Global Trade and Fuels Assessment—Additional ECA Modeling Scenarios

United States
Environmental Protection
Agency

Global Trade and Fuels Assessment—Additional ECA Modeling Scenarios

Assessment and Standards Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

Prepared for EPA by

RTI International

and

EnSys Energy & Systems Inc.

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SECTION 1
INTRODUCTION

The U.S. Environmental Protection Agency (EPA), along with other regulatory bodies in the United States and Canada, is considering whether to designate an Emission Control Area (ECA) along the North American coastlines, as provided for by MARPOL Annex VI. This addition to the international MARPOL treaty went into effect on May 19, 2005, and was amended in October 2008. Annex VI places global limits on fuel sulfur levels and exhaust emission rates for NO_x In addition, countries participating in the treaty are also permitted to request designation of ECAs, in which ships must comply with more stringent limits on fuel sulfur levels and NO_x emissions. The Baltic and North Sea areas have already been designated as ECAs, and the effective dates of compliance in these bodies of water were 2006 and 2007, respectively. The current fuel sulfur limit in ECAs is 1.5%. This limit is reduced to 1.0% Sulfur in March 2010 and further reduced to 0.1% S in January 2015.

To evaluate possible recommendations regarding a North American ECA, EPA is performing a thorough examination of potential responses by the petroleum-refining and ocean-transport industries to such a designation, along with any resulting economic impacts. EPA contracted with RTI International to provide a foundation for these recommendations through developing the knowledge, data, and modeling capabilities needed for such an analysis; to assess technology alternatives for reducing sulfur emissions from ships; and to estimate the impact a ECA designation would have on the petroleum-refining and ocean transport industries.

Under the prior EPA contract number EP-C-05-040, the RTI, EnSys, and Navigistics team undertook an extensive analysis of the potential impacts of a U.S. ECA. That study is documented in the November 2008 report *Global Trade and Fuels Assessment—Future Trends and Effects of Requiring Clean Fuels in the Marine Sector* (U.S. Environmental Protection Agency [EPA], 2008). (Hereafter in this new report, the earlier document is referred to as the "2007 Study.") The 2007 Study was initiated in 2006 and used premises and forecasts available at that time to establish business-as-usual (BAU) outlooks, which in turn were used to establish ECA cases and costs. Since then, global energy markets and economies have seen dramatic changes.

The objective of this report is to supplement the prior work with additional analysis and refinery modeling to support EPA's ECA implementation analyses. First, RTI revised intra-ECA fuel consumption estimates to include estimates generated by Environment Canada (EC) and innocent passage of ships bound for U.S. ports in Canadian waters. The original analysis included only innocent passage of U.S.-flagged ships off the coast of British Columbia. EC provided RTI with fuel consumption estimates based on Canadian port calls. RTI included this data in the ECA fuel consumption estimates and new innocent passage estimates for U.S.-related voyages passing in Canadian waters. This revised fuel consumption demand for both the United States and Canada was supplied to EnSys for additional WORLD modeling cases.

Second, this new study and report were to reassess the potential cost and other impacts of a U.S. and Canadian ECA under updated assumptions and recognizing current uncertainty in the outlook for the world oil market and refining. The original 2007 Study analyzed scenarios against horizons of 2012 and 2020. This new 2008 study focused solely on 2020 but incorporated ECA analyses against two global projections for 2020, one based on the Energy Information Administration (EIA) *International Energy Outlook 2008* (U.S. Department of Energy [DOE], 2008) reference case and the second on the corresponding high price case. The results from additional modeling scenarios provide projections of the cost, refining, and CO_2 emissions impacts of a U.S. and Canadian ECA in the year 2020 and against two different world oil price, supply, and demand outlooks.

SECTION 2
REVIEW OF THE BUNKER FUEL DEMAND MODELING

This section discusses the demand side of the marine fuels market. The consumption forecasts in this section provide a baseline for the WORLD model, against which the shipping industry's possible response to the adoption of a U.S. or North American ECA regulation could be evaluated.

2.1 Summary of the Bunker Fuel Demand Modeling Approach

The final report, entitled *Global Trade and Fuels Assessment—Future Trends and Effects of Requiring Clean Fuels in the Marine Sector* (EPA, 2008), presents a detailed description and discussion of the bunker fuel demand modeling approach and its results. The following discussion is a summary that is presented for readers' convenience. In general, the approach used to estimate marine bunker fuel use can be described as an "activity-based" approach with a focus on the international cargo vessels that represent the majority of fuel consumption. Components of the estimation included the following:

- identifying major trade routes,
- estimating volumes of cargo of various types on each route,
- identifying types of ships serving those routes and carrying those cargoes,
- characterizing types of engines used by those ships, and
- identifying the types and estimated quantities of fuels used by those engines.

Implementing this approach involves combining information from a variety of sources: data on the existing fleet of shipping vessels from Clarksons (2005), information from Corbett and Wang (2005) and various industry sources on engine characteristics, and projections of future global trade flows from Global Insights (2005). The data on vessels and engines provide a characterization of fuel use associated with delivering a particular load of cargo, and the data on trade flows control how many times, and over what distances, these loads have to be delivered.

Estimating fuel consumption through an activity-based methodology that combines data on specific vessels with data on engine characteristics is similar to the approaches used in Corbett and Koehler (2003, 2004), Koehler (2003), Corbett and Wang (2005), and Gregory (2006). The approach in this report extends previous analyses by linking these ship data to projections of worldwide trade flows to determine the total number of trips undertaken in each year—and hence, fuel use—rather than using estimates of the number of hours a ship/engine typically runs in a year.

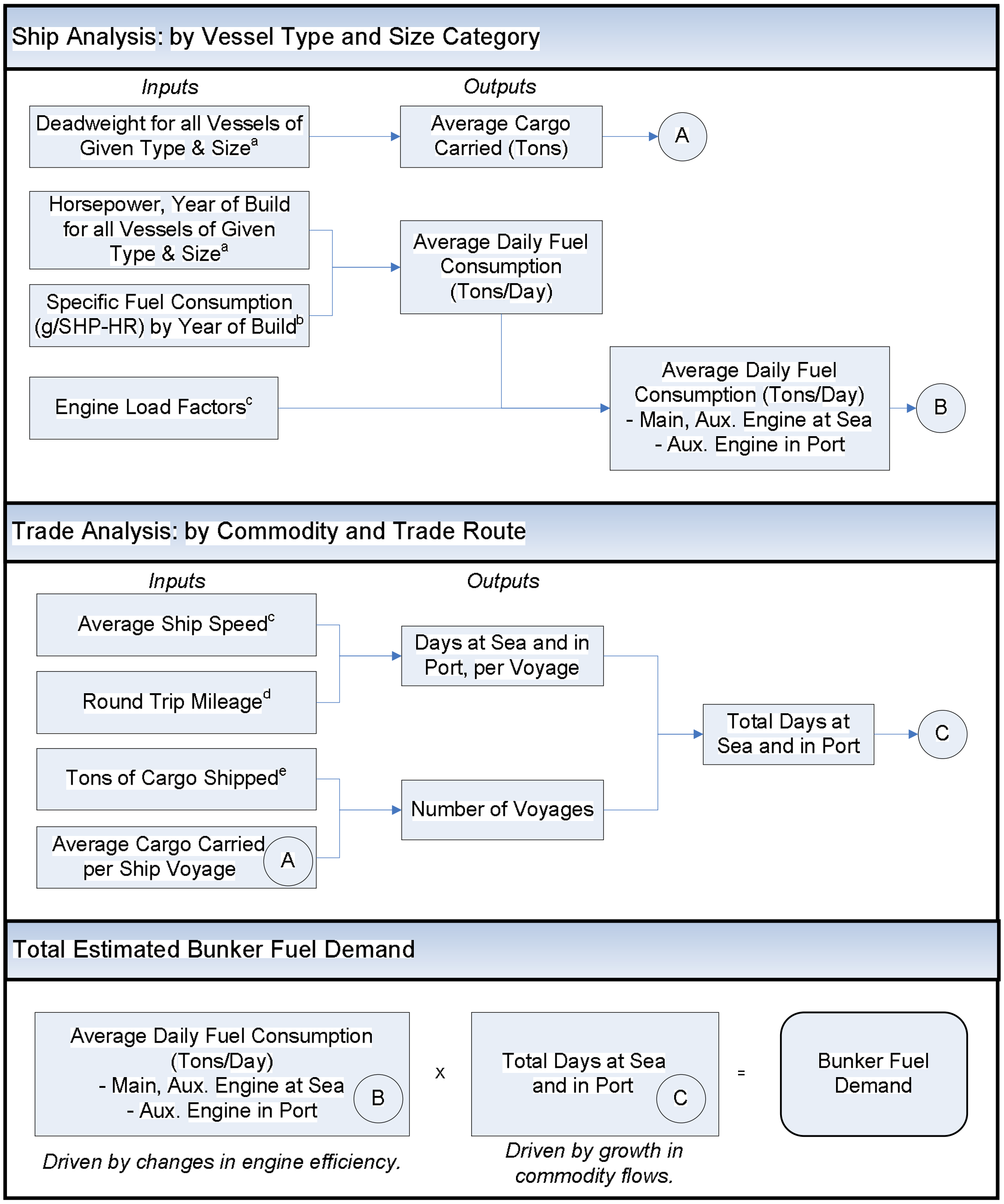
Accordingly, the model estimates fuel consumption based on an underlying economic model's projections of international trade by commodity category (Global Insights, 2005). Demand for marine fuels is derived from the demand for transportation of various types of cargoes by ship, which, in turn, is derived from the demand for commodities that are produced in one region of the world and consumed in another. The flow of commodities is matched with typical vessels for that trade (characterized according to size, engine horsepower, age, specific fuel oil consumption, and engine load factors). Next, typical voyage parameters are assigned, including average ship speed, round-trip mileage, tonnes of cargo shipped, and days in port. Fuel consumption for each trade route and commodity type thus depends on commodity projections, ship characteristics, and voyage characteristics.

Figure 2-1 illustrates the broad steps involved in developing baseline projections of marine fuel consumption. It is a multistep process that relies on data and forecasts from numerous sources, some of which are listed above, to inform the projections. The flow chart in the figure illustrates the relationships to be profiled in characterizing baseline marine fuel consumption by cargo vessels.

Also, although the focus of this analysis of bunker fuel forecasts is on projecting use by vessels carrying cargo among international ports, it includes other vessel types when estimating total demand for bunker fuels, as discussed below. These vessel types include passenger vessels, such as ferries and cruise ships; service vessels, such as tugs and offshore supply vessels (OSVs); and military vessels.

2.2 Results of Bunker Fuel Forecasts

Figure 2-2 shows estimated worldwide bunker fuel consumption by vessel type. Fuel consumption in year 2001 was equal to 278 million tonnes, which can be compared to the estimate in Corbett and Koehler (2004) of 289 million tonnes. By 2020, bunker fuel demand approaches 500 million tonnes per year. Note that the "historical" bunker fuel data shown going back to 1995 are also model estimates based on historical Global Insights trade flows. (Comparisons of these estimates with others in the literature are discussed in more detail in Section 4.2 of the 2007 Study, given their importance to the modeling of the petroleum-refining industry in the WORLD model.)



a – Clarksons Ship Register Database
b – Engine Manufacturers' Data, Technical Papers
c – Corbett and Wang (2005) "Emission Inventory Review: SECA Inventory Progress Discussion"
d - Combined trade routes and heavy leg analysis
e – Global Insight Inc. (GII) Trade Flow Projections

Figure 2-1. Method for Estimating Bunker Fuel Demand

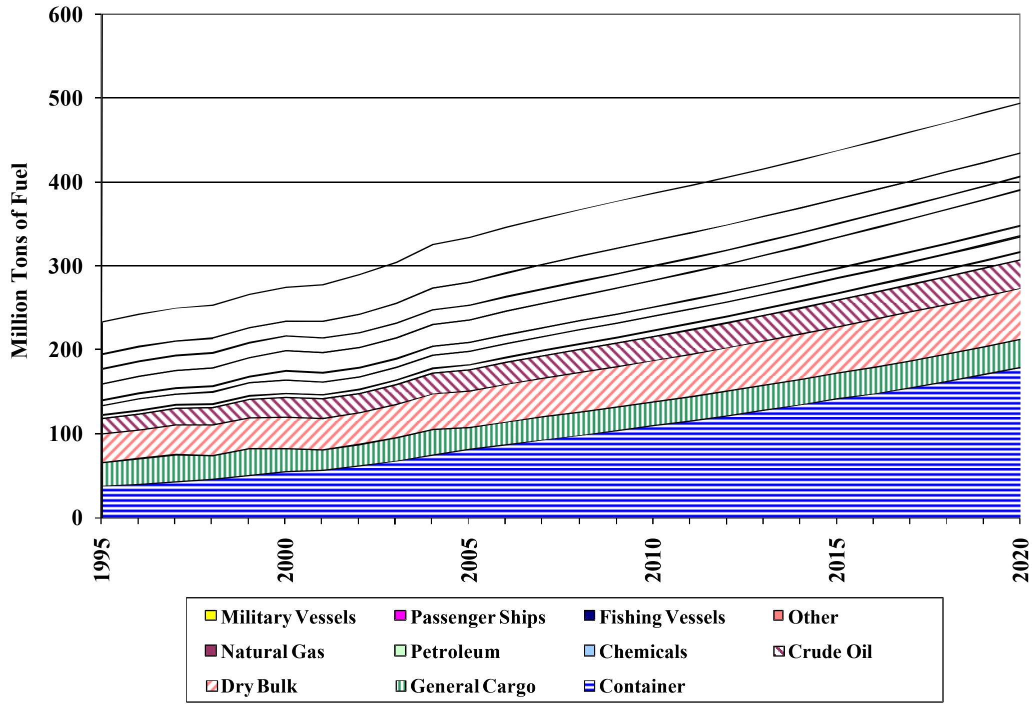


Figure 2-2. Worldwide Bunker Fuel Use

Source: Global Insights, Inc. 2005. World Trade Service. Customized Data Export.

Figure 2-3 shows the annual growth rates by vessel type/cargo that underlie the projections in Figure 2-2. The projected total annual growth is generally between 2.5% and 3.5% over the time period between 2006 and 2020 and generally declines over time, resulting in an average annual growth of around 2.6%. As shown in the "container" categories in Figures 2-2 and 2-3, fuel consumption by container ships is the fastest-growing component of worldwide bunker fuel demand; in 2004, consumption by container ships was around 75 million tonnes, growing to 87 million tonnes by 2006 and close to 180 million tonnes by 2020. (The historical estimates can be compared to Gregory [2006], which places container-ship consumption in 2004 at 85 million tonnes, based on installed power.) While overall growth is less than 3% per year, growth in container-ship demand remains above 5% per year on an average annual basis for the next 15 years. Across all vessel types, growth in bunker fuel consumption is somewhat lower than the worldwide GDP growth forecasts from EIA (*International Energy Outlook 2005* [DOE, 2005]) of around 3.9% per year but higher than International Energy Agency (IEA) estimates of overall fuel consumption growth (around 1.6% in the *World Energy Outlook 2005*). Demand estimates reflect the long-term outlook based on forecasted needs and not short-term economic scenarios. The estimated growth in marine bunker demand over the next 15 yearsIis consistent with the historical growth rate of 2.7% per year observed in IEA data between 1983 and 2003.

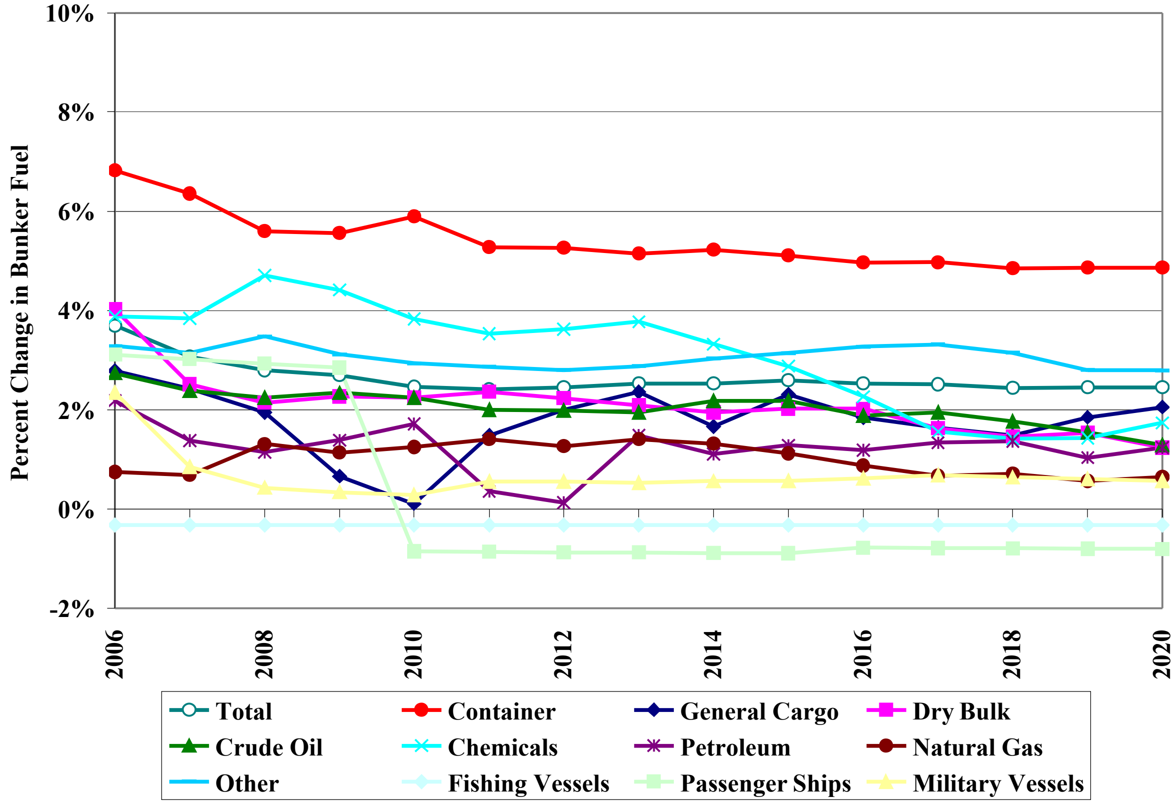


Figure 2-3. Annual Growth Rate in Worldwide Bunker Fuel Use

Source: Global Insights, Inc. 2005. World Trade Service. Customized Data Export.

Growth in fuel use by container ships and the overall contribution by these vessels to worldwide demand are driven by several factors. The first is overall growth in worldwide GDP mentioned above. This growth leads to increases in international trade flows over time (shown in Figures 2-4 and 2-5). These figures illustrate that, although container trade is smaller in total volume than other categories, it is the fastest-growing component of the trade flows. Measuring trade flows in tonnes of goods, as shown in Figure 2-4, also does not provide a good proxy for the fuel consumption needed to transport the goods. Liquids and dry bulk are much denser than container goods, for example. It is estimated that utilization rates for container ships (comparing deadweight tonnes of capacity to actual cargo transported) are around 50%. Thus, it takes approximately twice as many ships to transport the same amount of container tonnes compared to liquid/dry bulk tonnes. This relationship tends to influence total bunker fuel use and weight it toward container trade. In addition, growth rates in particular trade flows, such as Asia to the United States, will also influence overall fuel consumption, especially as related to container ships, as discussed below in relation to U.S. regional trade flows.

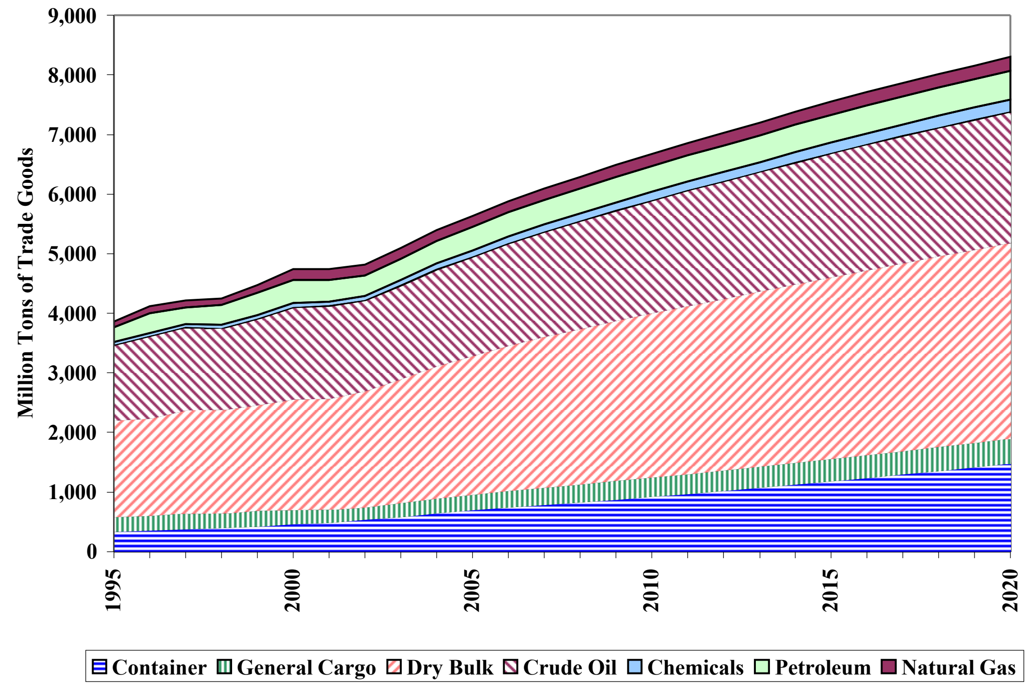


Figure 2-4. Worldwide Trade Flows

Source: Global Insights, Inc. 2005. World Trade Service. Customized Data Export.

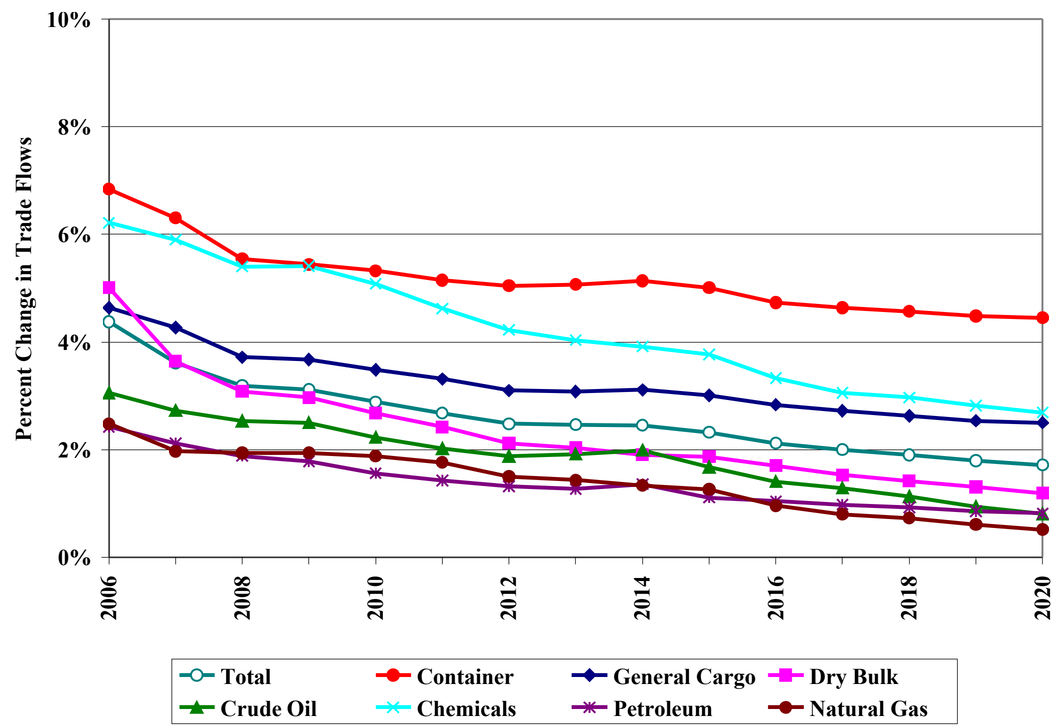


Figure 2-5. Annual Growth Rate in Worldwide Trade Flows

Source: Global Insights, Inc. 2005. World Trade Service. Customized Data Export.

Figures 2-6 through 2-8 show estimated consumption of specific grades of bunker fuels from Figure 2-2.

Figures 2-9 through 2-12 present estimates of fuel use by the international cargo fleet engaged in delivering trade goods to and exporting trade goods from the United States. These estimates comprise part of the total worldwide bunker fuel use shown in Figure 2-2 and do not include fuel used for domestic navigation. The results in Figure 2-9 show estimated historical bunker fuel use in year 2001 of around 47 million tonnes. (Note that, while this fuel is used to carry trade goods to and from the United States, it is not necessarily all purchased in the United States and is not all burned in U.S. waters.) This amount grows to over 90 million tonnes by 2020, with the most growth occurring on trade routes from the East Coast and the "South Pacific" region of the West Coast.

Figure 2-10 shows the annual growth rate projections for the fuel consumption estimates in Figure 2-9. The South Pacific and East Coast regions of the United States are growing the fastest, largely as the result of container ship trade (see Figures 2-11 and 2-12). Overall, the average annual growth rate in marine bunkers associated with future U.S. trade flows is 3.4% between 2005 and 2020. This growth rate is somewhat higher than worldwide totals but is similar to estimated GDP growth in the United States of 3.1% between 2005 and 2020 (DOE, 2006) and is influenced by particular components of U.S. trade flows.

The projected growth rate in bunker fuel consumption related to U.S. imports and exports is driven by container ship trade (see Figures 2-13 and 2-14), which grows by more than 4% per year. U.S. trade volumes are also influenced by high worldwide growth in GDP and resulting demand for U.S. goods. Along with the fact that container ships use a disproportionately large amount of fuel to move a given number of tonnes of cargo, fuel use by container ships is also influenced by shifts in trading routes over time. In the future, trade is expected to shift to the Pacific region (an increase in Asia-U.S. routes), which causes the average distance per voyage to increase. Thus, while ship efficiency is increasing over time as older ships retire, this effect is dominated by the increase in voyage distance, leading to higher bunker fuel growth.

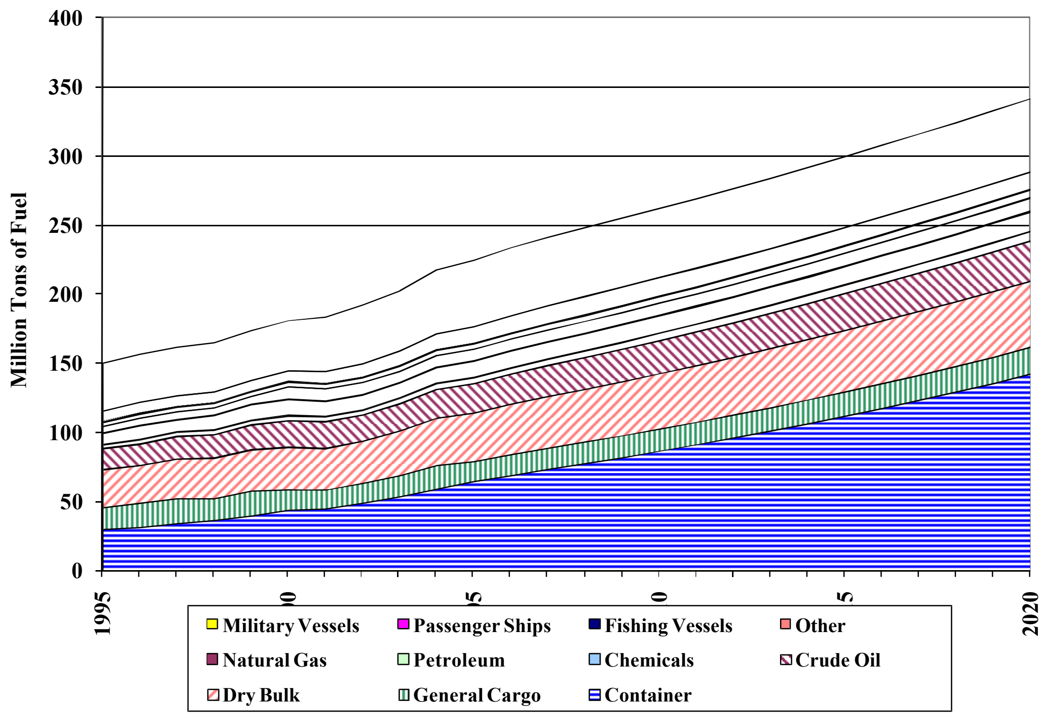


Figure 2-6. Worldwide IFO380 Use

Source: Global Insights, Inc. 2005. World Trade Service. Customized Data Export.

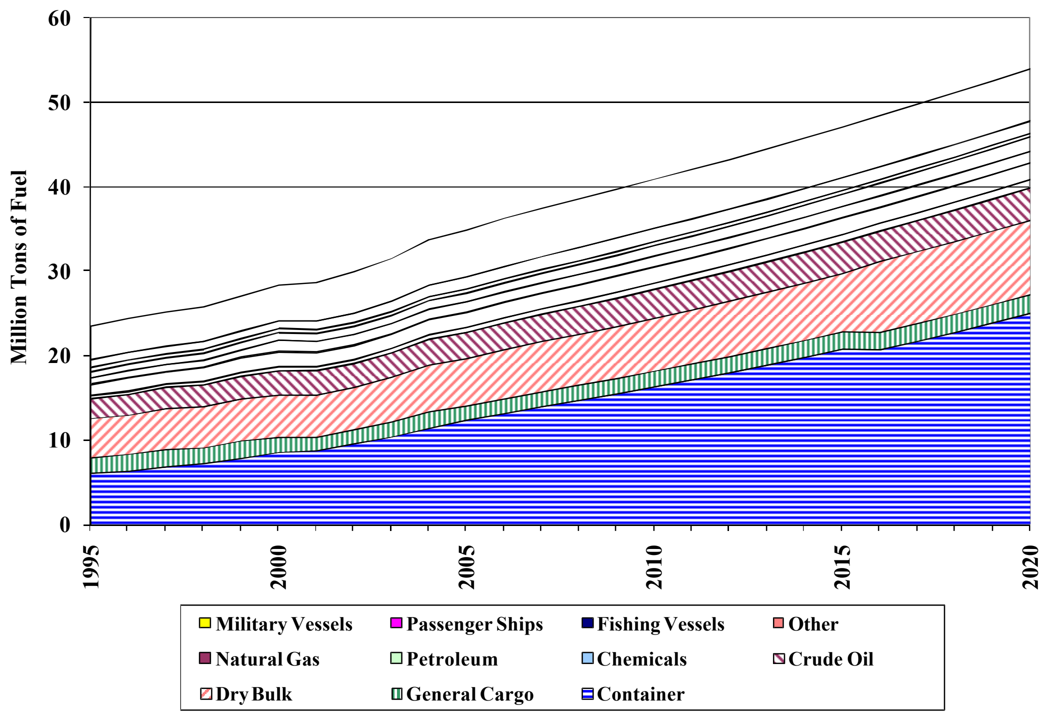


Figure 2-7. Worldwide IFO180 Use

Source: Global Insights, Inc. 2005. World Trade Service. Customized Data Export.

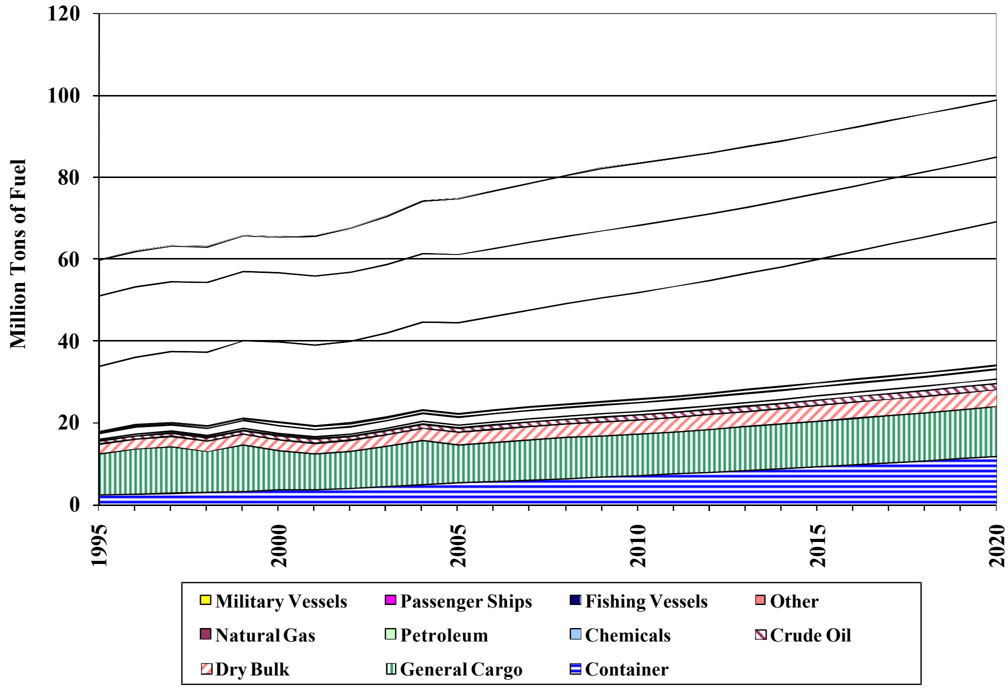


Figure 2-8. Worldwide MDO-MGO Use

Source: Global Insights, Inc. 2005. World Trade Service. Customized Data Export.

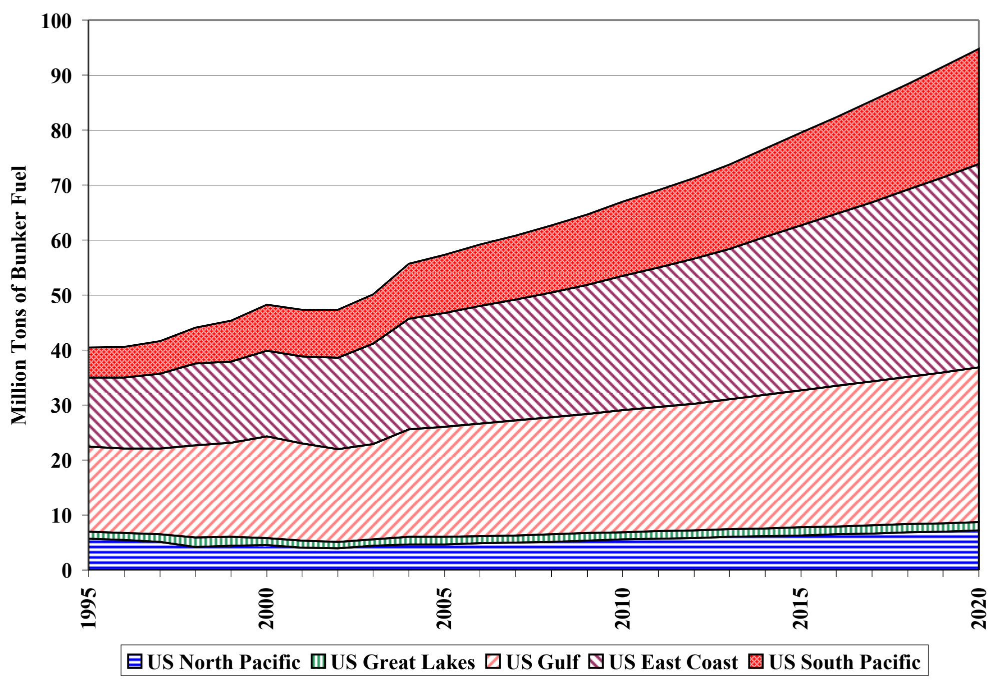


Figure 2-9. Bunker Fuel Used by the International Cargo Fleet Importing to and Exporting From the United States (by Region)

Source: Global Insights, Inc. 2005. World Trade Service. Customized Data Export.

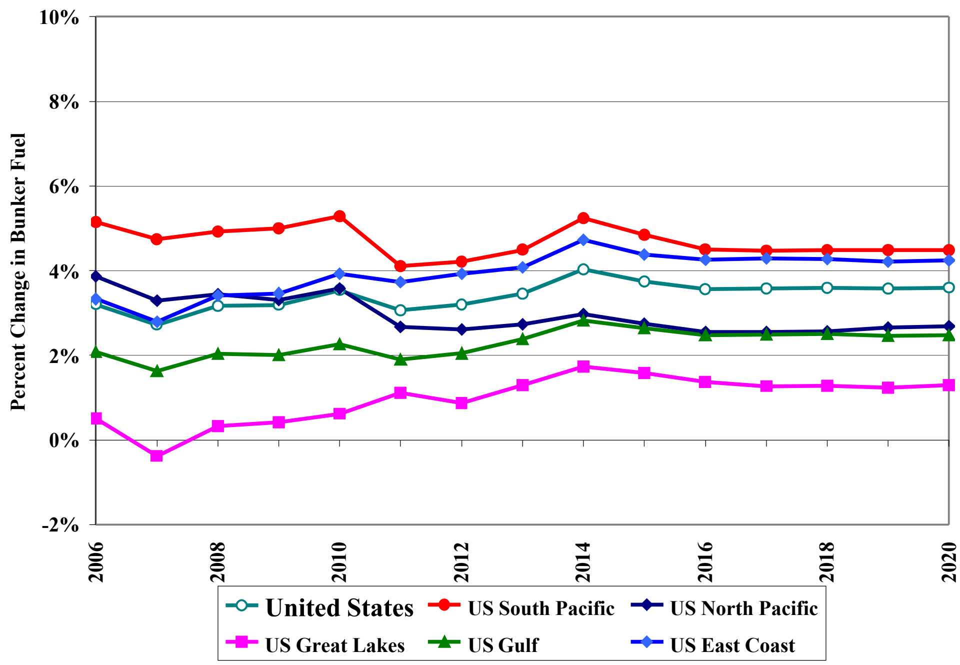


Figure 2-10. Annual Growth Rate in Bunker Fuel Used by the International Cargo Fleet Importing to and Exporting from the United States (by Region)

Source: Global Insights, Inc. 2005. World Trade Service. Customized Data Export.

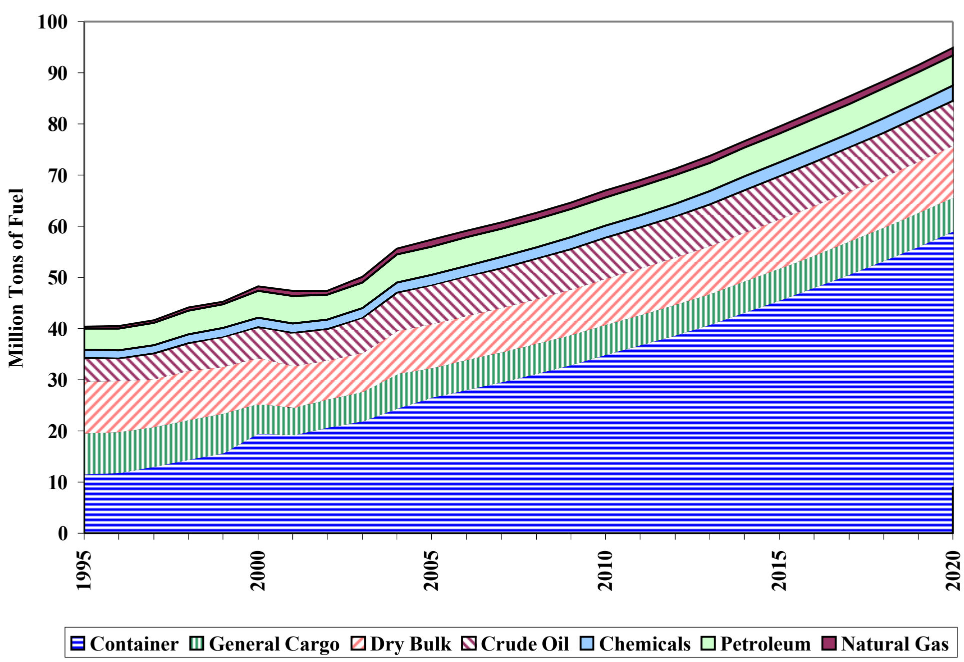


Figure 2-11. Bunker Fuel Used by the International Cargo Fleet Importing to and Exporting from the United States (by Vessel/Cargo Type)

Source: Global Insights, Inc. 2005. World Trade Service. Customized Data Export.

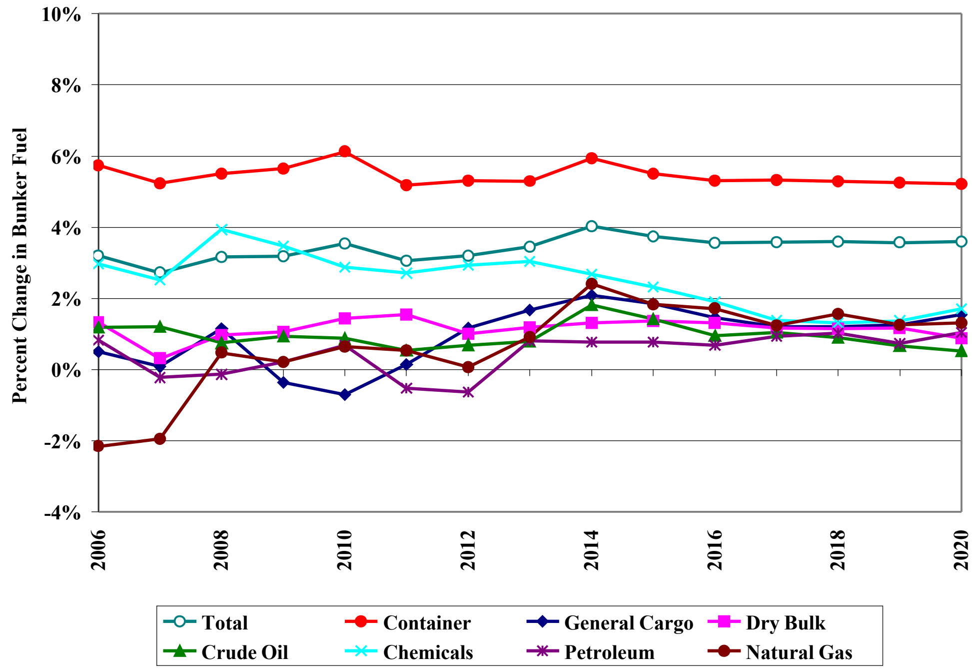


Figure 2-12. Annual Growth Rate in Bunker Fuel Used by the International Cargo Fleet Importing to and Exporting from the United States (by Vessel/Cargo Type)

Source: Global Insights, Inc. 2005. World Trade Service. Customized Data Export.

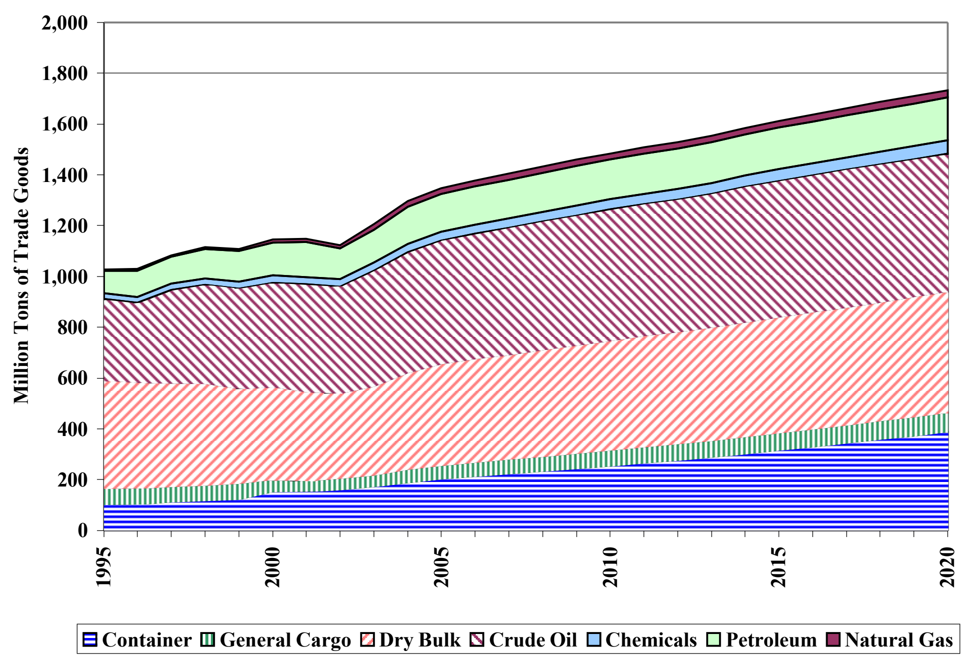


Figure 2-13. U.S. Trade Flows—Imports Plus Exports

Source: Global Insights, Inc. 2005. World Trade Service. Customized Data Export.

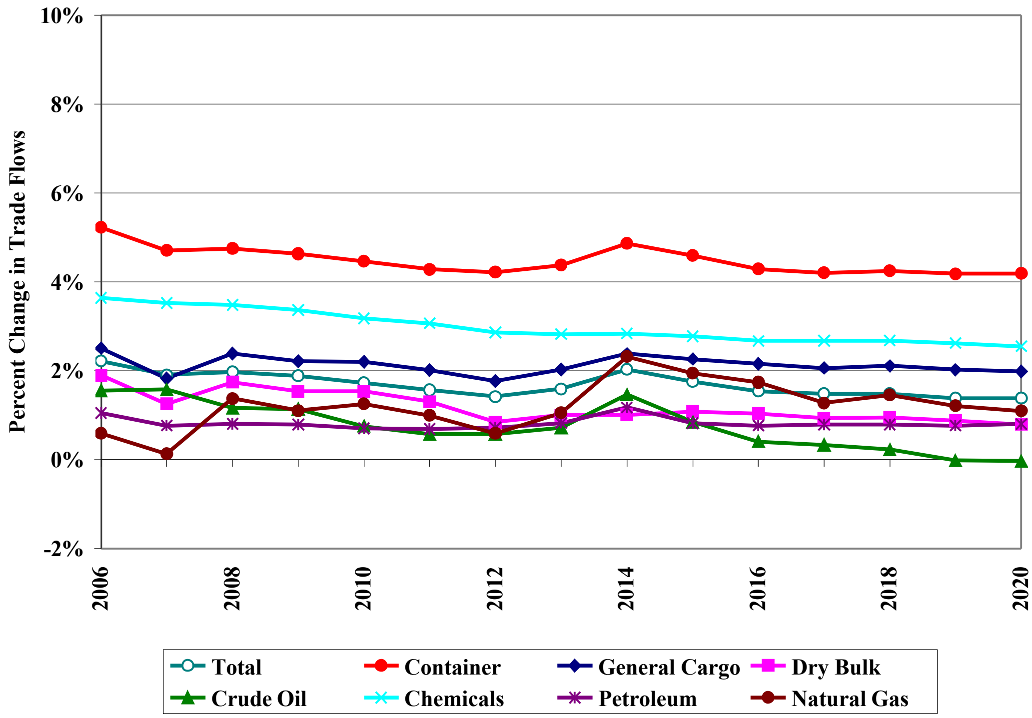


Figure 2-14. Annual Growth in U.S. Trade Flows—Imports Plus Exports

Source: Global Insights, Inc. 2005. World Trade Service. Customized Data Export.

SECTION 3
U.S. AND CANADIAN ECA FUEL DEMAND ESTIMATES

This section details combined fuel demand estimates for a potential U.S. and Canadian ECA. RTI's original ECA fuel demand estimates were combined with data from Environment Canada (EC) and were augmented with additional fuel demand modeling results for innocent passage of U.S.-related voyages in Canadian waters.

3.1 Summary of Original ECA Fuel Demand Modeling Approach

In general, estimating the amount of bunker fuel consumed within ECA boundaries involved reviewing U.S.-related trade routes, estimating whether and to what extent ships would alter their routing to minimize travel within the ECA, and calculating the volume of fuel consumed within the ECA boundaries. As such, the primary input for the ECA fuel consumption analysis was the time series of bunker fuel consumption from Section 2 disaggregated by route and by commodity type. The discussion in this section does not reiterate the activity-based methodology for developing the time-series data; rather, this discussion focuses on how fuel consumption in U.S. trading routes was apportioned to the ECA.

Key steps in the ECA fuel consumption analysis included the following:

- isolating the trading routes, voyage characteristics, and fuel consumption estimates for U.S.-related shipping activity;
- calculating the distance traveled within the ECA boundaries for each route;
- estimating whether ships would adjust routing to optimize time spent within the ECA;
- calculating the number of days each voyage spent in U.S. ports; and
- apportioning estimated intra-ECA fuel consumption estimates by major U.S. ECA zones by reviewing the distance each voyage traveled within the zones.

There are five distinct regions for which fuel consumption estimates were generated, as established by the U.S. coastline:

- North Pacific, including the Alaskan Coast from Kodiak Island east and south to the Oregon-California land border;
- South Pacific, including all U.S. waters off the coast of California;
- Gulf Coast, covering U.S. waters from Brownsville, Texas, to the Florida Keys;
- East Coast, encompassing U.S. waters from the Florida Keys and the Straits of Florida to Maine; and
- Great Lakes, including all of Lake Michigan and U.S. waters of the other four lakes up through the end of the U.S. portion of the St. Lawrence River at Cornwall Island.

EPA requested that RTI provide fuel consumption estimates for a potential ECA in which the outer ECA boundary is set at 200 nm off the Pacific, East, and Gulf Coasts. The potential ECA modeled in this effort included the following characteristics:

- The ECA boundary in the North Pacific is just east of Kodiak Island, Alaska; the Bering Sea and U.S. territorial waters established by the Aleutian Islands are excluded from the ECA.
- Western Canadian waters are assumed to be part of the ECA; innocent passage of U.S.-related voyages (i.e., commodities, containers, Jones Act, and other vessels) in Western Canadian waters is included in the U.S. North Pacific ECA fuel consumption estimates.
- U.S. territorial waters in the Great Lakes are included in the ECA.
- U.S. territorial waters established by Hawaii are excluded from the ECA scenarios.
- U.S. territorial waters established by overseas territories and protectorates are excluded from the ECA, with the exception of Puerto Rico, which is included in the East Coast estimates.

In brief, RTI and Navigistics reviewed the industry-standard distance, voyage time, and routing information employed in the global fuel consumption analysis to identify distance traveled within the ECA. We used the ratio of distance traveled in ECAs to total distance traveled to apportion global at-sea fuel consumption estimates. We derived estimates of port fuel consumption in the United States by reviewing the ports of call and assigning relevant in-port fuel consumption to the ECA.

3.2 Original ECA Fuel Demand Estimates for 2020

It is estimated that in 2020, international trading ships will consume 10.7 million tonnes of fuel within the modeled ECA boundary (Table 3-1). Including domestic ships, it is estimated that total ECA fuel consumption will amount to 16.2 million tonnes (Table 3-2).

3.3 Inclusion of Environment Canada's 2020 Fuel Demand Estimates and Innocent Passage of U.S.-Related Voyages in Canadian Waters

EC supplied EPA and RTI with results from its own fuel demand analyses for 2020 for operation within 200 nm of Canada's coasts. In consultation with EC, RTI converted EC's fuel demand estimates from megalitres to tonnes assuming that the distribution of fuel grades and average ship fuel consumption patterns for voyages in U.S. waters were the same as those in Canadian waters.

Table 3-1. 2020 ECA Fuel Demand Estimates, International Trading Ships

Commodity Group	Region	IFO380 (thousand tonnes)	IFO180 (thousand tonnes)	MDO/MGO (thousand tonnes)	Total (thousand tonnes)
International commodities trade	U.S.-Great Lakes	98	33	17	149
	U.S.-Gulf	1,528	358	190	2,076
	U.S.-North Pacific	121	45	28	194
	U.S.-South Pacific	141	51	41	233
	U.S.-East	748	207	159	1,114
	ECA subtotal	2,636	693	435	3,765
International container trade	U.S.-Great Lakes				
	U.S.-Gulf	630	222	61	914
	U.S.-North Pacific	573	183	54	810
	U.S.-South Pacific	1,089	514	115	1,719
	U.S.-East	2,335	884	231	3,451
	ECA subtotal	4,627	1,804	462	6,893
International trade subtotal	U.S.-Great Lakes	98	33	17	149
	U.S.-Gulf	2,159	580	251	2,989
	U.S.-North Pacific	694	228	82	1,004
	U.S.-South Pacific	1,230	565	156	1,952
	U.S.-East	3,083	1,091	390	4,564
	ECA subtotal	7,264	2,497	897	10,658

Source: Authors' calculations.

Table 3-2. 2020 ECA Fuel Demand Estimates, All Ships

Commodity Group	Region	IFO380 (thousand tonnes)	IFO180 (thousand tonnes)	MDO/MGO (thousand tonnes)	Total (thousand tonnes)
International trade subtotal	U.S.-Great Lakes	98	33	17	149
	U.S.-Gulf	2,159	580	251	2,989
	U.S.-North Pacific	694	228	82	1,004
	U.S.-South Pacific	1,230	565	156	1,952
	U.S.-East	3,083	1,091	390	4,564
	ECA subtotal	7,264	2,497	897	10,658
Domestic fleet (Jones Act and other vessels)	U.S.-Great Lakes	129	61	252	443
	U.S.-Gulf	707	107	401	1,214
	U.S.-North Pacific	578	119	722	1,419
	U.S.-South Pacific	369	71	607	1,046
	U.S.-East	557	90	746	1,393
	ECA subtotal	2,340	448	2,727	5,515
Total ECA	U.S.-Great Lakes	227	95	270	592
	U.S.-Gulf	2,865	687	651	4,203
	U.S.-North Pacific	1,272	347	804	2,423
	U.S.-South Pacific	1,599	636	763	2,998
	U.S.-East	3,639	1,181	1,136	5,957
	ECA total	9,603	2,945	3,624	16,173

Source: Authors' calculations.

RTI also modeled fuel consumption for innocent passage of U.S.-related voyages in Canadian waters because EC's analysis, which was based on port call data, did not capture this fuel demand. In essence, per the methodology in Section 3.1, the distance traveled in the modeled ECA for U.S. routes passing through Canadian waters was expanded and the incremental demand was grouped into EC's categories: Canada-East, Canada-West, and Canada-Great Lakes. Table 3-3 presents the summary fuel demand estimates for the modeled Canadian ECA in 2020. (The Saint Lawrence Seaway was assigned to Canada-East.)

Table 3-3. 2020 Canadian ECA Fuel Demand Estimates, All Ships (Including Innocent Passage of U.S.-Related Voyages)

	Region	IFO380 (thousand tonnes)	IFO180 (thousand tonnes)	MDO/MGO (thousand tonnes)	Total (thousand tonnes)
Canadian ECA (incl. innocent passage of U.S.-related voyages)	Canada-East	1,415	327	361	2,103
	Canada-Great Lakes	113	32	111	256
	Canada-West	864	284	76	1,223
	Total	2,392	642	548	3,583

Source: Environment Canada and authors' calculations.

3.4 2020 Fuel Demand Estimates for the United States and Canada

Table 3-4 presents the combined fuel demand estimates for the United States and Canada that were inputted into the additional WORLD modeling cases presented in the following chapters. Total fuel demand for the modeled ECA was estimated at 19,755 thousand tonnes.

Table 3-4. 2020 ECA Fuel Demand Estimates, All Ships, United States and Canada

	Region	IFO380 (thousand tonnes)	IFO180 (thousand tonnes)	MDO/MGO (thousand tonnes)	Total (thousand tonnes)
U.S. ECA	U.S.-Great Lakes	227	95	270	592
	U.S.-Gulf	2,865	687	651	4,203
	U.S.-North Pacific	1,272	347	804	2,423
	U.S.-South Pacific	1,599	636	763	2,998
	U.S.-East	3,639	1,181	1,136	5,957
	U.S. subtotal	9,603	2,945	3,624	16,173
Canadian ECA	Canada-East	1,415	327	361	2,103
	Canada-Great Lakes	113	32	111	256
	Canada-West	864	284	76	1,223
	Canada subtotal	2,392	642	548	3,583
United States and Canada		**11,996**	**3,587**	**4,172**	**19,755**

Source: Authors' calculations.

SECTION 4
REVISED BUSINESS-AS-USUAL WORLD MODEL CASES

The 2007 Study included extensive modifications to the WORLD model and then its application to BAU and ECA cases for 2012 and 2020. The purpose of these modifications was to create the ability to model ECA-type scenarios and to include the most recent information available in terms of both bunker fuel demand projections as developed by the RTI team and global oil outlook. The cases were based on the EIA *Annual Energy Outlook 2006* reference case for overall world oil price, supply, demand outlook and regional summaries. The 2008 Study relied on EIA's *International Energy Outlook 2008* (DOE, 2008). Two scenarios were developed, one based on the IEO reference case and the second on the high price case. The WORLD modifications made for the 2007 Study are briefly summarized below, followed by discussion of the specific premises used as the basis for the 2020 BAU cases.

4.1 WORLD Model Enhancements

WORLD is a comprehensive, bottom-up model of the global oil downstream that includes crude and noncrude supplies; refining operations and investments; the trading and transport of crude, products, and intermediates; and product blending/quality and demand. Its detailed simulations are capable of estimating how the global system can be expected to operate under a wide range of different circumstances, generating model outputs, such as price effects and projections of refinery operations and investments. As a key component of the 2007 Study, a series of upgrades was made. These were fully documented in the 2007 Study Report. They included the following:

- A major expansion of the detail with which WORLD represents marine bunker fuels, their demand, types, specifications, and blending
- Building in the ability within WORLD to switch between "IEA" and "RTI" bases for bunker fuel demand. The RTI basis has now essentially been adopted by the International Maritime Organization (IMO), as IMO's own projections are very close to those developed by RTI and Navigistics under the 2007 Study. The RTI projections essentially double the demand volume for bunker fuels versus that which is reported by the IEA. The view was taken in both the 2007 Study and 2008 Study that current low reported bunker demand represents a misreporting of fuel rather than missing barrels.
- A detailed review of actual marine bunker grades and qualities in the marketplace, based in part on then-parallel EnSys and Navigistics assignments for the American Petroleum Institute (API) and IMO

- Enhancements to the model to address issues related to bunker fuel stability, leading to processing constraints and to limits on the levels of certain component streams that could be blended into IFO bunker grades
- Enhancements to the model, first added under work for API, to compute refinery emissions of CO_2, based on refining operations and fuels, and the emissions from combustion of marine fuels, based on their type. This feature enabled potential reductions in CO_2 emissions, resulting primarily from switching to marine distillates from IFO, to be compared with the CO_2 emissions increases resulting from the additional refinery processing required to produce lower sulfur marine fuels and to convert heavy IFO fuels to distillate grades.

In addition, procedures have been embodied into the model to enable iteration on results so that there is close convergence between the assumed (input) and produced (output) gravities for marine fuels. This is necessary because marine fuel demands are defined in tonnes.

4.2 WORLD Model Revised Assumptions

4.2.1 IEO 2008 Outlook—Supply/Demand/Price Basis

Since the 2007 Study, we have revised the WORLD model, primarily to make use of new information available from the EIA. Overall oil supply, demand, and price parameters were set in the model based, on the International Energy Outlook (IEO) 2008 reference and high price cases. Key information from these projections is summarized in Tables 4-1 through 4-6 and in Figure 4-1. These exhibits show the marked difference between the two scenarios. Under the reference case, global total oil demand is projected to rise from 84.3 million barrels per day (bpd) in 2005 to 101.3 million bpd in 2020, a rise of 16 million bpd. In the high price case, 2020 demand is projected at 91.7 million bpd, 9.6 million bpd lower than under the reference case. Equally significant, the increase in demand versus 2005 is cut to 7.4 million bpd, half that of the reference case.

The two scenarios represent appreciably different views of how the world's oil sector, economics, policies, and oil intensity could evolve. Under the reference case (Figure 4-1), prices for light sweet crude oil follow a relatively flat profile and are at $(2006) 60/barrel (bbl) in 2020. Under the high price case, they maintain an update trajectory and are at $(2006) 102/bbl by 2020. Nominal prices will be higher. Associated with this, and driven also by policy initiatives, oil demand growth in Organisation for Economic Co-operation and Development (OECD) regions is low in the reference case (0.3% per year average from 2005 through 2030) and slightly negative (- 0.1% per year) under the high price case. Under both scenarios, the oil demand growth takes place in non-OECD regions. What varies is the rate of growth: 2.2% per year

Table 4-1. IEO 2008 World Total Liquids Production, by Region and Country, Reference Case, 1990–2030 (Million Barrels Oil Equivalent per Day)

Region/Country	History 1990	History 2005	Projections 2010	Projections 2020	Projections 2030	Average Annual Percentage Change, 2005–2030
OPEC	**25.2**	**36.1**	**37.4**	**44.4**	**49.3**	**1.3**
Asia (Indonesia)	**1.5**	**1.1**	**0.9**	**0.9**	**1.0**	**- 0.7**
Middle East	**16.1**	**23.8**	**23.7**	**28.8**	**31.8**	**1.2**
Iran	3.1	4.2	4.1	4.0	4.5	0.2
Iraq	2.1	1.9	2.0	3.4	4.0	3.1
Kuwait	1.2	2.7	2.6	3.0	3.3	0.9
Qatar	0.4	1.1	1.6	2.7	3.2	4.3
Saudi Arabia	7.0	11.1	10.5	12.6	13.7	0.8
United Arab Emirates	2.3	2.8	2.9	3.0	3.1	0.3
North Africa	**2.7**	**3.8**	**4.7**	**5.1**	**5.8**	**1.7**
Algeria	1.3	2.1	2.7	3.4	4.0	2.6
Libya	1.4	1.7	2.0	1.8	1.7	0.1
West Africa	**2.3**	**3.9**	**5.1**	**5.9**	**6.7**	**2.2**
Angola	0.5	1.3	2.5	2.8	3.1	3.7
Nigeria	1.8	2.6	2.6	3.1	3.5	1.2
South America	**2.5**	**3.4**	**3.0**	**3.6**	**4.1**	**0.8**
Ecuador	0.3	0.5	0.4	0.5	0.6	0.5
Venezuela	2.3	2.9	2.5	3.1	3.5	0.9
Non-OPEC	**41.1**	**48.2**	**51.8**	**57.0**	**63.2**	**1.1**
OECD	**20.0**	**21.8**	**21.5**	**21.5**	**22.3**	**0.1**
OECD North America	**14.7**	**15.1**	**16.2**	**17.2**	**18.0**	**0.7**
United States	9.7	8.2	9.4	10.2	9.8	0.7
Canada	2.0	3.1	3.8	4.6	5.3	2.2
Mexico	3.0	3.8	3.0	2.4	2.8	- 1.1
OECD Europe	**4.5**	**5.9**	**4.5**	**3.5**	**3.4**	**- 2.1**
OECD Asia	**0.8**	**0.7**	**0.8**	**0.8**	**0.9**	**0.8**
Japan	0.1	0.1	0.1	0.2	0.2	1.4
South Korea	0.0	0.0	0.0	0.0	0.1	5.8
Australia and New Zealand	0.7	0.6	0.6	0.6	0.7	0.4
Non-OECD	**21.1**	**26.5**	**30.3**	**35.5**	**40.9**	**1.8**
Non-OECD Europe and Eurasia	**11.6**	**11.9**	**14.0**	**16.8**	**18.9**	**1.8**
Russia	10.1	9.5	10.2	12.1	13.5	1.4
Caspian area	1.1	2.1	3.5	4.5	5.1	3.6
Other	0.4	0.3	0.3	0.2	0.3	- 0.9
Non-OECD Asia	**4.4**	**6.5**	**6.9**	**7.4**	**7.7**	**0.7**
China	2.8	3.7	3.8	4.0	4.1	0.4
India	0.7	0.8	1.1	1.2	1.3	1.8
Other	1.0	1.9	2.0	2.2	2.3	0.7
Middle East (Non-OPEC)	**1.3**	**1.7**	**1.5**	**1.5**	**1.6**	**- 0.2**
Africa	**1.7**	**2.6**	**3.0**	**3.7**	**4.5**	**2.3**
Central and South America	**2.1**	**3.8**	**4.9**	**6.0**	**8.2**	**3.1**
Brazil	0.8	1.9	3.2	4.3	5.7	4.4
Other	1.3	1.8	1.7	1.7	2.5	1.2
Total World	**66.3**	**84.3**	**89.2**	**101.3**	**112.5**	**1.2**

Table 4-2. IEO 2008 World Unconventional Liquids Production, by Region and Country, Reference Case, 1990–2030 (Million Barrels Oil Equivalent per Day)

Region/Country	History 1990	History 2005	Projections 2010	Projections 2020	Projections 2030	Average Annual Percentage Change, 2005–2030
OPEC	**0.0**	**0.8**	**0.9**	**1.3**	**1.6**	**3.1**
Biofuels	0.0	0.0	0.0	0.0	0.0	—
Ultra-heavy oil (Venezuela)	0.0	0.6	0.9	1.0	1.3	3.0
Coal-to-liquids	0.0	0.0	0.0	0.0	0.0	—
Gas-to-liquids (primarily Qatar)	0.0	0.0	0.0	0.2	0.3	—
Non-OPEC	**0.6**	**1.7**	**3.6**	**6.1**	**8.1**	**6.4**
OECD	**0.5**	**1.5**	**2.7**	**4.7**	**6.1**	**5.9**
Biofuels	0.0	0.2	0.6	1.0	1.4	7.7
Oil sands/bitumen (Canada)	0.4	1.1	1.9	3.3	4.2	5.5
Ultra-heavy Oil (Mexico)	0.0	0.0	0.0	0.0	0.1	—
Coal-to-liquids	0.0	0.0	0.0	0.2	0.3	25.0
Gas-to-liquids	0.0	0.0	0.0	0.0	0.0	—
Shale oil	0.0	0.0	0.0	0.0	0.0	—
Non-OECD	**0.1**	**0.2**	**0.9**	**1.4**	**2.0**	**8.7**
Biofuels	0.1	0.3	0.6	1.0	1.3	5.7
Ultra-heavy oil	0.0	0.0	0.0	0.0	0.0	—
Coal-to-liquids	0.1	0.1	0.2	0.3	0.7	6.7
Gas-to-liquids	0.0	0.0	0.1	0.1	0.1	—
Shale oil	0.0	0.0	0.0	0.0	0.0	1.7
World						
Biofuels	0.2	0.5	1.3	2.1	2.7	6.7
Oil sands/bitumen	0.4	1.1	1.9	3.3	4.2	5.5
Ultra-heavy oil	0.0	0.6	0.9	1.1	1.3	3.2
Coal-to-liquids	0.1	0.1	0.2	0.5	1.0	8.2
Gas-to-liquids	0.0	0.0	0.1	0.3	0.3	—
Shale oil	0.0	0.0	0.0	0.0	0.0	1.7
World Total	**0.6**	**2.5**	**4.5**	**7.4**	**9.7**	**5.6**
Selected Country Highlights						
Biofuels						
Brazil	0.1	0.2	0.3	0.5	0.7	5.4
China	0.0	0.1	0.2	0.2	0.1	2.6
India	0.0	0.0	0.1	0.1	0.1	3.6
United States	0.0	0.2	0.5	0.9	1.2	8.1
Coal-to-liquids						
Australia and New Zealand	0.0	0.0	0.0	0.0	0.0	—
China	0.0	0.0	0.0	0.0	0.2	—
Germany	0.0	0.0	0.0	0.0	0.0	0.0
India	0.0	0.0	0.0	0.0	0.1	—
South Africa	0.1	0.1	0.2	0.3	0.3	3.9
United States	0.0	0.0	0.0	0.2	0.2	—
Gas-to-liquids						
Qatar	0.0	0.0	0.0	0.2	0.2	—
South Africa	0.0	0.0	0.1	0.1	0.1	—

Table 4-3. IEO 2008 World Total Liquids Production, by Region and Country, High Price Case, 1990–2030 (Million Barrels Oil Equivalent per Day)

Region/Country	History		Projections			Average Annual Percentage Change, 2005–2030
	1990	2005	2010	2020	2030	
OPEC	**25.2**	**36.1**	**37.3**	**35.0**	**35.5**	**-0.1**
Asia (Indonesia)	**1.5**	**1.1**	**0.9**	**0.7**	**0.7**	**-1.8**
Middle East	**16.1**	**23.8**	**23.7**	**22.3**	**22.1**	**-0.3**
Iran	3.1	4.2	4.1	3.0	2.9	-1.5
Iraq	2.1	1.9	2.0	2.5	2.6	1.3
Kuwait	1.2	2.7	2.6	2.3	2.2	-0.7
Qatar	0.4	1.1	1.6	2.4	2.8	3.7
Saudi Arabia	7.0	11.1	10.5	9.7	9.4	-0.7
United Arab Emirates	2.3	2.8	2.9	2.4	2.2	-1.0
North Africa	**2.7**	**3.8**	**4.7**	**4.0**	**4.1**	**0.2**
Algeria	1.3	2.1	2.7	2.6	2.8	1.2
Libya	1.4	1.7	2.0	1.3	1.2	-1.4
West Africa	**2.3**	**3.9**	**5.0**	**4.5**	**4.5**	**0.5**
Angola	0.5	1.3	2.4	2.1	2.0	1.9
Nigeria	1.8	2.6	2.6	2.4	2.4	-0.3
South America	**2.5**	**3.4**	**3.0**	**3.5**	**4.1**	**0.8**
Ecuador	0.3	0.5	0.4	0.4	0.4	-1.3
Venezuela	2.3	2.9	2.5	3.1	3.8	1.1
Non-OPEC	**41.1**	**48.2**	**51.4**	**56.7**	**63.7**	**1.1**
OECD	**20.0**	**21.8**	**21.5**	**23.8**	**27.6**	**1.0**
OECD North America	**14.7**	**15.1**	**16.2**	**19.9**	**23.8**	**1.8**
United States	9.7	8.2	9.2	10.3	11.5	1.3
Canada	2.0	3.1	3.9	7.3	9.8	4.7
Mexico	3.0	3.8	3.1	2.3	2.5	-1.6
OECD Europe	**4.5**	**5.9**	**4.5**	**3.2**	**3.0**	**-2.7**
OECD Asia	**0.8**	**0.7**	**0.8**	**0.8**	**0.8**	**0.4**
Japan	0.1	0.1	0.1	0.1	0.1	0.5
South Korea	0.0	0.0	0.0	0.0	0.1	8.4
Australia and New Zealand	0.7	0.6	0.6	0.6	0.6	-0.1
Non-OECD	21.1	26.5	29.9	32.9	36.1	1.3
Non-OECD Europe and Eurasia	**11.6**	**11.9**	**14.2**	**14.9**	**15.5**	**1.0**
Russia	10.1	9.5	10.4	10.7	11.0	0.6
Caspian Area	1.1	2.1	3.5	4.0	4.2	2.8
Other	0.4	0.3	0.3	0.2	0.2	-1.4
Non-OECD Asia	**4.4**	**6.5**	**6.4**	**7.0**	**7.2**	**0.4**
China	2.8	3.7	3.6	3.7	3.8	0.1
India	0.7	0.8	1.0	1.2	1.3	2.0
Other	1.0	1.9	1.9	2.0	2.1	0.3
Middle East (Non-OPEC)	**1.3**	**1.7**	**1.5**	**1.4**	**1.4**	**-0.9**
Africa	**1.7**	**2.6**	**2.9**	**3.7**	**4.3**	**2.1**
Central and South America	**2.1**	**3.8**	**5.0**	**5.9**	**7.8**	**2.9**
Brazil	0.8	1.9	3.2	4.3	5.5	4.2
Other	1.3	1.8	1.7	1.6	2.3	0.8
Total World	**66.3**	**84.3**	**88.7**	**91.7**	**99.3**	**0.7**

Table 4-4. IEO 2008 World Unconventional Liquids Production, by Region and Country, High Price Case, 1990–2030 (Million Barrels per Day)

Region/Country	History 1990	History 2005	Projections 2010	Projections 2020	Projections 2030	Average Annual Percentage Change, 2005–2030
OPEC	**0.0**	**0.8**	**1.0**	**2.0**	**2.7**	**5.2**
Biofuels	0.0	0.0	0.0	0.0	0.1	—
Ultra-heavy oil (Venezuela)	0.0	0.6	0.9	1.5	2.1	5.2
Coal-to-liquids	0.0	0.0	0.0	0.0	0.0	—
Gas-to-liquids (primarily Qatar)	0.0	0.0	0.0	0.4	0.5	—
Non-OPEC	**0.6**	**1.7**	**2.9**	**10.4**	**16.3**	**9.4**
OECD	**0.5**	**1.5**	**2.7**	**7.8**	**12.0**	**8.8**
Biofuels	0.0	0.2	0.6	1.1	1.5	8.0
Oil sands/bitumen (Canada)	0.4	1.1	2.0	6.1	8.7	8.7
Ultra-heavy oil (Mexico)	0.0	0.0	0.0	0.1	0.1	—
Coal-to-liquids	0.0	0.0	0.0	0.2	1.2	32.9
Gas-to-liquids	0.0	0.0	0.0	0.1	0.1	—
Shale oil	0.0	0.0	0.0	0.0	0.1	—
Non-OECD	**0.1**	**0.2**	**0.2**	**2.6**	**4.2**	**12.0**
Biofuels	0.1	0.3	0.7	1.8	2.7	8.9
Ultra-heavy oil	0.0	0.0	0.0	0.0	0.0	—
Coal-to-liquids	0.1	0.1	0.2	0.6	1.4	9.9
Gas-to-liquids	0.0	0.0	0.1	0.1	0.1	—
Shale oil	0.0	0.0	0.0	0.0	0.0	4.7
World						
Biofuels	0.2	0.5	1.3	3.0	4.2	8.6
Oil sands/bitumen	0.4	1.1	2.0	6.1	8.7	8.7
Ultra-heavy oil	0.0	0.6	0.9	1.6	2.3	5.4
Coal-to-liquids	0.1	0.1	0.2	0.8	2.7	12.8
Gas-to-liquids	0.0	0.0	0.1	0.6	0.7	—
Shale oil	0.0	0.0	0.0	0.0	0.2	13.6
World Total	**0.6**	**2.5**	**3.8**	**12.3**	**19.0**	**8.5**
Selected Country Highlights						
Biofuels						
Brazil	0.1	0.2	0.3	1.0	1.5	8.5
China	0.0	0.1	0.2	0.3	0.3	5.7
India	0.0	0.0	0.1	0.2	0.2	6.7
United States	0.0	0.2	0.5	0.9	1.2	7.9
Coal-to-liquids						
Australia and New Zealand	0.0	0.0	0.0	0.0	0.0	—
China	0.0	0.0	0.0	0.1	0.5	—
Germany	0.0	0.0	0.0	0.0	0.0	3.0
India	0.0	0.0	0.0	0.0	0.2	—
South Africa	0.1	0.1	0.2	0.5	0.7	7.0
United States	0.0	0.0	0.0	0.2	1.2	—
Gas-to-liquids						
Qatar	0.0	0.0	0.0	0.3	0.4	—
South Africa	0.0	0.0	0.1	0.1	0.1	—

Table 4-5. IEO 2008 World Liquids Consumption, by Region, Reference Case, 1990–2030 (Million Barrels Oil Equivalent per Day)

Region/Country	History		Projections			Average Annual Percentage Change, 2005–2030
	1990	2005	2010	2020	2030	
OECD						
OECD North America	**20.5**	**25.2**	**25.3**	**26.7**	**28.0**	**0.4**
United States	17.0	20.8	20.7	21.6	22.3	0.3
Canada	1.7	2.3	2.4	2.5	2.6	0.6
Mexico	1.8	2.1	2.2	2.6	3.1	1.6
OECD Europe	**13.7**	**15.5**	**15.4**	**16.0**	**16.0**	**0.1**
OECD Asia	**7.2**	**8.6**	**8.4**	**9.0**	**9.2**	**0.3**
Japan	5.3	5.4	5.0	5.0	4.9	-0.4
South Korea	1.0	2.2	2.4	2.7	3.0	1.3
Australia/New Zealand	0.8	1.1	1.1	1.2	1.3	0.9
Total OECD	**41.4**	**49.3**	**49.1**	**51.6**	**53.3**	**0.3**
Non-OECD						
Non-OECD Europe and Eurasia	**9.4**	**4.8**	**5.5**	**6.3**	**6.9**	**1.4**
Russia	5.4	2.8	3.0	3.3	3.5	0.9
Other	3.9	2.1	2.5	2.9	3.4	2.0
Non-OECD Asia	**6.6**	**15.3**	**18.1**	**24.3**	**30.8**	**2.9**
China	2.3	6.7	8.8	11.7	15.7	3.4
India	1.2	2.4	2.7	3.8	4.9	2.8
Other non-OECD Asia	3.1	6.1	6.6	8.7	10.3	2.1
Middle East	**3.5**	**5.9**	**6.8**	**8.2**	**9.5**	**2.0**
Africa	**2.1**	**2.9**	**3.4**	**4.0**	**4.3**	**1.6**
Central and South America	**3.8**	**5.5**	**6.3**	**7.0**	**7.8**	**1.4**
Brazil	1.5	2.2	2.5	2.8	3.3	1.7
Other Central and South America	2.3	3.3	3.8	4.1	4.5	1.3
Total non-OECD	**25.3**	**34.3**	**40.1**	**49.7**	**59.3**	**2.2**
Total World	**66.6**	**83.6**	**89.2**	**101.3**	**112.5**	**1.2**

Table 4-6. IEO 2008 World Liquids Consumption, by Region, High Price Case, 1990–2030 (Million Barrels Oil Equivalent per Day)

Region/Country	History 1990	History 2005	Projections 2010	Projections 2020	Projections 2030	Average Annual Percentage Change, 2005–2030
OECD						
OECD North America	**20.5**	**25.2**	**25.1**	**25.1**	**26.1**	**0.1**
United States	17.0	20.8	20.6	20.5	21.1	0.1
Canada	1.7	2.3	2.4	2.3	2.3	0.1
Mexico	1.8	2.1	2.1	2.4	2.7	1.0
OECD Europe	**13.7**	**15.5**	**15.3**	**14.4**	**14.4**	**-0.3**
OECD Asia	**7.2**	**8.6**	**8.4**	**7.9**	**8.0**	**-0.3**
Japan	5.3	5.4	4.9	4.4	4.3	-0.9
South Korea	1.0	2.2	2.4	2.4	2.5	0.6
Australia/New Zealand	0.8	1.1	1.1	1.1	1.2	0.5
Total OECD	**41.4**	**49.3**	**48.8**	**47.5**	**48.5**	**-0.1**
Non-OECD						
Non-OECD Europe and Eurasia	**9.4**	**4.8**	**5.4**	**5.7**	**6.2**	**1.0**
Russia	5.4	2.8	3.0	3.0	3.1	0.5
Other	3.9	2.1	2.4	2.6	3.1	1.6
Non-OECD Asia	**6.6**	**15.3**	**18.0**	**21.0**	**25.2**	**2.0**
China	2.3	6.7	8.7	10.1	12.5	2.5
India	1.2	2.4	2.7	3.2	3.7	1.7
Other non-OECD Asia	3.1	6.1	6.6	7.6	8.9	1.5
Middle East	**3.5**	**5.9**	**6.8**	**7.8**	**8.7**	**1.6**
Africa	**2.1**	**2.9**	**3.4**	**3.6**	**3.9**	**1.1**
Central and South America	**3.8**	**5.5**	**6.2**	**6.2**	**6.8**	**0.9**
Brazil	1.5	2.2	2.5	2.5	2.8	1.0
Other Central and South America	2.3	3.3	3.7	3.7	4.1	0.8
Total non-OECD	**25.3**	**34.3**	**39.7**	**44.2**	**50.8**	**1.6**
Total World	**66.6**	**83.6**	**88.6**	**91.7**	**99.3**	**0.7**

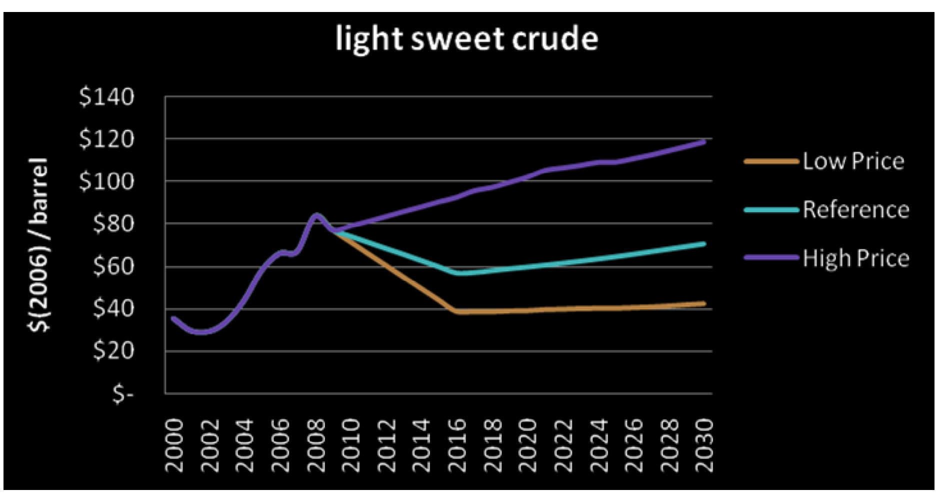


Figure 4-1. IEO 2008 Oil Price Projections

Source: U.S. Department of Energy, Energy Information Administration. 2008. *International Energy Outlook 2008*. Washington, DC: U.S. Department of Energy.

average under the reference case, and 1.6% per year under the high price case. In both scenarios, the highest growth rates are projected for non-OECD Asia, followed by the Middle East.

Both scenarios anticipate significant growth in "unconventional" liquids (Tables 4-3 and 4-4.). The combined categories of biofuels, oil sands, ultra-heavy oil, coal-to-liquids, and gas-to-liquids[1] are projected to experience total growth from 2005 through 2030 of 5.6% and 8.5% per year under the reference and high price cases, respectively.[2] Oil sands (mainly Canada) and ultra-heavy oil (mainly Venezuela) bring in a mixture of crude oil types, ranging from bitumen to fully upgraded synthetic crude oil. The other streams bring in light clean gasoline and diesel range streams that lower what would otherwise be the level of refinery crude processing and upgrading.

The top-down IEO global and regional projections for supply and demand were used to tune detailed supply premises, including production by crude type by country/region, based on internal WORLD model data and projections. Non-crude supply in the model was detailed by major fuel type and region. Detailed regional product demands for 2020 were set using a year 2000 basis of historical data by product type with base growth rates by region and product, which in turn were tuned to fit IEO region-by-region projections for total petroleum products demand. In addition, and as was performed for the 2007 Study and documented in prior reports, the detailed 2020 demand projections were adjusted from an "IEA" to "RTI" bunker basis. The latter employs higher and more accurate demand projections for marine bunker fuel. The adjustments reallocate grades within the distillate pool but have little impact on total distillate demand, reduce the size and growth rate of inland residual fuel, and increase the projected demand for marine IFO fuels. The net impact on total global oil demand was an increase under the 2020 reference case of 1.2 million bpd versus the original IEO figure. For the high price case, the increase was 1.65 million bpd. Details of the global supply and demand premises built in to the 2020 WORLD cases are set out in the case results tables (Tables 5-1 and 5-2 in Section 5).

Table 4-7 sets out the product growth rates (2000 to 2020) that applied in the 2020 reference and high price cases after demand adjustment to the RTI basis. These were based on regional and global parameters currently built in to the WORLD model.

[1] "Unconventional" supplies as defined by EIA also include shale oil, but this has no projected supply until after 2020.

[2] Minor adjustments were made to the EIA IEO biofuels projections to increase biofuels, especially biodiesel supply in Europe.

Table 4-7. Annual Product Growth Rates Applied in the 2020 Reference and High Price Cases

RTI Basis—Bunkers Projection	2000 to 2020 Reference Case	2000 to 2020 High Price Case
Ethane	1.41%	1.20%
LPG	0.98%	0.62%
Naphtha	3.22%	2.55%
Gasoline	1.08%	0.58%
Kero/jet	1.22%	0.66%
Gas oil/diesel/NO2	2.16%	1.58%
Gas oil/diesel—BKRS—MGO + MDO	3.08%	3.06%
Residual—Inland, including RFO	- 1.16%	- 1.83%
Residual—BKRS—IFO180	3.03%	3.05%
Residual—BKRS—IFO380	2.93%	2.94%
Other	0.98%	0.72%
Transport losses	1.15%	1.15%
Total oil demand	1.50%	1.02%

Again, the two scenarios are quite distinct. The reference case projects global oil demand growth at 1.5% per year from 2005 through 2030, while for the high price case, the rate is 1% per year. As discussed elsewhere, this leads to the reference case exhibiting a global oil demand increase by 2020 of 16 million bpd relative to 2005, whereas the increase under the high price case is under half that level. Key factors built in to the demand growth projections are believed to be broadly in line with those of other current forecasts:

- the strongest growth was for distillates among the major fuel categories, driven by its role as an engine of economic growth worldwide and supported by continuing dieselization in Europe;
- moderate growth for gasoline, especially under the high price scenario, with its underlying premises of transport fuel efficiency policy initiatives;
- moderate growth in demand for gasoline is partially compensated by projected strong growth for naphtha, driven by sustained increases in demand for petrochemical products;
- declining inland residual fuel consumption; and
- significant growth for marine fuels.

As can be seen, the growth rates for marine fuels are essentially identical in both scenarios. This is because, to maintain consistency with air quality modeling that had been undertaken by EPA, the "inventory" (i.e., projected demand) associated with marine fuels needed to be kept constant.[3] The bunker demand projections used in the 2020 cases were discussed in Section 3 and are summarized in Table 4-8.

4.2.2 Product Quality

The 2020 BAU case was on the basis of a "best estimate" of fuel quality, given implementation of already active regulations and continuation of current product quality trends. Specific premises built in to the cases are discussed below.

4.2.2.1 Industrialized World (United States, Canada, Europe, Japan, Australia)

- Gasoline and on-road and off-road diesel ultra-low sulfur regulations are fully in place by the 2010/2012 time frame (i.e., with an essentially total phase-out of nonultra low-sulfur gasolines and diesel fuels).
- Gasoline clear pool octanes remain flat.
- Methyl tertiary butyl ether (MTBE), although phased out in the United States, is assumed not to have been phased out in other world regions.
- Regulations that impact other fuels' quality (e.g., EPA toxics "anti-backsliding," Euro V, and CARBIII) are in place.
- Consumption of high-sulfur inland residual fuel has been entirely replaced by low-sulfur fuel (1% or less).

4.2.2.2 Non-OECD Regions

- Completion of lead phase-out in gasoline.
- An overall gradual upward trend in regional pool octanes, so that, by 2020, all non-OECD regions are within 1 octane or less of U.S. average pool octane. Globally, the octane rise is moderated by the fact that the large gasoline volumes in OECD regions are projected to remain at constant, or even slightly declining, octane levels.
- Progressive adoption of advanced (generally Euro II/III/IV) fuel standards for transport fuels, so that the majority of transport fuel demand has reached advanced standards by 2020.
- A gradual or partial trend toward mandates for low-sulfur residual fuel for inland use.

[3] While keeping global marine fuel demand constant across both scenarios arguably means that marine demand is overstated in the high price case, the impact or distortion is possibly less than it might at first appear. This is because marine fuel demand is driven primarily by trade, which in turn is driven by economic growth. The IEO 2008 reference and high price cases used the same underlying global economic growth rate (4% p.a. 2005 through 2030, per IEO Tables A3 and D4 [DOE, 2008]).

4.2.3 Regional Bunker Demands

As discussed above, the WORLD ECA modeling was performed using RTI projections for bunker fuel base demand and growth[4]. The bunker demand projections were taken directly from findings discussed in Section 3. The resulting 2020 volumes, totaling 495 million tpa, are detailed by region in Table 4-8. The table reflects the stark difference in bunker fuels consumption as computed by the RTI team, using rigorous methods, for the 2003 base year with the far lower figure reported by the IEA for that year. The table sets out the regional allocation of marine fuels demands totaling to the RTI figure. As discussed elsewhere in the report, the IMO has now adopted marine fuels demand data and projections very close to those that were developed by the RTI team. In addition, the IEA has a project under way to reassess its own estimates of bunker fuels demand.

4.2.4 Regulatory Outlook for Bunker Fuels

For the BAU case, the bunker demand and quality basis drew on prior work while also recognizing IMO regulations expected to be soon in place:

- The IMO MARPOL Annex VI regulations which have recently been agreed and which are expected to be ratified during 2009/2010 were projected to be the primary governing regulations in place in 2020, but on the following basis:
  - the global 3.5% sulfur standard for IFO fuels would be in effect, and thus—implicitly—the regulation to bring all non-ECA fuels to 0.5% sulfur maximum would not by then be in effect;
  - the 0.1% sulfur standard for ECA fuels, to apply from 2015, would be in effect; and
  - the only ECAs in operation in the base cases would be the two already in existence in Northern Europe (Baltic and North Sea/English Channel).
- In addition,
  - the EU 0.1% marine diesel sulfur rule would be in effect, and
  - the California low-sulfur marine diesel rule would be in effect.
- Based on industry feedback from prior studies for API and IMO:
  - a ratio of 70% MGO (ISO8217 DMA standard fuel) to 30% MDO (ISO8217 DMB standard fuel) was applied.

[4] Base cases were first developed using the “IEA” bunkers demand basis and were then adjusted to the “RTI” basis as the starting point for assessing ECA impacts.

Table 4-8. World Regional Bunker Sales

World Region Basis	Bunker Sales 2003 IEA	Bunker Sales 2003 RTI	Comparison Delta	RTI vs. IEA (Percent)	Bunker Sales 2020 RTI	Growth Rates From 2003 2020 RTI
USEC[a]	6.0	7.5	1.5	124%	11.2	2.7%
USGICE[b]	8.9	11.6	2.6	130%	17.2	2.7%
USWCCW[c]	5.5	8.4	2.9	152%	12.5	2.7%
GrtCAR[d]	4.5	11.7	7.2	260%	21.5	3.4%
SthAm[e]	5.4	16.8	11.4	312%	24.0	2.5%
AfWest[f]	1.2	2.3	1.1	186%	2.9	1.9%
AfN-EM[g]	4.6	12.3	7.6	265%	16.1	1.8%
Af-E-S[h]	3.7	7.1	3.5	194%	10.0	2.2%
EUR-No[i]	32.4	42.3	9.9	131%	60.0	2.5%
EUR-So[j]	14.9	27.1	12.2	182%	42.4	2.8%
EUR-Ea[k]	0.5	1.4	0.9	293%	2.6	4.0%
CaspRg[l]	0.0	0.0	0.0	0%	0.0	3.1%
RusFSU[m]	0.4	7.8	7.3	1,865%	12.3	3.2%
MEGulf[n]	10.3	25.0	14.7	242%	36.8	2.7%
PacInd[o]	6.1	25.9	19.8	421%	31.6	1.3%
PacHi[p]	37.6	57.0	19.5	152%	78.4	2.2%
China	5.4	31.5	26.1	587%	101.5	8.7%
RoAsia[q]	0.3	9.2	8.9	2,853%	14.1	2.9%
World	147.8	304.9	157.2	206%	495.3	3.2%

[a] U.S. East Coast
[b] U.S. Gulf Coast and Interior, plus Eastern Canada
[c] U.S. West Coast, plus Western Canada
[d] Greater Caribbean
[e] South America
[f] Africa West
[g] Africa North and the Mediterranean
[h] Africa East and South
[i] Europe North
[j] Europe South
[k] Europe East
[l] Caspian Region
[m] Russia/Former Soviet Union
[n] Middle East Gulf
[o] Pacific Industrialized
[p] Pacific High Growth
[q] Rest of Asia

The effect of these premises was to lead to a 2020 base case situation where, effectively, current bunker fuel standards apply in all regions.[5] The 70:30 MGO:MDO ratio was applied in essentially every region except Northern Europe. The projected global average proportion of marine distillate in total marine fuel was 27% (62% in Northern Europe). Projected proportions of IFO180 in total IFO180 plus 380 varied from region to region but averaged 14% worldwide.

Annex VI allows for alternative technologies to be used to achieve equivalent emission reductions as operating on low sulfur fuel. One approach may to be to continue to operate on high sulfur fuel and use an exhaust gas cleaning device (scrubber) to remove sulfur from the exhaust. For the purpose of this analysis, we did not consider the impact that the use of scrubbers could have on low sulfur fuel demand. To the extent that scrubbers are used in the future, the use of scrubbers would be expected to directionally reduce demand for low sulfur fuel in ECAs..

4.2.5 U.S. and Canadian ECA Affected Bunker Fuel Volume

As discussed in Section 3, affected fuel volumes under a potential U.S. and Canada ECA were estimated. These are summarized in Table 4-9. Under the potential U.S. and Canada ECA, the affected fuel volume was projected to be 19.8 million tpa. This comprises 4% of projected total global marine fuel demand. Of the 19.8 million tpa projected to be consumed within a U.S. and Canadian ECA, 65% is projected to be lifted in the United States and Canada, and the other 35% in other world regions as ships on voyages originating in those regions and bound for the United States or Canada take on bunkers that are compliant with the U.S. and Canadian ECA standards. The 12.9 million tpa of ECA-compliant fuel projected to be lifted within the United States or Canada comprises 32% of total liftings (40.9 million tpa) within the region.

4.2.6 Refinery Capacity and Projects

The WORLD model contains a detailed bottom-up database by process unit and refinery worldwide. This is brought up to date as new refinery capacity survey data are published. EnSys has found, however, that extensive cross-checking of and corrections to data presented in sources such as *Oil & Gas Journal* (*OGJ*) are necessary. The WORLD cases were run with a capacity database that was based on January 2008 *OGJ* data, with extensive review and revision. Assessed base capacity totaled 86.7 million bpcd, as listed in Table 4-10.

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[5] The MARPOL Annex VI rule cuts maximum worldwide IFO sulfur from 4.5% to 3.5%, but the current average is around 3%, with only few samples exceeding 4%. Thus, the intent of the regulation is understood to be primarily to prevent any material deterioration from the actual qualities of IFO fuels in the marketplace today.

Table 4-9. United States and Canada Affected Bunker Fuel Demand, 2020

Fuel Production Zones (United States and Canada Related Voyage Fuel Demand) million tonnes/year					
WORLD	**IFO380**	**IFO180**	**MDO**	**MGO**	**Total**
USEC	2.4	0.7	0.3	0.7	4.0
USGICE	2.6	0.7	0.3	0.7	4.3
USWCCW	2.4	0.7	0.5	1.1	4.6
GrtCAR	0.8	0.2	0.0	0.1	1.1
SthAm	0.2	0.1	0.0	0.0	0.3
AfWest	0.0	0.0	0.0	0.0	0.1
AfN-EM	0.1	0.0	0.0	0.0	0.1
Af-E-S	0.0	0.0	0.0	0.0	0.0
EUR-No	0.5	0.2	0.0	0.1	0.7
EUR-So	0.3	0.1	0.0	0.0	0.5
EUR-Ea	0.0	0.0	0.0	0.0	0.1
CaspRg	0.0	0.0	0.0	0.0	0.0
RusFSU	0.1	0.0	0.0	0.0	0.2
MEGulf	0.2	0.0	0.0	0.0	0.3
PacInd	0.2	0.1	0.0	0.0	0.3
PacHi	0.4	0.1	0.0	0.0	0.6
China	1.6	0.6	0.1	0.1	2.3
RoAsia	0.2	0.1	0.0	0.0	0.3
Total	12.0	3.6	1.3	2.9	19.8

The projects database used for the WORLD cases was based on detailed review of project announcements as of third quarter 2008. In WORLD, projects are classified at four levels: under construction, under engineering, planned, and announcement. These correspond to descending levels of follow-through to completion and also an increasing tendency for project delays versus the initial start-up target date. The model user sets parameters by region that govern both the proportion of each class of project to be completed and the associated delay profile.

Since mid-2005 especially, there have been numerous announcements of new projects, many for major refinery expansions or new grassroots refineries. Nearly 24 million bpd of refinery crude unit capacity expansion projects are currently listed. These span a spectrum from projects already under construction, and therefore almost certain to go ahead, to others that are little more than announcements and thus highly speculative or uncertain. Based on experience,

Table 4-10. Refinery Base Capacity and Assessed Additions

	Base Capacity	Additions Allowed	
	Jan. 2008	Reference Case	High Price Case
USEC	1.67	0.00	0.00
USGICE	13.95	0.94	0.77
USWCCW	3.80	0.09	0.07
GrtCAR	5.08	0.15	0.15
SthAM	3.06	0.27	0.25
AfWest	0.76	0.01	0.00
AfN-EM	2.27	0.06	0.06
Af-E-S	0.72	0.00	0.00
EUR-No	9.56	0.01	0.00
EUR-So	5.74	0.27	0.09
EUR-Ea	2.14	0.10	0.00
CaspRg	1.32	0.01	0.00
RusFSU	7.16	0.25	0.00
MEGulf	6.66	2.96	0.23
PacInd	5.50	0.02	0.02
PacHi	7.77	0.16	0.16
China	6.80	1.69	1.33
RoAsia	2.77	1.03	1.00
Total	86.70	8.01	4.12

Note: Base capacity plus allowed projects make up the total starting capacity before WORLD model additions million bpcd.

factors were applied to curtail less likely projects in order to arrive at a realistic level of projects likely to go ahead.

As discussed elsewhere in the report, the IEO reference case (DOE, 2008) projects an increase in global oil products demand of 16 million bpd between 2005 and 2020, with the high price case undergoing an increase of under half this. Recognizing these two different situations, different approaches were taken to assessing the level of projects to be allowed. For the reference case, the underlying premise was that essentially all of the projects currently under construction would go ahead and that additional probable projects (essentially those under engineering) should be allowed for. The result was to allow a total of 8 million bpd of new projects under the reference case scenario, as listed in Table 4-10. For the high price case, with its much-reduced demand growth through 2020, the more conservative assumption was made that refiners would forestall many projects. As a result, only those projects already under construction were allowed, resulting in 4.1 million bpcd, as set out in Table 4-10. The primary difference between the two sets of assessed projects was that, in the high price case, almost 2.75 million bpd of Middle East projects not yet under construction were removed.

The main regions expected to see expansions are the United States, the Middle East (depending on the scenario), China, and the rest of Asia (including India). Capacity expansion in Europe is projected to be minimal. While Table 4-10 lists crude unit major capacity additions, the complete project database covers the full suite of refinery processes, including upgrading and desulfurization (for further detail, see Table 5-4). In the BAU cases, the model adds capacity, on top of the input base plus assessed projects, to meet demand growth, product mix shifts, and quality changes. To do so, it uses first the low-cost revamp and debottlenecking potential allowed and then balances on major new unit additions.

4.2.7 Refinery Technology and Costs

As documented in the 2007 Study for the EPA, the WORLD technology database was the subject of extensive review by EnSys at that time. This review included yields and capital costs on several units. Further work was also undertaken in parallel studies for API and IMO.

The process unit capital costs in WORLD are based on the year 2000 (U.S. Gulf Coast). Since 2003 especially, there has been a considerable escalation in capital costs. By 2008, downstream capital costs were estimated to be in the region of 75% above those obtaining in 2000 (i.e., a factor of 1.75). As a result of the current economic recession, these costs are reported to be dropping. The assumption was made that, by 2020 and under the reference case outlook, a resumption of global economic growth would have reasserted pressures on all commodities, leading to cost levels similar to those of today. Therefore, a factor of 1.75 was applied, as shown in Table 4-11. Under the high price case (which has the same underlying economic growth projection but a lower level of energy intensity), the presumption was made that higher prices for crude oil and thus potentially for other commodities would lead to capital costs somewhat higher than those obtaining under the reference scenario. A factor of 2.0 was applied relative to base year 2000 cost levels for the high price cases. The same factors were used to escalate refinery other variable operating (OVC) costs, which include mainly catalysts and chemicals.

WORLD results are sensitive to the interplay between crude (and fuel) costs, refinery capital costs, and freight rates:

- § Raising crude oil prices results in more refinery capacity investment, especially in upgrading processes, with the logical effect of reducing the volume of (now high-cost) raw material used to make a given product slate.
- § Raising refinery process unit costs has an opposite effect; total dollar investments may rise, but the new capacity bought for the money is less, and the industry responds by using somewhat more crude oil.
- § Raising tanker freight rates has the effect of, in turn, justifying additional refinery process investment to minimize high-cost interregional movements of crude and products.

This analysis for the EPA reflects that we have entered into a high-cost world where the traditional levels of and relationships between capital cost, crude and fuel costs, and transport costs are being rewritten. In the BAU cases, higher crude oil price (vs. history) was a given and, hence, also higher refinery fuel and natural gas prices. Both refinery capital costs and tanker freight rates were moved upward relative to history. This resulted in scenarios where all costs—crude, fuel, OVCs, and freight—were elevated versus past historical levels.

Table 4-11 summarizes key cost parameters used in the reference and high price WORLD cases. The IEO projections primarily report prices for light sweet crude imported into the USA. These were close to $(2006) 60 and 102/bbl respectively. The IEO also contains information on the projected average price of crude oil imported to the USA. This is of lower quality than that of light sweet crude, and thus lower price. The average import prices were use to obtain prices for Saudi Light, the marker crude price that is the only crude price input to the WORLD model.

4.2.8 Transportation

WORLD contains details of interregional crude, noncrude, finished, and intermediate product movements by tanker, pipeline, and minor modes. Each tanker movement is assigned to one of five tanker size classes, and freight costs are built up based on the WorldScale flat rate times the percentage of WorldScale plus ancillary costs, such as canal dues and lightering, where applicable, as well as duties. Reflecting the factors reviewed above, WorldScale percentage rates were applied (Table 4-12) that were higher than recent freight rate history.

In WORLD, freight rates are arrived at by multiplying the percentage of WorldScale by the WorldScale 100 flat rate. (Other cost items, such as canal tariffs or lightering, are also added in, where relevant.)

Table 4-11. Key Price and Cost Premises for 2020 WORLD Cases

	IEO 2008 Reference	IEO 2008 High Price
Crude Price $2006/bbl		
Light Sweet	59.70	102.07
Average Import (1) (2)	51.55	88.14
Other Input Prices $2006		
Natural Gas Price $/MMBtu (3)(4)	6.21	7.29
Purchased Electricity c/kwh (4)	5.90	6.11
Steam Coal $/MMBtu	*1.72*	*1.82*
Steam Coal $/short ton	*34.97*	*37.13*
Petroleum Coke High Sulfur $/ton	35	37
Capital & Operating Costs		
Capital Costs Factor versus 2000	1.75	2.00
OVC Costs Factor versus 2000	1.75	2.00
Marine Freight Costs	1	1.25

Notes:

1. Average Import price for 2020 High Price case derived using same ratio of Average Import to Light Sweet as in Reference Case

2. Average Import price taken as approximating to OPEC basket price from which Saudi Light crude marker price derived

3. Basis is Industrial User natural gas prices taken from AEO 2008 Reference and High Price cases. (These are understood to be the same prices as used in the IEO 2008.)

4. US regional (PADD) and international prices for natural gas and electric power are derived from the US prices using regional differences.

Table 4-12. WORLD Tanker Rates

Tanker Class	Size DWT	Percent of WorldScale 2020
MR2	40,000	285
Pana Max	55,000	248
AFRA Max	70,000	230
Suez Max	135,000	180
VLCC	270,000	100

In the ECA cases, shifts from IFO to marine diesel will inevitably increase bunker fuel costs to affected shippers operating in a potential U.S. and Canadian ECA, thereby impacting freight rates. EnSys did not attempt to compute the effect that these would have on freight rates for tankers operating into and out of the United States and Canada.

As a component of recent assignments, care has been taken in WORLD to build in accurate representations of major new, expanded, and existing pipelines. Particular emphasis has been put on ensuring an accurate profile of pipelines and expansions for export routes for crudes (including syncrudes) from Canada and export routes both east and west from Russia and the Caspian. For Canada, the BAU premise was that one, but not both, of the export lines to the West Coast/PADD V/Pacific would go ahead. This premise impacts the amount of syncrude and conventional crudes routed into the U.S. PADDs II, IV, and potentially III, versus west to PADD V and Asian regions. For Russia, based on recent developments, the BAU case assumed the pipeline to the Pacific would go ahead and would have a spur into China. In reality, this latter scenario will most likely partially displace growing rail movements of crude into China from Russia that were already in the model.

4.3 Prices Input to the WORLD Model

4.3.1 Marker Crude Price

WORLD operates with a single marker crude price, and all other crudes and nearly all noncrude supplies and product demands are fixed. WORLD outputs prices for all crude oils, noncrude supply streams, and finished products based on the scenario and the single input marker crude price. WORLD model uses the Saudi Light FOB as the single input marker crude price; however, EIA does not provide projections for this price. Therefore, we use the average US import price as an approximation for the OPEC basket price from which the Saudi Light Crude marker price is derived. The average crude oil import price projections in the IEO outlook are shown in Table 4-11.

4.3.2 Natural Gas and Miscellaneous Input Prices

Certain other prices are also inputs in the model. The most important among these are natural gas prices, as natural gas is the balancing refinery fuel supply in most regions and a primary feedstock for hydrogen production. WORLD also uses input prices for purchased electricity and also petroleum coke and sulfur by-products. Prices for natural gas, electricity, and petroleum coke were derived from the IEO projections, petroleum coke being linked to coal prices (see Table 4-11).

The IEO high price case projects a significant increase in crude oil prices by 2020 but relatively small increases in natural gas and especially coal—and, hence, coke. In the WORLD model, decreases in the prices of natural gas and coke relative to crude oil simultaneously tend to increase the attractiveness of adding hydrogen derived from natural gas and to reduce the attractiveness of carbon rejection via coking. This is especially the case when crude prices are high, as in the IEO high price case. The effects on WORLD projections, in terms of raising projected expansions for hydrocracking and lowering those for coking, are evident in the WORLD cases results, as shown in Table 5-3.

4.4 Reporting

The WORLD model's standard reports had been previously modified to accommodate the revised distillate and residual fuels product structure. Standard reports provide global and regional information on the following:

- refinery throughputs, capacity additions, investments;
- interregional crude, intermediate, and product movements;
- supply/demand balance;
- crude free on board (FOB) and cost insurance and freight (CIF) prices; and
- regional product prices.

Blend reports had also been added for the marine fuel grades.

SECTION 5
REVISED WORLD MODEL FOR ECA

This section presents results for the 2020 WORLD BAU and ECA model cases, based on the projections and premises reviewed in Section 4. BAU projections were estimated for the two IEO scenarios using both the IEA and the RTI bunker demand assumptions. The RTI base cases were then used to assess the cost and other impacts of a potential U.S. and Canadian ECA. Thus, a total of six cases were run, comprising the IEA basis, the RTI basis, and RTI and ECA cases for each of the IEO reference and high price outlooks. Key inputs to and results from these cases are set out in Tables 5-1 through 5-9. These include comparisons of the RTI base case versus RTI and ECA cases to illustrate impacts of the U.S. and Canadian ECA.

5.1 Supply-Demand Balance

Tables 5-1 and 5-2 summarize the 2020 supply and demand inputs and model run results for the four base cases and the two ECA cases. As discussed in Section 4, the IEA base case was matched to the IEO 2008 scenario. A second base case was run with RTI's forecast, which increases bunker and total residual demand globally. Then the ECA base case was applied to the RTI base case. The needed incremental supply was taken to be OPEC crude. WORLD results generally do not match exactly the underlying forecast numbers for total oil supply and demand. This is because several demand factors, including internal refinery fuel, coke, and sulfur by-products, are dynamic within WORLD and are not fixed.

The 2020 cases reflect the overall global trend for an increase in demand to be predominantly light, clean products and for global growth to be concentrated in distillates.

As explained in Section 4.2.3, base cases were first developed using the "IEA" bunkers demand basis in order to be consistent with the implicit basis of the IEO projections. These were then adjusted to the "RTI" bunkers basis to generate base cases that were the basis of the ECA analyses. Adopting the RTI fuel demand forecasts leads to a 2020 reference case global demand for all residual fuels of 10.52 million bpd versus 9.44 million bpd, based on IEA forecasts. The 10.52 million bpd total, however, contains 6.64 million bpd of IFO fuel, as compared with 3.28 under the IEA basis. Thus, RTI's forecasts indicate that estimated impacts of ECAs or other marine fuel regulations will be greater than those projected by applying IEA forecasts. The same point applies to marine distillate fuels and under the high price scenario.

Table 5-1. WORLD Reference and ECA Case Inputs and Summary Results—Supply, 2020

Case	IEA Bkrs Ref	RTI Bkrs Ref	RTI ECA Ref	IEA Bkrs High	RTI Bkrs High	RTI ECA High	ECA vs RTI Ref	ECA vs RTI High
Year	2020	2020	2020	2020	2020	2020		
Bunkers Demand Basis	IEA	RTI	RTI	IEA	RTI	RTI		
MGO Fuel Type - North America SECAs	DMA	DMA	DMA	DMA	DMA	DMA		
MDO Fuel Type - North America SECAs	DMA	DMA	DMA	DMA	DMA	DMA		
MGO Sulfur Limit - North America SECAs			**0.1%**			**0.1%**		
MDO Sulfur Limit - North America SECAs			**0.1%**			**0.1%**		
IFO Sulfur - North America SECAs	**n.a**	**n.a**	**n.a**	**n.a**	**n.a**	**n.a**		
SECA Basis	Base	Base	**US/Can**	Base	Base	**US/Can**		
Bunkers Demand Basis	IEA	RTI	RTI	IEA	RTI	RTI		
Scrubber Usage	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**		
SUPPLY - CRUDES (INCLUDES SYNCRUDES & CONDENSATES)								
	MMBPD	MMBPD	MMBPD	MMBPD	MMBPD	MMBPD	MMBPD	MMBPD
Crude gross production	85.495	86.683	86.737	73.918	75.593	75.622	0.054	0.029
of which								
Crude Direct Use	0.339	0.339	0.339	0.339	0.339	0.339	0.000	0.000
Crude Direct Loss Total	0.151	0.151	0.151	0.132	0.132	0.132	0.000	0.000
Crude net to refineries before losses	**85.005**	**86.194**	**86.247**	**73.447**	**75.121**	**75.150**	**0.054**	**0.029**
Crudes net to refineries after transport losses								
GSY - SYN CRUDE	4.113	4.113	4.113	6.126	6.126	6.126	(0.000)	0.000
GCO - CONDENSATE	4.305	4.304	4.304	4.304	4.304	4.304	(0.000)	(0.000)
GSW - SWEET <0.5S	25.392	25.709	25.709	21.051	21.481	21.481	(0.000)	0.000
GLR - LT SR >36 API >0.5%S	10.849	11.067	11.067	9.070	9.366	9.367	(0.000)	0.000
GMR - MD SR 36-29 API >.5S	28.371	28.929	28.983	22.376	23.190	23.219	0.054	0.029
GHR - HVY SR 20-29 API >.5S	10.353	10.447	10.447	9.095	9.226	9.226	(0.000)	0.000
GXR - XHVY SR <20 API >.5 S	1.472	1.472	1.472	1.291	1.291	1.291	0.000	0.000
CRUDE SUPPLY TO REFINERIES	84.854	86.041	86.095	73.312	74.984	75.013	0.054	0.029
Crude Direct Loss in Refineries								
SUPPLY - NON CRUDES								
NGL ETHANE	1.680	1.680	1.680	1.680	1.680	1.680	0.000	0.000
NGLs C3+	6.255	6.255	6.255	6.096	6.096	6.096	0.000	0.000
PETCHEM RETURNS	0.955	0.955	0.955	0.844	0.844	0.844	0.000	0.000
BIOMASS	1.499	1.499	1.499	2.999	2.999	2.999	0.000	0.000
METHANOL (EX NGS)	0.147	0.149	0.148	0.127	0.127	0.126	(0.001)	(0.001)
GTL LIQUIDS (EX NGS)	0.303	0.303	0.303	0.603	0.603	0.603	0.000	0.000
CTL LIQUIDS (EX COAL)	0.500	0.500	0.500	0.800	0.800	0.800	0.000	0.000
HYDROGEN (EX NGS)	0.974	0.925	0.937	0.908	0.839	0.860	0.012	0.021
TOTAL	**12.313**	**12.266**	**12.277**	**14.057**	**13.988**	**14.009**	**0.011**	**0.021**
REFINERY PROCESS GAIN	3.028	2.956	2.978	2.470	2.403	2.408	0.021	0.005

As illustrated in Table 5-2, a primary effect of the U.S. and Canadian ECA is to shift some 0.26 million bpd of IFO fuel worldwide to marine distillate. The resulting increase in marine distillate is higher at 0.29 million bpd[1] because the model takes into account the lower heat content of marine distillates, per barrel, relative to that of IFO fuels.

[1] The shifted IFO and marine distillate volumes in million bpd are slightly different between the reference and high price cases. This is because the model starts with tonnes of marine fuel, and resulting gravities may differ slightly from case to case.

Table 5-2. WORLD Reference and ECA Case Inputs and Summary Results—Demand, 2020

Case	IEA Bkrs Ref	RTI Bkrs Ref	RTI ECA Ref	IEA Bkrs High	RTI Bkrs High	RTI ECA High	ECA vs RTI Ref	ECA vs RTI High
DEMAND								
million bpd								
EXTERNAL DEMANDS - FINISHED PRODUCTS NON SOLIDS								
ETHANE	1.680	1.680	1.680	1.680	1.680	1.680	0.000	0.000
LPG	7.498	7.498	7.498	6.716	6.716	6.716	0.000	0.000
NAPHTHA	8.131	8.131	8.131	7.146	7.146	7.146	0.000	0.000
GASOLINE	24.377	24.377	24.377	22.077	22.077	22.077	0.000	0.000
JET/KERO	8.152	8.152	8.152	7.301	7.301	7.301	0.000	0.000
DISTILLATE TOTAL	31.031	31.173	31.460	27.750	28.059	28.350	0.287	0.291
DISTILLATE (NON BUNKERS)	30.331	28.770	28.770	27.047	25.665	25.665	0.000	0.000
DISTILLATE (BUNKERS)	0.700	2.403	2.690	0.703	2.394	2.685	0.287	0.291
RESIDUAL (IFO BUNKERS)	3.279	6.641	6.379	3.291	6.653	6.389	(0.263)	(0.264)
RESIDUAL (NON BUNKERS)	6.163	3.877	3.877	5.489	3.468	3.468	0.000	0.000
RESIDUAL FUEL (TOTAL)	9.442	10.518	10.256	8.780	10.121	9.857	(0.263)	(0.264)
OTHER PRODUCTS (excl coke,sulphur)	4.467	4.467	4.467	4.011	4.011	4.011	0.000	0.000
CRUDE DIRECT USE	0.339	0.339	0.339	0.339	0.339	0.339	0.000	0.000
TOTAL	**95.117**	**96.336**	**96.359**	**85.800**	**87.450**	**87.477**	**0.024**	**0.027**
EXTERNAL DEMANDS - FINISHED PRODUCTS SOLIDS								
PETR COKE TOTAL MMBPD	1.417	1.287	1.327	1.037	0.947	0.971	0.040	0.024
ELEMENTAL SULPHUR MMBPD	0.183	0.169	0.173	0.156	0.141	0.144	0.003	0.003
TOTAL	1.600	1.456	1.500	1.193	1.088	1.115	0.043	0.027
INTERNAL DEMANDS/CONSUMPTION								
REFINERY FUEL - CRUDE BASED STREAMS								
PROCESS GAS	2.549	2.514	2.533	2.096	2.062	2.068	0.019	0.006
FCC CATALYST COKE	0.513	0.490	0.488	0.370	0.349	0.348	(0.002)	(0.001)
MINOR STREAMS	0.004	0.003	0.003	0.002	0.010	0.010	0.000	0.000
RESIDUAL FUEL	1.449	1.451	1.454	1.249	1.226	1.233	0.003	0.006
TOTAL CRUDE BASED STREAMS	**4.515**	**4.459**	**4.478**	**3.717**	**3.647**	**3.658**	**0.019**	**0.011**
NATURAL GAS TO RFO	2.037	2.058	2.055	1.991	2.034	2.046	(0.002)	0.012
TOTAL INCL NATURAL GAS	6.552	6.517	6.534	5.708	5.681	5.704	0.017	0.023
OTHER LOSSES	0.091	0.091	0.091	0.079	0.079	0.079	0.000	0.000
							0.000	0.000
TOTAL INTERNAL CONS & LOSS EXCL NAT (	**4.612**	**4.555**	**4.574**	**3.802**	**3.732**	**3.744**	**0.019**	**0.011**
TRANSPORT/DISTRIBUTION LOSSES								
TRANSPORT LOSS TOTAL	0.211	0.213	0.213	0.188	0.192	0.192	0.000	0.000
- ALLOCATION TO CRUDE	0.151	0.152	0.152	0.135	0.137	0.137	0.000	0.000
- ALLOCATION TO PRODUCTS & INTERMEDI/	0.060	0.061	0.061	0.054	0.055	0.055	0.000	0.000

5.2 Refining Capacity Additions

Table 5-3 summarizes base capacity and projects data included as inputs into the WORLD model cases. The information reinforces the view that there is potential for surpluses among selected secondary units. Under the reference and high price outlooks, assessed coking project additions comprise increases of 44% and 23%, respectively, over base 2008 capacity. Total upgrading additions (coking plus FCC plus hydrocracking) are at the level of over 90% of the additions to distillation capacity under both the reference and high price cases. Desulfurization capacity additions are at the levels of, respectively, 131% and 147% of distillation additions. These additions are consistent with the result that “spare” coking capacity

Table 5-3. WORLD Input Refinery Base Capacity and Assessed Additions

Refinery Base Capacity & Assessed Additions

Base capacity plus allowed additions make up the total starting capacity before WORLD model additions

million bpcd	Base Capacity	Additions Allowed			
	Jan 2008	Reference Case	% increase on base	High Price Case	% increase on base
Crude distillation	86.70	8.01	9.2%	4.12	4.7%
Coking	4.77	2.11	44.3%	1.12	23.4%
Catalytic cracking (FCC)	15.45	2.23	14.4%	1.18	7.6%
Hydrocracking	5.37	2.96	55.2%	1.58	29.4%
Total upgrading	25.59	7.31	28.6%	3.88	15.2%
Total upgrading as % of distillation	29.5%	91.2%		94.2%	
Desulfurization	51.70	10.50	20.3%	6.08	11.8%
Desulfurization as % of distillation	59.6%	131.1%		147.6%	
Hydrogen plant (million SCFD)	9253	6006	64.9%	2448	26.5%
Sulfur plant (tons per day)	76909	24578	32.0%	12848	16.7%

especially is being used, at least in the high price cases, to process IFO (see below). This underlying situation acts, if anything, to moderate the ECA costs computed under the high price case.

Table 5-4 summarizes the WORLD results for refinery capacity additions, investments, and utilizations for each case. A major effect of switching bunker demand from the IEA basis to the RTI basis is to ease the requirement for residual fuel upgrading and desulfurization. As a consequence, less refining investment (on top of base capacity, plus allowed projects) is needed by 2020 under the RTI basis ($102.5 billion) in the reference case than under the IEA basis ($110.5 billion).[2] Under the high price case, the reduction is larger, from $151.7 billion to $139.1 billion. Note that the absolute levels of investment cannot be compared between the reference and high price scenarios because the former includes 8 million bpcd of projects, whereas the latter includes 4.1 million bpd, as discussed in Section 4.

[2] The capital investments detailed in current WORLD reports are generally lower than those projected by IEA, for example, for the same time frame. A reason for this is that the WORLD reports do not include an allowance for ongoing capital replacement. This is typically estimated at 1.5% to 3% per year of the total installed capital base (which, of course, grows over time). It is EnSys's intent to expand the WORLD reports in the future to make the basis consistent with IEA and others.

Table 5-4. WORLD Refinery Capacity Additions, Investments, and Utilizations 2020

	IEA Bkrs Ref	RTI Bkrs Ref	RTI ECA Ref	IEA Bkrs High	RTI Bkrs High	RTI ECA High	ECA vs RTI Ref	ECA vs RTI High
CAPACITY ADDITIONS & INVESTMENTS - OVER & ABOVE 2008 BASE + ASSESSED PROJECTS								
Note: the investments shown below are for original capital cost only. They not not include annual capital replacement, typically reckoned at 2-3% p.a. of the installed capacity base.								
WORLD INVESTMENTS OVER KNOWN PROJECTS $(2006) billion								
REVAMP	$ 4.2	$ 4.0	$ 4.2	$ 5.4	$ 5.5	$ 5.3	$ 0.16	$ (0.20)
DEBOTTLENECKING	$ 0.6	$ 0.7	$ 0.7	$ 1.3	$ 1.4	$ 1.4	$ 0.01	$ -
MAJOR NEW UNITS	$ 105.7	$ 97.8	$ 100.8	$ 144.9	$ 132.1	$ 138.0	$ 3.03	$ 5.91
TOTAL REFINING	$ 110.5	$ 102.5	$ 105.7	$ 151.7	$ 139.1	$ 144.8	$ 3.20	$ 5.70
CRUDE DISTILLATION BASE CAPACITY & ADDITIONS								
BASE CAPACITY	86.70	86.70	86.70	86.70	86.70	86.70	0.00	0.00
FIRM CONSTRUCTION	8.01	8.01	8.01	4.12	4.12	4.12	0.00	0.00
DEBOTTLENECKING ADDITIONS	0.60	0.70	0.68	0.52	0.68	0.68	(0.02)	0.00
MAJOR NEW UNIT ADDITIONS	6.70	7.89	7.95	1.90	3.19	3.14	0.05	(0.05)
TOTAL ADDITIONS OVER BASE	15.31	16.60	16.64	6.54	7.99	7.94	0.04	(0.05)
TOTAL BASE + ADDITIONS	**102.01**	**103.30**	**103.34**	**93.24**	**94.69**	**94.64**	**0.04**	**(0.05)**
TOTAL CRUDE CAP USED	84.85	86.04	86.10	73.31	74.98	75.01	0.05	0.03
REFINERY UTILIZATION	83.2%	83.3%	83.3%	78.6%	79.2%	79.3%	0.02%	0.07%
SECONDARY PROCESSING ADDITIONS - DEBOTTLENECKING PLUS MAJOR NEW UNITS								
VACUUM DISTILLATION	0.25	0.23	0.21	0.08	0.06	0.06	(0.02)	0.00
COKING+VISBREAKING	0.37	0.34	0.36	0.10	0.14	0.13	**0.02**	**(0.00)**
CATALYTIC CRACKING	0.02	0.02	0.02	0.00	0.00	0.00	(0.01)	0.00
HYDRO-CRACKING (TOTAL)	0.951	0.545	0.664	2.046	1.648	1.846	**0.12**	**0.20**
CATALYTIC REFORMING - New							0.00	0.00
CATALYTIC REFORMING - Revamp	1.003	0.969	1.024	0.884	0.916	0.882	0.06	(0.03)
DESULPHURIZATION (TOTAL)	6.244	5.699	5.867	4.608	4.065	4.124	**0.17**	**0.06**
- GASOLINE - ULS	2.631	2.589	2.585	1.855	1.832	1.827	(0.00)	(0.01)
- DISTILLATE ULS - NEW	1.57	1.28	1.42	0.79	0.56	0.55	0.14	(0.01)
- DISTILLATE ULS - REVAMP	1.328	1.250	1.250	1.024	0.987	0.991	0.00	0.00
- DISTILLATE CONV/LS	0.447	0.433	0.458	0.609	0.428	0.497	0.02	0.07
- VGO/RESID	0.264	0.151	0.154	0.327	0.254	0.259	0.00	0.00
HYDROGEN (MMBFOED)	0.583	0.530	0.541	0.666	0.570	0.599	0.011	0.029
HYDROGEN (million SCFD)	11,454	10,404	10,622	13,087	11,197	11,765	218	568
SULPHUR PLANT (TPD)	8200	8110	8250	9710	7840	7960	140	120

With the 8 million bpd of projects included under the reference scenario, global 2020 refinery utilizations are projected at 83.2%–83.3%. Even having dropped back projects to 4 million bpd under the high price case, the 11 million bpd reduction in demand under that scenario, plus the increase in noncrude supply, leads to projected 2020 high price utilization rates of around 79.3% (i.e., 4% below those in the reference cases). The implication is that, even if no more refinery projects are implemented by 2020 beyond those under construction today, under the high price scenario, there will be more primary and secondary capacity available. This could mitigate potential ECA impacts on fuel costs as output from the model in the high price scenario, as shown in Tables 5-4, 5-5, 5-6, and 5-8 (furthest right-hand-side column). Computed ECA costs will be higher if refinery utilizations are higher.

The high price cases illustrate the effects discussed in Section 4 of scenarios under which crude price rises substantially, while prices for natural gas and petroleum coke do not. Despite an

11 million bpd reduction in global oil demand, capacity additions for hydrocracking over and above known projects are approximately 1 million bpcd higher under the high price case than under the reference case. Coking additions also drop. In part, the extra hydrocracking capacity is offset by—or taking over the role of—desulfurization capacity additions, implying fairly fine economic choices between hydrocracking and desulfurization economics.

The overall effects of the ECA cases are to increase global refining investments (by $3.2–$5.7 billion). This results from increases in hydrocracking, desulfurization, coking, and supporting hydrogen and sulfur plant capacities required to undertake the conversion of high sulfur IFO to 0.1% sulfur marine distillate and to reduce the sulfur level of MGO and MDO volumes affected under the ECA cases. That coking unit throughputs increase is evident in the higher levels of petroleum coke output under the ECA cases. The low level of coker capacity increase indicates potential underutilization of coker units in the reference and especially the high price base cases. Again, the modeled ECA costs are sensitive to this. Recent EnSys WORLD studies indicate that recent and current coking capacity expansions, combined with declines in the output of heavy crudes from Venezuela and Mexico, plus growth under the RTI cases in total residual fuel demand, will lead to surplus coking capacity. Other analysts have also reached the same conclusion.

5.3 Refining Economics and Prices

Tables 5-5, 5-6 and 5-7 summarize key price results from the 2020 cases. In reviewing these results, it should be noted that the WORLD model was run for 2020 in the “long-run” mode. In other words, opportunities for investment were kept open, and price results equate to long-run equilibrium prices and not to the short-run ones, under which investment opportunities are not permitted. Long-run equilibrium prices are more stable than short-run prices because they incorporate an assumed long-run return on capital. Short-run prices can be relatively higher or lower, depending on whether refining capacity is tight or slack.

A central feature of these and other recent EnSys WORLD cases is that the global higher growth rates for distillates relative to gasoline, driven by Europe’s dieselization policy and distillate-oriented demand growth in many non-OECD regions, lead to a situation where future distillate prices are projected to exceed those for gasoline. In the projected 2020 reference scenario, ultra-low sulfur diesel to ultra-low sulfur gasoline premiums are projected to be in the range of $7/bbl U.S. Gulf Coast (USGC) and $12 to $17/bbl in Asia and, especially, Europe. Under the high price scenario, the differentials are correspondingly higher, over $16/bbl USGC and $24 to $27/bbl in Europe and Asia. Gasoline premiums relative to residual fuel are moderate,

Table 5-5. 2020 Price Results From WORLD Case Analyses

	IEA Bkrs Ref	RTI Bkrs Ref	RTI ECA Ref	IEA Bkrs High	RTI Bkrs High	RTI ECA High	ECA vs RTI Ref	ECA vs RTI High
CRUDE PRICES (FOB)	**$/barrel**							
SAUDI LIGHT (input marker crude price)	$ 51.55	$ 51.55	$ 51.55	$ 88.14	$ 88.14	$ 88.14	$ -	$ -
WORLD Output Crude Prices								
WEST TEXAS INTERMEDIATE	$ 56.46	$ 56.51	$ 56.51	$ 92.95	$ 92.47	$ 92.53	$ -	$ 0.06
BRENT	$ 55.27	$ 55.13	$ 55.11	$ 92.33	$ 91.76	$ 91.79	$ (0.02)	$ 0.03
DUBAI	$ 51.28	$ 51.30	$ 51.28	$ 87.26	$ 87.14	$ 87.13	$ (0.02)	$ (0.01)
SAUDI HEAVY	$ 48.34	$ 48.71	$ 48.67	$ 82.89	$ 84.14	$ 84.07	$ (0.04)	$ (0.07)
MAYAN	$ 48.21	$ 48.18	$ 48.16	$ 80.26	$ 81.23	$ 80.70	$ (0.02)	$ (0.53)
	$ 8.25	$ 8.33	$ 8.35	$ 12.69	$ 11.24	$ 11.83	$ 0.02	$ 0.59
WORLD Output Product Prices								
USEC								
LPG	$ 47.02	$ 47.27	$ 47.10	$ 75.59	$ 75.30	$ 75.24	$ (0.16)	$ (0.06)
PETCHEM NAPHTHA	$ 46.34	$ 46.34	$ 46.10	$ 73.08	$ 72.51	$ 72.26	$ (0.24)	$ (0.26)
CG - ULS PREMIUM	$ 60.98	$ 61.01	$ 60.89	$ 91.14	$ 89.79	$ 89.75	$ (0.11)	$ (0.04)
CG - ULS REGULAR	$ 58.72	$ 58.72	$ 58.59	$ 91.71	$ 91.21	$ 91.16	$ (0.13)	$ (0.06)
RFG - PREMIUM (0/5.7/10% ETOH)	$ 60.85	$ 60.87	$ 60.72	$ 92.38	$ 92.04	$ 91.91	$ (0.14)	$ (0.14)
RFG - REGULAR (0/5.7/10% ETOH)	$ 58.60	$ 58.57	$ 58.45	$ 89.50	$ 88.92	$ 88.77	$ (0.12)	$ (0.15)
KERO/JET JTA/A1	$ 64.49	$ 64.44	$ 64.70	$ 104.93	$ 104.07	$ 104.44	$ 0.26	$ 0.37
DSL NO2 ULSD (50 - 10 PPM)	$ 68.17	$ 68.12	$ 68.30	$ 110.10	$ 108.82	$ 109.18	$ 0.18	$ 0.36
NO2 HEATING OIL (US)	$ 62.91	$ 63.27	$ 63.41	$ 103.44	$ 103.14	$ 103.29	$ 0.14	$ 0.15
RESID .3-1.0%	$ 53.22	$ 53.04	$ 52.83	$ 88.61	$ 87.35	$ 87.18	$ (0.22)	$ (0.17)
MGO DMA	-	$ 62.39	$ 62.62	-	$ 101.75	$ 101.97	$ 0.23	$ 0.22
MDO HS	-	$ 60.19	$ 59.97	-	$ 99.71	$ 99.18	$ (0.22)	$ (0.52)
MDO LS (vs MDO HS)	-	-	$ 63.25	-	-	$ 102.94	$ 3.06	$ 3.24
IFO380 LS	-	-	-	-	-	-		
IFO380 HS	$ 50.35	$ 49.21	$ 48.38	$ 82.88	$ 82.33	$ 80.73	$ (0.82)	$ (1.60)
USGC	**$/barrel**							
LPG	$ 46.71	$ 46.95	$ 46.79	$ 75.48	$ 75.19	$ 75.13	$ (0.16)	$ (0.06)
PETCHEM NAPHTHA	$ 46.36	$ 46.43	$ 46.19	$ 72.81	$ 72.24	$ 71.98	$ (0.25)	$ (0.26)
CG - ULS PREMIUM	$ 61.22	$ 61.24	$ 61.13	$ 92.36	$ 91.07	$ 91.02	$ (0.11)	$ (0.05)
CG - ULS REGULAR	$ 59.53	$ 59.57	$ 59.45	$ 91.96	$ 91.62	$ 91.47	$ (0.12)	$ (0.15)
RFG - PREMIUM (0/5.7/10% ETOH)	$ 59.70	$ 59.71	$ 59.57	$ 91.21	$ 90.87	$ 90.74	$ (0.14)	$ (0.13)
RFG - REGULAR (0/5.7/10% ETOH)	$ 57.69	$ 57.73	$ 57.58	$ 88.59	$ 88.22	$ 88.06	$ (0.15)	$ (0.16)
KERO/JET JTA/A1	$ 63.47	$ 63.42	$ 63.68	$ 103.91	$ 103.05	$ 103.42	$ 0.26	$ 0.37
DSL NO2 ULSD (50 - 10 PPM)	$ 67.15	$ 67.10	$ 67.28	$ 109.08	$ 107.80	$ 108.16	$ 0.18	$ 0.36
RESID .3-1.0%	$ 52.95	$ 53.03	$ 52.99	$ 86.99	$ 86.66	$ 86.64	$ (0.04)	$ (0.02)
MGO DMA	-	$ 61.45	$ 61.67	-	$ 100.73	$ 100.92	$ 0.22	$ 0.19
MDO HS	$ 60.14	$ 60.50	$ 60.56	$ 99.68	$ 99.69	$ 99.71	$ 0.06	$ 0.02
MDO LS (vs MDO HS)	-	-	$ 62.02	-	-	$ 101.46	$ 1.52	$ 1.77
IFO380 LS	-	-	-	-	-	-	n.a.	n.a.
IFO380 HS	$ 49.89	$ 49.98	$ 49.99	$ 81.97	$ 81.74	$ 81.72	$ 0.01	$ (0.02)
USWC								
LPG	$ 49.37	$ 49.61	$ 49.45	$ 79.15	$ 78.85	$ 78.79	$ (0.16)	$ (0.06)
PETCHEM NAPHTHA	$ 43.35	$ 43.09	$ 42.94	$ 72.75	$ 70.71	$ 70.33	$ (0.16)	$ (0.39)
CG - ULS PREMIUM	$ 62.74	$ 62.70	$ 62.53	$ 96.36	$ 95.11	$ 95.07	$ (0.17)	$ (0.04)
CG - ULS REGULAR	$ 60.68	$ 60.70	$ 60.62	$ 94.06	$ 93.50	$ 93.25	$ (0.08)	$ (0.25)
CARB RFG PREMIUM (0/5.7% ETOH)	$ 61.67	$ 61.69	$ 61.56	$ 96.90	$ 96.36	$ 96.15	$ (0.13)	$ (0.21)
CARB RFG REGULAR (0/5.7% ETOH)	$ 60.37	$ 60.42	$ 60.34	$ 95.34	$ 94.77	$ 94.56	$ (0.08)	$ (0.22)
KERO/JET JTA/A1	$ 64.52	$ 64.46	$ 64.73	$ 106.87	$ 105.76	$ 106.05	$ 0.27	$ 0.29
DSL NO2 ULSD (50 - 10 PPM)	$ 67.62	$ 67.59	$ 67.86	$ 110.47	$ 108.75	$ 109.02	$ 0.27	$ 0.27
DSL NO2 RFD / CARB	$ 67.62	$ 67.59	$ 67.86	$ 110.47	$ 108.75	$ 109.02	$ 0.27	$ 0.27
RESID .3-1.0%	$ 53.18	$ 53.63	$ 53.47	$ 87.45	$ 88.34	$ 87.91	$ (0.17)	$ (0.42)
MGO DMA	-	$ 60.73	$ 61.66	-	$ 102.93	$ 103.49	$ 0.93	$ 0.56
MDO HS	-	$ 59.67	$ 59.46	-	$ 101.53	$ 101.67	$ (0.21)	$ 0.14
MDO LS	-	-	$ 62.73	-	-	$ 104.02	$ 3.06	$ 2.49
IFO380 LS	-	-	-	-	-	-	n.a.	n.a.
IFO380 HS	$ 49.56	$ 50.28	$ 50.03	$ 81.33	$ 83.13	$ 81.94	$ (0.25)	$ (1.19)

Table 5-6. 2020 Price Results From WORLD Case Analyses

Case	IEA Bkrs Ref	RTI Bkrs Ref	RTI ECA Ref	IEA Bkrs High	RTI Bkrs High	RTI ECA High	ECA vs RTI Ref	ECA vs RTI High
WORLD Output Product Prices								
Northwest Europe								
LPG	$ 50.06	$ 50.14	$ 49.97	$ 79.55	$ 78.88	$ 78.84	$ (0.16)	$ (0.04)
PETCHEM NAPHTHA	$ 45.92	$ 45.75	$ 45.52	$ 74.04	$ 72.98	$ 72.67	$ (0.23)	$ (0.31)
RFG - PREMIUM (EURO III/IV/V)	$ 56.66	$ 56.68	$ 56.58	$ 91.14	$ 90.50	$ 90.44	$ (0.10)	$ (0.06)
RFG - REGULAR (EURO III/IV/V)	$ 54.61	$ 54.58	$ 54.46	$ 88.12	$ 87.46	$ 87.38	$ (0.12)	$ (0.08)
KERO/JET JTA/A1	$ 67.34	$ 66.96	$ 67.28	$ 111.17	$ 110.81	$ 110.97	$ 0.32	$ 0.16
DSL NO2 MSD (1000-5000 PPM)	$ 66.97	$ 66.98	$ 67.32	$ 111.24	$ 111.10	$ 111.24	$ 0.33	$ 0.14
DSL NO2 RFD / CARB	$ 71.40	$ 71.09	$ 71.39	$ 115.17	$ 114.83	$ 114.99	$ 0.30	$ 0.16
RESID .3-1.0%	$ 51.10	$ 51.51	$ 51.40	$ 87.18	$ 86.90	$ 86.83	$ (0.10)	$ (0.07)
MGO DMA	$ 65.22	$ 65.01	$ 65.47	$ 107.83	$ 107.74	$ 107.90	$ 0.46	$ 0.16
MDO HS	$ 61.86	$ 61.44	$ 61.79	$ 101.57	$ 101.23	$ 101.42	$ 0.35	$ 0.19
MDO LS	$ 64.96	$ 64.39	$ 65.49	$ 106.85	$ 106.56	$ 107.93	$ 4.05	$ 6.70
IFO380 LS	-	-	-	-	-	-		
IFO380 HS	$ 49.35	$ 50.38	$ 50.26	$ 83.23	$ 84.87	$ 84.74	$ (0.13)	$ (0.13)
Asia - Singapore								
LPG	$ 52.51	$ 52.48	$ 52.55	$ 82.23	$ 81.93	$ 81.87	$ 0.07	$ (0.05)
PETCHEM NAPHTHA	$ 47.71	$ 47.66	$ 47.52	$ 77.05	$ 76.23	$ 75.95	$ (0.14)	$ (0.28)
RFG - PREMIUM (EURO III/IV/V)	$ 59.13	$ 59.38	$ 59.23	$ 91.73	$ 91.36	$ 91.25	$ (0.15)	$ (0.11)
RFG - REGULAR (EURO III/IV/V)	$ 55.97	$ 56.07	$ 55.92	$ 88.79	$ 88.24	$ 88.04	$ (0.15)	$ (0.20)
KERO/JET JTA/A1	$ 65.34	$ 64.47	$ 64.59	$ 109.09	$ 109.14	$ 109.31	$ 0.12	$ 0.18
DSL NO2 MSD (1000-5000 PPM)	$ 64.75	$ 63.96	$ 64.10	$ 108.57	$ 108.85	$ 109.03	$ 0.13	$ 0.18
DSL NO2 LSD (500 PPM)	$ 66.17	$ 65.30	$ 65.43	$ 110.14	$ 110.20	$ 110.39	$ 0.13	$ 0.19
DSL NO2 RFD / CARB	$ 68.56	$ 67.50	$ 67.65	$ 113.28	$ 113.34	$ 113.57	$ 0.15	$ 0.22
RESID .3-1.0%	$ 53.45	$ 53.28	$ 53.20	$ 87.43	$ 87.45	$ 87.34	$ (0.08)	$ (0.11)
MGO DMA	$ 64.49	$ 63.74	$ 63.88	$ 108.22	$ 108.60	$ 108.77	$ 0.14	$ 0.17
MDO HS	$ 63.23	$ 62.65	$ 62.76	$ 106.12	$ 106.64	$ 106.75	$ 0.11	$ 0.11
MDO LS (vs MDO HS)	-	-	$ 64.91	-	-	$ 109.92	$ 2.26	$ 3.28
IFO380 LS	-	-	-	-	-	-	n.a.	n.a.
IFO380 HS	$ 48.64	$ 49.75	$ 49.65	$ 81.41	$ 85.09	$ 84.83	$ (0.11)	$ (0.25)

Table 5-7. 2020 WORLD Output Product Price Differentials

Case	IEA Bkrs Ref	RTI Bkrs Ref	RTI ECA Ref	IEA Bkrs High	RTI Bkrs High	RTI ECA High	ECA vs RTI Ref	ECA vs RTI High
WORLD Output Product Price Differentials								
USEC	**$/barrel**							
Diesel (ULS) - Gasoline (CG Regular ULS)	$ 9.45	$ 9.40	$ 9.71	$ 18.39	$ 17.61	$ 18.02	$ 0.32	$ 0.41
Gasoline (CG Regular ULS) - Resid HS IFO 380	$ 8.37	$ 9.52	$ 10.21	$ 8.83	$ 8.89	$ 10.43	$ 0.69	$ 1.54
Diesel (ULS) - Resid HS IFO 380	$ 17.81	$ 18.91	$ 19.92	$ 27.23	$ 26.49	$ 28.45	$ 1.01	$ 1.95
MDO HS - IFO380 HS	n.a.	$ 10.98	$ 11.59	n.a.	$ 17.38	$ 18.46	$ 0.61	$ 1.08
Resid 1% S - IFO380 HS	$ 2.87	$ 3.84	$ 4.44	$ 5.73	$ 5.02	$ 6.45	$ 0.61	$ 1.43
Diesel ULS - MDO HS	n.a.	$ 7.93	$ 8.33	n.a.	$ 9.12	$ 9.99	$ 0.40	$ 0.88
USGC								
Diesel (ULS) - Gasoline (CG Regular ULS)	$ 7.62	$ 7.53	$ 7.83	$ 17.12	$ 16.18	$ 16.69	$ 0.31	$ 0.51
Gasoline (CG Regular ULS) - Resid HS IFO 380	$ 9.64	$ 9.59	$ 9.46	$ 10.00	$ 9.88	$ 9.75	$ (0.13)	$ (0.13)
Diesel (ULS) - Resid HS IFO 380	$ 17.26	$ 17.12	$ 17.30	$ 27.12	$ 26.06	$ 26.44	$ 0.18	$ 0.38
MDO HS - IFO380 HS	$ 10.25	$ 10.52	$ 10.57	$ 17.71	$ 17.94	$ 17.99	$ 0.05	$ 0.04
Resid 1% S - IFO380 HS	$ 1.75	$ 1.12	$ 1.15	$ 3.96	$ 2.03	$ 2.09	$ 0.02	$ 0.06
Diesel ULS - MDO HS	$ 7.01	$ 6.60	$ 6.73	$ 9.41	$ 8.11	$ 8.45	$ 0.12	$ 0.33
USWC								
Diesel (ULS) - Gasoline (CG Regular ULS)	$ 6.95	$ 6.89	$ 7.24	$ 16.41	$ 15.26	$ 15.77	$ 0.35	$ 0.52
Gasoline (CG Regular ULS) - Resid HS IFO 380	$ 11.11	$ 10.42	$ 10.59	$ 12.73	$ 10.37	$ 11.31	$ 0.16	$ 0.94
Distillate (ULS) - Resid HS IFO 380	$ 18.06	$ 17.32	$ 17.83	$ 29.14	$ 25.63	$ 27.08	$ 0.51	$ 1.46
MDO HS - IFO380 HS	n.a.	$ 9.40	$ 9.43	n.a.	$ 18.40	$ 19.73	$ 0.03	$ 1.33
Resid 1% S - IFO380 HS	$ 3.62	$ 3.36	$ 3.44	$ 6.12	$ 5.21	$ 5.97	$ 0.08	$ 0.76
Diesel ULS - MDO HS	n.a.	$ 7.92	$ 8.40	n.a.	$ 7.22	$ 7.35	$ 0.48	$ 0.13
Northwest Europe								
Diesel (ULS Euro) - Gasoline (RFG Regular Eurc	$ 16.79	$ 16.51	$ 16.93	$ 27.06	$ 27.37	$ 27.60	$ 0.42	$ 0.23
Gasoline (RFG Regular Euro) - Resid HS IFO 38	$ 5.26	$ 4.20	$ 4.20	$ 4.89	$ 2.59	$ 2.64	$ 0.01	$ 0.05
Diesel (ULS Euro) - Resid HS IFO 380	$ 22.05	$ 20.71	$ 21.13	$ 31.94	$ 29.96	$ 30.25	$ 0.42	$ 0.28
MDO HS - IFO380 HS	$ 12.51	$ 11.06	$ 11.53	$ 18.34	$ 16.36	$ 16.68	$ 0.47	$ 0.32
Resid 1% S - IFO380 HS	$ 1.75	$ 1.12	$ 1.15	$ 3.96	$ 2.03	$ 2.09	$ 0.02	$ 0.06
Diesel ULS - MDO HS	$ 9.54	$ 9.65	$ 9.60	$ 13.60	$ 13.61	$ 13.57	$ (0.05)	$ (0.04)
Asia - Singapore								
Diesel (ULS) - Gasoline (CG Regular ULS)	$ 12.59	$ 11.43	$ 11.73	$ 24.50	$ 25.10	$ 25.52	$ 0.30	$ 0.42
Gasoline (CG Regular ULS) - Resid HS IFO 380	$ 7.33	$ 6.31	$ 6.27	$ 7.38	$ 3.16	$ 3.21	$ (0.04)	$ 0.06
Diesel (ULS) - Resid HS IFO 380	$ 19.92	$ 17.74	$ 18.00	$ 31.88	$ 28.26	$ 28.73	$ 0.26	$ 0.48
MDO HS - IFO380 HS	$ 14.59	$ 12.90	$ 13.12	$ 24.71	$ 21.55	$ 21.92	$ 0.22	$ 0.36
Resid 1% S - IFO380 HS	$ 4.81	$ 3.52	$ 3.55	$ 6.03	$ 2.37	$ 2.51	$ 0.03	$ 0.14
Diesel ULS - MDO HS	$ 5.32	$ 4.85	$ 4.89	$ 7.17	$ 6.71	$ 6.82	$ 0.04	$ 0.11

around $9/bbl USGC and lower in Europe, especially, which has a systemic gasoline surplus as a result of active dieselization policies. Projected gasoline prices are essentially on a par with light sweet crude in both USGC and Northern Europe.

In short, the result is that—based on the premises which, *inter alia*, keep gasoline in relative surplus and have distillates as major growth products—the imbalances being experienced today in oil markets are likely to be sustained over time. High distillate price premiums and weak gasoline prices relative to crude could lead to some shift back to gasoline and away from diesel, but the scope would appear to be limited, given the mainly different uses for the two fuels. It must also be pointed out that the modeling undertaken here does not allow for the advent of any revolutionary new refinery processes (e.g., condensing naphtha/gasoline boiling range streams to diesel). Thus, sustained distillate premiums are underpinned by the high capital and operating costs of hydrocracking, the primary route to incremental diesel once distillate ex crude has been maximized.[3]

Growth in marine IFO demand, plus the availability of significant resid upgrading capacity, helps buoy residual fuel prices. IFO380 prices are around $6.50/bbl below light sweet crude in the reference cases; in the high price cases, prices are around $11/bbl below light sweet crude USGC and $7/bbl in Northwest Europe. Should heavy sour crude output resurge or less coking capacity be brought onstream than estimated, IFO380 prices are likely to be lower relative to distillate, potentially raising costs of conversion under a potential ECA.

The impact of the modeled ECA is to raise distillate prices (marine and nonmarine diesels, also jet fuel and kerosene) across all world regions and to lower those of gasoline, naphtha, LPG, and residual fuel. (The processes of coking and hydrocracking required to convert IFO to diesel do generate some gasoline, naphtha, and LPG streams, thus easing supply on these products.)

5.4 ECA Costs

Tables 5-8, 5-9, and 5-10 summarize WORLD results for product supply costs and CO_2 emissions. The results indicate increases in product supply costs[4] under the modeled U.S. and Canadian ECA of $0.45 and $0.65/bbl across all marine fuels worldwide and $0.02 and $0.06/bbl across all petroleum products worldwide; these costs are projected under, respectively, the reference and high price scenarios (Table 5-8). The cost effects are most marked in the United States and Canada. Marine fuels cost increase under the potential ECA in the United States and Canada is projected at $2.91/bbl under the reference scenario and $4.33/bbl under the high price scenario. Average impacts across all U.S. and Canadian products are $0.10 and $0.17/bbl, respectively.

Other regions are also affected to a lesser degree. Across regions outside the United States and Canada, marine fuel cost increases are projected to be $0.45/bbl and $0.65/bbl, respectively.

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[3] The version of the WORLD model used for this study embodied options for fluid catalytic cracking (FCC) units that exist and that raise FCC distillate (cycle oil) yields. FCC operations appear likely to move in that direction and also to take in more atmospheric residua over time, thereby raising distillate output. However, such distillate is of poor quality and requires further processing, either via hydrotreating or hydrocracking.

[4] Product supply costs are defined here as referring to the costs of finished petroleum products, refined and delivered to major market centers. They thus exclude costs of final distribution and of federal or other taxes.

5.5 Refining and CO_2 Emissions Impacts

Global refinery crude throughputs rise by 0.054 and 0.029 million bpd in the U.S. and Canadian ECA cases under, respectively, the reference and high price scenarios. These increases are occasioned by the increased use of coking, which produces solid by-product that does not contribute to (fixed) liquid product demand. The increase in crude use is smaller in the high price case because of the higher cost of using crude oil, including relative to increased use

Table 5-8. 2020 WORLD Output Product Supply Costs and CO_2 Emissions

	IEA Bkrs Ref	RTI Bkrs Ref	RTI ECA Ref	IEA Bkrs High	RTI Bkrs High	RTI ECA High	ECA vs RTI Ref	ECA vs RTI High
WORLD Output Global Total Oil Products Cost								
(excludes internal costs for refinery fuel consumption)			**$ million / day**					
LPG & Naphtha	$ 760	$ 760	$ 758	$ 1,086	$ 1,074	$ 1,072	$ (2.3)	$ (2.3)
Gasoline	$ 1,389	$ 1,389	$ 1,386	$ 1,991	$ 1,975	$ 1,973	$ (3.1)	$ (2.4)
Light Distillates (Jet/Kero)	$ 532	$ 528	$ 530	$ 793	$ 789	$ 791	$ 1.7	$ 1.9
Middle Distillates (excluding bunker fuels)	$ 2,036	$ 1,921	$ 1,927	$ 3,002	$ 2,836	$ 2,842	$ 5.5	$ 6.6
Residual Fuels (excluding bunker fuels)	$ 316	$ 201	$ 200	$ 476	$ 303	$ 302	$ (0.2)	$ (0.3)
Other Products	$ 313	$ 313	$ 313	$ 436	$ 438	$ 437	$ (0.2)	$ (0.8)
Marine Bunkers Fuels	$ 205	$ 485	$ 490	$ 345	$ 821	$ 830	$ 5.4	$ 8.4
Total $ million / day	**$ 5,551**	**$ 5,597**	**$ 5,604**	**$ 8,130**	**$ 8,236**	**$ 8,247**	**$ 6.8**	**$ 11.1**
Total $ billion / year	$ 2,026	$ 2,043	$ 2,046	$ 2,967	$ 3,006	$ 3,010	$ 2.5	$ 4.0
Global Marine Fuels Cost as Percent of Total	3.69%	8.66%	8.75%	4.25%	9.97%	10.06%	0.09%	0.09%
Marine Fuels Global Average Cost $/bbl	$ 51.47	$ 53.60	$ 54.05	$ 86.45	$ 90.76	$ 91.42	$ 0.45	$ 0.65
All Products Global Average Cost $/bbl	$ 54.66	$ 54.58	$ 54.60	$ 89.36	$ 89.07	$ 89.13	$ 0.02	$ 0.06

WORLD Output CO2 Emissions			**million tonnes per year**					
Global Marine Fuels CO2 Emissions	**689.6**	**1540.0**	**1539.3**	**690.4**	**1541.9**	**1540.0**	**(0.78)**	**(1.89)**
Global Refinery CO2 Emissions								
from H2 Plant	85.5	81.1	82.2	79.6	73.6	75.5	1.08	1.87
from Refinery Fuel	965.8	958.8	961.0	831.0	823.8	826.9	2.24	3.11
from Sulfur Plant Tail Gas Unit	2.1	2.0	2.0	1.8	1.6	1.7	0.04	0.04
from Flare Loss	47.1	47.8	47.8	40.7	41.6	41.7	0.03	0.02
Total	**1100.5**	**1089.7**	**1093.1**	**953.2**	**940.7**	**945.7**	**3.38**	**5.03**
Total from Petroleum Coke	308.0	279.8	288.5	225.5	205.9	211.1	8.71	5.13
Total from Refinery Incl Petroleum Coke	1408.5	1369.5	1381.6	1178.7	1146.6	1156.8	12.09	10.16
Combined Refinery + Marine Fuel CO2 Emissions								
Excl Petroleum Coke	1790.1	2629.7	2632.3	1643.5	2482.5	2485.7	2.61	3.14
Incl Petroleum Coke	2098.1	2909.6	2920.9	1869.1	2688.5	2696.7	11.31	8.27

Table 5-9. 2020 WORLD Output Refinery Investment, Throughput, and CO_2 Emissions, United States and Canada

	IEA Bkrs Ref	RTI Bkrs Ref	RTI ECA Ref	IEA Bkrs High	RTI Bkrs High	RTI ECA High	ECA vs RTI Ref	ECA vs RTI High
USA/Canada Detail								
WORLD Output Refinery Investments $(2006)bn								
US East Coast	$ 1.28	$ 1.37	$ 1.20	$ 0.60	$ 1.03	$ 0.94	$ (0.17)	$ (0.10)
US Gulf Coast, Interior, Canada East	$ 14.54	$ 14.52	$ 14.80	$ 27.56	$ 26.14	$ 27.30	$ 0.28	$ 1.16
US West Coast, Canada West	$ 2.23	$ 1.39	$ 1.57	$ 2.14	$ 1.38	$ 1.61	$ 0.18	$ 0.22
Total USA+Canada	**$ 18.05**	**$ 17.28**	**$ 17.56**	**$ 30.30**	**$ 28.56**	**$ 29.85**	**$ 0.29**	**$ 1.29**
Total Other Regions	$ 92.49	$ 85.23	$ 88.14	$ 121.38	$ 110.51	$ 114.92	$ 2.91	$ 4.41
Total World	$ 110.54	$ 102.51	$ 105.70	$ 151.69	$ 139.07	$ 144.77	$ 3.20	$ 5.70
WORLD Output Refinery Throughputs mmbpd								
US East Coast	1.38	1.38	1.38	1.38	1.38	1.38	0.00	0.00
US Gulf Coast, Interior, Canada East	12.65	12.59	12.63	11.28	11.20	11.23	0.04	0.03
US West Coast, Canada West	3.42	3.30	3.28	3.39	3.39	3.41	(0.02)	0.02
Total USA+Canada	**17.45**	**17.27**	**17.29**	**16.05**	**15.97**	**16.02**	**0.02**	**0.05**
Total Other Regions	67.41	68.77	68.81	57.27	59.02	58.99	0.04	(0.02)
Total World	84.85	86.04	86.10	73.31	74.98	75.01	0.05	0.03
WORLD Output Refinery CO2 Emissions million tonnes/year								
US East Coast	17.5	17.4	17.1	16.1	16.6	17.2	(0.26)	0.54
US Gulf Coast, Interior, Canada East	191.2	189.6	190.2	170.9	168.0	169.2	0.57	1.14
US West Coast, Canada West	52.5	50.2	50.3	48.6	46.9	47.7	0.17	0.81
Total USA+Canada	**261.2**	**257.2**	**257.6**	**235.6**	**231.6**	**234.1**	**0.48**	**2.49**
Total Other Regions	790.0	782.8	785.6	675.0	665.8	668.3	2.83	2.49
Total World	1051.2	1039.9	1043.2	910.6	897.4	902.4	3.31	4.97

These CO2 emissions do not include those from sulfur plant tail gas unit or from flare

of natural gas for hydrogen. Hydrogen from natural gas is projected to increase by 0.011 million bfoed in the reference scenario ECA and 0.021 million bfoed in the high price ECA scenario (Table 5-1). The refinery throughput increases occur primarily in the United States and Canada.

Under the ECA cases, global CO_2 emissions from marine fuels decline by 0.8 and 1.9 million tpa under, respectively, the reference and high price scenarios. This compares to refinery CO_2 emissions increases associated with additional processing to produce the higher standard marine fuels of 3.4 and 5.0 million tpa. If the CO_2 emissions associated with the additional outputs of petroleum coke are added in, total refinery plus coke CO_2 emissions rise by, respectively, 12.1 and 10.1 million tpa. Under the high price scenario, 50% of the global refinery CO_2 emissions increases occur in the United States and Canada. Under the reference scenario, the proportion is lower.

Table 5-10. 2020 WORLD Output Product Supply Costs, United States and Canada

	IEA Bkrs Ref	RTI Bkrs Ref	RTI ECA Ref	IEA Bkrs High	RTI Bkrs High	RTI ECA High	ECA vs RTI Ref	ECA vs RTI High
WORLD Output US & Canada Oil Products Supply Cost								
(excludes internal costs for refinery fuel consumption)			**$ million / day**					
LPG & Naphtha	$ 89	$ 90	$ 89	$ 135	$ 134	$ 133	$ (0.34)	$ (0.22)
Gasoline	$ 576	$ 576	$ 575	$ 833	$ 829	$ 827	$ (1.17)	$ (1.29)
Light Distillates (Jet/Kero)	$ 126	$ 126	$ 127	$ 194	$ 192	$ 192	$ 0.52	$ 0.64
Middle Distillates (excluding bunker fuels)	$ 364	$ 354	$ 355	$ 554	$ 532	$ 534	$ 1.04	$ 1.64
Residual Fuels (excluding bunker fuels)	$ 25	$ 23	$ 23	$ 39	$ 36	$ 36	$ (0.02)	$ (0.02)
Other Products	$ 75	$ 74	$ 74	$ 106	$ 106	$ 106	$ 0.19	$ (0.14)
Marine Bunkers Fuels	$ 35	$ 40	$ 43	$ 58	$ 66	$ 71	$ 3.01	$ 4.50
Total $ million / day	**$ 1,291**	**$ 1,283**	**$ 1,286**	**$ 1,919**	**$ 1,895**	**$ 1,900**	**$ 3.24**	**$ 5.11**
Total $ billion / year	$ 471	$ 468	$ 470	$ 700	$ 692	$ 693	$ 1.18	$ 1.87
USA - Canada Total Demand	24.50	24.37	24.39	23.21	23.09	23.10		
All Products USA/Canada Average Cost - $/bbl	$ 52.67	$ 52.65	$ 52.75	$ 82.70	$ 82.08	$ 82.25	**$ 0.10**	**$ 0.17**
US & Canada Marine Fuels Cost as Percent of Total	2.73%	3.12%	3.35%	3.03%	3.50%	3.73%	0.20%	0.21%
Marine Fuels US & Canada Average Cost $/bbl	$ 50.30	$ 52.87	$ 55.78	$ 82.73	$ 87.39	$ 91.73	**$ 2.91**	**$ 4.33**
PRODUCT MANUFACTURING/SUPPLY COSTS								
WORLD Output Other Regions Oil Products Supply Cost								
(excludes internal costs for refinery fuel consumption)			**$ million / day**					
LPG & Naphtha	$ 671	$ 670	$ 669	$ 952	$ 941	$ 938	$ (1.91)	$ (2.09)
Gasoline	$ 813	$ 813	$ 811	$ 1,158	$ 1,146	$ 1,145	$ (1.92)	$ (1.11)
Light Distillates (Jet/Kero)	$ 406	$ 402	$ 404	$ 600	$ 597	$ 599	$ 1.20	$ 1.27
Middle Distillates (excluding bunker fuels)	$ 1,672	$ 1,567	$ 1,571	$ 2,449	$ 2,304	$ 2,309	$ 4.46	$ 4.95
Residual Fuels (excluding bunker fuels)	$ 291	$ 177	$ 177	$ 437	$ 267	$ 266	$ (0.23)	$ (0.30)
Other Products	$ 238	$ 239	$ 239	$ 329	$ 331	$ 331	$ (0.38)	$ (0.64)
Marine Bunkers Fuels	$ 170	$ 445	$ 447	$ 287	$ 755	$ 759	$ 2.37	$ 3.87
Total $ million / day	**$ 4,260**	**$ 4,314**	**$ 4,318**	**$ 6,211**	**$ 6,341**	**$ 6,347**	**$ 3.59**	**$ 5.95**
Total $ billion / year	$ 1,555	$ 1,575	$ 1,576	$ 2,267	$ 2,314	$ 2,317	$ 1.31	$ 2.17
Total Other Regions Marine Fuels Cost as % of Total	4.0%	10.3%	10.4%	4.6%	11.9%	12.0%	0.05%	0.05%
Marine Fuels Total Other Regions Average Cost $/bbl	$ 51.72	$ 53.67	$ 53.89	$ 87.24	$ 91.07	$ 91.39	$ 0.23	$ 0.32
Marine Fuels Total All Regions Average Cost $/bbl	$ 51.47	$ 53.60	$ 54.05	$ 86.45	$ 90.76	$ 91.42	$ 0.45	$ 0.65

5.6 Marine Fuels Composition

Table 5-11 contains the breakdown of marine bunker demand, which drives the refining changes under the ECA scenarios. It illustrates the projected shift from IFO to low sulfur marine distillate (MDO) and, secondarily from high sulfur to low sulfur MDO. Although not evident from the table, ECA-affected MGO volumes were also reduced in sulfur content. The table further shows how the US/Canada ECA is projected to impact marine fuels lifted both within and outside the USA and Canada as ships trading in to the USA and Canada from overseas must taken on ECA fuel for eventual passage through the US/Canada ECA zones.

Table 5-12 summarizes the global compositions of IFO, high and low sulfur MDO and of MGO across the cases. The IFO blends are dominated by residual streams and secondarily cracked stocks. The significant proportions of projected atmospheric resid in IFO are driven by the high volumes of IFO demand – some 6.6 million bpd - projected for total IFO in the 2020 base cases. Also, regions with more complex refineries, including the USA and Canada, have low proportions of atmospheric resid in IFO, other regions, notably the FSU, Middle East and Asia, have much higher proportions.

Table 5-11. 2020 Projected Bunker Fuel Demands

	IEA Bkrs Ref	RTI Bkrs Ref	RTI ECA Ref	IEA Bkrs High	RTI Bkrs High	RTI ECA High	ECA vs RTI Ref	ECA vs RTI High
Marine Bunkers Demands								
Total USA+Canada		**million bpd**						
MGO	0.000	0.142	0.142	0.000	0.142	0.142	0.000	0.000
MDO - HS	0.002	0.055	0.035	0.002	0.055	0.034	(0.020)	(0.021)
MDO - LS	0.000	0.000	0.201	0.000	0.000	0.201	0.201	0.201
Total Distillate Bunkers	**0.002**	**0.197**	**0.378**	**0.002**	**0.197**	**0.377**	0.181	0.180
IFO180 LS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
IFO180 HS	0.076	0.064	0.027	0.076	0.064	0.027	(0.037)	(0.037)
IFO380 LS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
IFO380 HS	0.622	0.497	0.367	0.624	0.498	0.368	(0.130)	(0.130)
Total IFO Bunkers	**0.698**	**0.561**	**0.395**	**0.701**	**0.562**	**0.395**	(0.166)	(0.167)
Grand Total Bunkers - USA/Canada	**0.700**	**0.758**	**0.773**	**0.703**	**0.759**	**0.772**	0.015	0.013
Other World Regions		**million bpd**						
MGO	0.183	1.282	1.277	0.185	1.273	1.274	(0.005)	0.001
MDO - HS	0.154	0.483	0.483	0.154	0.482	0.482	0.000	0.000
MDO - LS	0.361	0.441	0.552	0.362	0.442	0.552	0.092	0.091
Total Distillate Bunkers	**0.698**	**2.206**	**2.312**	**0.701**	**2.197**	**2.308**	**0.106**	**0.111**
IFO180 LS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
IFO180 HS	0.345	0.859	0.834	0.349	0.861	0.837	(0.025)	(0.024)
IFO380 LS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
IFO380 HS	2.235	5.221	5.150	2.242	5.230	5.157	(0.071)	(0.073)
Total IFO Bunkers	**2.580**	**6.080**	**5.984**	**2.591**	**6.091**	**5.994**	**(0.096)**	**(0.097)**
Grand Total Bunkers - Other Regions	3.278	8.286	8.296	3.292	8.288	8.302	0.009	0.014
Total World Bunkers Demand		**million bpd**						
MGO	0.183	1.424	1.419	0.185	1.415	1.416	(0.005)	0.001
MDO - HS	0.156	0.538	0.518	0.156	0.537	0.516	(0.020)	(0.021)
MDO - LS	0.361	0.441	0.753	0.362	0.442	0.753	0.312	0.311
Total Distillate Bunkers	**0.700**	**2.403**	**2.690**	**0.703**	**2.394**	**2.685**	0.287	0.291
IFO180 LS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
IFO180 HS	0.421	0.923	0.861	0.425	0.925	0.864	(0.062)	(0.061)
IFO380 LS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
IFO380 HS	2.858	5.719	5.517	2.866	5.728	5.525	(0.201)	(0.203)
Total IFO Bunkers	**3.279**	**6.641**	**6.379**	**3.291**	**6.653**	**6.389**	(0.263)	(0.264)
Grand Total Bunkers - All Regions	**3.979**	**9.044**	**9.068**	**3.994**	**9.047**	**9.074**	**0.024**	**0.027**
IFO HS Shifted to Distillate - million bpd							0.263	0.264
IFO HS Shifted to Distillate - % of Global Total IFO							4.0%	4.0%
Total World Bunkers Demand		**million tpa**						
MGO	9.0	69.5	69.5	9.1	69.5	69.5	0.0	0.0
MDO - HS	7.8	26.8	26.0	7.7	26.8	25.8	(0.8)	(0.9)
MDO - LS	17.9	21.9	36.9	17.9	21.9	37.0	15.1	15.1
Total Distillate Bunkers	34.7	118.1	132.4	34.8	118.2	132.4	14.3	14.2
IFO180 LS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IFO180 HS	23.7	51.6	48.0	23.8	51.4	48.1	(3.6)	(3.4)
IFO380 LS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IFO380 HS	162.1	322.2	311.0	162.3	322.7	311.1	(11.2)	(11.6)
Total IFO Bunkers	185.9	373.8	359.0	186.1	374.2	359.2	(14.8)	(15.0)
Grand Total Bunkers - All Regions	**220.6**	**491.9**	**491.4**	**220.8**	**492.4**	**491.6**	**(0.5)**	**(0.8)**
IFO HS Shifted to Distillate - million tpa							14.8	15.0
IFO HS Shifted to Distillate - % of Global Total IFO							4.0%	4.0%

The MDO (DMB) grades are dominated by middle distillate and heavy distillate/light vacuum gasoil streams. The low (0.1%) sulfur MDO contains much higher proportions of low sulfur light and middle distillates than present in the high sulfur MDO. The MGO compositions show a shift away from heavy distillate/light vacuum gasoil fractions and toward light and middle distillates in the ECA cases.

Table 5-12. WORLD Projected Bunker Fuel Compositions

Case	IEA Bkrs Ref	RTI Bkrs Ref	RTI ECA Ref	IEA Bkrs High	RTI Bkrs High	RTI ECA High
Composition of Total IFO Fuel Global Average						**volume %**
light and middle distillates low S	0%	0%	0%	0%	0%	0%
light and middle distillates medium / high S	1%	1%	1%	2%	1%	1%
heavy distillate / light vacuum gasoil	6%	6%	6%	5%	9%	9%
heavy vacuum gasoil	2%	0%	1%	1%	1%	1%
atmospheric residua	54%	63%	65%	61%	62%	62%
vacuum residua	13%	11%	10%	11%	11%	10%
visbroken residua	6%	6%	6%	7%	7%	8%
cracked stocks	18%	12%	11%	14%	10%	9%
total	100%	100%	100%	100%	100%	100%
Composition of Marine Diesel (MDO DMB Grade) High Sulfur Global Average						**volume %**
light and middle distillates low S	1%	1%	1%	0%	1%	1%
light and middle distillates medium / high S	45%	57%	53%	55%	54%	48%
heavy distillate / light vacuum gasoil	47%	30%	33%	39%	34%	34%
heavy vacuum gasoil	1%	3%	3%	1%	4%	5%
atmospheric residua	0%	0%	0%	0%	0%	0%
vacuum residua	0%	0%	0%	0%	0%	0%
visbroken residua	0%	0%	0%	0%	0%	0%
cracked stocks	7%	10%	10%	5%	8%	12%
total	100%	100%	100%	100%	100%	100%
Composition of Marine Diesel (MDO DMB Grade) Low Sulfur (0.1%) Global Average						**volume %**
light and middle distillates low S	17%	14%	21%	22%	18%	20%
light and middle distillates medium / high S	48%	52%	56%	50%	49%	52%
heavy distillate / light vacuum gasoil	28%	23%	16%	24%	23%	26%
heavy vacuum gasoil	0%	4%	0%	4%	4%	0%
atmospheric residua	0%	0%	0%	0%	0%	0%
vacuum residua	0%	0%	0%	0%	0%	0%
visbroken residua	0%	0%	0%	0%	0%	0%
cracked stocks	6%	7%	6%	0%	6%	2%
total	100%	100%	100%	100%	100%	100%
Composition of Marine Gasoil (MGO DMA Grade) Global Average						**volume %**
light and middle distillates low S	4%	5%	6%	4%	7%	2%
light and middle distillates medium / high S	64%	69%	71%	62%	69%	76%
heavy distillate / light vacuum gasoil	27%	21%	19%	26%	20%	16%
heavy vacuum gasoil	0%	0%	0%	0%	0%	0%
atmospheric residua	0%	0%	0%	0%	0%	0%
vacuum residua	0%	0%	0%	0%	0%	0%
visbroken residua	0%	0%	0%	0%	0%	0%
cracked stocks	4%	4%	3%	7%	4%	6%
total	100%	100%	100%	100%	100%	100%

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