

## SECTION 4 FUEL AVAILABILITY

The fuel supply chain (Section 4.1), regional low sulfur fuel availability (Section 4.2), typical fuel sulfur contents (Section 4.3) and future availability for low sulfur fuels (Section 4.4) are discussed in this section. An initial discussion of marine fuel sales worldwide provides context for the more detailed discussions that follow.

A number of sources were consulted to obtain international and domestic marine fuel sales and consumption data. Refining capabilities and marine fuel sales were identified from:

- *Bunkerworld* market surveys
- International Bunker Industry Association (IBIA) port information
- International Energy Agency (IEA) market reports
- U.S. Energy Information Administration (EIA) country briefs

Also, several reports and articles on the marine fuel market and low sulfur fuel were reviewed, including European studies published in light of the European Commission's regulations on marine fuels and IMO MARPOL Annex VI:

- BeicipFranlab, *Advice on Marine Fuel*, 2003 (BeicipFranlab 2003)
- MARINTEK, *Summary Report - Application of Low Sulphur Marine Fuels*, 2003
- ENTEC U.K. Ltd, *Quantification of emissions from ships associated with ship movements between ports in the European community*, Chapter 3, "Market Survey of Marine Distillates With 0.2% Sulfur Content," July 2002 (ENTECC 2002)
- Lloyds List Article by Det Norske Veritas Petroleum Services (DNV PS), "Marpol Annex VI sets sulphur test," 2005
- Shell Marine Products Article, "Bunkering in 2003: New patterns, new challenges"
- California Air Resources Board, Discussion of Draft Proposal to Reduce Emissions from Ship Auxiliary Engines, May 2005

Marine fuels account for 20% of the total fuel oil demand worldwide. Marine residual fuel sales account for approximately 80% of the total worldwide marine fuel sales, while 20% are attributed to marine distillate fuel sales. World consumption of marine residual fuel is expected to continue increasing. Europe and Asia led marine residual fuel sales in 2001 as shown in Figure 4.1.<sup>34</sup> Europe and the Americas (including North and South America) led marine distillate fuel sales in 2001,<sup>35</sup> as shown in Figure 4.2. According to ARB's estimates, less than 1% of the total marine distillate fuel available worldwide would be required under their draft proposal, which would require ocean-going vessels at dockside or in California coastal waters to use low sulfur marine distillate fuel (either MGO or MDO) in the auxiliary engines.<sup>36</sup>

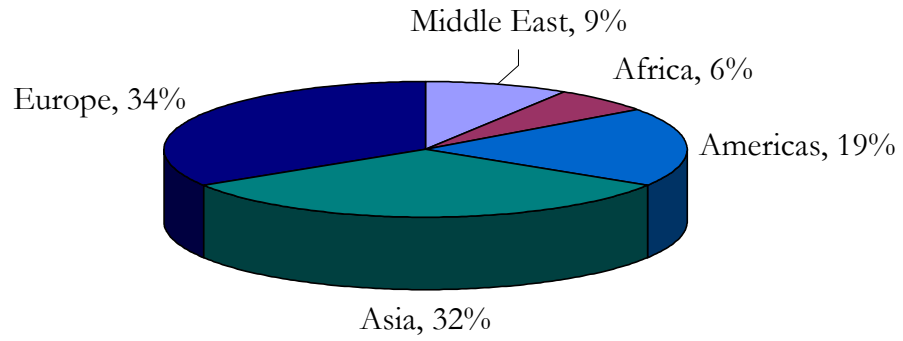
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<sup>34</sup> BeicipFranlab 2003.

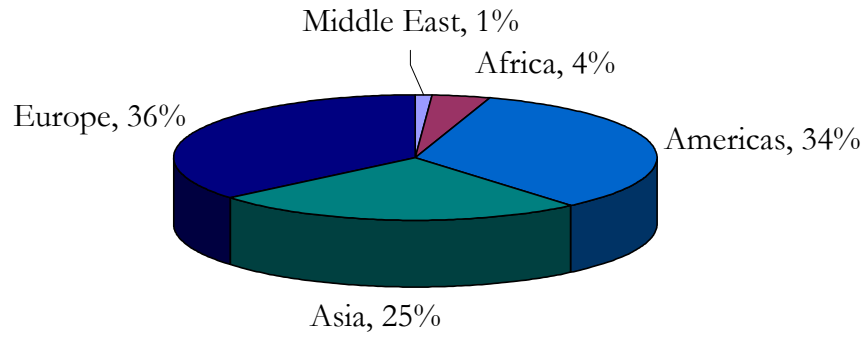
<sup>35</sup> *Ibid.*

<sup>36</sup> ARB 2005. ARB, Public Workshop on Draft Proposal to Reduce Emissions from Ship Auxiliary Engines, 18 May 2005.

**Figure 4.1: International Marine Residual Fuel Sales, 2001**



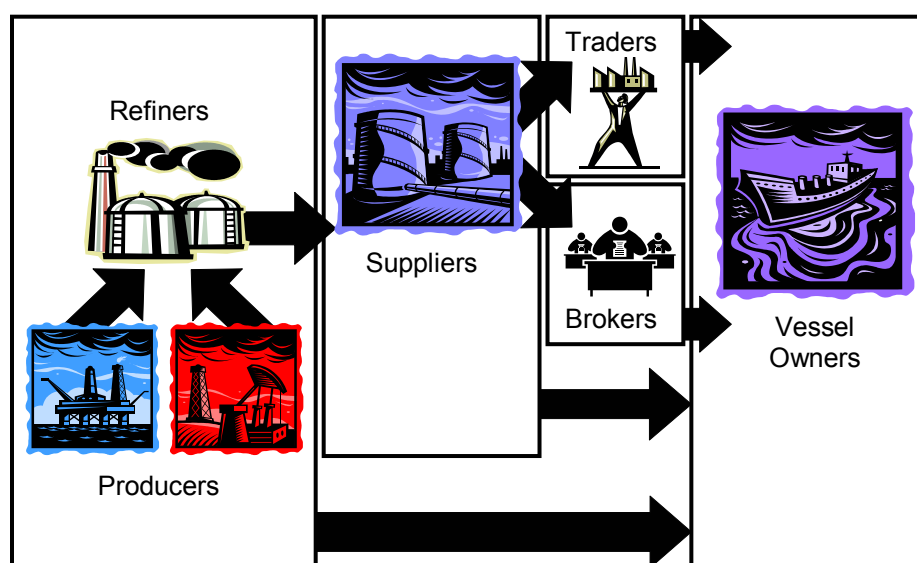
**Figure 4.2: International Marine Distillate Fuel Sales, 2001**



## 4.1 Fuel Supply Chain

As Figure 4.3 illustrates, the marine fuel supply chain is from the oil field (crude oil) to the refinery (for processing) to the supplier (as fuel). From the supplier, the fuel may get to the vessel by one of three routes – directly, through a broker (who does not take title to the product) or through a trader (who does take title to the product). The refining company may also be the fuel supplier.

**Figure 4.3: From Crude Oil to Marine Vessel Fuel: The Supply Chain**<sup>37</sup>



Within this supply chain, cost is the driving force for a vessel in selecting a fueling location. For over fifty years, residual fuel, a refinery by-product, has been the fuel of choice for medium and slow speed engines used by ocean-going vessels due to its low cost compared to other fuels. ARB's recent survey showed 99% of the shipping line respondents use residual fuel for their main engines and 78% use residual fuel for the auxiliary engines.<sup>38</sup> 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 since its quality is a function of the crude processed at the refinery, has been unpredictable. In order to meet the upcoming environmental regulations which will vary by region, shipping lines will not only

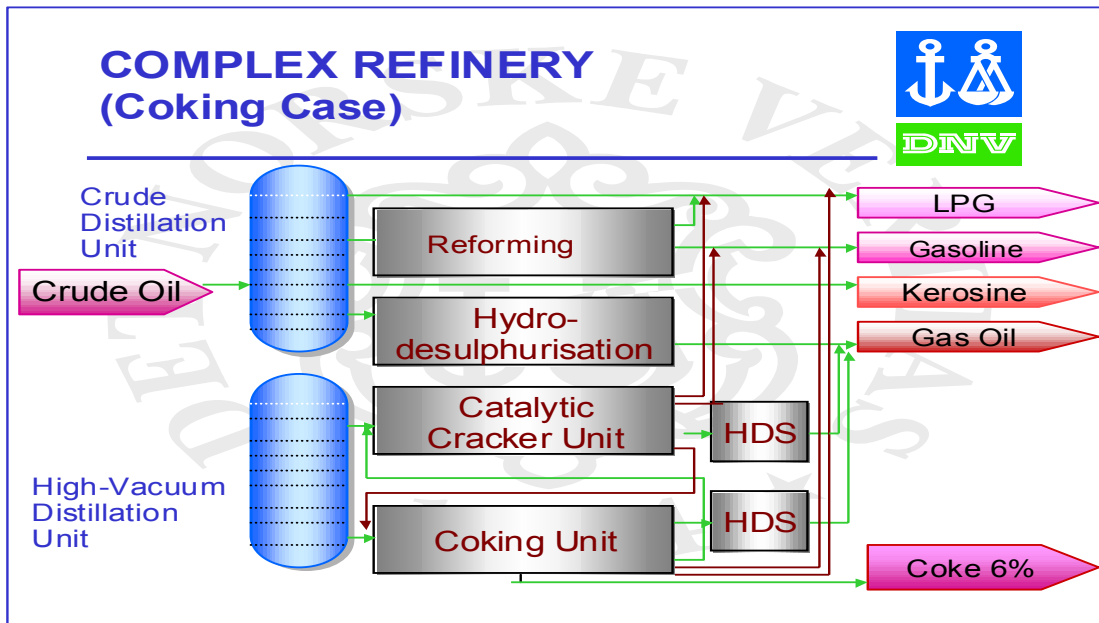
<sup>37</sup> Concept adapted from work by Mercator Transport Group, personal communication, April 2005.

<sup>38</sup> ARB 2005.

be concerned about cost, but fuel quality, extra fuel storage, and operational procedures for switching fuel.

Twenty percent of the product produced by refineries worldwide, excluding those in the U.S., is residual fuel.<sup>39</sup> This contrasts sharply to the U.S. refining market, where only 4% of the refined product is residual fuel. As illustrated in Figures 4.4 and 4.5,<sup>40</sup> refineries with coking units have coke as a by-product instead of residual fuel, and refineries without coking units produce residual fuel oil. In these figures, LPG is liquefied petroleum gas and HDS is hydrodesulphurization.

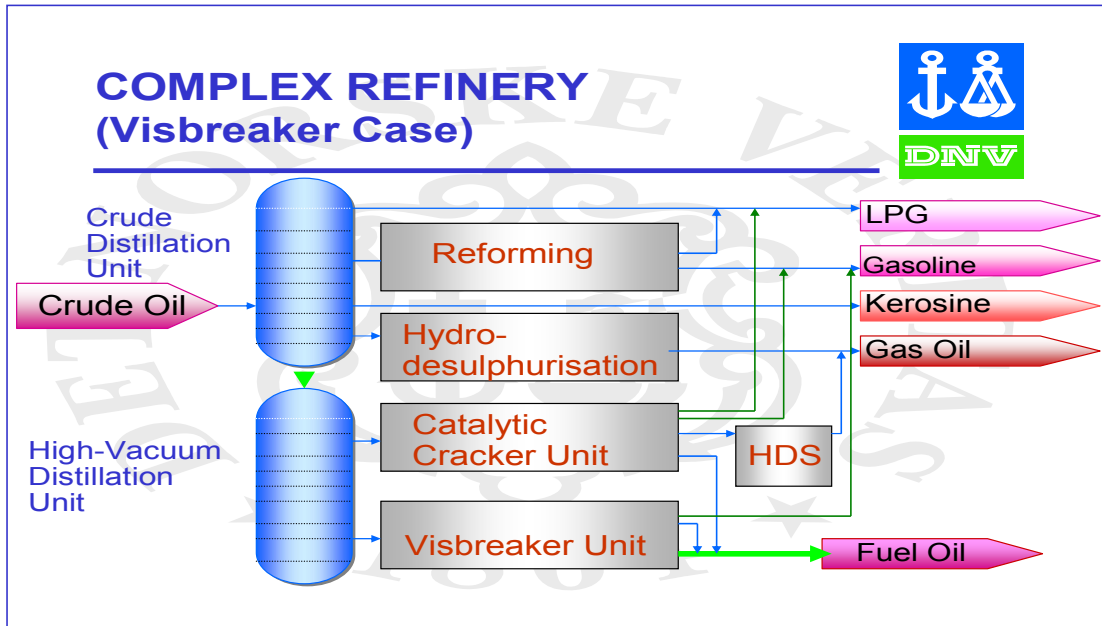
Figure 4.4: Complex Refinery with Coking Unit



<sup>39</sup> DNV PS 2005. Personal communication with Dr. Rudolph Kassinger, consultant to DNV PS, May 2005.

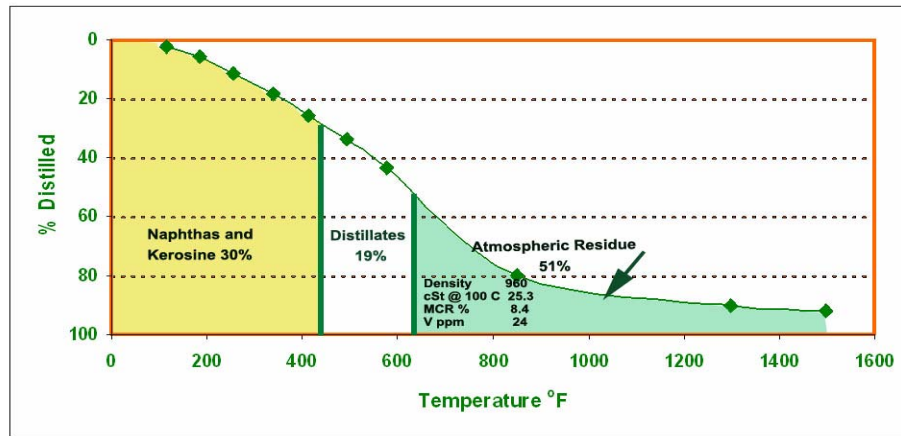
<sup>40</sup> DNV PS.

Figure 4.5: Complex Refinery with Visbreaker Unit



As shown in Figure 4.6,<sup>41</sup> distillates, considered “clean products,” typically constitute about one-fifth of the refined fractions produced by a refinery.

Figure 4.6: Major Refinery Fractions



In determining the availability of low sulfur marine fuels in various countries, it is useful to consider the initial source within the supply chain. In general, lower sulfur fuels are more likely to be available, or more likely to become available, in countries with a low sulfur crude

<sup>41</sup> Ibid.

oil source or access to low sulfur crude oil imports. As Figure 4.7<sup>42</sup> illustrates, at least for seaborne crude oil trade, much of the crude oil for Asia originates in the Middle East, which is a higher sulfur (1.0 – 1.5% by weight sulfur in feedstock) crude oil.<sup>43</sup> Because the sulfur in the crude oil is concentrated in the residual during the refining process, residual fuels have a much higher concentration of sulfur than the crude oil feedstock.<sup>44</sup> In comparison with low-sulfur feedstock produced from North Sea crude oil and supplied to Europe, the feedstock produced from Middle Eastern crude is also more difficult to process.<sup>45</sup> In Latin America, Brazil, Chile, Argentina, Columbia and Mexico produce low-sulfur (sweet) crude oil. These countries are thus in a better position to meet low-sulfur fuel demand. Venezuela, however, has a great supply of heavy high-sulfur (sour) crude oil.<sup>46</sup> In the U.S. (including offshore), the crude oil is predominantly sweet, with the exception of California and Alaska which supply predominantly sour crude. The U.S. also receives sour crude from Mexico and Canada for refining.<sup>47</sup> Africa (Libya, Nigeria, Algeria) also generally produce low sulfur crude oil<sup>48</sup> and the U.S. and, more recently, China draw crude oil from West Africa.<sup>49</sup>

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<sup>42</sup> IMO, 1994. See:

[http://www.oceansatlas.com/unatlas/uses/transportation\\_telecomm/maritime\\_trans/worldtrade/Graphic,%20oil%20seaborne%20trade.PDF](http://www.oceansatlas.com/unatlas/uses/transportation_telecomm/maritime_trans/worldtrade/Graphic,%20oil%20seaborne%20trade.PDF).

<sup>43</sup> JPEC 2001. Japan Petroleum Energy Center, *Survey of Petroleum Refining Technology for High-quality (Ultra-low Sulfur Content) Diesel Fuel*, 2001.

<sup>44</sup> DNV PS 2005.

<sup>45</sup> JPEC 2001.

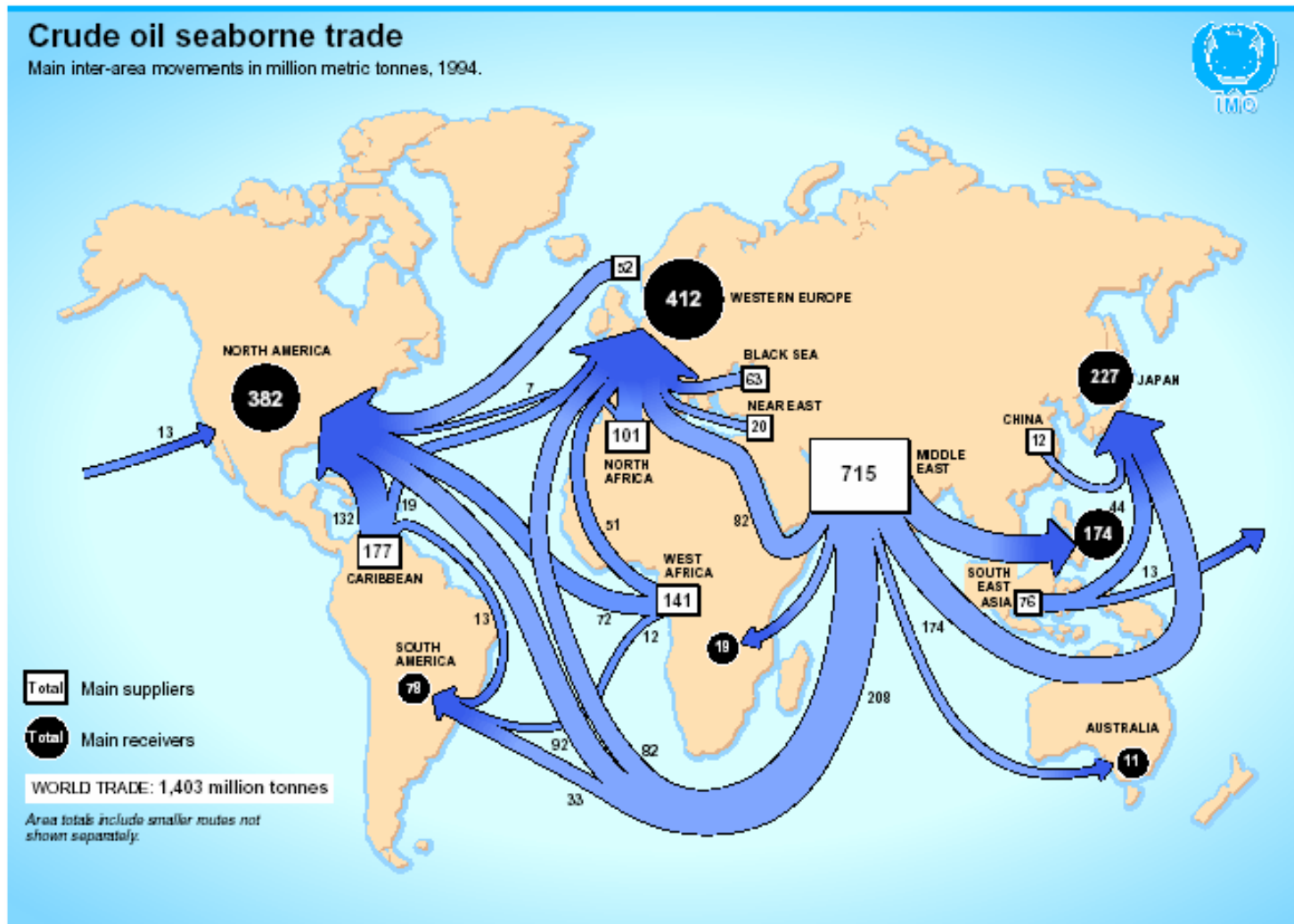
<sup>46</sup> *Bunkeworld*, “Low Sulphur limits will benefit Latin American suppliers,” 10 Nov 2004.

<sup>47</sup> Personal communication between Starcrest and Polaris Engineering, 23 April 2005.

<sup>48</sup> BeicipFranlab 2003.

<sup>49</sup> Personal communication between Starcrest and Don Gregory, BP Marine, 23 May 2005.

Figure 4.7: Seaborne Crude Oil Trade



#### 4.2 Current Low Sulfur Fuel Availability

To obtain information regarding the current and near future availability of low sulfur fuels (<0.2% sulfur), fuel suppliers and producers were contacted, and data was collected from government agencies and other organizations. A standard approach was developed prior to contacting the various suppliers, producers and bunker personnel, although the information obtained from each interview varied based on the willingness and knowledge of the participant. *Bunkeworld*, a leading resource for the bunker industry, was consulted, along with other sources, to identify fuel suppliers for each port and/or region. Suppliers were selected and contacted by phone, fax and/or e-mail to obtain information. The entities that were contacted included:

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

Based on the information obtained from these contacts, the table below summarizes the lowest sulfur concentration currently available for marine distillate fuels at the ports studied for the Americas, Europe and Asia.

**Table 4.1: Currently Available Low Sulfur Marine Distillate Fuel**

<b>Region</b>	<b>Lowest % S readily available upon request</b>
Americas	0.5% S
Europe	0.2% S
Asia	0.5 % S

Generally speaking:

- Lower sulfur marine distillates are available at a higher cost than the marine distillate fuel normally supplied worldwide. Lower sulfur marine residuals are not available.
- The low sulfur fuel must be specifically requested when ordering.
- Lower sulfur marine distillates may be available, although not necessarily consistently, in ports such as (but not limited to):
  - Los Angeles, Long Beach, and New York/New Jersey in the U.S.
  - Singapore and Hong Kong in Asia
  - European ports

Table 4.2 and Figure 4.8 summarize, by country, the availability of  $\leq 0.2\%$  sulfur fuel based on responses from marine fuel suppliers and DNV PS test data. Figure 4.8 corresponds to the data in Table 4.2 as follows:

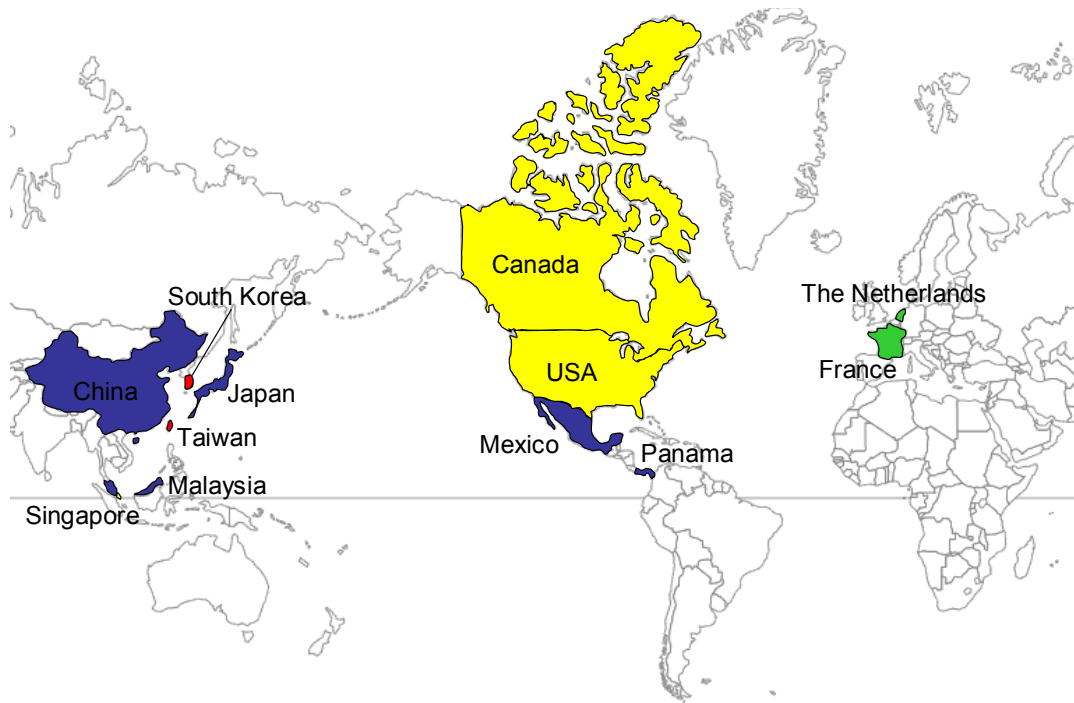
- Green – France and the Netherlands - currently supplying  $\leq 0.2\%$  sulfur fuel
- Yellow – Canada, the U.S., and Singapore - can supply  $\leq 0.2\%$  sulfur fuel on case-by-case basis
- Blue – Japan, Malaysia, China, Mexico and Panama - can supply  $\geq 0.5\%$  sulfur fuel
- Red – Taiwan and South Korea - can supply  $\geq 1.0\%$  sulfur fuel

Although the entire country is colored in each case, only those ports/regions identified in Section 3 have been considered for the basis of this illustration.

**Table 4.2: Summary of Low Sulfur Marine Distillate Fuel Availability by Country**

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

**Figure 4.8: Summary of Low Sulfur Marine Distillate Fuel Availability by Country**



Lower sulfur content residual fuels (<1.5% sulfur) may be supplied upon request at major European ports (e.g., Port of Rotterdam) since the IMO MARPOL SECA requirements and an amended EU marine fuel directive requiring the <1.5% sulfur residual fuel for passenger vessels on regular services between EU ports comes into effect in 2006. The <1.5% sulfur residual fuel is not expected to be widely available in Asia or North America until there is a greater demand for it. None of the Asian suppliers that responded indicated that marine distillate with less than 0.2% sulfur content was available, with the exception of Singapore (and Hong Kong, which indicated that they could request the product from Singapore). The test results indicate, however, that in some cases marine distillate with less than 0.2% sulfur content was supplied.

### **4.3 Typical Sulfur Contents**

Since most fuel suppliers, producers, and shipping lines could not provide the study with actual fuel test data for many reasons (i.e., considered confidential, not readily available in one place, short duration of project), DNV PS, which claims to test 70% of the marine fuel tested worldwide, was solicited to provide average sulfur contents for the marine distillates and residual fuels tested in 2004 at the various ports serving the Ports of Los Angeles and Long Beach. Of the marine distillate test samples, 19% (507 tests) were  $\leq 0.2\%$  sulfur and 81% (2,193 tests) were  $> 0.2\%$  sulfur. There were 18,810 tests for residual fuel, representing 87% of the test data; a total of 21,510 samples were analyzed, as shown in Table 4.3. It is

likely that distillate fuel sampling is less frequent than residual fuel sampling because of the lower likelihood of problems associated with marine distillates.<sup>50</sup>

**Table 4.3: Number of Marine Fuel Sulfur Content Tests Reported by DNV PS for Selected Ports, 2004**

Grade	Sulfur Content	Tests Reported	
		Number	Percent
IFO 380	>1.5 %	14,723	68.4%
IFO 380	≤1.5 %	267	1.2%
IFO 180	>1.5 %	3,709	17.2%
IFO 180	≤1.5 %	111	0.5%
MDO/MGO	>0.2 %	2,193	10.2%
MDO/MGO	≤0.2 %	507	2.4%

Table 4.4 and Figures 4.9 and 4.10 present the average sulfur contents for marine distillate fuel and residual fuel by ports and region. Table 4.5 summarizes the availability of marine distillates with a sulfur content of ≤0.2%, based on test data and supplier responses. Based on the ports considered for this study, the average for marine distillate fuel greater than 0.2% sulfur content (the MDO most likely used by container ships) is 0.58% sulfur, much lower than the marine distillate fuel specifications of <1.5% sulfur (DMA) and <2% sulfur (DMB/DMC). The 0.58% sulfur is also similar to ARB’s ship survey data which showed an average of 0.56% sulfur for distillate fuel.<sup>51</sup> The DNV PS data did not make a precise identification (DMA, DMB, or DMC) of the marine distillate fuel provided to the vessels since it is difficult to distinguish between grades due to the different names used by the suppliers.

The ports shown in these tables and figures may represent more than one port as follows:

- Acapulco represents Lazaro Cardenas, Manzanillo (Mexico), and Salina Cruz
- Panama Canal represents Balboa, Coco Solo, Colon, Cristobal, Las Minas, Manzanillo (Panama), and Panama
- Charleston represents Georgetown
- Honolulu represents Barbers Point Terminal and Pearl Harbor
- Los Angeles represents Long Beach, Off Los Angeles, Port Hueneme, San Pedro, and Wilmington
- New York represents Bayonne, Bayway, Bridgeport, Brooklyn, Elizabeth Port, Gravesend Bay, Hoboken, Howland Hook, Jersey City, New Haven, Newark, Perth Amboy, Port Newark, Riverhead, and Stapleton
- Norfolk represents Hampton Road, Newport News, Portsmouth, and Yorktown
- San Francisco represents Avon, Benicia, Crockett, Martinez, Oakland, Richmond, and Stockton

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<sup>50</sup> Personal communication between Starcrest and Don Gregory, BP Marine, 23 May 2005.

<sup>51</sup> ARB Ship Survey preliminary results, personal communication from Paul Milkey to Starcrest, 6 April 2005.

- Savannah represents Brunswick, and Port Royal
- Seattle represents Anacortes, Cherry Point, Everett, Ferndale, Manchester, March Point, Port Angeles, Port Townsend, and Tacoma
- Guangzhou represents Chiwan, Huangpu, Shekou, and Zhuhai
- Qingdao represents Huangdao, Lianyungang, and Rizhao
- Shanghai represents Badong, Baoshan, Beilun, Chengxi, Chongqing, Jiangsu, Jiangyin, Nanjing, Nantong, Ningbo, Zhangjiagang, Zhenhai, and Zhenjiang
- Xiamen represents Mawei, Quanzhou, and Shantou
- Xingang, represents Jinzhou, Yantai (understood to be Yantian), and Yingkou
- Nagoya represents Gamagori, Kinuura, Shimizu, Tahara, Toyohashi, Tsu, and Yokkaichi
- Tokyo Bay represents Chiba, Funabashi, Kawasaki, Kimitsu, Kisarazu, Negishi, Ogishima, Shinagawa, Tagonoura, Tokyo, Yokohama, and Yokosuka
- Port Klang represents Lamut
- Tanjung Pelepas represents Off Malaysia and Tanjung Pelepas
- Singapore represents Bukom, Jurong, and Pulau Bukom
- Busan represents Bukpyung, Chinhae, Donghae, Hadong, Jangseungpo, Jinhae, Koje Island, Kwangyang, Masan, Mipo, Okpo, Onsan, Pohang, Pusan, Samchonpo, Tongyong, Ulsan, and Yosu
- Kaohsiung represents Mai-liao, Suao, and Yun-an
- Keelung represents Taichung
- Le Havre represents Antifer, Caen, Gravenchon, Honfleur, Notre Dame de Gravenchon, Port Jerome, and Yainville
- Rotterdam represents Bolnes, Dordrecht, Europoort, Hook of Holland, Kroonvlag, Maasvlakte, Moerdijk, Rozenburg, Scheveningen, Schiedam, and Vlaardingen

In each figure, the lower sulfur concentration samples are represented by the short bars, and the higher sulfur concentration samples are represented by the tall bars.

**Table 4.4: Average Sulfur Content of Marine Fuels for Selected Ports, 2004**

Port	Country	Region	(< 0.2% S)	(> 0.2% S)	(<1.5% S)	(>1.5% S)
			MGO (%)	MDO (%)	LS IFO 380 (%)	IFO 380 (%)
Vancouver	Canada	Americas	0.07	0.29	1.38	1.82
Acapulco	Mexico	Americas	0.05	na	na	3.37
Panama Canal	Panama	Americas	0.14	0.42	1.43	2.68
Charleston	U.S.	Americas	0.09	0.30	na	2.05
Honolulu	U.S.	Americas	0.14	0.38	1.49	1.79
Los Angeles	U.S.	Americas	0.06	0.69	1.32	2.33
New York	U.S.	Americas	0.16	0.82	1.20	3.02
Norfolk	U.S.	Americas	0.16	0.29	1.00	2.21
San Francisco	U.S.	Americas	0.06	1.35	na	2.49
Savannah	U.S.	Americas	0.19	0.33	na	2.18
Seattle	U.S.	Americas	0.07	0.37	1.38	2.01
<b>Minimum</b>			<b>0.05</b>	<b>0.29</b>	<b>1.00</b>	<b>1.79</b>
<b>Maximum</b>			<b>0.19</b>	<b>1.35</b>	<b>1.49</b>	<b>3.37</b>
Guangzhou	China	Asia	0.15	0.39	na	2.61
Hong Kong	China	Asia	0.18	0.44	1.48	2.76
Qingdao	China	Asia	0.12	0.35	na	3.09
Shanghai	China	Asia	0.14	0.68	na	2.89
Xiamen	China	Asia	na	0.43	na	2.62
Xingang	China	Asia	0.1	0.36	na	2.82
Kobe	Japan	Asia	na	0.84	na	2.73
Nagoya	Japan	Asia	0.05	0.8	na	2.51
Tokyo Bay	Japan	Asia	0.05	0.85	1.27	2.68
Port Klang	Malaysia	Asia	0.18	0.36	na	2.96
Tanjung Pelepas	Malaysia	Asia	<0.05	na	1.15	3.15
Singapore	Singapore	Asia	0.12	0.55	1.24	3.12
Busan	S. Korea	Asia	na	0.95	na	3.07
Kaohsiung	Taiwan	Asia	na	0.73	na	3.22
Keelung	Taiwan	Asia	0.06	0.65	na	2.61
<b>Minimum</b>			<b>0.05</b>	<b>0.35</b>	<b>1.15</b>	<b>2.51</b>
<b>Maximum</b>			<b>0.18</b>	<b>0.95</b>	<b>1.48</b>	<b>3.22</b>
Le Havre	France	Europe	0.16	0.34	na	2.99
Rotterdam	Netherlands	Europe	0.17	1.07	1.45	2.69
<b>Minimum</b>			<b>0.16</b>	<b>0.34</b>	<b>1.45</b>	<b>2.69</b>
<b>Maximum</b>			<b>0.17</b>	<b>1.07</b>	<b>1.45</b>	<b>2.69</b>

**Table 4.5: Availability of Marine Distillate Fuels  $\leq 0.2\%$  Sulfur by Port**

<b>Port</b>	<b>Country</b>	<b>Region</b>	<b>Average Sulfur Content (%)</b>	<b>Number of Test Results</b>
<b>Available</b>				
Le Havre	France	Europe	0.16	32
Rotterdam	Netherlands	Europe	0.17	130
<b>Supplied on Case-by-case Basis</b>				
Vancouver	Canada	Americas	0.07	32
Los Angeles	United States	Americas	0.06	57
New York	United States	Americas	0.16	41
San Francisco	United States	Americas	0.06	40
Seattle	United States	Americas	0.07	27
Singapore	Singapore	Asia	0.12	39
<b>Not Reliably Supplied</b>				
Acapulco	Mexico	Americas	0.05	19
Panama Canal	Panama	Americas	0.14	6
Charleston	United States	Americas	0.09	7
Honolulu	United States	Americas	0.14	6
Norfolk	United States	Americas	0.16	13
Savannah	United States	Americas	0.19	1
Guangzhou	China	Asia	0.15	1
Hong Kong	China	Asia	0.18	2
Qingdao	China	Asia	0.12	2
Shanghai	China	Asia	0.14	25
Xingang	China	Asia	0.1	4
Nagoya	Japan	Asia	0.05	8
Tokyo Bay	Japan	Asia	0.05	3
Port Klang	Malaysia	Asia	0.18	5
Keelung	Taiwan	Asia	0.06	6
<b>Not Available</b>				
Xiamen	China	Asia	na	0
Kobe	Japan	Asia	na	0
Tanjung Pelepas	Malaysia	Asia	<0.05	1
Busan	South Korea	Asia	na	0
Kaohsiung	Taiwan	Asia	na	0

Figure 4.9: Average Sulfur Content of Marine Distillate Fuel Tested, 2004

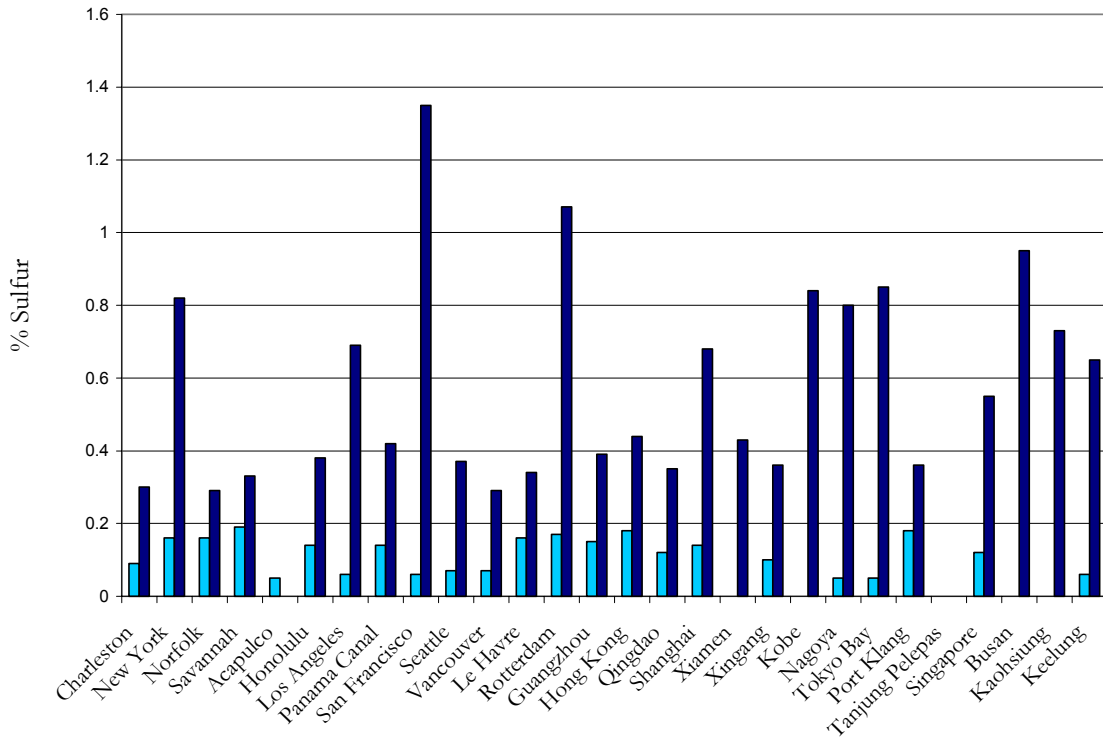
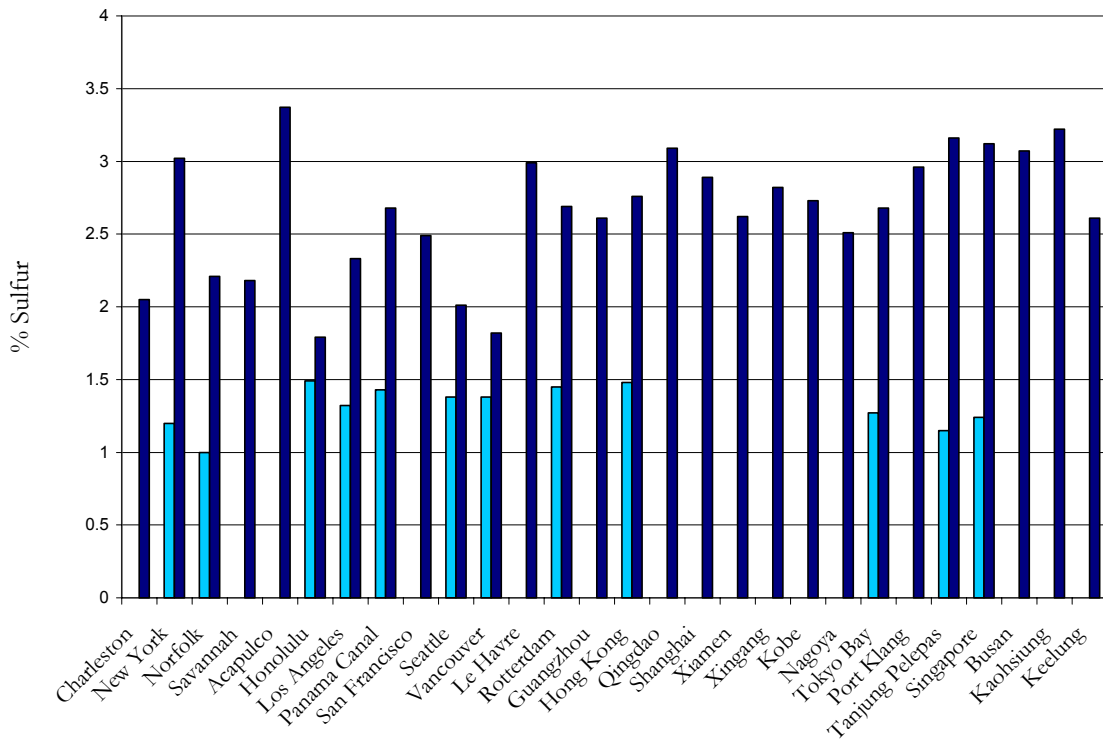


Figure 4.10: Average Sulfur Content of Marine Residual Fuel Tested, 2004



For purposes of the discussion on the production and supply of low sulfur fuels, the ports are presented by region as follows:

- North America
  - Canada (Vancouver)
  - Mexico (Lazaro Cardenas)
  - Panama (Manzanillo, Balboa)
  - United States (Los Angeles, Long Beach, Oakland, Seattle, Honolulu, New York/New Jersey, Charleston, Norfolk, Savannah)
- Europe
  - France (LeHavre)
  - The Netherlands (Rotterdam)
- Asia
  - China (Yantian, Shanghai, Xiamen, Ningbo, Chiwan, Qingdao)
  - Hong Kong, China
  - Taiwan (Kaohsiung)
  - South Korea (Busan, Kwangyang)
  - Japan (Yokohama, Kobe, Nagoya, Tokyo)
  - Malaysia (Tanjung Pelepas)
  - Singapore

Information sources include suppliers and/or refiners and/or DNV PS test results. The mention of a local refinery for a port or country does not necessarily mean that they are the source of the marine fuel supplied in that port; marine fuel may be imported in whole or in part.

#### **4.3.1 North America**

In North America, the most frequent ports of origination/call for vessels calling on the Ports of Los Angeles and Long Beach included Vancouver (Canada), Manzanillo and Balboa (Panama), and in the U.S., several East and West coast ports, including Honolulu, Hawaii.. The fuel available is summarized below by country.

##### *Canada*

Typical product specifications provided by a local marine fuel supplier in Vancouver, British Columbia show low sulfur marine distillate fuel meeting ISO 8217 DMB standards currently available with 0.4% average sulfur content. DNV's data show that marine distillate fuel with even lower sulfur content can be supplied (700 ppm average) in Vancouver, although it may not be currently guaranteed to be supplied on a full time basis. If there is a future market demand, it could be produced and supplied.

Some of the marine fuel supplied to Vancouver is produced at the ConocoPhillips and Tesoro refineries in Puget Sound, Washington, along with the ExxonMobil refinery in Canada. DNV test data shows average sulfur content of 1.38% for IFO 380 (less than 1.5% sulfur) and 1.82% for

IFO 380 (greater than 1.5% sulfur). Fuel specifications, provided by one supplier, are included in Appendix A.

*Mexico*

The national oil company, Petróleos Mexicanos (Pemex), is the only producer in Mexico. Pemex refineries produce marine diesel oil with an average 0.4% sulfur content, according to a local supplier. Marine distillate fuel with sulfur content lower than 0.4% is not reliably supplied in Mexico. DNV data (see Acapulco in Table 4.2) show that marine distillate fuel with lower sulfur content (500 ppm) has been supplied in the last year for the ports of Lazaro Cardenas and Manzanillo.

IFO 180 is the only marine residual fuel currently produced by Pemex with a typical 3% sulfur content. In the future, Pemex may start producing IFO 380 possibly containing higher sulfur content. Fuel specifications are included in Appendix A.

*Panama*

The Panamanian government created the Petroleum Export Zone (PEZ) in 1992 which allows any company to establish operation in a PEZ and sell directly to foreign vessels transiting the Panama Canal.<sup>52</sup> According to EIA, nearly 12,000 ships transit the Panama Canal every year, and about 52,000 barrels per day of residual bunker fuel were delivered there in 2001. The country of Panama does not have its own crude refining capacity or oil production.

2004 DNV data show an average 0.42% sulfur content for marine distillate fuel and 2.68% sulfur content for residual fuel. Lower sulfur marine distillate (<0.2% sulfur) and residual (<1.5% sulfur) fuels were also supplied, although not guaranteed at this time. A major supplier in Panama noted that the marine distillate fuel currently supplied averages 0.5% sulfur, as the DNV test results showed. The supplier stated that since Panama does not have its own refineries and has to import the fuel supplied at the Port, it can only afford to import the products with a sufficient demand.

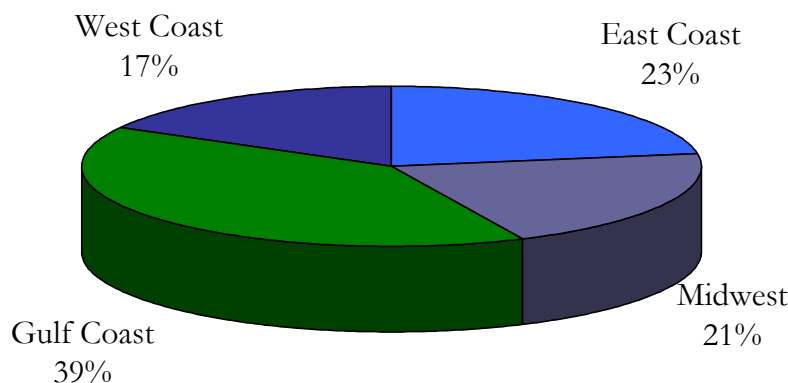
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<sup>52</sup> EIA, Panama Country Analysis Brief, November 2004.

*United States*

Marine distillate fuel sales for vessel bunkering in the U.S. totaled 7 million tonnes (metric tons) in 2003.<sup>53</sup> As shown in Figure 4.11, almost 40% of the marine distillate fuel sold in the U.S. was in the Gulf Coast, while 17% was sold in the West Coast in 2003.

**Figure 4.11: U.S. Marine Distillate Fuel Use, 2003**



The DNV data shows low sulfur marine distillate fuel (<0.2% sulfur) supplied in 2004 had an average sulfur content of 0.06% in Los Angeles and San Francisco, 0.07% in Seattle, 0.09% in Charleston, 0.16% in New York and Norfolk, and 0.19% in Savannah. Approximately half of the marine distillate fuel tests in Los Angeles in 2004 contained <0.2% sulfur. The average sulfur content for the marine distillate fuel (>0.2% sulfur) was 0.29% in Norfolk, 0.30% in Charleston, 0.33% in Savannah, 0.37% in Seattle, 0.69% in Los Angeles, 0.82% in New York, and 1.35% in San Francisco.

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<sup>53</sup> EIA, Fuel Oil and Kerosene Sales, 2003, Table 11, *Sales for Transportation Use: Distillate Fuel Oil and Residual Fuel Oil*, 2003.

Fuel suppliers for the West Coast and East Coast were contacted, along with suppliers for the Hawaiian port of Honolulu. Suppliers at key U.S. ports that were part of this study, such as the Ports of Los Angeles and Long Beach, the Port Authority of New York/New Jersey, and Port of Seattle, state that low sulfur marine fuel (<0.2% sulfur) is available upon request. At other ports, the lowest sulfur content marine fuel could be supplied if requested in advance is 0.5%. In Hawaii, MGO with an average sulfur content of 0.5% is currently supplied, but not guaranteed at that sulfur content. For the port in Norfolk, Virginia a supplier stated lower sulfur fuel (<0.2% sulfur) are not currently offered and will not be offered at this port until regulations require it or customers demand it due to the fact that it is not a major bunker port. At the Port of Savannah in Georgia, marine gas oil (<0.5% sulfur) is typically available with advance notice.

Although lower sulfur marine distillate fuel (<0.2% sulfur) may be currently sold at some U.S. ports, it is not guaranteed to be widely available upon demand since it may be stored in the same tanks as any other marine distillate that meets the standard specifications, thus potentially increasing the sulfur concentration from cross-contamination with higher sulfur fuel stocks. If there is a future market demand for low sulfur marine distillate, plans may need to be made for separate storage facilities in order to ensure the fuel meets the lower sulfur content for those vessels requesting it.

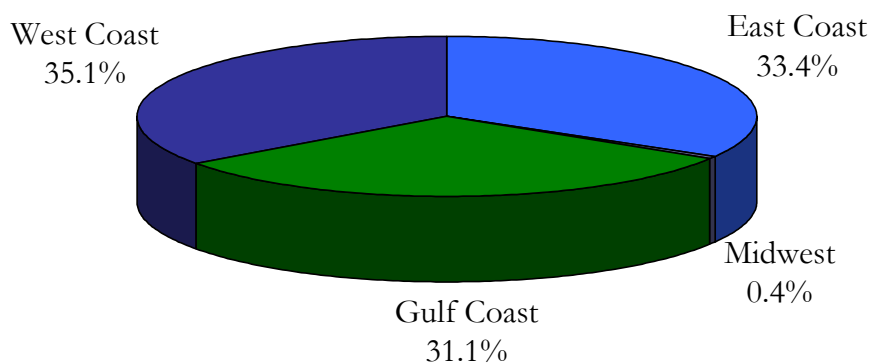
In 2004, residual fuel oil averaged 2.7% sulfur content in California. Residual fuel oil with sulfur content less than 1.5% was supplied and tested in California with an average 1.3% sulfur content. This lower sulfur residual fuel oil was not necessarily segregated from the rest of the residual fuel oil supplied. It is an example of how the sulfur content of a marine fuel can vary due to the crude oil origin and the refining process. The residual fuel oil in New York averaged 3% sulfur in 2004; in Seattle, residual fuel oil averaged 2% sulfur, and in San Francisco, 2.5% sulfur. The residual fuel averaged 2.2% sulfur at Port of Savanna and % sulfur in Honolulu, Hawaii.

Marine residual fuel sales for vessel bunkering in the U.S. in 2003 totaled 12.4 million tonnes.<sup>54</sup> Of that total, 26% was sold in California and 35% was sold in the West Coast, from California to Washington State. As shown in Figure 4.12, the East and Gulf Coast follow closely with 33% and 31%, respectively.

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<sup>54</sup> Energy Information Administration, Fuel Oil and Kerosene Sales, 2003, Table 11, *Sales for Transportation Use: Distillate Fuel Oil and Residual Fuel Oil*, 2003.

**Figure 4.12: U.S. Vessel Bunkering Residual Fuel Use, 2003**



### 4.3.2 Europe

An analysis by BeicipFranlab found that the average sulfur content of residual fuel oil produced in Europe is approximately 2.91% by weight.<sup>55</sup> Marine distillate fuel with 0.2% maximum sulfur content is currently supplied at European ports. Le Havre (France) and Rotterdam (the Netherlands) and were included as part of this study in order to obtain a representation of European ports.

#### *France*

Total, the world's fourth largest oil company, has the largest refining capacity in Europe, and half of the refining capacity in France.<sup>56</sup>

Residual fuel (IFO 380) averaged 2.9% sulfur content in 2004 for Le Havre. Only one marine distillate fuel with sulfur content greater than 0.2% was tested by DNV, and that fuel had a sulfur content of 0.34%. A marine distillate fuel with sulfur content below 0.2% was tested and averaged 0.16% sulfur content.

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<sup>55</sup> BeicipFranlab 2003.

<sup>56</sup> EIA, France Country Analysis Brief, April 2004. See: <http://www.eia.doe.gov/emeu/cabs/france.html>.

*The Netherlands*

The Port of Rotterdam has been the largest port in the world for decades, surpassed only in recent years by the Ports of Singapore and Shanghai. Roughly 8 to 10 million tonnes of marine fuel are sold in Rotterdam, with much of it sourced from the local refineries.<sup>57</sup> Local refineries that produce marine fuels supplied in Rotterdam<sup>58</sup> include:

- Pernis (Royal Dutch/Shell)
- NEREFECO (Netherlands Refining Co; BP-69% and Texaco-31%)
- Q-8 (Kuwait Petroleum Corporation)
- ExxonMobil (Antwerp, Belgium)

Residual fuel (IFO 380) averaged 2.8% sulfur content in 2004 for Rotterdam. The marine distillate fuel (sulfur content greater than 0.2%) tested averaged 1.1% sulfur content. The marine distillate fuel (below 0.2% sulfur content) tested averaged 0.17% sulfur content. In Rotterdam, there were more tests for higher sulfur marine distillates fuels than the lower sulfur marine distillate fuel, as compared to Le Havre. As a major bunker port, Rotterdam supplies fuel to a wide range of ocean-going vessels.

#### **4.2.3 Asia**

There were many ports of call in Asia for the vessels that call at the Ports of Los Angeles and Long Beach. The study found that although there are no current low sulfur marine fuel regulations in the area, marine gas oil can be supplied as low as 0.5% sulfur content.

*China*

According to EIA statistics, China has become the world's second largest consumer of petroleum products with a continued increase in oil demand. Oil consumption far exceeds oil production and China is dependent on oil imports. China Petrochemical Corporation (Sinopec) is the national oil refining company of China. The crude oil refining capacity in 2004 was about 4.5 million barrels per day.<sup>59</sup>

Residual fuel (IFO 380) averaged 3.1% sulfur content in 2004 for Qingdao, China. The marine distillate fuel (sulfur content greater than 0.2%) tested averaged 0.35% sulfur content. One quarter of the marine distillate tested averaged 0.12% sulfur content.

Residual fuel (IFO 380) averaged 3.3% sulfur content in 2004 for Shanghai, China. The marine distillate fuel (sulfur content greater than 0.2%) tested

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<sup>57</sup> IBIA, Port Information. See: <http://www.ibia.net/>.

<sup>58</sup> *Bunkerworld*, Rotterdam Market Survey, September 2000. See: <http://www.bunkerworld.com>.

<sup>59</sup> EIA, China Country Analysis Brief, July 2004. See: <http://www.eia.doe.gov/emeu/cabs/china.html#oil>.

averaged 0.68% sulfur content. Over 75% of the total marine distillate fuel tested averaged 0.14% sulfur content.

#### *Hong Kong*

Hong Kong does not have its own refining capacity, thus the majority of marine fuels are imported from Singapore, and also from Taiwan and South Korea. Hong Kong remains one of the world's biggest container ports. Fuel storage capacity is essentially controlled by Shell, ExxonMobil, Caltex and China Resources Petroleum and Chemical Company (CRC). Feoso and Bomin Bunker are major independent suppliers.<sup>60</sup> In 1999, around 3 million tonnes of marine fuel were sold in Hong Kong.

Residual fuel (IFO 380) averaged close to 3% sulfur content in 2004 for Hong Kong. The marine distillate fuel (>0.2% sulfur) tested averaged 0.44% sulfur content. Approximately 1% of the marine distillate tested averaged 0.18% sulfur content. According to suppliers in Hong Kong, the typical distillate fuel supplied has a sulfur content of 0.5% sulfur, but distillate fuel with 0.2% sulfur content can be supplied if requested, possibly imported from Singapore.

#### *Taiwan*

Chinese Petroleum Corporation (CPC), Taiwan's national oil company, is the dominant player in all sectors of the country's petroleum industry, including refining, with three refineries. Formosa Petrochemical Company (FPC), a subsidiary of the private Taiwanese petrochemical firm Formosa Plastics Group, operates one refinery.<sup>61</sup>

Residual fuel (IFO 380) averaged to 3.4% sulfur content in 2004 for the port of Kaohsiung, Taiwan. The marine distillate fuel (>0.2% sulfur) tested averaged 0.73% sulfur content. DNV did not test any lower sulfur (<0.2% sulfur) marine distillate fuel in 2004.

#### *South Korea*

South Korea imports all its crude oil mainly from the Persian Gulf region since it has no domestic oil reserves.<sup>62</sup> In South Korea, only refineries may be suppliers, although there are contractual means for working around this requirement.<sup>63</sup>

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<sup>60</sup> *Bunkerworld*, Hong Kong Market Report, September 2000. See: <http://www.bunkerworld.com>.

<sup>61</sup> EIA, Taiwan Country Analysis Brief, July 2004. See: <http://www.eia.doe.gov/emeu/cabs/taiwan.html>.

<sup>62</sup> EIA, South Korea Country Brief, March 2005.

<sup>63</sup> *Bunkerworld*, Korea Market Survey, September 2000. See: <http://www.bunkerworld.com>.

Four refineries<sup>64</sup> operate in Korea, including, from largest to smallest:

- SK Corporation
- LG-Caltex
- S-Oil Corporation
- Hyundai Oilbank Corporation

According to *Bunkerworld*, the Korean bunker market is the third largest in the world with 12 million tonnes per year of marine fuel sold. In 1999, the estimated market share for the main bunker ports were 51% for Busan, 16% for Ulsan, 13% for Inchon, and 11% for Kwangyang. Smaller ports had the remaining 9% of the Korean bunker market.

Residual fuel (IFO 380) averaged 3.2% sulfur content in 2004 for Korean ports. The marine distillate fuel (sulfur content greater than 0.2%) tested averaged 0.95% (9,500 ppm) sulfur content. In 2004, there was no low sulfur marine distillate (below 0.2%) or residual fuel (below 1.5%) tested, which would be a good indication that it was not available in South Korea.

### *Japan*

As of January 2004, Japan had oil refining capacity of 4.7 million barrels per day<sup>65</sup> through the following companies:

- Nippon Mitsubishi Oil
- Idemitsu Kosan Company
- Cosmo Oil
- Showa Shell Sekiyu K.K
- Japan Energy
- Tonen General Sekiyu (ExxonMobil)
- Fuji Kosan Company, Ltd.

Nippon Mitsubishi Oil, controlling 40% of the refining market in Japan, is the largest refining company in Japan, followed by Idemitsu Kosan and Cosmo Oil.<sup>66</sup> Fuji Kosan Company, Ltd. has an affiliation with Nippon Mitsubishi Oil Company.<sup>67</sup> Japan's refineries typically use feedstock produced from high sulfur Middle Eastern crude oil which generally contains greater amounts of sulfur, total aromatics, and polycyclic aromatics,<sup>68</sup> posing a greater challenge to achieve the lower the sulfur contents.

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<sup>64</sup> *Bunkerworld*, *Singapore set to benefit as Korean fuel oil exports shrink*, 29 March 2004.

<sup>65</sup> EIA, Country Analysis Brief: Japan, August 2004.

<sup>66</sup> Yahoo! Finance business center; <http://biz.yahoo.com/ic/52/52342.html>.

<sup>67</sup> Business.com Directory, accessed 7 March 2005. See:

[http://www.business.com/directory/energy\\_and\\_environment/oil\\_and\\_gas/wholesale\\_distribution\\_and\\_marketing/fuji\\_kosan\\_company%2C\\_ltd](http://www.business.com/directory/energy_and_environment/oil_and_gas/wholesale_distribution_and_marketing/fuji_kosan_company%2C_ltd).

<sup>68</sup> JPEC 2001.

According to the Japan Petroleum Institute, the refineries in Japan mainly produce marine distillate (DMB) and residual fuel (IFO 380) for the ocean-going vessels at all the ports in Japan. However, IFO 180 is normally used by coastal vessels which burn residual fuels. The five major ports in Japan include the Ports of Tokyo, Yokohama, Nagoya, Osaka and Kobe, of which all but Osaka were among the top ports of call for the Port of Los Angeles. Nagoya's total cargo throughput was 182 million tons in 2004.<sup>69</sup>

At the various Japanese ports, IFO 380 averaged from 2.8% to 3.3% sulfur content in 2004. IFO with 1.5% sulfur content or less is not widely supplied in Japan, if at all. The marine distillate fuel (sulfur content greater than 0.2%) averaged from 0.68% to 0.85% sulfur content in 2004. Marine distillate fuels with sulfur content lower than 0.2% were tested by DNV in 2004 in Japan. Approximately 47% of the marine distillate tested in Nagoya averaged less than 0.05% sulfur content. At Tokyo Bay, 8% of the marine distillate tested by DNV averaged 0.05% sulfur content.

### *Malaysia*

Malaysia's oil production continues to rise and the country exports the majority of its crude oil to markets in Japan, Thailand, South Korea, and Singapore. Malaysia has six refineries with a total processing capacity of 544,832 barrels per day, operated by three companies:<sup>70</sup>

- Shell (Port Dickson and Lutong)
- Petronas (Melaka-I, -II [Petronas-45%, Conoco-40%, Statoil-15%], and Kerteh)
- Esso (Port Dickson)

Data for the Port of Tanjung Pelapas and Port Klang was obtained. The Port of Tanjung Pelapas started operations in 1999 and is competing with Singapore and other major ports for Southeast Asia's sea freight. According to fuel suppliers in Malaysia, marine distillate fuel with maximum 0.5% sulfur is currently supplied. Malaysian suppliers do not expect to supply lower sulfur marine distillate fuel (<0.2% sulfur) until there is a high demand for it. Residual fuel (IFO 380) averaged 3.1% sulfur content in 2004 for Port Klang and 3.15% sulfur for Tanjung Pelapas. The marine distillate fuel (sulfur content greater than 0.2%) tested averaged 0.36% sulfur content. Less than 2% of the marine distillate tested averaged 0.18% sulfur content.

### *Singapore*

Singapore is the world's leading bunker port and one of the major petroleum refining centers of Asia.<sup>71</sup> According to Singapore's Maritime and Port

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<sup>69</sup> Statistics Center of Nagoya Port Authority, 22 March 2005.

<sup>70</sup> EIA, Malaysia Country Analysis Brief, January 2005. See: <http://www.eia.doe.gov/emeu/cabs/malaysia.html#oil>.

<sup>71</sup> EIA, Singapore Country Analysis Brief, May 2004. See: <http://www.eia.doe.gov/emeu/cabs/singapor.html>.

Authority (MPA), Singapore retained its position as the number one bunkering hub in the world in 2004. Singapore sells approximately 15% of the total amount of marine fuel sold annually around the world.<sup>72</sup> In 2004, Singapore's total shipping tonnage was 1,042.4 million gross tons with 21 million twenty-foot equivalent units (TEU) in container throughput,<sup>73</sup> making it one of the world's busiest ports. According to EIA, Singapore's refining capacity of nearly 1.3 million barrels per day is nearly double its rate of petroleum products consumption. Refineries in Singapore include:

- ExxonMobil
- Shell Eastern Petroleum
- Singapore Refining Corporation (SRC)
- Singapore Petroleum Company Limited
- Caltex Singapore

The marine fuel suppliers in Singapore currently supply <0.5% sulfur and <1% sulfur marine gas oil (DMA). For some suppliers, the clients have to specify the lower sulfur MGO (<0.5%) in order to receive it, while BP Singapore guarantees to supply the lower sulfur MGO (<0.5% sulfur) and distillate fuel with 0.2% sulfur content or lower can be supplied if requested. The top marine fuel suppliers by volume in Singapore for 2004 are listed below.

- BP Singapore
- Shell International Eastern Trading Co.
- Global Energy Trading
- ExxonMobil Asia Pacific
- Consort Bunkers

Petrobras, the Brazilian oil company, is also one of the low sulfur fuel oil suppliers in the Singapore market. Brazil has low sulfur crude oil and thus is in position to benefit from the low sulfur marine fuel market.<sup>74</sup> Residual fuel (IFO 380) averaged 3.12% sulfur content in 2004 for Singapore. The marine distillate fuel (>0.2% sulfur) tested averaged 0.55% sulfur content. Approximately 4% of the marine distillate tested averaged 0.12% sulfur content.

As illustrated in Figure 4.13 below, out of Singapore's 23.6 million tonnes of bunker fuel sold in 2004, 92% was residual fuel (IFO 380 and 180). MGO sales were 6%, while MDO sales were 1% of the total bunker sale.

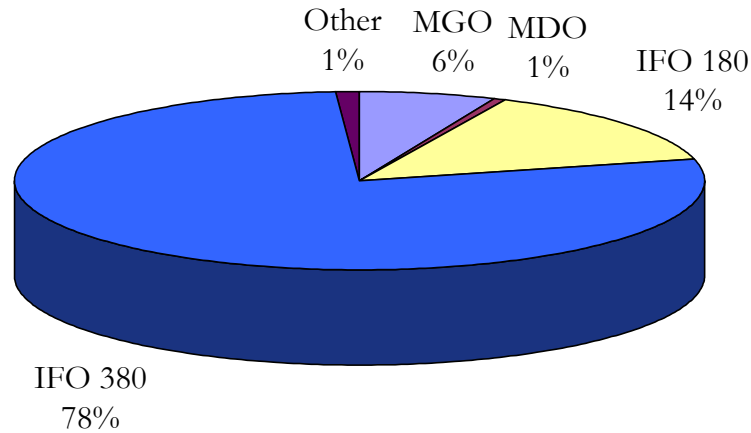
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<sup>72</sup> International Bunker Industry Association, Port information. See: <http://www.ibia.net/>.

<sup>73</sup> MPA, News Releases, *Strong Port and Maritime Performance Recorded in 2004*, 31 January 2005.

<sup>74</sup> *Bunkerworld*, *Low sulphur limits will benefit Latin American suppliers*, 10 November 2004. See: <http://www.bunkerworld.com>. (*Bunkerworld*, 10 Nov 2004)

**Figure 4.13: Singapore Bunker Sale by Fuel, 2004**



#### **4.4 Future Low Sulfur Fuel Availability**

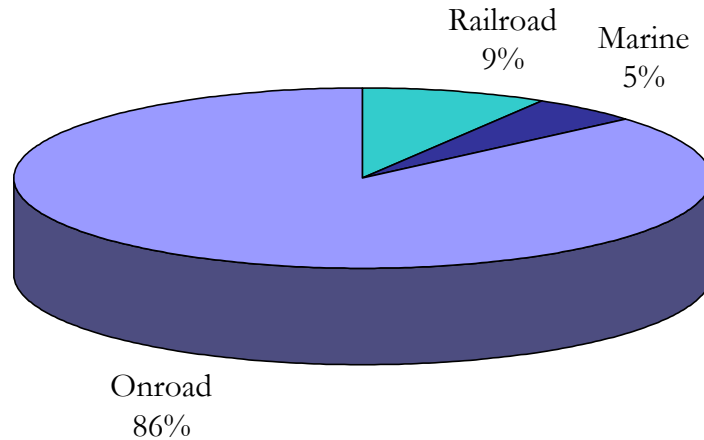
Although onroad and offroad diesel fuels do not currently meet the flashpoint requirement for ocean-going vessels as discussed in Section 2, they were included in the scope of the study as a possible future source for marine vessel fueling due to their low sulfur content and broad availability. As shown in Figure 4.14, of the total diesel fuel sold in the U.S. in 2003 for transportation purposes, 86% was sold for onroad use, 9% was sold for railroad use, while 5% was sold for marine use. Of the total 118.9 million tonnes of onroad diesel sold in 2003 in the U.S., roughly 12% was sold in California.<sup>75</sup> The in-use sulfur levels of fuels consumed in California are currently 140 ppm for CARB diesel, 340 ppm for EPA onroad diesel, and 3,200 ppm for EPA offroad diesel.<sup>76</sup>

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<sup>75</sup> EIA, Fuel Oil and Kerosene Sales, 2003, Table 11, *Sales for Transportation Use: Distillate Fuel Oil and Residual Fuel Oil*, 2003.

<sup>76</sup> ARB Hearing, 23 October 2003, Informational Item on Locomotives and Marine Vessels.

**Figure 4.14: U.S. Transportation Distillate Fuel Use, 2003**



U.S. refiners were interviewed to evaluate whether onroad and offroad diesel fuel could be produced to meet the flashpoint requirement for marine fuels. Some West Coast refineries that currently produce onroad diesel (less than 500 ppm sulfur) with the minimum flashpoint specification for onroad diesel of 125 degrees Fahrenheit (°F) could produce limited quantities of diesel fuel with 140°F (60°C) minimum flashpoint, at such time as required. After 2006, when these refineries produce the 15 ppm ULSD required by the current state and federal regulatory requirements, they could also produce limited ULSD quantities meeting the >140°F flashpoint. Again, a demand would need to be established in order to produce it and with the USLD, a study or test would need to be conducted to see how the auxiliary engines would operate with such a low sulfur diesel fuel.

Although the major marine suppliers for the Ports of Los Angeles and Long Beach currently supply the harbor craft with offroad diesel, separate storage fuel tank(s) may be required at the Port for this special batch in order not to contaminate it with diesel that has higher sulfur content and/or differing flashpoint. Procedures would also need to be set forth to test the fuel to ensure it meets all the standards. As for fuel verification, samples would need to be taken from the tanks immediately upstream of the engines to determine the actual sulfur content supplied.

Other countries, such as Japan and Singapore, provided insight into future possibilities for lower sulfur fuels. As of early 2005, automotive gas oils in Japan contain less than 10 ppm sulfur content. Although not all automotive gas oil meets the SOLAS flashpoint requirement for ocean-going vessels, some of the automotive gas oil can exceed the flashpoint of 60°C (140°F) and is supplied to any vessel requiring marine gas oil (DMA). Also, Japanese refineries produce low sulfur marine distillate (DMB, <0.1% sulfur) and residual fuels (<0.3% sulfur) for boiler applications on the land. In Japan, marine fuels conform to ISO 8217 while diesel fuel used on land conforms to Japanese Industrial Standard (JIS) K 2204 (not available in English). Singapore’s onroad diesel currently has a sulfur content of 500 ppm (0.05% sulfur). Marine fuel suppliers stated that this fuel is produced in limited quantities and may pose logistical problems to supply to the vessels, thus adding to the cost of the fuel. Possible onroad diesel sulfur contents that may become available in the future are presented in Table 4.6.

**Table 4.6: Possible Future Low Sulfur Diesel Fuel**

<b>Region</b>	<b>Onroad Diesel Sulfur Content, (ppm)</b>
North America	500
Europe	50
Asia	500

In summary, the low sulfur onroad diesels (<0.2%) studied:

- Do not currently meet the flashpoint requirement for marine fuels,
- Are produced in limited quantities in some countries,
- May prove logistically difficult to supply to vessels at some Ports,
- May be very expensive,
- May require testing on actual medium speed engines,
- May only become more widely available at Ports worldwide if required by regulation.

In light of the current EU regulations, proposed California regulations for marine fuel used on ocean-going vessels and an increased interest by other countries for lower sulfur fuel, a greater demand for 0.1% sulfur and 0.2% sulfur marine fuel may drive the availability worldwide for ocean-going vessels at major ports where use of segregated tanks and distribution economics are more likely to be feasible.