MARINE ENVIRONMENT PROTECTION COMMITTEE
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Agenda item 4

MEPC 57/4
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REVIEW OF MARPOL ANNEX VI AND THE NOx TECHNICAL CODE

Report on the outcome of the Informal Cross Government/Industry Scientific Group of Experts established to evaluate the effects of the different fuel options proposed under the revision of MARPOL Annex VI

Note by the Secretariat

SUMMARY

Executive summary:	The Secretary-General, at the fifty-sixth session of the Marine Environment Protection Committee, proposed the setting up of an informal Cross Government/Industry Scientific Group of Experts to undertake a comprehensive study to evaluate the effects of the different fuel options proposed under the revision of MARPOL Annex VI and the NOx Technical Code. The annex to this document provides the main report of the informal Cross Government/Industry Scientific Group of Experts
Action to be taken:	Paragraph 6
Related documents:	MEPC 56/4/15, MEPC 56/23 and MEPC 57/INF.7

Introduction

1 The Committee will recall that the Secretary-General, at its fifty-sixth session, proposed the setting up of an informal Cross Government/Industry Scientific Group of Experts to undertake a comprehensive study to evaluate the effects of the different fuel options proposed under the revision of MARPOL Annex VI and the NOx Technical Code.

2 MEPC 56 endorsed the course of action proposed by the Secretary-General and approved a relaxed deadline for submission of the Scientific Group of Experts' report to both BLG 12 and MEPC 57. MEPC 56 agreed to include the revision of MARPOL Annex VI and the NOx Technical Code among the urgent matters emanating from BLG 12 to be considered by MEPC 57.

3 The informal Cross Government/Industry Scientific Group of Experts was established at a "kick-off" meeting held in IMO's temporary headquarters during MEPC 56 on 11 July 2007. The Group held three additional meetings and delivered its report, which is set out in the annex, by 18 December 2007. The Secretary-General attended all the meetings.

* This document has also been submitted to BLG 12 as document BLG 12/6/1.

Funding

4 The Secretary-General made available an initial contribution of US$20,000 from the balance of funds from the Onassis International Prize for the Environment awarded to the Organization in 1997. The Secretary-General called upon Members and organizations to contribute towards the funding and is grateful to those who responded positively to his request. The work was funded by voluntary contributions as follows:

Donors	**Pledged contribution**	**Invoice**	**Received remittances**
Japan	US$ 7,000	IMO/07/089	US$ 7,000.00 (6,987.46 + Bnk chrg 12.54)
Norway	NOK 55,000	IMO/07/090	US$ 10,077.64 (NOK 55,000)
Sweden	US$ 5,000	IMO/07/091	US$ 5,000.00 (4,987.63 + Bnk chrg 12.37)
United Kingdom	US$ 20,000	IMO/07/092	US$ 20,000.00 (£9,800)
INTERTANKO	USD 5,000	IMO/07/093	US$ 5,000.00
OCIMF	US$ 10,000	IMO/07/094	US$ 10,000.00
IPIECA	US$ 10,000	IMO/07/095	US$ 10,000.00
IMO Onassis Fund	US$ 20,000		US$ 20,000
Total	**≈US$ 85,000**		**US$ 86,982.73**

Costs

5 The main cost related to the study has been that incurred by purchasing and analysis of data. All costs related to the work of the Group can be found itemized in the table below. Unless the donors decide otherwise, the balance will be transferred back to the Onassis Fund and used for environmental work by the Organization in the future.

Consultant	**Task**	**Cost**
EnSys Energy & Systems, Inc.	Analysis of impacts on global refining and CO_2 emissions of potential regulatory scenarios for international marine bunker fuel	US$ 23,500
MSR-Consult ApS (Denmark)	Analysis and projection of ship data	US$ 4,000
Entec UK Limted	Preparation of data for EMEP model run	US$ 9,103.82 (£3,750+VAT)
Norwegian Meteorological Institute	Environmental impact runs with the EMEP Unified model and presentation of findings	US$ 5,763.69 (4,000 EUR)
Ms. Veronica Eyring	Presentation of study	US$ 1,264.85 (£641.40)
Entec UK Limited	Additional work on data for EMEP model run	US$ 2,000
EnSys Energy & Systems, Inc.	Final analysis of impacts on global refining and CO_2 emissions of potential regulatory scenarios for international marine bunker fuel	US$ 14,500
Total costs		**US$ 60,132.36**
Balance		**US$ 26,850.37**

Action requested of the Committee

6 The Committee is invited to consider the information provided in the attached report, together with the outcome of the consideration of the same report by BLG 12, when considering draft amendments to MARPOL Annex VI; and to take action as appropriate.

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ANNEX

REPORT ON THE OUTCOME OF THE COMPREHENSIVE STUDY UNDERTAKEN BY THE INFORMAL CROSS GOVERNMENT/INDUSTRY SCIENTIFIC GROUP OF EXPERTS ESTABLISHED TO EVALUATE THE EFFECTS OF THE DIFFERENT FUEL OPTIONS PROPOSED UNDER THE REVISION OF MARPOL ANNEX VI

Terms of Reference

1 The informal Cross Government/Industry Scientific Group of Experts was provided with the following Terms of Reference:

.1 The scope of the study is to review the impact on the environment, on human health and on the shipping and petroleum industries, of applying any of the options identified as possible amendments to MARPOL Annex VI to introduce measures aiming at reducing emissions from ships into the atmosphere.

.2 The study will be conducted by a group of selected members, nominated by Member Governments and industry organizations, with appropriate expertise on matters within the scope of the study, who, in the discharge of their duties, will serve the group in their personal capacity. Although the experts as members of the group will be expected to assist in its deliberations independent of the entities nominating them, they may draw on the expertise of others, as it may be necessary, to fulfil their task.

.3 While aiming at addressing issues as specified in paragraph 1, the study will specifically address the effects of the proposed fuel options to reduce sulphur-oxides (SOx) and particulate matter (PM) emissions generated by shipping, as well as the consequential impact such emission reductions may have on others (e.g., carbon-dioxide (CO_2)) resulting from changes in the refining industry that may be necessary to meet potential new MARPOL Annex VI requirements.

.4 The end result, aimed at assisting the MEPC to make well-informed decisions, should be an objective study containing facts and data and specifying the pros and cons of any proposed solution. Thus, the study, while refraining from making comments, which might jeopardize the impartial and objective character of the exercise, should not make recommendations on policy issues, leaving them to MEPC to make when weighing up the outcome of the study.

.5 Within the above remit, the Group should:

.1 ***assess***:

.1.1 the number of ships in the world fleet to which the amended MARPOL Annex VI will apply, distributed by gross tonnage, age, ship type and installed power;

.1.2 the total volume of bunkers being consumed by international shipping at present, showing the proportion of distillate and residual fuels;

.1.3 the predicted fuel and emission trends leading to 2020, based on current MARPOL Annex VI regulations;

.1.4 any other relevant trends in the global fuel markets and the world fleet leading up to 2020; and

.1.5 the incidence and trend of emission-reduction measures already adopted voluntarily by the shipping industry;

.2 ***evaluate***:

.2.1 the repercussions for the relevant industry sectors (shipping, petroleum, bunkering, engine and equipment manufacturers) resulting from the application of those options requiring the use of specific fuels, with a view to ascertaining the feasibility of these approaches in terms of global availability of the fuels in question;

.2.2 where applicable, the related future capacity for the production of marine engines and relevant abatement technologies;

.2.3 the implications arising from various proposed implementation dates (e.g., 2012, 2015, 2018, etc.), taking into account commercial considerations for different trades and segments of the shipping industry; and

.2.4 the relevant safety and operational aspects;

.3 ***assess***:

.3.1 the impact on human health and the environment associated with the scenarios identified in subparagraph .2, with regard to SOx and PM emissions from ships and consequential impact on other emissions, such as nitrogen-oxides (NOx); and

.3.2 the waste associated with production and operation of abatement technologies;

.4 ***assess*** the consequential impact on CO_2 emissions from ships and refineries taking into account the availability of CO_2 abatement, capture and storage technologies; and

.5 ***present*** its conclusions in a written report to BLG 12 and MEPC 57, to be submitted by mid-December 2007.

Method of work

2 The composition of the Scientific Group of Experts is set out as annex 1 to this report.

3 The six options for reduction of sulphur oxides and particulate matter emissions identified by BLG 11 are set out as annex 4 to this report.

4 At the kick-off meeting on 11 July 2007, the Group reviewed the Terms of Reference and four Subgroups were formed:

Shipping Subgroup	led by	Mr. Niels Bjørn Mortensen
Fuel Supply Subgroup	led by	Mr. Eddy Van Bouwel
Health and Environment Subgroup	led by	Ms. Gillian Reynolds
Modelling Subgroup	led by	Mr. Koichi Yoshida

5 The following meeting dates were agreed:

First meeting: from Wednesday, 26 – to and including – Friday, 28 September 2007 (3 working days).

Second meeting: from Monday, 5 – to and including – Friday, 9 November 2007 (5 working days).

Final meeting: from Monday, 3 – to and including – Friday 7 December 2007 (5 working days).

6 The Subgroups covered relevant parts of the ToR as follows:

ToR	**Responsible Subgroup***
5.1.1	Shipping Subgroup
5.1.2	Shipping Subgroup
5.1.3	Shipping Subgroup Modelling Subgroup
5.1.4	Fuel Supply Subgroup
5.1.5	Shipping Subgroup
5.2.1	Fuel Supply Subgroup Shipping Subgroup
5.2.2	Shipping Subgroup
5.2.3	Fuel Supply Subgroup Shipping Subgroup Modelling Subgroup
5.2.4	Shipping Subgroup
5.3.1	Health/Environment Subgroup Shipping Subgroup
5.3.2	Health/Environment Subgroup Shipping Subgroup
5.4	Fuel Supply Subgroup Shipping Subgroup

* where more than one Subgroup covered the same ToR, the first Subgroup mentioned was responsible for coordination between the involved Subgroups.

7 Members of the Group were assigned to the Subgroups and were encouraged by the Chairman to follow as many Subgroups as possible, the composition of the Subgroups is set out as annex 2.

8 The Subgroups were instructed to: develop the necessary assumptions; identify breaking points, key issues and any relationship between them, as well as knowledge gaps and plans to fill them; and develop a skeleton draft report.

9 The Subgroups exchanged information and data by e-mail and held telephone conferences between the meetings of the Group.

10 The methodology, scientific basis and associated assumptions developed by each subgroup are described in detail under the respective parts of the report.

Co-operation with international organizations

11 The Group requested the Secretariat to appeal to relevant intergovernmental and UN organizations to support the Group in its work and to designate a technical focal point to advise the Group on matters related to the mandate and provide input and comments on the data sources and methodologies being used, as well as on the Group's draft report, once it had been prepared.

Organization	Areas of interest
IEA	current and future energy consumption and refining capacity
WHO	human health impact of air pollution
WMO	air pollution dispersion modelling
UNEP	environmental impact of air pollution
UNCTAD	current and future trade patterns and growth in world trade and transport

Report of the Informal Cross Government/Industry Scientific Group of Experts

12 In addition to this document which contains the final report and the main findings agreed by the entire Group, an information document with the symbol BLG 12/INF.10 (MEPC 57/INF.6) is being submitted to supplement the information provided in the main report. BLG 12/INF.10 contains background data and discussions undertaken on the various items in the subgroups, but is not as such agreed by the entire Group. A report commissioned by the Group is also being submitted as BLG 12/INF 11 (MEPC 57/INF.7) (EnSys Energy & Systems, Inc: Analysis of impacts on global refining & CO_2 emissions of potential regulatory scenarios for international marine bunker fuel).

THE WORLD MERCHANT FLEET

Assessment of the number of ships in the world fleet to which the amended MARPOL Annex VI will apply, distributed by gross tonnage, age, ship type and installed power

13 The first item of the Terms of Reference (T.o.R.) for the Scientific Group of Experts was to assess the number of ships in the world fleet to which MARPOL Annex VI applies.

14 The base data for this assessment is derived from the Lloyds/Fairplay Database of the world's fleet of merchant ships as of 1 January 2007. MARPOL Annex VI applies to all ships and the number retrieved from the database is 100,473. Of these, 59,612 are above 400 GT and are, as such, required to demonstrate compliance with Annex VI. It should be noted that naval ships are not included in this study.

FUEL CONSUMPTION BY THE WORLD MERCHANT FLEET

Assessment of the total volume of bunkers being consumed by international shipping at present, showing the proportion of distillate and residual fuels

15 A model comprising a detailed breakdown into 70 categories of the ships over 400 GT was created in order to assess fuel oil consumption based on the installed horsepower; utilization factors for main engine; auxiliary engines and boilers; number of operation days; and specific fuel oil consumption.

Emissions in 2007 and 2020

16 Based on the total fuel consumptions calculated above, the various emissions are calculated and set out below:

Calculation assessment	Result 2007 Mill. Tonnes	Result 2020 Mill. Tonnes
Total Fuel Consumption by ships	369	486
HFO Consumption by ships	286	382
Marine Distillate consumption by ships	83	104
CO_2 emissions from ships	1,120	1,475
CO_2 emission reductions for a 0.5% S Marine Distillate global cap[1]	- 43	- 59
Total SOx Emission from Ships	16.2	22.7
SOx emission reduced by current SECAs	- 0.78	*
SOx emission reductions for a 0.5% S Marine Distillate global cap	- 12.7	- 17.8
SOx emission reductions in a multiple SECA environment with a 0.5% Marine Distillate SECA cap	*	-3.4
SOx emission reductions in a multiple SECA environment with a 0.1% Marine Distillate SECA cap	*	-3.7
NOx emissions from Ships	25.8	34.2
PM_{10} emissions from ships	1.8	2.4
PM_{10} emission reductions for a 0.5% S Marine Distillate global cap	- 1.5	- 2.0

* Not applicable.

1 **0.5% S MDO global cap is offered as an example of emission reduction to align with the EnSys model which is used elsewhere in this report.**

Total fuel consumption for the year 2007

Ships of 400 GT and above

17 Based upon the foregoing assumptions the sub-division assessment for the use of the two differing categories of fuel gives the following estimated total consumption:

Total Bunker Cons. (Mill. Tonnes)	**339**
Assessed HFO Cons. (Mill. Tonnes)	**286**
Assessed Marine Distillate Cons. (Mill. Tonnes)	**53**

Ships below 400 GT

18 The ships below 400 GT have been treated as one homogeneous group, which contribute with a total of 30 million tonnes. This consumption is considered to be 100% distillates,

All ships

19 Combining the results above produces a global merchant marine fuel oil consumption in the range of:

Total Bunker Cons. (Mill. Tonnes)	**369**
Assessed HFO Cons. (Mill. Tonnes)	**286**
Assessed Marine Distillate Cons. (Mill. Tonnes)	**83**

TRENDS IN THE WORLD FLEET

Assessment of any other relevant trends in the world fleet leading up to 2020

20 The model used for projecting the 2007 ship data was provided by MSR-Consult ApS (Denmark), using a different database than the one used above. With some adjustment, it was, however, possible to achieve compatibility between the two sets of data.

21 The projections of the long-term new-building and decommissioning requirements, up to and including 2020, cover: Fleet growth in number of ships; Fleet growth in GT; and Fleet growth in DWT.

22 The projection for 2020 considered two factors:

.1 the decommissioning and fleet replacement requirement i.e., the tonnage that replaces the ships reaching end life; and

.2 the fleet growth, i.e., the tonnage required to handle the forecast increase in seaborne trade.

23 The projections of future decommissioning activity, by ship type and size-range, were based on the age profile of the fleet-segment by year of build; life expectancy distribution; and average lifetime assumption.

24 It was assumed that the ships replacing the decommissioned ships have a higher productivity, i.e., higher performance in terms of tonne*miles per DWT per year, therefore the tonnage being decommissioned is presumed replaced by more efficient ships.

25 The model assumes a 15% efficiency improvement during the period from 2007 to 2020 for all ships irrespective of type, size and age.

Total fuel consumption by the year 2020

Ships of 400 GT and above

26 Based upon the foregoing assumptions, the forecast fuel demand in 2020 for ships of GT>400 is:

Total Bunker Cons. (Mill. Tonnes)	**446**
Assessed HFO Cons. (Mill. Tonnes)	**382**
Assessed Marine Distillate Cons. (Mill. Tonnes)	**64**

Ships below 400 GT

27 Finally, the consumption for the ships below 400 GT has been projected along the same trend line, and this gives a forecast of 40 million tonnes. This consumption is assumed to be 100% distillates.

All ships

28 Combining the results above produces a global merchant marine fuel oil consumption in the range of:

Total Bunker Cons. (Mill. Tonnes)	**486**
Assessed HFO Cons. (Mill. Tonnes)	**382**
Assessed Marine Distillate Cons. (Mill. Tonnes)	**104**

Modelling of area based standards

29 A model developed and provided by the National Maritime Research Institute of Japan was used to extract emission data related to option B1 and B2, which both proposes quite tight sulphur emission limits in coastal areas (x miles from shore/port areas and estuaries). If not stated otherwise, the model used the same data set and assumptions as described above.

30 The traffic density of each ship type and size as well as actual shipping routes were extracted from ship movement data provided by Lloyds Maritime Information Service (United Kingdom). Coastal sea areas applied in the model includes the current SECAs and is elsewhere defined to be within 100 nm from the west coast of North America and 50 nm from the coast in all other areas, including islands. The length of each voyage or route, and the part of it in either "coastal sea areas" or in "open-ocean" (i.e. other than the "coastal sea areas"), were calculated. Using this definition, an average of 60.2 % of the estimated shipping routes is within "coastal sea areas". This percentage can be used to estimate the consumption of the different fuels in question and/or the operating time of abatement equipment, for the options (B1 and B2) requiring lower SOx emissions in such "coastal sea areas".

31 On the condition that, within "coastal sea areas" low sulphur (0.5%) marine distillate fuel is used and marine residual fuel is used on the "open ocean", the following fuel consumption in 2020 was estimated:

Year 2020	HFO Mt ships >400GT	MDO Mt ships >400GT	Total Mt ships >400GT	MDO Mt ships<400GT	Grand total Mt
Baseline	382	64	446	40	486
Fuel switch from HFO to MDO in coastal sea areas	137	297	434	40	474
Increase	-245	233	-12	0	-12

32 If low sulphur (0.5%) fuel should be required within "coastal sea areas" ships engaged in some trades, such as in East and South-East Asia as shown in the figure below, will have to change fuel many times along the route. Frequent fuel switching is not desirable for operational reasons and is also challenging to enforce. To avoid frequent fuel switching, ships may use low sulphur fuel or operate abatement technology for the entire voyage.

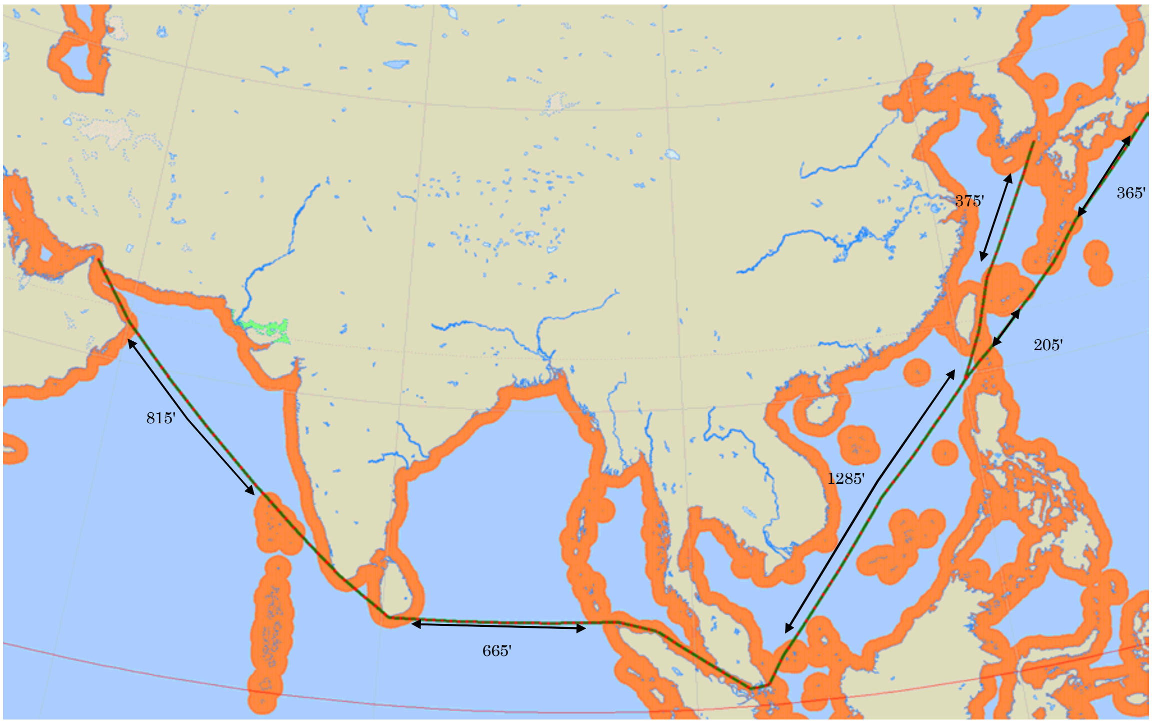


Figure – Voyage route of VLCCs between Far-East and Middle East
The sea area in orange colour shows the "coastal sea areas" (50 nm from the coast), all distances in nautical miles (nm)

33 CO_2 and SO_2 emissions were calculated based on the method specified in MEPC/Circ.471. Fuel consumption is based on the estimation given in the table in paragraph 28 above. In the calculation below, the net CO_2 emission due to acidic balance of sea water was taken into account. The table below shows the calculation results and indicates that fuel switch from HFO to marine distillate fuel in "coastal sea areas" will give extensive reduction of emission of CO_2 and SO_2, although total fuel switch will give an even greater reduction of emission of these gases.

	2020 Baseline	2020 Total switch from HFO to distillate	2020 Fuel switch from HFO to marine distillate fuel in coastal sea areas
Total fuel consumption by ships	486 Mt	467 Mt	474 Mt
HFO consumption by ships	382 Mt	0 Mt	137 Mt
Marine distillate fuel consumption by ships	104 Mt	467 Mt	337 Mt
CO_2 emission from ships	1475 Mt	1442 Mt	1453 Mt
CO_2 emission by acidic balance of sea water*	30 Mt	6 Mt	15 Mt
CO_2 emission reduction from the baseline	---	58 Mt	37 Mt
SO_2 emission from ships	21.6 Mt	4.7 Mt	10.8 Mt
SO_2 emission reduction from the baseline	---	16.9 Mt	10.8 Mt
SO_2 emission reduction from the baseline (%)		78.2	50.0

* Assuming that all the SO_2 is absorbed into sea water.

Figure – Estimated CO_2 and SO_2 emissions

TRENDS IN THE GLOBAL FUEL MARKETS LEADING UP TO 2020

Assessment of relevant trends in the global fuel markets leading up to 2020

34 Energy projections have been produced by several organizations and companies. The common themes emerging from these outlooks are that:

.1 global energy usage is forecast to grow until at least 2030, primarily driven by emerging economies (e.g., China and India);

.2 fossil fuels remain the largest energy source;

.3 power generation is the largest energy consuming sector;

.4 transport is the fastest-growing sector;

.5 demand for petroleum products is not expected to grow equally across all products;

.6 middle distillates are expected to show the highest growth rates; and

.7 total demand for heavy fuel oil (land based + marine) has been steadily declining and this trend is expected to continue.

Changes in the crude supply slate

35 Oil is currently providing about a third of the world's primary energy needs and the outlook is that this will still be the case in 2030. Current proven reserves should be sufficient to cover these needs. Amongst the reserves, there are more heavy crudes and crudes containing relatively high sulphur levels (so-called "sour crudes") than the mix of crudes that is produced today. An analysis by OPEC (OPEC, 2007), however, suggests that all crude types (light, medium and heavy) are expected to grow in the coming years with only small changes in their relative share.

36 The average crude sulphur content is expected to increase from the current 1.2% to almost 1.4% by 2020. As a result of changes in the crude supply slate, the price differential between sweet and sour crudes can be expected to increase, and refineries may invest in additional processing facilities to cope with heavier and higher sulphur crudes.

Demand for refinery products

37 Over the past 30 years, the demand for refinery products has grown at different rates across the range of fuel products. This is illustrated in the following figures, prepared by the International Energy Agency (IEA, 2007). Demand for LPG, gasoline, aviation fuels, middle distillates and other products have shown a steady growth, whilst the overall demand for heavy fuel oil declined from about 919 Mt in 1973 to 609 Mt in 2005. This represents a reduction of 1.85% per year over this period.

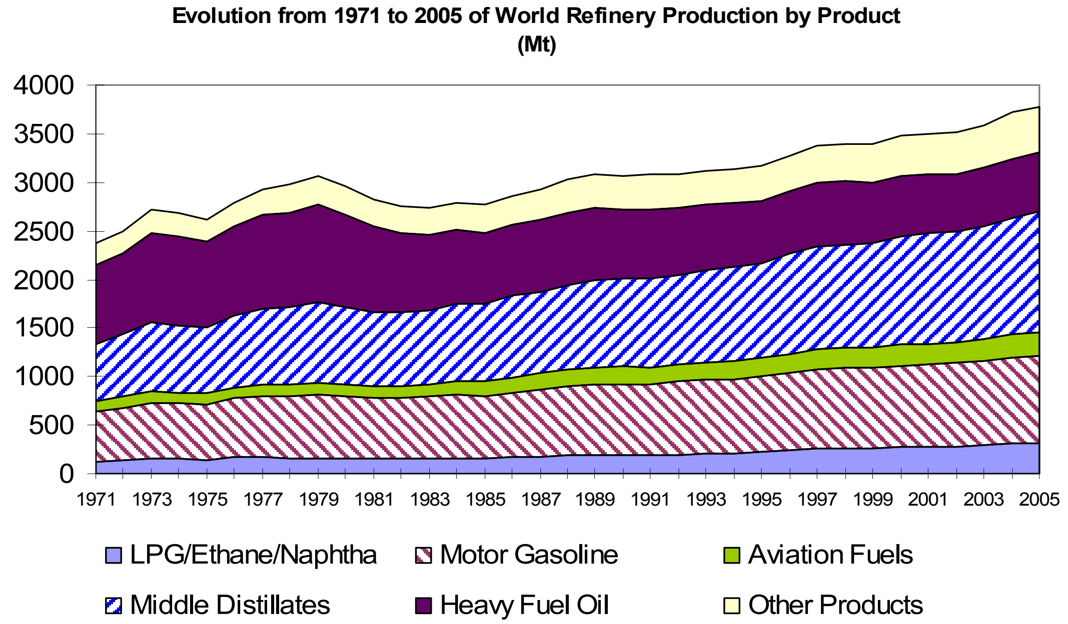


Figure – Evolution of refinery Products (IEA, 2007)

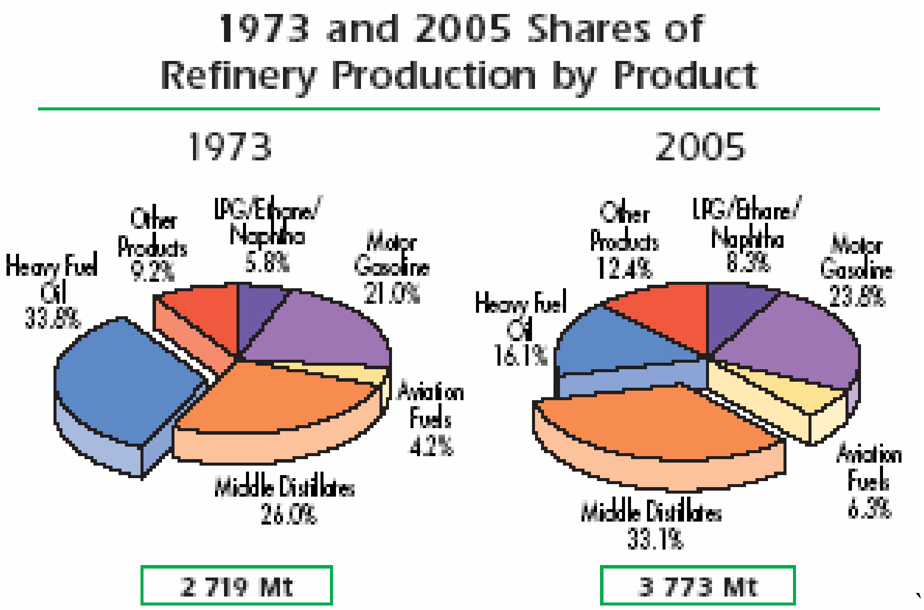


Figure – Evolution of refinery product slate (IEA, 2007)

Demand for middle distillate is growing

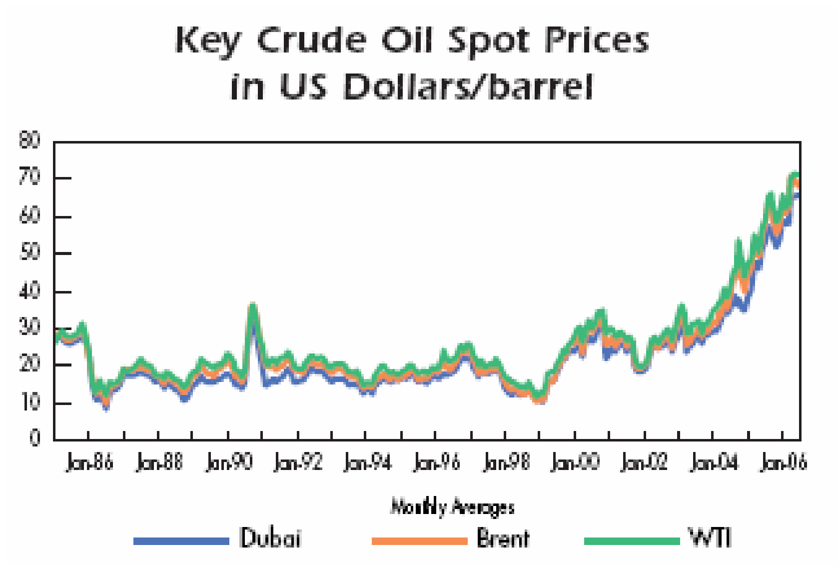
38 As can be seen from the figure above, heavy fuel output from the refining sector in 1973 represented 33.8% of the total product output. By 2005 the heavy fuel fraction was only 16.1% of refinery output. Demand for land based fuel applications has been declining, as e.g., power stations have switched to coal or gas for economic or environmental reasons. Over this period, the world refining capabilities have evolved gradually in response to market signals to include more capacity to crack heavy molecules and convert them into lighter, higher valued road transport fuels.

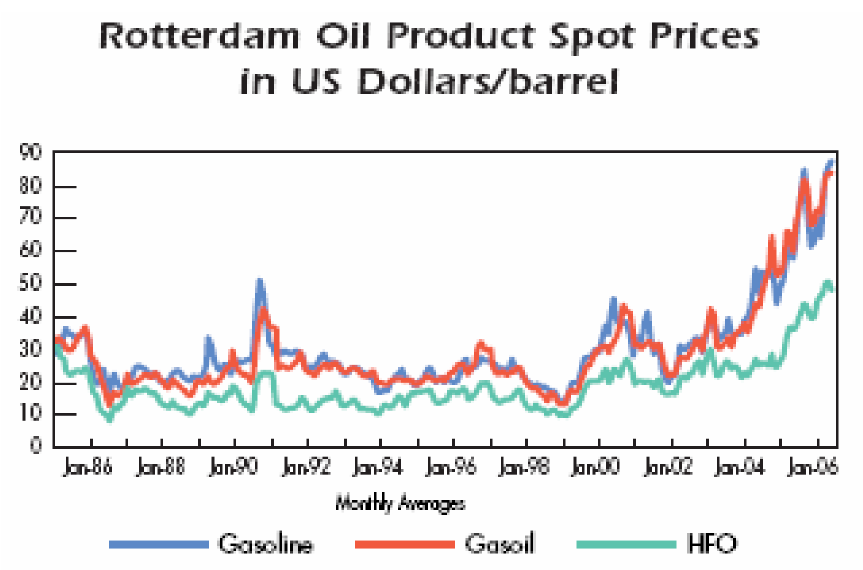
39 Demand for so-called middle distillate products has been growing faster than demand for most other petroleum products in the past decades. This is reflected in the figure above. By 2005, a third of the refinery product output was in the middle distillate range. The growth in middle distillates is driven by road transport growth and an increasing share of diesel passenger cars (in particular in Europe).

Significant increase in petroleum prices

40 Heavy fuel oil prices have increased significantly in recent years, following the crude oil price trend. Nevertheless, the heavy fuel price remains below the crude oil price (see figures below). This relatively low value of heavy fuel provides an incentive for upgrading the molecules to higher value fuel products.

Crude and fuel oil prices 1985 to 2007





Figures – Evolution of crude oil and petroleum product prices (IEA, 2007)

Refinery processes

41 Refineries are built to segregate crude oil into various fractions and to convert these fractions into specific fuels and other products that meet defined specifications.

42 Refinery products include:

.1 Transport fuels for cars (gasoline, LPG, diesel), trucks and locomotives (diesel), airplanes (kerosene), ships (marine gasoil and diesel, heavy fuel oil) and other forms of transport (non-road diesel).

.2 Combustion fuels for industrial generation of heat and power (gasoil, heavy fuel oil) and for home heating (gasoil).

.3 Raw materials for the petrochemical and chemical industries.

.4 Speciality products: lubricating oils, paraffins, white oils, waxes and bitumen.

Marine heavy fuel oil

43 The main component in marine heavy fuel oil is residual oil, which is a by-product of the refinery process ("the bottom of the barrel"). The residual oil used is the bottom fractions from the Atmospheric, Vacuum or Visbreaker units. Vacuum residue (the residue after vacuum distillation) is on a global basis the primary component in fuel oil. It is however blended with other refinery streams and used as fuel for land based industry (mainly power generation), as refinery fuel and as marine heavy fuel oil.

44 Different refinery processes are used to produce the desired range of products. The output of a specific refinery will depend on the nature of the crude oil that it processes and the configuration of processing units available at the refinery concerned. In addition, refineries can deliver "by-product" energy in the form of heat (steam) and/or power (electricity). For a given crude slate, refineries have some flexibility to adjust operations to meet the desired demand.

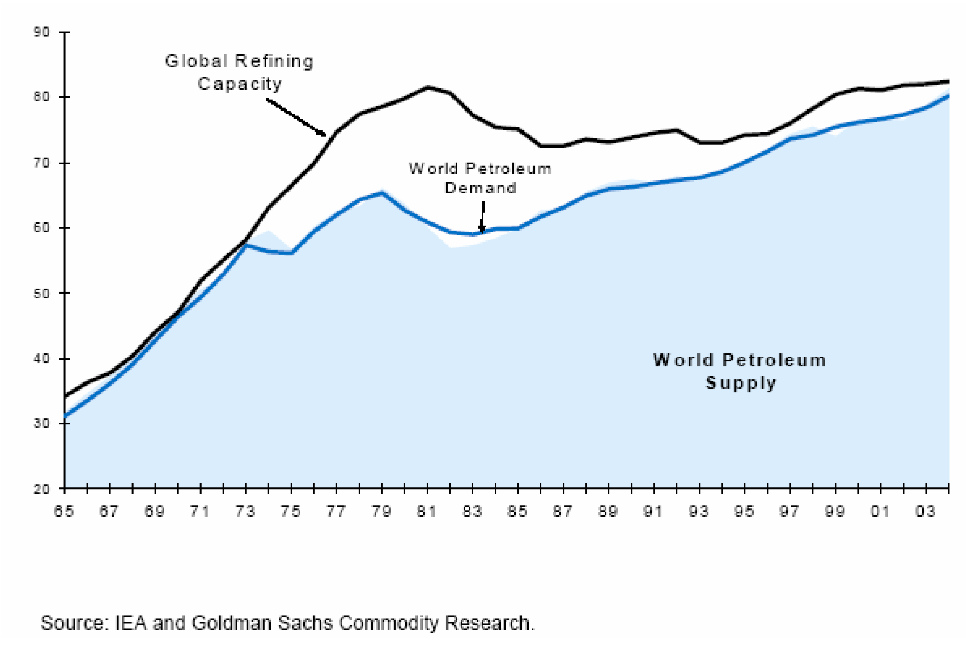


Figure – Refinery capacity evolution. Shown as crude distillation capacity in million barrels per day – 80 million bpd is equivalent to about 4000 million ton/y (reproduced from Mandil, 2005).

Increasing demand for lighter and cleaner products

45 The world oil products demand structure is changing with an expected continued move towards lighter products. At the same time, and driven by environmental concerns, product specifications are moving towards significantly cleaner products that will necessitate substantial reductions in sulphur content. To meet these challenges, the refineries will make significant investment to ensure that sufficient distillation capacity is in place, supported by adequate conversion and desulphurization units, as well as other secondary processes and facilities. Over the last 10 years there has been significant growth in refinery process units that can increase the yield of light products.

46 This is based on the increasing demand, particularly for low sulphur transport diesel and on the declining demand for heavy fuel oil (from refineries and land-based industry). The growth has been particularly high with respect to hydro-treating (removal of sulphur and impurities), hydro cracking (production of middle-distillates) and coking (to convert heavy residual oil to lighter products and coke). As both hydro-treating and hydro-cracking units require hydrogen, there has been a significant growth in hydrogen production units. The above trend is forecasted to continue into the future.

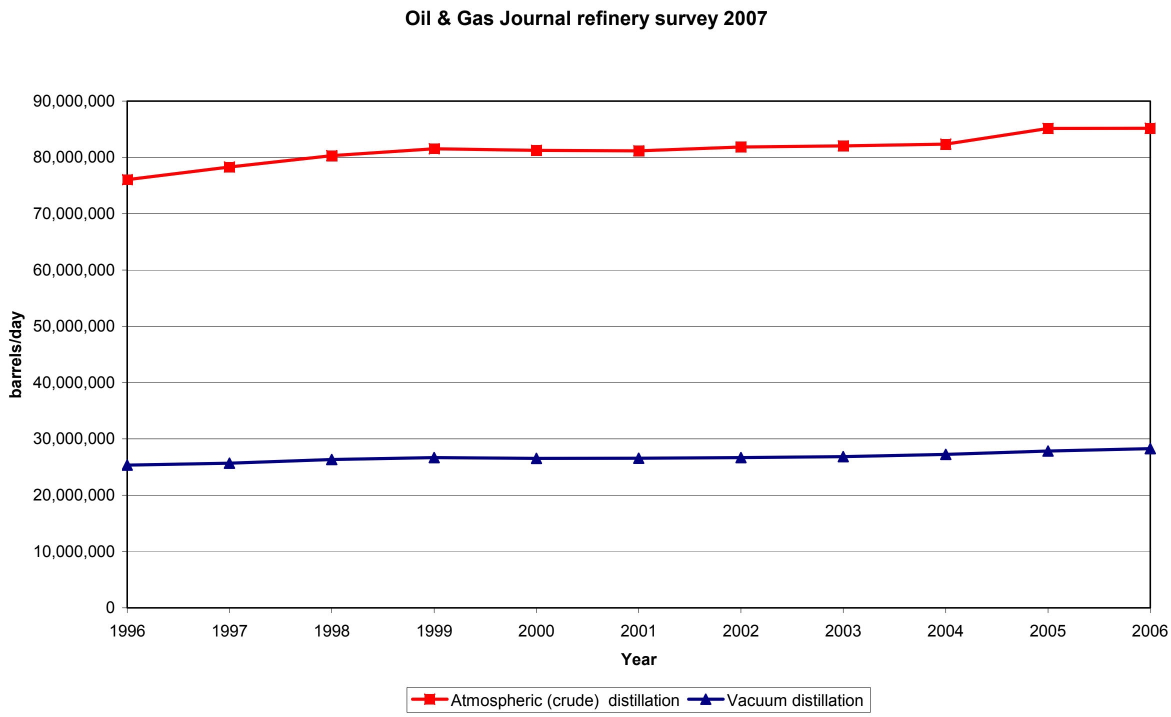
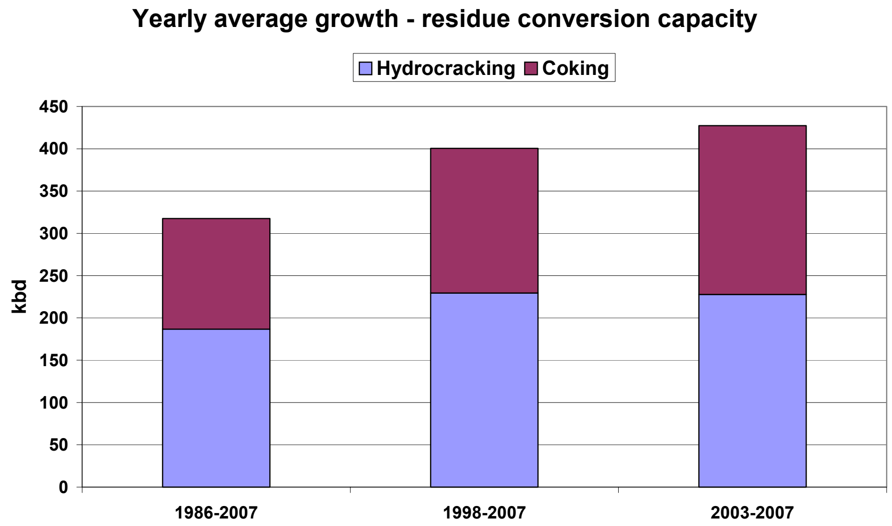


Figure – Developments in crude distillation capacity

Growth in residue conversion capacity

47 The figure below illustrates the rate at which conversion facilities have been added to refineries worldwide over the past 20 years (data source: Parpinelli Tecnon). In the 1980s and 1990s refiners have also invested in residue desulphurization facilities. However, Parpinelli Tecnon data shows that in the last 5 years some residue desulphurization capacity has been decommissioned, as additional residue conversion facilities were added.

Capacity growth



kbd	1986-2007	1998-2007	2003-2007
Hydrocracking	187	230	228
Coking	131	171	199

Mt/y	1986-2007	1998-2007	2003-2007
Hydrocracking	10.6	13.1	13.0
Coking	7.4	9.7	11.4

Conversion factor from kbd to Mt/y: *57*

Data source: Parpinelli Tecnon

Figure – Capacity growth in terms of refinery conversion units

Technology developments

48 The refinery industry invests in technology development and process optimisation. Catalyst development is a key focus area of research, e.g., for catalysts that are more resistant to poisoning by trace elements present in crude or catalysts that enable desired reactions to take place at lower temperature and/or pressure. Other research is directed to increasing processing flexibility and novel ways of integrating process units, optimizing energy consumption and optimizing the carbon and hydrogen balance in the refinery. Bottom-of-the-barrel processing is receiving significant attention, as more heavy products are converted to lighter fuel products to meet demand (see e.g., Zuideveld and Wolff, 2006). In case the regulation would mandate the use of marine distillate fuels globally, there will be an even higher incentive for new conversion technology development, including for the more difficult to crack residual streams. It needs to be kept in mind that conversion technology is complex, involving sometimes special construction materials, and major new technology options typically have a long lead-time.

49 There are several implemented and ongoing refinery energy efficiency projects that have reduced refinery fuel consumption and thus reduce emissions from these refineries. Energy saving potentials of 10-20% have been mentioned as realistic. New refineries and refineries that are planning substantial upgrades may have a higher potential (e.g., through investment in co-generation plants delivering steam and electrical power). As the global distillate case would require more substantial upgrades, more such energy efficiency opportunities may be captured.

Refinery CO_2 emissions

50 CO_2 releases from refineries are largely a function of refinery fuel consumption and the supporting processes such as hydrogen production. As per the IPCC Carbon Capture and Storage report (2005), the oil refineries emitted 798 million tons of CO_2 in 2002.

VOLUNTARILY ADOPTED EMISSION REDUCTION MEASURES

Assessment of the incidence and trend of emission-reduction measures already adopted voluntarily by the shipping industry

51 Ship designers and shipbuilders seek to optimize ships design and construction as this is an important competitive parameter. For shipowners it will always be an advantage to operate ships with lower fuel oil consumption than the ships of competitors. However, in the present market it is very difficult (i.e., expensive) to incorporate new fuel saving measures in the standard new-building designs.

52 Efficiency gains can be best captured with new-buildings where measures are incorporated into the design from the outset. There are, however, a number of relatively simple measures that many shipowners have adopted for existing ships. Below is a table listing some of the measures which can be utilized by new and/or existing ships.

Measure no.	Description	Existing ships gain %	Newbuildings gain %
1	Main Engine efficiency rating	2	
2	Main Engine optimisation		2
3	Waste Heat Recovery		5-10
4	Optimize hull shape, incl. reduced Cb*		3-10
5	Optimized propeller	2	3-6
6	Maintenance of wetted hull surface	2-5	2-5
7	Improved anti fouling paints	2-8	1-2
8	Twin skeg + twin propeller		5-8
9a	Trim optimisation – large Cb ships	1-2	1-2
9b	Trim optimisation – small Cb ships	Max 10	Max 10
10	Misc. Fuel saving devices	2-6	2-6

* Block coefficient.

53 It is difficult to estimate a total gain from the above listed measures, as not all of them are applicable in all cases. A 10% gain for existing ships and up to 30-40% or more for new-buildings should be achievable.

54 Besides the above listed "hardware" measures there exists a range of operational measures such as speed reduction, weather routeing, logistic improvements to avoid waiting for vacant berths, etc.

REPERCUSSIONS FOR THE SHIPPING INDUSTRY

Evaluation of the repercussions for the shipping industry resulting from the application of those options requiring the use of specific fuels, with a view to ascertaining the feasibility of these approaches

Introduction

55 This section compares, from the ship operators' perspective, the options to use marine distillate fuel only and the use of HFO together with abatement equipment. The use of abatement equipment is relevant for all proposed options except for the proposal to introduce distillate quality as a minimum fu el standard globally (Option C).

General comments

56 Marine distillate fuel is already in use in many ships and there are two scenarios under examination in this study where the more widespread use of distillate fuel is considered. One scenario is a proposed requirement for all ships to burn distillate fuel globally and another scenario is to require ships to burn distillate in specific emission control areas as a compliance option in parallel with an option to use some form of abatement control equipment.

57 It should be noted that the refiners now believe that 1% sulphur content is the realistic cut-off for low sulphur HFO. For any emission limit equivalent to the use of fuels with a sulphur content of less than 1%, the greater proportion of suitable fuel would be a marine distillate fuel, for ships not fitted with abatement equipment.

58 This section comments upon the practical issues for ships when considering using distillate globally compared to a situation where distillate is used for part or parts of the voyage and heavy fuel oil is used for the remainder (i.e., on the high seas). The issue of the supply and availability of distillate fuel for marine customers is addressed in the respective section of this report. In all scenarios the requirement for a greater supply of distillates is implicit. However, the total amount required depends on the region and scale to which the option refers. Bunker fuel prices will be subject to significant increases. The use of either LSFO or abatement technology will increase the costs of maritime transport. In some trades, such as short sea, this may create economic competition between maritime transportation and alternative transport systems.

59 Distillate fuel is a cleaner option in all aspects of shipboard life and there are advantages in terms of lower maintenance and hence work load on board ship. In the case of a new ship being ordered with an engine tuned for distillate throughout its life, the advantages are optimized.

Future cost of distillate

60 Bunker fuel prices will be subject to significant increases but a qualified estimate is not possible to provide. The price difference between HFO and distillate fuel has varied from 50% to 72% over the last 7 years, see figure below.

Year	Average price MDO (USD)	Average price HFO (USD)	Annual price increase/decrease MDO (USD)	Annual price increase/decrease HFO (USD)	HFO/MDO
2000	273	156			57%
2001	202	127	-26.1%	-18.3%	63%
2002	203	146	0.5%	14.8%	72%
2003	239	166	17.5%	13.9%	70%
2004	343	176	43.8%	5.8%	51%
2005	503	258	46.5%	46.4%	51%
2006	617	311	22.7%	20.7%	50%
2007	655	365	6.2%	17.2%	56%

Source: Bunkerworld (based on prices in Singapore and Fujairah)

61 The Ensys WORLD model runs performed for the Group calculates the refineries manufacturing/supply costs of marine fuels. The below table indicates the incremental increase above the 2020 base case for two of the specified options based on a crude oil price of US$48.

2020 Scenarios (Ensys WORLD model). Incremental cost vs. base case 2020

Options	**USD/bbl***	**USD/ton***	**Affected quantity (mill ton)**	**Increase vs. base case (mill USD/year)**
Option C	12.97	87	460	40,042
Option B2 (DMB)	2.54	17	460	7,842
Option B2 (DMA)	2.67	18	460	8,243

*Marine fuels global average cost

Note: In terms of option B and B1 the costs are not derived from the Ensys model.

62 A study by Concawe (report 2/06) indicates cost of different options covering a European Scenario for 2015 assuming a demand of 50 million MT. The resulting total manufacturing/supply cost per ton for different alternatives are given as follows:

Totals for 0.5% S for all fuels consumed in Europe:	65-95 USD/ton
Totals for 1.5% S for all fuels consumed in Europe:	30-45 USD/ton
Base case MARPOL Annex VI (North Sea & Baltic SECAs incl.)	0-15 USD/ton

All costs/premium above are based on a conversion factor Euro/USD=1.46.

Operation on Distillate Only (Option C)

63 Generally, the use of distillate fuel globally would have the following influences on ship design and operation:

- Mandatory application of a single marine distillate fuel minimum standard would produce the same conditions without any competitive advantage to any vessel with respect to bunker quality. Possibilities to circumvent the requirements are limited. Administrations and PSC would benefit from a single fuel specification with respect to enforcement.

- Combustion characteristics in engines could be improved and emission levels reduced. Engine design could be optimized with a view to emissions and efficiency.

- Workload on board could be reduced due to simplified operation. Human element as a source of failure could be reduced accordingly.

- The use of marine distillates as a single fuel standard may create economic competition between maritime transportation and alternative transport systems, e.g., short sea trades.

- There will be minimal production of sludge from fuel treatment and commensurate cost savings.

Existing engines

64 In the case of a change in fuel type for an existing ship currently using HFO, then certain factors need to be considered. In principle, all marine engines can burn distillate. However, they may need some adjustments, e.g., to the fuel system, and engine manufacturers should be consulted. This raises the potential problem that if the manufacturer is no longer trading, then advice and spare parts may not be available. Injection pumps are the most likely component to require replacement. Injection timing may need to be adjusted. Measures should be taken to avoid increased leakages in high pressure systems. The lower concentration of sulphur in marine distillate means that a different lube/cylinder oil may be needed.

Existing boilers

65 Existing boilers can use distillate fuels but only after certain safety and technical considerations have been taken into account.

On Distillates and HFO (Options B)

66 The proposed options B, B1 and B2 require fuels with different sulphur content in Designated Areas (DA) such as SECAs.

Fuel switching for SECA compliance

67 Ships already conduct fuel change-over between HSFO and LSFO on entry/exit to/from SECAs. This can be a time consuming procedure depending upon the fuel system lay-out, engine load and relative sulphur contents.

68 However, where ships are required to operate a part of the voyage on marine distillate and the remainder on HFO, the most significant operational challenge arises from the different temperature requirements. This can be overcome by automated fuel change-over systems.

69 The ship needs to be configured to bunker a significant quantity of a second fuel type. A third fuel will be required in the case that a particular State or region imposes ‘at berth’ requirements with an even lower sulphur specification. Additional bunker tanks and fuel systems need to be fitted and operated. Separate fuel systems ease the problem, but in every case a time allowance has to be made before the ship enters an emission control area.

70 The need to address the lube oil in use depends upon the length of time that the engine will be required to operate on low sulphur fuel, i.e., below 1%. Generally it appears that 72 hours is a cut-off time subject to advice from engine manufacturers.

71 In ships where engine rooms are periodically un-manned, the requirements for fuel change-over may incur extra workload for the engine room staff.

72 The routine switching between marine distillate and HFO has safety implications for existing boilers. The boiler combustion systems may require to be modified to prevent the risk of boiler furnace explosion in distillate operation.

73 Wherever distillates are used the amount of fuel-related sludge will be reduced and related costs will be saved, however this reduction is not as great as when distillates are used globally.

74 Where all ships must use marine distillates continuously, engine manufacturers will focus on optimizing engines specifically for this fuel. However, in this scenario where engines are required to also burn HFO, manufacturers are not expected to optimize performance for marine distillate fuels. This situation is more likely to stimulate technical development in abatement equipment related to HFO.

Use of abatement equipment for SECA compliance

75 This report only addresses the SOx abatement techniques. It has to be taken into account that with currently available technologies NOx and SOx abatement techniques may be mutually exclusive in a single ship. This particularly applies to SCR techniques where the required SCR inlet gas temperature is incompatible with that coming from the scrubbing equipment.

SOx abatement equipment

76 Evaluation of the future potential of SOx abatement equipment as a viable emission control option for the shipping industry is currently hampered by the lack of equipment in the market place and the consequent lack of operational experience and of data on capital and operating costs. A ship utilizing the full potential of abatement equipment could have lower SOx and PM emissions than a ship operating on 0.5% sulphur content fuel and this is material to the C2 option. The related disposal of components scrubbed from the exhaust gas including sulphur, metals, soot and oil have to be taken into account and are dealt with elsewhere in the report.

77 Two different options for cleaning of ship's exhaust gas have been developed and are currently undergoing further research and development including full scale trials:

> Seawater Scrubbing. The natural alkaline characteristic of seawater is used to neutralise the acidic exhaust gases through absorption and subsequent discharge back into the sea after extracting and storing the relevant sludge from scrubbing.
>
> Fresh Water Scrubbing. This variation on the basic principle requires the use of caustic soda (NaOH) to react with and absorb the sulphurous emission gases. The resulting sludge must be stored on board prior to ultimate discharge to a shore reception facility.

Technical considerations for the ship

78 As a basic principle, each engine (main and auxiliary) requires its own dedicated Exhaust Gas Cleaning System (EGCS) unit. Each scrubber is entirely independent in operation and requires its own dedicated control equipment; its operation is also independent of the engine itself. In the case of fresh water scrubbers, an on board storage tank is required for the sludge until the ship is able to discharge the residue ashore.

79 Challenges to Exhaust Gas Cleaning Systems:

- ECGS (scrubbers) require considerable quantities of water. Normally this is delivered high in the ship and it may have an impact on ship stability.
- The whole system including pipe work must be corrosion resistant, have low flow losses and be lightweight to ease installation.
- The pumps have an electrical power requirement that is around 1% of the engine power and it is likely that some redundancy will be required in a ship whose only means of SECA compliance is ECGS equipment.
- Sludge storage and disposal.
- Monitoring of gas and water discharge.
- Automation to avoid additional workload.
- Failure of the equipment could result in non-compliance and therefore redundancy needs to be considered.

New ships

80 In the case of new construction ships, design will be required to make the necessary provision for scrubbing equipment. There will be an imposition of space in the engine room and more significantly in, or close to, the funnel. This will be more challenging in smaller ships.

Existing ships

81 In the case of existing ships, there are considerable challenges. Each design of ship will present different retro-fit challenges and the greater the installed power then the larger will be the equipment. The problem of managing large quantities of washwater is more difficult in an existing ship. It is understood that where retrofitting is feasible the ship will be out of service for 3-7 days during installation and therefore linkage of any carriage option with a 5-yearly survey seems important.

General considerations

82 It needs to be stressed that currently there is very limited production and installation capacity and it is not possible to predict how long it would take to stimulate this capacity. Lack of experience makes it impossible to comment upon likely reliability of the scrubbing equipment but experience on board the two ships equipped with an EGCS unit has not revealed any specific reliability issues associated with these techniques.

83 In the near future, IMO is expected to adopt criteria for the discharge of washwater. Port States are permitted to set more stringent criteria for discharge into the waters of their ports. Some regions do not currently permit EGCS washwater discharges to sea. As a general principle, MARPOL normally states that where discharges are prohibited, shore reception facilities shall be provided. If the shore reception facility is unable to receive the volume of the discharge water, then the ship will be unable to operate its EGCS units.

84 Ships relying on abatement equipment for compliance with emission control regulations will be subject to recording requirements such as the SECA compliance plan and an EGCS-SOx record book or equivalent. In the case of operation in a SECA the IMO Guidelines require that records of equipment operation should also be linked to a navigational record such as GNSS.

85 The capital cost of purchasing and installing abatement equipment is likely to be in the region of US$4M to US$7M per ship (2007 prices) depending on the number of engines and installed power. Any operational cost will have to be taken into account, including the fuel cost of 1% of the engine power.

86 The study assumed that around 10% of ships would fit abatement equipment and that, therefore, some shipowners would choose to fit the equipment as an alternative to the use of distillate fuel as a largely commercial decision on compliance options.

REPERCUSSIONS FOR THE PETROLEUM INDUSTRY

Evaluation of the repercussions for the petroleum industry resulting from the application of those options requiring the use of specific fuels, with a view to ascertaining the feasibility of these approaches in terms of global availability of the fuels in question

Refinery Model

87 To assess the refinery impact of the different options under consideration for MARPOL Annex VI, the Group has engaged EnSys Energy & Systems, Inc. This US based consultancy operates a model (WORLD) of the global downstream and refining sector.

88 WORLD is a linear programming model that simulates the activities and economics of the world regional petroleum industry against short, medium or long term horizons. It models and captures the interactions between, e.g., crude and non-crude supply, refining operations, refining investment, transportation of crudes, products and intermediates, product blending/quality, product demand, market economics and pricing. The model includes a database representing over 180 world crude oils and holds detailed, tested, state-of-the-art representation of fifty-plus refinery processes.

89 It is important to acknowledge that the scope of the model is to optimise petroleum product supply and demand at the overall lowest refinery cost and it is not a model that forecasts supply, demand and price. The model does not optimise supply and investments reflecting the overall highest refinery revenue potential. Nor does the model take into account competition, potential excess capacity, refinery upgrade/construction time or e.g., marine fuel or distillate availability constraints or surplus.

90 The following limitations in the model runs/assumptions, that may have impact on the model results, have been identified:

.1 Allocation of Marine fuel oil demand to world regions:
The model allocates a certain marine fuel quantity to different geographical regions based on trade patterns, but does not take into account fuel blending and supply outside the refinery gate. One effect of this may be that fuel demand allocated to a refinery in one region may be higher than reality;

.2 Marine heavy fuel oil composition:
The global average calculated heavy fuel oil composition indicates that marine heavy fuel oil would be primarily made up of atmospheric residual oil in the 2020 scenario. Based on current make-up, it is considered more likely that it would be made up of more Vacuum residue;

.3 MDO demand assumptions:
When converting heavy fuel oil demand to distillates, the higher net specific energy (NSE) of distillates compared to heavy fuel oil is taken into account. However, the method applied by Ensys is not in accordance with the formula used in the marine bunker industry and gives a margin of error of 2-2.5%. The effect of this is to overstate distillate demand by a similar amount for the global distillate case;

.4 Global average sulphur level in marine heavy fuel oil:
An outcome of the model is that the global average sulphur level in marine fuels will exceed the IMO three year rolling global average of 2.7%. The 2020 calculated average was 3.2% in 2020 and it may therefore be expected that IMO would have reduced the global cap. There was insufficient time for further iterations of the model to reach the 2.7% S level and hence the base case cost, energy requirements and CO_2 emissions predicted for 2020 are lower than would have been the case if an average of 2.7% had been achieved. As a result the incremental cost and CO_2 emissions for the global distillate case are slightly overstated;

.5 Marine diesel oil composition:
The model has set forth requirements to marine diesel oil quality (DMB) that are more stringent than what is proposed as a part of the option C. Accordingly, the required refinery investments and emissions in case of a global change to distillates is higher than would be expected. This has been dealt with later in this overview;

.6 Technology developments and energy efficiency:
The model assumes that current (2007) best available technology is used for required new refinery process units, i.e., more attractive emerging technology, as well as technology with higher energy efficiency will not be taken into account;

.7 Low sulphur fuel oil demand:
The low sulphur demand in existing and new SECA's and/or designated areas as per options B, B1 and B2, is set to approx. 15% of the total global marine bunker demand. This may appear somewhat low when considering the extent of some of the areas in question; and

.8 Additional crude and natural gas:
The model only considers energy and CO_2 emissions from refineries. Energy and CO_2 emissions associated with additional crude and natural gas that may be required is not included in the calculations.

Results of model work - refining impact of the different options

91 As a reference for evaluating the impact of changes to the Annex VI regulations, EnSys has developed a 2020 base case, based on a 2020 fuel product demand outlook developed by the International Energy Agency. The residual fuel outlook has been adjusted to reflect the demand for marine fuels developed in the current IMO study. These demand numbers are shown in the table below, and compared with estimated demand for 2007. The projected 2020 demand outlook in this table reflects the base case demand outlook for marine fuels under the current Annex VI regulation, including the 2 existing SECAs (Baltic and North Sea).

million ton/year	2007 estimate	2020 base case
Ethane	31	42
LPG	226	269
Naphtha	204	277
Gasoline	945	1087
Kero/jet	317	384
Gasoil/diesel land	1147	1411
Residual inland	380	272
Other	307	273
Marine Fuels:		
Distillate	83	104
Residual bunkers	286	381
Total	3926	4500

92 It should be noted that the 2020 base case includes expanded refining capacity that will need to come on line to meet significant increases in demand for lighter fuels in the land side market as well as growing demand for marine fuels. For example, demand for lighter fuels is expected to increase significantly in Asia and Latin America. EnSys has estimated that a total refining investment of $318 billion will be required to meet existing and forecasted demands – independent of those demands created by any future regulations adopted by the IMO. This includes a number of projects already underway or announced (shown as "projects underway" in the table below).

Million ton/year (except when otherwise specified) *	4Q2006 installed capacities	Projects underway	Total base capacities	Additional capacities required to meet 2020 base case demand
Atmospheric Distillation Unit	4232	303	4535	486
Vacuum Distillation Unit	1475	118	1593	90
Hydrocracker	241	83	323	140
Coker	227	52	279	18
Hydrogen plant (Mbfoed)			-	0.93

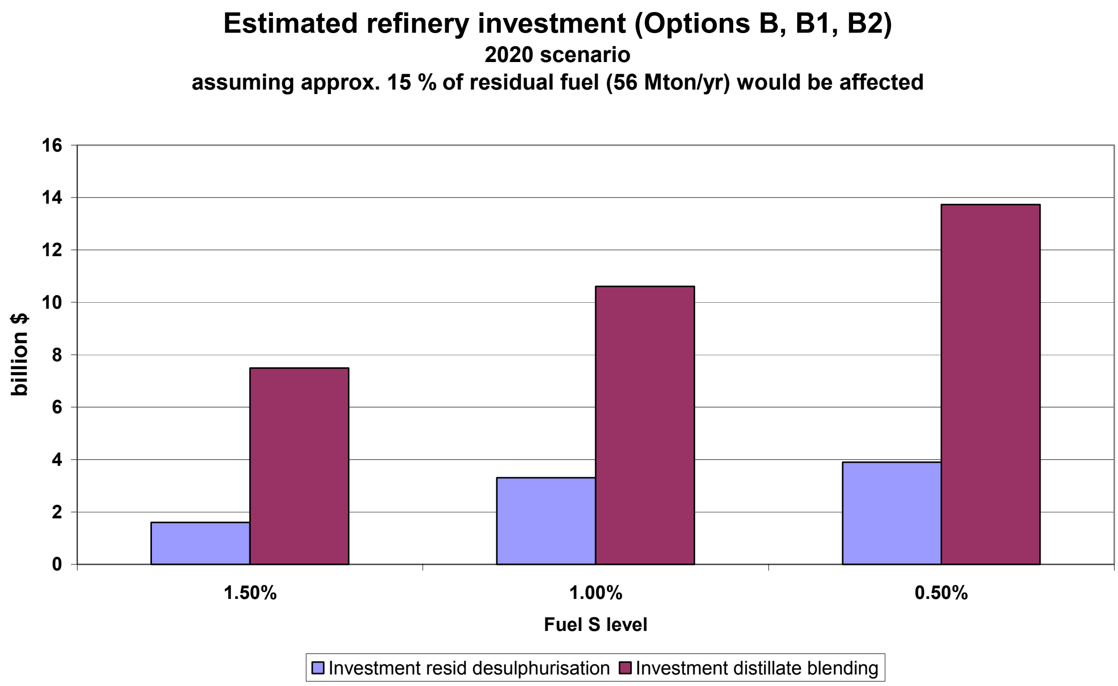
** Approximate values - all numbers converted from Mbpcd to Mt/y with factor 49.8*

93 The 2020 base case capacities represent the optimal model solution to meet the projected demand. As marine fuel bunker demand is projected to increase faster than the decline in the inland fuel oil demand, an increase in the total residual fuel oil demand is projected, which is different from trends in recent years. As a result, the additional capacities required for the 2020 base case show a relatively small addition of vacuum distillation compared to atmospheric distillation additions. Actual project decisions taken by refiners are likely to include more vacuum distillation than strictly needed to meet the 2020 demand. This would increase the cost of the base case for 2020, and may lead to some market distortions.

Geographically diversified options (options B, B1 and B2)

94 The volume of fuel that would be affected by any of these options depends upon which sea areas would be established as SECAs or otherwise designated areas. Initiatives to establish such areas rest with the IMO Member States. For a previous study EnSys executed for API, a rough estimate of how much fuel could be affected by the establishment of additional SECAs was developed, by considering fractions of fuel demand that could be affected in major fuel markets. Based on this exercise, a value of 15% of the total marine residual fuel demand was retained as a reasonable volume to estimate effects of potential marine fuel measures under options B, B1 and B2.

95 In the work for API, EnSys has assessed cost for providing low S fuels for the 15% of the residual fuel volume (1 million bpd or approx. 56.5 Mt/y) at 1.5%, 1% and 0.5% S in a 2012 demand scenario.



96 Again, these are results from an optimized model that will determine processing required to meet exactly what has been demanded. In these cases, a demand for low S residual fuel is imposed, and the model will indicate this can be done by installation of residual desulphurization capacity (left hand bars in the figure above). A study by CONCAWE (CONCAWE, 2006) has demonstrated that residual desulphurization is not an economically attractive residue upgrading option for a refinery, compared to upgrading through conversion to lighter transport fuels. This means that in practice, a significant volume of the low S fuel would need to be provided by blending of lower S distillate fuels, which would add significantly to the cost. A very rough

estimate of refinery investment that would be necessary to have sufficient low S distillate available to blend with HFO to meet the SECA specification has been developed. This required investment has been scaled down from the 0.1% S case discussed further in this report. It should be noted that there may be quality issues related to blending that would need to be overcome. Nevertheless, this very simple calculation provides some insight in what would be an approximate level of investment that would be needed to provide about 56 million tonnes of low S fuel at different S levels (right hand bars in the figure above).

97 For the case of imposing a 0.1% S limit in designated areas (option B1), a detailed model run has been made by EnSys using the IMO marine fuel demand forecasts. In this case, the low S fuel is specified as a distillate fuel. The volume of fuel affected was estimated to be slightly higher than in the API cases. Because of the low S limit, marine distillate fuel would need further desulphurization, while also fuel for the current SECAs was included (77 million tonnes of residual fuel, 11 million tonnes of marine distillate). Two separate runs were made using DMB and DMA as specification respectively. The table below shows the additional capacities for the DMB case, compared with the IMO 2020 bases case.

Multi-SECA (DMB-0.1%) (Option B1)

		Additional capacities		
Million ton/year (except when otherwise specified)*	Total base capacities	to meet 2020 base case demand	for Multi-SECA (DMB-0.1%) case	Delta
Atmospheric Distillation Unit	4535	486	499	13
Vacuum Distillation Unit	1593	90	125	36
Hydrocracker	323	140	207	66
Coker	279	18	38	20
Hydrogen plant (Mbfoed)	-	0.93	1.08	0.15

** Approximate values - all numbers converted from Mbpcd to Mt/y with factor 49.8*

98 The table below translates the required conversion capacities into an approximate number of units that would need to be built.

Process unit	Typical unit size	Additional capacity for 2020 base case	Additional number of units for 2020 base case	Additional capacity for 2020 Multi-SECA (DMB 0.1%)	Additional number of units for 2020 Multi-SECA (DMB 0.1%)	Delta number of units global dist. versus base case
Atmospheric Distillation Unit	95	9760	103	10030	106	3
Vacuum Distillation Unit	47.5	1800	38	2520	53	15
Hydrocracker	45	2820	63	4150	92	29
Coker	45	360	8	770	17	9

All capacities in thousnads of barrel per calendar day (kbpcd)

Additional investment required for this case compared to the base case amounts to US$ 28.6 billion.

Lowering the global marine fuel S cap

99 Option B2 includes a reduction of the global S cap in combination with a reduction of the S level in designated areas (SECAs). While a case combining these two measures has not been studied, EnSys evaluated the cost of a reduction of the global fuel S cap in a 2012 demand scenario in their work for API. Results are shown in the figure below (left hand bars).

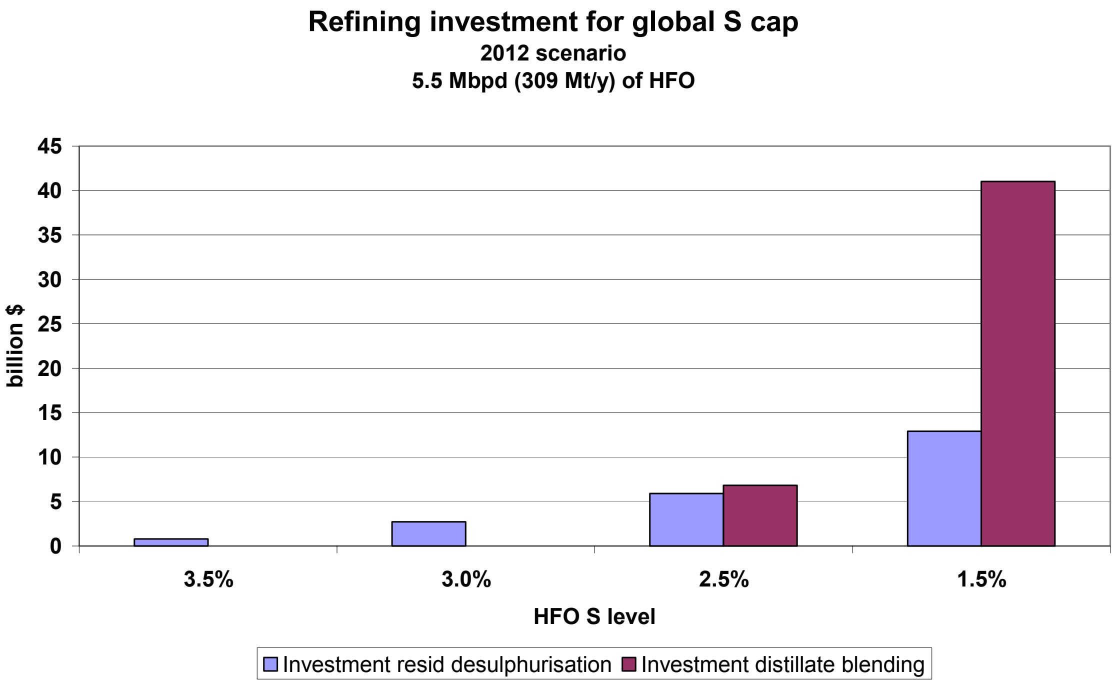


Figure – Refining investments required as a function of global S cap

100 The same observation applies that was made for the API study results for 1.5%, 1% and 0.5% S – the results reflect an optimized case with processing required to meet exactly what has been demanded. The model indicates that installation of residual desulphurisation units would be needed. As established in the CONCAWE report, residue desulphurization is not considered to be a realistic upgrading route. Therefore in practice, an increasingly significant volume of the residual fuel would need to be blended with lower S distillate fuels, which would add significantly to the cost. In a similar way as for the SECA S level case, a rough estimate has been made of the investment that would be required to achieve the desired global S level through distillate blending (right hand bars in the figure above). The amount of distillate required for the 1.5% S case would be about three times the volume of distillate considered under the 0.1% S case. The result of this calculation therefore understates the cost, due to the non-linearity of cost when higher volumes are involved.

Global distillate case – 2020 (option C)

101 The EnSys model has been used to evaluate the impact of a global switch to distillate fuel using the IMO fuel demand forecast. In this case, the model takes the actual residual fraction of the marine residual fuel and identifies the optimum way (i.e., the lowest cost to the refining industry) to upgrade these residual streams. A combination of hydro-cracking facilities to upgrade medium sulphur residual streams and vacuum gasoils and coking facilities to treat the most resilient vacuum residue streams will be required to produce the necessary volume of distillate fuel.

102 The marine distillate is assumed to be DMB. In the model run, the carbon residue content (MCR) was limited at 0.05%, which is well below the ISO 8217 specification. This was done to simulate current industry average DMB quality ex refinery, allowing a safe margin for contamination in the logistics chain. For the global distillate case, this safety margin may no longer be necessary. A more relaxed MCR specification would allow use more vacuum gasoil in the DMB, resulting in a lower cost versus the EnSys model run. A manual correction has been made to estimate this effect, using information from EnSys' earlier work for API. The table below reflects this corrected data.

103 The table provides an overview of the capacities for the different refinery processes that would be required over and above the total base capacities in comparison with capacities required for the IMO 2020 base case. The difference between the Global Distillate column and the IMO base case column represents the additional facilities required for delivering all marine fuel as DMB with a 0.5% S level. This difference is shown in the last "Delta" column. From this table it can be seen that the global distillate case would require very significant additional unit capacities over and above the already significant investment required for the IMO base case. Additional investment required is estimated at US$ 126 billion, which comes in addition to the US$ 318 billion required to meet the 2020 bases case demand. This number is believed to be more accurate than the EnSys estimate of US$ 147 billion with the tighter DMB specification.

Global distillates (Option C)

Million ton/year (except when otherwise specified) *	Total base capacities	Additional capacities to meet 2020 base case demand	Additional capacities for IMO Global Distillate case	Delta
Atmospheric Distillation Unit	4535	486	540	54
Vacuum Distillation Unit	1593	90	340	250
Hydrocracker	323	140	354	214
Coker	279	18	60	42
Hydrogen plant (Mbfoed)	-	0.93	1.44	0.51

** Approximate values - all numbers converted from Mbpcd to Mt/y with factor 49.8*

104 The table below translates the required conversion capacities into an approximate number of units that would need to be built.

Process unit	Typical unit size	Additional capacity for 2020 base case	Additional number of units for 2020 base case	Additional capacity for 2020 global distillate	Additional number of units for 2020 global distillate	Delta number of units global dist. versus base case
Atmospheric Distillation Unit	95	9760	103	10843	114	11
Vacuum Distillation Unit	47.5	1800	38	6827	144	106
Hydrocracker	45	2820	63	7108	158	95
Coker	45	360	8	1205	27	19

All capacities in thousands of barrel per calendar day (kbpcd)

Energy efficiency and refinery CO_2 emissions

105 A brief survey of some upgrading projects indicate that they are often accompanied by significant energy efficiency gains. Further, in the CONCAWE report it is specified that on average energy efficiency gains of 0.5% per year have been achieved. In other parts of this report, the potential is set considerably higher. However, the model does not take into account any such energy efficiency measures. As the energy efficiency potential tends to increase with the installation of more complex units, it is anticipated that this will have direct impact on the refinery fuel consumption and therefore the emissions, but it is not obvious if and how these reductions can be directly linked to changes in marine fuel requirements.

106 The table below shows the estimated CO_2 emissions from the global refining industry in the 2020 demand scenario, for the different cases considered in the current study. The refinery CO_2 emissions include emissions from refinery fuel combustion as well as emissions from process units, most specifically the hydrogen production unit. Refinery fuel-related CO_2 emissions are the largest contributor (80 to 90% of total).

million ton/yr	IMO Base Case	Multi-SECA case DMB	Multi-SECA case DMA	Global Distillate case DMB
Total refinery CO2 emissions	1115	1141	1143	1208
Incremental CO2 emissions versus base case		26	28	93

Other studies

107 A number of other studies have been completed by different organizations for different regions of the world (CONCAWE – Europe, ECN – Netherlands, JPEC – Japan). While the Group did not review these studies in detail, these studies also conclude that the global switch to distillate fuel would require significant refinery investments and would increase refinery CO_2 emissions.

REPERCUSSIONS FOR ENGINE AND EQUIPMENT MANUFACTURERS

Evaluation of the repercussions for engine and equipment manufacturers resulting from the application of those options requiring the use of specific fuels, with a view to ascertaining the feasibility of these approaches

108 Marine diesel engines have been optimized to fulfil the following primary requirements:

.1 "maximum reliability": safety on board may depend on the availability of the engines;

.2 "minimum fuel consumption": fuel costs for many vessels represent about 60% of the total operating costs;

.3 "flexibility in fuels": to allow operation with the low cost HFO (for larger engines, i.e., low-speed and medium-speed engines); and

.4 "significant reduction of NOx emission": to meet IMO Tier 1 requirements.

109 Fuel economics have dictated that optimum engine performance be achieved with HFO operation; however, operation with distillate fuels, as standardized in ISO 8217, should be possible. However, ISO 8217 does not completely capture all the fuel properties which influence ignition, combustion, corrosion, abrasion, and compatibility with other fuels etc. But, in the past, "distillate fuels" according to ISO 8217 resulting from straight run refinery processes, i.e., distillation without visbreaker, catalytic cracking, etc., did not present any significant technical difficulties. Therefore, if in the future very-low-sulphur distillates must be used in designated areas and refinery HFO blend streams from vacuum distillation, cat crackers, etc., which today form major components of the HFO blend, are to be converted to light products, the possible properties of such "distillates" must be considered.

PRODUCTION CAPACITY FOR MARINE ENGINES

Evaluation, where applicable, of the related future capacity for the production of marine engines and relevant abatement technologies

110 One of the expected bottlenecks in the future shipbuilding capacity is the engine manufacturers' ability to keep up with the pace of shipbuilders.

111 Based on information from a major engine producer, the prediction in two-stroke engine demand will continuously increase up till 2009, where it will peak at 30 Giga Watt per year. From 2010 the demand is expected to decrease and level out to around 20 GW annually until 2014.

IMPLEMENTATION DATES

Evaluation of the implications arising from various proposed implementation dates (e.g., 2012, 2015, 2018, etc.), taking into account commercial considerations for different trades and segments of the shipping industry

112 To comment on fuel availability as a function of implementation dates, an appreciation is needed of timing required for implementation of refinery projects, as well as the capacity of the engineering and construction industry to deliver such projects.

113 Two types of refinery investments can be distinguished:

.1 Minor unit adjustments and logistics investments:
These are investments to make relatively small changes to processing units and/or changes to blending and storage facilities. Scope of these projects will typically be of the order of a few million $ or less. When they can be executed without requiring a full refinery shutdown, individual projects may be completed within a 2-3-year time frame. To allow for orderly planning, appropriation of funds, and scheduling within each refinery organization, a lead time of 4 years between decision as to the measures and implementation date of the measures would be reasonable; and

.2 Major revamp or addition of units:
This concerns the addition of major facilities, e.g., the construction of a residue desulphurization unit or a coking unit. Scope of investment is typically several hundred million $ to over 1 billion $. These projects necessitate a complete

rebalancing of refinery streams and process units and, therefore, require revamp work to many of the existing refinery units. Execution of such projects typically requires the shutdown of the refinery for several months. Implementation of a single project typically takes 4-5 years, to allow for planning, appropriation of funds, etc. In the situation where multiple projects are required, capacity of the engineering and construction industry also needs to be considered and the time line will stretch.

114 Refinery projects that require a full or partial refinery shutdown need to take account of the refinery's so-called turnaround schedule. Refinery units are typically designed to operate continuously for several years. Their shutdown and startup takes several days, and is costly in terms of energy requirements and off-spec material produced while the units are being lined out. Modern integrated refineries can be operated for 5 years or more between shutdowns for major maintenance, the so-called turnarounds. Some smaller projects can only be executed during such turnaround, and major projects almost always need to be combined with a refinery shutdown. This puts further constraints on the time required to implement major refinery projects.

Current project load and resource constraints

115 Current project activity in the refining and chemical process industry is significantly higher than the average activity in the past two decades. Engineering and construction resources are strained, following a rapid rise in capital spending in the past 3 years. This is reflected in rapidly rising cost of construction projects and schedule delays due to shortages in certain high alloy steels, and selected equipment items, especially large vessels and heavy-wall reactors. The US based consultancy Independent Project Analysis estimates project cost increases from 2002 to 2007 between 71 and 100% (Merrow, 2007). Based upon these considerations, care should taken when making assumptions about a potential acceleration of project implementation.

Major refinery project capacity

116 Coking, hydrocracking and residue desulphurization are the highest cost units that would be required in the scenarios considered. All of these units include heavy wall, high temperature and/or high pressure vessels that can be supplied by a limited number of engineering manufacturers around the globe. Refinery projects involving these units are estimated at upwards of US$ 300 million each, and, when combined with other refinery upgrades, can be mega-projects of US$ 1 billion or more.

117 To address required lead time for refinery modifications, recognizing the extent and scope of investments identified above, it can be reasonably expected that additions of significant refining capacity will represent a large logistical challenge. This challenge is greater in some areas of the world since the presence of advanced refining capacity is not evenly distributed across the globe.

118 The global distillate option represents a predictable and defined demand profile, but the ability of the construction industry to respond to such a significant demand for new hydrocracking and coking units is subject to a variety of uncertainties. If current building rates represent maximum capacity in the refining construction sector, clearly a significant problem would exist for meeting such demand. By contrast, there is a business opportunity in this scenario that could result in a level of investment and expansion that would depart dramatically from existing capacity in the industry.

119 For the various SECA-based options, the aggregate volume of fuels required is substantially less than those required in the global distillate case. Nonetheless, the volume of fuels needed is subject to what SECAs are in fact designated and what penetration rates may materialize with respect to exhaust gas cleaning applications.

120 To make an assessment of realistic implementation dates for a global distillate standard would require an in-depth study of engineering and construction capacity. With respect to the SECA-based options, one would need to evaluate multiple scenarios where different assumptions are made about the number and extent of SECAs adopted in a given time frame. Such an analysis was not feasible in the time frame available for the present study.

Fuel demand

121 The table below shows the fuel demand in million tonnes based on linear interpolation between 2007 and 2020 figures for the Base Case considered by the Study (no changes in IMO rules until 2020).

Year	2007	2012	2015	2018	2020
Total Fuel	369	414	441	468	486
HFO	286	323	345	367	382
MDO	83	91	96	101	104

IMPACT ON HUMAN HEALTH AND THE ENVIRONMENT

Assessment of the impact on human health and the environment associated with the application of the six identified options for reduction of SOx and PM emissions from ships and consequential impact on other emissions, such as nitrogen-oxides (NOx)

Introduction

122 Marine diesel engines, especially those used on ocean-going vessels, contribute to ambient particulate matter (PM) and sulphur oxides (SO_x) exposure, particularly in ports and along coastal areas where population concentrations are high. This is due primarily to the use of heavy fuel in these engines, which contain organic compounds, metals, and has a sulphur content up to 45,000 ppm (4.5%). The contribution of ocean-going vessels to ambient levels of these emissions will increase as the international transportation sector continues to grow.

Health and environmental effects

Particulate Matter

123 Airborne particles are the main component of haze, smoke, and airborne dust, and present serious air quality problems throughout the world. Particulate matter (PM) is produced by many forms of combustion including the use of both residual fuels and distillates as marine bunkers. In scientific studies from many regions of the world, PM has been linked to a range of serious respiratory and cardiovascular health problems, from both short-term and long-term exposure. Shipping contributes to ambient levels of PM, but it should be noted that adverse health effects

associated with PM are a function of multiple sources and not solely those emissions from shipping. Smaller particles, often referred to as $PM_{2.5}$, are of particular concern since smaller particles penetrate deeper into the lung cavity and are associated with respiratory problems. Lower levels of PM result from the combustion of distillate fuels when compared to heavy fuel oil.

124 The key effects associated with exposure to PM include: premature mortality, aggravation of respiratory and cardiovascular disease (as indicated by increased hospital admissions and emergency room visits, school absences, work loss days, and restricted activity days), aggravated asthma, acute respiratory symptoms, chronic bronchitis, decreased lung function, and increased risk of myocardial infarction. Recent epidemiologic studies estimate that in the United States alone exposures to PM contribute to in tens of thousands of excess deaths per year, and many more cases of illness. It is however not yet clearly established which components of PM (e.g., soot or inorganic aerosols such as sulphates) are associated with which specific health effects. (U.S. EPA 2002) In addition, the U.S. EPA, the World Health Organization, the International Agency for Research on Cancer, U.S. National Institute for Occupational Safety and Health, U.S. Department of Health and Human Services, and the California Environmental Protection Agency have all identified diesel exhaust or diesel PM as a probable human carcinogen. Particulate matter also has serious impacts on ecosystems, visibility, and damage and soiling to buildings.

Sulphur Oxides

125 Emissions of sulphur oxides (SOx) including sulphur dioxide (SO_2) are also of concern from a human health point of view. There are a number of studies that directly link increased ambient concentrations of these pollutants to cardiovascular and respiratory causes of death, from both short-term and long-term exposure. Studies examining multiple pollutants in exposure-response assessments, however, face an inherent challenge in separating the effects of individual pollutants in the air pollution mixture.

Climate

126 In addition to local and regional health and environmental impacts, shipping has impacts on climate principally through CO_2, NO_x, SO_2 and PM emissions. For some components (CO_2, O_3 and black carbon), the effect is positive i.e., there is a warming effect, whilst for others (direct effect of sulphate particles, reduced methane from NO_x emissions) the effect is negative, i.e., there is a cooling effect. Particulates can also have an indirect effect on climate through their ability to act as cloud condensation nuclei or by changing the optical properties of the clouds which makes them more reflective (a cooling effect).

127 The impact of ships on global climate is complex, and current estimates indicate that the present-day global mean effect for shipping may be negative. However, an overall global mean negative effect does not imply that it is benign or good for the climate, cancelling the warming effects from CO_2. This is because CO_2 is a long-lived homogeneously distributed species. Sulphate negative forcing, however, is short-lived, regional and exhibits a highly heterogeneous pattern that cannot necessarily cancel the homogeneous positive forcing of CO_2 in terms of climate impacts.

Occupational health

128 The occupational health risks for both seafarers and onshore workers exposed to marine fuels, fuel additives and their combustion products in the course of their work will depend on the type of fuel used. Very few of these risks have been characterised in detail hence the assessment relies in many places on extrapolation from exposures in other workplaces.

129 While data is very limited concerning the relative occupational health risks from these two forms of fuel, distillate fuels could be expected to result in fewer occupational risks than residual fuel oils, because of reduced exposure of engine room staff during machinery repairs and routine maintenance procedures.

Summary of health and environment effects

130 In summary, and despite the limitations of many of the data-sets, almost all of the available information points in the direction of a lower level of adverse environmental and human health effects when distillate fuels are used rather than residual fuel oils.

Regional and Global Studies Assessing the Impact of Air Emissions from Ships

131 Several studies have estimated the distribution of pollutants from shipping and some investigate the effects on human health. These include studies in Canada, Japan, Europe, and the United States. All of these studies show high values adjacent to major shipping lanes with the largest effects on human health in areas where major ports and shipping lanes are located adjacent to major population centres. However, elevated concentrations may also be attributable to shipping well inland (>100 km) of marine sources. All these findings depend upon meteorological and dispersion modelling as well as human health risk assessments. Studies which assess health effects indicate reduction in harm comparable with that seen with the control of on-shore sources when optimum emission control measures are implemented for vessels. These studies have demonstrated that shipping emissions contribute to elevated levels of PM, SOx, and NOx.

Modelling of the environmental impact of the different SOx and PM control options

132 An air pollutant dispersion modelling study was commissioned to analyse specifically the environmental impact of the different SOx and PM control options. The study was geographically based on the European EMEP (European Monitoring and Evaluation Programme) area since the necessary shipping emissions and land based emissions data was already available. Studies in other regions were not possible in the time available since the necessary data sets and air pollution models were not available. In order to make the study more generally applicable, existing Europe-specific ship emissions control measures (i.e., measures associated with the currently existing SECAs and EU fuel sulphur directive) were excluded from the study.

133 Geographic inventories of shipping emissions were developed by ENTEC UK Ltd based on the different SOx and PM control options, B, B1, B2 and C. C2 was considered sufficiently close to C in terms of SO_2 emissions reduction and, therefore, did not warrant separate modelling in the limited time available.

134 Dispersion modelling was carried out by the Norwegian Meteorological Institute using the EMEP model. This modelling assessed the contribution of shipping emissions resulting from the scenarios assessed to land based air quality. The air quality indicators used were sulphur

deposition and air concentrations of $PM_{2.5}$. The study focused on projected shipping densities and emissions for the year 2020. For those options which included 'use of abatement technologies', a 10% reduction in SO_2 emissions below the level of the fuel S cap was utilized. This was intended to allow for the effect of the use of different abatement strategies to meet the fuel sulphur cap. The overall reductions in SO_2 and PM emissions from ships associated with the different control options modelled are shown in the table below.

Conclusions

135 The largest reduction of SO_2 from shipping (79%) occurs under Option C (global distillates). Option B1 (USA) results in a 78% reduction in SO_2 through application of a 0.1% (1000ppm) standard in specific waters. If the European SECA was expanded to include the Atlantic waters adjacent to France, Spain, and Portugal, the greatest emission reductions in SO_2 and PM in Europe would be achieved through Option B1. With respect to $PM_{2.5}$, Option C offers the greatest reduction (73%) while Option B1 offers the second most significant reduction of 65%.

Table: Overall reductions in SO_2 and PM emissions from ships associated with the different control options modelled

Scenario	SO_2 % change with respect to 2000	PM % change with respect to 2000	SO_2 % change with respect to 2020	PM % change with respect to 2020
R1 (no SECA or EU measures) 2000	Reference case	Reference case	-	-
R3 (no SECA or EU measures) 2020	+65%	+65%	Reference case	Reference case
R4 (existing N Sea/ Eng Channel and Baltic SECAs included; no EU measures)	+42%	+54%	-14%	-6%
Proposal B	-44%	-34%	-66%	-60%
Proposal B1 (US)	-64%	-43%	-78%	-65%
Proposal B2 (BIMCO)	-60%	-42%	-75%	-59%
Proposal C (distillates only)	-66%	-55%	-79%	-73%

136 Option B (SECAs at 0.5% fuel S (5000ppm)) results in a 66% reduction in SO_2 from shipping and a 60% reduction in PM in 2020. Option B2 (BIMCO) results in a 75% reduction in SO_2 from shipping and a 59% reduction in $PM_{2.5}$ in 2020. Option C2 was not specifically modelled, but would result in reductions comparable to Option C with greater reductions possible should extensive use of exhaust gas cleaning technology be employed.

137 With respect to concentrations of SO_2 and PM in specific countries, the results show that the long-range (> 1000km) transport of SOx and PM over the European Continent is significant. The model further shows that control of ship emissions under a number of the options result in reductions of 30-60% in sulphur deposition in some coastal states (e.g., Malta, Denmark, the Netherlands, Sweden, and Norway) with 10-20% reductions in sulphur deposition for most other European states. Total $PM_{2.5}$ concentrations are reduced in 2020 by around 50% in Malta; 20%

in Cyprus, Denmark, and Greece, while most other European states would see around an 8-18% reduction in total PM concentrations.

138 In should be noted that modelling in Japan has shown much shorter transport distances as a result of different meteorological conditions and that the specific transport and fate of PM and SO_2 emissions will vary with specific locations.

139 Other significant conclusions of the European modelling exercise include:

.1 long-range transport (>1000 km) of SOx and PM is evident where prevailing metrological conditions support such transport;

.2 increasing the number and geographical limits of SECAs in the European area will effectively improve air quality in Europe;

.3 adopting the (C) distillate standard will improve air quality in European coastal states, such as the United Kingdom, Ireland and Portugal, which border the North Eastern Atlantic; and

.4 use of fuel with a sulphur content of 1000 to 5000ppm (0.1-0.5%S) significantly improves air quality when compared to current limits.

140 While the specific improvements in air quality to be expected in other areas of the world will depend on prevailing meteorological conditions, the density of marine traffic and regulatory standards applicable to land-based sources, it is reasonable to conclude that similar improvements in air quality can be expected in areas with comparable meteorological conditions, marine traffic density, and on-shore regulation.

Broader environmental impacts associated with proposed SO_2 and PM control options

141 In practical terms, the use of heavy fuel oil onboard ships is a more complicated procedure than the use of distillate fuel. The need to pre-heat HFO prior to combustion requires some energy and this in turn produces a small amount of CO_2 whose volume has not been examined. Distillate is a cleaner fuel in all practical respects and brings commensurate benefits on board ship and in environmental terms, should a spill occur. The lower density and viscosity of distillate fuels also makes them less likely to form stable emulsions in the bilge, enabling gravimetric oily water separators to function better. A spill of distillate fuel will have a far smaller environmental impact than an equivalent of volume of HFO and present a much reduced clean up problem. The greatly reduced amount of sludge generated when distillate is used means that there will be less sludge for disposal and this is likely to address to an equivalent degree concerns with illegal disposal. HFO sludge contains high levels of heavy metals and other toxic components that require specialist disposal, with CO_2 emission and cost impacts.

Waste associated with production and operation of abatement technologies

142 In considering the waste associated with production and operation of abatement technologies, it was considered that the intention behind this term of reference was that the Group should focus solely on SOx scrubbing technology. It was agreed that only those technologies which were in commercial use should be included. Hence seawater scrubbers alone were considered since utilisation of freshwater scrubbers onboard ship had not yet commenced at the time this report was compiled.

143 Although the Group were directed to assess the waste associated with the production and operation of abatement technologies, it was not possible within the timescale to address 'production' or the associated energy consumption and related CO_2 emissions.

144 Insufficient data was available on the composition of wastes from seawater scrubbers to enable assessment of the waste associated with the operation of seawater scrubbers. However, on the basis of established information on the composition of exhaust emissions and the solubility of SO_2 in seawater, it can be inferred that heavy metals, PAH and dilute sulphuric acid will be present in the washwater prior to discharge. Solid-liquid separation systems employed to clean the washwater result in the heavy metals and PAH being concentrated in a semi-solid residue or sludge fraction; the liquid fraction will contain the dissolved SO_2 and will be acidic, but not less than pH 6.5. Thus although seawater scrubbers result in reduced exhaust emissions, they do raise other environmental concerns associated with the generation of contaminated residue/sludge and potentially the discharge of acidic washwater.

145 The sludge generated must be discharged ashore to port reception facilities and disposed of in an environmentally sound manner.

146 Acid formed from the dissolution of sulphur oxide in seawater will primarily be neutralised by carbonates in the oceans and coastal waters. Acidification of the world's oceans is a serious and troubling trend. However, acidic inputs by seawater scrubbers are likely to be negligible in terms of acidification of the ocean.

147 To estimate the effects of seawater scrubbers and their impact on estuaries and other semi-enclosed ecosystems, one would need to evaluate the extent of scrubber usage, the aggregate impacts, and the characteristics of the estuary in question.

148 The alternative to removing SO_2 from exhaust emissions is to remove sulphur from the fuel prior to usage. Studies which assess the relative CO_2 emissions associated with these two options suggest little difference in CO_2 emissions overall taking into account emissions associated with neutralisation, scrubber operation, combustion and refinery emissions, as applicable. This comparison does however not take into account requirements for installation and operation of port reception facilities to deal with the residue from seawater scrubbers nor the potential processing of scrubber residue prior to disposal.

CONSEQUENTIAL IMPACT ON CO_2 EMISSIONS FROM SHIPS AND REFINERIES

Assessment of the consequential impact on CO_2 emissions from ships and refineries taking into account the availability of CO_2 abatement, capture and storage technologies

149 Carbon Capture and Storage (CCS) is a technology for CO_2 abatement that is being considered and researched. Some first projects that are being developed focus on (large) power plants and concentrated CO_2 streams (e.g., from a hydrogen plant in a refinery), while taking advantage of availability of a nearby storage facility, e.g., related to idled oil or gas wells, or enhanced oil recovery. It is not expected that CCS will be widely available to capture all refinery CO_2 emissions by 2020.

150 In regions/countries that are subject to the Kyoto protocol, the addition of major new refinery equipment resulting in an increase in CO_2 emissions may be a concern, which could lead e.g., to a longer period to obtain a building and operating permit.

* * *

Annex 1

Informal Cross Government/Industry Scientific Group of Experts to evaluate the effects of the different fuel options proposed under the revision of MARPOL Annex VI

Chairman	Mr. Mike Hunter Maritime and Coastguard Agency United Kingdom
Bahamas	Mr. Ken McLean The Bahamas Maritime Authority
China	Mr. Shiming Xu China Maritime Safety Administration
Germany	Ms. Petra Bethge Ministry of Transport, Building and Urban Affairs (Germany)
Japan	Mr. Koichi YOSHIDA National Maritime Research Institute (Japan)
Norway	Mr. Olav Tveit DNV Petroleum Services (Norway)
Saudi Arabia	Mr. Mohammed H. Al-Zayer Ministry of Petroleum and Mineral Resources (Saudi Arabia)
Singapore	Mr. Mark Lim Yew Guan Maritime and Port Authority of Singapore
Sweden	Mr. Stefan Lemieszewski Swedish Maritime Administration
United Kingdom	Dr. Gillian Reynolds Lloyd’s Register United Kingdom
United States	Mr. Bryan Wood-Thomas U.S Environmental Protection Agency (United States)
ICS	Mr. Peter Hinchliffe International Chamber of Shipping United Kingdom
BIMCO	Mr. Niels Bjørn Mortensen BIMCO Denmark
INTERTANKO	Mr. Dragos Rauta INTERTANKO Norway
OCIMF	Mr. J.A.D. Hunter International Marine Transportation Ltd United Kingdom
IPIECA	Mr. Eddy Van Bouwel ExxonMobil International Services Belgium
IBIA	Mr. Ian Adams The International Bunker Industry Association United Kingdom

EUROMOT	Mr. Fritz Fleischer MAN Diesel SE Germany
IMarEST	Mr. Donald M. Gregory BP Marine Ltd United Kingdom
RINA	Mr. Donald J DeMers Atkins United Kingdom
FOEI	Mr. Eelco Leemans Friends of the Earth International The Netherlands
ICFTU	Mr. John Bainbridge ITF United Kingdom
INTERCARGO	Mr. Roger Holt International Association of Dry Cargo Shipowners United Kingdom
IACS	Mr. John De Rose IACS United Kingdom
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Secretariat
The Secretary-General Mr. Miguel Palomares Director, Marine Environment Division Mr. Dachang Du Senior Deputy Director, Sub-Division for Pollution Prevention Marine Environment Division Mr. Eivind S. Vågslid Technical Officer, Chemical and Air Pollution Section Sub-Division for Pollution Prevention Marine Environment Division

* * *

Annex 2

Composition of the Subgroups

Shipping Subgroup	**Fuel Supply Subgroup**	**Health/Environment Subgroup**
Mr. Niels Bjørn Mortensen (co-ordinator)	Mr. Eddy Van Bouwel (co-ordinator)	Ms. Gillian Reynolds (co-ordinator)
Mr. Ian Adams	Mr. Ian Adams	Mr. Mohammed H. Al-Zayer
Mr. John Bainbridge	Mr. Mohammed H. AlZayer	Mr. John Bainbridge
Ms. Petra Bethge	Mr. Mark Lim Yew Guan	Ms. Petra Bethge
Mr. Donald DeMers	Mr. Donald M. Gregory	Mr. Eddy Van Bouwel
Mr. Fritz Fleischer	Mr. J.A.D. (Ian) Hunter	Mr. Tim Carter
Mr. Mark Lim Yew Guan	Mr. Dragos Rauta	Mr. Peter Hinchliffe
Mr. Peter Hinchliffe	Mr. Olav Tveit	Mr. Eelco Leemans
Mr. Roger Holt	Mr. Koichi Yoshida	Mr. Stefan Lemieszewski
Mr. J.A.D. (Ian) Hunter	Mr. Shiming Xu	Mr. Bryan Wood-Thomas
Mr. Eelco Leemans		
Mr. Stefan Lemieszewski		
Mr. Ken McLean		
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Mr. John De Rose		
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Modelling Subgroup
Mr. Koichi Yoshida (co-ordinator)
Mr. Niels Bjørn Mortensen
Mr. Dragos Rauta
Ms. Gillian Reynolds
Mr. Olav Tveit
Mr. Bryan Wood-Thomas

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Annex 3

Fuel and Refining Glossary

Catalyst	A chemical that enables chemical reactions go faster at lower temperatures and/or pressures, without taking part in the reaction itself. Most catalysts contain metals fixed onto an inert carrier. They are loaded into a reactor and the chemicals or petroleum streams that need to react are send through the catalyst bed in the reactor. Often the catalyst will slowly loose its activity, e.g., through the formation of deposits and needs to be regenerated after some time. Sometimes the catalyst is used in a so-called fluidized bed, allowing to couple the reactor continuously with a catalyst regeneration unit. This is the case in the Fluid Catalytic Cracking (FCC) process.
Coking	A severe form of cracking of heavy hydrocarbon molecules, whereby part of the hydrocarbon is converted to coke (essentially elemental carbon).
Cracking	Thermal or catalytic conversion of heavy hydrocarbon molecules into lighter products.
Crude oil	Also called Petroleum. This is unrefined oil produced at oil wells on land or sea. Crude oil as produced at the well usually contains some dissolved gas and water, which are removed at the production location (the so-called stabilization process) before shipment to a refinery.
Cutter stock	Distillate streams that are blended into heavy fuel oil to adjust certain properties to meet fuel oil specifications (e.g., viscosity).
Cycle oils	Bottom stream form the FCC process, containing a high percentage of aromatics. They are often blended with visbroken residue as the aromatic content improves the stability of the residue (i.e., prevention of asphaltene deposition. Cycle oils however contain some remaining catalyst fines form the FCC process.
Diesel fuel	Generic name used for a range of distillate fuels, including: Diesel fuel no. 2: automotive and off-road diesel Diesel fuel no. 4: marine diesel fuel, railroad diesel
Distillate fuels	Petroleum fractions obtained through distillation processes. The term is mostly used to cover the range of products from gasoline through heavy gasoils.
Distillation	Also called fractionation. A process to segregate a mixture of chemicals that is based on the difference in boiling point between the components. It involves successive vaporisation and condensation steps within a column. Light products are recovered at the top of the column, heavy products accumulate in the bottom.
Fluidized bed reactor	A reactor whereby a solid (typically a catalyst) is maintained in suspension in a liquid or gas flow.
Gasoil	Intermediate boiling range fuel. Home heating oil and diesel fuel are fuels of the gasoil boiling range.
Gasoline	Fuel for cars (automotive gasoline or mogas) and light aircrafts (aviation gasoline). Different grades exist, characterised by the octane number.

Heavy distillate fuel	Sometimes referred to as Fuel Oil No. 4; typically used for industrial burners.
Heavy fuel oil	Fuel oil consisting mainly of the residue from crude distillation, vacuum distillation or the visbreaking process. Sold as bunker fuel oil mainly for electricity generation and as fuel for ocean going vessels.
Hydroskimming refinery	A simple refinery consisting mainly of an atmospheric distillation unit, with some reforming, hydrotreating and sulphur recovery facilities.
Hydrotreating	Process whereby hydrocarbon streams react with hydrogen over a catalyst, under pressure and at elevated temperature, to remove sulphur or nitrogen compounds, aromatics and/or olefins.
Intermediate Fuel Oil (IFO)	Designation for heavy fuel oils for the marine market. Followed by number indicating the viscosity range of the fuel. Most common are IFO180 and IFO 380, but in recent years also the heavier IFO500 and IFO 700 grades have gained presence in the market.
ISO 8217	ISO standard for marine fuels providing specifications for MGO, MDO and IFO marine fuels.
Jet fuel	Kerosone fuel for jet aircraft.
Liquified Peroleum Gases (LPG)	The lightest petroleum fraction, consisting mostly of propane and butane. These molecules are liquefied under pressure for storage and transport.
Marine diesel oil (MDO)	Distillate fuel mixed with some residual fuel oil. Most common grade is DMB. Less common is DMC, which may contain up to about 10% residual.
Marine distillate	Light marine fuels, either marine gasoil or marine diesel
Marine gasoil (MGO)	High quality distillate fuel for marine use with clear appearance. Most common grade is DMA. DMX is a grade that can be used at low ambient temperature and is typically only used for emergency equipment (lifeboat motors, emergency generators).
Middle distillates	Fuels in the kerosene and gasoil boiling range
Naphtha	Light distillates that are used as feedstock for gasoline production or as feedstock for the chemical industry.
Refinery fuel gas	Light gases recovered from process units that are used to cover part of the refinery internal fuel needs.
Residual fuel oil	Heavy high-viscosity fuel oil that is difficult to pump and requires heating before use. Mostly used in large-size industrial burners, power generation and as marine bunkering fuel. Other names that are sometimes used are Bunker C or Fuel Oil no. 6.
Straight run residue	Bottom product from an atmospheric distillation column
Vacuum gasoil	The top product of a vacuum distillation unit.
Vacuum residue	Bottom product from a vacuum distillation unit.

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Annex 4

OPTIONS FOR REDUCTION OF SULPHUR OXIDES AND PARTICULATE MATTER EMISSIONS

	GLOBAL/AREA BASED STANDARDS			GLOBAL BASED STANDARDS	
REFERENCE BASELINE	**OPTION B: CHANGE TO SECA REQUIREMENTS**	**OPTION B1: PROPOSAL BY THE UNITED STATES**	**OPTION B2: PROPOSAL BY BIMCO**	**OPTION C: CHANGE TO DISTILLATE FUELS**	**OPTION C2: ALTERNATIVE MECHANISMS**
Description					
Current requirements of regulation 14	Keep the current structure of regulation 14 with: - A Global sulphur cap (unchanged or lowered) - SECA sulphur cap lowered in two tiers as follows: • 1.0% in [2010] • 0.5% in [2015]	Defined areas [x miles from shore] effective in [2011]: - SO_x [0.4 g/kW-hr] or use a distillate fuel with a sulphur level not exceeding [0.1]% - Shipowners may choose to comply through the use of low-sulphur distillate fuel and/or the use of exhaust gas cleaning technology. PM limits: - [0.50] g/kW-hr for engines with a per-cylinder displacement of 15 litres or more; - [0.27] g/kW-hr for engines with a per-cylinder displacement of 5 litres but less than 15 litres; and - [0.20] g/kW-hr for engines with a per-cylinder displacement of less than 5 litres.	Gradually lowering of the global cap sulphur content as follows: - Max 3.0% in 2012 - Max 1.5% in 2016 - Or use of alternative mechanisms (such as exhaust gas cleaning systems) to obtain equivalent levels of emission reduction. Requiring use of distillate in SECAs, port areas and estuaries, with gradually lowering of the sulphur content as follows: - Max 1.0% in 2011 - Max 0.5% in 2015 - Or use of alternative mechanisms (such as an exhaust gas cleaning systems) to obtain equivalent levels of emission reduction.	This is a fuel solution which would require: - Use of distillate fuels for all ships as follows - A Global sulphur cap: • 1.0% in [2012] • 0.5% in [2015] - Include in MARPOL Annex VI the specification for the distillate fuel to be used by ships.	Global caps as specified in Option C, but allowance for alternative mechanisms (such as an exhaust gas cleaning system) in combination with residual fuel oil with a higher sulphur content (maximum 4.50% m/m or lower) to obtain an equivalent level of emission reduction as in C for SOx and PM.

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