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ACRONYMS AND ABBREVIATIONS

°C  degrees Celsius
°F  degrees Fahrenheit
AN  Acid Number
ARB  (California) Air Resources Board
ASTM American Society for Testing and Materials
BN  Base Number
CARB California Air Resources Board
CCR California Code of Regulations
CE  cost effectiveness
CIMAC International Council on Combustion Engines
CFR Code of Federal Regulations
CO₂ carbon dioxide
CPC Chinese Petroleum Corporation
CRC China Resources Petroleum and Chemical Company
DMA marine fuel A, sulfur content maximum 1.5%, m/m
DMB marine fuel B, sulfur content maximum 2.0%, m/m
DMC marine fuel C, sulfur content maximum 2.0%, m/m
DMX marine fuel X, sulfur content maximum 1.0%, m/m
DNV Det Norske Veritas
DNV PS DNV Petroleum Services
EC European Commission
EIA (United States) Energy Information Administration
EPA (United States) Environmental Protection Agency
EU European Union
FPC Formosa Petrochemical Company
FR Federal Register
HDS hydrosulphurization
HMM Hyundai Merchant Marine
hp horsepower
IBIA International Bunker Industry Association
IEA International Energy Agency
IFO intermediate fuel oil
IMO International Maritime Organization
ISO International Organization for Standardization
g/kW-hr grams per kilowatt-hour
kW kilowatt
JECE Japan Petroleum Energy Center
JIS Japanese Industrial Standard
LA Los Angeles
lbs pounds
LPG liquefied petroleum gas
LS low sulfur
MarEx Marine Exchange of California
MARPOL Regulations for the Prevention of Air Pollution from Ships
MDO marine distillate oil
mg/kg milligrams per kilogram
## ACRONYMS AND ABBREVIATIONS, CONTINUED

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGO</td>
<td>marine gas oil</td>
<td></td>
</tr>
<tr>
<td>m/m</td>
<td>mass per mass (ratio)</td>
<td></td>
</tr>
<tr>
<td>MOL</td>
<td>Mitsui O.S.K. Lines</td>
<td></td>
</tr>
<tr>
<td>MPA</td>
<td>(Singapore) Maritime and Port Authority</td>
<td></td>
</tr>
<tr>
<td>MSC</td>
<td>Mediterranean Shipping Company</td>
<td></td>
</tr>
<tr>
<td>NNI</td>
<td>No-Net-Increase</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Number</td>
<td></td>
</tr>
<tr>
<td>NOX</td>
<td>nitrogen oxides</td>
<td></td>
</tr>
<tr>
<td>NYK</td>
<td>Nippon Yushen Kaisha Line</td>
<td></td>
</tr>
<tr>
<td>OGV</td>
<td>ocean-going vessel</td>
<td></td>
</tr>
<tr>
<td>OPIS</td>
<td>Oil Price Information Services</td>
<td></td>
</tr>
<tr>
<td>Pemex</td>
<td>Petroleós Mexicanos</td>
<td></td>
</tr>
<tr>
<td>PEZ</td>
<td>Petroleum Export Zone</td>
<td></td>
</tr>
<tr>
<td>PM10</td>
<td>particulate matter less than 10 microns in diameter</td>
<td></td>
</tr>
<tr>
<td>Port</td>
<td>Port of Los Angeles</td>
<td></td>
</tr>
<tr>
<td>PWBAEI</td>
<td>(Port of Los Angeles) Port-wide Baseline Air Emission Inventory</td>
<td></td>
</tr>
<tr>
<td>ppm</td>
<td>parts per million</td>
<td></td>
</tr>
<tr>
<td>RM</td>
<td>residual marine fuel</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>sulfur</td>
<td></td>
</tr>
<tr>
<td>SCAQMD</td>
<td>South Coast Air Quality Management District (of California)</td>
<td></td>
</tr>
<tr>
<td>SECA</td>
<td>SOX Emission Control Area</td>
<td></td>
</tr>
<tr>
<td>SFC</td>
<td>specific fuel consumption</td>
<td></td>
</tr>
<tr>
<td>SO2</td>
<td>sulfur dioxide</td>
<td></td>
</tr>
<tr>
<td>SOLAS</td>
<td>International Convention for the Safety of Life at Sea</td>
<td></td>
</tr>
<tr>
<td>SOX</td>
<td>sulfur oxides</td>
<td></td>
</tr>
<tr>
<td>SRC</td>
<td>Singapore Refining Corporation</td>
<td></td>
</tr>
<tr>
<td>TCEQ</td>
<td>Texas Commission on Environmental Quality</td>
<td></td>
</tr>
<tr>
<td>TEU</td>
<td>twenty-foot equivalent unit</td>
<td></td>
</tr>
<tr>
<td>ULSD</td>
<td>ultra low sulfur diesel</td>
<td></td>
</tr>
<tr>
<td>U.S.</td>
<td>United States</td>
<td></td>
</tr>
</tbody>
</table>
EXECUTIVE SUMMARY

In response to concerns about the potential health impacts to surrounding communities from Port of Los Angeles (Port) operations, and to provide the Port with a planning document to reduce these impacts, the Port commissioned the preparation of a comprehensive air emissions inventory. The report, published in 2004, documented the emissions from marine vessels, locomotives, heavy duty vehicles, and cargo handling equipment operating within the Port for the baseline year of 2001. The baseline emissions inventory formed the basis for the development, prioritization and implementation of emission control strategies to reduce emissions in line with then Los Angeles Mayor James Hahn’s goal of “no net increase.” This goal, adopted on 10 October 2004 by the Board of Harbor Commissioners, acting on the request of the Mayor, stated the “goal that there will be no net increase in air emissions or traffic impacts from future Port operations.” The comprehensive project launched to work toward this goal has been termed “No-Net-Increase” (NNI).

Several of the many control measures being considered for marine vessels are based upon the use of cleaner fuels in auxiliary and propulsion engines, including the use of low sulfur fuels. This report summarizes the results of a study to evaluate the availability of lower sulfur fuels containing less than 2,000 ppm sulfur (<0.2% sulfur) for use in containerships calling on the Ports of Los Angeles and Long Beach, as well as operational issues, emissions benefits, and emission reduction costs associated with their use. The study was completed in response to part of a settlement agreement between the Port of Los Angeles and the National Resource Defense Council with regard to development of the China Shipping terminal.

At the same time that this study was conducted, the California Environmental Protection Agency Air Resources Board (ARB) conducted a similar study to support the development of proposed regulations to reduce the emissions from ship auxiliary engines. Information was shared between the Port of Los Angeles consultant and ARB staff preparing the respective studies. Many entities were contacted directly and various sources were researched to obtain information for this report:

- Bunker experts
- Engine manufacturers
- Federal and international energy agencies
- Fuel producers
- Fuel suppliers
- Lubricant manufacturers
- Port authorities
- Petroleum associations
- Regulatory agencies and ministries
- Shipping lines using the Ports of Los Angeles and Long Beach

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1 Starcrest Consulting Group, LLC, *Port-wide Baseline Air Emissions Inventory*, July 2004, as revised.
It was found that low sulfur marine distillate fuel is available upon request at some ports but usually in limited volumes because worldwide shipping demand for these fuels is low. Fuels with lower sulfur contents than that listed in Table ES.1 are not widely and readily available at most bunker ports because the prices for very low sulfur blends are not competitive.

### Table ES.1: Currently Available Low Sulfur (S) Marine Distillate Fuel

<table>
<thead>
<tr>
<th>Region</th>
<th>Lowest % S readily available upon request</th>
</tr>
</thead>
<tbody>
<tr>
<td>Americas</td>
<td>0.5% S</td>
</tr>
<tr>
<td>Europe</td>
<td>0.2% S</td>
</tr>
<tr>
<td>Asia</td>
<td>0.5% S</td>
</tr>
</tbody>
</table>

Since marine fuel accounts for a large percentage of a vessel’s annual operating cost due to the large fuel consumption required by the vessel’s engines, shipping lines study the bunker market and make decisions of where and when the marine fuel will be bought based on price. With the recent fuel price increases and new environmental regulations for cleaner marine fuel, there is concern among the shipping lines about the high cost of fuel. Historically, the quality of marine fuel, specifically residual fuel, has been unpredictable. In order to meet the upcoming environmental regulations which will vary by region, shipping lines will not only be concerned about cost, but fuel quality, extra fuel storage, and operational procedures for switching fuel. The bunker market is driven by supply and demand, and at the current moment, there is no demand for marine distillate fuel with less than 0.2% sulfur other than in Europe. With regard to lower sulfur fuels:

- Lower sulfur marine distillate fuels are available at a higher cost than the marine distillate fuel normally supplied. Lower sulfur residual fuels are not available.
- The lowest sulfur content readily available is not guaranteed, it may only be supplied if the lower sulfur content is specifically requested.
- Lower sulfur marine distillate may be available upon request at certain ports, but not guaranteed to be available on a constant basis or regionally.

Table ES.2 summarizes the response by country to the <0.2% sulfur fuel availability question posed to marine fuel suppliers.
Table ES.2: Summary of Low Sulfur Marine Distillate Fuel Availability by Country

<table>
<thead>
<tr>
<th>Country</th>
<th>Region</th>
<th>Can low sulfur marine distillate fuel (&lt;0.2% sulfur) be supplied if requested?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>Americas</td>
<td>Yes, but cannot be reliably supplied at this time.</td>
</tr>
<tr>
<td>Mexico</td>
<td>Americas</td>
<td>Fuel with &lt;0.4% sulfur cannot be reliably supplied at this time.</td>
</tr>
<tr>
<td>Panama</td>
<td>Americas</td>
<td>Fuel with &lt;0.5% sulfur cannot be reliably supplied at this time. At major ports, fuel with &lt;0.2% sulfur can be supplied on a case by case basis.</td>
</tr>
<tr>
<td>U.S.</td>
<td>Americas</td>
<td>Fuel with &lt;0.2% sulfur can be supplied on a case by case basis.</td>
</tr>
<tr>
<td>China</td>
<td>Asia</td>
<td>Fuel with &lt;0.5% sulfur cannot be reliably supplied at this time.</td>
</tr>
<tr>
<td>Japan</td>
<td>Asia</td>
<td>Fuel with &lt;0.5% sulfur cannot be reliably supplied at this time.</td>
</tr>
<tr>
<td>Malaysia</td>
<td>Asia</td>
<td>Fuel with &lt;0.5% sulfur cannot be reliably supplied at this time.</td>
</tr>
<tr>
<td>Singapore South Korea</td>
<td>Asia</td>
<td>Fuel with &lt;0.2% sulfur can be supplied on a case by case basis.</td>
</tr>
<tr>
<td>Taiwan</td>
<td>Asia</td>
<td>Fuel with &lt;1.0% sulfur cannot be reliably supplied at this time.</td>
</tr>
<tr>
<td>France</td>
<td>Europe</td>
<td>Yes, already supplying 0.2% sulfur and will start supplying 0.1% sulfur by 2008.</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Europe</td>
<td>Yes, already supplying 0.2% sulfur and will start supplying 0.1% sulfur by 2008.</td>
</tr>
</tbody>
</table>

Based on DNV PS test data and supplier responses, marine distillates ≤0.2% sulfur is available as follows in the ports reviewed for purposes of this study:

- **Available** – France: Le Havre; the Netherlands: Rotterdam
- **Some availability** – Canada: Vancouver; U.S.: Los Angeles, New York, San Francisco, Seattle; Singapore
- **Little availability** – Mexico: Acapulco; Panama Canal; U.S.: Charleston, Honolulu, Norfolk, Savannah; China: Guangzhou, Hong Kong, Qingdao, Shanghai, Xingang; Japan: Nagoya, Tokyo Bay; Malaysia: Port Klang; Taiwan: Keelung
- **No availability** – China: Xiamen; Japan: Kobe; Malaysia: Tanjung Pelepas; South Korea: Busan; Taiwan: Kaohsiung

The typical sulfur content of marine distillate fuel averaged 0.58% (5,800 ppm) for the ports considered in this study in 2004, much lower than their ISO sulfur limits of 2% sulfur for DMB/DMC grades and 1.5% sulfur for DMA grades, but considerably above the 0.2% sulfur mark.

Table ES.3 summarizes the typical sulfur content of diesel fuels included in this study and whether the fuel is required to meet the minimum flashpoint of 60°C that applies to fuel for marine use.
Table ES.3: Typical Sulfur Content and Flashpoint

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Typical Sulfur Content (%)</th>
<th>Meets Flashpoint &gt;60°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residual &lt; 4.5% S</td>
<td>2.74%</td>
<td>Yes</td>
</tr>
<tr>
<td>Residual &lt; 1.5% S</td>
<td>1.5%</td>
<td>Yes</td>
</tr>
<tr>
<td>MDO &gt; 0.5% S</td>
<td>0.6%</td>
<td>Yes</td>
</tr>
<tr>
<td>MGO &lt; 0.2% S</td>
<td>0.1%</td>
<td>Yes</td>
</tr>
<tr>
<td>Grade No. 2 S500</td>
<td>0.03%</td>
<td>No</td>
</tr>
<tr>
<td>CARB Diesel S500</td>
<td>0.015%</td>
<td>No</td>
</tr>
<tr>
<td>ULSD S15</td>
<td>0.0015%</td>
<td>No</td>
</tr>
</tbody>
</table>

Although the onroad fuels (Grade No. 2 S500, CARB Diesel S500, and ULSD S15) were included in this study and in the cost effectiveness section, these fuels:

- are not required to meet the 60°C flashpoint requirement for marine fuels,
- have not been tested on ocean-going vessels’ engines, and
- are not currently supplied by marine suppliers for large-volume bunker sales.

This study evaluated the cost effectiveness of using cleaner fuels for main and auxiliary engines. The three-month average, three-year-average and maximum fuel costs for the various fuels studied were used to estimate the incremental fuel costs. The incremental fuel cost were estimated by subtracting the fuel costs summarized in Figure ES.1 from the baseline fuel prices for IFO 380 2.7% sulfur and MDO 0.6% sulfur.
Three different scenarios using three-month average, three-year average and three-year maximum incremental prices are given for each pollutant (see Section 6) due to the uncertain nature of fuel prices. The cost effectiveness for MGO < 0.2% sulfur is illustrated in Figures ES.2 through ES.4 for of the three incremental prices. The higher the dollar amount in the tables, the less cost effective it is for that pollutant. For comparison, the California Carl Moyer program requires a $12,000/ton of NOX reduced (or better) cost effectiveness in order for projects that use cleaner marine vessel and other heavy duty diesel engines to be eligible for funding.3 In those figures where no bar is presented for NOX or CO₂, it is because there were no reductions associated with those changes in fuel.

---

Figure ES.2: Cost Effectiveness for MGO <0.2% Sulfur using 3-month Average Prices

Figure ES.3: Cost Effectiveness for MGO <0.2% Sulfur using 3-year Average Prices
The shipping lines that call on the Port of Los Angeles and Long Beach were asked to comment on safety and operational issues regarding the switching of residual fuel or regular marine distillate fuel to a much lower sulfur marine distillate fuel. Some shipping lines expressed the following concerns over switching fuels:

- Filter clogging due to fuel incompatibility is related to the solvent effect of diesel fuel removing deposits from fuel lines.
- The filtering system, main engine cylinder oil, fuel pumps and piston liner may stick due to differences in viscosity at the time of fuel switching.
- Moving parts wear down if exposed to lower sulfur fuels for a long period, and there could be possible malfunction of the propulsion gear if the vessel is not properly equipped with extra tanks and electronically controlled lubricators.
- Each fuel has its own appropriate temperature and a bunker operation plan would be needed when using more than one kind of fuel due to possibility of sudden loss of propulsion or auxiliary power.

As new regulations arise for low sulfur marine fuels, it is recommended that there be:

- additional research for trial use of lower sulfur fuel in marine engines,
- actual emissions testing of the various pollutants especially particulate matter,
- fuel quality testing,
- fuel switching procedures development similar to those already in place by vessels that routinely switch fuels,
- consideration of other alternatives for lowering emissions, such as gas scrubbers and cleaner engines.