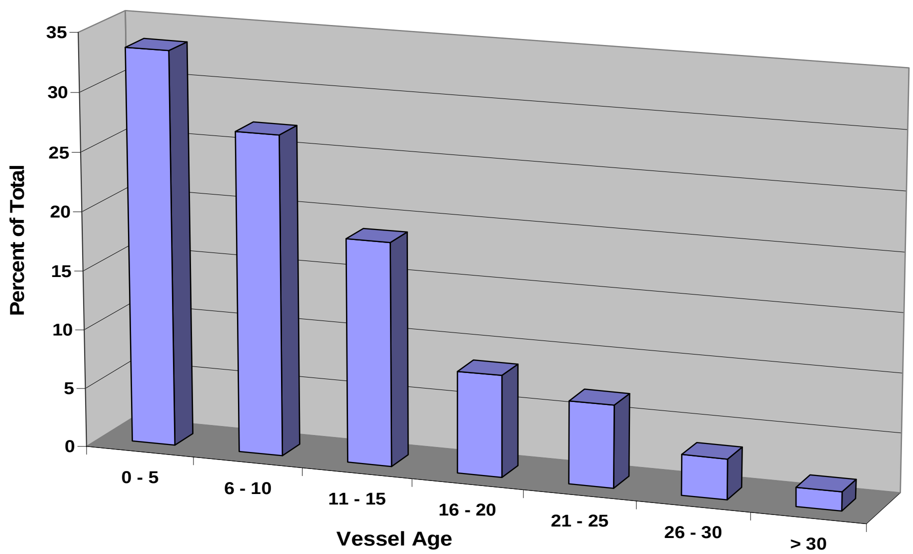
Ocean-going vessels subject to the proposed regulation have both main propulsion (main engines) and auxiliary diesel engines. The main engine for most vessels is a diesel-mechanical propulsion system, where the diesel engine is directly coupled to the propeller through a transmission. The exception is 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.

Vessel Age

The age of the vessels reported in the 2006 Survey ranged from 38 years old to new, with an average vessel age of about nine years. Approximately 80 percent of the vessels were less than 15 years old. The distribution of vessel age is shown in Figure III-1.

Figure III-1: Age Distribution of Vessels



Auxiliary Engines

Table III-4 summarizes the number of auxiliary engines reported in the Survey. As is shown, all vessels had at least one auxiliary engine. On average, vessels were reported to have 2-3 auxiliary engines.

Table III-4: Number of Auxiliary Engines

Vessel Type	Minimum	Maximum	Average	Engines
Auto Carrier/Ro-Ro	1	4	2	243
Bulk Carrier/General Cargo	1	4	2	405
Container Ship	1	6	2	1,052
Motor Ship/Container	1	5	3	24
Passenger	1	6	3	167
Product Carrier	1	3	2	3
Reefer	1	4	2	24
Tanker	1	6	2	582

Of the auxiliary engines reported in the Survey, 99 percent are four-stroke diesel-fueled 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. Table III-5 presents the number and percent of the auxiliary engine diesel type reported.

Table III-5: Auxiliary Engine Type

Auxiliary Engine Diesel Type	Number of Engines Reporting in Survey	Percent of Total Engines
2 Stroke	28	1%
4 Stroke	2,381	99%

An earlier survey conducted by the ARB found that about 75 percent of auxiliary engines operated on heavy fuel oil, and 25 percent distillate (ARB, 2005). The 2006 Survey requested information on the fuel sulfur levels of the distillate fuels used to comply with the ARB's Auxiliary Engine regulation. Table III-6 provides the minimum, maximum, and average sulfur content of the distillate fuel type used to power the auxiliary engines when operating out to 24 nm from California shoreline.

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

Fuel	Minimum Sulfur Content (%)	Maximum Sulfur Content (%)	Average Sulfur Content (%)
MDO	0.01	2.00	0.52
MGO	0.002	1.50	0.42

The manufacturers of the auxiliary engines were numerous, but six manufacturers accounted for almost 92 percent of the engines reported. These manufacturers are shown below in Table III-7.

Table III-7: Auxiliary Engine Manufacturers

Engine Maker	Number of Engines	Percent of Total Engines
MAN B&W	806	32
Daihatsu	691	28
Yanmar	375	15
Wartsila	309	12
Sulzer	71	3
MAK	56	2
Other	192	8

Figure III-2 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-2: Auxiliary Engine Age Distribution

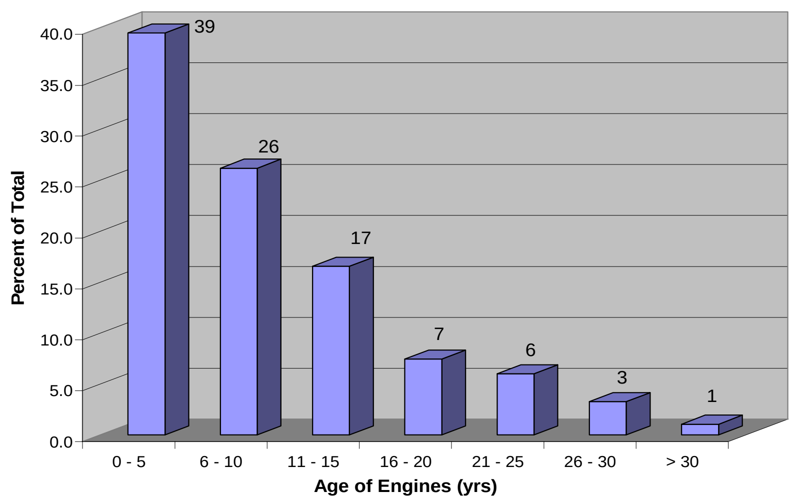


Table III-8 provides information on the average power generated by the auxiliary engines when vessels are hotelling (dockside), maneuvering at ports, and transiting at sea. The diesel generator set engines on passenger cruise vessels are defined as “auxiliary engines” for the purposes of the proposed 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)
Auto Carrier/Ro-Ro	600	1,000	600
Bulk Carrier/General	400	600	500
Container	1,100	2,300	1,400
Motor Ship/Container	1,200	3,200	1,400
Passenger	6,700	14,400	28,000
Product Carrier	500	1,000	800
Reefer	1,100	1,100	1,000
Tanker	600	1,400	1,700
Average of all Vessels	1,525	3,125	4,425

Main Engines

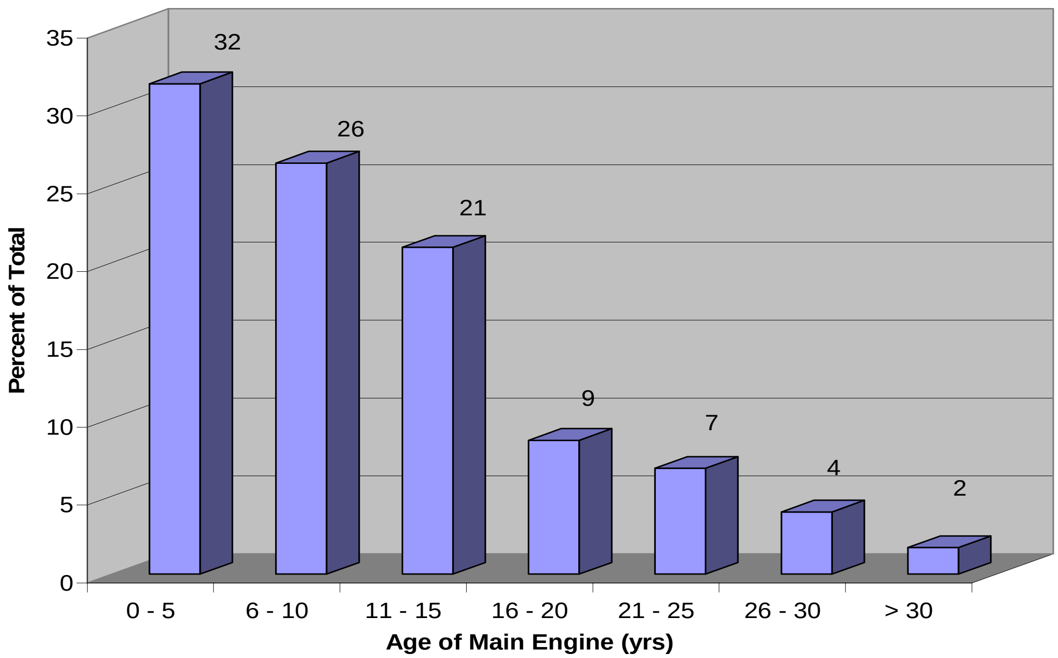
The 2006 Survey reported several different engine manufacturers; however three companies, Man B&W, Sulzer, and Mitsubishi were shown to make the majority of the engines. The Man B&W and Sulzer engines that are clearly identified are shown below. Most of the other engines are likely Man B&W or Sulzer designs produced by the shipyards under licensing agreements. Table III-9 provides the major manufacturers reported.

Table III-9: Main Engine Manufacturers

Engine Maker	Number of Engine Makes	Percent of Total Engines
Man B&W	479	66
Sulzer	117	16
Mitsubishi	88	12
Sulzer/Wartsila	14	2
General Electric	12	2
Other	13	2

Figure III-3 shows the age distribution of main engines, which reveals about 80 percent of the main engines are less than 15 years old, with 32 percent less than 5 years old, and the average age of a main engine is 12 years.

Figure III-3: Main Engine Age Distribution



According to the Survey, as reported in Table III-10, 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-10: Main Engine Types

Engine Type	Number of Engines	Percent of Total Main Engines
Diesel Compression-Ignition	704	98
Steam Turbine	8	1
Gas Turbine	6	1

Additional information was gathered regarding whether the diesel engines were either two or four-stroke. As shown in Table III-11 below, 96 percent of the main engines on ocean-going 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 stoke 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-11: Diesel Main Engine Types

Diesel Engine Type	Number of Engines	Percent of Total Diesel Engines
2-stroke	670	96
4-stroke	26	4

D. Auxiliary Boilers

Most ocean-going vessels have boilers. A boiler is a closed vessel in which water is heated under pressure to produce steam. In marine boilers, the steam is used for a variety of purposes such as: (1) heating residual fuel; (2) production of hot water and space heating for passengers or crew; (3) distillation of seawater to generate fresh water; (4) driving steam turbine pumps to offload crude oil or other petroleum products carried by tankers; and (5) driving steam turbines for ship propulsion on steamships. Marine boilers vary in size from the small "auxiliary boilers" used on most cargo vessels primarily to heat residual fuel, to the largest boilers used to propel steamships. This discussion focuses on auxiliary boilers, rather than the main boilers used to propel some steamships. Because there are very few steamships still in service, they are proposed to be exempt from the proposed regulation.

Auxiliary marine boilers may be categorized broadly based on function as follows: (1) relatively small auxiliary boilers used on most ocean-going vessels primarily to heat residual fuel; and (2) larger auxiliary boilers used on tankers to drive steam turbine pumps for crude oil.

Boiler output is typically rated in terms of steam capacity (weight of steam produced per hour at a given pressure). Cargo ship auxiliary boilers are typically rated in the 1-10 tonnes steam per hour range, while tankers, using boilers to power steam turbine discharge pumps, will typically be rated above 10 tonnes per hour. Boilers may also be rated by their thermal output (in terms of megawatts, horsepower, or Btu/hour). Table III-12 lists some models offered by major manufacturers and their output.

Table III-12: Typical Marine Boilers

Manufacturer	Model	Steam Capacity (tonne/hr)	Thermal Output (MW)	Typical Marine Application
Kangrim	MA Series	1-7 @ 6 bar	Not listed	cargo ship
Aalborg	UNEX-CHB	0.75-15 @ 10-18 bar	Up to 10	cargo ship
Aalborg	AQ-10/12W	0.6-6.3 @ 10 bar	Up to 4.4	cargo ship
Aalborg	Mission OS	1.6-6.5 @ 10 bar	Up to 4.6	cargo ship
Aalborg	Mission OM	8-20 @ 11 bar	5.6-14	tanker
Kangrim	MB Series	8-40 @ 16 bar	6-29	tanker
Aalborg	Mission OL	12.5-55 @ 18 bar	8.8-38.8	tanker

* Information from www.aalborg-industries.com and www.kangrim.com

Boiler Design: Marine boilers are similar to land-based industrial boilers except that they are generally smaller, less complex, and generally do not include heat recovery equipment. Marine boilers are manufactured in a variety of different configurations. Some are designed to burn fuel while others use main engine exhaust heat. In addition, there are differences in burner designs, and the physical heat exchange ("convection") surfaces. Control systems are also incorporated into the design, which handles the operation of pumps, fans, burners, and other equipment.

Marine boilers can be oil-fired, exhaust gas-fired, or combination ("composite") boilers. Oil-fired boilers have a burner which combusts fuel to supply heat for steam production. These boilers generally burn residual fuel (heavy fuel oil), although they can also use marine distillate fuels, and in some cases, waste oil or sludge. Exhaust gas-fired boilers (also called economizers) use heat from the exhaust of the main engine. Composite boilers can use either the main engine exhaust or fuel, depending on the operation of the vessel.

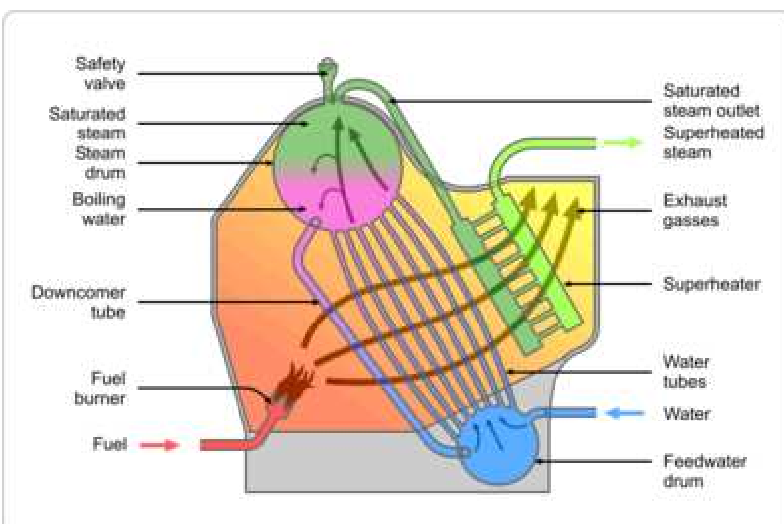
For most cargo ships, the main engine is turned off at dockside, and an auxiliary boiler(s) must continue to operate to keep the ship's heavy fuel oil warm. Therefore, an economizer alone is not sufficient, and most ships must have either separate oil-fired boilers and exhaust gas-fired boilers, or a combination boiler.

Burners are designed to atomize the fuel, mix it with air, and shape the flame for optimum efficiency as combustion gases flow through the furnace. In many cases, different burner options are available with the installation of a new boiler, and they may be upgraded or replaced while leaving the rest of the boiler in place. Since most oil-fired boilers use heavy fuel oil, this fuel must be heated, and then atomized through high pressure or with the aid of steam. There are different burner designs including pressure jet burners, rotary cup burners, and steam atomizing burners. Pressure jet burners atomize fuel by passing it through burner nozzles at high pressure. Rotary cup burners use centrifugal force. Specifically, fuel oil is delivered into a spinning cup where centrifugal force moves the fuel forward until it is thrown off the cup rim as a fine, uniform film that is subsequently atomized by high velocity air discharged around the cup (Aalborg, 2008). Steam atomizing burners inject steam together with the fuel to help disperse the fuel. The steam can by injected together with the fuel at the nozzle tip, or the steam and fuel can be mixed inside the nozzle prior to injection.

Many marine boilers can be broadly classified as either fire tube (smoke tube), or water tube boilers. Fire tube boilers circulate hot combustion gases through tubes which are surrounded by water. Water tube boilers circulate water within tubes which are heated externally by exhaust gases. To improve the efficiency of heat transfer within a compact space, manufacturers seek to increase the total convective surface area on the gas side of the tubes. One such approach utilizes a “pin-tube” structure where water is contained within tubes that have numerous smaller “pins” projecting out radially from the tubes. One manufacturer claims that the addition of the pins expands the tube surface area such that the length of the tube can be reduced by a factor of eight compared to plain tubes (Aalborg, 2002). Other designs use “gilled” tubes with flat plates attached to the tubes (Aalborg, 2007a). Some modern boilers also use hybrid designs that are essentially water tubes within fire tubes (Aalborg, 2007b).

A diagram of a marine-type water tube boiler is shown in Figure III-4.

Figure III-4: Water Tube Boiler



As described below, the operation of marine auxiliary boilers varies with the type of vessel.

Cargo Ships

On most cargo vessels, the small auxiliary boilers are generally used to heat residual fuel, lubricating oil, main engine coolant, and water for use by crew (APL, 2007a; Matson, 2007). These boilers are generally only used when the main engine is not up to full operating temperature. This is when a vessel is at dockside, maneuvering, at anchorage, or approaching or leaving port (APL, 2007b; Matson, 2007). This is because the exhaust from the main engine generally provides enough waste heat when the main engine is at full operating temperature for the economizer to provide steam for heating residual fuel and other uses. The transition from the use of the economizer at sea to the auxiliary boiler when arriving (and the reverse on departure) will depend on the specific ship, port geography and vessel speed restrictions. Nevertheless, ship operators and other sources have reported relatively similar estimates for auxiliary boiler operation which include: (1) about an hour prior to picking up the pilot, and an hour after dropping of the pilot (APL, 2007b; MARAD, 2007); or (2) about an hour prior to maneuvering on arrival at port, and about an hour after maneuvering on departure (Matson, 2007).

Cruise Ships

Cruise ships use their auxiliary boilers for domestic hot water and space heating (for passengers and crew), and also to heat heavy fuel oil, heat pool water, and in the galley for dishwashers and soup kettles (Crystal Cruises, 2007). In addition, some cruise ships use their auxiliary boilers to generate freshwater by distilling seawater. Cruise ships use their boilers when the main engines are not up to full operating temperature, and, unlike cargo ships, may also use them when the vessel is transiting at sea (Crystal Cruises, 2007). Cruise ship boilers generally use more fuel than cargo ships because they need to more hot water and space heating for passenger cabins, in addition to keeping residual fuel warm.

Tankers

The operation of boilers on tankers varies widely with the type and function of the boilers on the individual vessel. Most tankers have much larger boilers than other ships because they drive high power steam driven centrifugal pumps used to discharge liquid cargo at dock. Therefore, during discharging of cargo, the boiler fuel consumption and emissions will be much greater than for other vessels. These tankers also use their boilers to heat residual fuel, certain viscous cargos (such as heavy petroleum crude and asphaltic roofing flux), and for hot water and space heating for crew. When not used for discharge pumps, the boiler fuel consumption and emissions may be similar to cargo ships, and at sea the economizer often provides sufficient steam. Tankers with large boilers for discharge pumping often also have a smaller boiler that provides steam for uses such as hot water for the ship's crew.

Not all tankers use steam driven pumps to discharge cargo. Some vessels use diesel auxiliary or main piston engines, or electric motors to drive the discharge pumps. For these ships, the boiler size and operation will be similar to other cargo ships.

There are numerous manufacturers of marine boilers. Table III-13 lists some of the major manufacturers.

Table III-13: Boiler Manufacturers

Aalborg Industries	Mitsubishi Heavy Industries
Hitachi Zosen Corporation	Mitsui Engineering and Shipbuilding
Ishikawajima-Harima Heavy Ind.*	Osaka Boiler Mfg. Company
Kawasaki Heavy Industries	Tortoise Engineering

* IHI no longer manufactures boilers, but some ships still use them

Aalborg Industries, with headquarters in Denmark, is the leading manufacturer of marine boilers (Aalborg, 2007b) and some of the other manufacturers make Aalborg designs under license. There are also many smaller manufacturers based near shipyards.

E.   Vessel Fuels and Fuel Systems

As explained in Section C, most ocean-going 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 generally run on HFO but some operate on 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 and HFO in their main engine are referred to as dual-fueled vessels.

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. (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℃. 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℃. (EPA, 1999)

Listed below in Table III-14 are the common marine fuels discussed above, and the range in their allowable properties.

Table III-14: Selected ASTM Specifications for Marine Fuels

	Distillate Fuels		**HFO/Residual Fuels**	
Specification	**MGO (DMA)**	**MDO (DMB)**	**IFO 180 (RME/F-25)**	**IFO 380 RMG/H-35**
Min. Flash Pt. (℃)	60	60	60	60
Kinematic Viscosity (cSt@40℃)	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℃, ** IMO Annex V I limits sulfur to 4.5%.

On-Board 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.

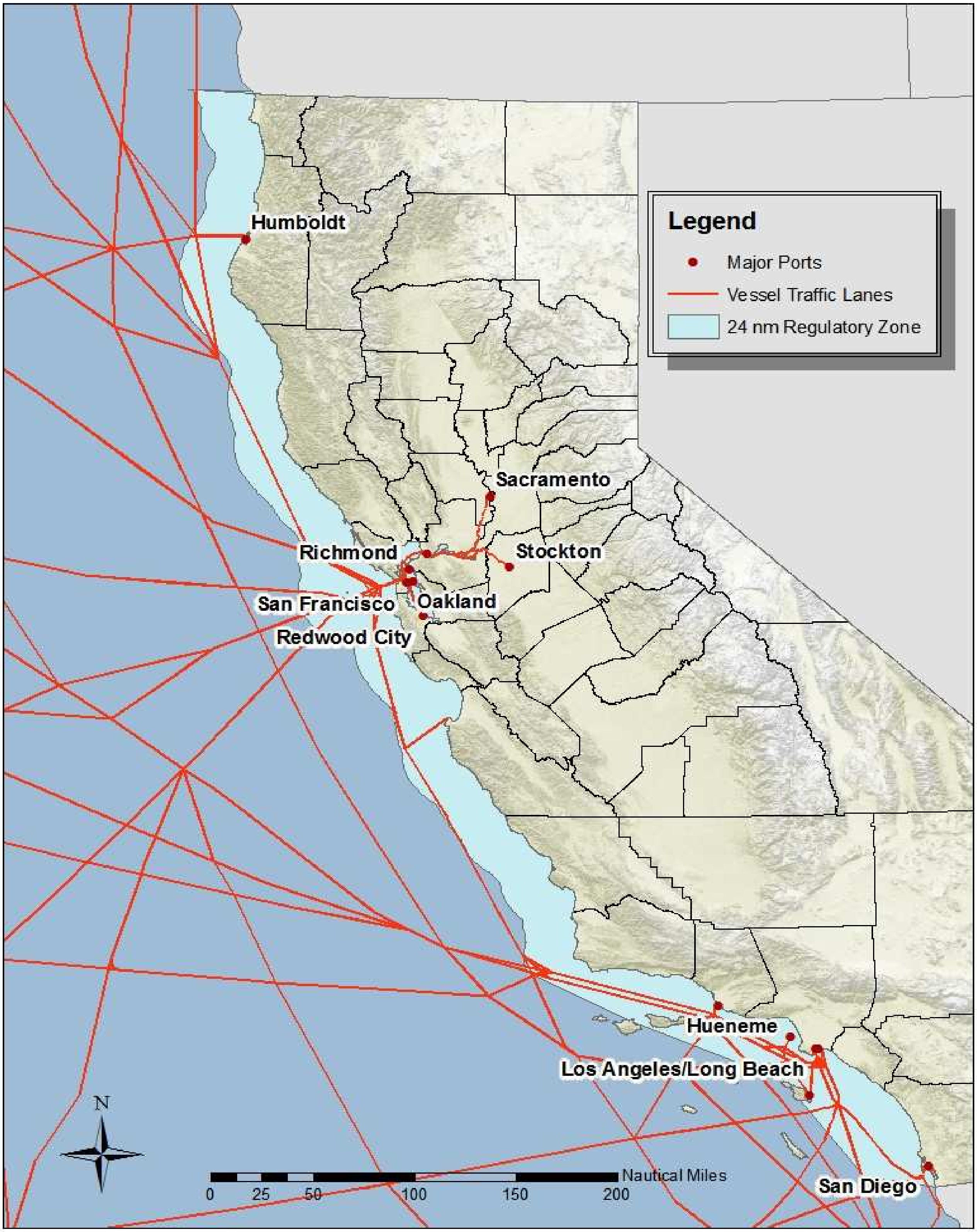
The fuel processing steps mentioned above apply to both HFO and distillate fuels. However, heavy fuel oil must also be heated to 100 to 200 degrees Celsius to reduce its viscosity to a point where it can be pumped and combusted in the engine. Because HFO is so viscous, vessel operators switch to distillate 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.

F. 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 2006, California's ports were visited by more than 2,000 ocean-going vessels. These vessels made approximately 11,000 visits to one or more of California's deep-water ports.

Ships typically travel in designated shipping lanes (similar to airplane flight paths) in high traffic areas near California's ports. For example, there are designated shipping lanes that ocean-going vessels use within the Santa Barbara Channel and approximately 25 nautical miles south of the Ports of Los Angeles and Long Beach. (MXSoCal, 2005). 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. (MXSF, 2005). 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 ocean-going vessels off California's coastline, including both designated traffic lanes and other areas, ARB staff used a network of vessel traffic lanes which was a composite of lane information from the United States Army Corps of Engineers (USACE) National Waterway Network, the Ship Traffic Energy and Environment Model (STEEM) developed by Dr. James Corbett, and data from ship automated instrumentation system (AIS) data. The vessel traffic lanes, major California ports, and the 24 nm regulatory zone are shown in Figure III-5.

Figure III-5: Vessel Shipping Lanes and the 24 nm Contiguous Zone



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(Matson, 2007) Matson Navigation Company. Personal communication with ARB staff dated August 31, 2007.

(MXSF, 2005) Marine Exchange San Francisco. Personal communication with ARB staff. September 26, 2005.

(MXSoCal, 2005) Marine Exchange of Southern California. Personal communication with ARB staff, September 26, 2005.

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IV. EMISSIONS, POTENTIAL EXPOSURES, AND RISK

This chapter provides a summary of the emissions inventory for ocean-going vessels (OGVs). Emissions were estimated within two distinct zones; a 24 nm zone which was used for implementation of the 2005 auxiliary engine regulation and development of the Goods Movement Emission Reduction Plan, and a 100 nautical mile zone that is used for ARB's emissions inventory system and the State Implementation Plan. In this chapter, the emissions inventory for the 24 nm zone is presented. The reader is directed to Appendix D for information on the emissions estimates within the 100 nm zone as well as for additional details on the methodology and contributions of OGVs emissions attributed to the main engine, auxiliary boilers, and auxiliary engines. In addition, this chapter includes a discussion on the impacts of OGV emissions on California air quality and the potential cancer and noncancer health risks that may occur due to the operation of these engines.

A. Estimated Emissions from Ocean-Going Vessels

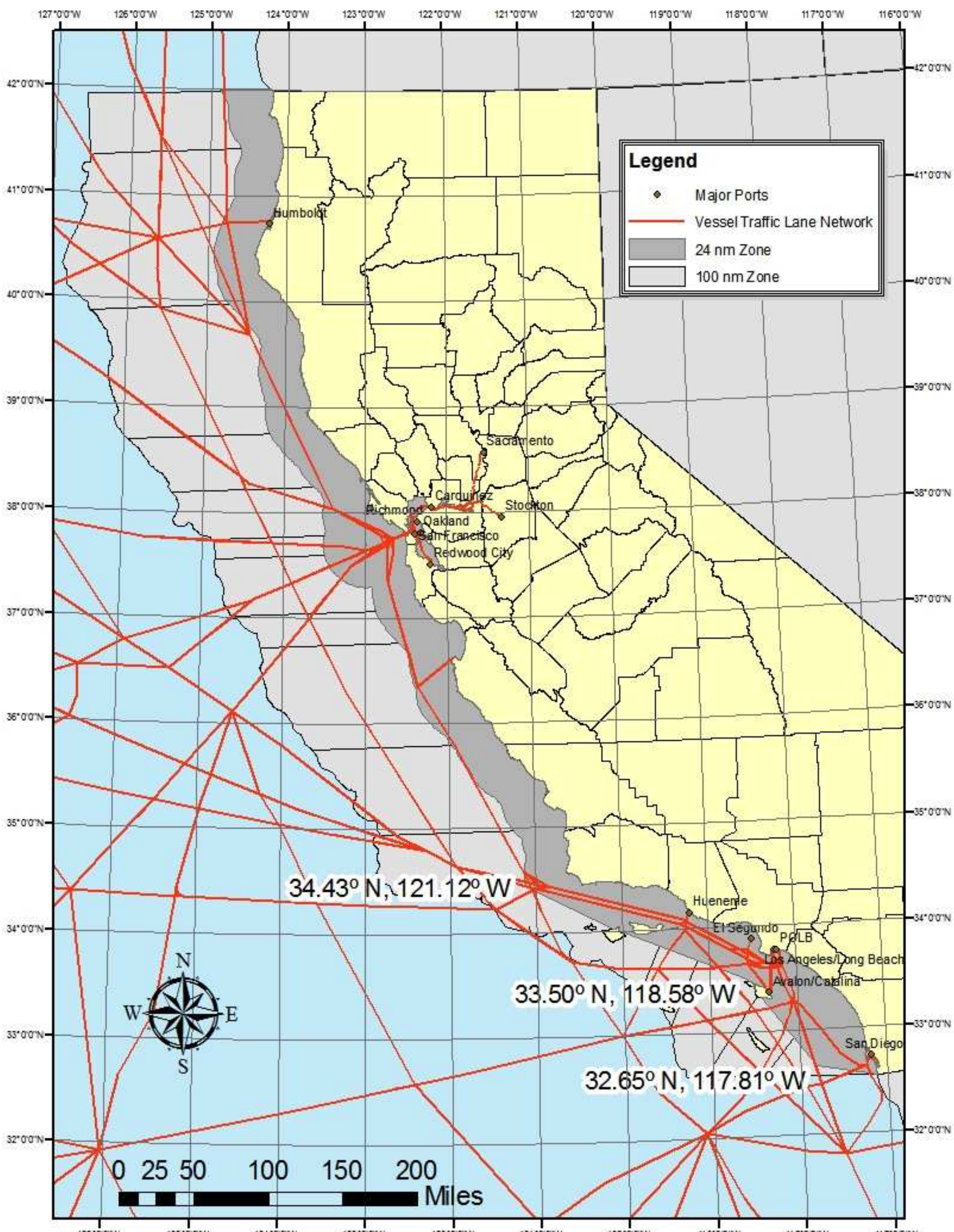
ARB staff has updated the emissions inventory for OGVs to reflect new information and improved methodologies. This inventory is a revision of the 2005 emissions inventory developed by staff in 2005 in support of a number of programs, including the Auxiliary Engine Regulation. The main changes from the 2005 inventory include:

- Updating the inventory to reflect recent (2006) activity data
- Inclusion of more specific information on ship and port calls
- Alignment of the inventory to reflect recent port inventories
- Revision of growth assumptions and methods
- Assessment of the benefits of adopted regulations

The proposed inventory increases the specificity of the earlier inventory by including vessel specific characteristics and port call specific activity data, including port call specific hotelling times for individual vessel visits; vessel-specific power and speed ratings, and a more accurate shipping lane network. It is also based on more recent activity data: the earlier inventory used a 2004 base year; the new inventory uses a 2006 base year. The growth factors were updated with additional years of trend data, a port and vessel type specificity, and a more robust growth surrogate. Finally, existing control strategy emission reductions are built into the inventory model, rather than being applied from the forecasting database.

Emissions are calculated by estimating ship emissions on a ship by ship and a port call by port call basis, using actual ship engine power estimates, speeds, and actual ship hotelling times where possible. Base year emissions were forecasted using a set of growth factors specific to each port and each ship type. Emissions were estimated within two zones which differed by the distance from the California coastline wherein the emissions were counted. As shown in figure IV-1, emissions were estimated within 24 nm and 100 nm of the California coastline. On the figure, the outer black line, which mirrors the California coastline, represents the 100 nm emission inventory boundary while the shaded gray area is the 24 nm zone emission inventory boundary. This area is also known as the "regulatory" boundary as it is within this region where the proposed regulation would be implemented.

Figure IV-1: Ocean-Going Vessel Emissions Inventory 24 nm and 100 nm Boundaries



The most recent year with activity data, 2006, was chosen as the base year. Base year emissions were forecasted by assessing trends in the growth of vessel net registered tonnage for the years 1994-2005. Net registered tonnage (NRT) is a measure of the volume of a ship's cargo capacity; the growth in NRT is directly proportional to the growth in installed power of a vessel's main propulsion engine. Controlled future year emissions for 2010 and 2020 were forecasted using the above methodology by including the benefits of adopted regulations including the 2007 Shore Power regulation. 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 OGVs.

Emission Estimates for Ocean-Going Vessels Operating in the 24 nm Zone

The emissions presented here include all OGV emissions within the 24 nautical mile regulatory zone. These include all emissions from the main engine, auxiliary boilers, and auxiliary engines used during transiting, maneuvering, at anchorage, or at berth. The updated emissions inventory and estimated future emissions inventories are presented for the years 2006, 2010, and 2020. The effects of adopted regulations and voluntary measures are also reflected in these estimates.[1]

Estimates of statewide 2006 PM_{10}, NOx, SOx, carbon monoxide, and reactive organic gases (ROG) from OGV within the 24nm zone are presented in Table IV-1. ARB staff estimates that the statewide PM_{10} emissions for OGVs operating within the 24 nm zone are approximately 15 tons per day or approximately 5,330 tons per year in 2006. As shown in Table IV-1, there are approximately 2,100 vessels that visited California's ports in 2006. Of these, about 30% were container vessels which represented more than 45% of the vessel port call visits to California's ports.

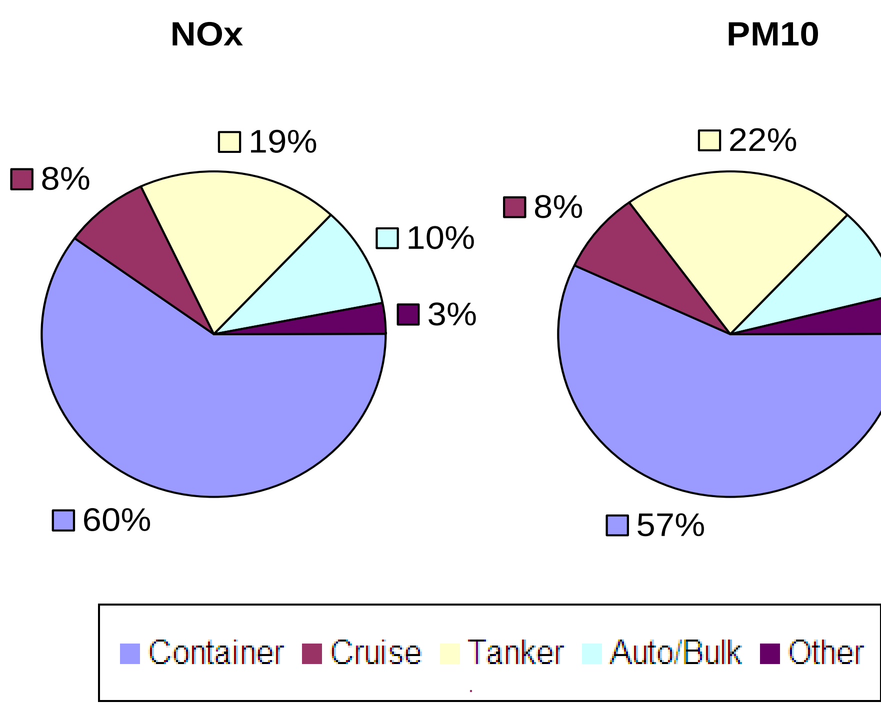
[1] The following regulations and measures are incorporated into the emission inventory projections: 1997 MARPOL Annex VI Emission Standards; 2004 Los Angeles/Long Beach Voluntary speed Reduction Zone; 2005 U.S. EPA Category 3 Engine Standards; 2007 Shore Power Regulation.

Table IV-1: Estimated Statewide 2006 Ocean-Going Vessel Emissions (24 nm)

Vessel Types	Numbers of Vessels	Numbers of Vessel Visits	2006 Pollutant Emissions, Tons/Day				
			NOx	ROG	CO	PM_{10}	SOx
Auto	234	1,006	7.2	0.3	0.6	0.6	4.6
Bulk	475	983	7.9	0.3	0.6	0.7	5.1
Container	593	5,038	94.2	3.7	7.7	8.4	60.1
Passenger	52	770	12.0	0.4	0.9	1.2	9.0
General	147	371	3.3	0.1	0.3	0.3	2.1
Reefer	68	315	2.2	0.1	0.2	0.2	1.7
Ro-Ro	28	112	0.7	<.1	0.1	0.1	0.5
Tanker	458	2,391	29.5	1.2	2.4	3.2	34.1
Totals	2,055	10,986	157	6	13	15	117

As shown in Figure IV-2, container vessels represent approximately 60% of all the PM_{10} and NOx emissions emitted by OGVs; followed by tankers, auto/bulk carriers, and cruise vessels.

Figure IV-2: 2006 PM_{10} and NOx Emission Distributions for Ocean-Going Vessels, 24 nm



The ARB staff also estimated district-specific emissions associated with OGVs. 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 OGVs operating in 24 nm zone.

Table IV-2: Estimated 2006 Ocean-Going Vessel Emissions by District (24 nm)

District	2006 Pollutant Emissions, Tons/Day				
	NOx	ROG	CO	PM_{10}	SOx
Bay Area AQMD	37.7	1.5	3.0	3.6	31.4
Mendocino County AQMD	6.8	0.3	0.5	0.6	4.2
Monterey Bay Unified APCD	20.1	0.8	1.6	1.7	12.3
North Coast Unified APCD	5.5	0.2	0.4	0.5	3.4
Northern Sonoma County APCD	3.9	0.1	0.3	0.3	2.4
San Diego County APCD	5.9	0.2	0.5	0.6	4.2
San Joaquin Valley Unified APCD	0.3	<.1	<.1	<.1	0.5
San Luis Obispo County APCD	2.8	0.1	0.2	0.2	1.7
Santa Barbara County APCD	22.0	0.9	1.7	1.9	13.4
South Coast AQMD	44.9	1.7	3.8	4.5	39.0
Ventura County APCD	7.3	0.3	0.6	0.6	4.8
Yolo/Solano AQMD	0.1	<.1	<.1	<.1	0.1
Total	157	6	13	15	117

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. Emissions attributed to Northern Sonoma air district are included in Bay Area pollutant totals. Total emissions in Table IV-2 may vary from values in Table IV-1 due to rounding.

The projected emission estimates within the 24 nm zone for the years 2010 and 2020 are presented in Table IV-3. Details of the growth assumptions used to determine growth rates are contained in Appendix D, Emissions Estimation Methodology for Ocean-Going Vessels.

Table IV-3: Ocean-Going Vessels Projected Year 2010 and 2020 Emission Estimates (24nm)

Vessel Types	2010 Emission, Tons per Day					2020 Emission, Tons per Day				
	NOx	ROG	CO	PM_{10}	SOx	NOx	ROG	CO	PM_{10}	SOx
Auto	7.6	0.3	0.6	0.7	4.9	9.3	0.4	0.7	0.8	6.0
Bulk	7.8	0.3	0.6	0.7	5.1	8.3	0.3	0.7	0.7	5.4
Container	114.9	4.5	9.5	10.2	73.5	175.7	7.0	14.6	15.8	114.3
Passenger	14.3	0.5	1.1	1.4	10.7	20.6	0.7	1.6	2.0	15.6
General	3.5	0.1	0.3	0.3	2.2	3.9	0.2	0.3	0.3	2.5
Reefer	2.5	0.1	0.2	0.2	1.8	3.4	0.1	0.3	0.3	2.5
Ro-Ro	0.8	<.1	0.1	0.1	0.5	0.9	<.1	0.1	0.1	0.6
Tanker	30.6	1.2	2.5	3.3	35.5	34.3	1.4	2.8	3.8	40.2
Totals	182	7	15	17	134	256	10	21	24	187

B. Transport of Offshore Ocean-Going Vessel Emissions and Impacts on California Air Quality

As discussed earlier in this staff report, OGV exhaust results in emissions of diesel PM, PM, NOx and SOx. In addition, NOx and SOx are transformed by atmospheric chemical and physical mechanisms resulting in the formation of secondary pollutants such as ozone and PM. During the development of the Auxiliary Engine Regulation, ARB staff provided extensive documentation to demonstrate that air pollution can be transported and that emissions from OGVs released offshore the California Coast can impact onshore air quality (ARB, 2005). Since that time, ARB staff has conducted additional analysis to further our understanding of the atmospheric impacts of these emissions, especially on regional air quality in California.

ARB staff conducted two studies in 2008 that evaluated the impacts of emissions from OGVs on California air quality. The first study - Air Quality Modeling Analysis of the Impacts of OGV Emissions on the South Coast Air Basin – used the CMAQ air quality photochemical model to estimate the impact of OGV emissions on secondary PM and ozone in the South Coast Air Basin (SCAB). The second study - Statewide CALPUFF Dispersion Modeling of Ocean-Going Vessel Emissions – used the CALPUFF dispersion model to estimate statewide diesel PM concentration due to OGV emissions. The reports are provided in Appendix E1 and E2.

For Southern California, the CMAQ air quality model was run for the year 2005 emission using two different emissions scenarios; one scenario included the emissions (PM, Reactive Organic Gases (ROG), NOx, SOx) from all sources in the SCAB and the other was identical to the first except the emissions from OGV were excluded. In this study, the contribution from OGV to ambient levels of pollutants was calculated from the difference between the two emissions scenarios. In the summary provided below, the results of annual maximum 8-hour ozone (O_3) concentration, and the annual average concentrations of $PM_{2.5}$, primary $PM_{2.5}$, $PM_{2.5}$ sulfate (SO4), and $PM_{2.5}$nitrate (NO3) are reported.

The second study evaluated the impacts of OGV diesel PM emissions on statewide ambient levels of diesel PM. In this study the CALPUFF air dispersion was used along with the OGV 2005 diesel PM emissions and meteorological data from 2002. Statewide annual average concentrations of diesel PM due to OGV emissions were estimated.

Combined, the results of these two studies demonstrate that OGV emissions impact air quality in California and the control of OGV emissions is necessary to mitigate air pollution and protect public health. Below, we provide a summary of the key findings from the studies. Additional details are provided in Appendix E1 and E2.

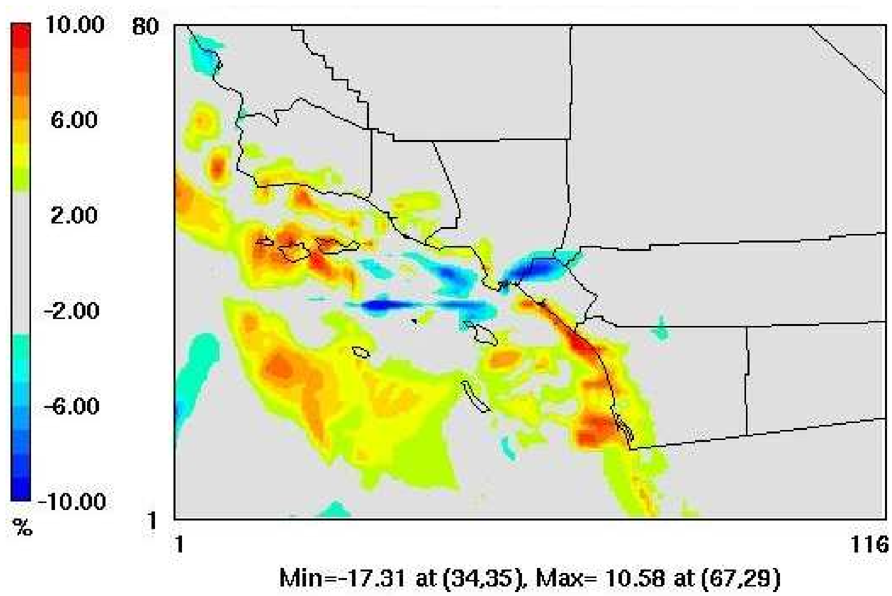
CMAQ OGV Modeling Analysis - Ambient Ozone Concentrations

Figure IV-3 provides the impacts on maximum 8-hr ozone background concentrations due to OGV emissions. In the figure, the relative (%) difference between ozone concentrations with all emissions (including OGVs), and concentrations resulting from non-OGV emissions only, are provided. Note that positive values indicate increases in concentrations due to OGV emissions, while negative values indicate decrease in concentrations due to OGV emissions.

The greatest positive percent changes (increase in ozone due to OGV emission) take place along the coast of Orange and San Diego counties. Increases in ozone are also seen in Santa Barbara, Ventura, and San Luis Obispo counties. Increases or decreases in ozone concentrations due to OGV emissions depend upon the intensity of local precursor emissions, especially NOx to ROG ratio, and other factors such as temperature. In the areas around the Ports of Los Angeles and Long Beach, the modeling shows relatively small increases or decreases in ozone concentrations from OGV emissions. This may be explained by the fact that these areas tend to be NOx rich, and further increases in NO_2 due to OGV emissions may lead to a decrease in ozone concentration. (Griffin et al., 2004)

Note: Figures IV-3 through IV-7 are best viewed in color as the legend encompasses the entire color spectrum, which, when presented in black and white obscures the data. The color versions of the figures can be found electronically at http://www.arb.ca.gov/regact/2008/fuelogv08/fuelogv08.htm.

Figure IV-3: Relative Change of Annual Maximum 8-Hour O_3 Concentrations Due to OGV Emissions
(only the relative changes > 4% and < -4% are shown in the plot)



<u>CMAQ OGV Modeling Analysis - Ambient PM concentrations</u>

The SCAB region exhibits some of the highest levels of ambient PM and experiences a large number of days with ambient PM concentrations exceeding the State and federal air quality standards (CARB, 2007). In addition to direct emission of particles from combustion and other sources, a significant fraction of fine PM is formed through secondary processes from gas-phase emissions. In this section, the relative contribution of OGV emissions to ambient PM is quantified by analyzing model predicted PM concentrations for modeling cases with and without OGV emissions.

Figures IV-4, IV-5, IV-6, and IV-7 show the estimated relative contributions from OGV emissions for annual averaged total $PM_{2.5}$ (summation of primary and secondary $PM_{2.5}$), primary $PM_{2.5}$, $PM_{2.5}$ sulfate, and $PM_{2.5}$ nitrate. Since primary $PM_{2.5}$ is not explicitly defined in the CMAQ model, the summation of primary $PM_{2.5}$ sulfate and the non-reactive $PM_{2.5}$ species in the emissions inventory, including PM2.5 elemental carbon (EC), primary organic carbon, and unspeciated $PM_{2.5}$ was assumed to represent total primary $PM_{2.5}$. For this study, primary $PM_{2.5}$ sulfate included direct emissions and contributions from boundary and initial conditions. The primary $PM_{2.5}$ did not include concentrations of nitrate because it is not feasible to use the model to distinguish between the primary and secondary components of this species. This may not be a significant source of error since there are no significant amounts of primary nitrates in the emissions inventory (based on the ARB speciation profile, about 0.01% of direct PM is assumed to be nitrate). The total secondary $PM_{2.5}$ includes $PM_{2.5}$ NO_3, $PM_{2.5}$ NH_4, secondary $PM_{2.5}$ SO4 and organic carbon.

Figure IV-4: Estimated Relative Contributions of OGV Emissions to Annual Averaged Total $PM_{2.5}$

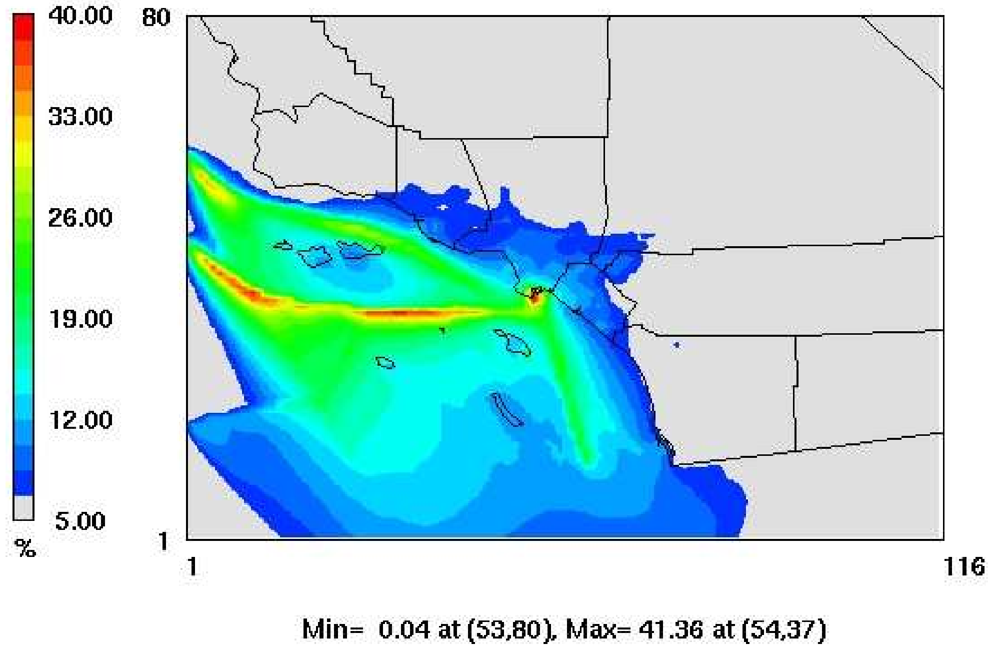


Figure IV-5: Estimated Relative Contributions of OGV Emissions to Annual Averaged Primary $PM_{2.5}$

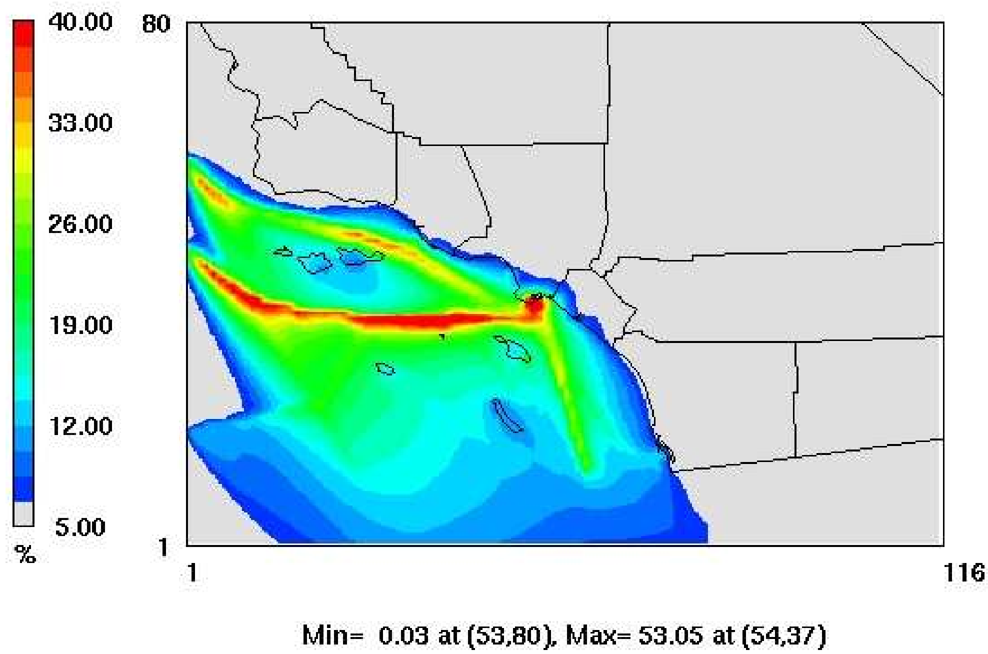


Figure IV-6: Estimated Relative Contributions of OGV Emissions to Annual Averaged $PM_{2.5}$ Sulfate

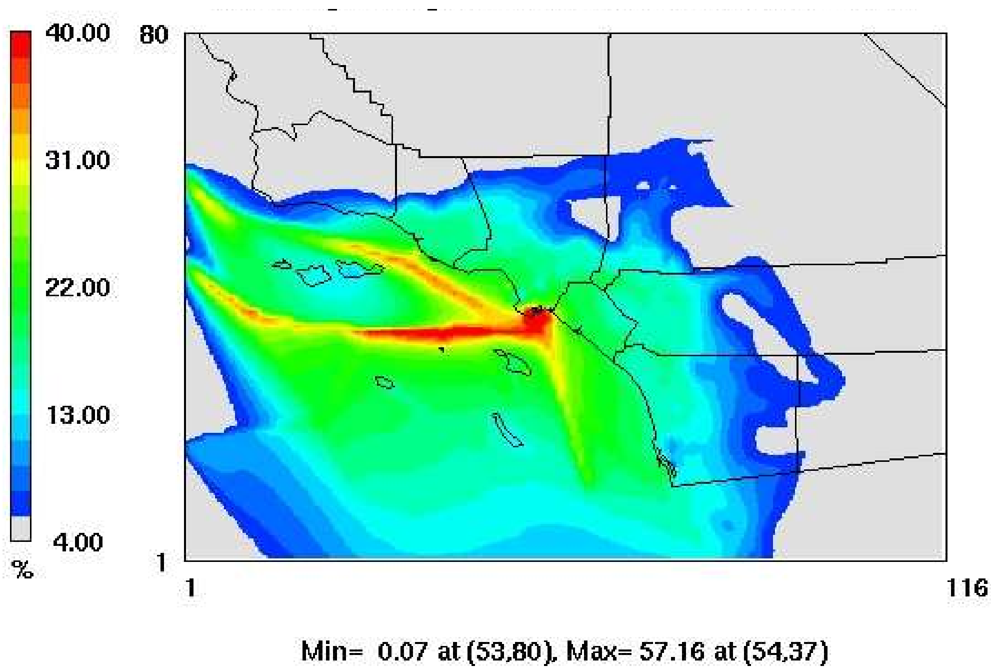
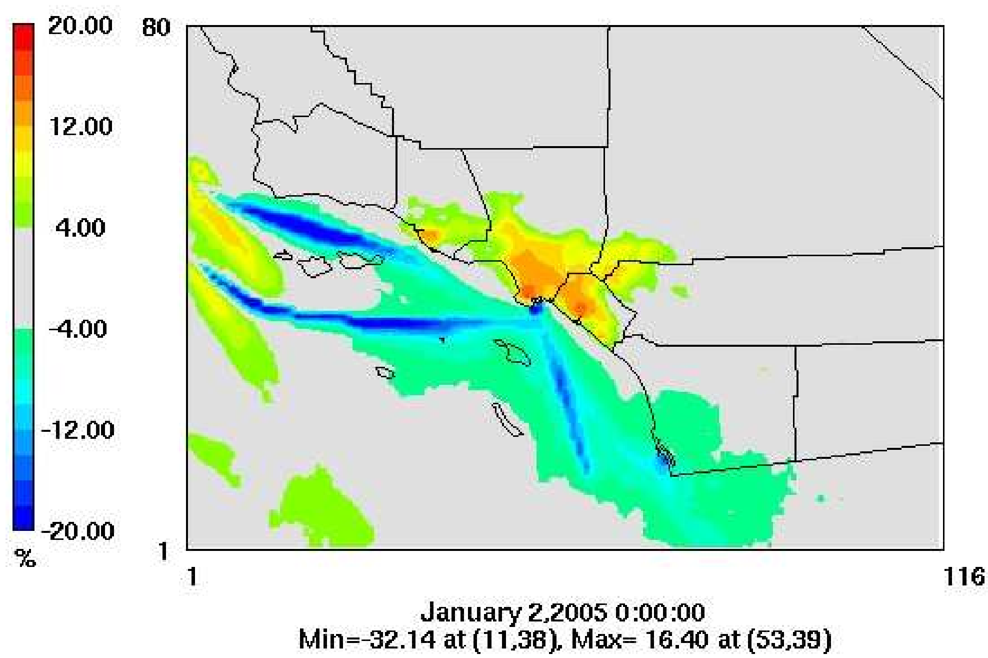


Figure IV-7: Estimated Relative Contributions of OGV Emissions to Annual Averaged $PM_{2.5}$ Nitrate



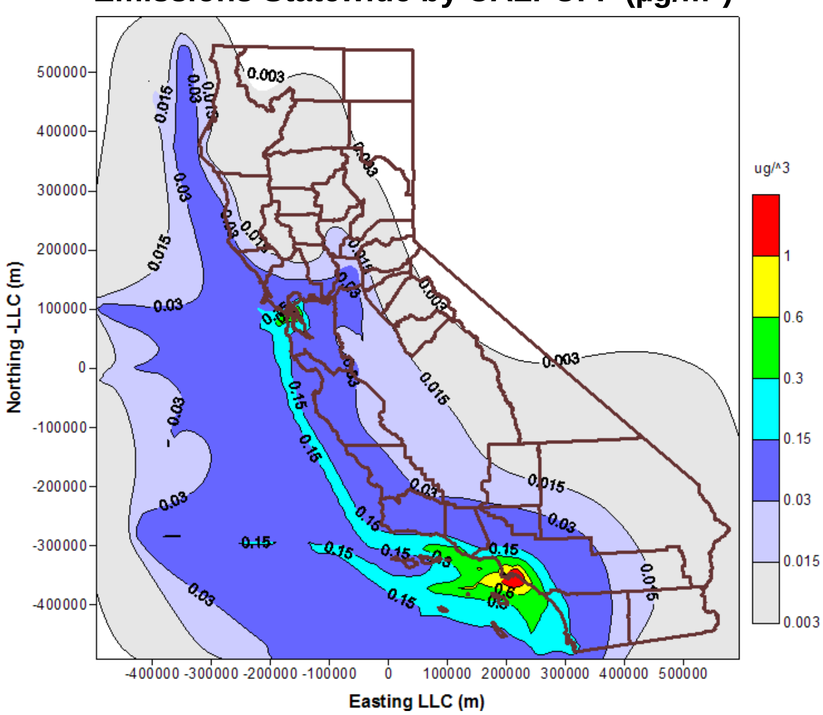
The greatest impact of OGVs on onshore $PM_{2.5}$ concentrations occurred in the vicinity of the Ports of Los Angeles and Long Beach, where emissions from OGVs accounted for approximately 25% of the $PM_{2.5}$ and 33% of the primary $PM_{2.5}$. The maximum relative contribution of OGV emissions to the total ambient PM2.5 is estimated to be about 41% which occurs in the area of the Ports of Los Angeles and Long Beach. More than 40% of the difference in $PM_{2.5}$ in the Ports area was attributed to SO_4 concentrations. A broad area (>4% difference) of OGV impacts on SO_4 was predicted, covering most of the ocean area, coastline, and the Los Angeles Basin. For secondary $PM_{2.5}$ NO_3, the maximum relative contribution of OGV emissions is estimated to be about 16% which occurs at an area about 2-3 miles northwest of the Ports of Los Angeles and Long Beach. There is less impact of OGVs on NO_3 compared to SO_4. Overall a significant fraction of the contribution from OGV emissions to onshore PM comes as secondary PM from gas-phase emissions.

Researchers at UC Irvine conducted a similar modeling effort for investigating the effects of ship emissions on the Southern California air quality (Vutukurk, 2008). The study also showed that ship emissions impact Southern California air quality.

<u>CALPUFF OGV Modeling Analysis - Ambient Diesel PM Concentrations</u>

Figure IV-8 shows statewide annual average diesel PM concentrations resulting from OGV directly emitted diesel PM emissions. The CALPUFF modeling results estimate annual average diesel PM concentrations in the range of 0.03 to 1.0 µg/m^3 along the California coastline. These concentrations correspond to a 70-year cancer risk estimate of between 10 and 300 chances in a million. The highest concentrations are seen in areas near the Ports of Los Angeles and Long Beach and in the San Francisco Bay Area. These findings are consistent with the results from the Health Risk Assessments for the Ports of Los Angeles and Long Beach and the West Oakland Community.

Figure IV-8: Estimated Annual Average Concentrations of Diesel PM from OGV Emissions Statewide by CALPUFF (µg/m^3)



C. Potential Exposures and Health Risks from Ocean-Going Vessel Engine Diesel PM Emissions

This section examines the exposures and potential health risks associated with PM emissions from OGV. A brief qualitative discussion is provided on the potential exposures of Californians to the diesel PM emissions from OGV engine operations. In addition, a summary is presented of three health risk assessments conducted to determine the 70-year potential cancer risks associated with exposures to diesel PM emissions from OGV traveling in the California waterways and operating at the Port of Oakland, Port of Los Angeles, and Port of Long Beach. The noncancer health impacts resulting from the OGV PM emissions within the South Coast Air Basin were also investigated and are summarized in this section.

Exposures to Diesel PM

As discussed previously, OGVs visit California ports and travel in waters along the coastline of California and within certain inland waterways. The diesel PM emissions from OGV engines contribute to ambient levels of diesel PM emissions. Based on the most recent emissions inventory, there are about 11,000 vessel visits to California ports by OGVs each year. Most California ports are in urban areas and located near where people live, work, and go to school. This results in substantial exposures to diesel PM emissions from OGV operating in waters off the California coast and at the California ports. Because analytical tools to distinguish between ambient diesel PM emissions from OGVs and that from other sources of PM do not exist, we cannot measure the actual exposures to emissions from diesel-fueled vessel engines. However, modeling tools can be used to estimate potential exposures.

Health Risk Assessments

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 cancer risks for OGV traveling in California waterway and the operations of OGV engines at California ports, ARB staff conducted three health risk assessments. The first assessment examined the statewide impact of diesel PM emissions from OGV. The other two assessments look at the regional impacts of OGV activity in the San Francisco Bay Area and in the area surrounding the Ports of Los Angeles and Long Brach. The statewide assessment used the U.S. EPA air dispersion model – CALPUFF and the 2005 OGV emissions inventory. The San Francisco Bay Area analysis used the CALPUFF model and the 2005 emission inventory for OGV activity in the Bay Area to look at the impact of OGV emissions on the greater Bay Area. The Ports of Los Angeles and Long Beach assessment used the U.S. EPA ISCST3 air dispersion model and a 2002 emissions inventory for all sources of diesel PM emissions at the two ports.

The potential cancer risks for all of the assessments 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, 2003; OEHHA, 2005). 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 $(mg/kg\text{-}d)^{-1}$).

A brief summary of the results of the statewide assessment is presented below. The results of the two regional studies are discussed in Appendix E-3.

Cancer Risk Characterization – Statewide CALPUFF Modeling

Based on the 2008 statewide CALPUFF modeling, diesel PM emissions of OGVs have a significant health risk impact statewide. Figure IV-9 shows the risk isopleths for diesel PM emissions from all OGV emissions in California. We can see that OGV diesel PM emissions impact almost the entire state. The potential cancer risk level of 10 chances in a million extends inland at variable distances from the coastline. The area in which the potential cancer risks are predicted to exceed 10 chances in a million is about 22,100 square miles. The estimated population in this area is 27.3 million people or about 80 percent of the total California population. For potential cancer risk levels over 500 chances in a million, the impacted areas encompass about 80 square miles with an estimated population of 400,000. (see Table IV-4).

Figure IV-9: Estimated Potential Statewide Cancer Risk from OGV Diesel PM Emissions (chances in a million)

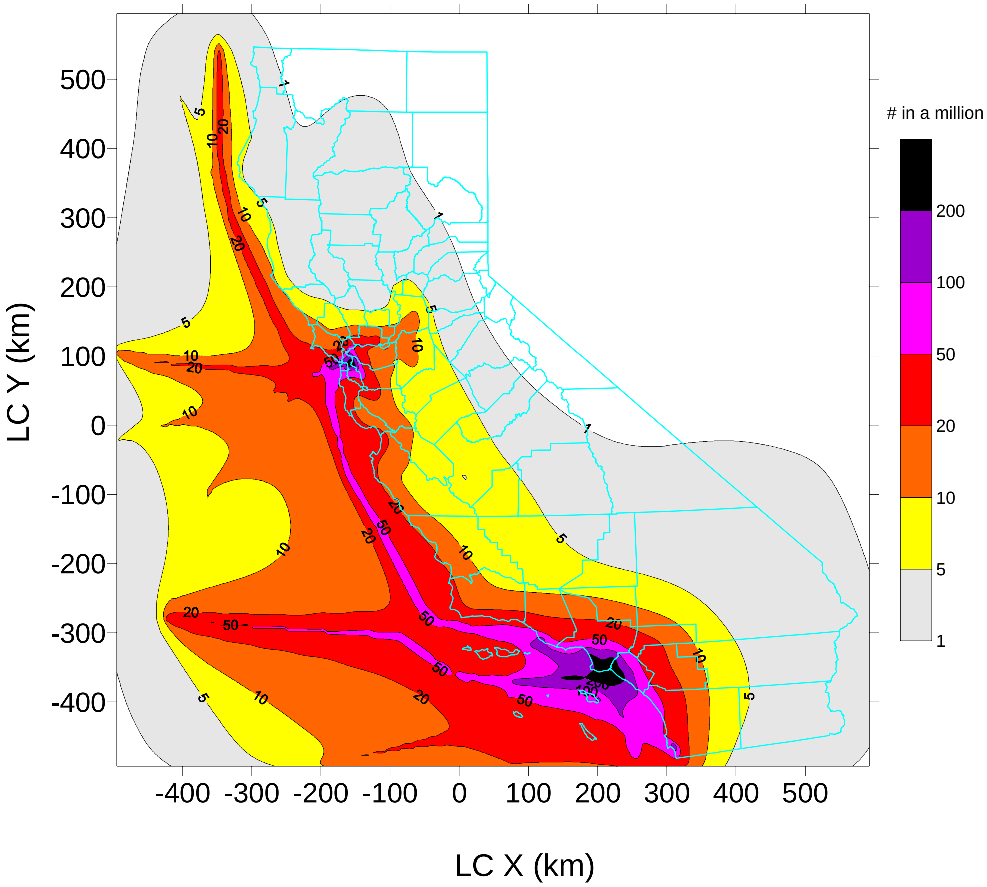


Table IV-4: Summary of Area Impacted and Population Affected by Risk Levels Statewide

Risk Level	Impacted Inland area (mile^2)	Affected population # (million)
Risk > 500	80	0.4
Risk > 200	400	2.4
Risk > 100	1,300	7.6
Risk > 10	22,100	27.3

Note: The population statistics is based on the U.S. Census Bureau's year 2000 census data

It also can be seen from Figure IV-9 that the highest impacts occur near the Ports of Los Angeles and Long Beach and the San Francisco Bay Area.

Non-Cancer Health Impacts

A substantial number of epidemiologic studies have found a strong association between exposure to ambient particulate matter (PM) and adverse health effects (ARB, 2002, 2006, 2008). As part of this assessment, ARB staff conducted an analysis of the potential non-cancer health impacts associated with exposures to the model-predicted statewide ambient levels of directly emitted diesel PM (primary diesel PM) and secondary PM (from SOx and NOx) in the South Coast Air Basin resulting from OGV emissions. The noncancer health effects evaluated include premature death, hospital admissions, asthma-related and other lower respiratory symptoms, work loss days, and minor restricted activity days.

To assess the potential non-cancer health impacts associated with the OGV emissions (including primary diesel PM and the secondary PM), staff relied on four air dispersion and photochemical modeling studies that were discussed earlier. The four studies are the: (1) Statewide CALPUFF OGV modeling (2008), (2) San Francisco Bay Area CALPUFF modeling (2008), (3) Ports of Los Angeles and Long Beach ISCST3 modeling (2006), and (4) SCAB CMAQ photochemical modeling (2008). The first three studies estimated ambient concentrations of directly emitted diesel PM resulting from the OGV activities statewide, in the San Francisco Bay Area, and in the communities around the Ports of Los Angeles and Long Beach. The fourth study simulated the secondary PM resulting from OGV emissions in Southern California. The details of these studies can be found online at http://www.arb.ca.gov/ports/marinevess/documents/portstudy0406.pdf and in Appendix E.

To estimate the potential non-cancer health impacts, staff developed population exposure estimates using the model-predicted concentrations of directly emitted diesel PM (primary diesel PM) and secondary PM within each modeling grid cell to the population within the grid cell. The populations within each grid cell were determined from U.S. Census Bureau year 2000 census data.

ARB staff used the same PM-mortality relationship as were used in the Ports and Goods Movement Emission Reduction Plan (ARB, 2006). The methodology for estimating these health impacts is described in Appendix A of the Emission Reduction Plan for Ports and Goods Movement in California (ARB, 2006) and Methodology for Estimating the Premature Deaths Associated with Long-term Exposures to Fine Airborne Particulate Matter in California (ARB, 2008). We calculated the number of annual cases of death and other health effects associated with exposure to the PM concentration modeled for each of the grid cells. The totals over the entire modeling area were then calculated. 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 selection of the concentration-response functions was based on the latest epidemiologic literature, as described in Emission Reduction Plan for Ports and Goods Movement in California (ARB, 2006).

Based on our analysis, we estimated the average numbers of cases per year for each study in the corresponding modeling areas. We estimated the statewide non-cancer health impacts due to directly emitted PM and the noncancer health impacts in the

South Coast Air Basin due to $PM_{2.5}$ nitrate and sulfate in the South Coast Air Basin. These estimates are presented in this section. The non-cancer health impacts due to directly emitted PM estimated from the regional modeling conducted for the Ports of Los Angeles and Long Beach and the San Francisco Bay Area are presented in Appendix E-3.

<u>For direct emitted diesel PM from OGV activities statewide in 2005</u>:

- 300 premature deaths (80 – 510, 95% CI)
- 7,700 cases of asthma-related and other lower respiratory symptoms (3,000 – 12,500, 95% CI)
- 100 hospital admissions – respiratory (25 to 170, 95% CI)
- 120 hospital admissions – cardiovascular (65 to 170, 95% CI)
- 650 acute bronchitis (0 to 1,400, 95% CI)
- 50,000 work loss days (43,000 – 58,000, 95% CI)
- 300,000 minor restricted activity days (241,000 – 351,000, 95% CI)

<u>For $PM_{2.5}$ nitrate and sulfate due to OGV activities in the Southern California domain in 2005</u>

- 770 premature deaths (210 – 1,300, 95% CI)
- 23,000 cases of asthma-related and other lower respiratory symptoms (8,800 – 37,000, 95% CI)
- 260 hospital admissions – respiratory (60 to 450, 95% CI)
- 300 hospital admissions – cardiovascular (170 to 440, 95% CI)
- 1,900 acute bronchitis (0 to 4,300, 95% CI)
- 140,000 work loss days (120,000 – 160,000, 95% CI)
- 800,000 minor restricted activity days (660,000 – 960,000, 95% CI)

Note that these estimated values for each study may not be comparable each other because of their different modeling selection, domain, emission inventory, population density, meteorological conditions, and other factors. For example, the estimates provided in Appendix E-3 for the Ports of Los Angeles and Long Beach were limited to a relative small domain of 20 mi x 20 mi and the smaller size of population (2 million) in the Southern California, while the study for the San Francisco Bay Area was applied to the domain of about 60 mi x 60 mi with the population size of about 5 million in Northern California.

In addition, in May 2008 ARB released a draft methodology for estimating premature deaths associated with long-term exposures to fine airborne particulate matter in California that proposes increasing the relative risk factor from 6% to 10% increase in premature death per $10\mu g/m^3$ increase in PM2.5 exposures (ARB, 2008). Once this is finalized, the estimated premature deaths above could be increased by 67%.

Several key assumptions were used in our estimation. They involve the selection and applicability of the concentration-response functions to California data, exposure estimation, subpopulation estimation, and baseline incidence rates. These are briefly described below.

- 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 was assumed to be exposed uniformly to modeled concentration. This assumption is typical of this type of estimation.

- 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.

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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 engines, diesel-electric engines, main propulsion diesel engines and auxiliary boilers operated on ocean-going vessels (OGV engines and auxiliary boilers). 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 operators of ocean-going vessels use marine distillate fuels in OGV engines and auxiliary boilers while operating within 24 nautical miles (nm) of the California coastline. Using cleaner burning marine distillate fuels will significantly reduce particulate matter (PM), diesel PM, nitrogen oxide (NOx), and sulfur oxide (SOx) emissions. The proposed regulation includes two phases of implementation with increasingly more stringent fuel sulfur limits on the marine distillate fuels required. For auxiliary engines and diesel-electric engines, the Phase 1 fuel requirements begin upon the effective date of the regulation (30 days after approval by the Office of Administrative Law). For main engines and auxiliary boilers, the Phase 1 fuel requirements begin July 1, 2009. For Phase 1, the operators must use either marine gas oil (MGO) or marine diesel oil (MDO). The MGO has a sulfur limit of 1.5% for Phase 1. The MDO has a sulfur limit of 0.5 percent in Phase 1. Phase 2, which begins on January 1, 2012, requires operators to use either MGO or MDO, both with a 0.1 percent sulfur limit, in the OGV engines and auxiliary boilers while operating within the 24 nm zone.

The proposed regulation includes several exemptions to accommodate special circumstances or situations where it may not be feasible or practical to use the required fuel. For example, a safety exemption is included for situations where the master of the vessel determines that compliance would endanger the safety of the vessel, crew, cargo or passengers. Exemptions are also provided for vessels that use alternative fuels, for military vessels, and for vessels that are evaluating technologies that will advance the state of knowledge pertaining to exhaust control technology or emissions characterization.

In the event a vessel owner needs to undertake essential modifications to enable the vessel to use the low sulfur distillate fuel within the 24 nm zone, the proposed regulation also includes a provision to grant an exemption from the fuel-use requirement provided certain criteria are met. If the operator elects not to use the exemption for essential modifications, the proposal also includes a noncompliance fee option where the operator, under special circumstances, is allowed to pay a fee in lieu of direct compliance with the fuel requirements. ARB staff believes these provisions will not be used to a great extent, as most vessels will not require modifications to comply with the proposed regulation.

Because there is uncertainty about the availability marine distillate fuels that meet the 0.1 percent sulfur limit at fueling ports throughout the world, a provision is included to allow the purchase of the fuel in California. This provision will be implemented coinciding with the Phase 2 fuel requirements which are effective January 1, 2012.

B. Purpose

The purpose of this proposed regulation is to reduce emissions of diesel PM, PM, NOx, SOx, and "secondarily" formed PM (PM formed in the atmosphere from NOx and SOx). If adopted, the proposed regulation will achieve immediate, significant emission reductions upon implementation. Specifically, the proposed regulation will have the following benefits:

- diesel PM and 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 and PM emission reductions will reduce regional exposure to PM, and help continue progress toward State and federal ambient air quality standards for PM_{10} and $PM_{2.5}$;
- NOx emission reductions will reduce the formation of regional ozone and secondary nitrate PM; and
- 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 a 24 nm zone 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 several exemptions. The proposal does not apply to vessels while in "innocent passage." Innocent passage generally means travel within the 24 nm zone off the 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. The proposal does not apply to emergency generators or to large boilers that are used to supply propulsion for a vessel (steamships). An exemption is also included for military and government vessels. Military vessels primarily use military specification distillate fuels that must be used on a consistent basis for military equipment globally. The proposal contains a safety exemption if the master determines that compliance would endanger the vessel, its crew, cargo or passengers due to severe weather conditions, equipment failure, fuel contamination or other reasons beyond the master's control. The proposal includes a temporary experimental or research exemption for experimental purposes as granted by the Executive Officer for up to three years with one two-year extension.

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 Boiler

An auxiliary boiler is defined as any fuel-fired combustion equipment designed primarily to produce steam for uses other than propulsion. The steam is typically used to heat residual fuel and liquid cargo, heating of water for crew and passengers, powering steam driven pumps, freshwater generation and space heating.

Auxiliary Engine

An auxiliary engine is defined as a diesel engine on an ocean-going vessel designed primarily to provide power for uses other than propulsion or emergencies, except that all diesel-electric engines shall be considered "auxiliary diesel engines" for purposes of this proposed regulation.

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).

Main Engine

A main engine is defined as a diesel engine on an ocean-going vessel designed primarily to provide propulsion. Main engines are typically slow-speed two-stroke diesel engines.

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 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 the large vessels that travel domestically and 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 are subject to more stringent fuel requirements. Currently, diesel fuel sold to harbor craft in California is required to meet California on-road "vehicular" standards.

Regulated California Waters

The Regulated California Waters (RCW) is a zone along the California coastline that extends approximately 24 nm off the California baseline.[1] North of Point Concepción, the zone extends to 24 nm offshore of the California mainland baseline and is aligned with the outer boundary of the Contiguous Zone, an internationally recognized boundary which is noted on most nautical charts. For the most part the contiguous zone extends 24 nm offshore the California mainland baseline, however, there is a "bubble" outside the Golden Gate where the Contiguous Zone extends out beyond the Farralon Islands and is approximately 45 nm from the Golden Gate Bridge. South of Point Concepción, a boundary approximately 24 nm off the shoreline is defined by straight line segments. We selected this linear boundary south of Point Concepción because extending the regulated waters around the Channel Islands, consistent with the Contiguous Zone, would bring the effective zone of the proposed regulation significantly beyond the intended boundary of approximately 24 nm offshore of the California mainland baseline – up to 90 nm offshore. RCW also includes California internal waters; estuarine waters, all California ports, roadsteads, and terminal facilities. It includes the all waters within 3, 12 and 24 nautical mile zones of the California coastline, starting at the California-Oregon border and ending at the California-Mexico border at the Pacific Ocean. By definition, RCW include all waters within the area, not including any islands, between the California baseline and a line starting at 34.43 degrees North, 121.12 degrees West; thence to 33.50 degrees North, 118.58 degrees West; thence to 32.65 degrees North, 117.81 degrees West; and ending at the California-Mexico border at the Pacific Ocean.

F. In-Use Operational Requirements

This section describes the fuels that must be used by operators of ocean-going vessels to comply with the requirements of the proposed regulation and the implementation dates. The proposed regulation requires vessels operating in Regulated California Waters to use the following fuel:

[1] 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. 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.

Phase 1

For auxiliary engines and diesel-electric engines, the Phase 1 fuel requirements begin upon the effective date of the regulation (30 days after approval by the Office of Administrative Law). For main propulsion engines and auxiliary boilers, Phase 1 begins on July 1, 2009. The Phase 1 fuel requirements are as follows:

- marine gas oil (MGO) with a sulfur content of 1.5 percent or less, or
- marine diesel oil (MDO) with a sulfur content of 0.5 percent or less.

Phase 2

For auxiliary engines, diesel-electric engines, main engines and auxiliary boilers, Phase 2 begins January 1, 2012. The Phase 2 fuel requirements are as follows:

- MGO with 0.1 percent sulfur or less or
- MDO with 0.1 percent sulfur or less.

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 effective date of the regulation, any person who owns or operates an ocean-going vessel within RCW 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, diesel-electric engines, main engine and auxiliary boilers 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. MDO or MGO) in the main engine and auxiliary boilers operated within the region covered by the proposed regulation; and

- the types and amounts of fuels purchased for use in the main engine and auxiliary boiler 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.

Documentation of Fuel Switch Over Procedures

Beginning with the effective date of the regulation, any person who owns or operates an ocean-going vessel within 24 nm of the California coastline will be required to maintain records (in English) that document the fuel switch over procedures for the vessel. 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:

- A fuel system diagram that shows all storage, service, and mixing tanks, fuel handling, pumping, and processing equipment, valves, and associated piping. The diagram or other documentation shall list the fuel tank capacities and locations, and the nominal fuel consumption rate of the machinery at rated power;

- Description of the fuel switch over procedure with detailed instructions and clear identification of responsibilities; and

- The make, model, rated power, and serial numbers of all main engines and auxiliary engines and make, model, rated output and serial numbers of all auxiliary boilers subject to the proposed regulation.

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 main engines and auxiliary boilers.

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 operators may be requested to provide additional information needed to determine compliance with the proposed regulation 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. Violations

Any person who is subject to this proposed regulation and commits a violation of any of the requirements is subject to penalties as specified in Health and safety codes as applicable under California law. Any noncompliance with the in-use fuel requirements, recordkeeping and other requirements shall amount to a separate violation for each hour that a person operates the vessel in Regulated California Waters until the requirements are met. Any person who is subject to this propped regulation is responsible and liable for meeting the requirement not withstanding any contractual requirement with a third-party.

I. Vessels Needing Essential Modifications to Comply

In the event a vessel owner needs to undertake essential modifications to enable the vessel to use the required low sulfur distillate fuel within the Regulated California Waters (RCW), the proposed regulation also includes a provision to grant an exemption from the fuel requirement provided certain criteria are met. This provision terminates December 31, 2014. After that date, vessels must meet the fuel use requirements. This provision has a notification requirement and a demonstration of need requirement. For the notification requirement, the operator must notify the Executive Officer, prior to entering RCW, that the vessel will not meet the fuel requirements. The demonstration of need requirement includes providing a written Essential Modification Report to the Executive Officer at least 45 days before entering RCW. The Essential Modification Report must address the following to the satisfaction of the Executive Officer:

- identifies the essential vessel modifications that are necessary to meet the fuel requirements,
- demonstrates that the modifications are essential, and
- identifies the extent to which the vessel can use the required fuel without essential vessel modifications (e.g. for a portion of the voyage or in any or all of the regulated OGV engines and auxiliary boilers).

The Executive Officer has 30 days to act on the Essential Modification Report. Additional information may be provided by the operator or requested by the Executive Officer. The Executive Officer has an additional 15 days to address any additional information.

While in Regulated California Waters, the vessel operator shall operate any OGV engines and auxiliary boilers on the required fuel to the maximum extent feasible and safe without the essential modifications.

J. Noncompliance Fee Option

The proposal contains a “Noncompliance Fee Option” 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 direct compliance with the fuel requirement. The funds collected under this provision would be deposited in the Air Pollution Control Fund, 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 zone boundary (Regulated California Waters or 24 nm zone). 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 later visits would result in increasing fee amounts.

This option could only be used in the following circumstances:

- Non-Compliance for Reasons Beyond Control

    - Unplanned Redirection: 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;
    - Inadequate Fuel Supply: 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. Note that an “offramp” provision has been included under this scenario, once the Phase 2 requirement begins January 1, 2012. This provision has been provided to account for the situation where MGO or MDO, both meeting 0.1% sulfur limit, is not available. Under this provision, the noncompliance fee will be waived once per vessel during each calendar year until December 31, 2014. To use this provision, compliant fuel must be acquired at the first California port and used the remainder of the voyage within RCW. In addition, the vessel must operate on fuel meeting the Phase 1 fuel requirement during the noncompliant portion of the voyage. This provision provides the vessel owner/operator the option of purchasing Phase 2 compliant fuel in California if it was not available at other ports outside California.
    - Defective Fuel: 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;

If the operator elects not to use the exemption for essential modifications, discussed in subsection I, the proposed regulation includes a noncompliance fee provision for circumstances where the vessel must go into dry-dock for modification or where infrequent visits and the need for modifications make it impractical to comply directly with the fuel requirements. Under this provision, the operator is allowed to pay a fee in lieu of direct compliance with the fuel requirements for the following cases:

- Vessels to be taken out of service for modifications
    - 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 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.
- Modifications on Infrequent Visitors
    - 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 the effective date of the regulation. This provision terminates December 31, 2014.

The non-compliance fees would be paid to the port's Noncompliance Fee Settlement and Air Quality Mitigation Fund prior to leaving the port. If no such port fund exists, the person shall deposit the fees into the California Air Pollution Control Fund, as directed by the Executive Officer. 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 vessel visits a California port and uses the noncompliance fee option for the first time, the vessel's owner would pay a fee of $45,500. 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 $91,000; since this was the second port visited under this provision. The fees are calculated based on the cost differential between heavy fuel oil and distillate for an average vessel visit. The noncompliance fee for the first port visit is 1.5 times the fuel differential cost. The noncompliance fee then increases for every additional port visited during a voyage. The fee schedule is shown in Table V-1, Noncompliance Fee Schedule.

Table V-1: Noncompliance Fee Schedule, Per Vessel

Noncompliance Fee Schedule	
Visit	**Fee (per vessel)**
1st Port Visited	$45,500
2nd Port Visited	$91,000
3rd Port Visited	$136,500
4th Port Visited	$182,000
5th or more Port Visited	$227,500

K. 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 2005. 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.

L. Sunset and California Baseline 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 benefits from ocean-going vessels in California, compared to the benefits 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.

California Baseline Review

The proposed regulation requires the Executive Officer to periodically review the California baseline determinations by the National Oceanic and Atmospheric Administration to determine if updates to the baseline maps incorporated by reference in the regulation are necessary.

M. 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.

N. 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 four alternative strategies to the current proposal. Based on the analysis, none of the alternative control strategies were considered more effective in reducing emissions 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 the Goods Movement Emission Reduction Plan; and (2) achieving State and federal air quality standards for PM and ozone. This section discusses each of the four alternatives and provides reasons for rejecting those alternatives.

<u>Alternative 1: Do Nothing</u>

As discussed in Chapter VII, the proposed regulation will result in significant reductions in diesel PM, PM, NOx, and SOx emissions. The diesel PM reductions are an important element of the Diesel Risk Reduction Plan and the Goods Movement Emission Reduction Plan. The reductions from the proposed regulation, along with other regulations to be adopted by ARB, will reduce 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, NOx and SOx emissions form "secondary" nitrate and sulfate PM in the atmosphere, while NOx emissions contribute to the formation of ozone.

In addition, ARB is required by H&S section 39658 to establish regulations for toxic air contaminants (TACs) such as diesel PM. Further, H&S 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. PM, and ozone, staff rejected Alternative 1.

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

As discussed in subsection L 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 benefits compared to 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, as discussed below, existing IMO and U.S. EPA regulations will not achieve the needed emission reductions from the proposal in the near term. Pending modifications to IMO regulations could provide a route for the necessary emission reductions in 2015. However, due to the significant public health impacts associated with OGV engines and boiler emissions, we believe it is appropriate to regulate this source at the state level until such time as U.S.

EPA or IMO implement regulations that will achieve equivalent benefits. 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

IMO Annex VI ("Regulations for the Prevention of Air Pollution from Ships") of the MARPOL Convention was adopted in 1997, and established some relatively modest emission standards for ocean-going ships. Annex VI entered into force 12 months after being accepted by 15 countries with at least 50 percent of world merchant shipping tonnage. This occurred in May 2005, one year after ratification by Somoa. However, marine engine manufacturers have generally produced engines that comply with the IMO standards beginning in 2000.

Annex VI limits marine fuels to 4.5 percent fuel sulfur, and provides a process for the creation of sulfur emission control areas (SECAs), which require the use of 1.5 percent sulfur fuel (generally heavy fuel oil). Annex VI also establishes NOx standards for diesel engines greater than 130 kilowatts installed on vessels constructed on or after January 1, 2000. The 4.5 percent sulfur fuel limit has only a minor effect on ship SOx and PM emissions because marine fuels, even heavy fuel oils, rarely approach this level of sulfur. As discussed below, even the use of 1.5 percent sulfur fuel under a SECA would achieve far less emission reductions compared to the proposed regulation. We estimate that the engine NOx standards are achieving about a five percent NOx emission reduction compared to pre-2000 engines. Over ten years after original adoption in 1997, the U.S. has still not begun to implement it. Although the Senate has ratified Annex VI, the United States is still in the process of passing legislation necessary to enforce it.

Sulfur Emission Control Area (SECA)

The U.S. EPA, in association with the 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 provides a mechanism to require the use of marine fuel (generally heavy fuel oil) with a 1.5 percent sulfur content limit in designated areas. Two such areas now exist, in the Baltic Sea and the North Sea. 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 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 0.5 percent sulfur distillate fuel will result in a 75 percent PM reduction, an 80 percent SOx reduction, and a 6 percent NOx reduction.

Pending Revisions to Annex VI

The Marine Environment Protection Committee (MEPC) of the IMO has approved proposed amendments that would significantly strengthen Annex VI. The United States was a significant participant in the discussions that led to this proposal. The revisions will be considered for adoption in October of 2008 at the 58th session of the MEPC in London. Among the more significant revisions would be progressive reductions in the sulfur content of fuel as follows:

- A 1% sulfur limit in "Emission Control Areas," beginning March 1, 2010 (reduced from the current 1.5% sulfur level in SECAs);
- A global sulfur limit of 3.5%, beginning January 1, 2012 (reduced from the current 4.5% sulfur)
- A 0.1% sulfur limit in "Emission Control Areas," beginning January 1, 2015;
- A global sulfur limit of 0.5%, beginning January 1, 2020 (subject to a feasibility review to be completed in 2018 that could shift implementation to 2025)
- A fuel availability provision would be introduced to outline the actions that should be taken if a ship operator is unable to obtain complying fuel.

The proposed revisions also specify a three tier system of NOx standards for new engines, as well as standards for existing engines, as follows:

- Tier I NOx standard of 17 g/kWh for slow speed engines (in existing Annex VI) would continue until January 1, 2011
- Tier II NOx standard of 14.4 g/kWh starting January 1, 2011
- Tier III NOx standard of 3.4 g/kWh starting January 1, 2016 within Emission Control Areas (tier II standard would apply outside of ECAs)
- Existing large engines (with a power output greater than 5,000 kW and a per cylinder displacement at or above 90 liters) installed on ships constructed between January 1, 1990 and January 1, 2000, would be subject to a 17 g/kWh NOx standard.

Assuming the amendments to Annex VI are adopted, the U.S. EPA could pursue an "Emission Control Area" (ECA) that would include California's coastline under the pending amendments to IMO Annex VI. Under an ECA, a one percent sulfur limit could be implemented starting in 2010, although implementation would likely start later depending on the time necessary to complete the process. Beginning January 1, 2015, a 0.1% sulfur limit could be implemented, which would be equivalent to the 2012 0.1% sulfur limit in the ARB proposed regulation.

The difference in PM and SOx emission reductions between the IMO ECA and the ARB proposal are shown in Table V-2 and Figure V-1. With regard to PM emissions, the ARB proposal achieves substantially greater emission reductions from 2009 to 2014. Specifically, for vessels currently using HFO in their OGV engines and auxiliary boilers, the ARB proposal would achieve an estimated 74 percent emission reduction when implementation begins in 2009, and about 83 percent in 2012, compared to an estimated 30 percent PM emission reduction from the ECA. In total, the ARB proposal would achieve nearly 20,000 tons more emission reductions from 2009 to 2014. For SOx, the ARB proposal would achieve an estimated 80 percent emission reduction when implementation begins in 2009, and about 95 percent in 2012, compared to an estimated 60 percent SOx emission reduction from the ECA. In total, the ARB proposal would achieve nearly 100,000 tons more SOx emission reductions from 2009 to 2014. Moreover, as shown in Figure V-2, the number of premature deaths avoided will be significantly higher for the ARB proposed regulation (1355) compared to the IMO ECA proposal (396) from 2010 to 2015. In total, ARB's proposed regulation would avoid about 960 premature deaths compared to the IMO-ECA proposal. In 2015, the emission reductions of the two proposals will be similar with similar values for premature deaths avoided.

Table V-2: Comparison of Annual Costs and PM Emission Reductions Between an IMO ECA and the ARB Proposed Regulation

	Estimated SOx Reductions (tons/yr)			Estimated PM Reductions (tons/yr)		
Year	IMO ECA	ARB Proposal	Loss	IMO ECA	ARB Proposal	Loss
2009	0	19,285	19,285	0	2,192	2,192
2010	29,110	39,703	10,593	1,826	4,566	2,740
2011	29,950	40,835	10,885	1,863	4,712	2,849
2012	30,790	49,418	18,628	1,936	5,406	3,470
2013	31,667	50,806	19,139	1,972	5,552	3,580
2014	32,617	52,267	19,650	2,045	5,734	3,689
Total			98,180			18,520

Figure V-1: Comparison of Diesel PM Emission Reductions Between the Proposed ARB Regulation and an ECA Provided for in the April 2008 Proposed Amendments to Annex VI

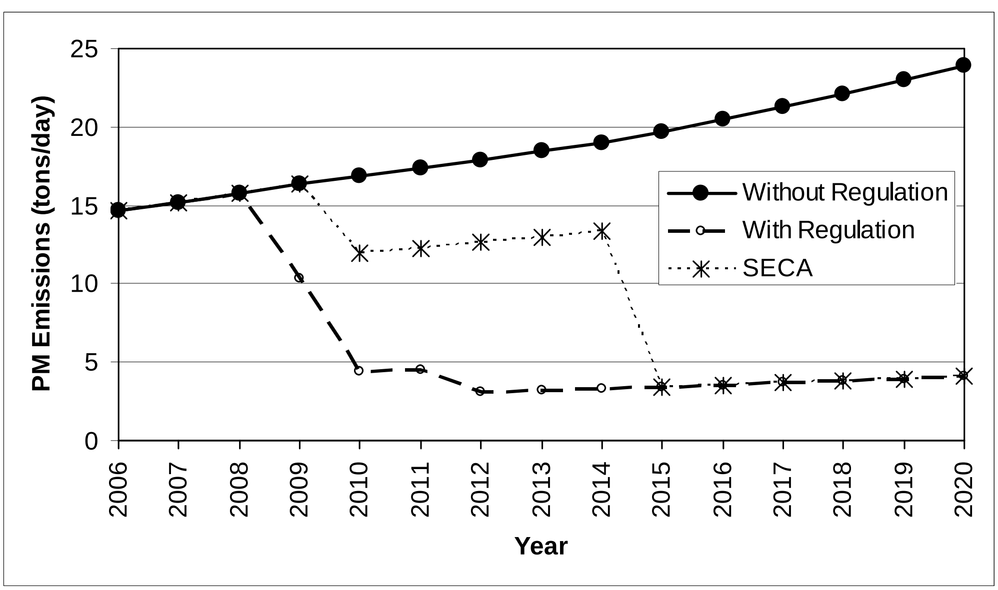
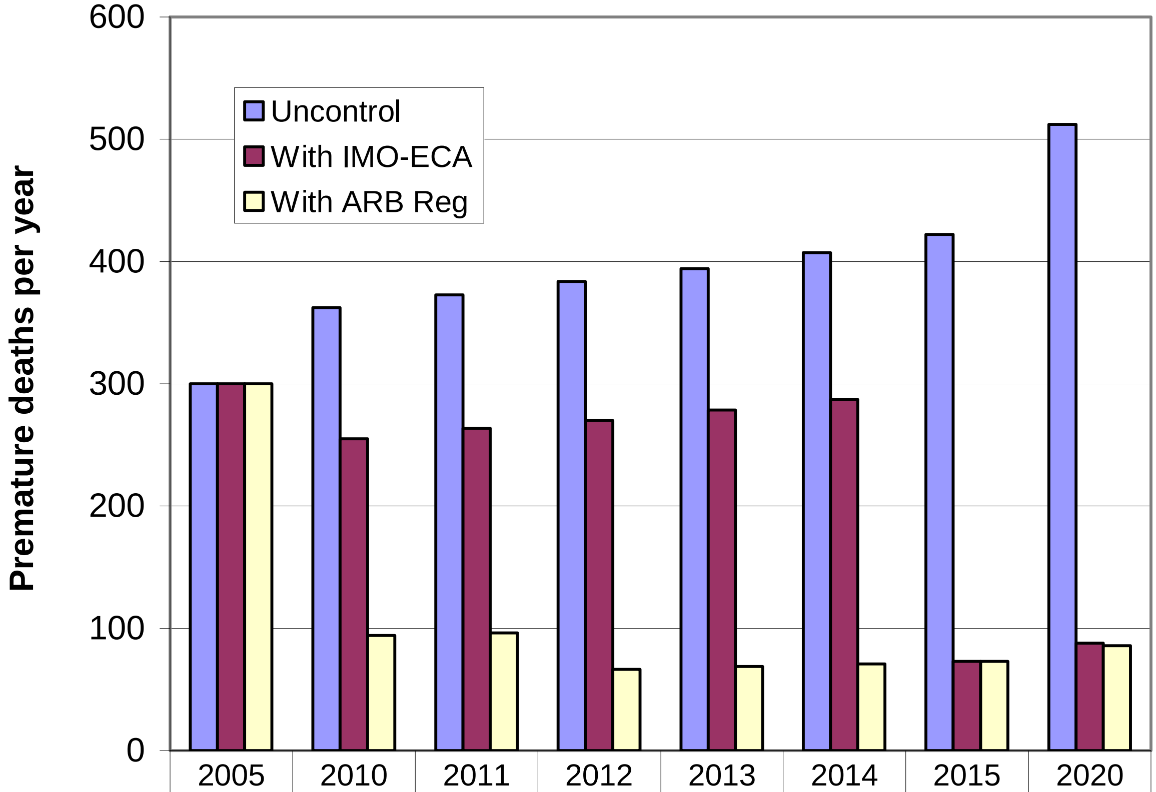


Figure V-2: Projection of Estimated Annual Statewide Premature Deaths Per Year Due to OGV PM Emissions Under Different Regulatory Scenarios



	2005	2010	2011	2012	2013	2014	2015	2020
Uncontrol	300	362	373	384	394	407	422	512
With IMO-ECA	300	255	264	270	279	287	73	88
With ARB Reg	300	94	96	66	69	71	73	86

U.S. EPA Category 1 & 2 Engine Standards

In 1999, U.S. EPA established “Tier II” standards for new “category 1 and 2” engines, those engines with a displacement less than 30 liters per cylinder (U.S. EPA considers the IMO Annex VI NOx standards as the “Tier I” standard). The U.S. EPA standards would apply to most auxiliary engines covered by the ARB staff proposal (if they are on U.S.-flagged vessels) because these engines are most often category 2 engines. The large diesel-electric engines used primarily on cruise ships are an exception because these engines are generally category 3 engines. This rule specifies standards for NOx plus hydrocarbons (combined), PM, and carbon monoxide. However, this rule only applies to new engines in U.S.-flagged vessels, which make up a small percentage of the auxiliary engines operating in California (most vessels visiting California ports are foreign-flagged vessels). There was originally a foreign-trade exemption for U.S.-flagged vessels, which would apply to auxiliary engines used on cargo ships, but this exemption was later removed in the U.S. EPA’s 2003 rulemaking for category 3 engines (as discussed below).

In March, 2008, EPA issued a final rule establishing more stringent “Tier III,” and “Tier IV” new engine standards for category 1 and 2 engines. The rule establishes standards for NOx, PM, and hydrocarbons. The Tier III standards will be implemented on new engines beginning 2009 to 2014, depending on the engine power and per cylinder displacement. The Tier IV standards, which reflect the use of high-efficiency exhaust treatment technology, will be implemented beginning 2014 to 2017, depending on the rated engine power. As with the 1999 rule, this rule only applies to U.S.-flagged vessels, which make up a small proportion of the vessels that visit California ports. In addition, vessel owners that routinely travel outside the United States can petition U.S. EPA for an exemption from the “Tier IV” standard. This is due to the need for ultra low sulfur diesel fuel (used in conjunction with after-treatment devices) to meet the Tier IV standards. Such fuel is not readily available in some regions outside the United States.

U.S. EPA Category 3 Engine Rules

In 2003, the U.S. EPA adopted NOx standards for new “category 3” engines, the large engines used for propulsion of ocean-going vessels. These standards would apply to engines manufactured on or after January 1, 2004. In terms of the engines covered in the proposed rule, these standards would apply to propulsion engines on cargo ships and the large generator set engines used on diesel-electric vessels, such as cruise ships. However, the standards are identical to the IMO Annex VI NOx standards and would only achieve modest NOx emission reductions and no PM reductions. In addition, they only apply to new engines on U.S.-flagged vessels, which represent a very small proportion of the engines operating in California.

In the 2003 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, new engines would be subject to the U.S. EPA’s standards for category 1 and 2 engines as discussed above. To meet these standards, these engines will also need to use distillate fuels. 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.

In the 2003 rulemaking, U.S. EPA also set a deadline of April 2007 to promulgate more stringent Tier II standards for ships. However, U.S. EPA later released a rule to extend this deadline to December 2009, to allow more time for the IMO process to work and to further evaluate emission control technologies. 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 not become effective for new engines until the 2011 timeframe at the earliest, 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 2011.

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. However, this rule does not apply to marine diesel oil or heavy fuel oil. Since most ocean-going vessel engines use heavy fuel oil in the absence of a regulation, this would have little impact in reducing emissions from the engines covered in the ARB's proposed auxiliary engine rule.

Comparison of ARB staff proposal and IMO and U.S. EPA Rules

A comparison between the ARB staff proposal and the existing and potential regulations discussed in Alternative 2 are summarized in Table V-3. As shown, none of the existing regulations would achieve PM emission reductions comparable to the proposed ARB regulation for auxiliary engines. As discussed above, the potential revisions to IMO Annex VI might eventually achieve equivalent reductions in PM and SOx emissions, as well as greater NOx emission reductions, within defined Emission Control Areas. However, the potential implementation of these standards is not until 2015. Therefore, considering the adverse health impacts to the public resulting from exposure to diesel PM and ozone, we believe the best approach is to pursue the proposed regulation until IMO or U.S. EPA regulations achieve substantially equivalent emission reductions.

Table V-3: Comparison Between the ARB Staff Proposal and Existing and Potential IMO and U.S. EPA Rules

Regulation	Comparison to the ARB Staff Proposal
Proposed Amendments to IMO Annex VI	▪ Potential to achieve equivalent emission reductions in PM and SOx in 2015 within IMO "Emission Control Areas" ▪ Would achieve greater NOx emission reductions ▪ Results in 20,000 tons less PM and 100,000 tons less SOx reductions prior to 2015
Existing IMO Annex VI NOx Standards & Fuel Sulfur Limits	▪ Standards do not reduce PM or SOx significantly, achieve about a 5% NOx reduction
Potential IMO 1.5% Sulfur SECA off California Coast	▪ Significantly less reductions in diesel PM and SOx reductions ▪ No NOx benefit
U.S. EPA 1999 & 2008 Category 1&2 Engine Rule	▪ Standards only apply to U.S.-flagged vessels ▪ Benefits phase in slowly with engine turnover
U.S. EPA 2003 Category 3 Engine Rule	▪ Standards only apply to U.S.-flagged vessels ▪ Standards same as IMO and do not reduce PM significantly
Potential Tier II EPA Category 3 Standards (2009 adoption possible)	▪ Standards may only apply to U.S.-flagged vessels
U.S. EPA Nonroad Diesel Rule	▪ Specifies sulfur limits for diesel fuel used in marine applications, but exempts marine diesel oil & heavy fuel oil

In consideration of the significant public health impacts associated with OGV engines and boilers emissions and the uncertainty surrounding U.S. EPA or IMO regulatory efforts, ARB staff rejected Alternative 2.

Alternative 3: Implement the Regulation as Proposed Except Without the Lower Sulfur Limit of 0.1 Percent in 2012

Under this alternative, ocean-going vessels visiting California ports would be required to use the marine distillate fuels specified in the regulation for 2009-2011, but would not be required to meet the more stringent 0.1 percent sulfur limit in 2012. Instead, it would be anticipated that by 2015, a Sulfur Emission Control Area could be established under pending IMO Regulations that would require the use of 0.1 percent sulfur fuel or equivalent emission controls. As summarized in Table V-4, there would be about 600 less tons PM reduced annually under the proposed alternative from 2012 to 2014. This alternative would also reduce cost by over $50 million annually. Overall, the cost effectiveness of the proposed alternative is slightly lower than the original proposal. However, given the significant health impacts associated with PM, we recommend the proposed regulation.

Table V-4: Comparison of Annual Costs and PM Emission Reductions Between Alternative #3 and the Proposed Regulation

	Estimated Cost ($ millions)			**Estimated Reductions (tons/yr)**			**Cost-Effectiveness ($/ton)**	
Year	Alt. #3	Proposal	Savings	Alt. #3	Proposal	Loss	Alt. #3	Proposal
2012	$290.6	**$343.8**	$53.2	4,821	5,406	585	60,300	63,600
2013	$298.5	**$353.0**	$54.5	4,967	5,552	585	60,100	63,600
2014	$306.8	**$362.7**	$55.9	5,114	5,734	620	60,000	63,300

In consideration of the greater PM reductions from the ARB proposal (1790 tons) and the similar cost effectiveness, ARB staff rejected Alternative 3.

Alternative 4: Implement the Regulation Within 24 nm of California's Major Ports Rather than within 24 nm of the California Coastline

Under this alternative, ocean-going vessels visiting California ports would be required to use the marine distillate fuels specified in the proposed regulation only within 24 nautical miles of major ports, rather than along the entire coastline. This would reduce the transiting emission reductions by about 70 percent, while having little impact on the reductions that could be achieved from maneuvering and hotelling. Overall, the PM emissions subject to the proposed regulation would be reduced by about 53 percent. This alternative would retain emission reductions near California's major population centers, which are generally located near California's major ports, but would substantially decrease the emissions reduced in other coastal areas. This could be of particular concern to several coastal counties such as San Luis Obispo, Ventura, and

Santa Barbara Counties, which are impacted by ship emissions due to a major shipping line that traverses relatively close to their shoreline. In addition, statewide modeling conducted by ARB staff has shown that emissions from transiting along the coast can impact not only coastal areas but areas well inland as well. See Appendix E-1.

As summarized in Table V-5, with alternative #4, there would about 2,400 less tons PM reduced in year 2010 (the first full year of implementation), and an estimated $146 million cost reduction. Overall, the cost-effectiveness of the proposed alternative would remain the same because the costs and emission reductions are both reduced by the same percentage. Although this alternative would reduce costs and target emission reductions near population centers, the proposal would not achieve emission reductions in other coastal areas. In addition, pollutants from ships can be transported long distances, reaching sensitive areas. For these reasons, we recommend the proposed regulation.

Table V-5: Comparison of Annual Costs and PM Emission Reductions Between Alternative #4 and the Proposed Regulation for 2010

Estimated Cost ($ millions)			**Estimated Reductions (tons/yr)**			**Cost-Effectiveness ($/ton)**	
Alt. #4	Proposal	Savings	Alt. #4	Proposal	Loss	Alt. #4	Proposal
$129.3	$275	$146	2,146	4,566	2,420	60,200	60,200

In consideration of the greater PM reductions from the ARB proposal (2400 tons) and similar cost-effectiveness, ARB staff rejected Alternative 4.

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.

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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 required fuels and the ability of ocean-going vessels (OGVs) to use those fuels in the auxiliary diesel and diesel-electric engines, main propulsion diesel engines, and auxiliary boilers. We also address safety and other issues that were raised during this rulemaking (similar to those raised in the rulemaking process for the Auxiliary Engine Regulation in 2005). ARB staff carefully analyzed the fuel availability, safety, operational, and other issues and concluded that the fuel sulfur limits and other requirements in the proposal are technologically feasible and can be met safely by vessel operators.

ARB staff is proposing a regulation to require operators of OGVs to use cleaner-burning marine distillate fuels in auxiliary diesel and diesel-electric engines, main propulsion engines and auxiliary boilers (OGV engines and auxiliary boilers) on vessels operating within a 24 nautical miles (nm) zone of the California coastline (Regulated California Waters). Unless they already use complying distillate fuels or choose to use distillate fuels on a permanent basis, vessel operators will need to switch from using heavy fuel oil to compliant marine distillate fuel prior to entering Regulated California Waters (RCW). The proposed regulation will apply to both U.S.-flagged and foreign-flagged vessels. As described previously in this report, the proposed regulation is implemented in two phases beginning in 2009 and requiring a more stringent fuel sulfur level again in 2012. The proposed regulation would establish the most comprehensive and stringent marine fuel-use requirement in the world.

The proposed regulation contains a safety exemption if the master of the vessel determines that compliance would endanger the safety of the vessel, crew, cargo or passengers. An exemption is also provided for ship operators that can demonstrate the need for essential modifications to comply.

A. Availability of Marine Distillate Fuels

ARB staff investigated the availability of low sulfur marine distillate fuels to meet both the Phase 1 and Phase 2 requirements. For the Phase 2 requirements, staff also considered two different implementation years – 2010, consistent with the Auxiliary Engine Regulation, and 2012, which is the Phase 2 implementation date for the proposed OGV Regulation. The investigation focused on the Pacific Rim ports where California-bound vessels would likely obtain the fuel necessary to comply with the proposed OGV Regulation. ARB staff relied on fuel test data provided by Det Norske Veritas (DNV) Petroleum Services, outreach to and feedback from fuel suppliers and providers, and other technical information regarding world refining markets to provide information that could provide indications regarding fuel availability. Our key findings are briefly summarized below, and additional details on the investigation can be found in Appendix F.

Overall, we believe the fuel specified in the proposed OGV Regulation will be available for vessel operators to purchase; however, there is some uncertainty in our findings, particularly with respect to the availability of fuels to meet the Phase 2 specifications. There are thousands of ports throughout the world where OGV can obtain fuel and, out of necessity, we focused our investigation on selected Pacific Rim ports and assumed that our findings also represent the ports not addressed.

While we have a reasonable basis for our belief that sufficient low sulfur marine distillate fuels will be available to comply with the proposal, reaching this conclusion was not without difficulty. First, it was difficult to obtain definitive fuel volume data, and many marine fuel suppliers' responses hinged on whether or not the demand would be sufficient to warrant a change in fueling infrastructure or supply from the refiners. In some cases, language barriers existed, and it is not certain if the fuel supplier fully understood our questions or discussions. At other times, some suppliers were somewhat hesitant in providing data due to confidentiality concerns.

Perhaps one of the more significant concerns is with Phase 2 of the proposal. Given the current global fuel and economic issues, constraints on supply, and uncertainty with the overall fuel markets, predicting marine fuel markets several years in the future is risky at best. But there are current market and regulatory trends that suggest the market for low sulfur marine distillate fuels may continue to expand. Indeed, some have suggested that the shipping industry may need to move away from bunker fuel, as refiners see diminishing returns with continuing to supply bunker fuel and instead switch to increasing production of higher value distillates.[1] Nevertheless, it will be important for ARB staff to monitor implementation of the regulation and be prepared to make mid-course adjustments in the event the fuel is not available or if the fuels available cannot meet the ISO specifications for marine distillate fuels.

Key Findings – Phase 1 Fuel Availability

- The amount of fuel needed to comply with the proposed regulation, about 1 million tons or about 1% of the worldwide volume of marine distillate fuels, is unlikely to have a significant impact on worldwide supply or demand for fuels that meet the Phase 1 fuel sulfur specifications.
- There is, and should continue to be a sufficient worldwide supply of MGO and MDO meeting the Phase 1 fuel specifications and this fuel should be available at all key fueling ports servicing California-bound OGVs. Most ports worldwide have MGO that meets the Phase 1 fuel specifications. About half of the ports worldwide have MDO that can meet the Phase 1 0.5% sulfur specification for MDO.
- Overall, we expect the average fuel sulfur content of MDO or MGO purchased to be about 0.3%.

[1] Unni Einemo, *Rude Awakening?*, quoting Dr. Rudy Kassinger of DNV (visited June 3, 2008) <http://www.sustainableshipping.com/news/2007/07/68368>. (SustainableShipping, 2007)

- There may be some limited logistical or spot supply issues in obtaining Phase 1 fuel at some ports. However, we expect the number of ports that do not have marine distillate fuels to be very small.

Key Findings – Phase 2 Fuel Availability in 2010

- We expect in 2010, the worldwide volume of MGO or MDO that can meet the Phase 2 fuel specifications will exceed the 1 million tons required for implementation of the proposed regulation.
- For 2010, there will not be sufficient supply of the Phase 2 (0.1% sulfur) MGO or MDO at key Pacific Rim ports serving California-bound OGVs.
- The average sulfur content of MGO and MDO in 2007 at 25 of the 31 Pacific Rim ports exceeded the Phase 2 fuel sulfur specifications.
- It is unlikely that a sufficient supply will be available prior to 2012 due to crude supply, refining capacity, and fueling infrastructure improvements that will be needed.

Key Findings – Phase 2 Fuel Availability in 2012

- For 2012, the issues outlined above for 2010 should be lessened due to the additional time for fuel providers and suppliers to develop and implement the necessary fueling infrastructure.
- We expect supplies of LSMDF across the world to increase as refinery upgrades are made to meet the increasing demands for cleaner diesel fuels for land-based equipment, including on- and off-road vehicles. However, while there will be increases in lower sulfur fuels for land-based equipment, we cannot assume that this same fuel could also be used for marine (due to specifications, price premium, and competition).
- There are significant refinery projects underway and planned that are expected to provide additional refining capacity near those bunkering ports where LSMDF will be in demand. Refineries have a strong economic incentive to produce higher-value products, such as LSDMF, over residual fuel as long as the demand is present.

B. Feasibility of Fuel Switching in Ocean-Going Vessel Engines

Currently, a majority of the vessels that will be subject to the proposed regulation use heavy fuel oil in their main engines, according to ARB's 2007 Ship Survey (2007 Survey). Because heavy fuel oil is a thick, viscous material 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 liquid 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 changes in temperature and viscosity. This helps reduce fuel gassing; and ensure smooth, steady-state operation of the engine. 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. The rate of mixing is controlled to limit the change in fuel temperature to approximately 1°F every 2 minutes (Morgante, 2008).

Considering the available information as discussed below, we believe that vessel operators can safely operate their main and auxiliary diesel engines and auxiliary boilers with compliant distillate fuels while operating within Regulated California Waters and fuel switch between to HFO and distillate upon entering and leaving the regulated waters.

Fuel Switching Procedures and Safety

As discussed above, main engines and auxiliary 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. While the procedures for fuel switching are published and vessels currently fuel switch prior to dry-docking or major repair, fuels switching will occur more frequently due to the requirements of this proposed regulation.

For safety reasons, it is very important for all operators to ensure that their vessels have detailed fuel switching procedures available and that vessel personnel are all fully trained in the process. Because this is such an important safety issue, the proposed regulation requires documented fuel switch over procedures to be kept onboard the vessel. The fuel switch over procedures must include the following:

- a description and diagram of the fueling system,
- a description of the fuel switch over procedure with detailed instructions and clear identification of responsibilities; and
- information on all OGV engines and auxiliary boilers.

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 power to the vessel. For the case of an auxiliary engine, a vessel's emergency backup generators, which run solely on marine distillate fuel, would become operational.

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) This recommendation addresses the issue of compromised maneuverability in the case of loss of power. The Office of Spill Prevention and Response (OSPR) made a similar recommendation, during the rulemaking for the Auxiliary Engine Regulation, for any fuel switching during transit to be done at or beyond 24 nm offshore.[2] 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. Arguably, switching fuels at or prior to entering the 24 nm boundary should provide a greater margin for safety than conducting the switch much closer to the ports, which is the practice for some vessels.

Existing Practice

Actual in-use experience demonstrates that marine vessels are able to operate both on HFO and low sulfur marine distillate fuel (MGO/MDO), and it is feasible to switch fuels during operation. 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. In addition, 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)

The vast majority of ocean-going vessels visiting California ports during the 14 months that the Auxiliary Engine Regulation was enforced complied with the regulation by switching the fuel for their auxiliary engines to distillate fuel prior to entering within 24 nm of the California coastline. And no significant problems associated with the fuel switching were reported to ARB during that time. This not only confirmed ARB staff's

[2] California Air Resources Board, *Final Statement of Reasons for Rulemaking: Public Hearing to Consider the Adoption of Regulations to Reduce Emissions from Auxiliary Diesel Engines and Diesel-Electric Engines Operated on Ocean-Going Vessels within California Waters and 24 Nautical Miles of the California Baseline*, Dec. 8, 2005, pp. 69-70, (downloaded June 4, 2008) <http://www.arb.ca.gov/regact/marine2005/fsor.pdf>. (ARB, 2005b) The OSPR recommendation was based on the navigational risk analysis it conducted with other agencies and stakeholders. *West Coast Offshore Vessel Traffic Risk Management Project: Final Project Report and Recommendations*, Pacific States/British Columbia Oil Spill Task Force and the United States Coast Guard, July 2002. (OSPR, 2002)

belief during the auxiliary engine rulemaking that fuel switching to low sulfur distillate fuel is feasible and safe for auxiliary engines, but it also provides persuasive evidence that fuel switching can be successfully accomplished under the proposed regulation. While the Auxiliary Engine Regulation was being enforced, of the 234 ships that were boarded for compliance purposes, only 3 were cited for not using compliant fuel and 2 were cited for not switching at the required distance from the coastline. During this time there were only six vessels that opted to pay the non-compliance fee, as listed in Table VI-1 below.

Table VI-1: Ocean-Going Vessels and Associated Companies that Paid the Non-Compliance Fee (NCF)

Date Fee Paid	Vessel Type	Reason for Paying NCF
1/29/07	Tanker	Unable to find complying fuel
1/23/07	Cruise Ship	Infrequent Visitor Needs Modifications
2/9/07	Bulk Vessel	Unable to find complying fuel
6/28/07	Tanker	Unplanned redirection
2/08	Cruise Ship	Infrequent Visitor Needs Modifications
4/17/08	Tanker	Unable to find complying fuel

The diesel-electric engines on passenger vessels, which generally are large diesel generator sets that provide power for both propulsion and onboard electrical power, were subject to the Auxiliary Engine Regulation, and are an example of engines providing propulsive power which complied with this regulation without issue.

Further, some passenger liners regularly switched fuels in their diesel-electric engines for air quality reasons even before the Auxiliary Engine Regulation. 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)

There are also vessels that routinely switch from heavy fuel oil to distillate fuels in their main engines during California port visits. Specifically, A.P. Moller-Maersk Group, a major container ship operator, has a Pilot Fuel Switch West Coast Initiative (Maersk Pilot Program) where they are voluntarily using low (0.2% maximum) sulfur marine gas oil in their main engines within 24 nm of port. (Maersk, 2007) This is in addition to compliance with ARB’s Auxiliary Engine Regulation that required them to operate their auxiliary engines on compliant distillate within 24 nm of the California coast while the

Auxiliary Engine Regulation was in effect. Maersk has indicated that they feel that the program has been successful and are happy with the results to date, it has come with a high price tag. Since March 2006, it has cost Maersk Line approximately $12 million dollars to use the low sulfur distillate. (Morgante, 2008)

The Maersk Pilot Program began in March 31, 2006, with the container ship Sine Maersk, and has included 577 fuel switches and 105 vessels, as of April 2008. The participating vessels have main engines manufactured by either MAN Diesel or Wärtsilä/Sulzer. Maersk's program includes using MGO with a sulfur level at or below 0.2% sulfur, for both the main engine and auxiliary engines. This is lower than the proposed requirements to use MGO or MDO (MDO with a 0.5% sulfur limit). In 2006, Maersk reported an average MGO fuel sulfur level of 0.17% for all participating visits in both the main and auxiliary engines. In 2007, the average MGO fuel sulfur level was 0.09%.

In Maersk's program, main engine fuel switching is completed by 24 nm from port. For the auxiliary engines, fuel switching is completed prior to the vessel entering the Regulated California Waters, 24 nm from the California coast, as required by ARB's Auxiliary Engine Regulation (until that regulation was suspended).[3] Because of ARB's requirement to use distillate within 24 nm of the coast, the auxiliary engines operate on distillate much longer, compared to the main engines under the Maersk Pilot Program. The auxiliary engines sometimes operate on distillate for as long as 5 days: as they approach the Ports of Los Angeles and Long Beach (POLA/POLB) and enter the 24 nm regulated waters at Point Conception (approximately 160 nm), as they hotel at port, and if they travel between POLA/POLB and the Port of Oakland within the regulated waters (approximately 430 nm).

The Maersk Pilot Program has included 105 different vessels and 577 successful fuel switches as of early 2008. The fleet of participating vessels is made up of a wide range of vessel build dates, and main engine make, model, model year and power rating. (*ARB, 2005a, Appendix C*) Out of the 105 participating vessels, Maersk has only reported issues related to fuel switching on 5 vessels. The issues are primarily associated with the fuel supply pumps that are used in the fuel delivery system. The issues in the fueling system have included leakage of booster and fuel feed pumps, failure of booster and fuel feed pump seals in two vessels and a crack in a fuel pump plunger in one vessel. In addition, two vessels required replacement and/or relapping of pump plunger components. (Morgante, 2008) None of these problems resulted in interruption or operational failure with the main engine.

In addition, the Maersk vessels are continuing to fuel switch when visiting California ports. There was one report concerning an auxiliary engine failure to start. It was determined that pump wear, combined with low fuel viscosity, was the cause. All of these issues were reported for vessels that had build dates in the 1990s and have Wärtsilä/Sulzer main and auxiliary engines.

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[3] While the Auxiliary Engine Regulation was recently suspended due to the *PMSA* lawsuit, it is staff's understanding that Maersk remains committed to voluntarily meeting that regulation's requirements.

Maersk has indicated that a number of their chief engineers have concerns about the long term impacts of using distillate fuels in engines that were designed to operated on heavy fuel oil. They believe that it is still too early to determine what, if any, long term effects the fuel switch may have on their engines. (Morgante, 2008)

Maersk also reported that while running on low sulfur MGO, the main engines are operated on a BN 70 cylinder lubricant which is typically used with HFO, but with a lower feed rate than would be used for HFO operation. Maersk has not reported any excess cylinder wear or deposit build-up in the main engines as a result of fuel switching between the low sulfur MGO and heavy fuel oil. In addition, Maersk's fuel switching procedures include a maximum fuel temperature change of 1°F per every two minutes during fuel switch to minimize thermal impacts to the equipment and fuel viscosity.

Another example of fuel switching in the main engines 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%) 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 to reduce emissions of nitrogen oxides.

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 main engines during maneuvering is a relatively recent development made possible by improvements in fuel heating technology. (BMT, 2000)

C. Feasibility of Using Distillate Marine Fuels in Ocean-Going Vessel Main Propulsion Engines

Currently, a majority of the vessels that will be subject to the proposed regulation use heavy fuel oil in their main engines. To comply with the in-use fuel requirements for the proposed regulation, the operators can either use compliant fuel in main engines during all operation or can use compliant fuel in Regulated California Waters and switch to a lower cost HFO outside the regulated waters. The proposed regulation would likely result in ship operators using compliant fuel within Regulated California Waters and switching to HFO outside the regulated zone. The previous section addressed the feasibility of switching fuel. The following sections will concentrate on the feasibility of using compliant fuel in the Regulated California Waters.

Vessel Fuel Infrastructure Needs

Most vessel operators are equipped to run their main engines on distillate fuel as needed to comply with the proposed regulation. About 13 percent of the companies responding to our 2007 survey indicated the need for vessel modifications to use MGO/MDO in their main engines within 24 nm of the California coastline. Specifically, 168 out of 761 vessels (22 percent) were reported to need modifications to operate on distillate within 24 nm of the California coastline.[4] These changes may or may not require that the vessel be dry-docked. Dry-dock maintenance typically occurs every five years, while many other maintenance operations are performed while the vessel is at dockside.

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

- fuel valves
- fuel piping and pumps
- fuel tank(s)
- cylinder lube oil system
- engine fuel pumps
- engine fuel injectors.

Several companies reported that they would need fuel tank modifications to use MGO/MDO in their main engines out to 24 nm. Of the vessels reporting, about half indicated that they would need fuel tank modifications. Most vessels have multiple fuel tanks and adequate MDO/MGO capacity to meet the requirements of this regulation. (Herbert, 2007). Some vessel operators may choose to make modifications to provide for a more convenient fuel-switching operation since fuel-switching will occur more frequently than what is traditionally done. If the vessels does need additional capacity, vessel owners may need to add new storage or day tanks, convert an existing heavy fuel oil tank to distillate, or segregate an existing tank to carry sufficient quantities of distillate.

If a new or segregated tank is desired, ancillary equipment such as pumps, piping, vents, filing pipes, gauges, and access would be required, as well as tank testing. (Entec, 2002) In addition, fuel processing systems include settling tanks, filters, and centrifuges may also be necessary. 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 to prevent sudden changes in fuel temperature or viscosity may cause damage to fuel pumps and injectors. (Wärtsilä, 2005a) Fuel coolers may be installed to

[4] As noted in later in this chapter, the Economic Impacts chapter (Ch. 9), and Appendix C, ARB staff believes this survey result overestimates the modifications needed, and the actual figure is likely to be substantially lower.

assist in controlling fuel temperatures and viscosity during fuel transitions. Furthermore, fuel coolers can be used to increase the viscosity of the compliant distillate fuels if the fuel viscosity is below the minimum, as specified by the engine manufacturer. (Herbert, 2007)

A small number of survey participants reported the need to modify engine components such fuel pumps, injectors, and nozzles. However, engine manufacturers have stated that, with certain caveats, the engines they designed for heavy fuel oil can also operate on MGO without these modifications. Additional information on the type of modifications reportedly needed is discussed in the summary of the survey results provided in Appendix C.

Staff believes that these figures may overestimate the number of vessels that will require essential modifications to comply with this proposal. All vessels are configured to switch to distillate fuel while going into dry-dock, in certain emergency conditions and prior to large-scale engine work. (Briers, 2008) Maersk, the world's largest shipping line, has reported that no capital investments were necessary to implement their voluntary program using marine distillate fuel in 105 vessel main engines while visiting California ports (Maersk, 2007). In addition, many ocean-going vessels that frequently visit California have been using distillate in their auxiliary engines to comply with ARB's Auxiliary Engine Regulation. Therefore, many of the fuel system modifications necessary to use distillate will have already been completed for compliance with the Auxiliary Engine Regulation.

Based on the survey, of the 168 vessels (22 percent of the total) that were reported to need modifications, approximately 62 vessels reported modifications for fuel system piping and pumps. These modifications most likely would have been performed to comply with the Auxiliary Engine Regulation. In addition, over half (90) of the 168 vessels were owned by two shipping companies. Neither company could provide follow-up information to confirm that these modifications were essential to comply with this regulation. Another vessel operator confirmed that the modifications they reported to be needed were to comply with potential Sulfur Emission Control Areas (SECA) requirements to use the distillate out over much larger regions.

Based on the reasons discussed above, ARB staff believes that the vast majority of vessels will not require modifications to comply with the proposed regulation. However, in the event that a vessel cannot use the low sulfur fuels without modifications, we have included in the proposal an exemption for vessel operators who can demonstrate the need for essential modifications to comply with the fuel-use requirements.

Technical and Safety Considerations

ARB staff met with the major manufacturers of main engines used on ocean-going vessels to determine whether these engines could operate on marine distillate fuel (marine gas oil or marine diesel oil). Engine manufacturers uniformly reported that their main engines, designed for use with heavy fuel oil, can also operate on distillate fuels. (Herbert, 2007) 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. Each of the 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% sulfur fuel for 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. And manufacturers have stated that incompatibility problems are a concern during fuel transitions as well. However, while these concerns are theoretically possible, they have not translated to real-world problems under the Auxiliary Engine Regulation. Our experience implementing that regulation in 2007-2008 shows that fuel compatibility was not reported to be problematic when the vast majority of ocean-going vessels transitioned from heavy fuel oil to distillate prior to entering Regulated California Waters.

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) Again, based on experience from implementing the Auxiliary Engine Regulation, we know that some distillate fuels meeting the CARB on-road diesel sulfur limits (15 to 500 ppm) have been used in ship auxiliary engines. Even though such on-road fuels are not expressly designed for use in marine auxiliary engines, there have been no reports to date of compatibility issues with these very low-sulfur, on-road fuels.

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 need to be 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.

For two-stroke engines using 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 two-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. (Wärtsilä, 2005b) 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. We do not expect vessels to spend anywhere close to 300 hours of operation while traveling within 24 nm zone. This is because a vessel would only need 40 hours to travel at 20 knots along the entire 800 nm California coastline. In the Maersk Pilot Program, the BN 70 cylinder lubricant was not switched to a lower BN number lubricant due to the limited duration of distillate use in the main engine. The BN 70 feed rate was, however, decreased.

D. Feasibility of Using Marine Distillate Fuels in Ocean-Going Vessel Auxiliary Boilers

<u>Feasibility of Using Distillate Marine Fuels</u>

According to both ship operators and boiler manufacturers, ship auxiliary boilers can be safely operated on distillate fuels. As summarized below, most ship operators reported that a switch to distillate fuels in California could be easily implemented. However, as with the use of distillate fuels in auxiliary and main diesel piston engines, there are certain technical precautions that need to be considered. A few operators reported that evaluations of their boilers would be needed to determine if modifications would be necessary to ensure safe operation of their boilers on distillate fuels. However, the proposed regulation provides an exemption for vessel operators that can demonstrate the need for essential modifications to comply with the fuel requirements.

Ship Operators: Numerous ship operators were contacted to determine whether marine distillate fuels could be used in existing ship auxiliary boilers that normally use heavy fuel oil. Matson Navigation, a container shipping line, reported that the auxiliary boilers used on their vessels are not fuel sensitive, and can use either distillate or residual fuels (Matson, 2007). Matson also reported that they currently use distillate fuel at all times in some of their auxiliary boilers because it results in less fouling (buildup of soot deposits on boiler convective surfaces) compared to heavy fuel oil. They reported that use of distillate fuels does not introduce any additional safety concerns beyond the usual precautions with operation on heavy fuel oil. However, in some of their larger vessels, they reported that they may need to add more tank capacity and associated piping for distillate fuel if it were to be required in both the auxiliary engines and boilers.

Another large container shipping line, American Presidents Line (APL), reported that distillate fuels could be used in their boilers (APL, 2007). They did not expect that any modifications would be needed.

Crystal Cruises, a passenger cruise liner, reported that they already voluntarily use distillate fuel in or near California ports to ensure that they don't have any visible PM emissions (Crystal Cruises, 2007).

Tanker operators also reported that distillate fuel could be used in their boilers. However, they reported that their boilers may need modifications. Tankers are a special case because they have much larger auxiliary boilers because of the high power requirements to discharge crude and other products. Chevron Shipping Company (Chevron) reported that the use of distillate in new vessels would not be a concern, but it could be for older vessels. For one of their large auxiliary boilers, they are considering an upgraded combustion system and associated piping (Chevron, 2007). BP reported the need to evaluate each of their boilers on their tankers to determine if any modifications would be necessary to safely us the required distillate fuel. (BP, 2007)

Boiler Manufacturers: The leading manufacturer of marine auxiliary boilers, Aalborg-Industries, reported that their boilers can be used with distillate fuel (Aalborg, 2007). However, it was reported that the burners on older models would need to be adjusted for distillate fuel to achieve maximum efficiency (although you could still burn distillate without this adjustment). Specifically, they reported that their newer boilers, manufacturer after about 1993 or 1994, would automatically adjust their burners for maximum efficiency with distillate fuel without any manual input. For their earlier models, a manual adjustment would be needed to optimize the efficiency of the boiler.

Another boiler manufacturer, Osaka Boiler Manufacturing Company, reported that distillate fuel can be used without adjustment in all their boilers, with the exception that marine gas oil (DMA grade fuel) with a viscosity below 2.5 centistokes (cSt) would require the replacement of the fuel oil pump in boilers made prior to April, 2004 (Osaka, 2007).

Auxiliary Boilers: Marine auxiliary boilers can be operated on marine distillate fuels, as long as certain precautions are taken. Distillate fuel is a lighter, less viscous fuel with different properties than heavy fuel oil, and in some cases this will require some adjustments or modifications to marine boilers and fuel pumps. Table VI-2 below discusses some of the technical considerations identified by a marine boiler manufacturer (Aalborg, 2005) and ship classification society (DNV, 2005).

Table VI-2: Technical Considerations Associated with the Use of Marine Distillate Fuel (MGO) in Marine Auxiliary Boilers

Technical Issue	Solution
Distillate fuel has a slightly higher fuel heat value, which may result in a less than optimal air fuel ratio and an increase in smoke.	Readjust air/fuel ratio.
Distillate fuel has lower fuel viscosity, and associated lower lubricity. If the viscosity is below about 4-5 cSt it could result in damage to some boiler fuel pumps or the supply fuel pumps.	Shut off trace heating normally used with residual fuel. If necessary, install a fuel cooling system to increase viscosity of the fuel. Modify or replace fuel pump with a newer design more tolerant of low viscosity fuel. Modify the control system to turn off fuel pumps when boiler is on standby with distillate fuel.
Distillate fuel has a lower fuel density which means the amount of fuel to the burner will differ from the pre-set amount. This could result in increased smoke or ignition problems.	Readjust fuel flow based on lower density of fuel.
Distillate fuels have a lower flash point that is occasionally lower than the required 60C (140F). This presents a greater risk of fire.	Only purchase fuel meeting flash point requirements.
The lower viscosity of distillate fuel could result in an increase in the fuel input through pressure jet burner nozzles. This could increase smoke emissions.	Adjust fuel pressure or modify burner nozzles to avoid smoke. On steam atomizing burners.
Rotary cup burner compatibility with distillate fuel. Smoke. Accidental ignition of main burner when ignition flame out.	Install heat shield on rotary cup burners. Adjust control system for lighter fuels to ensure main burners do not accidentally ignite.
Steam atomizing burner compatibility with distillate fuel. Coke deposits on rotary cup burners. Accidental ignition of main burner when ignition flame out. Burner overfiring or fuel gassing with steam atomizing burners.	Adjust control system for lighter fuels to ensure main burners do not accidentally ignite.
Fuel gassing during changeover to distillate.	Use procedures that allow for gradual mixing to avoid large temperature changes.

E. Feasibility of Using Distillate Marine Fuels in Ocean-Going Vessel Auxiliary Engines

The feasibility of using distillate marine fuels in ocean-going vessel auxiliary engines is discussed in detail in the Initial Statement of Reasons for the Auxiliary Engine Regulation, which is incorporated by reference in this document. (ARB, 2005a) Like the proposal, the Auxiliary Engine Regulation also required the use of distillate marine fuels in ocean going vessel auxiliary engines. It was enforced for approximately 14 months starting in January 2007. As mentioned previously, the overwhelming compliance rate of ocean-going vessels with that regulation amply demonstrates the feasibility for auxiliary engines.

Vessel Fuel Infrastructure Needs

Most vessels are equipped to run their auxiliary engines on either distillate fuel or heavy fuel oil. About 6 percent of the vessels that participated in the 2007 Survey reported the need for vessel modifications to use marine gas oil in their auxiliary engines. However, PMSA has admitted in its legal challenge to the Auxiliary Engine Regulation that no vessel changes are necessary for vessels to run their auxiliary engines on distillate and that engine manufacturers uniformly reported that their auxiliary engines designed for use with heavy fuel oil can also use compliant distillate fuels as long as proper fuel switching procedures are used. (PMSA, 2008) PMSA has also stated publicly that it requested its members to voluntarily comply with the Auxiliary Engine Regulation even though that regulation currently is not being enforced. (SustainableShipping, 2008)

Technical and Safety Considerations

We believe that vessel operators already can and do safely use distillate fuels when they follow the engine manufacturers' recommendations. Only one safety exemption was issued during the 14-month enforcement period of the Auxiliary Engine Regulation and that exemption was for fuel that was not within the fuel flashpoint specification. Issues related to the use of distillate fuels in auxiliary engines were addressed in the Initial Statement of Reasons for the Auxiliary Engine Regulation. (ARB, 2005a)

F. Impact of Reducing Marine Distillate Fuel Sulfur Levels

The process used to reduce the fuel sulfur levels during distillate processing may affect the physical properties such as lubricity, viscosity and flashpoint. While sulfur is not a lubricant, the process used to reduce the sulfur level can impact fuel lubricity (CIMAC, 2007). The viscosity of distillate fuel is already considerably lower than HFO. Concerns have been raised that the viscosity of distillate fuel will further decrease as the sulfur level decreased. In addition, stakeholders voiced concerns about the potential impacts on the availability marine fuels which have a higher flashpoint than on-road diesel fuels, since the distillate market is dominated by lower flashpoint on-road distillates. The following sections address both the distillate fuel properties and any differences in properties as a function of the fuel sulfur levels.

Lubricity: Lubricity can be defined as the ability to provide surface contact lubrication. Adequate levels of fuel lubricity are necessary to protect the internal contact points in fuel pumps and injection systems to maintain reliable performance. Natural lubricity of diesel fuel is dependent on the presence of trace levels of oxygen- and nitrogen-containing compounds that provide surface-active molecules that adhere to or combine with metallic surfaces to produce a protective film that reduces wear. (Nikanjam, 1993)

Several sources reported that lower sulfur fuels have lower lubricity, which could potentially cause fuel pump damage. (DNV, 2005; CIMAC, 2004; MAN B&W, 2005) Unlike low sulfur automotive diesel fuels, marine fuel standards do not include minimum lubricity standards. The California diesel fuel specification (Title 13, CCR, Sections 2281-2285 Title 17, CCR, Section 93114) requires a minimum level of lubricity. This is measured as a wear scar diameter (WSD) at 60℃ of 520 µm or less using the ASTM D6079-02 method. The European diesel fuel specification (EN 590) requires a WSD at 60℃ of 460 µm or less using the ISO 12156-1 method. (Dieselnet, 2006)

Desulfurization or hydrotreating processes, used to reduce the sulfur levels in the distillate fuel, have been reported to lower the lubricity of the fuels due to the reduction of trace surface-active molecules. (Nikanjam, 1993) When these fuels are sold into the marine market, there is no lubricity requirement to ensure a minimum level of fuel lubricity as would be required in the on-road distillate market.

Because there is limited experience using these hydrotreated low sulfur distillates in the main engine and there is very limited data on marine distillate lubricity, it is unknown what minimum level of lubricity would be required to prevent fuel pump problems. For example, one source states that sulfur levels below 0.05%, in conjunction with a viscosity below 2 cSt, 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% (100 ppm) (*Wärtsilä, 2005b*). Still another source noted that lubricity additives could be added by the fuel manufacturer or marketer. (Wärtsilä, 2005b)

Information from a number of sources indicates that some of the compliant distillates may have very low sulfur levels, even in Phase 1 of the fuel requirements in the proposed regulation. The low levels of sulfur in the marine distillates are possibly due to the influence of automotive diesel sulfur standards of 0.0015% sulfur (15 ppm). For example, in California, the majority of marine distillate samples tested by DNV in 2007 were below their lowest detection limit of 0.05% sulfur. (DNV, 2007) ARB's Auxiliary Engine Regulation field inspections data found a number of marine distillate samples below 0.01% (100 ppm) sulfur. The International Council on Combustion Engines (CIMAC, 2007) guidelines indicate that if marine distillate fuels fulfill the limits of the European diesel fuel lubricity standard, having a WSD at 60℃ of 460 µm or less, there is a high probability that these fuels will not cause lubricity problems. (CIMAC, 2007)

To gather data on the lubricity of lower sulfur in-use marine distillates, ARB conducted a study to test the lubricity, along with a number of other fuel properties, of a portion of the marine distillate samples taken during inspections. A total of 28 MGO and MDO samples, ranging from 0.007% to 1.5% sulfur, were tested in this study. Lubricity testing was performed at 25, 40 and 60℃, using the high-frequency reciprocating rig method per ASTM D 6079-04. Although 60℃ is the standard test temperature, testing was performed at the three temperatures since the fuel temperatures at the inlet to the engine may vary, depending on fuel switching procedures and other operational parameters. Figure VI-1 shows the WSD diameter of all the samples tested for the lubricity study. Table VI-3 lists the bunkering information and additional properties for each of the fuel samples.

Figure VI-1: HFRR Lubricity Results for Enforcement Samples (Wear Scar Diameter in Micrometers at 25, 40 and 60°C)

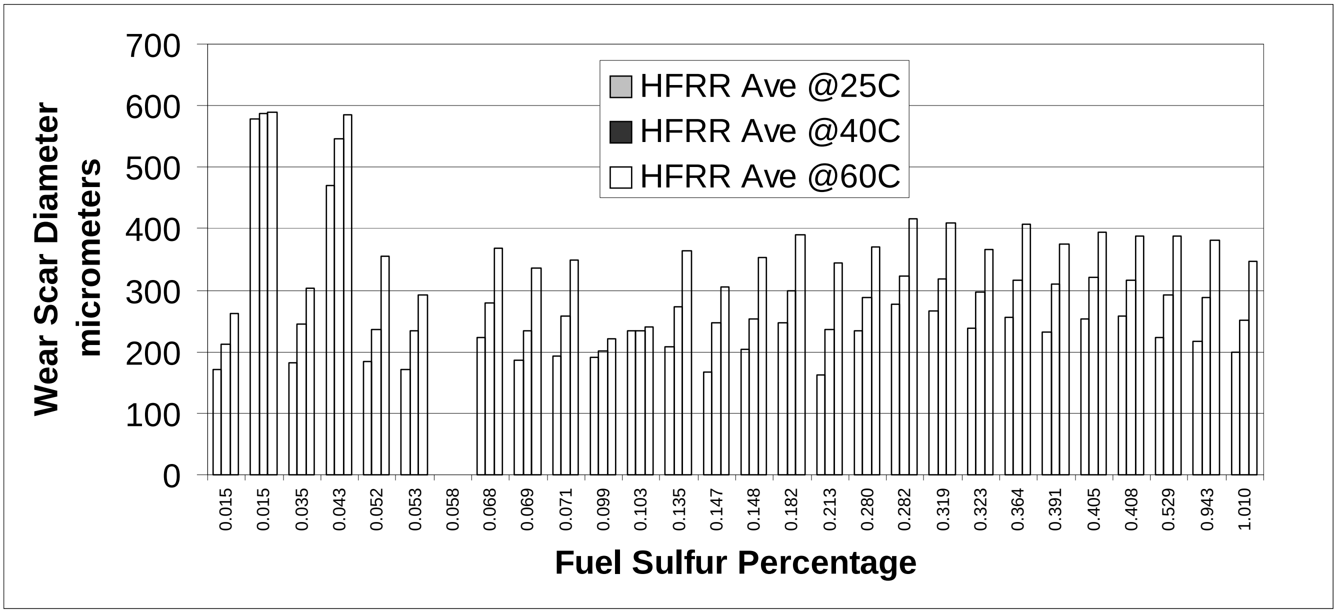


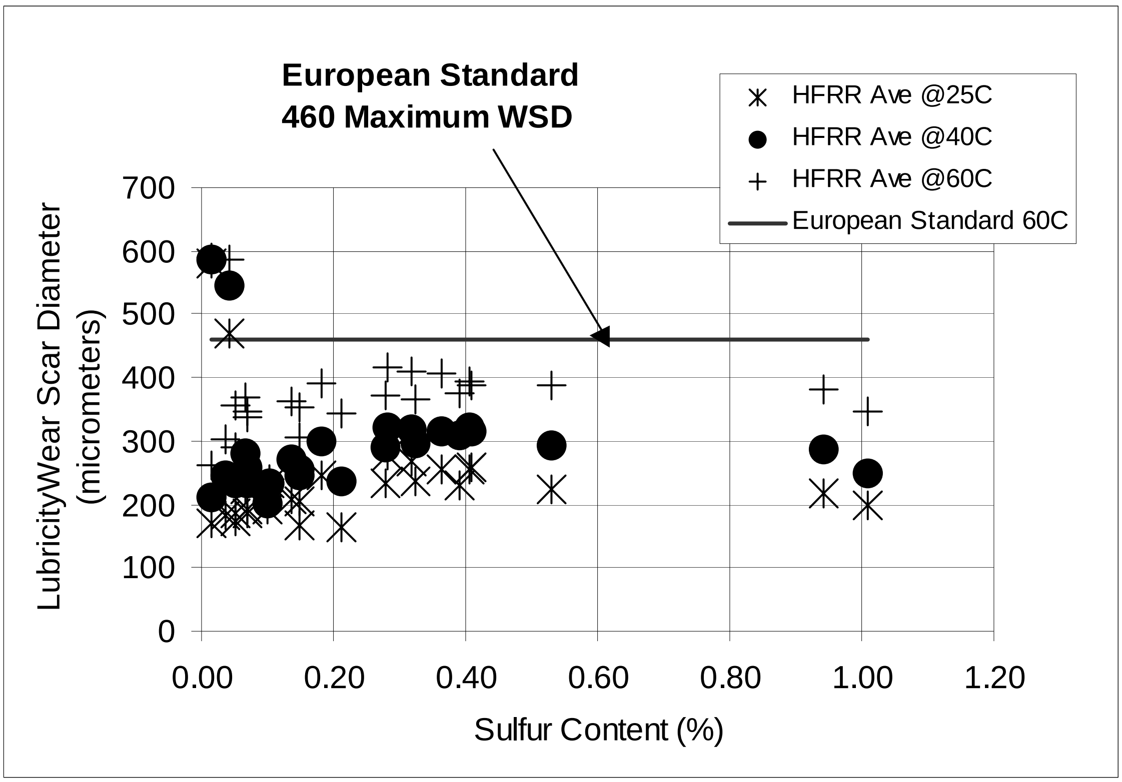
Table VI-3: Distillate Lubricity and Fuel Property Test Results for Inspection Samples

Bunker Location City/Port	Fuel Type	% Fuel Sulfur	Flash Point ℉	Cetane Index	Kinematic Viscosity @40C cSt	HFRR(1) Ave @25℃	HFRR Ave @40℃	HFRR Ave @60℃
Long Beach	MGO	0.02	178	41.9	3.0	172	213	262
Richmond	LSD	0.02	154	51.8	2.8	580	587	589
Tokyo	MGO	0.04	168	54.9	3.2	183	246	304
Manzanillo	MDO	0.04	146	52.7	3.8	470	547	585
Long Beach	MGO	0.05	178	44.7	3.2	185	237	356
Busan	MGO	0.05	156	51.7	2.8	172	233	292
Tokyo (2)	MDO	0.06	-	-	3.9	-	-	-
POLA	MGO	0.07	154	50.2	2.9	223	280	370
Tauranga	MGO	0.07	192	56.4	2.5	187	235	336
Tokyo (3)	MDO	0.07	158	47.5	2.8	194	258	348
POLA	MDO	0.10	150	53.0	3.8	192	203	222
Savannah	MGO	0.10	156	46.9	2.6	234	234	241
Busan	MGO	0.14	152	44.6	3.0	209	272	364
Busan	MGO	0.15	154	50.6	2.9	166	247	306
Zeebrugge	MGO	0.15	164	48.7	3.6	205	255	353
Ama	MGO	0.18	164	47.6	2.8	247	299	391
Singapore	MGO	0.21	166	52.8	3.6	164	236	345
Barcelona	MGO	0.28	178	48.5	3.7	234	289	371
Hong Kong	MGO	0.28	166	52.9	3.8	278	323	417
Long Beach	MGO	0.32	166	50.7	3.5	268	318	410
Busan	MGO	0.32	158	52.4	3.4	238	297	367
Singapore	MGO	0.36	176	51.4	3.5	255	317	407
Hong Kong	MGO	0.39	166	51.9	4.2	231	309	376
Hong Kong	MGO	0.41	170	51.0	4.2	255	322	394
Busan	MGO	0.41	158	52.9	3.7	258	317	389
Kokura	MGO	0.53	168	47.5	3.8	224	292	389
Rotterdam	MGO	0.94	186	46.0	4.3	217	289	383
Rotterdam	MGO	1.01	180	42.0	3.9	199	251	347

(1) Average of two tests at each temperature. Wear Scars are in micrometers.
(2) Sample was unstable due to water in fuel. Only partial analysis was completed.
(3) Fuel additive-Econofree 50liters /100 tons

The results from the lubricity study indicate that a majority of the marine distillates tested meet the more stringent European diesel fuel WSD standard of 460 µm, when tested at 60℃, as well as at the lower temperature s. This is shown in Figure VI-2 below. Although the two samples with WSDs higher than 460 um were measured for distillates with very low sulfur levels, there is no clear trend showing a relationship between fuel sulfur level and lubricity in this study. This data indicates that lubricity is not likely to be a significant issue during the Phase 1 requirements, even if very low sulfur distillates are used in some instances. It does indicate that it may be a bigger concern in Phase 2, when only marine distillates at or below 0.1% sulfur are required. Ship operators can add lubricity additives at low cost if they feel it is necessary or they may be able to request a minimum lubricity level when purchasing fuel. ARB staff believes that a two phase approach, such as that contained in the proposal, will allow time to obtain more data on fuel lubricity and its impact on longer term engine performance.

Figure VI-2: HFRR Measured Lubricity Wear Scar Diameter vs. Sulfur Content



Low Viscosity: Both major main engine manufacturers, MAN and Wärtsilä, 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) Another potential impact is that the lower viscosity fuels may fail to provide a hydrodymanic film between moving components to prevent wear and damage in the fuel pumps. MAN has recommended a minimum of 1.5 to 2.5 cSt (cSt) at the inlet to the engine in order to ensure a hydrodynamic film between the wear surfaces. (Aabo, 2008). Wärtsilä has recommended minimum viscosities in the range of 1.8 to 3 cSt, depending on the engine model and whether the engine is 2-stroke or 4-stroke. (Wärtsilä, 2007)

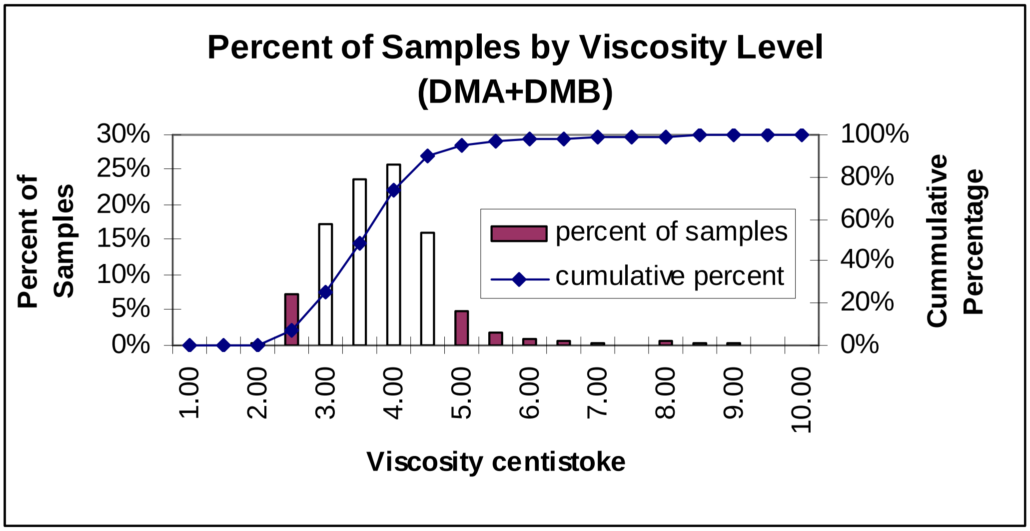
CIMAC has indicated that a minimum viscosity level of 2 cSt is recommended to avoid operational problems to the fuel equipment. (CIMAC, 2007) The minimum fuel viscosity for MGO per ISO 8217 is 1.5 cSt, which is below the CIMAC recommendation. As listed in Table VI-4, results from the analysis of the 2007 DNV fuel sample data indicate that the minimum viscosity of MGO is1.5 cSt and MDO is 1.97, both below the minimum recommended by CIMAC. However, the average viscosity of MGO (DMA) is 3.5 cSt and MDO (DMB) is 3.9 cSt, which is above both the CIMAC and engine manufacturers' recommendations.

As shown in Figure VI-3, the majority of samples analyzed are above 2.0 cSt and 50 percent of the samples analyzed are above 3.5 cSt. Because of these values, one engine manufacturer suggested that that a viscosity level could be specified when ordering distillate fuels. Another approach to control fuel viscosity would be to add a fuel cooler since lowering the fuel temperature will increase its viscosity. This modification could be installed at a ship's normal dry-docking. (Herbert, 2007)

Table VI-4: Range in Fuel Viscosity of Marine Distillate Fuels Analyzed (DNV, 2007)

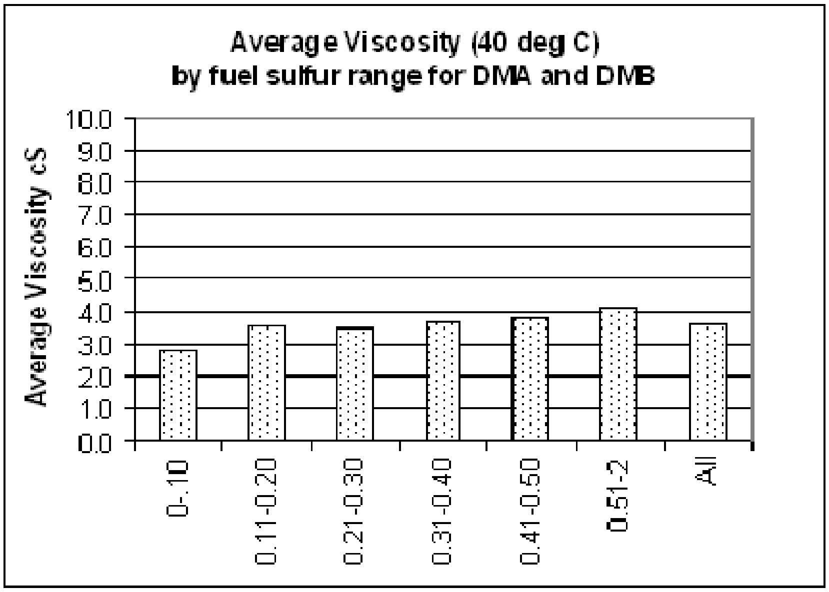
Fuel Type	Min cSt	Max cSt	Ave cSt
DMA	1.5	9.7	3.5
DMB	2.0	9.9	3.9
DMA+DMB	1.5	9.9	3.6

Figure VI-3: Fuel Viscosity Distribution of DMA and DMB Marine Distillate (DNV, 2007)



As shown in Figure VI-4, the average viscosity of fuels in the range of 0 to 0.1% sulfur is slightly lower than the average viscosity of fuels with higher sulfur content. However, there is no strong correlation in viscosity as a function of sulfur content for the distillate fuels, and all averages are above 2.0 cSt.

Figure VI-4: Average Fuel Viscosity by Sulfur Level for DMA and DMB Marine Distillate Fuels (DNV, 2007)



A two-phase approach will allow the operators more flexibility in managing fuel viscosity issues, specifically during the first phase of the rule implementation. Because the sulfur levels are not as restrictive in Phase 1, the operators will have more flexibility in specifying higher viscosity levels when purchasing the fuel. Operators and engine makers will have additional data and experience prior to Phase 2, where fuel availability of 0.1% sulfur MGO/MDO may make finding compliant fuels with higher viscosity more difficult.

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 an engine by approximately 6-15 percent depending on the engine design and model. (Wärtsilä, 2005b; Yanmar, 2005; Pielstick, 2004) Depending on the engine, governor adjustments or a change in the fuel "rack" position may address this issue.

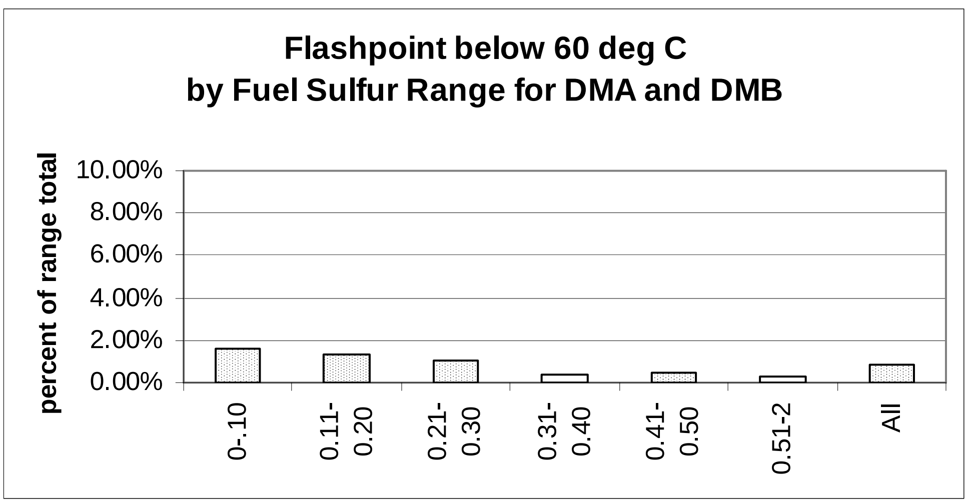
Flash Point: The flash point is the temperature at which a combustible liquid gives off just enough vapor to produce a vapor/air mixture that will ignite when a flame is applied. The importance of flash point is primarily related to safe handling of the product. If the flash point is too low, there could be a fire hazard. The minimum flash point for marine fuels is 60℃.

Marine fuels differ from land-based distillates in the minimum flash point specification. Marine fuels have a minimum flash point of 60℃, while land-based diesel fuels typically have a minimum flash point of 52℃. Analysis of the 2007 DNV distillate fuel properties indicate that less than 1 percent of all samples analyzed were below 60℃ and that there was no correlation between sulfur level and flash point.

As shown in Figure VI-5, the DNV data shows a slightly higher percentage of below minimum flash point fuels in the range of 0 to 0.1% sulfur. (DNV, 2007) However, the percentage of below minimum flash point samples was below 2 percent for all the ranges analyzed. Since fuel flash point is tested for acceptance and the specified flash point is a requirement to sell, these fuels would be defective. These results indicate that in all sulfur level ranges, 98 percent of all samples meet the marine fuel specifications.

It should be noted that, while the larger on-road diesel market has not significantly impacted the availability of marine distillates meeting the higher flashpoint requirement, a sufficient supply of on-road diesel, with its lower flashpoint, does not insure sufficient quantities of low sulfur marine distillates meeting the 0.1% sulfur limit and higher flashpoint.

Figure VI-5: The Percent of Samples Below Minimum Flash Point (60℃) by Sulfur Level for DMA and DMB Marine Distillates (DNV, 2007)



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 seals, gasket materials or o-rings, and tightening connections. Technical issues such as fuel system leaks are relatively manageable if attention is paid to fuel specification, maintenance, and training. A two-step implementation process will provide the operators added flexibility, such as specifying and using higher viscosity fuels, to manage such leakage issues to the extent they may occur.

Further Studies

Engine makers and some ship operators have expressed concerns that use of very low sulfur MGO/MDO may cause damage to ocean-going vessel main engines because of low fuel viscosity and/or low fuel lubricity. While very low sulfur fuels, in the range of 15 ppm sulfur, are not a requirement of this regulation, they may make up a significant portion of the available compliant fuel used the meet the Phase 2, 0.1% sulfur requirement. Lubricity testing of fuel samples having sulfur levels above 0.1% shows that those fuels met the stringent European on-road diesel standard, and average viscosity values were higher for the ranges above 0.1% sulfur.

By contrast, the lubricity of the samples below 0.1% sulfur did not meet the stringent European on-road lubricity standard, in limited cases, and the average viscosity level was slightly lower than in the higher sulfur MGO/MDO. Furthermore, there is very limited information and data on the operation of these engines on very low sulfur distillates, and the impact of operating on very low sulfur MGO/MDO on the long-term performance of modern two-stroke ocean-going vessel main engines.

To further study these issues, ARB is performing two additional studies to investigate the impacts of fuel switching in OGV main engines. The first study investigates the acceptable lower limits of fuel viscosity and lubricity in the high pressure injection fuel pumps. The second study investigates the long term impacts of fuel switching on main engine performance, component wear and failure rates.

Investigate the Impacts of Using Low Sulfur Marine Distillate Fuels in Marine Fuel Injection Pumps

Some ship operators have expressed concern that use of low sulfur fuels (especially below 0.05% sulfur) would be damaging to fuel injection pumps because these fuels are low in viscosity and may be low in lubricity. In this study, ARB is partnering with the major marine engine manufactures to bench test low sulfur distillate fuels in simulated a "pump rig test." For this program, a fuel injection pump, typical of a large two-stroke, slow-speed engine, would be operated on a test stand. The pump will be operated with the designated fuel for a specified period of time and then disassembled and inspected for wear. The goal of this testing is to determine the lower limits of fuel lubricity and viscosity for marine fuel injection pumps used on large two-stroke, slow-speed OGV main engines.

Evaluate the Effect of Low Fuel Viscosity and Low Fuel Lubricity on Large Slow-Speed Two-Stroke Ocean-Going Vessel Main Engines

In this study, fuel switching between heavy fuel oil (HFO) and low sulfur-clean burning distillate would be done on a select number of ocean-going vessel main engines.

Currently, there have been no documented long term studies or demonstrations on the effect of low sulfur marine fuels on the long term performance and operation of modern two-stroke ocean-going vessels which routinely fuel switch between HFO and distillate. In this program, the long term operation, such as engine performance, component failure rate, and component wear would be evaluated to determine the long term effects of fuel switching. Shipping companies and engine makers would provide in-kind services to partner with the ARB. In addition, emission testing for diesel PM, criteria pollutants and greenhouse gasses would be performed to determine emission benefits of fuel switching.

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VII. ENVIRONMENTAL IMPACTS

This chapter describes the potential environmental impacts of this 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 vessels. An additional consideration is the impact that implementation of the proposed control measure 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 with the exception of a small, potential increase in greenhouse gas emissions. This chapter describes the potential impacts that the proposed regulation may have on water quality, hazardous waste disposal, air quality and greenhouse gas emissions

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 control measure, 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 control measure.

Regarding reasonably foreseeable 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.

Compliance with the proposed control measure is expected to directly affect air quality and potentially affect other environmental media as well. Our analysis of the reasonably foreseeable environmental impacts of the methods of compliance is presented below.

The proposed control measure is needed to reduce the risk from exposures to diesel PM as required by Health and Safety Code (H&S) section 39666 to meet the requirements of H&S sections 43013(b) and 43018, and to fulfill the goals of the Diesel Risk Reduction Plan and the Goods Movement Emission Reduction Plan. The proposed regulation is also needed to reduce emissions of directly-emitted PM, NOx, and SOx; reduce secondarily-formed PM from NOx and SOx; and help with attaining the federal and State ambient air quality standards for PM_{10}, $PM_{2.5}$ and ozone. Alternatives to the proposed control measure 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&S section 39666 that would equivalent or greater diesel PM emission reductions at a lower cost.

B. Potential Water Quality Impact

ARB staff does not expect this regulation to have any adverse impacts on water quality. The proposed regulation's requirements, particularly the reduction in sulfur content of the engine fuels, should result in reduced formation of sulfuric acid, nitric acid and other harmful compounds to the extent the vessel emissions actually come into contact with ocean or inland waters. And because scrubbers and other exhaust treatment technologies are not allowable methods of compliance with this proposal, there are no impacts that might otherwise result from the byproducts of such methods (e.g., ash, salts, heavy metals from catalytic oxidizers, etc.).

C. Potential Hazardous Waste Impact

ARB staff does not expect this regulation to have any adverse impacts on hazardous wastes. The proposal is a straightforward low-sulfur fuel use requirement. And as noted previously, the proposal does not allow for alternative methods of compliance, such as the use of catalytic oxidizers or scrubbers. Thus, staff does not expect this regulation to have any adverse impacts on hazardous wastes.

D. Potential Air Quality Impact

The proposed regulation will provide diesel PM, PM, NOx, and SOx 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 PM10, PM2.5 and ozone. Air quality benefits will result from the reduction of SOx emissions as well because SOx secondarily forms PM in the atmosphere.

Emission Reduction Estimates

The emission reductions that would result from the proposed regulation were estimated based on the differences in emissions between the use of marine heavy fuel oil (HFO), and the cleaner burning marine distillate fuels specified in the regulation (marine gas oil (MGO) or marine diesel oil (MDO)). Specifically, from July 1, 2009 through 2011, we estimated the emission reductions that would occur from switching from 2.5% sulfur HFO to 0.5% sulfur marine distillate fuel. For 2012 and beyond, we estimated the emission reductions from switch from 2.5% sulfur HFO to 0.1% sulfur marine distillate fuel, as specified in the regulation.

The 2.5% sulfur level assumed for HFO is based on ARB's 2005 Ship Survey (ARB, 2005), and ARB's more recent 2007 survey (ARB, 2007) indicates a similar sulfur level. The sulfur levels used for marine distillate fuels are based on the proposed regulation. Specifically, the proposed regulation requires the use of 0.5% sulfur MDO, or MGO with no limit in 2009. We are confident that the sulfur level for MGO will average below 0.5% sulfur without imposing a sulfur limit, based on enforcement samples taken for the auxiliary engine regulation that yielded an average sulfur level of about 0.3%.

Based on the results of ARB's 2007 survey and discussions with ship operators, we believe that the vast majority of main engines and auxiliary boilers use HFO. Therefore, we approximate the emissions from these sources assuming that they use HFO only. For auxiliary engines prior to regulation, we estimate that 78 percent use HFO, and 22 percent use marine distillate fuels. This is based on the ARB's 2005 ship survey (the ARB's 2007 survey was not used because in 2007 the use of distillate fuel was mandated by ARB in California).

When vessel operators switch from heavy fuel oil to distillate fuels, the PM emissions decrease, in large part, because of the lower sulfur content of distillate fuel, which in turn 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 SOx emissions. For example, lowering the sulfur content from 2.5% to 0.5% (an 80 percent reduction in fuel sulfur) reduces SOx emissions by 80 percent. The lower nitrogen content of distillate fuels also results in a reduction in NOx emissions (EPA, 2002).

The estimated emission factors for main engines, auxiliary engines, and auxiliary boilers are shown in Table VII-1 below. Emission factors are used to estimate the average emissions for a class of engines or boilers under specified conditions; under the proposal, these factors are not used for compliance testing or for determining emissions from individual engines or boilers. While the emissions from an individual engine will vary significantly based on the engine model, engine condition, and specific fuel used, these emission factors represent our best overall estimates based on the available engine test data. We recognize that emissions test results for PM vary widely depending on the source of information, and others have estimate PM emission factors differently. These emission factors are discussed in more detail in Appendix D**.**

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

Pollutant	HFO @ 2.5% sulfur	MGO @ 0.5% sulfur	MGO @ 0.1% sulfur
Main Engines (transiting)			
NOx	18.1	17.0	17.0
SOx	10.5	1.9	0.36
PM	1.5	0.38	0.25
Auxiliary Engines (all modes)			
NOx	14.7	13.9	13.9
SOx	11.1	2.1	0.4
PM	1.5	0.38	0.25
Auxiliary Boilers (all modes)			
NOx	2.1	2.0	2.0
SOx	16.5	3.0	0.6
PM	0.8	0.2	0.13

The estimated percent emission reductions from main engines, auxiliary engines, and auxiliary boilers that switch from HFO to distillate fuels are shown in Table VII-2 below. As shown, the emission reductions in PM and SOx are dramatic, while there is also a smaller NOx reduction.

Table VII-2: Estimated Emission Reductions for All Sources Switching from 2.5% Sulfur Heavy Fuel Oil to the Distillate Fuels

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

Table VII-3 below shows the current and projected OGV emissions within the 24 nautical mile zone for main and auxiliary engines and auxiliary boilers. The future year projections are based on the growth assumptions discussed in Appendix D.

Table VII-3: Projected Emissions from OGV in 24 Nautical Mile Zone

Pollutant Source	2006	2010	2020
	PM (tons/day)		
Main Engine	10	12	18
Auxiliary Engine	3.4	3.9	4.2
Auxiliary Boiler	1.2	1.3	1.8
Total	15	17	24
	NOx (tons/day)		
Main Engine	115	133	203
Auxiliary Engine	39	45	48
Auxiliary Boiler	3.1	3.5	4.6
Total	157	182	256
	SOx (tons/day)		
Main Engine	68	79	120
Auxiliary Engine	25	28	31
Auxiliary Boiler	25	27	36
Total	118	134	187

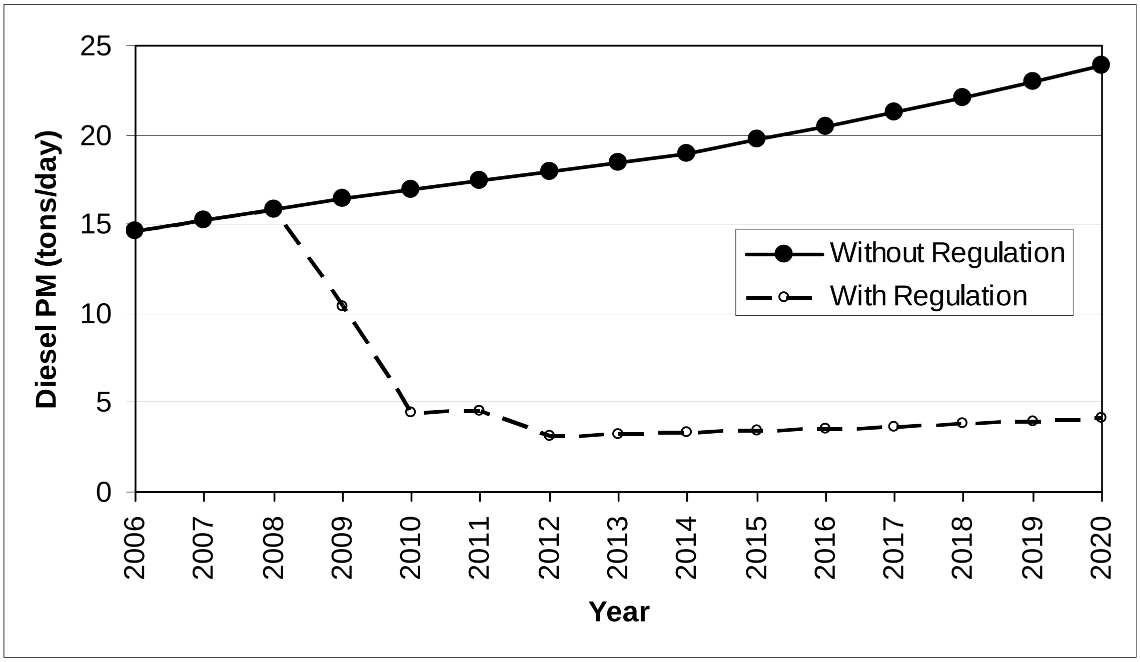
ARB staff estimates that implementation of the proposed regulation will result in immediate and substantial reductions in diesel PM, PM, NOx, and SOx emissions, as shown in Table VII-4 below. Upon the first full year of implementation in 2010, this represents a 74 percent reduction in PM emissions from the baseline emissions subject to the regulation (emissions within the 24 nautical mile zone). For 2012 and later, we estimate an overall 83 percent reduction in PM emissions

Table VII-4: Projected Reductions in OGV Emissions in 24 nm Zone Due to Proposed Control Measure

Year	Total Emission Reductions (Tons per Day)		
	PM	NOx	SOx
2010	13	10	109
2015	16	12	148
2020	20	15	178

Figure VII-1 illustrates how the PM emissions from ship auxiliary engines within the 24 nautical mile zone will grow with and without the proposed control measure. As shown, the proposed regulation will significantly reduce emissions as compared to the uncontrolled baseline.

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



E. Potential Greenhouse Gas Impact

Impact of Proposed Regulation on CO_2 Emissions

Shipping is a relatively small but significant contributor to worldwide emissions of greenhouse gases (GHG). The primary GHG from shipping is carbon dioxide (CO_2) resulting from fuel combustion. By some estimates, shipping is responsible for about two percent of worldwide CO_2 emissions. (Marintek, 2000)

The proposed regulation would only cover a small percentage of the travel by ocean-going vessels worldwide (i.e., travel within 24 nautical miles of the California coastline). As a result, the CO_2 emissions from vessels traveling within 24 nautical miles of California are estimated to be less than one percent of worldwide shipping emissions. Nevertheless, we wanted to determine the overall impact of the proposed regulation on GHG emissions. The use of the marine distillate fuels specified in the proposed regulation would be expected to reduce CO_2 emissions in California because marine distillate fuels have a higher energy content by weight as compared to heavy fuel oil, resulting in lower fuel consumption. On the other hand, some sources have indicated that producing distillate fuels at the refinery requires more energy than heavy fuel oil, resulting in more CO_2 emissions.[1]

[1] Guy Wilson-Roberts, *Industry Rejects CO2 Arguments*, (visited June 2, 2008) <http://sustainableshipping.com/news/2007/09/69050>.

To examine the net impact of the proposed regulation on CO_2 emissions, ARB contracted with Dr. James Corbett and Dr. James Winebrake of Energy and Environmental Research Associates for a study of the total fuel-cycle emissions. The complete study can be found in Appendix H. Their analysis estimated the total fuel-cycle CO_2 and SOx emissions associated with fuel extraction, fuel processing, fuel distribution, and fuel consumption. To estimate the emissions at each stage, they used a modification of the peer-reviewed Total Energy & Emissions Analysis for Marine Systems (TEAMS) model, which was originally based on Argonne National Lab's GREET model (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation). The TEAMS model was modified to allow analyses for the particular set of fuels under study.

Corbett and Winebrake estimated that requiring a switch from residual fuel to the distillate fuels specified in the regulation would correspond to a net increase in CO_2 emissions of approximately 1 to 2 percent over the total fuel cycle (and an 86 to 97 percent decrease in SOx emissions). This slight increase in net fuel-cycle CO_2 emissions is primarily a function of the increased energy required at refineries that produce compliant distillate fuels. This offsets the localized decrease in CO_2 emissions from ship operations (fuel combustion) in California due to the higher energy content of the distillate fuel, as compared to heavy fuel oil. But this study assumes that refineries will make no efforts to improve energy efficiency while maintaining, upgrading, or expanding their capacity to produce distillate fuels. This is unlikely given rising energy costs and global efforts to reduce GHG.

Any potential increase due to the proposal may also be temporary, as pending amendments to IMO treaty protocols are likely to provide for the creation of Emission Control Areas, where equivalent fuel standards could be implemented by 2015 in sensitive regions worldwide. An ECA is functionally similar to the 24 nm jurisdictional zone under the proposed regulation, except that an ECA potentially can be much larger.

In addition, the study points out that the global refining industry is on a steady path toward greater production of higher value distillate fuels, and the modest increase in distillates produced by the proposal may already be accommodated by planned refinery upgrades. Therefore, the potential fuel-cycle increase in CO_2 emissions due to greater use of more highly refined marine distillate fuel may be overestimated.

If CO_2 emissions associated with the cleaner fuels specified in the proposal do increase by 1 to 2 percent under this proposal, we project such an increase could result in up to 50,000 metric tons per year of additional CO_2. While this is a very small increase relative to the overall CO_2 emissions from shipping, we nevertheless believe this may represent a significant adverse environmental impact.

Staff evaluated a number of alternatives to this proposal (see Chapter V, section N). However, staff was not able to identify any feasible alternatives that would substantially reduce the potential adverse impacts of this regulation while at the same time ensuring that the positive environmental impacts (e.g., the reduction in exposure to diesel PM, PM, NOx, and SOx emissions) would be achieved. Staff was also unable to identify any feasible mitigation measures that could be incorporated into the proposed regulation that would substantially reduce the potential adverse impacts, while at the same time ensuring that the positive environmental impacts that would be achieved. However, other ARB programs will substantially reduce greenhouse gas emissions and will more than offset the potential increase in greenhouse gas emissions from this regulation. These programs are discussed below in the section entitled *Reasonable Foreseeable Mitigation Measures*.

Despite our finding of a potential significant adverse environmental impact, we believe the very substantial health and environmental benefits from the proposal clearly constitute overriding considerations that justify the proposal. Staff believes that reducing diesel PM and exposure to diesel PM, PM, NOx and SOx emissions as described in this Staff Report is a consideration that overrides the very small adverse impacts that may occur as a result of this proposed regulation.

Specifically, the potential 1 to 2 percent increase in CO_2 must be weighed against the benefits of the estimated 75-83 percent reduction in diesel PM, the 80-96 percent reduction in SOx, and the 6 percent reduction in NOx emissions. And as discussed in Section D below, these emission reductions are estimated to result in substantial reductions in premature death, asthma attacks, lost work days, and other health impacts. Thus, staff believes these substantial health and environmental benefits clearly outweigh and override the very small adverse impacts from a potential 1 to 2 percent increase in the shipping CO2 emissions associated with vessels that visit California.

Climate Change Impacts from Reductions in Non-CO_2 Emissions

In the above analysis, we discussed potential CO_2 impacts associated with the proposed regulation. The proposed regulation will significantly reduce several criteria air pollutants, including NOx, SOx, and fine PM, that may contribute to global warming or cooling. The science to quantify the net impact that changes in these pollutants will have on the global climate is still evolving and definitive estimates are not yet possible. However, the following section provides an overview of the current understanding of the potential climate impacts of these pollutants.

Nitrogen oxides (NO_X)

Through the production of tropospheric ozone, emissions of NO_X have a climate warming impact. However, by affecting the concentration of hydroxyl radical (OH) they reduce the levels of methane, providing a cooling effect. The net climate impact of changes in NO_X emissions will depend on whether ozone or methane production dominates. At this time, there is no consensus on which action is likely to dominate or on the overall magnitude of the impact due to changes in NOx emissions resulting from the regulation.

Sulfur oxides (SOx)

Sulfur dioxide is oxidized to sulfate, and about 3% of the annual atmospheric global sulfate load originates from ship emissions. Sulfate aerosols scatter sunlight, thus cooling the earth–atmosphere system. One would expect that reducing the sulfur content in marine fuel could have a net warming effect due to reductions in light-scattering sulfate aerosols. Currently it is not possible to estimate the magnitude of these effects.

Particulate Matter (PM)

PM from OGV engine exhaust is composed of combustion particles consisting of elemental and organic carbon, and sulfate, all of which can form aerosols. Atmospheric aerosols play an important role in the climate system through modifications of the global energy budget: directly, by the scattering and absorption of radiation; indirectly, by the modification of cloud properties.

Black carbon (BC), typically emitted as a fraction of PM from combustion processes, is the main light-absorbing component of aerosols and thereby causes global warming. In recent years there has been increased attention to BC for its global warming potential through direct and semi-direct effects. BC, as a short-lived GHG, is believed to have a net climate warming impact. Reductions in BC may be an effective means to reduce global warming in the near term. The light-scattering or light-absorbing properties of individual aerosol particles depend on the extent to which black carbon is mixed with primarily scattering aerosol components, such as sulfates and organics. Organic carbon PM, which is emitted along with BC and generally has a light-scattering effect, may act to offset some of the global warming impact of BC emissions.

In general, black carbon and sulfate particles are expected to have a strong impact on the atmospheric radiation budget. The magnitude of the overall direct climate impact of BC emitted from OGVs, the properties of particles emitted by OGVs, and their fate of the particles in the marine environment are not well known.

Aerosols emitted by OGV have also been known to contribute to the formation of clouds over the ocean. The interactions of aerosols and clouds have been identified as one of the most important uncertainties in understanding the rate of climate change, or global warming, because clouds reflect energy and thereby reduce the net warming effect of long-lived greenhouse gases. Since aerosols have a much shorter lifetime in the atmosphere -- about a week compared to decades and hundreds of years for greenhouse gases -- these effects have been difficult to quantify.

F. Estimating the Health Benefits Associated with the Reductions of Diesel PM Emissions

Reduced Ambient PM Levels

Implementing the proposed regulation will mitigate air quality impacts from OGVs emissions significantly. Staff estimated that ambient diesel PM concentrations resulting from OGV emissions will be decreased by 74% in 2010 and 83% in 2012. Similarly, ambient $PM_{2.5}$ SO_4 concentrations resulting from OGV emissions will be reduced by about 80% in 2010 and 95% in 2012. Staff also expects that implementing the proposed regulation would reduce ambient levels of $PM_{2.5}$ NO_3, and ozone.

Reduced Cancer Risk Levels

The proposed regulation would reduce diesel PM emissions from OGV activities substantially. Staff estimated that potential cancer risk level statewide will be decreased by almost 75% by 2010 and by over 80% in 2012. Staff estimates that the average statewide cancer risk due to diesel PM emissions from OGV will be reduce from 70 chances in a million in 2006 to 15 chances in million in 2012 with implementation of the proposed regulation.

Reduced Non-cancer Health Impacts

A substantial number of epidemiologic studies have found a strong association between exposure to ambient particulate matter (PM) and adverse health effects (ARB, 2002, 2006, 2008). For this report, ARB staff conducted a quantitative analysis of seven potential non-cancer health endpoints associated with the change in exposures to the model-predicted ambient levels of directly emitted diesel PM and $PM_{2.5}$ sulfate (primary and secondary). Below are the estimated non-cancer health impacts from direct PM avoided between 2009 and 2015 due to the proposed regulation.

- 1,650 premature deaths (450 to 2800, 95% CI)
- 42,000 asthma attacks (16,000 to 68,000, 95% CI)
- 540 hospital admission – respiratory (130 to 950, 95% CI)
- 640 hospital admission – cardiovascular (350 to 930, 95% CI)
- 3,600 acute bronchitis (0 to 8,000, 95% CI)
- 280,000 work loss days (240,000 to 300,000, 95% CI)
- 1,600,000 minor restricted activity days (1,300,000 to 1,900,000, 95% CI)

Below are the estimated non-cancer health impacts from PM2.5 sulfate (primary and secondary) avoided between 2009 and 2015 due to the proposed regulation.

- 1,920 premature deaths (520 to 3,300, 95% CI)
- 56,000 asthma attacks (21,000 to 90,000, 95% CI)
- 650 hospital admission – respiratory (160 to 1,100, 95% CI)
- 750 hospital admission – cardiovascular (400 to 1,100, 95% CI)

- 4,700 acute bronchitis (0 to 10,,000, 95% CI)
- 340,000 work loss days (290,000 to 390,000, 95% CI)
- 2,000,000 minor restricted activity days (1,600,000 to 2,300,000, 95% CI)

In May 2008 ARB released a draft methodology for estimating premature deaths associated with long-term exposures to fine airborne particulate matter in California that proposes increasing the relative risk factor from 6% to 10% increase in premature death per 10µg/m^3 increase in PM2.5 exposures (ARB, 2008). The premature deaths avoided listed above were calculated using the 6% value. If the 10% value were used the estimates of premature deaths avoided would increase by 67%.

Methodology: The methodology used to estimate the health endpoints is discussed in Chapter IV with the following additions. To estimate the ambient concentrations of directly emitted PM and PM2.5 sulfate (primary and secondary) for different scenarios, we decreased the ambient concentration in each grid cell by the projection factor (or growth factor) and the ratio of the emission reductions anticipated from the proposed regulation to the estimated total emissions without the regulation for the pollutant of interest. We believe that this assumption of linearity between reduction in mass emission and reduction in ambient concentration is reasonable for direct PM and primary and secondary sulfate. However, we believe that this assumption is not appropriate for secondary nitrate since the fate of NOx is highly dependent on a number of factors including the concentration of other chemicals in the air and the environmental conditions during release and transport. Because of these uncertainties, and because the expected NOx reductions were about 5%, we did not estimate changes in the concentration of PM2.5 nitrate (or the associated health benefits) due to NOx reductions from the proposed regulation.

Assumptions and Limitations of Health Impacts Estimation: Several key assumptions were used in our estimation. They involve the selection and applicability of the concentration-response functions to California data, exposure estimation, subpopulation estimation, and baseline incidence rates. These are briefly described below.

- 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 was assumed to be exposed uniformly to modeled concentration. This assumption is typical of this type of estimation.

- 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.

- The uncertainty in the mortality estimates are on the order of $\pm$50 percent.

Value of Premature Deaths Avoided: The U.S. EPA has established $6.3 million (in 2000 $) for a 1990 income level as the mean value of avoiding one death (U.S. 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. ARB staff developed the valuation of avoiding various health effects, complied from ARB and U. S. EPA publications, updated to 2005 dollars (Table A-8, ARB, 2006). Based on the valuations, we calculated the cumulative health benefits (in 2005 dollars) resulting from avoiding premature deaths through this regulation from year 2009 to 2015 and projected to year 2008 to reflect current values.

Using these estimates, the total valuation of the avoided premature deaths (1650) due to directly emitted diesel PM emission reductions from the proposed rule is about $15 billion in 2008 dollars. For $PM_{2.5}$ sulfate emission reductions due to the proposed regulation the estimated total valuation of the avoided premature deaths in the SCAB is about $18 billion in 2008 dollars. Note that the values of certain non-mortality health effects, such as asthma attack, work loss day, and minor restricted activity day, are very small compared to the value of premature dearth. Mortality dominates the valuation of health effects. Because of this, we only estimated the valuation of the avoided premature deaths.

Conclusion: The health benefits of implementing the proposed OGV regulation are substantial. The estimated statewide benefit from reductions in directly emitted diesel PM from OGV over 2009 to 2014 is about $15 billion. The estimated health benefit from reductions in PM2.5 sulfate between 2009 and 2014 of reduced premature mortality is about $18 billion in the South Coast Air Basin. The total health benefits will be even greater since we have not considered the reductions in $PM_{2.5}$ sulfate in area outside of the SCAB. We also were not able to account for the heath benefits associated with reductions in $PM_{2.5}$ nitrate.

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

While we expect the regulation to have substantial benefits for air quality improvements and some potentially significant adverse impacts on GHG emissions, there may be other air quality effects that can result if ship operators decide to alter current practices.

Use of Alternative Overwater Routes to Avoid Regulatory Requirements

It is possible that some vessel operators may use longer alternative routes to minimize the amount of travel within “Regulated California Waters (RCW),” which is approximately 24 nautical miles (nm) offshore of the California coastline. This is because many vessel operators currently travel significant distances along California’s coastline within RCW, when alternative routes somewhat farther offshore (outside of the RCW) are possible. For example, cargo ships travelling to and from the Ports of Los Angeles and Long Beach (POLA/POLB) most often travel over 100 nm within RCW along the California coastline from Point Conception to the ports. Cargo ships traveling the 400 nm route between the POLA/POLB and the Port of Oakland also typically travel primarily within RCW. Cruise ships on the most common Mexico cruises typically travel roughly 100 nm within RCW from the ports to the overwater U.S./Mexico border.

In deciding whether to use alternative routes, ship operators will likely weigh the added fuel use and travel time associated with the longer alternative routes against the added cost of using the more expensive distillate fuels specified in the proposed regulation on existing routes. Ship operators will likely also consider company policies, safety, and other factors associated with alternative routes.

If vessel operators frequently choose alternative routes outside of RCW, there could be some potential environmental impacts. The existing shipping routes are primarily chosen to minimize the overwater distances, travel time and fuel use. If ship operators choose longer alternative routes, fuel use and associated emissions will increase. In addition, emissions will increase because the cleaner fuels will not be used outside of RCW. The associated emissions increase will be mitigated to some extent by the fact that the emissions are occurring farther offshore. However, for greenhouse gas emissions from the vessels, where the location of emissions is relatively unimportant, there would be a disbenefit.

Another potential impact is associated with U.S. Navy missile test ranges surrounding the Ports of Los Angeles and Long Beach (POLA/POLB). The Navy missile test ranges occupy vast overwater regions extending well offshore along the California coast from San Luis Obispo in the north, to San Diego and into international waters off the coast of Mexico in the south (U.S. Navy). This region is comprised of the Operating Area of Southern California Range Complex (SOCAL OPAREA), to the south of POLA/POLB, and the Point Mugu Sea Range, northwest of the POLA/POLB.

Although numerous vessels currently travel within these test ranges, the Navy has expressed concern that their weapons testing and training activities could be more difficult if there is a large increase in vessel traffic to routes that move outside the Channel Islands. Specifically, they said that most of their operations are conducted south and west of the Northern Channel Islands (San Miguel, Santa Rosa, Santa Cruz and Anacapa), and north and west of San Nicolas Island. The Navy has also said that such a route change could result in greater NOx emissions transported to California communities.

While some individual vessel operators may decide to change their existing routes, ARB staff does not expect that there will be a significant shift to alternative routes by the shipping lines. This potential existed during implementation of the Auxiliary Engine Regulation, and ARB staff did not see such a change when that regulation was in force for most of 2007. However, if the proposed regulation is adopted, ARB will monitor vessel traffic patterns. If there are significant shifts in vessel traffic to alternative routes that have significant environmental impacts, ARB will propose to the Board for its consideration modifications to the proposed regulation, including potential boundary changes, that will reduce the incentive for ship operators to use alternative routes. This should minimize or eliminate any possible adverse environmental impacts from this possibility.

Need for Additional Bunkering Tanks on Some Vessels

The regulation requires the use of marine distillate fuels. A vessel complying with the regulation will need more than one fuel tank if the vessel also operates on HFO. Most vessels already have multiple fuel tanks and are able to have multiple fuels on board. Historically, multiple fuel tanks were common. In those cases, one fuel tank generally was used to store distillate fuel that would be used for maneuvering and starting engines in the port.

In the event a vessel operator chooses to add an additional fuel tank to operate the vessel within RCW, it is possible, albeit unlikely, that the additional fuel tank will displace cargo space, resulting in additional vessel trips to deliver the same volume of cargo. We do not believe this is a likely scenario because the number of vessel operators indicating a desire to increase tankage represents only a very small fraction of the overall fleet.

In addition, the additional fuel tanks may require increased the fuel delivery to the ship increasing possibility of fuel spills. But we believe this is also an unlikely scenario, as refueling personnel can lower or minimize the possibility of fuel spills with training and following standard refueling operating procedures**.**

H. Reasonably Foreseeable Mitigation Measures

The ARB is required to do an analysis of reasonably foreseeable mitigation measures. Because staff identified a potentially significant adverse environmental impact on GHG emissions, an analysis of such measures is necessary.

As part of its climate change program, ARB is planning to develop programs to reduce GHG emissions from shipping operations in California; these programs are expected to more than offset whatever increase in CO2 emissions might occur under the proposed regulation. The ARB is required to develop a GHG Scoping Plan under AB 32 (Stats. 2006, ch. 488). The Scoping Plan[2], among other things, will identify strategies for reducing GHG emissions from various shipping-related sectors.[3] These include shore-power electrification for ships at berth[4], requirements for commercial harbor craft,[5] and vessel speed reduction measures. The shore-power measure alone will more than fully offset the potential 50,000 tons per year increase in GHG emissions under the proposal.[6]

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[2] AB 32 Scoping Plan is due to be proposed to the Board at its November 2008 hearing. Air Resources Board, *AB 32 Scoping Plan*, (visited June 3, 2008) <http://www.arb.ca.gov/cc/scopingplan/scopingplan.htm>.

[3] Air Resources Board, *Greenhouse Gas Sectors Portal*, (visited June 2, 2008) <http://www.arb.ca.gov/cc/ghgsectors/ghgsectors.htm>.

[4] Approved for adoption by the Board at the December 2007 hearing.

[5] Approved for adoption by the Board at the November 2007 hearing.

[6] The shore-power regulation is expected to reduce CO2 emissions from ships at berth in California by 122,000 to 242,000 metric tons by 2020. California Air Resource Board, *Regulations To Reduce*

Further, vessel speed reduction programs are currently being evaluated for possible control of CO_2 and NOx emissions. These programs have the potential to dramatically reduce fuel consumption and associated CO_2 emissions. For example, a ten percent reduction in speed can reduce CO_2 emissions by over 25 percent.

In addition, ARB is planning to develop "green ship" programs that will bring cleaner new and retrofitted vessels to California ports. Specifically, these programs would encourage ship operators frequenting California ports to reduce their GHG emissions and other pollutants through a variety of technologies and control strategies. Recent studies indicate that there are a number of technologies that can by used in new or existing vessels to reduce GHG emissions, including advanced heat recovery systems that capture main engine exhaust heat, new fuel injection systems, advanced hull and propeller designs, new hull coatings that reduce drag, and even wind assistive devices (Marintek, 2000).

Based on these reasons, we believe the reasonably foreseeable mitigation measures will more than offset the potential slight increase in GHG emissions that may result from the proposed regulation.

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

The ARB is required to do an analysis of reasonable foreseeable alternative means of compliance with the proposed regulation. Alternatives to the proposed control measure 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 emissions of diesel PM and other air pollutants emitted from main and auxiliary diesel engines and auxiliary boilers used on ocean-going vessels in Regulated California Waters.

J. Environmental Justice

The ARB is committed to evaluating community impacts of proposed regulations, including environmental justice concerns. As noted previously, many communities experience elevated exposures to toxic and criteria pollutants emitted from the regulated vessels. Because of this, it is a priority of ARB to ensure that full protection is afforded to all Californians. The proposed regulation is not expected to result in significant negative impacts in any community. Rather, the proposed regulation is designed to reduce emissions of diesel PM, PM, NOx and SOx from the regulated vessels, resulting in decreased exposures to these pollutants and lowering their associated potential health risks for all communities, particularly those located near the ports.

Emissions From Diesel Auxiliary Engines On Ocean-Going Vessels While At-Berth At A California Port, Staff Report: Initial Statement of Reasons for Proposed Rulemaking, (visited June 2, 2008) <http://www.arb.ca.gov/regact/2007/shorepwr07/isor.pdf>.

K. State Implementation Plan Impacts

As noted, the proposed regulation is expected to reduce emissions of diesel PM, PM, NOx, and SOx. Therefore, this regulation will contribute to progress toward compliance with the air quality standards for PM and ozone.

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VIII. ECONOMIC IMPACTS

In this chapter, we present the estimated costs and economic impacts associated with implementation of the proposed regulation to regulate the sulfur content of fuels used in main engines, auxiliary engines, and auxiliary boilers on ocean-going vessels that visit California (the “proposed regulation” or “proposal”). The estimated total annual costs are presented, as well as the cost-effectiveness of the proposed regulation. The economic impacts associated with the costs of the proposed regulation are also presented for typical businesses that operate ocean-going vessels.

This analysis is similar to the analysis conducted in 2005 for ARB’s Auxiliary Engine Regulation[1], except that the analysis now includes main engines and auxiliary boilers in addition to auxiliary engines. Although the proposed rule requirements are very similar, fuel costs have increased significantly since 2005, increasing the costs of proposed regulation. In addition, for the reasons discussed in detail below, we estimate that capital costs for ship modifications will not be significant.

Legal Requirements

In this section, we will discuss the 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 H&S section 43013(b) to adopt standards and regulations, consistent with H&S 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&S 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 nonvehicular by definition.[2] However, because the Legislature placed the authorization to regulate marine vessels in H&S 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.”

[1] Section 2299.1, title 13, California Code of Regulations (CCR) and section 93118, title 17, CCR.
[2] See H&S § 39039.

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 must include any non-discretionary cost or savings to local agencies and the cost or savings in federal funding to the State.

Finally, H&S 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 exceeds ten million dollars in a single year, although much of the cost will be borne by businesses based outside of California. Nevertheless, we conducted the required economic impact analysis of submitted alternatives to the proposal.

A. Summary of the Economic Impacts

Methodology

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

Under the proposed regulation, ocean-going vessel (or "vessel") operators would comply by using cleaner burning distillate marine fuels in the regulated engines and boilers. This requirement would apply when ships are within "Regulated California Waters," a zone that extends to approximately 24 nautical miles (nm) off the California coastline.

Since the majority of vessels currently use heavy fuel oil in their OGV engines and auxiliary boilers, most vessel operators will need to switch to the more expensive marine distillate fuel in California. We estimated the costs of implementing the proposed regulation from 2009 through 2014. This is because in 2015 there is a possibility that an Emission Control Area (ECA) can be established under the pending amendments to the International Maritime Organization (IMO) MARPOL Annex VI protocol for reducing emissions from ships. Such an ECA would likely require the use of 0.1% sulfur fuel off the California coastline (see Chapter V). If an ECA is established that achieves substantially equivalent benefits to the proposed regulation, ARB staff will propose terminating or modifying this regulation to the Board at that time.

For the period from 2009 through 2011, we estimated the added costs for vessel operators to switch from the most common grade of heavy fuel oil (IFO 380) to the most common grade of marine distillate fuel, marine gas oil (MGO). For the three year period from 2012 through 2014, we estimated the added costs for vessels to switch from IFO 380 to MGO limited to 0.1% sulfur. These periods correspond to the first and second tiers, respectively, of fuel sulfur restrictions in the proposed regulation.

Costs to Businesses

The added cost to businesses due to the higher cost of using distillate fuel will vary widely based on the amount of fuel they use in California. For example, a business that owns a single vessel that makes a single annual visit to a California port may incur an added cost of about $30,000, while an operator of a large fleet of vessels that make frequent California port visits may incur costs in the millions of dollars annually. On average, we estimate the annual additional fuel cost for a typical vessel operator at about $300,000 to $700,000 per company. For the entire ocean-going shipping fleet that visits California, we estimate an added annual fuel cost of about $140 million to $360 million. We estimate the total present value cost of the regulation for the entire fleet at about $1.5 billion, assuming a regulation life from July 1, 2009 to the end of 2014. As discussed in detail below, we do not expect that the proposed regulation will result in significant capital costs to ship operators.

Impacts on Government Agencies and Business Competitiveness, Employment, Creation, Elimination or Expansion

We do not expect significant economic impacts to the industry based on the added costs of the proposed regulation. While the added costs of the regulation are substantial, they are relatively small compared to the overall operating expenses of these vessels. In addition, based on an analysis of the change in "return on owner's equity" (ROE) for typical businesses, the added costs of the proposed regulation would result in about a 1.5 percent decline in ROE. Generally, a decline of more than 10 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 and government owned or operated vessels, used for government non-commercial purposes, are exempt from the proposed regulation.

Impacts on Individuals

We 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. Under a typical scenario, we estimate that the added cost of the proposed regulation would add about six dollars per shipping 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 $15 per passenger, representing about a 3 to 4 percent fare increase.

Cost-Effectiveness and Value of Health Benefits

Cost effectiveness is the total annual costs of the proposal (including annualized costs) divided by the annual emission reductions of a specified pollutant or pollutants. This figure is generally expressed in terms of dollars per unit mass of pollutant reduced. The ARB uses cost-effectiveness values to compare the relative efficiency of a proposed measure with other measures already adopted by the Board (i.e., to compare how much "bang for the buck" each measure gets).

The overall cost-effectiveness of the proposed regulation, considering only reductions in diesel PM, is estimated to be about $63,000 per ton of diesel PM reduced ($32 per pound of 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 would be about $31,000/ton ($16/pound) of diesel PM reduced. We estimate the cost-effectiveness of the combined NOx+SOx control at about $3,200/ton ($1.60/pound). The PM cost-effectiveness of the proposed regulation is similar to that of other regulations adopted by the Board to reduce diesel particulate matter.

The health benefits of implementing the proposed regulation are substantial. The estimated statewide benefit of reduced premature mortality is about $15.4 billion dollars for directly emitted PM only. This figure represents the present value of health benefits occurring from July 1, 2009 to the end of 2014.

B. Capital Costs

We do not expect that the proposed regulation will result in significant capital costs to ship operators. Ocean-going vessels already have the capability to store and use marine distillate fuels on board. Vessel operators need to use this fuel to operate their engines prior to going into dry-dock, to assist with engine emergencies, and to comply with environmental regulations and programs such as port-lease requirements and (until recently) California's Auxiliary Engine Regulation. Under the proposed regulation, they would simply be using the distillate fuels more frequently and for longer periods of time.

In the ARB surveys conducted in 2005 and 2007, most shipping lines reported that none of their vessels would need modifications to use distillate fuels. In addition, the world's largest shipping line, Maersk, has been voluntarily using low sulfur distillate fuels in California ports for over two years and has not needed to make modifications to their vessels. For the minority of shipping lines that have reported the need for modifications, we believe that most of these are either non-modifications (e.g., at least one company reported cleaning out a tank as a "modification") or nonessential changes made for more convenient fuel switching.

In addition, the proposed regulation includes an exemption for ships needing essential modifications, subject to verification by ARB. This provision would sunset in 2015, when equivalent IMO regulations are expected to be implemented. A more detailed discussion of why we do not believe the proposal will result in significant capital costs for main engines, auxiliary engines, and auxiliary boilers is presented below.

Main Engines

The ARB 2007 Vessel Survey (ARB 2007a) was designed to collect information necessary to estimate the number of vessels requiring main engine modifications to use distillate fuel. In the Survey, we requested that the shipping lines identify whether their vessels would require modifications to use marine distillate fuel, and the nature and cost of the changes. The Survey requested information assuming the use of marine distillate fuel extended 24 nautical miles (nm), 50 nm, and 100 nm offshore. However, we only considered the information for the 24nm case here, because that is what is being proposed in the regulation.

Table VIII-1 below provides a summary of the survey responses regarding ships reported to need modifications. Individual company names are not provided because much of the survey data was designated as confidential. As shown in the table, 154 out of the 178 companies (87 percent) reported that none of their vessels visiting California would need modifications. In terms of the number of vessels, 168 out of 761 vessels (22 percent) were reported to need modifications to use distillate fuel. However, just two companies accounted for more than half of the vessels reported to need modifications.

ARB staff made several attempts to contact these companies to verify their survey data. One company reporting 57 ship modifications did not respond to our inquiries. The other company reporting 33 ship modifications did not provide information in the survey on the cost or nature of the modifications, and follow-up contacts with the company provided little additional information. Based on these results, we cannot assign much weight to the survey responses from these companies. We therefore believe that the overall survey data significantly overestimates the need for ship modifications.

Table VIII-1: Summary of Reported Ship Modifications by Company

Number of Companies	Ships Reported to Need Modifications
154	0
9	1
4	2
2	3
2	4
1	6
1	8
1	9
1	10
1	14
1	33
1	57
178	168

Nevertheless, even assuming all the information provided in the Survey is accurate, we estimated that the capital costs would not significantly alter the overall cost analysis. This is because the added fuel costs represent a much larger percentage of the overall cost of the proposal. Specifically, if we apply the (uncorrected) 22 percent of ships reported to need modifications from the Survey to the total number of vessels visiting California, and use the average cost of modifications reported in the survey, the resulting capital costs would total roughly $150 million in 2008 dollars. This represents about 10 percent of the present value cost of the proposed regulation ($1.5 billion) over a six year timeframe from 2009 to 2014, as described later in this chapter.

In addition, Maersk, the world's largest shipping line, has reported that no capital investments were necessary to implement their voluntary Pilot Program to use marine distillate fuel in the main engines of their vessels that visit California. The Maersk Pilot Program has included 105 different vessels and 438 successful fuel switches as of October 2007 (Maersk, 2007). Chapter VI provides a detailed discussion of this program.

Auxiliary Engines

For several reasons, we do not expect the proposed regulation to result in significant capital costs for auxiliary engines. Since the ARB's ship auxiliary engine regulation was in place for over a year, the vessels that regularly visit California would have already made modifications, if needed. In addition, many ship operators will be preparing to use distillate fuels in their auxiliary engines for other environmental regulations, including the European Union Directive 2005/33/EC, which requires ships to use 0.1% sulfur fuel at dockside in 2010. Ship operators have also been under pressure to make whatever changes are needed to use low sulfur distillate fuels because of the pending amendments to IMO's MARPOL Annex VI and U.S. EPA's marine diesel engine standards (i.e., auxiliary engines on new U.S.-flagged vessels will need to be equipped to use distillate fuel at all times to meet U.S. EPA marine diesel engine emission standards).

In addition, ARB's ship surveys indicated that very few vessels would need modifications to use distillate fuel in auxiliary engines. ARB staff conducted a ship survey in 2005 (ARB, 2005a) that asked respondents whether fuel system modifications would be needed to use distillate fuel in their auxiliary engines. According to the survey, less than 10 percent of vessels were reported to need modifications. However, in ARB's retrospective follow-up 2007 Vessel Survey (ARB, 2007a), respondents were asked whether they actually made ship modifications to comply with the ship auxiliary engine rule, which was in place at the time.

Based on the 2007 follow up survey, only about six percent of vessels were reported to have been modified. Even though this is already a low percentage of the fleet, we believe this result still overestimates the actual number of vessels that need modifications to comply with the regulation. To illustrate, when we further questioned some respondents who initially reported needing modifications, they described their modifications as simply *using* distillate fuel. We are uncertain of the exact number of respondents who reported modifications that were clearly not modifications. However, it is clear that the survey may have overestimated the number of modifications actually made. The 2007 survey also indicated that modifications were less expensive than anticipated, averaging $50,000 per vessel (instead of $100,000 previously estimated for cargo vessel).

In addition, even if we assume as accurate the high rate of modifications reported from the 2005 survey, the capital costs would not significantly alter the overall cost analysis. Similar to the discussion for main engines above, this is because the added fuel costs represent a much larger percentage of the overall cost of the proposal. In the 2005 cost analysis performed for the auxiliary engine rule implemented in 2007 (using the higher costs and rate of modifications from the 2005 survey), the estimated capital costs ($10.5 to 17.1 million) were only about 10 percent of the added fuel costs ($154 million) even with the lower fuel cost estimates used in that earlier analysis.

<u>Auxiliary Boilers</u>

Based on discussions with ship operators and boiler manufacturers, we do not expect the proposed regulation to result in significant capital costs associated with auxiliary boilers. First, the large boilers used to propel steamships are not covered by the proposal. The smaller auxiliary boilers used on cargo ships can already use distillate fuel (Aalborg Industries, 2007a and 2007b; Crystal Cruises, 2007; Matson, 2007).

Tankers, which represent about 20 percent of the unique vessels visiting California, are a special case because their auxiliary boilers are larger than those on other vessels, and there are unique safety considerations on tankers. Tanker operators have reported that they will evaluate their auxiliary boilers to ensure that they are prepared to use distillate fuel for longer periods of time (BP, 2007; Chevron, 2007). It is possible that some tanker operators may ultimately decide to modify their auxiliary boilers (e.g., to update burners or control systems). However, the capital costs associated with these potential modifications are not expected to be significant relative to the added fuel costs of the regulation. Assuming that half of the tankers visiting California (~225) made modifications costing $100,000 per vessel, the resulting $22.5 million capital cost would represent about 1.5 percent of the present value total cost of the proposed regulation ($1.5 billion), as described later in this chapter.

C. Recurring Costs

The recurring (on-going) costs associated with the proposed regulation are due to the higher incremental cost of using marine distillate fuel in California. We calculated these costs based on the difference between: (1) the current estimated fuel consumption and the price of the most common grade of heavy fuel oil (IFO 380); and (2) the estimated fuel consumption and price of the cleaner marine distillate fuels specified in the regulation. For years 2009-2011, we used the price differential between HFO and standard marine gas oil (MGO). For 2012 through 2014, we used the price differential between HFO and 0.1% sulfur marine gas oil (MGO), as specified in the proposed regulation. We did not attempt to forecast fuel price increases over the six years covered by this analysis given the highly volatile and unpredictable nature of petroleum prices. Our assumptions for fuel consumption rates and the price differential between MGO and HFO are described below.

Fuel Consumption Estimates

The estimated fuel consumption within the 24 nautical mile boundary is based on the ARB's Emissions Inventory, which is discussed in Appendix D. The estimate is based on: (1) the estimated energy consumed by vessels within 24 nm using vessel specific information and shipping lane distances within the 24 nm boundary; (2) the appropriate brake specific fuel consumption figures for medium-speed, four-stroke auxiliary engines and slow-speed, two-stroke main engines; and (4) estimated average auxiliary boiler fuel consumption by vessel type. This analysis also accounts for the impact of the voluntary vessel speed reduction program at the Ports of Los Angeles and Long Beach, which has a definite effect on fuel consumption and will continue to do so as long as that program is in effect.

For the pre-regulation base case, we assume that all fuel used by main engines and auxiliary boilers is heavy fuel oil. This is based on the ARB's 2007 Ship Survey, which indicates that over 90 percent of main engines operate on heavy fuel oil. For auxiliary engines under the base case without the proposed regulation, we assume that about 78 percent of the fuel used is heavy fuel oil (72 percent by cargo vessels and 92 percent by cruise ships) based on the ARB's 2005 Ship Survey (ARB, 2005a). We recognize that many shipping lines may be voluntarily using distillate fuel subsequent to the court injunction preventing ARB from enforcing the previous auxiliary engine rule. However, we cannot estimate the extent of this voluntary compliance.

As shown in Tables VIII-2 and VIII-3, based on these assumptions, we estimate the total annual fuel consumption in California is roughly 2600 to 3000 tons per day (about 860,000 to 980,000 tonnes[3] per year) from 2009 to 2014. To estimate the fuel consumption after implementation of the marine distillate fuel standards specified in the proposed regulation, we reduced the estimated fuel consumption figures for heavy fuel oil by five percent due to the higher energy content of marine distillate fuels on a weight basis (Entec, 2002). As shown in Tables VIII-2 and VIII-3, based on the use of marine distillate fuel (MGO), we estimate the total fuel consumption in California ranges from about 2500 to 2800 tons per day (840,000 to 930,000 tonnes per year).

Table VIII- 2: Fuel Use Estimates (Tons per Day)[1]

Fuel Use Scenario	2009	2010	2011	2012	2013	2014
Base Case w/o proposal[1]						
Main Engine HFO	1408	1463	1522	1583	1648	1717
Auxiliary Boiler HFO	490	502	515	528	543	558
Auxiliary Engine HFO	545	545	543	539	533	524
Auxiliary Engine MGO	154	154	153	152	150	148
Total Base Case HFO	2443	2510	2580	2650	2724	2799
Total Base Case MGO	154	154	153	152	150	148
Regulated Case[2] (All MGO/MDO)						
Main Engine	1373	1390	1446	1504	1566	1631
Auxiliary Boiler	478	477	489	502	516	530
Auxiliary Engine	685	671	669	664	656	646
Total Regulated	2536	2538	2604	2670	2738	2807

1. Base case includes ARB shore-side power regulation. Main engine and auxiliary boiler fuel use assumed to be 100% HFO. Auxiliary engine fuel use assumed to be 78% HFO, 22% distillate.
2. Regulated case includes shore-side power regulation and proposed regulation implemented starting July 1, 2009.

[3] 1 tonne = 1 metric ton

Table VIII- 3: Fuel Use Estimates (Tons per Year)

Emissions Scenario	2009	2010	2011	2012	2013	2014
Base Case[1] HFO	811,200	833,400	856,700	879,900	904,500	929,400
Base Case[1] MGO	51,100	51,100	50,900	50,500	49,900	49,100
Regulated Case[2] (MGO/MDO)	842,100	842,700	864,600	886,600	909,100	932,000

1. Base case includes ARB shore-side power regulation. Main engine and auxiliary boiler fuel use assumed to be 100% HFO. Auxiliary engine fuel use assumed to be 78% HFO, 22% distillate.
2. Regulated case includes shore-side power regulation and proposed regulation starting July 1, 2009.

Table VIII-4 provides a breakdown of the fuel use by vessel type for a representative year (2010). As shown, container ships are estimated to account for over half of the fuel consumed in California, followed by tankers and cruise ships.

Table VIII-4: 2010 Estimated Fuel Use by Vessel Type

Vessel Type	OGV Fuel Use (tons/day)	Percentage of Total Fuel Use
Auto Carrier	91	3.6%
Bulk	96	3.8%
Container	1396	55%
Cruise	220	8.7%
General	42	1.1%
Reefer	36	1.4%
RORO	10	0.4%
Tanker	648	25.5%
Total	2539	100%

Price Premium for Marine Distillate Fuel Compared to Heavy Fuel Oil

To determine the estimated price differential between heavy fuel oil and marine distillate fuels complying with the proposed regulation, we estimated the cost of the most common grade of heavy fuel oil, IFO-380, and the most common grade of marine distillate fuel, marine gas oil. Prices were averaged over seven months, October, 2007 through April, 2008, at five major bunkering ports: Singapore, Rotterdam, Fujairah, Busan, and Los Angeles (Bunkerworld, 2008b). The ports of Singapore, Rotterdam, and Fujairah were chosen because they are the world's largest bunkering ports by volume (Bunkerworld, 2008a). Busan and Los Angeles were chosen because they are major Pacific Rim bunkering ports for ships visiting California. As shown in Table VIII-5 below, the average price differential between IFO-380 and MGO was about $373 per metric ton (tonne). 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 less volatile than prices overall.

Table VIII-5: Marine Fuel Prices ($/tonne)*

Fuel	Los Angeles*	Busan	Singapore	Fujairah	Rotterdam	Average
MGO	891.57	860.36	839.71	845.00	850.50	857.43
IFO-380	494.93	513.07	478.50	482.29	453.50	484.46
Difference	396.64	347.29	361.21	362.71	397.00	372.97

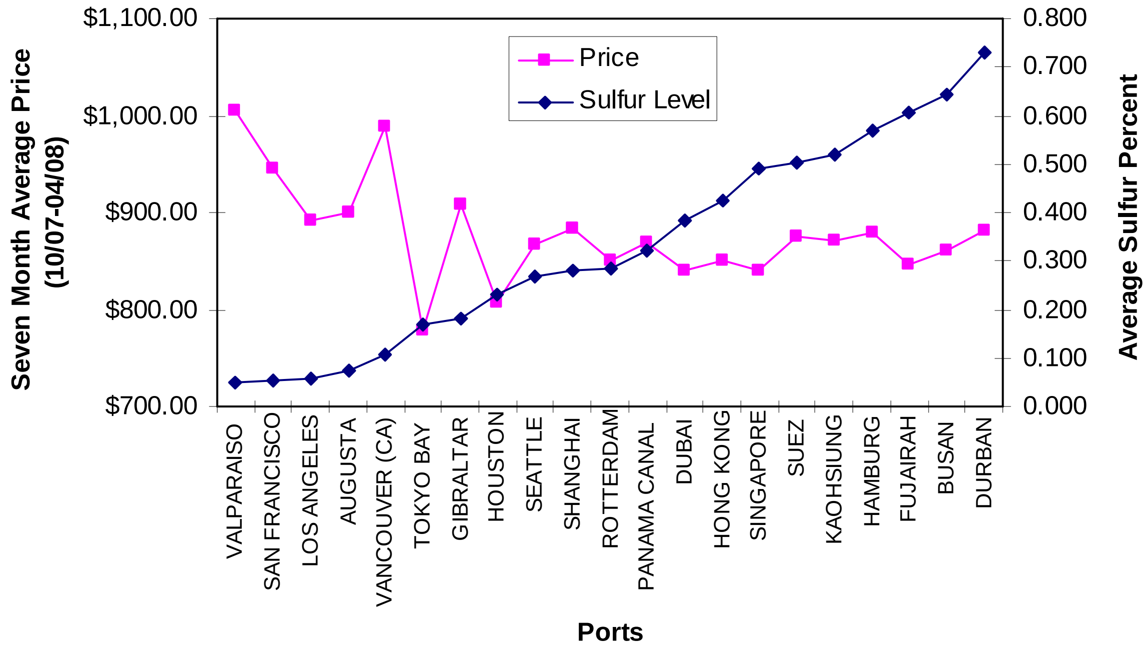
* Bunkerworld, 2008. Prices averaged from seven monthly reports from October, 2007 through April, 2008. Los Angeles marine distillate fuel is listed as MDO by Bunkerworld, but it is actually a mix of both MGO and MDO, with the majority of fuel expected to be MGO (Bunkerworld, 2008c).

Price Premium for 0.1% Sulfur Marine Distillate Fuel

To estimate the cost differential between standard marine gas oil and 0.1% marine distillate fuel (specified in the proposed regulation in 2012), we relied, in part, on existing estimates in the literature. A report prepared for the European Union (Beicip-Franlab, 2002) estimated the price premium for 0.1% sulfur marine gas oil compared to standard marine gas oil with no sulfur limit at 14-21 €/metric ton, or about $22 to $33/metric ton, using a current exchange rate of 0.63 Euros per U.S. dollar. While this information is dated, a more recent report prepared for the European Commission (IIASA, 2007) estimated the price premium for 0.1% sulfur fuel over 0.2% sulfur fuel at an extra 20 €/metric ton (~ $32/metric ton). However, this figure may underestimate the current premium between 0.1% sulfur and standard marine gas oil because it compares 0.1% sulfur fuel to 0.2% sulfur fuel rather than to standard marine gas oil.

Given that the information from the literature cited above is not definitive, we also examined the current price difference between ports selling high and low sulfur fuel. In particular, we wanted to examine the price of marine distillate fuels from ports where the average fuel is below 0.1% sulfur. To do this, we examined the average price from Bunkerworld.com over the same seven month period used in Table VIII-5 (from October, 2007 through April, 2008) and the average sulfur content from 2007 fuel testing performed by Det Norske Veritas Petroleum Services at 21 ports worldwide with a range in average sulfur content. As shown in Figure VIII-1 below, we did see a trend toward higher prices at ports offering lower sulfur fuel.

Figure VIII-1: Price vs. Distillate Fuel Sulfur Content at Selected Ports



Specifically, we found that the average price ($946/tonne) at the five ports selling low sulfur marine distillate fuel at or below 0.1% sulfur (Valparaiso, San Francisco, Los Angeles, Augusta, and Vancouver) was about $89 per tonne higher than the price ($857/tonne) at the16 ports selling fuel that averaged above 0.1% sulfur. This analysis does not necessarily indicate that there will be a premium on the order of $89 to purchase 0.1% sulfur fuel. For the ports that already sell marine distillate fuel that averages below 0.1% sulfur there may be little price premium. However, it does indicate that the lower sulfur fuel commands a higher price.

Considering the above information from the literature and our price versus sulfur content data, we assumed a $60 price premium for 0.1% sulfur fuel above standard marine distillate. This represents a midpoint between the low-end $32/tonne price premium based on the recent IIASA report mentioned above, and the upper-end $89/tonne figure cited above.

Table VIII-6 summarizes the estimated price premium we used for the cleaner fuels specified in the proposed regulation.

Table VIII-6: Estimated Fuel Price Differential Due to Proposed Regulation

Year	Fuel Change	HFO Price ($/tonne)	Distillate Fuel Price ($/tonne)	Price Premium ($/tonne)
2009 to 2011	IFO-380 to Standard MGO	484	857	+373
2012 to 2014	IFO-380 to 0.1% Sulfur MGO	484	917	+433

*Reflects data from Table VIII-5 above, and an estimated $60 premium for 0.1% sulfur MGO compared to standard MGO with no sulfur limit. A "tonne" equals a metric ton, or 2200 pounds.

Total Recurring (Fuel) Costs

The total annual recurring costs for 2009-2014 are provided in Table VIII-8. These estimates are based on the difference between the estimated fuel cost using primarily HFO (no regulation base case as shown in Table VIII-7) and the estimated fuel cost using the specified complying marine distillate fuels. The fuel consumption estimates are for the use of main engines, auxiliary engines, and auxiliary boilers, within 24 nm of the California Coastline, as specified in Tables VIII-2 and VIII-3. The fuel consumption figures for marine distillate fuel, as shown in Table VIII-8, are lower than those for HFO due to the higher energy content of marine distillate fuel on a mass basis. As shown in Table VIII-8, the added annual fuel costs are estimated to range from about $143 to $363 million, depending on the year.

Table VIII-7: Estimated Fuel Costs Without Proposed Regulation

Year	Total Estimated HFO Use (tonne/yr)	Total Estimated MGO Use (tonne/yr)	Estimated MGO Price ($/tonne)	Estimated HFO Price ($/tonne)	Total Estimated HFO Cost (millions)	Total MGO Cost (millions)	Total Fuel Cost (millions)
2009*	405,600	25,550	$857	$484	$196.3	$21.9	$218.2
2010	833,400	51,100	$857	$484	$403.4	$43.8	$447.2
2011	856,700	50,900	$857	$484	$414.6	$43.6	$458.2
2012	879,900	50,500	$857	$484	$425.9	$43.3	$469.2
2013	904,500	49,900	$857	$484	$437.8	$42.8	$480.6
2014	929,400	49,100	$857	$484	$449.8	$42.1	$491.9

*Covers half year starting July 1, 2009

Table VIII-8: Estimated Added Fuel Costs With Proposed Regulation

Year	Total Est. Distillate Use (tonne/year)	MGO Price ($/tonne)	Total Cost with Rule (millions)	Total Cost w/o Rule (millions)	Total Added Fuel Cost (millions)
2009*	421,100	$857	$360.8	$218.2	$142.6
2010	842,700	$857	$722.2	$447.2	$275.0
2011	864,600	$857	$741.0	$458.2	$282.8
2012	886,600	$917	$813.0	$469.2	$343.8
2013	909,100	$917	$833.6	$480.6	$353.0
2014	932,000	$917	$854.6	$491.9	$362.7

*Regulation would apply for a half year starting July 1, 2009

D. Total Industry Cost and Total Annual Cost

Total Industry Cost

We estimate the total statewide cost of the proposed regulation over the six year period from July 1, 2009 to the end of 2014 to be about $1.5 billion dollars. This estimated cost was derived from the present value of recurring (added fuel) costs shown in Table VIII-8 (see Appendix G).

Total Annual Cost

The total annual cost of the proposed regulation is the same as the add fuel costs shown in Table VIII-8 because we estimate no significant capital costs. In 2009, the cost is lower because the proposed regulation is implemented mid year in July. In 2012 and later years, the annual cost is higher due to the requirement to use 0.1% sulfur fuel.

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.

Capital costs

Although we do not expect that the proposed regulation will result in significant capital costs, there will probably be some capital costs undertaken in response to the regulation. Nevertheless, even if we use upper-end estimates for these costs, as discussed in section B above, we would estimate that they would not increase the overall cost of the proposal by more than ten percent.

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 and boilers due to a reduction in deposit formation (Croner, 2002; Matson, 2007). 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. However, it is likely that at least some of this effect can be offset by the use of stronger pipe joints that are better suited to distillate fuels.

Crew time for fuel switching and recordkeeping

The proposed regulation would require vessel crews to perform fuel switches and keep certain records. For example, in a typical vessel visit to California, the crew would need to switch the OGV engines and auxiliary boilers from heavy fuel oil to complying distillate fuel upon entrance into Regulated California Waters, and then back again when exiting California. The crew time involved in the fuel switching operations would vary with the vessel. Some vessels have equipment to automate this process, requiring little crew time, while others use a manual process, requiring more crew time. While these activities will require additional crew time, we expect that in most cases these activities can be performed with existing crews.

Regarding recordkeeping, 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; (2) fuel purchases, and the types of fuels used within the 24 nm boundary; and (3) documentation of fuel switchover procedures. The recording of fuel purchases and fuel use is already performed in accordance with standard practices as well as other regulations and Vessel Classification Society requirements. We also expect that documentation of the fuel switchover procedures would already be available on the vessel. 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. The proposed regulation does not require periodic reporting of records. Reporting is only required upon request.

Fueling costs

The proposed regulation may result in more frequent refueling because some vessels 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.

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; and
- power generated by engines, and thus fuel consumed.

For example, a business that owns a typical vessel that makes a single annual visit to a California port visit may incur an added fuel cost of about $30,000 dollars. On the other hand, a large vessel operator with several vessels making frequent California port visits would incur added fuel costs in the millions of dollars annually.

Table VIII-9 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 smaller number of large operators would incur costs in the millions of dollars annually. The average added fuel costs for travel in the 24 nm boundary associated with a California port visit (~$30,000/visit) was approximated by dividing the total annual industry recurring cost from Table VIII-8 ($275-363 million dollars, not counting 2009 with half year implementation) by the roughly 11,000 port visits to California ports.

Table VIII-9: Estimated Average Added Annual Fuel Cost to Vessel Operators*

Number of Companies	Number of California Port Calls	Estimated Added Fuel Cost @ $30,000 per Call
1	600-699	$18 to 21 million
1	500-599	$15 to 18 million
3	400-499	$12 to 15 million
3	300-399	$9 to 12 million
7	200-299	$6 to 9 million
10	100-199	$3 to 6 million
24	50-99	$1.5 to 3 million
71	10-49	$300,000 to1,470,000
70	5-9	$150,000 to 270,000
32	4	$120,000
55	3	$90,000
87	2	$60,000
160	1	$30,000
524 Total	~11,000 Total	--

* Company and port visit information based on 2006 California State Lands Commission data.

We do not believe that the vessel operators subject to this proposed regulation 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 recurring (fuel) costs to typical businesses are discussed below. The cost is based on the ongoing higher cost of marine distillate fuels that would be required by the proposed regulation. However, it should be noted that the total cost to a particular company will vary directly with the amount of fuel consumed by the company’s vessels operated in California, as shown in Table VIII-9 above.

Recurring (Fuel) Costs to Typical Businesses

The recurring cost for a typical business is presented below. To determine the average annual recurring cost for a typical business, we divided the total annual recurring cost of the proposed regulation for all vessels by the number of shipping companies that operated ocean-going vessels in California in 2006, as reported by the California State

Lands Commission (CSLC, 2007). Specifically, we divided the total annual recurring cost of $142 to $363 million for years 2009-20014 as shown in Table VIII-8, by the approximately 524 ship companies reported by the California State Lands Commission. This resulted in an average added annual fuel cost per company of about $272,000 to $692,000.

Table VIII-10: Estimated Average Added Annual Fuel Costs per Company

Year	Annual Fuel Cost (millions)	Number of Operators	Average Annual Fuel Cost Per Company
2009*	$142.6	524	$272,100
2010	$275.0	524	$524,800
2011	$282.8	524	$539,700
2012	$343.8	524	$656,100
2013	$353.0	524	$673,700
2014	$362.7	524	$692,200

* Regulation would apply for a half year starting July 1, 2009

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 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 2005 to 2007 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-11 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-11: ROE Analysis of Businesses

SIC Code	Description of SIC Code	Percent Change in ROE
4412	Deep Sea Foreign Transportation of Freight	-0.24
4424	Deep Sea Domestic Transportation of Freight	-3.86
4481	Deep Sea Passenger Transportation	-0.30
Average		-1.47

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, as discussed above, a typical vessel would be expected to incur added costs of about $30,000 per California port visit**.** 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 (Mercator, 2005). The $30,000 added cost represents about six dollars extra per shipping container for a 5,000 TEU (transport equivalent unit) vessel. This extra cost per TEU represents roughly one percent of the total trans-Pacific using a total oversea cost on the order of $500 per TEU, as estimated by Mercator. (*Ibid*) However, fuel costs and other fees have risen significantly since the Mercator report. Using a current cost estimate provided by a major shipping line, $2,200 to transport a 40 foot shipping container from Hong Kong to Los Angeles, the added six dollars per TEU would represent about a half percent of the voyage cost.

For a typical cruise ship, the added cost of the regulation would also be roughly $30,000 per California port visit. For a ship that carries about 2,000 passengers (Carnival, 2008), the added cost would be about $15 per passenger. For a relatively low cost 3 or 4 day Mexico cruise, about $400-500 (*Ibid*), a three to four percent increase in fare would be needed to offset the increased fuel cost.

Because the added costs of the proposed regulation are such as 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 2012, when the 0.1% sulfur fuel requirement becomes effective. This is because California is expected to have 0.1% sulfur fuel available, whereas some ports worldwide may not.

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 transport their goods overseas. Second, other vessel operators find that the overall cost of transporting goods to their final destination beyond California is lowest by using California ports because of the ports' existing and well established infrastructure, including road and rail access. Third, in some cases, vessel operators would have to factor in the added costs of fuel and other costs of traveling greater distances to non-California ports, 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. For 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 that the proposed regulation will result in a positive impact on business creation due to additional sales of marine fuels in California beginning in 2012, when the 0.1% sulfur fuel requirement becomes. This is because we expect to have 0.1% sulfur fuel available in California at that time, whereas some ports worldwide may not.

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 H 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. Government owned or operated vessels are exempted from the regulation. In addition, ARB staff was already enforcing the previous auxiliary engine rule with existing resources. However, additional resources will be needed as the implementation of this and other port-related measures occur, and the industry grows.

Federal Agencies

We are not aware of any impacts on federal agencies. Military and government 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 NOx and SOx.

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

The estimated cost-effectiveness of the proposed regulation is shown in Table VIII-12 below. The cost-effectiveness is expressed in terms of dollars per ton of NOx, diesel PM, and SOx removed, with the total annual cost attributed to each pollutant individually. As shown, the average cost effectiveness is estimated at about $63,000 per ton of PM reduced, $84,000 per ton of NOx reduced, and about $7,000 per ton of SOx reduced. The cost-effectiveness values in 2012 are slightly higher due to the higher cost of the 0.1% sulfur fuel.

Table VIII-12: Cost-Effectiveness of the Proposed Regulation (Attributes All Costs to Each Pollutant Individually)

Year	Total Annual Cost ($ millions)	Emission Reductions* (tons per year)			Cost-Effectiveness ($/ton)		
		NOx	PM	SOx	NOx	PM	SOx
2009	$142.6	1,498	2,192	19,285	95,200	65,100	7,400
2010	$275.0	3,689	4,566	39,703	74,500	60,200	6,900
2011	$282.8	3,799	4,712	40,835	74,400	60,000	6,900
2012	$343.8	3,908	5,406	49,418	88,000	63,600	7,000
2013	$353.0	4,054	5,552	50,806	87,100	63,600	7,000
2014	$362.7	4,164	5,734	52,267	87100	63,300	6,900
Average Cost Effectiveness					84,400	62,600	7,000

* The emission reductions are based on the ARB Marine Emissions Model Version 2.1, updated May 22, 2008.

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

In Table VIII-13 below, we calculate the cost-effectiveness by attributing half of the costs of the proposed regulation to 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. As shown, the average cost-effectiveness is estimated at about $31,300 per ton of PM reduced, and about $3,200 per ton of combined NOx and SOx emissions reduced.

Table VIII-13: Cost-Effectiveness of the Proposed Regulation (Attributes Half of the Costs to PM and Half to NOx+SOx)

Year	Half of Total Annual Cost (millions)	Emission Reductions* (tons per year)		Cost-Effectiveness ($/ton)	
		PM	NOx+SOx	PM	NOx+SOx
2009	$71.3	2,192	20,783	32,500	3,400
2010	$137.5	4,566	43,392	30,100	3,200
2011	$141.4	4,712	44,634	30,000	3,200
2012	$171.9	5,406	53,326	31,800	3,200
2013	$176.5	5,552	54,860	31,800	3,200
2014	$181.4	5,734	56,431	31,600	3,200
Average Cost Effectiveness				31,300	3,200

* The emission reductions are based on the ARB's 2008 Emissions Inventory.

As shown in Table VIII-14 below, the cost-effectiveness values of the proposed regulation for PM (as calculated in Table VIII-13) are similar to other regulations recently adopted by the Board. For comparison purposes, all cost-effectiveness estimates shown attribute half of the regulation costs to PM and half to NOx or other pollutants, except for the In-Use Off-road Diesel Vehicle Rule, as noted.

Table VIII-14: PM Cost-Effectiveness of the Proposal and Other Diesel Regulations (Attributes Half of All Costs to PM)

Regulation or Airborne Toxic Control Measure	PM Cost-Effectiveness		Source of Estimate
	Dollars/Ton	Dollars/pound	
Public Fleets Rule	$320,000	$160	ARB, 2005b
In-Use Off-road Diesel Vehicle Rule[1]	$80,000	$40	ARB, 2007b
Solid Waste Collection Vehicle Rule	$64,000	$32	ARB, 2003a
Cargo Handling ATCM	$42,000	$21	ARB, 2005c
Ship Main/Aux/Boiler Proposal (2008)	**$31,300**	**$16**	**Staff Report**
Ship Auxiliary Engine Regulation (2005)	$26,000	$13	ARB, 2005a
Stationary Diesel Engine ATCM	$15,400	$7.70	ARB,2003b

1. Attributes all regulation costs associated with diesel emission controls to PM and splits other regulation costs equally between PM and NOx.

L. Analysis of Alternatives

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

Alternative 1: Implement the Regulation as Proposed Except Without the Lower 0.1% Sulfur Limit in 2012

Under this alternative, ocean-going vessels visiting California ports would be required to use the marine distillate fuels specified in the regulation for 2009-2011, but would not be required to meet the more stringent 0.1% sulfur limit in 2012. Instead, it would be anticipated that by 2015, an Emission Control Area could be established under pending amendments to IMO Regulations that would require the use of 0.1% sulfur fuel or equivalent emission controls. As summarized in Table VIII-15, there would about 600 fewer tons PM reduced annually under the proposed alternative from 2012 to 2014. This alternative would also reduce cost by over $50 million annually. Overall, the cost effectiveness of the proposed alternative is slightly lower than the original proposal. However, given the significant health impacts associated with PM, we recommend the proposed regulation.

Table VIII-15: Comparison of Annual Costs and PM Emission Reductions Between Alternative #1 and the Proposed Regulation

	Estimated Cost ($ millions)			**Estimated Reductions (tons/yr)**			**Cost-Effectiveness ($/ton)**	
Year	Alt. #1	Proposal	Savings	Alt. #1	Proposal	Loss	Alt. #1	Proposal
2012	$290.6	$343.8	$53.2	4,821	5,406	585	60,300	63,600
2013	$298.5	$353.0	$54.5	4,967	5,552	585	60,100	63,600
2014	$306.8	$362.7	$55.9	5,114	5,734	620	60,000	63,300

Alternative 2: Implement the Regulation Within 24 nm of California's Major Ports Rather than within 24 nm of the California Coastline

Under this alternative, ocean-going vessels visiting California ports would be required to use the marine distillate fuels specified in the proposed regulation only within 24 nautical miles of major ports, rather than along the entire coastline. This would reduce the transiting emission reductions by about 70 percent, while having little impact on the reductions that would be achieved from maneuvering and hotelling. Overall, the PM emissions subject to the proposed regulation would be reduced by about 53 percent. This alternative would retain emission reductions near California's major population centers, which are generally located near California's major ports, but would substantially decrease the emissions reduced in other coastal areas. This could be of particular concern to California coastal counties such as Santa Barbara, Ventura, and San Luis Obispo, which are impacted by ship emissions due to a major shipping line that traverses relatively close to their shorelines.

As summarized in Table VIII-16, with alternative #2, there would about 2,400 less tons PM reduced in year 2010 (a representative year), and an estimated $146 million cost reduction. Overall, the cost-effectiveness of the proposed alternative would remain the same because the reduction in costs and emission reductions are both reduced by the same percentage. Although this alternative would reduce costs and target emission reductions near population centers, the proposal would not achieve emission reductions in other coastal areas. In addition, pollutants from ships can be transported long distances, reaching sensitive areas. For these reasons, we recommend the proposed regulation.

Table VIII-16: Comparison of Annual Costs and PM Emission Reductions Between Alternative #2 and the Proposed Regulation for 2010

Estimated Cost ($ millions)			**Estimated Reductions (tons/yr)**			**Cost-Effectiveness ($/ton)**	
Alt. #2	Proposal	Savings	Alt. #2	Proposal	Loss	Alt. #2	Proposal
$129.3	$275	$146	2,146	4,566	2,420	60,200	60,200

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