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MARINE ENVIRONMENT PROTECTION COMMITTEE 70th session Agenda item 5	MEPC 70/5/3 15 July 2016 Original: ENGLISH

AIR POLLUTION AND ENERGY EFFICIENCY

Assessment of fuel oil availability – executive summary

Note by the Secretariat

SUMMARY

Executive summary:	This document contains in its annex the executive summary of the final report of the "Assessment of fuel oil availability". The complete final report is contained in document MEPC 70/INF.6.
Strategic direction:	7.3
High-level action:	7.3.2
Output:	7.3.2.1
Action to be taken:	Paragraph 9
Related documents:	MEPC 68/21, MEPC 69/5/4, MEPC 69/21 and MEPC 70/INF.6

Background

1 In accordance with regulation 14.8 of MARPOL Annex VI, a review of the standard set forth in regulation 14.1.3, i.e. 0.50% m/m maximum sulphur content fuel oil on and after 1 January 2020, shall be completed by 2018 to determine the availability of fuel oil for ships to comply.

2 MEPC 68 approved terms of reference for the review of fuel oil availability as required by regulation 14.8 of MARPOL Annex VI (MEPC 68/21, annex 5).

3 In addition, MEPC 68 established a Steering Committee to provide input to the IMO tender process and confirmed that the Steering Committee is de facto the "group of experts" required in regulation 14.9 of MARPOL Annex VI and so responsible for the development of the appropriate information to inform the decision to be taken by the Parties to MARPOL Annex VI.

4 Further, MEPC 68 agreed to the composition of the Steering Committee as follows:

Member States

Brazil, China, France, India, Japan, Liberia, Marshall Islands, Netherlands, Nigeria, Republic of Korea, Singapore, South Africa, United States

Intergovernmental organization

European Commission (EC)

Non-governmental organizations

International Chamber of Shipping (ICS), BIMCO, International Petroleum Industry Environmental Conservation Association (IPIECA), The Institute of Marine Engineering, Science and Technology (IMarEST), International Bunker Industry Association (IBIA) and Clean Shipping Coalition (CSC).

5 In this regard, MEPC 68 requested the Secretariat to initiate the fuel oil availability review in accordance with the agreed terms of reference, including the establishment of the Steering Committee, so that the review could begin on 1 September 2015, with a view to the final report being submitted to MEPC 70 (MEPC 68/21, paragraph 3.97).

6 Following a competitive tender, the contract to undertake the assessment was awarded in September 2015 to an international consortium under the lead of CE Delft.

7 MEPC 69 considered a progress report of the Steering Committee (MEPC 69/5/4) together with document MEPC 69/5/11 (ICS and INTERTANKO) and:

.1 noted the progress made by the Steering Committee and reiterated that, in accordance with the agreed terms of reference, the review is expected to be completed in time for reporting to MEPC 70; and

.2 agreed, in principle that a final decision on the date of implementation of the 0.50% sulphur limit should be taken at MEPC 70, so that maritime Administrations and industry can prepare and plan accordingly (MEPC 69/21, paragraph 5.26).

8 To enable the assessment to be undertaken, financial contributions were received from Australia, the United Kingdom and the United States.

Action requested of the Committee

9 The Committee is invited to approve the assessment of fuel oil availability and to take action as appropriate.

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ANNEX

Assessment of Fuel Oil Availability

Executive Summary
July 2016

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Contents

List of abbreviations and acronyms and Glossary

2DO	#2 Diesel
2FO	Heating oil
AGO	Atmospheric gasoil, a CDU product
AGO HDS	Atmospheric gasoil hydro desulphurization
API	American Petroleum Institute
ATRES	Atmospheric residue, a CDU product
ATRES HDT	Atmospheric residue hydrotreating
BWMC	Ballast Water Management Convention
BWMS	Ballast Water Management System
CAGR	Compound Annual Growth Rate
CDU	Crude Distillation Unit
COKER/VBR HY DIST	Heavy distillate blend coming from hydrocrackers and visbreakers
CUTTER STOCK	Lighter product used to lower fuel oil viscosity (e.g. FCC heavy naphtha)
CNRB	Canadian Natural Resource Board
Delayed coker	Delayed coker, converts vacuum residue to naphtha, diesel, and coker gas oil via thermocracking
DME	Dimethyl Ether
EGCS	Exhaust Gas Cleaning System
EGR	Exhaust Gas Recirculation
EIA	US Energy Information Administration
EPA	US Environmental Protection Agency
FCC	Fluid Catalytic Cracking
FCC LCO	Fluidized Catalytic Cracker light cycle oil
GHG	Greenhouse Gas
GloTraM	Global Transport Model
GASOIL HDS	Gasoil hydrodesulphurization. Includes AGO and LCO desulphurization
GOHDS TOTAL	Gasoil hydrodesulphurization (FCC feed)
HC UCO	Hydrocracker unconverted oil
HFO	Heavy Fuel Oil
H-OIL®	Vacuum and Atmospheric Oil Catalytic hydrogenation. H-Oil® uses a catalytic hydrogenation technology in which considerable hydrocracking takes place. The process is used to upgrade atmospheric and vacuum residue to low sulphur distillates
H-OIL BTMS	Bottom product from H-Oil® Process (Vacuum residue hydrocracking)
H-OIL HY DIST	Heavy distillate coming from H-Oil® process
HOL	Residue Hydrocracking
HP	Hydrocarbon Processing
HSD	High sulphur diesel
Hydrocracker	Upgrades residues from the atmospheric or vacuum distillation columns (bottoms), FCC and coking units into jet fuel, diesel and gasoline via heavy molecules cracking in the presence of hydrogen and a catalyst

IAMs	Integrated Assessment Models
IEA	International Energy Agency
ISOMERIZATION	An Isomerization unit converts low octane n-paraffins (light naphtha from CDU) into high octane iso-paraffins via a chloride fixed bed reactor
IMO	International Maritime Organization
IMP CUTTER	Imported cutter stock
Kerosene	Kerosene, a CDU product
LCO	Light cycle oil, a FCC product used as a blending component in the heavy fuel oil pool
LCO HDS	Light cycle oil hydro desulphurization
LNG	Liquefied Natural Gas
LP	Linear Programming
LPG	Liquid Propane Gas
LSD	Low-sulphur diesel
MARPOL	International Convention for the Prevention of Pollution from Ships
Middle distillate hydroprocessing	Atmospheric gasoil hydro desulphurization
MECL	Marine and Energy Consulting Limited
MGO	Marine Gas Oil
MMSCFD	Million Standard Cubic Feet per Day
NGL	Natural Gas Liquids
NPRA	National Petroleum Refiners Association
OGJ	Oil & Gas Journal
PADD	Petroleum Administration for Defense Districts
PAHs	Polyaromatic Hydrocarbons
REFORMER	A Reformer converts low octane linear paraffins into branched isoparaffins and cyclic naphthenes, which are then partially dehydrogenated to produce high-octane aromatic hydrocarbons in the presence of a catalyst
Residue hydroprocessing	Atmospheric residue hydrotreatment
RCPs	Representative Concentration Pathways
SCF	Standard Cubic Feet
SCFD	Standard Cubic Feet per Day
SDDG	Gasoil hydrotreatment

Slurry	Heaviest product from the FCC, also known as Decanted Oil (DO)
SR AGO	Straight run atmospheric gas oil
SR DIESEL	Straight run diesel, a CDU Product
SSP	Shared Socio-Economic Pathway
TR LT DIST	Treated light distillate
TRT AGO 85%	Treated atmospheric gasoil up to 85% desulphurization
TRT ATRES	Treated Atmospheric Residue
TRT KERO	Hydrotreated Kerosene
TRT KERO (DSL TR)	Hydrotreated Kerosene desulfurized Jet blend
TRT LCO	Treated light cycle oil
TRT LT DIST -MED HDS	Treated Light Distillate under medium-severity hydrodesulphurization conditions
TRT PURCH GASOIL	Imported/purchased hydrotreated gas oil
ULSD	Ultra-low-sulphur diesel
UULSD	Ultra-Ultra-low-sulphur diesel
VCRES	Residue coming from the VDU
VDU	Vacuum Distillation Unit
Visbreaking	Reduction of the viscosity and pour point of VDU bottoms via thermal cracking of large hydrocarbon molecules in a furnace.
VISBR TAR	Visbreaker Tar

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1 Brief summary

MARPOL Annex VI requires all ships to use fuels with a sulphur content of 0.50% m/m from 1 January 2020 onwards (in emission control areas, other limits apply). The implementation date is subject to a decision by the Parties to MARPOL Annex VI that these fuels are by then sufficiently available. In order to inform this decision, the IMO has commissioned the present study, which aims to assess the availability of fuel oil with a sulphur content of 0.50% m/m or less in 2020.

The study comprises three elements. First, the demand for marine fuels in 2020 has been estimated, based on the fuel consumption of ships in 2012, projected increases in energy demand, the use of alternative compliance options such as exhaust gas cleaning systems (EGCSs) and the use of LNG.

The study has developed three scenarios, a base case with transport demand growth, fleet renewal, LNG and EGCS uptake in line with current projections; a high case with higher transport demand growth and fleet renewal and lower uptake of EGCSs and LNG, leading to greater demand for compliant petroleum fuels; and a low case which is the mirror image of the high case. Table 1 shows the fuel demand in each of these scenarios.

Table 1 - *Fuel demand projections in the base case, high case and low case in 2020*

Sulphur (% m/m)	Petroleum derived fuels			LNG
	<0.10%	0.10-0.50%	>0.50%	
	Million tonnes per year			
Base case	39	233	36	12
High case	48	290	14	12
Low case	33	198	38	13

Second, a refinery supply model has been developed and calibrated to global fuel production in 2012. This model has subsequently been updated to 2020 by taking into account all refinery expansions and closures that are expected to be completed by mid-2019 (see Table 2).

Table 2 - ***Global Refinery Capacity (2012 and mid-2019)***

	2012	**2019**	**Change**
	Million tonnes per year		
Crude Distillation	4,630	5,020	+8%
Light Oil Processing			
Reforming	610	626	+3%
Isomerization	94	122	+30%
Alkylation/polymerization	117	118	+1%
Conversion			
Coking	312	421	+35%
Catalytic cracking	862	916	+6%
Hydrocracking	388	532	+37%
Hydroprocessing			
Gasoline	148	204	+38%
Naphtha	759	810	+7%
Middle distillates	1,109	1,306	+18%
Heavy oil/residual fuel	439	507	+15%

Third, the model has been used to assess whether the global refinery sector will be able to produce the marine fuels in sufficient quantities in 2020, while at the same time meeting demand from other sectors, and whether the production of these fuels is economically viable. These model runs were based on the projected crude slate for each region (which is different from the 2012 crude slate). The model was run conservatively, by e.g. limiting the capacity utilization of key units to 90% of stream day capacity and using conservative estimates of sulphur removal rates while setting sulphur contents of marine fuels that were 10% lower than the limit.

The main result of the assessment is that in all scenarios the refinery sector has the capability to supply sufficient quantities of marine fuels with a sulphur content of 0.50% m/m or less and with a sulphur content of 0.10% m/m or less to meet demand for these products, while also meeting demand for non-marine fuels (see Table 3).

Table 3 - ***Global Refinery Production (2012 and 2020) - million tonnes per year***

	Production in 2012	**Production in 2020**
Gasoline	963	1,086
Naphtha	256	305
Jet/Kero Fuel	324	331
Middle Distillate	1,316	1,521
of which MGO	64	39
Total Marine Heavy Fuel Oil (HFO)	228	269
of which Marine HFO (S ≤ 0.50% m/m)	0	233
of which Marine HFO (S > 0.50% m/m)	228	36
LPG	113	110
Other	784	537
Total	3,984	4,159

That future demand can be met is due to several developments. Capacity growth of crude distillation units enables production of larger quantities of fuel oil, while expansion of hydrocracking capacity increases the potential supply of unconverted gas oil, with a very low sulphur content which can be blended with heavy fuel oil to lower its sulphur content.

Moreover, the increase in middle distillate and heavy fuel oil hydroprocessing helps meet the low sulphur requirements for marine distillates and heavy fuel oils, respectively.

In addition to these developments, the high-demand case requires refineries in the Middle East and Asia to increase the utilization rates of their refining and processing units and to change their crude oil slate. For example, the average sulphur content of the crude slate in the Middle East will need to be lowered from 2.01% in the base case to 1.99% in the high-demand case.

All compliant fuels (petroleum fuels with a sulphur content of 0.50% m/m or less) are blends of several refinery streams. Untreated atmospheric residue is typically only a fraction of the total blend. Most of these fuels have a considerably lower viscosity than HFO.

While supply and demand are balanced globally, regional surpluses and shortages are projected to occur. In most cases the Middle East has an oversupply, while in some cases other regions have a higher production than consumption as well. Regional imbalances can be addressed by transporting fuels or by changing vessels' bunkering patterns.

2 Introduction

2.1 Policy context

Since its adoption in 1997, MARPOL Annex VI has included a 4.50% m/m limit to the sulphur content of marine fuel. In October 2008, MEPC 58 agreed to reduce the maximum sulphur content to 3.5% m/m from 2012 and to 0.50% m/m from 2020 onwards (in emission control areas, stricter limits apply) by prohibiting the use of any fuel oil that exceeds this limit. These fuels may be petroleum fuels or other fuels with a sulphur content below the limit, such as LNG.

Apart from using compliant fuels, MARPOL Annex VI allows ships to comply by using alternative compliance options, as long as those options are at least as effective in terms of emission reductions as the sulphur content limits. In the case of sulphur, alternative compliance options comprise the use of exhaust gas cleaning systems that remove sulphur oxides from the exhaust (commonly called EGCSs).

MEPC 58 also agreed on a review provision. By 2018, a group of experts are to have conducted a review of the availability of fuel oil to comply with the standard, taking into account global market supply and demand for compliant fuel oil, an analysis of trends in fuel oil markets and any other relevant issue.

The Parties to MARPOL may then decide whether it is feasible for vessels to comply with the 2020 implementation date, based on the information developed by the group of experts.

2.2 Aim of this study

The overall objective of the present project is to conduct an assessment of the availability of fuel oil with a sulphur content of 0.50% m/m or less in 2020.

In order to meet the overall objective, there are three specific objectives:

.1 develop quantitative estimates of the demand for fuel oil meeting the global 0.50% m/m sulphur limit, both globally and for individual world regions, based on:

  .1 the 2012 fuel volumes reported in the Third IMO GHG Study 2014;

  .2 appropriate growth factors to project fuel demand volumes for 2020; and

  .3 variations in the input assumptions, representing the foreseeable high to low ranges of each assumption that will result in high to low ranges in demand;

.2 assess the ability of the refinery industry to supply the projected demand by:

  .1 building a base case for 2012; and

  .2 modelling 2020 supply, taking into consideration fuel demand and specifications from other sectors; and

.3 compare the demand and supply scenarios to assess their implications with respect to the availability of compliant fuels.

2.3 Scope of the analysis

The time horizon of the study is 2020. The study compares demand for and supply of compliant fuel oil in 2020. In order to account for uncertainty in projections and forecasts, we develop a range of estimates for both supply and demand, comparing these both globally and regionally to assess whether supply will be sufficient to meet demand.

In line with the definition in MARPOL Annex VI, regulation 2, 'fuel oil' means any fuel delivered to and intended for combustion purposes for propulsion or operation on board a ship, including gas, distillate and residual fuels (Resolution MEPC. 258(67) (MEPC, 2014).

Since regulation 14 of MARPOL Annex VI sets limits for '[t]he sulphur content of any fuel oil used on board ships', the analysis includes demand from all ships, including ships on domestic voyages.

Although not all States are Party to MARPOL Annex VI and consequently are not bound by the sulphur limit imposed by regulation 14, the analysis is aimed at all fuel used on board ships, regardless of where they sail.

In addition to MARPOL Annex VI, the EU and China, amongst others, have set regional limits on the sulphur content of marine fuels, some of which are currently in place and some of which will be implemented at a later stage. To the extent that they are implemented by 2020, these limits are taken into account in the analysis.

2.4 Outline of the report

This report is structured as follows:

.1 Chapter 3 presents an overview of the maritime fuels market in 2012, the latest year for which comprehensive data on both supply and demand are available. The chapter also reviews global refinery production as a context for the information presented on the maritime fuels market;

.2 Chapter 4 develops the projections of maritime fuel demand by 2020. It presents a projection of the energy demand by maritime transport and a projection of the use of EGCSs. It also includes a projection for non-maritime fuel demand by 2020;

.3 Chapter 5 focuses on the projection of refinery capacity and fuel supply by 2020. It analyses whether and, if so, how refineries can meet demand for compliant fuels in different scenarios;

.4 Chapter 6 presents the assessment of fuel availability in 2020; and

.5 Chapter 7 contains the main conclusions.

3 Supply and demand of maritime fuels in 2012

3.1 Introduction to 2012 supply and demand

This chapter presents quantitative data on the supply and demand of maritime fuels in 2012, both globally and regionally. These data serve as the starting point for the demand projections for 2020 in Chapter 4. In combination with the supply of non-maritime fuels, the supply figures serve to calibrate the refinery model employed to project 2020 production in Chapter 5.

The size of the maritime fuels market (both supply and demand) is presented in Section 3.2. Section 3.3 analyses how fuel sales (fuel demand) are distributed over world regions, while Section 3.4 assesses the refining capacity in the same regions. Section 3.5 concludes this chapter.

3.2 Size of the maritime fuels market in 2012

The estimation of global demand for maritime fuels in 2012 is based on the bottom-up approach used in the Third IMO GHG Study 2014. In that year total global consumption of maritime fuels was estimated to be 300 million tonnes. Using the data from the Third IMO GHG Study 2014, total global fuel consumption can be broken down by fuel type (HFO, MGO, LNG) and machinery component. The resultant values are reported in Table 4.

Table 4 - *Global shipping fuel consumption in 2012 by fuel type and machinery component based on the Third IMO GHG Study (million metric tonnes)*

	HFO	MGO(1)	LNG(2)
Main engine	188	18	7
Auxiliary	33	42	1
Boiler	7	5	0
TOTAL	228	64	8

Source: This study, based on Third IMO GHG Study 2014.
(1) The reported MGO total is lower than the sum of consumption per machinery component owing to rounding.
(2) LNG was used both by gas carriers as a boil-off and to a lesser extent by LNG-fuelled ships.

The confidence interval of the 2012 fuel consumption data is between -17 and +5% of the values shown in Table 4.

3.2.1 Global supply of maritime fuels in 2012

Petroleum fuels for ships are supplied by refineries. Typically, various products are blended to achieve a product meeting specifications for sulphur content, viscosity, specific gravity, et cetera. Table 5 summarizes the global supply of refinery fuels in 2012, based on calibration model results.

Table 5 - *Global Refinery Production (2012) - million tonnes per year*

Refinery Production[5]		
		Sulphur (% m/m)
Gasoline	963	
Naphtha	256	
Jet/Kerosene Fuel	324	
Middle Distillate Oil	1,316	
of which MGO[1,4]	64	0.14[3]
Marine Heavy Fuel Oil (HFO)	228	2.51[3]
LPG	113	
Other[2]	784	
Total	3,984	

Source: Stratas Advisors, 2015-2016.

(1) Global marine fuel demand. Source: (IMO, 2014).
(2) Includes petroleum coke, refinery fuel, non-marine fuel oil and other products.
(3) MEPC 65/4/19. Production volume and quality (% m/m sulphur) is the model output.
(4) MGO is part of Middle Distillate.
(5) Biofuel is included in the gasoline and middle distillate quantity.

In order to supply the products shown in Table 5, the supply model calculates average regional utilization rates[1]. Table 6 shows that the CDU utilization rates vary from 56% in Africa to 85% in Russia and CIS. CDU utilization reasonably matches available historical data, given that the reported rates for 2012 are based on 92% of stream day capacity and crude throughput (Africa 67%, Asia 85%, Europe 80%, North America 86%, Latin America 79%, Middle East 79%, Russia & CIS 85% (BP, 2013)). The utilization rates are plausible and indicate that the refinery model was appropriately calibrated.

[1] Utilization rate is the percentage ratio of the total amount of liquids run through a process unit to the capacity of the unit. It is based on nameplate capacity, considering 8,000 hours of continuous operation, which is about 8.6% lower than stream day capacity (based on 8,760 hours of annual operation). For CDU, the utilization rate is the ratio of the total amount of crude run through crude distillation unit to the capacity of the CDU.

Table 6 - *Regional Refinery Utilization rates for major units (2012)*[1,2]

PROCESS[3]	Africa	Asia	Europe	North America	Latin America	Middle East	Russia & CIS
CDU	56%	76%	76%	64%	72%	77%	85%
HYDROCRACKER	92%	69%	92%	77%	89%	92%	92%
GOHDS TOTAL	0%	91%	57%	84%	33%	92%	92%
ATRES HDT	0%	23%	46%	2%	0%	92%	0%
H-OIL	92%	92%	52%	36%	0%	92%	84%
GASOIL HDS	92%	92%	92%	10%	0%	0%	0%
AGO HDS	92%	92%	92%	6%	0%	0%	0%
LCO HDS	0%	0%	0%	5%	0%	0%	0%
DELAYED COKER	0%	75%	87%	88%	81%	92%	71%
FCC	92%	69%	81%	80%	63%	92%	92%
REFORMER	66%	70%	92%	83%	83%	70%	61%
ISOMERISATION	92%	92%	92%	64%	4%	92%	92%

Source: Stratas Advisors, 2015-2016.
(1) The numerical values are reported as percentages.
(2) Utilization rates are calculated based on 92% of stream day capacity (92% of stream day capacity is about 8,000 hours of continuous operation out of 8760 hours maximum a year).
(3) Processes are described in the Glossary.

In 2012 global HFO and MGO demand accounted for 46% and 5%, respectively, of global fuel oil and middle distillate supply (Table 7).

Table 7 - *Global Marine Fuel sales as a percentage of refinery production (2012)*

Marine Fuel share of global supply	
Marine HFO share (%)	46
MGO share (%)	5

Source: Stratas Advisors.

3.3 Regional demand for maritime fuels in 2012

The data on regional demand for maritime fuels in 2012 adopted in this study are provided in Table 8. The first set of columns reports absolute regional demand, the second the relative regional share for each fuel type.

Table 8 - *Regional demand for maritime fuels and relative shares in 2012 (million tonnes per year)*

	HFO	MGO	LNG	HFO	MGO	LNG
	Million tonnes			**Regional share (%)**		
Africa	7	3	0.51	3	5	7
Asia	95	31	1.92	42	48	24
Europe	52	15	0.64	23	23	8
North America	21	7	2.04	9	11	26
Latin America	18	6	0.17	8	9	2
Middle East	25	1	1.29	11	2	16
Russia & CIS	10	2	1.34	4	3	17
TOTALS	228	64	8	100%	100%	100%

Source: This report.
Note: Because of rounding values may not add to totals.

The approach used to derive disaggregated regional demands was as follows:

.1 disaggregate global fuel demand based on the IEA shares of regional fuel sales;

.2 verify regional fuel demand data against third-party data sources, adjusting as required; and

.3 specifically for LNG a slightly different approach was adopted, using spatially explicit data from the bottom-up method of the Third IMO GHG Study and IEA statistics on natural gas.

3.4 Regional supply of maritime fuels in 2012

Asia is the world's largest petroleum product producer. In 2012, Asia's total refinery production reached 1,266 million tonnes per year, accounting for 32% of global total refinery production (Table 9). Asia's marine heavy fuel oil and MGO made up 42% and 48% of global production, respectively.

Table 9 - *Regional Refinery Production (2012) - million tonnes per year*

	Refinery Production(1)							
	Africa	**Asia**	**Europe**	**North America**	**Latin America**	**Middle East**	**Russia & CIS**	**Global**
Gasoline(2)	17	234	135	399	78	50	51	963
Naphtha	12	130	38	12	11	33	20	256
Jet Fuel	7	81	37	72	16	23	14	250
Kerosene	2	38	12	1	1	19	1	74
Middle Distillate Oil	34	453	280	257	105	98	89	1,316
of which MGO	3	31	15	7	6	1	2	64
Marine HFO	7	95	52	21	18	25	10	228
LPG	2	41	17	21	8	5	18	113
Other(3)	28	194	121	141	103	89	108	784
Total	109	1,266	692	924	340	342	311	3,984
Non-Marine Total	99	1,140	625	896	316	316	299	3,692

Source: Stratas Advisors, 2015-2016, CE Delft.
(1) Because of rounding values may not add to totals.
(2) Gasoline and Diesel both include biofuel blended volume.
(3) Includes lubricants, asphalt, refinery fuel gas, non-marine fuel oil, coke and miscellaneous products.

3.5 Conclusions on 2012 supply and demand

In 2012, the global consumption of HFO and MGO by ships amounted to 228 and 64 million metric tonnes, respectively, representing 46% and 5%, respectively, of global fuel oil and middle distillate supply. In addition, ships used 8 million metric tonnes of LNG, mainly in gas carriers.

In addition to marine refinery fuel production, non-marine refinery fuel production amounted to 3,692 million tonnes in 2012. Average regional refinery utilization rates varied considerably between regions. The highest rates were typically in Russia & CIS, the lowest in Africa.

4 Projections of fuel demand in 2020

4.1 Introduction to 2020 demand analysis

This chapter develops the projections of fuel demand by 2020 that have been used to run the refinery models. Global demand is disaggregated by fuel type and by region.

The projections are developed in four steps:

.1 project the energy demand of maritime transport using the projections of the Third IMO GHG Study 2014 as a basis, taking into account the possible impacts of the short-term business cycle (Section 4.2);

.2 project investments in exhaust gas cleaning systems (EGCSs), which can remove SO_x from the exhaust, enabling ships to use fuels with a sulphur content over 0.50% m/m (Section 4.3);

.3 project demand for non-petroleum fuels with a sulphur content of 0.50% m/m or less (Section 4.4); and

.4 calculate global and regional demand for marine fuels, taking into account the amount of fuel consumed by ships with an EGCS, the amount of non-petroleum fuels used, and demand for 0.10% S and 0.50% S fuels (Section 4.5).

To enable modelling of supply from refineries, which encompasses all petroleum fuels, Section 4.6 projects the demand for non-marine fuels. Section 4.7 presents the estimates of total fuel demand by 2020.

Three projections of marine fuel demand are developed; a base case, a high-demand case which reflects a high but still plausible demand for marine fuels with a sulphur content of 0.50% m/m or less, and a low-demand case reflecting a scenario in which demand for such fuels is low. The main input assumptions are summarized in Table 10, with further details provided in Section 4.2. In all scenarios it has been assumed that there are no additional regulatory driven fuel efficiency improvements.

All cases take into account that, independent of the decision of MEPC, from 2019 ships sailing in areas near the Pearl River Delta, Yangtze River Delta and the Bohai Sea will be obliged to use fuel with a sulphur content of 0.50% or less, as well as in Hong Kong, China (L.N. 51/2015). Similarly, ships sailing in territorial seas, exclusive economic zones and pollution control zones of EU Member States, other than in ECAs, will be obliged to use fuel with a sulphur content of 0.50% or less as per Directive 2012/33/EC. Finally, ships sailing in the North American, the United States Caribbean Sea and European ECAs will continue to be obliged to use fuel with a sulphur content of 0.10% m/m or less or an alternative compliance option.

These regional regulations affect demand for fuel with a sulphur content of 0.50% or less in a scenario where the IMO decides to defer the implementation of regulation 14 until after 2020. If the implementation date remains unchanged, ships sailing in the aforementioned areas will be required to use fuel with a sulphur content of 0.50% or less anyway, and total demand for fuel of this quality will not be affected.

Table 10 - ***Input assumptions for fuel demand projections***

	Base case	**High-demand case**	**Low-demand case**
Socio-economic scenarios	RCP 6.0/SSP 1	RCP 8.5/SSP 5	RCP 4.5/SSP 3
Uptake of EGCS	Central-range stakeholder consultation	Lower than base case	Higher than base case
Uptake of alternative fuels	Central range	Lower than base case	Higher than base case
Additional market-driven fuel efficiency improvements	Central Marginal Abatement Cost Curve (MACC) results	Low-range MACC results	High-range MACC results

Source: CE Delft.

The projections distinguish the following fuel types:

a petroleum fuels with a sulphur content of 0.10% m/m or less;
b petroleum fuels with a sulphur content of more than 0.10% m/m but equal to or less than 0.50% m/m;
c petroleum fuels with a sulphur content of more than 0.50% m/m;
d LNG;
e Methanol;
f Biofuels;
g LPG; and
h DME.

Fuel types a, d, e, f, g and h can be used in emission control areas, as well as b and c provided that the SO_x emissions are reduced to a level at least equivalent to using petroleum fuels with a sulphur content of 0.10% m/m. After 1 January 2020 (or 2025 if so decided by IMO), fuel type c can only be used in combination with an EGCS that reduces SO_x emissions to a level at least equivalent to using petroleum fuels with a sulphur content of 0.50% m/m outside ECAs and 0.10% m/m in ECAs (as of 1 January 2015).

4.2 Projections of global maritime energy demand

Global maritime energy demand has been estimated using the emissions projection model employed in the Third IMO GHG Study 2014. The model has been rerun to take into account recent developments in economic activity, fuel prices and fleet composition.

This section first presents the model and the inputs used. It then goes on to present the results of the energy demand projections.

4.2.1 Energy demand projection model

The energy demand projection model projects the energy demand of maritime transport in a future year based on energy demand in a base year and developments in relevant factors between the base year and the projection year. Because the Third IMO GHG Study 2014 has detailed data on energy demand in 2012, this has been chosen as the base year. The model takes into account the following factors:

.1 market-driven vessel efficiency developments. The model employs a MACC model in which all major options for efficiency improvements are included.

It calculates the cost-effective emission reduction potential at a given fuel price and assumes that a certain fraction of cost-effective measures are implemented. The ship energy efficiency management plan (SEEMP) is assumed to draw attention to cost-effective measures;

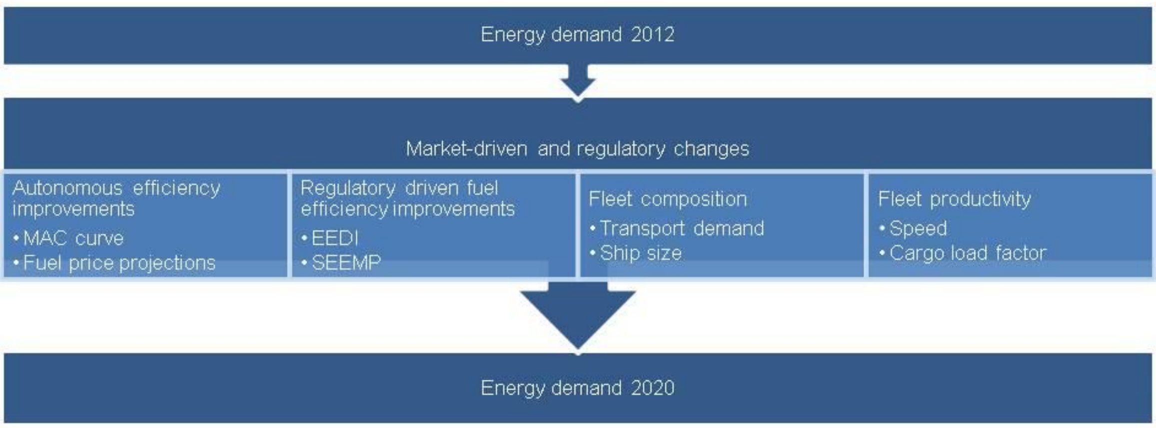
.2 regulatory efficiency improvements. The energy efficiency design index (EEDI) requires new ships for which the building contract is placed in or after 2013 to meet or exceed an increasingly stringent energy efficiency standard. The model assumes that ships will meet these EEDI requirements. In addition, ships sailing to and from EU ports will have to monitor and report their fuel use, emissions and several efficiency parameters. The efficiency improvements stemming from these operational efficiency measures are expected to total 2% on relevant voyages (EC, 2013);

.3 fleet composition, which may change in response to developments in transport demand. Transport demand has been projected based on socio-economic trends, using the method employed in the Third IMO GHG Study 2014 (IMO, 2014). Besides transport demand, developments in vessel size also affect fleet composition; and

.4 fleet productivity, the amount of transport work per unit vessel deadweight, which may change as a result of changes in average speed or cargo load factor. The Third IMO GHG Study 2014 assumes a gradual return of fleet productivity to longyear averages, through higher cargo load factors, faster sailing or a combination of both. This means that fleet productivity in 2020 is projected to be higher than in 2012.

Figure 1 presents a schematic overview of the energy demand model.

Figure 1 - *Schematic overview of energy demand model*



4.2.2 Plausibility check of maritime energy demand modelling

Three scenarios were run using the data employed for the Third IMO GHG Study 2014. To check the plausibility of the results, the results were checked against recently available data (Table 11). The checks show that transport work in 2015 is almost the same as projected by the model. The model projects a higher rate of global GDP growth between 2015 and 2020 than the latest IMF forecast at the time of writing of this report, which will result in a higher rate of transport work growth. The rate of fleet renewal is in close agreement with the fleet renewal in the period 2012 to 2015.

Table 11 - ***Scenario plausibility checks***

Parameter	Plausibility check	Results
2012-2015 Growth in maritime transport work	2012-2015 maritime transport work forecast (UNCTAD 2015)	The UNCTAD forecast for transport work in 2015 (made in October of that year) is 11% higher than transport work in 2012. The base case modelled transport work increase as 10.50%, the high case as 14% and the low case as 9.8%.
2015-2020 GDP forecasts	World Economic Outlook (IMF, 2015)	IMF projects that world GDP will increase by 20% between 2015 and 2020. The base case assumes a GDP increase of 27%, the high case 28% and the low case 25%.
2012-2020 Fleet renewal	New ships in the fleet 2012-2015 (Clarksons Research, 2016)	Clarksons reports that 18% of the ships in the fleet in December 2015 have entered the fleet in or after 2012. If fleet renewal continues at this rate, 41% of the ships in the 2020 fleet will have been built after 2012. The base case projects 45% new ships in the fleet by 2020; the high case 46% and the low case 44%.

Source: CE Delft.

The plausibility check shows that the energy demand of maritime transport in 2015 is very likely to be close to the modelled energy demand, because the share of new ships as well as the amount of transport work are close to the modelled values. In the coming years, economic growth and, by implication, transport demand growth may be lower than projected in the model if IMF forecasts are realised. This suggests that the energy demand projections and the fuel projections are more likely to be an overestimate than an underestimate of the 2020 energy demand. Still, we consider the differences to be small enough to continue to use the base case scenario of the Third IMO GHG Study 2014, while at the same time opting to develop new high and low cases, as explained in Section 4.2.3.

4.2.3 Accounting for the economic cycle

The long-term socio-economic and energy policy scenarios used in the Third IMO GHG Study 2014 were developed to analyse long-term trends and, as such, do not take into account short-term fluctuations of the business cycle. Since this study analyses the situation in 2020, less than four years after the analysis was performed, the potential impacts of the short-term economic cycle cannot be ignored, however.

Table 12 shows the fuel use and transport work of the maritime sector from 2007 through to 2012. While transport work shows a steady upward trend (with a dip in 2009), fuel use shows greater variation. Focusing on the period 2009 to 2012, i.e. after the start of the financial crisis and the adoption of slow steaming, Table 12 shows that the amount of fuel used per unit of transport work may be up to 13% higher or 11% lower than the average. Guided by these figures, we account for the economic cycle in the energy demand projections by assuming an 11% higher energy demand in the high case and an 11% lower energy demand in the low case.

Table 12 - *Shipping emissions and transport work, 2007-2012*

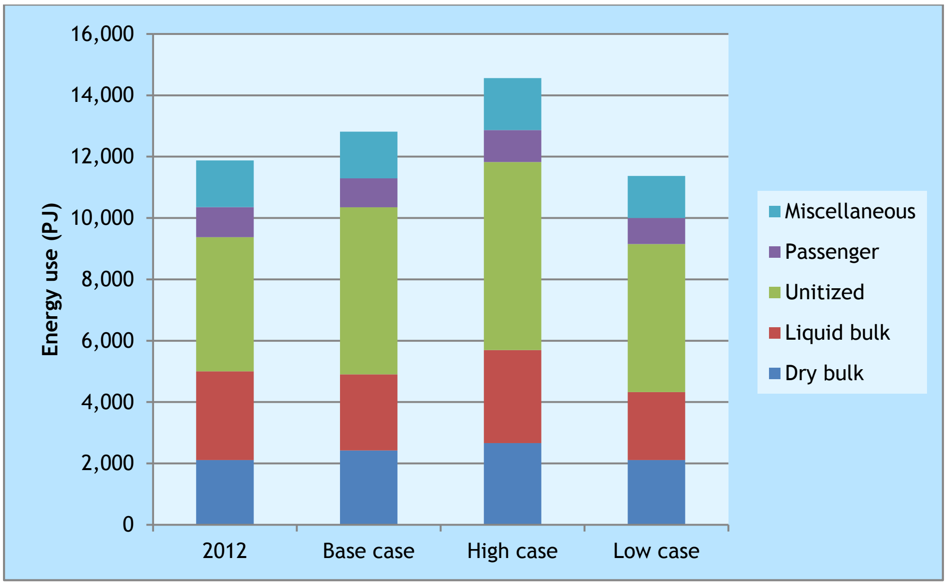
Year	Transport work	Fuel use	Fuel/unit of transport work
	Billion tonne-miles	Million tonnes	Tonne/million tonne-miles
2007	40,759	352	8.64
2008	41,926	363	8.66
2009	40,099	313	7.81
2010	44,369	293	6.60
2011	46,617	327	7.01
2012	48,864	300	6.14

Source: Third IMO GHG Study 2014 (IMO, 2014); (UNCTAD, 2015).

4.2.4 Energy demand projection model results

The energy demand of the shipping sector is projected to vary from 11.9 EJ in 2012 to 11.4 to 14.6 EJ in 2020, depending on the scenario. The base case projection is 12.8 EJ. The energy demand projection model results are presented in Figure 2.

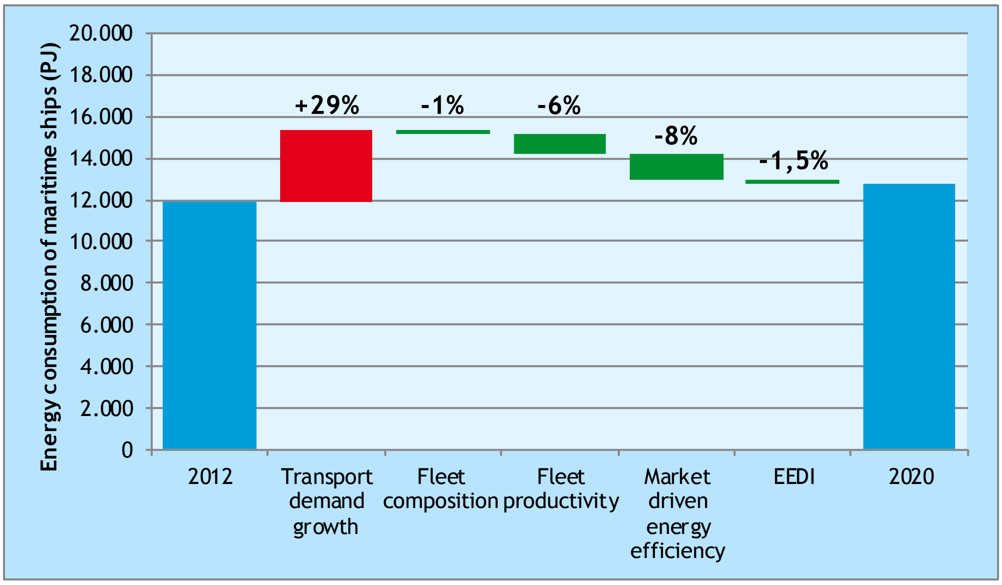
Figure 2 - *Energy use per ship type in 2012 and 2020*



Source: CE Delft.

Figure 3 shows the contribution of the different factors to the change in energy use between 2012 and 2020. Transport demand grows by 35% and translates into a proportional change in energy demand of cargo ships. The energy use of non-cargo ships is assumed to remain constant, resulting in an overall increase in energy demand of 29%. Because there are more large ships in the fleet in 2020, especially container ships, the energy demand is reduced by 1%. A further 6% reduction stems from higher cargo load factors as they gradually return from low 2012 values to long term averages (a process that will not be completed by 2020 in our modelling). The EEDI reduces the energy consumption by 1.5%, and market driven efficiency improvements by 8%.

Figure 3 - *Decomposition of changes in energy use between 2012 and 2020, base case*



Source: CE Delft.

4.3 Projections of use of Exhaust Gas Cleaning Systems (EGCSs)

The projection of uptake of EGCSs and their use in 2020 is based on economic considerations, technical and operational constraints, availability of EGCSs and installation capacity, and regulatory uncertainty. We apply a five-stage filter model to each of the 53 generic ship type and size categories defined in the Third IMO GHG Study 2014:

.1 Economic analysis. For each generic ship category, the costs and benefits of an EGCS are estimated. The costs are the sum of annualized capital expenditures and operational expenditures. The benefits are the savings of fuel expenditures, which depend on the price difference between low-sulphur and conventional fuels. This is discussed in more detail in Section 4.3.1.

.2 Regulatory constraints to operating EGCSs. While the use of EGCSs is allowed under MARPOL Annex VI (regulation 4) and under the national and regional ECA regulations, the discharge of washwater is sometimes constrained or prohibited because of water quality considerations. The impact of these regulations on the business case and investments are discussed in Section 4.3.2.

.3 Technical and operational feasibility. Even if the cost-benefit analysis is positive, there may be reasons why EGCSs cannot be installed on ships, e.g. because of space limitations, impacts on stability or compatibility with Tier III NO_x regulations. The impact of the technical and operational feasibility is analysed in Section 4.3.3.

.4 Availability of EGCSs. Even if the cost-benefit analysis is positive and installing EGCSs is technically and operationally feasible, their availability may be limited due to the production capacity of EGCSs or the installation capacity. These are analysed in Section 4.3.4.

.5 Other constraints. Finally, there may be other considerations, discussed in Section 4.3.5, that may limit the uptake of EGCSs.

4.3.1 Economics of EGCS use

The costs of an EGCS are the sum of the costs of investment in an EGCS and operational costs. The investment depends on type of EGCS, engine size and whether the EGCS is installed on a new ship or retrofitted on an older vessel.

There are three types of EGCS: open loop, closed loop and hybrid. Open loop EGCSs are, on average, cheaper than closed loop EGCSs, which require additional pumps, cooling units for washwater, tanks for sludge, et cetera. Hybrid EGCSs, which can operate both in open and closed loop mode, thus requiring two sets of pumps and piping, are the most expensive.

We have liaised with EGCS manufacturers and with shipping companies that have recently invested in EGCSs or studied the costs and benefits of doing so. This has resulted in an estimate of investment costs (acquisition of the EGCS and installation), as presented in Table 13.

Table 13 - *EGCS investment costs used in this study*

EGCS type	Fixed investment costs (million USD)	Variable investment costs (USD per kW of installed engine power)
Open loop, retrofit	2.3	55
Open loop, newbuild	1.9	38
Hybrid, retrofit	2.8	58
Hybrid, newbuild	2.4	44

Source: CE Delft.

The operational expenditures of EGCSs comprise:

.1 the additional energy required for the pumps, heat exchangers, hydrocyclones and other equipment;

.2 disposal of sludge;

.3 maintenance; and

.4 in the case of closed loop EGCSs and hybrid EGCSs operating in closed loop mode, consumption of caustic soda.

The estimated operational cost data used in this study, based on the stakeholder consultation, are presented in Table 14.

Table 14 - ***EGCS operational costs used in this study***

EGCS type	Operational costs
Open loop	1% additional fuel + USD 13,000 + 0.4 * $P_{M.E.}$ (kW)
Hybrid	0.50% additional fuel + USD 25,000 + 0.4 * $P_{M.E.}$ (kW)

Source: CE Delft.
Note: $P_{M.E.}$(kW) is the power of the main engine in kilowatt.

When evaluating investments, different shipping companies employ different methods, which fall broadly into two groups. The first, which is most common in retrofit projects, is to assess the payback time. The investment is divided by the annual sum of the operational expenditures and fuel expenditure savings. The second, which is most common for newbuilds, is to compare the annuity of the investment with the projected fuel cost savings. The annuity is calculated from the investment costs, discount rate and economic life.

Based on a stakeholder consultation, this study uses the parameters summarized in Table 15.

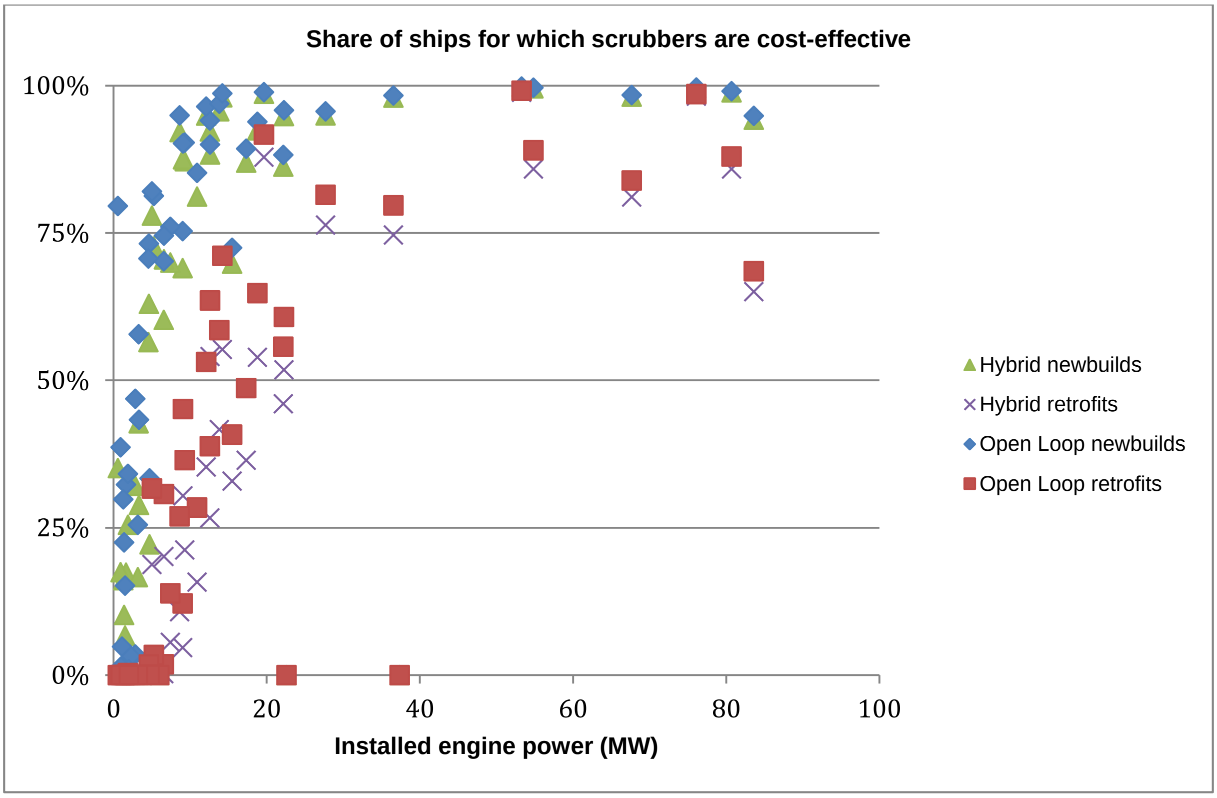
Table 15 - ***Financial parameters used in this study***

Newbuilds: discount rate	3%
Newbuilds: economic life	10 years
Retrofits: payback period	3 years

Source: CE Delft.

Figure 4 shows, for each of the 53 ship type and size categories used in the Third IMO GHG Study 2014, the share of ships for which EGCSs are cost-effective as a function of the total installed engine power of the ship. For these calculations, a price difference between conventional fuels and low-sulphur fuels of USD 129 per tonne has been assumed (see Section 5.5). Figure 4 shows that for engines up to about 5 MW, retrofitted EGCSs are hardly ever cost-effective at the assumed fuel prices. For newbuilds, the share of ships for which EGCSs are cost-effective is higher. The cost-effectiveness improves for engines between 5 and 20 MW, while for most ships with over 20 MW of engine power EGCSs are a cost-effective option to comply with the sulphur limit at the assumed fuel price difference.

Figure 4 - *Cost-effectiveness of EGCSs as a function of engine size*



Source: CE Delft.

4.3.2 Regulatory constraints on EGCS use

Discharge of washwater is restricted or prohibited in several ports (e.g. Antwerp, Hamburg), estuaries (e.g. the Wese) and coastal waters (e.g. Alaska, Belgium, Italy). There is an ongoing debate in several European countries about whether washwater discharges are compatible with the Water Framework Directive (EC, 2000) and the Marine Strategy Framework Directive (EC, 2008). The uncertainty resulting from this discussion currently has a negative impact on demand for EGCSs.

Based on the stakeholder consultation, we expect that shipowners that opt to invest in an EGCS will invest in a unit that can operate in a zero discharge mode when sailing in waters where discharge is prohibited. Hence, in our modelling we assume that the costs of EGCSs will be those of a hybrid EGCS.

4.3.3 Technical and operational constraints on EGCS use

Technical and operational constraints on installing EGCSs may comprise:

.1 the space required for EGCSs and the impact on cargo space;

.2 impacts on vessel stability;

.3 impacts on power requirements; and

.4 compatibility of EGCSs with NO_x Tier III requirements.

The evidence presented to us in the stakeholder consultation suggests that, in many cases, EGCSs can be designed to fit the available space. For ships that have free deck space available or large engine rooms, fitting EGCSs is almost never a problem. In some cases, however, cargo space may need to be sacrificed. This appears to be especially the case for container ships. For large container ships with equally large EGCSs, examples are available of EGCSs that would take up the space of a few forty-foot containers. Whether this is acceptable depends on the company.

In new ships, EGCSs can be incorporated in the design of the ship, thus eliminating space constraints.

Many small container ships and RoRo feeders have insufficient power generation capacity to retrofit EGCSs. For these ships, the installation would require expanding the power generation capacity which generally renders the investment uneconomical.

The other constraints are only of minor importance for the uptake of EGCSs, because they can be taken into account in EGCS design for both newbuilds and retrofits.

4.3.4 EGCS availability

EGCSs can be installed during regular dry dockings, though some of the work can be done while the ship is in service or in a port. Hence, as long as the demand for EGCSs does not exceed the dry docking capacity, yard availability is not a constraint. The production capacity is also not a constraint.

4.3.5 Other constraints

Many studies have shown that cost-effective solutions in shipping are not always implemented. A prime reason is the split incentive between the shipowner and the charterer. When the former makes the investment but micro-economics dictate that he will only be able to reap a share of the benefits, the business case deteriorates. Moreover, the risk of underperformance lies with the owner and he may demand an additional reward. A second reason may be financial constraints.

This study has accounted for these constraints by assuming that 25% of the ships for which an EGCS is cost-effective will nevertheless decide not to install one.

4.3.6 Conclusions on EGCSs

In summary, our analysis points to the following conclusions:

.1 installation of EGCSs on ships will continue at the current rate until 2017;

.2 provided that IMO decides in 2017 to uphold the 2020 implementation date for the 0.50% sulphur limit, we expect that shipowners will make the following investment decisions:

  .1 small container ships and RoRo feeders will not install EGCSs, because of power limitations;

  .2 shipowners will generally opt for EGCSs that can operate in zero discharge model for a sufficient length of time, so they can operate in areas where discharges are prohibited. We have modelled this as if they opt for hybrid EGCSs;

.3 in the base case, 75% of the ships built in 2018 and 2019 will be fitted with an EGCS if it is cost-effective to do so;

.4 of the existing container ships for which it is cost-effective to do so, 75% will retrofit EGCSs during their regular dry docking in the base case. The cost-effectiveness of EGCSs for container vessels takes into account that cargo space needs to be sacrificed;

.5 in the base case, 75% of the other existing ships for which an EGCS is cost-effective will retrofit EGCSs during regular dry docking;

.6 the total number of ships installing EGCSs will not exceed 3,000 per year due to yard availability;

.7 should IMO decide before 2017 to uphold the 2020 implementation date, this will only have a limited impact on the uptake of EGCSs, because installation prior to 2018 would imply there is hardly a return on investment for over two years;

.8 should IMO decide after 2017, this will reduce the number of EGCSs installed, because lead time and yard capacity will become limiting factors; and

.9 installations will be scheduled as closely as possible to the implementation date of the sulphur limit. We expect installations to begin in the second half of 2018.

In total, in the base case we expect about 3,800 ships to be installed with EGCSs on 1 January 2020. Collectively, these vessels consume 36 million tonnes of HFO with a sulphur content of more than 0.50% m/m a year.

The most important assumption in the sensitivity analysis is the price difference between HFO and low-sulphur fuels. If this difference were to disappear and the other assumptions remained unchanged, demand for HFO would all but die out and demand for low-sulphur fuels would be 13% higher. Most other assumptions have a smaller impact.

In the high case, 14 million tonnes of HFO with a sulphur content of more than 0.50% m/m will be consumed by ships with EGCSs, in the low case 38 million tonnes.

4.4 Projections of consumption of alternative marine fuels

Alternative fuels are defined as fuels with a sulphur content of 0.50% m/m or less that are not derived from petroleum. The use of alternative fuels is an option for regulatory compliance. The following alternative fuel types are considered:

.1 LNG;
.2 methanol;
.3 biofuels;
.4 LPG; and
.5 DME.

Of these alternative fuels, LNG currently has the largest market share and its possible use is therefore analysed in more detail than the uptake of the other alternative fuels, which are briefly discussed in Section 4.4.5. We assess the share of such fuels by 2020 as negligible.

In this study we distinguish the use of LNG consumed on board gas carriers from the use of LNG as fuel market. In the former case, evaluation is based on the projected number of LNG carriers operating in 2020, which will determine LNG consumption by 2020. In the latter case, evaluation is based on a quantitative estimate using the shipping model GloTram, comprising the following steps:

.1 alignment of the shipping model GloTraM with the assumptions used in this study (e.g. scrubber costs, fuel price projections, transport work);

.2 sourcing of estimates for model input assumptions that could not be aligned (because of differences in model structure), using existing literature and where necessary expert judgment;

.3 comparison of the total energy demand obtained with GloTraM with that obtained with CE Delft's model, for validation of the use of GloTraM as a source for LNG demand estimates; and

.4 estimation of global fleet LNG consumption by 2020 by extrapolating 2020 LNG use of the fleet analysed within GloTraM (the GloTraM fleet is deemed a representative subset of the energy demand of the total fleet).

The final estimate includes both LNG use on board carriers and LNG use as a fuel market. The total use is disaggregated by region using regional shares by 2020 found in the existing literature.

4.4.1 Evaluation of LNG use by 2020

The evaluation of the use of LNG consumed on board LNG carriers is based on the projected number of LNG carriers that will be operating in 2020. The estimated LNG use in 2012 presented in Section 3.2 is associated with the consumption of LNG in gas carriers. Approximately 8 million tonnes are estimated to have been consumed in 2012. Based on our analysis, we estimate that the number of LNG carriers that will be operating in 2020 may increase by 20% to 35% relative to 2012. Table 16 presents estimated LNG demand for the three cases (base, high and low) in million tonnes.

Table 16 - *Estimated LNG demand for gas carriers over the period 2012 to 2020 in shipping*

	2012	2020 base	2020 high	2020 low
LNG consumed on board LNG carriers	8	9.8	10.8	9.7

Source: This study.

In order to evaluate the use of LNG as a fuel market by 2020, we used the shipping model GloTraM, which ensures that a number of key input assumptions are taken into account. These include:

.1 socio-economic developments (e.g. transport work);
.2 marine fuel price projections;
.3 LNG prices;
.4 costs of LNG engines, storage tanks and other required equipment;
.5 costs of other compliant technologies (e.g. scrubbers);
.6 technical aspects (e.g. efficiency, space required for LNG tanks, impact on vessel autonomy, required power of LNG engines); and

.7 regulatory compliance.

4.4.2 LNG input assumptions

LNG has for a long time had a lower price per unit energy than conventional fuels, although there may be variations in LNG prices across world regions at any given time. In this study we performed an analysis of the potential uptake of LNG based on the assumption that up to 2020 LNG will be sold at a discounted price per unit of energy relative to HFO. The LNG price projection is provided in Table 17. LNG price is a key variable for evaluating the potential LNG market in 2020: the greater the reduction relative to the HFO and MGO price, the greater the uptake of LNG.

Table 17 - ***LNG price projection used in this study (USD/tonnes)***

Product	2016	2018	2020
LNG	292	462	583

Source: This study.
Note: Gas is typically priced in dollars per MMBtu, but in this study we converted the LNG price in dollars per tonne of fuel by assuming the energy density of LNG to be 53.6 MJ per kg and converting MMBtu to Joules: 1 MMBtu = 0.94782 Giga Joules.

LNG-fuelled ships require higher investments than conventional vessels (CE Delft; TNO, 2015). In general, investment costs will depend on ship type and size. There are cost differences between newbuilds and retrofit. There is some evidence of retrofitting of LNG machinery, but the number of retrofits is expected to be small because of the additional costs associated with the required modifications. We therefore focus on LNG for newbuilds, as this is expected to be the predominant way the technology enters the global fleet. On new ships, the LNG fuel system can be taken into account during the design of the ship (DNV-GL, 2014); (Wärtsilä, 2012), possibly reducing the additional costs. The assumed capital cost for newbuilds used in this study is presented in Table 18.

Table 18 - ***LNG capital costs for newbuilds used in this study***

Description	Investment costs
LNG dual-fuelled engines + LNG storage system	1.40 million USD per MW

Source: This study.

Technical constraints might influence investment decisions for LNG-powered ships. For example, there is currently a limit to the size of LNG engines, with dual-fuelled engines available up to approximately 35 MW (DNV, 2014), which is sufficient for most ships except for large container and cruise ships. However, based on our consultation, dual-fuelled engines could go up to 60 to 70 MW. In this analysis we assumed no constraints on the size of LNG engines.

LNG tanks require a different piping system, which, in combination with the lower energy density of LNG (compared with petroleum-derived fuels), could reduce cargo space or reduce vessel autonomy compared with conventional marine fuels. LNG on board therefore affects a ship’s energy and economic performance, to an extent likely to vary according to ship type and size. In our analysis it is assumed that, in comparison with conventional marine fuels, a LNG-fuelled ship will lose 0.09 tonnes of cargo capacity per MWh of energy stored on board.

Based on an internal consultation, this study uses the financial parameters for LNG newbuilds summarised in Table 19.

Table 19 - *Financial parameters for LNG newbuilds used in this study*

Discount rate	5%
Life time	30 years
Payback period	3 years

Source: This study.

4.4.3 LNG as a bunker fuel by 2020

For the three cases: base, high and low, estimated demand in 2020 for LNG as a fuel market is presented in Table 20. The fleet analysed within GloTraM is considered representative of the major part of the total fleet. The LNG consumption of the global fleet by 2020 was obtained by extrapolating the LNG use obtained using GloTraM.

Table 20 - *Estimated LNG demand over the period 2012 to 2020 in shipping (million tonnes per year)*

	2020 base case	2020 high case	2020 low case
LNG as a fuel market	3.22	3.66	3.00

Source: This study.
Note that the designators 'high' and 'low' refer to the demand for compliant fuels, not to the consumption of LNG. A high LNG consumption results in a low-demand for compliant fuels.

Based on this analysis, a total of 170 ships among dry, container and oil tanker ship types will be powered by LNG in 2020.

These results seem to be in the range of the values for LNG market size in 2020 found in the existing literature.

4.4.4 Regional LNG availability and demand as a bunker fuel by 2020

There is growing availability of LNG as a bunker fuel. The existing LNG bunkering infrastructure is focused mainly in the Baltic Sea and the North Sea. In all European regions a number of planned projects will expand LNG infrastructure and increase LNG availability. As emphasized by the European Directive 2014/94, strategic refuelling points for LNG should be available at least by the end of 2030. In North America, a few ports have planned new LNG projects and additional projects are under discussion. Similarly, in the Asia-Pacific region there are ports in the Republic of Korea, China, Japan and Singapore that are offering LNG bunkering or will start doing so in the coming years. Hence, the availability of LNG as a bunker fuel is improving along the major shipping routes and will continue to improve in the coming years.

An average of regional shares of LNG bunkering demand is reported in Table 21.

Table 21 - *Estimated regional shares for LNG demand over the period 2012 to 2020 in shipping*

	2012	**2020 average**
Africa	7%	5%
Asia	24%	25%
Europe	8%	11%
North America	26%	28%
Latin America	2%	1%
Middle East	16%	15%
Russia & CIS	17%	15%
TOTAL	**100%**	**100%**

Source: This report, based on spatially explicit data analysis, LNG bunkering infrastructure data and informed by LNGi - DNV GL's intelligence portal for LNG as a shipping fuel.

4.4.5 Other alternative shipping fuels by 2020

Driven particularly by MARPOL Annex VI air pollution regulations on NO_x and SO_x emissions, a number of alternative marine fuels may see increased uptake by 2020. These alternatives include methanol, biofuels, LPG and DME.

Methanol has a low sulphur content and is widely available (albeit with little bunkering infrastructure developed for use as a marine fuel). While it can be considered alternative to petroleum-derived low-sulphur fuels, it has several limitations from a technical and commercial perspective. Although methanol fuel systems consist mainly of familiar components, among other additions a ship requires certain modifications to engines and tanks (e.g. an inert gas system for the tanks) and methanol is therefore likely to be used only on ships specifically designed for its use (as opposed to being installed as a retrofit). Even assuming that a methanol-propelled ship requires only minor additional capital investment, methanol needs to be available and cheaper than MGO on an energy-equivalent basis for it to be commercially competitive (FCBI Energy, 2015) (DNV-GL, 2016).

According to IEA (IEA, 2011), to achieve the ambitious biofuel projections presented in its Blue Map scenario, biofuel demand needs to increase rapidly, reaching approximately 760 Mtoe (32 EJ) in 2050, but only 5 EJ in 2020, of which a share of 5% would be used as transport fuel (0.25 EJ). The international shipping fleet could adopt biofuels by blending them with conventional marine fuels and consuming about 11% of the biofuels used in the transport sector, which corresponds to approximately 0.03 EJ (30 million GJ). This amount represents less than 0.3% of the total energy demand of the base case estimate of this study, which makes biofuels share by 2020 negligible.

While LPG (Liquid Propane Gas) and DME are potential marine fuel candidates, there is limited information available on their viability. As LPG is a premium product, it seems to be too expensive compared with other alternative fuel options and in addition presents safety issues, which could limit its use on board ships (IEA, 2014). For LPG and DME, owing to the lack of significance of these fuels in the shipping market today, in 2016 we deem it unlikely that they will contribute significantly by 2020.

Given the above considerations, we assess that the share of other alternative shipping fuels by 2020 will be negligible.

4.4.6 Conclusions on LNG consumption

The final estimate of the use of alternative fuels in shipping by 2020 relates solely to the use of LNG, as the projected shares of other alternative fuels in 2020 is found to be negligible. Use of LNG as a fuel market and its consumption on board LNG carriers has been evaluated independently. Total LNG consumption in 2020 is presented in Table 22, distinguishing three cases (base, high and low), which represent the sensitivity of LNG use to changes in transport demand.

Table 22 - *Estimated LNG demand in million tonnes over the period 2012 to 2020 in shipping*

	2012	2020 base case	2020 high case	2020 low case
LNG carriers	8	9.76	10.85	9.70
LNG as a fuel market (global fleet)	0	3.22	3.66	3.00
Total	8	13.0	14.5	12.7
Percentage of total energy demand	3.6%	5.4%	5.3%	6%

Source: This study.

Table 23 shows regional LNG demand for the three cases.

Table 23 - *LNG potential regional use in 2020 in million tonnes as estimated in this study*

	2020 base	2020 high	2020 low
Africa	0.7	0.7	0.6
Asia	3.3	3.6	3.2
Europe	1.4	1.6	1.4
North America	3.6	4.1	3.6
Latin America	0.1	0.1	0.1
Middle East	2.0	2.2	1.9
Russia & CIS	2.0	2.2	1.9
TOTALS	**13.0**	**14.5**	**12.7**

Source: This study.

Based on our analysis we estimate that in the period up to 2020 LNG consumption may increase by 60% to 80% relative to 2012. We expect about 75% to be consumed by LNG carriers, with the remainder consumed by unitized, passenger vessels, dry bulk oil and chemical tankers and miscellaneous types of ship, as well as inland vessels.

4.5 Global and regional demand of maritime fuels by 2020

This section presents the base case projection of global and regional demand for maritime fuels by 2020, based on projected global maritime energy demand (Section 4.2). This energy demand can be met by four types of fuel:

.1 petroleum fuels with a sulphur content of 0.10% or less will be used in ECAs as well as in some auxiliary engines;

.2 petroleum fuels with a sulphur content of over 0.10% but no more than 0.50% will be used outside ECAs;

.3 petroleum fuels with a sulphur content of over 0.50% will be used by ships with an EGCS both inside and outside ECAs; and

.4 LNG will be used by LNG carriers and other ships fitted with LNG engines.

Section 4.2 estimates the global marine energy demand in the base case to be 12.8 EJ in 2020.

Section 4.3 projects the amount of fuel consumed in 2020 by ships that will be fitted with EGCSs to be 36 million tonnes of HFO, with an estimated energy content of 1.4 EJ.

Section 4.4 projects the amount of LNG used by ships in 2020 to be 13 million tonnes, with an estimated energy content of 0.6 EJ. In order to arrive at a conservative estimate and given the uncertainties in the development of LNG infrastructure under current fuel prices, we have lowered our projections of LNG by 10% to 12 million tonnes in 2020, with an estimated energy content of 0.5 EJ.

The remaining 10.8 EJ will need to be supplied by petroleum fuels with either a sulphur content of less than 0.10% m/m or a sulphur content between 0.10 and 0.50% m/m. 0.10% fuel is used in ECAs. While the market offers 0.10% HFO, most of this fuel is MGO. Conversely, most MGO offered has a low sulphur content.

The Third IMO GHG Study 2014 estimated that, in 2012, 14% of the energy provided by petroleum fuels was MGO and 86% HFO. MGO was typically consumed by smaller auxiliary engines and high-speed diesel engines, although an increasing share of auxiliary engines are fitted to be able to run on HFO.

The Third IMO GHG Study 2014 estimated that in 2012 the share of fuel used in ECAs was 6.3%. A large proportion of this fuel will be MGO, but some will be HFO (for ships fitted with a scrubber) or LNG.

It is expected that by 2020, more ships will be able to run their auxiliary engines on HFO than in 2012. In total, we expect that 15% of the energy consumed by ships that do not have an EGCS and do not run on LNG will be provided by MGO with a sulphur content of 0.10% or less and the remainder by HFO with a sulphur content between 0.10% and 0.50% m/m. This is a conservative estimate, because increasing the amount of MGO by increasing middle distillate production requires less hydroprocessing capacity and is therefore easier to realise than increasing the amount of compliant HFO.

Assuming that the regional shares of fuels do not change between 2012 and 2020, the projection of base case marine fuel demand is presented in Table 24.

Table 24 - *Global and regional marine fuel demand (2020) - base case*

Sulphur (% m/m)	Petroleum-derived fuels			LNG
	<0.10%	0.10-0.50%	>0.50%	
	In ECAs	Outside ECAs	Globally in combination with an EGCS	Globally
	Million tonnes per year			
Africa	2	12	1	0.6
Asia	18	110	15	3.1
Europe	9	54	8	1.2
North America	4	26	3	3.4
Latin America	3	21	3	0.1
Middle East	1	5	4	1.8
Russia & CIS	1	7	1	1.8
Global	39	233	36	12

Source: This report.
Note: Because of rounding values may not add to totals.

Table 25 presents global fuel demand for the low case and high case. In the low case, the demand for petroleum fuels with a sulphur content of 0.50% m/m or less is 15% lower than in the base case. In the high case, the demand for petroleum fuels with a sulphur content of 0.50% m/m or less is 24% higher than in the base case.

Table 25 - *Global marine fuel demand (2020) - low case and high case*

Sulphur (% m/m)	Petroleum-derived fuels			LNG
	<0.10%	0.10-0.50%	>0.50%	
	In ECAs	Outside ECAs	Globally in combination with an EGCS	Globally
	Million tonnes per year			
Low case	33	198	38	13
High case	48	290	14	12

Source: This report.

4.6 Non-marine fuel demand

The demand forecast of refinery products is based on Stratas Advisors' database of market data, pulled from a wide variety of sources including the IEA, EIA and country reporting agencies for major global energy consumers. It takes into account key structural factors like economic growth, population, energy intensity/efficiency and urbanization.

Table 26 summarizes product demand per region and globally. Product demand, refinery configuration and refinery capacity permit assessment of whether or not petroleum and refined products trade flow is required to meet regional supply-demand balances.

In 2020, global non-maritime fuel demand will approach 4,190 million tonnes/year, versus 3,692 million tonnes/year in 2012 (Table 9, Table 26). From 2012 to 2020 global non-maritime fuel demand will increase by 13%, driven by strong growth of refined product demand in Latin American, Middle Eastern, African and Asia-Pacific markets. The majority of the remaining growth will originate in the North American region.

Table 26 - *Non-Marine Product Demand (2020) - million tonnes per year*[(1)]

	Africa	Asia	Europe	North America	Latin America	Middle East	Russia & CIS	Global[(2)]
Gasoline[(4)]	45	277	81	421	136	76	49	1,086
Naphtha	3	214	47	16	13	7	22	322
Jet/Kero Fuel	15	124	62	75	19	21	15	331
Middle Distillate[(4)]	85	524	290	233	167	125	58	1,482
LPG	15	120	36	89	36	42	19	357
Other[(5)]	27	195	70	90	91	98	40	611
Total, non-marine	190	1,454	585	925	462	371	203	4,190

Source: Stratas Advisors, 2015-2016.
Note: Rounding of modelling outputs has led to differences in the totals.
(1) For marine (MGO/HFO) demand, which is not included in this table, see Table 24.
(2) Non-marine refinery product demand is 4,190 million tonnes. Of this, 338 million tonnes is met by other installations than refineries, such as NGL plants and direct from oil production sources: 17 million tonnes as Naphtha, 247 million tonnes as LPG, and 74 million tonnes as other products.
(3) Gasoline and Middle distillate includes biofuel demand.
(4) Includes petroleum coke, refinery fuel, non-marine fuel oil and other products.

Refinery fuels (gasoline, naphtha, jet fuel, kerosene and middle distillate) will make up 77% of global refined-product, non-marine demand in 2020. Middle distillate will be dominant, comprising 36% of the market. Gasoline will be close to this volume (26% of product demand) and jet fuel/kerosene will make up 8% of the market. Non-marine heavy fuel oils will account for 4% of product demand and LPG will make up 8% of the market. Other products, which will make up 13% of product demand, include lubricants, asphalt, refinery fuel gas, non-marine fuel oil, coke and miscellaneous products. The non-marine fuel oil market includes the heavy fuel oil used as heating oil in steam power plants, furnace/forced air heating systems and high-pressure steam boilers. Large reductions in non-marine fuel oil demand have resulted and will likely come from its substitution in power generation plants in favour of environment-friendly natural gas.

This study projects a 13% increase in total petroleum fuel demand between 2012 and 2020, translating to a compound annual growth rate (CAGR) of 1.5%. This is higher than projections in OPEC's World Oil Outlook 2015 (6.7% demand growth between 2014 and 2020, a CAGR of 1.1%); IEA's Medium Term Oil Market Report 2016 (6.5% demand growth between 2015 and 2020, a CAGR of 1.3%) and EIA's International Energy Outlook 2016 (EIA, 2016) (11% demand growth between 2012 and 2020, a CAGR of 1.3%). The main reasons for the differences between the studies are different assumptions about economic growth and the fuel economy of road transport. Chapters 5 and 6 analyze what the consequences of lower overall fuel demand would be for the supply of marine fuels.

4.7 Conclusions on 2020 fuel demand

Marine fuel demand by 2020 is driven by transport demand, fleet composition and operational efficiency, which together determine total energy demand, and by the share of fuel consumed in ECAs, the share of MGO, the share of LNG and the use of scrubbers on ships.

Marine energy demand will increase by 8% between 2012 and 2020. The mass of marine petroleum fuels will increase by 5.5% in the base case, while LNG will increase by 50% (Table 27). The amount of HFO with a sulphur content of over 0.50% m/m will decrease from 228 to 36 million tonnes in the base case. In addition, there will be demand for 233 million tonnes of HFO with a sulphur content of 0.50% m/m or less and 39 tonnes of MGO, most of which will have a sulphur content of 0.10% m/m or less.

Global fuel demand will increase from approximately 4,000 million tonnes in 2012 to approximately 4,500 million tonnes in 2020, a 13% increase. Non-marine fuel demand will increase by 13%; marine fuel demand will grow by 5% in the base case, increase by 21% in the high case and decrease by 8% in the low case.

Table 27 - *Total fuel demand in 2020 (million tonnes per year)*

		Marine petroleum			**Marine LNG**		
	Non-marine	**Base case**	**High case**	**Low case**	**Base case**	**High case**	**Low case**
2012	3,692	292	292	292	8	8	8
2020	4,190	308	352	269	12	13	12

Source: This study.

5 Projections of maritime fuel supply in 2020

5.1 Introduction to the 2020 supply analysis

This chapter presents projections of maritime fuel supply in 2020. Because maritime fuels account for about 7.3% of refinery production by mass (in 2012), the modelling underlying this chapter analyses all refinery product streams.

Section 5.2 briefly describes the model used for the base case run. Section 5.3 presents the assessment of refinery capacity in 2020, which is an important constraint in the model. Section 5.4 presents another constraint, viz. the quantity and quality of the crude oil slate in 2020. Section 5.5 presents the projected product prices used by the model for optimizing refinery outputs. The results of the model run are presented in Section 5.6. Section 5.7 contains the results of the sensitivity analyses and Section 5.8 conclusions.

5.2 Fuel supply projection model

The supply model is a linear programming (LP) mathematical model that accurately describes regional refinery operations. The supply model maximizes the refinery margins while meeting the required refinery fuel volume within given quality constraints. In doing so, each model calculates refinery fuel products and inputs constrained with respect to product quality, using refinery capacity and configuration. Higher value products like gasoline and diesel are produced to meet demand, while intermediate streams of fuel oil are routed to conversion units and hydro-desulphurization units until volume and quality constraints are met. The model calculates blending volume of biofuels (ethanol, bio-diesel) and oxygenates (MTBE, ETBE) based on regional specification and availability of biofuel. Subsequently, the intermediate streams (such as hydrocracker unconverted oil) are blended to meet volume requirements of other oils. For example, once the low-sulphur fuel oil production requirement is met, the additional intermediate oil streams are then blended with high-sulphur oil streams to meet the latter’s production requirement. The model maintains material balance as well as optimizing on marginal revenue. The supply model includes interregional trade flow in a purchase and sell table. Further purchase in one region is balanced in the sell from other region.

The model comprises seven regions, which are the same regions as used throughout this report. Most regions are represented as a single refinery, but North America comprises several sub-regions: all five PADDs and Canada. Refinery representation in the model is based on the known capacity of central distillation units and other refinery units in 2012 and on the capacities projected for 2020. The crude oil used in each region and the flow of intermediary and final products between regions is ensured in the model solver. The overall material balance is performed for material streams (Crude, Products) and their constituent components (Sulphur, Metal). The model results are provided once the material balance is met, with a material imbalance error otherwise being reported. Without a material balance, the model does not yield a converged solution.

Table 28 - ***Regions in the supply model***

Africa
Asia
Europe
North America
Latin America
Middle East
Russia & CIS

Source: Stratas Advisors, 2015-2016.
Before assessing scenarios in 2020, each model was calibrated with a 2012 base case, as indicated in Section 3.2.1.

The refinery model is customized for each region taking into account historical refinery throughput, crude slate, refinery capacity and product slate. Historical data are used to calibrate the model in order to reduce the risk of over-optimization of the model.

The gas oil is required as a feedstock for FCCs and hydrocrackers, while residue serves as a feedstock for cokers, asphalt plants and residual fuel hydrocrackers. In addition to being sold as product streams, the atmospheric gas oil, vacuum gas oil and residue are also produced as intermediate streams and are modelled using conversion units, hydrocrackers, FCCs and cokers to calculate blend stock for fuel oil as well as lighter products. The conversion units convert the heavier oil fractions to lighter fractions (to be blended with gasoline and middle distillate) and leave unconverted fuel oil to be recycled back or used for fuel oil/residual fuel oil blending. The unconverted fuel oil from hydrocrackers is hydroprocessed oil, so the sulphur content is lowered.

Model runs for 2020 projections-Case 1 were based on assessing the supply of marine middle distillate oil (MGO) and demand for marine heavy fuel oil (HFO), as specified in Table 24. For assessing the availability of compliant marine fuels in 2020, the refinery products were assigned to fulfil marine fuel demand, as indicated in Table 29.

Table 29 - ***Refinery products categories used to assess availability of marine fuels in 2020***

Fuels categories	**Case 1**
Refinery product	Marine fuel
Marine middle distillate oil (low-sulphur)	MGO (S <0.10% m/m)
Heavy fuel oil (% S <0.50)	HFO (S <0.50% m/m)
Heavy fuel oil (% S > 0.50%) (high sulphur)	HFO (S > 0.50% m/m)

Source: Stratas Advisors.

5.2.1 How the model is run

The model was calibrated using 2012 EIA/IEA data for all refinery inputs (crude volume and quality, NGLs, …) and the volumes of refinery products (LPG, Naphtha, Gasoline, Middle Distillate..). Refinery capacity, utilization and configurations are at the core of the model calibration. Capacity and configuration are mostly sourced from O&G Journal data. To fine tune product and input volumes, the utilizations rates of different refinery units are allowed to vary for the model to generate a solution, thus ensuring the model does not make unrealistic assumptions about e.g. the amount of sulphur removed from products, amount of crude used or intermediary products purchased.

Before starting a model run, the global demand of refinery products is defined, with regard to both quantity and quality (including sulphur content). The crude slate is also defined and a range of quantities is assigned to each crude, as well as the sulphur content and specific gravity. Minimum and maximum amounts of each product are assigned to regions, as well as quantity ranges for different crudes.

The model is then run for each region separately. After each run, product and crude quantity ranges assigned to the other regions are reassessed and adjusted if necessary. So, for example, if a region produces more of a certain product than there is demand for in that region, the excess production is exported to other regions, taking into account trade statistics, and production in the importing regions is lowered accordingly. Transport of products and intermediary feedstocks between regions is controlled for. The model is run in iterations until the model has yielded results for all regions and a global material balance has been achieved.

In running the model, a conservative approach is taken. The utilization rates of units that are in operation both in 2012 and 2020 are capped to the 2012 values. New units have a utilization rate that cannot exceed 90% of the nameplate capacity. Only expansions that are expected to be operational by June 2019 are taken into account. Sulphur removal in hydrodesulpurization units was limited to 90% or less, depending on the grade of oil. Marine product sulphur specifications are 10% below the limit values.

5.3 Refinery capacity in 2020

Global crude distillation capacity is projected to increase from 4,630 million tonnes in 2012 to 5,020 million tonnes in June 2019 (Table 30). Major initiatives include additional large refineries/expansions in China, India and the Middle East. Additional refineries and expansions are underway and/or have been announced for all other regions, including North America, Latin America, Russia & CIS and Africa. The expansion projects include all identified new refineries, as well as expansions at existing refineries deemed highly probable to be completed.

Global middle distillate hydroprocessing capacity is expected to increase from 1,109 million tonnes per year to 1,306 million tonnes by mid-2019 (an increase of 17% relative to 2012), with this expansion occurring mainly in the Middle East, Asia, Russia & CIS and North America.

For heavy fuel oil/residual fuel oil, hydroprocessing capacity is expected to rise from 439 to 507 million tonnes per year (an increase of 15 % relative to 2012), owing mainly to expansion in the Middle East, Russia & CIS and Asia. Capacity in both Europe and North America will be slightly down, by 3%.

Table 30 - ***Regional Refinery Capacity June 30, 2019 (change since 2012) - million tonnes per year***

	Africa	**Asia**	**Europe**	**North America**	**Latin America**	**Middle East**	**Russia & CIS**	**Global**
Crude Distillation	197 (+11%)	1,630 (+9%)	723 (-9%)	1,047 (+2%)	484 (+33%)	502 (+26%)	437 (+23%)	5,020 (+8%)
Secondary Processing Units								
Light Oil Processing								
Reforming	23 (+15%)	163 (+5%)	105.9 (-8%)	186 (-6%)	29 (+5%)	58 (+52%)	61 (+15%)	626 (+3%)
Isomerization	2.8 (+100%)	13.4 (+47%)	24.3 (-8%)	38 (0%)	2.4 (0%)	22.6 (+163%)	17.8 (+324%)	122 (+30%)
Alkylation/ polymerization	2 (+54%)	17 (+9%)	14.3 (-8%)	65 (-2%)	11.2 (0%)	5 (+6%)	3.8 (+153%)	118 (+1%)
Conversion								
Coking	4.4 (-2%)	132 (+28%)	33.7 (+23%)	159 (+20%)	45 (+62%)	23 (+461%)	23 (+78%)	421 (+35%)
Catalytic cracking	16.6 (+38%)	298 (+16%)	111 (-7%)	309 (-4%)	91.6 (0%)	48.6 (+54%)	41 (+50%)	916 (+6%)
Hydrocracking	11.3 (+126%)	177 (+16%)	102 (+18%)	124 (+27%)	6.59 (+18%)	54.39 (+63%)	56 (+700%)	532 (+37%)
Hydroprocessing								
Gasoline	0 (0%)	49.9 (+73%)	20.6 (+1%)	96 (+5%)	6.22 (+196%)	15.5 (+638%)	15.7 (+362%)	204 (+38%)
Naphtha	25.5 (+9%)	163 (-1%)	175 (-8%)	272 (+10%)	47 (+53%)	68 (+33%)	59 (+13%)	810 (+7%)
Middle distillates	26.4 (+44%)	407 (+11%)	250 (-5%)	305 (+14%)	49 (+23%)	140 (+118%)	128 (+49%)	1,306 (+18%)
Heavy oil/residual Fuel	4.5 (+13%)	184 (+22%)	75 (-6%)	156 (-2%)	31.1 (+23%)	32 (+36%)	23 (+17%)	507 (+15%)

Source: Stratas Advisors, 2015-2016. On the basis of Oil and Gas Journal Data, FuelsEurope, IEA, EIA, OPEC. Announced projects as of Dec 2015, assumed to be online on June 2019 when no start-up year is indicated.

Note: The numbers in bracket () are capacity changes since 2012.

5.4 Crude quality and volume for each region

The crude slate used by refineries in each region comprises an indigenous-imports pool and is particular for each region. All regions primarily use indigenous oil, resorting only to crude imports if their indigenous crude does not represent the best fit for their refineries or if indigenous production does not meet their domestic demand.

The crude slate outlook to 2020 is based on Stratas Advisors' global crude outlook, trade flow outlook to 2020 and crude oil assay database.

Table 31 summarizes Stratas Advisors' best estimates of the volume and quality of crude slate processed on each region in 2020, used in model runs to assess 2020 refinery production projections (base case).

Table 31 - *Refinery Input, Crude Oil and Quality (2020, (2012))*

	Africa	Asia	Europe	North America	Latin America	Middle East	Russia & CIS
Crude Oil (million tonnes per year)	136 (108)	1,328 (1,233)	527 (662)	932 (827)	323 (285)	448 (334)	320 (329)
API gravity	35.41 (35.92)	35.26 (35.76)	34.48 (35.71)	30.6 (30.8)	26.2 (25.2)	31.34 (31.46)	32.5 (32.5)
Sulphur %S (m/m)	0.68 (0.64)	1.07 (1.03)	1.01 (0.77)	1.59 (1.55)	1.44 (1.45)	2.01 (1.92)	1.32 (1.32)

Source: Stratas Advisors.
Note: 2012 numbers are in brackets ().

Africa refinery input is light sweet crude (35° API, S<0.70% m/m). Middle East refinery input is sour crude (S>1.90% m/m). Latin America refinery inputs is mostly heavy crude (<25° API) while North America refineries input is medium sour (mostly imports) and light sweet crude (mostly domestic production).

5.5 Projected Crude and Refinery Products prices

Stratas Advisors maintain price historical data on major refinery inputs and product prices. The forecasting methodology starts by assessing these data to identify major drivers influencing global benchmark prices. The model incorporates the drivers that factor in a variety of assumptions and potential scenarios. The refinery fuel prices are highly influenced by input cost (mainly crude price) and other factors such as demand, supply, GDP and geopolitical risks.

The price differences between HFO with a sulphur content of max. 1% m/m and MGO with a sulphur content of 0.10% m/m or less are inputs to the assessment of the uptake of scrubbers and alternative fuels.

The following prices are added as a guidance to assess the fuel price used in the model.

Table 32 - *Refinery Products and Crude Oil prices (USD/tonnes except for Brent)*

Product	2010	2012	2014	2016	2018	2020
MGO 0.10% m/m SUL	672	997	896	452	552	616
Fuel oil 0.50% m/m SUL	-	-	-	-	-	595
Fuel oil 1% m/m SUL	625	918	809	390	497	569
Fuel oil 3% m/m SUL	521	741	616	252	377	466
Brent crude (USD/bbl)	80	112	99	49	63	77

Source: Stratas Advisors; CE Delft, www.bunkerindex.com.

The fuel oil sulphur quality and crude oil price are major drivers of fuel oil price. The current fuel grade of 0.10% m/m S is high-sulphur diesel and is the price benchmark for MGO (0.10% m/m S). For HFO (0.50% m/m), the price will be above the fuel oil price of 1% m/m S. The guidance of 0.50% m/m sulphur HFO is taken from 0.10% high-sulphur diesel (MGO) and 1% S (heavy fuel oil). For 2020 (Table 32) the 0.50% HFO price is guided entirely by 0.10% high-sulphur diesel (MGO) and fuel oil 1% m/m S. Depending on the demand supply gap, the price will remain between the price of 0.10% S MGO and 1% S HFO, maintaining a price differential of about $ 47/tonne.

5.6 Projection results: base case

The calibrated model developed for 2012 was updated using the following information for the base case for 2020:

.1 regional refinery capacities were updated with the latest information on projects that will be completed before 1 July 2019;

.2 the capacity of hydroprocessing units (hydrocrackers, FCC gasoil feed hydrotreating, residue hydrocracking (HOL) and gasoil hydrotreating) were downsized to 90% in order to give a realistic representation of capacity utilization (90% max.) in various regions (see Table 35);

.3 the sulphur removal in hydrodesulphurization units (such as gas oil hydrotreaters, residual hydrotreaters and atmospheric oil hydrotreaters) was limited to 90% or less (Table 36);

.4 fuel specifications were updated for 2020. The MGO/HFO sulphur specification was further tightened by 10%. For HFO the max. specification of 0.50% m/m S was thus reduced to 0.45% m/m S, and for MGO from 0.10% to 0.09% m/m S. This was done to guarantee a certain margin in the model;

.5 based on 2020 demand numbers, the maximum and minimum of refinery products and refinery inputs range were updated; and

.6 the price for 2020 was updated. Fuel oil and crude updated prices are reported in Table 32.

Table 33 and Table 34 summarize the global and regional refinery projections for 2020, including marine fuels. The projections show that global supply will just be able to meet global demand for marine fuel oils in 2020 in terms of both quantity and sulphur specification.

Table 33 - *Global Refinery Production (2020 (2012)) - million tonnes per year*

Refinery Production (Base case - 2020 (2012)) (1, 2, 3)		
	Production in 2020 (2012)	**Demand in 2020 (2012)**
Gasoline	1,086 (963)	1,086 (963)
Naphtha	305 (256)	305(3) (256)
Jet/Kero Fuel	331 (324)	331 (324)
Middle Distillate	1,521 (1,316)	1,521 (1,316)
of which MGO (S ≤ 0.10% m/m) (4)	39 (64)	39 (64)
Total Marine Heavy Fuel Oil (HFO)	269 (228)	269 (228)
of which Marine HFO (S ≤ 0.50% m/m) (5)	233 (0)	233 (0)
of which Marine HFO (S > 0.50% m/m)	36 (228)	36 (228)
Non-marine Heavy Fuel Oil (6)	194 (272)	194 (272)
LPG	110 (113)	110(3) (113)
Other (7)	343 (512)	343 (512)
Total (marine + non-marine, refinery only)	4,159 (3,984)	4,159 (3,984)
Total (non-Marine only from refinery) (8)	3,852 (3,692)	3,852 (3,692)

Source: Stratas Advisors; CE Delft.

(1) Production numbers in brackets () are 2012 numbers from Table 4 and Table 5.
(2) Demand numbers are from Table 4 and Table 26.
(3) For LPG, naphtha and other products demand is also met from NGL (Natural Gas Liquids) plants, coal mining and upstream, the table shows only demand met from refineries.
(4) Note that this is just MGO with a sulphur content of 0.10% m/m or less. Low-sulphur marine HFO also contains low-viscosity fuels.
(5) Some of these fuels have a sufficiently low viscosity to be used in small main engines and auxiliary engines instead of MGO.
(6) Non-marine fuel oil is intended for a well-defined industrial market (power plants, high pressure steam boilers, etc.).
(7) Includes petroleum coke, lubes, asphalt, other oils and miscellaneous products and does not include "Non-marine Heavy Fuel Oil".
(8) Numbers for "MGO (S ≤ 0.10% m/m)" and "Total Marine Heavy Fuel Oil (HFO)" subtracted from number for "Total (marine+ non-marine, refinery only)". Rounding of modelling outputs has led to a 1 million tonnes difference in the total (non-Marine only from refinery).

The various factors impacting the supply of marine fuel oil (both MGO and HFO) are discussed below:

− Capacity:

.1 crude Distillation Units (CDU): CDU capacity is set to increase globally by 390 million tonnes (8%), with the exception of Europe. The additional CDU capacity adds to capacity for atmospheric and vacuum gas oil and residue, adding in turn to fuel oil volume;

.2 hydrocracking: Globally, hydrocracking capacity will increase by 144 million tonnes (37%). The unconverted gas oil from hydrocrackers is already hydroprocessed and helps lower heavy fuel oil sulphur after blending. It also produces blend stock for middle distillate marine fuel (MGO);

.3 middle distillate hydroprocessing is set to increase globally by 197 million tonnes (17%), helping to meet the low-sulphur requirement for MGO;

.4 heavy oil/residual fuel capacity will increase globally by 68 million tonnes (15%). The increase in residue hydroprocessing helps reduce sulphur from heavy oil/ residue. The 15% capacity increase will help reduce the sulphur from heavy oil of high sulphur content; and

.5 catalytic cracking capacity is set to rise by only 6% globally, compared with 8% for CDU. This helps ensure an additional volume of gas oil will be available for marine fuel oil and middle distillate, provided diesel demand is already met.

In addition to the catalyst replacement cost, the hydrogen (H_2) cost is the major expense associated with fuel oil desulphurization. However, fuel oil blends comprise mainly light distillates when the lowering of fuel oil sulphur content of is the aim. In this regard the refinery supply model calculates the H_2 consumption in the whole plant and each specific unit. Globally, H_2 consumption increases owing to the overall tightening of the sulphur fuel specification in middle distillate oil. Refiners anyway have to meet the hydrogen consumption requirement calculated when capacity is added. Furthermore, hydrogen is also available from flashed streams, which are recycled back for hydroprocessing, in addition to hydrogen available from steam and naphtha reformers.

Table 34 - ***Base case for Regional Refinery Production (2020, (2012)) - million tonnes per year***

Refinery Production (1)							
	Africa	**Asia**	**Europe**	**North America**	**Latin America**	**Middle East**	**Russia & CIS**
Gasoline	22 (17)	236 (234)	120 (135)	472 (399)	104 (78)	80 (50)	52 (51)
Naphtha	14 (12)	145 (130)	49 (38)	16 (12)	13 (11)	45 (33)	22 (20)
Jet/Kero Fuel	10 (9)	120 (119)	43 (49)	84 (73)	21 (17)	36 (42)	18 (15)
Middle Distillate	51 (34)	513 (453)	269 (280)	304 (257)	103 (105)	166 (98)	115 (89)
Of which: MGO <0.10 % m/m S	2 (3)	18 (31)	9 (15)	4 (7)	3 (6)	1 (1)	1 (2)
Marine HFO <0.50 % m/m S	9 (0)	104 (0)	55 (0)	17 (0)	24 (0)	18 (0)	7 (0)
Marine HFO >0.50 % m/m S	1 (7)	15 (95)	8 (52)	3 (21)	3 (18)	4 (25)	1 (10)
Non-marine Heavy Fuel Oil	15 (21)	11 (6)	2 (32)	13 (13)	49 (53)	70 (67)	34 (80)
LPG	2 (2)	41 (41)	12 (17)	24 (21)	11 (8)	11 (5)	9 (18)
Other products(2)	9 (7)	58 (188)	44 (89)	101 (128)	64 (50)	20 (22)	47 (28)
Total	133 (109)	1,241 (1,266)	602 (692)	1,036 (924)	392 (340)	449 (342)	306 (311)

Source: Stratas Advisors, 2015-2016.
(1) Numbers in brackets () are for 2012. 2012 production numbers are from Table 9.
(2) Includes petroleum coke, lubes, asphalt, other oils and miscellaneous products.

Table 35 shows the regional refinery capacity utilization for major units in 2020 and, for comparison, in 2012. In most regions, the hydrocracker and hydrotreatment units have utilization rates that are very similar or lower than in 2012, with the obvious exception of regions that did not have these units in 2012.

Table 36 shows the sulphur removal on fuel for selected processes. As noted above, the values look conservative, which is why they are often lower than the corresponding values obtained in the model calibration for 2012. The values assume that all hydrocracking and hydroprocessing units come with sufficient sulphur plant capacity in order to convert hydrogen sulfide in elemental sulphur. Sulphur plants usually have a higher capacity, so that the operation of the hydroprocessing units is not constrained. This is not always supported by our capacity projections, however. This assumption is not accurate; refineries will need to expand the capacity of their sulphur plants to fulfill 2020 demand.

Table 35 – Percentage *Regional Refinery Capacity Utilization for major units (2020 and 2012)* *(1,2,3)*

PROCESS	Africa	Asia	Europe	North America	Latin America	Middle East	Russia & CIS
CDU	57% (56%)	68% (76%)	60% (76%)	64% (64%)	55% (72%)	74% (77%)	60% (85%)
HYDROCRACKER	83% (92%)	76% (69%)	83% (92%)	69% (77%)	83% (89%)	83% (92%)	56% (92%)
GOHDS TOTAL	0% (0%)	83% (91%)	83% (57%)	81% (84%)	65% (33%)	83% (92%)	75% (92%)
ATRES HDT	0% (0%)	83% (23%)	83% (46%)	10% (2%)	0% (0%)	46% (92%)	0% (0%)
H-OIL	83% (92%)	83% (92%)	83% (52%)	76% (36%)	0% (0%)	83% (92%)	36% (84%)
GASOIL HDS	81% (92%)	51% (92%)	83% (92%)	13% (10%)	83% (0%)	0% (0%)	0% (0%)
AGO HDS	81% (92%)	30% (92%)	83% (92%)	2% (6%)	83% (0%)	73% (0%)	0% (0%)
LCO HDS	0% (0%)	22% (0%)	0% (0%)	11% (5%)	0% (0%)	2% (0%)	0% (0%)
DELAYED COKER	83% (0%)	48% (75%)	46% (87%)	70% (88%)	55% (81%)	83% (92%)	38% (71%)
FCC	92% (92%)	66% (69%)	70% (81%)	92% (80%)	82% (63%)	92% (92%)	78% (92%)
REFORMER	68% (66%)	58% (70%)	65% (92%)	83% (83%)	80% (83%)	86% (70%)	55% (61%)
ISOMERISATION	28% (92%)	92% (92%)	62% (92%)	92% (64%)	35% (4%)	11% (92%)	13% (92%)

Source: Stratas Advisors, 2015-2016.

(1) 2012 and 2020 utilization rates are based on 92% of stream day capacity (92% of stream day capacity is about 8,000 hours of continuous operation out of 8780 hours maximum a year).

(2) 2020 Utilization is calculated based on 90% capacity of hydroprocessing units.

(3) 0% utilization is for regions where no capacity is reported for the processing in question.

Table 36 - ***Percentage(1, 2) of sulphur removal on fuel for selected hydrotreating processes - 2020 (2012)***

Regional Process Sulphur Removal Percentage (2020, (2012))							
PROCESS	**Africa**	**Asia**	**Europe**	**North America**	**Latin America**	**Middle East**	**Russia & CIS**
HYDROCRACKER(1)	100% (100%)	100% (100%)	100% (100%)	100% (100%)	100% (100%)	100% (100%)	100% (100%)
GOHDS TOTAL(1)	0% (0%)	87% (93%)	86% (96%)	89% (96%)	86% (93%)	87% (98%)	87% (94%)
ATRES HDT (1)	0% (0%)	89% (89%)	89% (89%)	90% (89%)	0% (0%)	89% (89%)	0% (0%)
H-OIL(1)	81% (78%)	87% (86%)	86% (82%)	90% (89%)	0% (0%)	91% (91%)	86% (86%)
GASOIL HDS (1)	85% (97%)	83% (85%)	85% (97%)	88% (96%)	85% (0%)	85% (0%)	0% (0%)
AGO HDS (1)	85% (97%)	83% (85%)	85% (97%)	88% (96%)	85% (0%)	85% (0%)	0% (0%)
LCO HDS (1)	0(0%)	0% (0%)	0% (0%)	88% (96%)	85% (0%)	0% (0%)	0% (0%)

Source: Stratas Advisors, 2015-2016.
(1) Percentage sulphur removal in fuel oil is limited to 90% or less for 2020.
(2) Percentages are rounded to the nearest integer; therefore 100% sulphur removal does not mean total sulphur removal. When 0% is indicated, it means either non-existent or unused capacity.

At the regional level (Table 37), Africa, Asia and North America will be short of HFO (<0.50%) to fulfil demand. These regions will be able to import HFO (<0.50%) from Europe, Latin America and Middle East, which will have a supply surplus.

Table 37 - ***Global marine fuel demand and supply (2020) base case - million tonnes per year***

Base case marine fuel demand 2020 (supply)				
	Petroleum-derived fuels			**LNG**
Sulphur (% m/m)	**<0.10%**	**0.10-0.50%**	**>0.50%**	
Africa	2 (2)	12 (9)	1 (1)	0.6
Asia	18 (18)	110 (104)	15 (15)	3.1
Europe	9 (9)	54 (55)	8 (8)	1.2
North America	4 (4)	26 (17)	3 (3)	3.4
Latin America	3 (3)	21 (24)	3 (3)	0.1
Middle East	1 (1)	5 (18)	4 (4)	1.8
Russia & CIS	1 (1)	7 (7)	1 (1)	1.8
World	39 (39)	233 (233)	36 (36)	12

Source: Stratas Advisors, 2015-2016.
Note: Because of rounding values may not add to totals.
Supply model results are in brackets.

Stratas Advisors' fuel oil trade flow outlook to 2020 suggests that North America could import HFO (<0.50%) from Latin America, and Europe. Africa could import HFO (<0.50%) from Middle East. Asia could import HFO (<0.50%) from Middle East (Table 38).

Table 38 - ***Trade flows of HFO <0.50 m/m S % for (2020), million tonnes per year***

From/to	Africa	Asia	Europe	North America	Latin America	Middle East	Russia & CIS
Middle East	3	6	0	4	0	0	0
Europe	0	0	0	1	0	0	0
Latin America	0	0	0	3	0	0	0

Source: Stratas Advisors. 2015-2016.

5.7 Projection results: sensitivity analysis

The supply model runs were organized around a base case scenario with sensitivities as shown in Table 39. The cases include the high and low case, as well tests of the maximum amount of compliant fuel (petroleum fuels with a sulphur content of 0.50% m/m or less) that can be produced and sensitivities with regards to the sulphur content of the crude oil slate. A further explanation of each model run is provided below the table.

Table 39 - ***Supply model runs to assess availability of marine fuels in 2020 - million tonnes per year***

	Fuel sulphur content			
Scenario	**<0.10 % SUL m/m**	**<0.50 % SUL m/m**	**>0.50 % SUL m/m**	**Notes**
Case 1 - Base case demand (production)	39 (39)	233 (233)	36 (36)	Base case
Case 2 - Flash point demand (production)	39 (39)	233 (233)	36 (36)	Sensitivity Lower flash point
Case3 - High-demand case (production)	48 (48)	290 (290)	14 (14)	High-demand case
Case 4 - Low-demand case (production)	33 (33)	198 (198)	38 (38)	Low-demand case
Case 5 - Maximum production case (production)	(48)	(296)	(14)	Largest (Maximum) production of compliant oil
Case 6 - High-sulphur case (production)	(39)	(233)	(36)	Sensitivity Blending of high-sulphur crude 10% increase on %S m/m in crude slate
Case 7 - Low viscosity case (production)	(39)	(233)	(36)	Sensitivity Increasing low viscosity blending stocks (Kerosene, light gas oil)
Case 8 - Maximum non-marine fuel demand case (Production) (2020)	(39)	(233)	(36)	Sensitivity maximum Middle distillate and gasoline production by maximizing utilization

Source: Stratas Advisors, 2015-2016; CE Delft.
Note: Numbers in bracket () are production numbers for 2020, numbers not enclosed in brackets are the demand number for 2020.

The supply model was used to estimate the ability of the refinery industry to supply the projected demand of marine and non-marine fuels in 2020 as per the scenarios outlined in Table 39 and discussed individually in subsequent subsections.

5.7.1 Case 1: base case

Case 1 is the base case. It uses the capacity projected for 30 June 2019 and assesses the global MGO and HFO fuel supply. It assumes the base case demand shown in Table 24 for marine fuel and in Table 26 for non-marine fuel, given that both MGO and HFO marine fuels are integral elements of total middle distillate and fuel oil demand, respectively. For assessing marine fuels availability, the sulphur content in high-sulphur middle distillate (MGO 0.10% S m/m), low-sulphur fuel oil (HFO S <0.50% m/m) and high-sulphur fuel oil (HFO >0.50% S m/m) were specified in the model input to calculate marine fuels sulphur demand.

In this base case, production is in line with demand for both MGO and HFO. For low-sulphur HFO (<0.50% S m/m), the blend stock includes residue, cutter stock, unconverted hydrotreated oil, treated light distillate and very small fractions of kerosene in some cases.

Section 5.6, Table 36, provides details about hydrodesulphurization conversion for different units. Hydrocracker unconverted oil contains almost no sulphur, but other hydrotreater sulphur removal rates are between 80% and 90%. Africa has no reported capacity for atmospheric residue hydrotreaters and conversion is reported as 0%.

5.7.2 Case 2: low flash point

This case assesses fuel availability if the minimum flash point were to be lowered from 60°C to 52°C. It assumes the base case demand shown in Table 24 for marine fuel and Table 26 for non-marine fuel, given that both MGO and HFO marine fuels are integral elements of total middle distillate and heavy fuel oil demand, respectively. For assessing marine fuels availability, low-viscosity fuel oil (HFO) volume was increased to meet the marine fuels sulphur specification indicated in Table 26.

The blend stock is mostly residue, unconverted oil from hydrocrackers, hydrotreated oil and hydrotreated light distillate. These blend stocks are only available for fuel oil after meeting middle distillate demand, and regional refineries can divert treated hydrotreated oil to the fuel oil pool. The model output gives no indication of a flash point issue.

While the minimum flash point of most of the blend stock is over 60°C, that of kerosene varies from 38°C to 70°C. Refiners must ensure a minimum flash point for the fuel blend stock as per specification, as North America and Middle East have less than 2% of kerosene stream blending into fuel oil. Further reducing the minimum flash point to 52°C will certainly help improve fuel oil availability, if kerosene can be used to meet volume requirements.

5.7.3 Case 3: high-demand case

This is the high-demand case. For assessing marine fuels availability, non-marine fuels refinery production was handled as in the base case (Case 1). Under this demand scenario, Asia and Middle East produce all additional marine fuels, because these regions will have sufficient capacity (Table 40). Furthermore, these regions enjoy greater flexibility with the crudes available to them (both volume and quality).

Each region will be able to supply MGO and high-sulphur marine HFO (>0.50% m/m S). However, Europe, Africa, Latin America, Russia & CIS and North America will be in short supply for marine low-sulphur HFO (<0.50% S m/m), which can be supplied from the Middle East. In this high-demand case, Asia will be self-sufficient (Table 41).

Table 40 - ***Global marine fuel demand and supply (2020) high case - million tonnes per year***

Marine Fuels Case 3: High marine fuels demand (supply)				
	Petroleum-derived fuels			**LNG**
Sulphur (% m/m)	**<0.10 % SUL m/m**	**<0.50 % SUL m/m**	**>0.50 % SUL m/m**	
Africa 2020 Demand 2020 Production	2.40 (2.40)	14.49 (8.77)	0.41 (0.41)	0.00
Asia 2020 Demand 2020 Production	22.60 (22.60)	136.17 (135.75)	5.68 (5.68)	3.59
Europe 2020 Demand 2020 Production	11.06 (11.06)	66.64 (55)	3.11 (3.11)	3.88
North America 2020 Demand 2020 Production	5.29 (5.29)	31.87 (17.24)	1.22 (1.22)	2.49
Latin America 2020 Demand 2020 Production	4.33 (4.33)	26.08 (24)	1.08 (1.08)	0.81
Middle East 2020 Demand 2020 Production	0.96 (0.96)	5.79 (42.09)	1.49 (1.49)	0.81
Russia & CIS 2020 Demand 2020 Production	1.44 (1.44)	8.69 (7.02)	0.54 (0.54)	0.00
World 2020 Demand 2020 Production	48 (48)	290 (290)	14 (14)	11.57

Source: CE Delft; Stratas Advisors, 2015.
Note: Supply model results are in brackets.

For assessing marine fuels availability, marine fuels refinery production was handled as in the base case (Case 1).

Table 41 - ***Global marine fuel trade flow (2020) - million tonnes per year***

Trade flow fuels with a Sulphur content of 0.50% m/m or less From/to	**Africa**	**Asia**	**Europe**	**North America**	**Latin America**	**Middle East**	**Russia & CIS**
Middle East	5	0	12	15	2	0	2

Source: Stratas Advisors, 2015-2016.

The crude volume was increased for high-demand case in both Asia (1,312 million tonnes). For the high-demand case, crude volume was increased in both Asia (1,312 million tonnes instead of 1,267) and the Middle East (502 million tonnes instead of 448). H_2 consumption and sulphur production were likewise increased. In Asia the former was increased from 7,526 to 7,705 MMSCFD, relative to base case, in the Middle East from 2,827 to 2,889 MMSCFD. The increased H_2 consumption is to meet the higher demand for low-sulphur fuel.

The blend component for HFO takes the naphtha/kerosene swing for the high case and will impact the flash point, as the naphtha/kero swing flash point is 40 to 70°C. Refineries will therefore need to ensure that the flash point of their blending components are over 60°C.

5.7.4 Case 4: low-demand case

This case assumes low-demand for assessing marine fuels availability, non-marine fuels refinery production was handled as in the base case (Case 1). Under this demand scenario, marine fuels demand and production were as presented in Table 42.

Table 42 - *Global marine fuel demand and production - low case (2020) million tonnes per year*

Marine Fuels Case 4 (Low-demand case for marine fuels)				
	Petroleum derived fuels			**LNG**
Sulphur (% m/m)	**<0.10 % SUL m/m**	**<0.50 % SUL m/m**	**>0.50 % SUL m/m**	
Africa 2020 Demand 2020 Production	1.65 (1.65)	9.92 (8.77)	1.14 (1.14)	0.00
Asia 2020 Demand 2020 Production	15.48 (15.48)	93.26 (69.66)	15.96 (15.96)	4.07
Europe 2020 Demand 2020 Production	7.57 (7.57)	45.64 (55)	8.74 (8.74)	4.40
North America 2020 Demand 2020 Production	3.62 (3.62)	21.83 (17.24)	3.42 (3.42)	2.83
Latin America 2020 Demand 2020 Production	2.96 (2.96)	17.86 (24.00)	3.04 (3.04)	0.92
Middle East 2020 Demand 2020 Production	0.66 (0.66)	3.97 (17.54)	4.18 (4.18)	0.92
Russia & CIS 2020 Demand 2020 Production	0.99 (0.99)	5.95 (7.02)	1.52 (1.52)	0.00
World 2020 Demand 2020 Production	32.93 (32.93)	198 (198)	38.01 (38.01)	13.14

Source: CE Delft; Stratas Advisors, 2015.
Note: Supply model results are in brackets.

Each region will be able to supply MGO and high-sulphur marine HFO (>0.50% m/m S). However, Asia, Africa and North America will be in short supply for marine low-sulphur HFO (<0.50% m/m S), which can be supplied from other regions.

Asia will be able to reduce production of low-sulphur fuel oil (HFO <0.50%S m/m). Asia refinery crude input is projected to decrease from 1,328 to 1,294 million tonnes, with minor changes to crude API and sulphur.

Compared with the base case, sulphur production decreases in the Middle East and increases in Asia. In Asia, H_2 consumption increases slightly from 7,759 to 7,787 MMSCFD, owing to a slightly higher volume being processed in hydrocrackers and a higher volume in gasoil hydrotreatment (SDDG) relative to the base case. The reduced sulphur production is a result of the lower demand for low-sulphur fuel.

In Asia, capacity utilization also decreases for most of the major processing units except delayed coker and LCO HDS, as feedstock availability increases towards coker.

The blending components move towards heavier product, with 15% of treated light distillate being replaced by 9% of naphtha/kero swing and the rest replaced by hydrotreated oil blend.

5.7.5 Case 5: maximum amount of compliant marine fuels

This case assesses the maximum amount of compliant marine fuels that can be produced given projected refinery capacity in 2020. For assessing marine fuels supply, non-marine fuels refinery production was handled as in the base case (Case 1).

Asia and Middle East will be able to supply a greater volume of compliant fuel oil thanks to the additional refinery capacity added by mid-2019. Asia will be able to increase output of HFO (<0.50% S), but will need sweeter crude to process. The maximum supply is indicated in Table 43.

Table 43 - *Asia and Middle East marine fuel maximum production (2020) - million tonnes per year*

Marine Fuels Case 5 (Marine Fuel Maximum Production)[(1)]			
	Petroleum-derived fuels		
Sulphur (% m/m)	**<0.10 % SUL m/m**	**<0.50 % SUL m/m**	**>0.50 % SUL m/m**
Asia 2020 Demand 2020 Production	23 (23)	136.17 (135.75)	6.0 (6)
Middle East 2020 Demand 2020 Production	0.96 (0.96)	5.79 (42.09)	1.49 (1.49)

Source: CE Delft, Stratas Advisors, 2015-2016.
(1) 2020 Production numbers are in brackets (); demand numbers are not bracketed.

Compared with the base case, Asia refinery input sulphur will have to decrease by 2% (1.07 to 1.05) and refinery crude input increase from 1,328 to 1,371 million tonnes per year. Middle East refinery sulphur input will remain almost the same, with minor adjustments for sulphur and API.

Capacity utilization increases further in Asia for all processing units. In the Middle East, atmospheric residue hydrotreater utilization increases. In Asia, higher coker utilization indicates availability of high-sulphur residue oil for processing.

In the Middle East, H_2 consumption and sulphur production both increase. In Asia, the H_2 consumption increases significantly from 7,759 to 8,238 MMSCFD, relative to the base case. Sulphur production decreases, however, as crude slate becomes sweeter to maximize production.

There is little change in the HFO blend.

5.7.6 Case 6: the impact of high-sulphur crude

This case assesses the uncertainty of the quality of future crude oil production by studying the impact of worsening the quality of the crude oil processed (higher-sulphur crude). For assessing marine fuels availability, non-marine fuels refinery production was handled as in the base case (Case 1).

The Middle East, Africa, Asia and Europe regions will be able to meet the demand for all fuels when crude has a 10% higher sulphur content than in the base case (see Table 31). Russia & CIS, Latin America and North America are projected to have difficulties meeting the fuel specification with respect to diesel and/or gasoline. For example, the Russia & CIS region will have difficulty meeting the gasoline sulphur specifications if the sulphur content of the crude increases, while Latin America will have a problem meeting the ultra-low-sulphur diesel fuel specification. Compared with the base case, the Middle East could process up to 10% higher sulphur in the crude (2.22%S m/m).

From the capacity point of view, the Middle East will be able to absorb a 10% rise in sulphur increase in crude; refiners will increase their production of other products, however, as production is dynamic with regard to meeting distillate and gasoline demand. Owing to higher crude consumption for other products, CDU utilization will be higher, though utilization of other processing units will be close to the base case.

The low-sulphur blending component will increase towards hydrotreated oil, while the treated atmospheric residue blending fraction will decrease owing to heavier sour crude slate.

5.7.7 Case 7: increasing low-viscosity blend stock in HFO

This case assesses adding/increasing low-viscosity blend stocks towards low-sulphur fuel oil (HFO<0.50%S m/m). By increasing kerosene blending into the diesel pool and blending light gas oil and light cracked naphtha into the distillate pool, fuel oil production will increase. After fulfilling kerosene demand, the supply model shifts the remaining fractions to the diesel blend pool. After meeting gasoline demand, the additional light cracked naphtha will be shifted towards distillate fuels. For assessing marine fuels availability, marine fuels refinery production was handled as in the base case (Case 1).

Low-viscosity blend stock is needed for increasing the volume of low-sulphur HFO (<0.50% m/m S). In the high Case 3 and maximum Case 5, the amount of blend stock needed is included in the model.

5.7.8 Case 8: maximum refinery utilization

This case assesses maximum middle distillate and gasoline production by hydrocracker, coker, VGO hydrotreater, residual desulphurization, visbreaker and oligomerization utilization. By running refinery conversion units at maximum utilization, the higher yields of desired product (middle distillate and gasoline) are assessed here. For assessing non-marine fuels availability, marine fuels refinery production was handled as in the base case (Case 1).

Table 44 presents the maximum refinery production per region. North America, Latin America and Middle East have sufficient capacity to increase the output of middle distillates. Africa, Europe and Middle East can increase their output of gasoline. Overall, most regions can increase their output, with total production 2.6% higher by mass than assumed in the other cases.

Table 44 - *Regional Refinery Maximum Production 2020- million tonnes per year*

Refinery Production (1)								
	Africa	Asia	Europe	North America	Latin America	Middle East	Russia & CIS	Total
Gasoline	26 (22)	236 (236)	146 (120)	474 (472)	123 (104)	86 (80)	52 (52)	1,143 (1,086)
Naphtha	14 (14)	145 (145)	49 (49)	16 (16)	13 (13)	45 (45)	22 (22)	305 (305)
Jet/Kero Fuel	10 (10)	120 (120)	43 (43)	84 (84)	21 (21)	36 (36)	18 (18)	331 (331)
Middle Distillate	53 (51)	513 (513)	269 (269)	321 (304)	120 (103)	174 (166)	115 (115)	1,565 (1,521)
Of which MGO <0.10 % S m/m (2)	2 (2)	18 (18)	9 (9)	4 (4)	3 (3)	1 (1)	1 (1)	39 (39)
marine HFO <0.50 % S m/m (3)	9 (9)	104 (104)	55 (55)	17 (17)	24 (24)	18 (18)	7 (7)	233 (233)
marine HFO >0.50 % S m/m	1 (1)	15 (15)	8 (8)	3 (3)	3 (3)	4 (4)	1 (1)	36 (36)
LPG	2 (2)	41 (41)	12 (12)	24 (24)	11 (11)	11 (11)	9 (9)	110 (110)
Other(4)	24 (24)	68 (68)	46 (46)	115 (115)	113 (113)	90 (90)	81 (81)	537 (537)
Total	138 (133)	1,241 (1,241)	628 (602)	1,055 (1,036)	392 (392)	463 (449)	306 (306)	4,260 (4,159)

Source: Stratas Advisors, 2015-2016.

(1) Numbers in brackets () are the base case (Case 1) production number for 2020. Unbracketed numbers are 2020 maximum production numbers.
(2) Note that this is just MGO with a sulphur content of 0.10% m/m or less. Low-sulphur marine HFO also contains low-viscosity fuels.
(3) Some of these fuels have a sufficiently low viscosity to be used in small main engines and auxiliary engines instead of MGO.
(4) Includes petroleum coke, lubes, asphalt, non-marine fuel oil, other oils and miscellaneous products.

5.8 Conclusions on 2020 fuel supply

The modelling results indicate that the refinery industry can produce sufficient amounts of marine fuels of the required quality in the base case, the high case and the low case while at the same time supplying other sectors with the petroleum products they require.

Maritime fuel demand can also be met when the minimum flash point for marine fuels is lowered from 60 to 52°C. Only in the Middle East can regional demand production be met if the crude slate contains 10% more sulphur; other regions have insufficient capacity. The maximum amount of compliant fuels that the global refinery industry can produce is 24% above the demand projected in the base case and 2% above the demand projected in the high case. This maximum amount can only be produced if the crude slate is sweeter than in the base case, especially in Asia.

Although the utilization rates of the major conversion units will need to be high, they remain within realistic limits. We have assumed that all units have sufficient sulphur plant capacity. If this assumption is not accurate, refineries will need to expand the capacity of their sulphur plants to fulfill 2020 demand.

In all cases, but especially in the high-demand case, interregional transport of marine fuel will be required. If supply and demand is to be balanced in all regions, the Middle East and in some cases Europe and Latin America may have to export fuel with a sulphur content of 0.50% m/m or less to other regions.

6 Assessment of fuel oil availability

6.1 2020 Assessment Introduction

This chapter presents our assessment of maritime fuel availability in 2020 under the assumption that MEPC will decide to maintain the 2020 date for implementation of the global sulphur limit of 0.50% m/m. It compares the demand projections of Chapter 4 with the results of the supply modelling of Chapter 5 with the aim of assessing whether the refinery industry can and will produce enough to meet demand. It also considers under what circumstances demand or supply could evolve differently from expected and how this would impact on the assessment. Finally, the chapter discusses possible implications of occurrences of global or regional over- or undersupply.

6.2 Projected 2020 demand

This study projects global demand for marine fuels to amount to 319 million metric tonnes in the base case, 14% higher in the high case and 12% lower in the base case. The drivers of overall fuel demand are transport demand and operational efficiency of ships. The base case assumes an increase in transport demand between 2012 (the model base year) and 2020 that is in line with the UNCTAD maritime transport work projection and the most recent IMF global economic growth forecast. The high case and the low case have a 8.5% higher and a 2.3% lower transport demand. The operational efficiency of the fleet is 5% worse in the high case, which has more new and efficient ships which sail slower, and 11% better in the low case, which sees ships sail considerably slower.

It is conceivable that the economy will pick up rapidly or hit another recession; transport demand will then fall outside the range considered here and ships speed up or slow down to an even greater extent, although we are not aware of any such projections. In 2007 and 2008, the amount of fuel consumed per tonne-mile was 25% higher than in the period 2009 to 2012, owing mainly to faster sailing ships. We consider a return to these speeds unlikely, however, because the fleet is currently much larger than in 2007 and 2008, so the increase in transport demand would need to be very large to induce ships to increase their average speeds to previous levels.

The fuel split is driven by investments in EGCSs and LNG-fuelled ships. If more ships are fitted with EGCSs or capable of sailing on LNG (and provided the prices of LNG and high-sulphur fuels are sufficiently attractive), demand for petroleum fuels with a sulphur content of 0.50% m/m or less will be lower and vice versa. Many factors affect investments in EGCSs, as was discussed in Section 4.3: their costs, relative fuel prices, cost of capital, regulatory constraints, availability and yard capacity.

It is conceivable that investments in EGCSs will be higher or lower than projected in any of the scenarios, either because assumptions pan out higher or lower than in any of our cases, or for other reasons. One factor that might be relevant in this respect is the ability of shipping companies to raise capital. If in the coming years the Ballast Water Management Convention (BWMC) enters into force, this will require shipping companies to invest in ballast water management systems, which require a similar amount of capital as EGCSs. If market conditions for shipping companies are unfavourable in the coming years, not all the owners of the 3,000 to 4,000 ships projected to invest in scrubbers may be able to raise sufficient capital to do so. Such market circumstances will likely be due to low transport demand, however, thus reducing overall demand for marine fuels. On balance, the demand for fuel with a sulphur content of 0.50% m/m or less is therefore unlikely to be higher than projected.

If, on the other hand, market conditions are favourable, more companies could invest in EGCSs. Favourable market circumstances would be brought about by high-demand, resulting in higher demand for fuels. If more of that demand can have a high-sulphur content, because more ships are equipped with EGCSs, it will be even higher.

Another reason for possible diversion from the projections could be that more or fewer new ships are built. For these new ships, EGCSs require lower investments because they can be incorporated in the original design. Consequently, EGCSs are more often cost-effective. If more new ships are built, demand for high-sulphur fuels would likely increase. The impact in 2020 would not be that great, however, because ships built in 2018 and 2019 make up a relatively small share of the fleet.

It is also conceivable that there will be more LNG-fuelled ships by 2020 than projected in any scenario. But even if the number of ships were to double or triple, which is more than even the most optimistic outlooks project, this would not have any major impact on demand for compliant fuels (petroleum fuels with a sulphur content of 0.50% m/m or less) because the share of LNG in the fuel mix is so low.

In summary, the base case, low case and high case are plausible estimates and demand for marine fuels in 2020 will therefore in all likelihood be within the range presented here. Still, scenarios are conceivable, but unlikely, in which demand will be either higher or lower. The main reason for demand being outside the ranges projected here would be unexpected economic developments (either a prolonged economic slowdown or unexpectedly rapid growth). Another reason could be an unexpectedly high or low investment in EGCSs, although this would have to coincide with much higher or lower transport demand to result in fuel demand lying outside the range projected by our cases. Although these possibilities cannot be ruled out entirely, it is most probable that demand in 2020 will be within the range bounded by the low case presented in this report.

6.3 Projected 2020 supply

This study shows that demand for petroleum-based marine fuels, which constitutes about 6.8% of the total demand for petroleum products in the base case in 2020, can be supplied by refineries in the base case, as well as in the high and low case. Fuel with a sulphur content of 0.10% m/m or less will be predominantly middle distillate, while fuel with a sulphur content between 0.10% and 0.50% m/m, as well as fuel with a sulphur content over 0.50% m/m, will be mostly high-viscosity fuel oil and in some cases low-viscosity fuel oil.

The main reason that the average sulphur content of marine fuels can be considerably lower by 2020 than it was in 2012 is that while global crude distillation capacity is projected to increase by 8% relative to 2012, middle distillate hydroprocessing capacity (which is used to desulphurize MGO and road diesel) is expected to increase by 17% and heavy fuel oil hydroprocessing capacity by 15%. In addition, coking and hydrocracking capacity will increase by 35% and 37%, respectively, and both processes also produce low-sulphur fuels. This allows refineries to lower the sulphur content in their products, despite a slightly higher average sulphur content and a 14% higher total amount of crude.

The maximum amount of compliant fuels that can be produced is 24% more than demand in the base case and 2% more than in the high case. In order to produce this amount, the Asian region needs crude oil with a lower sulphur content. If, on the other hand, the sulphur content of crude increases, only the Middle East has sufficient hydrotreatment capacity to produce compliant fuels in sufficient amounts.

Although to the best of our knowledge new hydroprocessing units or expansions of these units always include sufficient sulphur plant capacity, this is not always supported by our capacity projections. In our modelling, we have nevertheless assumed that the sulphur plant capacity will not limit the sulphur removal rates of hydroprocessing units. If this assumption is not accurate, refineries will need to expand the capacity of their sulphur plants to fulfill 2020 demand.

Although the assessment of refinery capacity has been conservative and, for example, only projects that are projected to be completed by June 2019 have been taken into account in this study, it is conceivable that projects are delayed or aborted, or that projects planned to be completed in or after June 2019 will come on stream early. Still, over half the expansion in middle distillate hydroprocessing capacity projected between 2012 and 2019 had already been realised by February 2016, as well as 20% of the heavy oil hydroprocessing capacity expansion. Moreover, the supply models have been run with a tighter fuel specification than required by MARPOL and the utilization rates have been limited to 90%. Hence, there is sufficient spare capacity and we do not consider this risk to be significant.

Another reason why supply could diverge from the modelling results presented here is that refineries may market new blends or intermediary streams. This occurred in 2015, for example, when several oil companies started marketing ultra-low-sulphur heavy fuel oil in ECA regions, a development that had not been foreseen by many studies and reports on the availability and prices of marine fuels published before 2015 (see e.g. (CONCAWE, 2009), (EPA, 2008) although (Purvin & Gertz, 2009) did consider this possibility). If this occurs, it is likely to increase supply and thus make it easier to meet demand for compliant fuels.

If downtime and maintenance for residual and gas oil hydrotreatment units in the second half of 2019 and the beginning of 2020 is much higher than expected, the availability of compliant fuel oil will be impacted negatively. However, maintenance can be planned well in advance, and refiners may even adopt new advanced hydroprocessing catalyst to mitigate this risk.

A faster than expected change in demand towards more ultra-low-sulphur diesel will lead to refiners producing more diesel from gas oil and will reduce the availability of low-sulphur HFO (<0.5% m/m S). Refiners can mitigate this risk by using more medium sweet crude.

Finally, a change in the crude slate, for example as a result of geopolitical tensions, may affect the availability of compliant fuels. If the resulting slate contains more high-sulphur crude, more hydrotreatment will be required to produce sufficient amounts of compliant fuels. Because of the conservative assumptions in the modelling, this need not change the conclusion. Conversely, if the crude slate is sweeter on average, more compliant fuel may be produced.

In summary, the refinery modelling indicates that a sufficient amount of fuel oil of the required quality can be produced for the base case, the low case and the high case for demand. In fact, there seems to be sufficient capacity to produce more than the high case as a result of anticipated capacity expansions, with capacity likely to increase still further after June 2019. Still, scenarios are conceivable, but unlikely, that refineries will be unable to supply a sufficient amount of compliant fuels. The main risks are that refinery expansion projects are delayed or aborted, suitable grades of crude are unavailable, demand shift towards ultra-low-sulphur diesel happens earlier than currently planned, or that refineries face capacity downsizing owing to unplanned shutdowns. Although unexpected developments cannot be ruled out, all information currently available indicates that the global refinery industry will be able to produce marine fuels in sufficient quantities in 2020.

6.4 Matching supply and demand

The previous two sections showed that a thorough analysis of the best available information indicates that a sufficient amount of marine fuels will be available in 2020 globally to comply with regulation 14 of MARPOL Annex VI. This section analyses what could happen if unexpected developments result in a global oversupply or shortfall of marine fuels and what the impact of regional surpluses or shortages would be.

If, unexpectedly, there were to be a global shortage of marine fuel with a sulphur content between 0.10 and 0.50% m/m, this would result in an increase in the price of this type of fuel. This would have the following consequences:

.1 EGCSs and LNG engines will become more economically viable for a larger number of ships. More shipping companies would invest in these technologies, but because there is a considerable lead time between an investment decision and actual installation, this will not start to have an impact on demand until about a year after the price increases;

.2 higher fuel prices will induce ships to slow down, thus reducing demand for fuel and mitigating the impact of the production shortfall. Speed changes cannot always be implemented instantaneously because of charter contracts and delivery schedules, but they can have an impact on demand on a shorter time scale than investments in EGCSs and LNG engines;

.3 As the price difference between fuel with a sulphur content of 0.50% and 0.10% becomes smaller, the latter becomes more attractive and ships may increasingly use it; and

.4 higher prices make blends that were previously uneconomical to market become viable alternatives, allowing fuel suppliers to increase the supply of compliant fuels.

All these actions would mitigate the impact of a global shortfall of compliant fuels.

Even though this report considers a global shortfall of the availability of marine fuels very unlikely, it expects regional shortfalls to occur, although they would be offset by surpluses in other regions. There are two ways in which this can be addressed:

.1 fuels can be transported from one region to another. Since an oversupply of fuel with a sulphur content of 0.50% or less is projected in Latin America, Europe and the Middle East and a shortfall in Africa, Asia and North America, fuel may be transported from any of the former regions to any of the latter regions in order to balance regional supply and demand. This is already standard practice and will not require a change in business practices; and

.2 ships can change their bunkering patterns. Regions that have an oversupply of compliant fuels will most likely have lower prices than regions that need to import fuels from elsewhere. As a result, interregional shipping will bunker to a greater extent in regions where there is an oversupply of fuel.

7 Fuel Availability Study Conclusions

The overall objective of the project has been to conduct an assessment of the availability of fuel oil with a sulphur content of 0.50% m/m or less by 2020. To that end, demand for marine fuels has been modelled and a thorough analysis conducted of the ability of the refinery industry to produce the required quantities of fuel while at the same time supplying refinery products to other sectors.

The total energy demand for maritime transport is projected to increase from 11.9 EJ (2012) to 11.4 to 14.6 EJ as a result of transport demand growth and changes in fleet composition and technical and operational efficiency. The base case projects energy demand to be 12.8 EJ in 2020.

Energy demand can be met by a mix of:

.1 petroleum fuels with a sulphur content of 0.10% m/m or less (in order to comply with emission control area requirements and in engines that use MGO);

.2 petroleum fuels with a sulphur content between 0.10% and 0.50% m/m;

.3 petroleum fuels with a sulphur content of over 0.50% m/m in combination with an EGCS; and

.4 LNG.

Other fuels are not projected to provide any significant share of the energy consumption of the marine sector.

The consumption of LNG, both in LNG carriers that use the boil-off cargo for propulsion and in ships with LNG engines, is projected to increase from 8 million tonnes in 2012 to 11 to 13 million tonnes in 2020.

EGCSs are projected to be installed on ships that collectively consume 14 to 38 million tonnes of HFO by 2020.

The study has developed three scenarios, a base case with moderate transport demand growth, fleet renewal, LNG and EGCS uptake, a high case with higher transport demand growth and fleet renewal and lower uptake of EGCSs and LNG, so that demand for compliant petroleum fuels is larger, and a low case which is the mirror image of the high case. Table 45 shows the fuel demand in each of these cases.

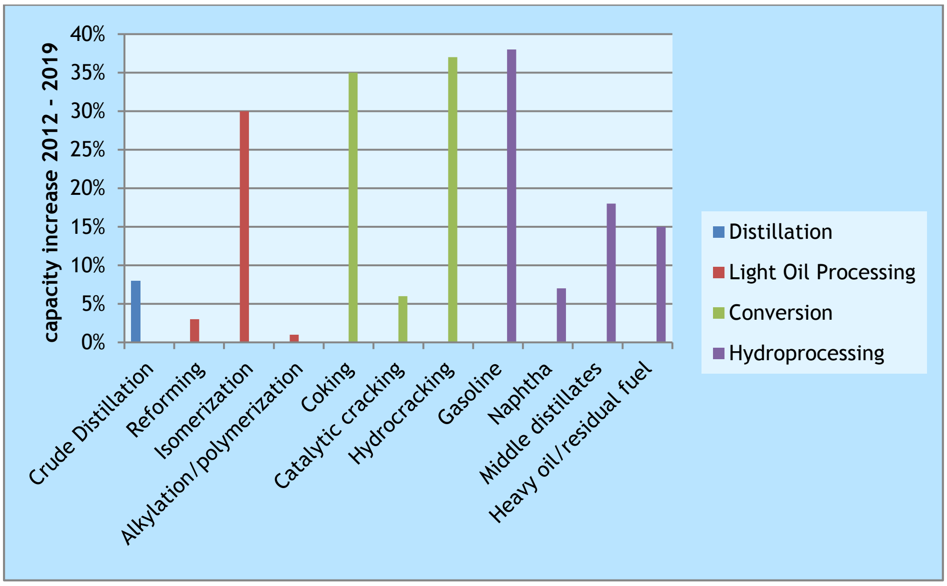
Table 45 - *Fuel demand projections in the base case, high case and low case*

Sulphur content (% m/m)	**Petroleum derived fuels**			**LNG**
	<0.10%	**0.10-0.50%**	**>0.50%**	
	Million tonnes per year			
Base case	39	233	36	12
High Case	48	290	14	12
Low Case	33	198	38	13

Non-marine petroleum demand will increase by 13% between 2012 and 2020 to 4,190 million tonnes per year.

Overall refinery capacity is projected to increase by 8% between 2012 and June 2019. Hydrocracking capacity will increase by 37%, middle-distillate hydroprocessing by 17% and HFO hydroprocessing by 15% (see Figure 5).

Figure 5 - *Refinery capacity increases 2012 - June 2019*



Source: Stratas Advisors, 2015-2016.

With projected refining capacity for June 2019 as an input, the refinery model was used to analyse whether sufficient amounts of compliant maritime fuels can be produced in 2020, while at the same time meeting demand for other products and not producing products for which there is insufficient demand. The model takes into account that the average sulphur content of crude oil will increase between 2012 and 2020 and that non-marine fuels will be subject to lower sulphur limits in many countries and territories.

In the base case, capacity utilization rates of Crude Distillation Units are close to 60% in all regions, while hydrocracking and hydroprocessing units have a higher utilization on average, although never higher than 83% and lower than the regional maximum observed in 2012.

The analysis demonstrates that in all cases, as well as in a number of sensitivity scenarios, the refinery sector can produce sufficient amounts of maritime fuels with a sulphur content of 0.50% m/m or less to meet demand, while at the same time producing fuels for other sectors of the required quality. The maximum amount of compliant fuels that the global refinery industry can produce is 24% above the demand projected in the base case and 2% above the demand projected in the high case.

The maritime fuels with a sulphur content between 0.10 and 0.50% m/m will typically be blends of residuals, hydrotreated residuals, heavy fractions from hydrocrackers and lighter hydrotreated fractions. The blend varies per region, depending on regional refinery capacity and crude inputs. The viscosity of the fuels ranges from 10 cSt to 180 cSt. The maritime fuels with a sulphur content of 0.10% m/m or less will be marine gasoil.

While globally, supply and demand are balanced, regional surpluses and shortages will occur. In most cases, the Middle East has an oversupply that can be transported to other regions to offset regional shortages. In some cases, other regions have a higher production than consumption as well.

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