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Quick Scan of the Economic Consequences of Prohibiting Residual Fuels in Shipping

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Abstract

The Energy Research Centre of the Netherlands has carried out a 'Quick Scan' on the economic impact on the Netherlands, resulting from a potential prohibition of residual fuels in international shipping.

The Dutch refinery industry annually produces about 8 million tons of refinery residues, the main component of the presently used shipping fuel. It is technically possible to convert all residues into lighter products, although this process will cause an additional energy use of about one million tons of crude oil and a related CO_2 emission of about 3.5 million tons. A fast introduction would lead to market disruptions and peak prices. These effects could be limited by a gradual introduction over about six years, preceded by a preparation phase for the refineries of approximately six years. The investment costs for the Netherlands are estimated at about € 1.5 tot 2 billion.

The Rotterdam bunker market processes both domestic and imported refinery residues. The residues are used to blend shipping bunker fuels, which are both sold to ships and exported to other harbours. Rotterdam will not necessarily be able to develop a similar position in import, export and bunkering of distilled shipping fuels. On balance, there is a reasonable chance that the bunker sector, where about 1500 people are employed, would decrease.

This report is a translation of a report originally written in Dutch, entitled 'Quick Scan economische gevolgen van een verbod op residuale brandstof in de zeevaart', ECN-E--07-036, June, 2007.

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The Netherlands Ministry of Transport, Public Works and Water Management has requested the Energy Research Centre of the Netherlands to conduct a 'Quick Scan' on the economical impact of a potential prohibition of residual fuels in international shipping.

The Dutch refinery industry annually produces about 8 million tons of refinery residues, the main component of the presently used shipping fuel. It is technically possible to convert all residues into lighter products, although this process will cause an additional energy use of about one million tons of crude oil and a related CO_2 emission of about 3.5 million tons. A fast introduction would lead to market disruptions and peak prices. These effects could be limited by a gradual introduction over about six years, preceded by a preparation phase for the refineries of approximately six years. The investment costs for the Netherlands are estimated at about € 1.5 tot 2 billion.

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Background

The potential prohibition of residual fuels in international shipping was proposed by the International Association of Independent Tanker Owners (Intertanko) to the International Maritime Organisation (IMO). The proposal involves a switch by 2012 from the presently used residual fuel to distillate fuel with a sulphur content of 1%, to be lowered to 0.5% by 2015. Worldwide, an annual residual fuel[1] consumption of approximately 200 million tons is to be replaced by low-sulphur distillates. The present quick scan provides a view/estimate of the economic impact on Dutch petroleum companies, the bunker market for ocean-going vessels in Rotterdam and possible effects on other stakeholders in the Netherlands. The quick scan is intended as independent support for the Dutch viewpoint in the IMO discussions. Any consideration of the broader context lies outside the scope of this report.

Technology for refining residual fuel oil

Bunker or heavy fuel oil (HFO) consists largely of the residues remaining after the distillation of crude oil in refineries. The approximately 8 million tons of residual fuel oil produced annually in the Netherlands can be reduced, firstly by subjecting all atmospheric residues to vacuum distillation (this primarily applies to the Nerefco refinery). In the Netherlands, this would decrease (now vacuum) residues to 5 million tons. It is technically possible to convert the heavy and viscous residues that cannot be distilled further into lighter (distillate) products (deep conversion). The Dutch Exxon Mobil refinery has shown in practice that this is technically possible and economically feasible. This conversion can be done by either separating carbon in processes such as flexicoking, as done by Exxon Mobil, or by adding hydrogen, as done in Shell's hycon process. The remaining 5 million tons of residual fuel could be processed by building 2 or 3 flexicokers. As an alternative to deep conversion, residual fuels can be gasified for power generation with gas turbines, and possibly combined with the production of hydrogen and/or heating.

Processing capacity and volume flows

The current primary refining capacity is 3,400 million barrels per year worldwide, of which 1.6% occurs in the Netherlands. The global capacity for deep conversion is about 206 million tons per year, corresponding to about 6% of the total primary refining capacity. The additional

[1] Residual fuel is assumed to resemble the composition in the Netherlands, containing vacuum residues, atmospheric residues, and some distillates for blending purposes (see § 3.3.4, 3.3.5).

refining of all the residual fuel currently used for ship propulsion would require a doubling of the present global capacity for deep conversion. This capacity has grown in recent years almost 4 times faster than primary processing capacity, a development that is mostly due to crude oil becoming heavier, as well as the comparatively strong increase in demand for relatively light products. Current increase in deep conversion capacity is therefore independent of any transition from residual ship fuel to distillates.

If this expansion in capacity continues at the same rate as the past 7 years, it would then take almost 35 years before the desired supplementary annual processing capacity for 200 million tons of residual ship fuel is reached. Worldwide, the *primary* conversion capacity has increased by about 170 million tons over the last seven years to reach its current level of 3,400 million barrels per year. Technically, it might also be possible to expand capacity for deep conversion by 200 million tons in roughly seven years. The main question is therefore whether deep conversion can be increased *concurrently* with the autonomous activities involving expansion of primary conversion. Potential difficulties involve the availability of technical knowledge and production capacity for the construction of new deep conversion installations, as well as the production decreases due to temporary stoppages in refineries in order to incorporate the new installations.

Furthermore, refinery capacity is, as far as possible, geared to regional demand for various types of fuel produced in the refining process. This can provide refineries with a reason to prefer expansion into growth markets such as Southeast Asia, where future sales of the entire spectrum of refinery products are very secure.

Economics of the refining industry

At present, approximately 3,240 people work in refineries located in the Netherlands. Including personnel from contracting companies, the number rises to 4,000-5,000 employees.

The Netherlands no longer have any industry or electrical energy plants that ‘run’ on heavy fuel oil. Dutch refineries therefore do not have any alternative domestic market on which to sell heavy fuel oil and that is why they mainly concentrate on the market for bunker fuels for shipping.

The investments for further refining of the residues in the Netherlands are estimated at approximately € 1.5 to 2 billion, on the basis of the ECN refining model. The investments for additional deep conversion capacity as reported in literature vary substantially, depending on the extent to which costs have been included for: (1) fitting the installations in the refinery, (2) additional processing of the intermediate products, and (3) distinguishing between new constructions and retrofit. Based on past actual investment, the installation of the necessary flexicoker capacity would now require an investment of approximately € 3.5 billion, at least if renovations are done more or less at the same time. The Oil & Gas Journal indicates an investment that is substantially lower, around 0.3-0.4 billion for the same capacity. This, however, is a ‘basic’ price for the flexicokers, one that still needs to be increased by the (high) costs of installation and modification for the refinery, as well as the substantial additional investments in capacity expansion of the installations in which the raw products from the flexicokers have to be processed.

An assessment of the willingness to invest in deep conversion capacity of the 6 largest refineries in the Netherlands, in response to any potential prohibition of the HFO use in sea-going shipping paints the following picture:

- The Exxon Mobile refinery (capacity of approximately 9.1 million tons) will not need to adjust its capacity because it already converts all its residual fuel into lighter products.
- The comparatively small Koch refinery (capacity of around 3.5 million tons) also does not have to make any changes as the raw material that it processes, natural gas condensate, does not produce any heavy residues.

- The Shell refinery (capacity of about 21 million tons) is a complex refinery that already has processing steps to reduce the proportion of residual fuel oil in production. The Netherlands, along with the UK, is 'home base' for Shell. The company also participates in the Gasunie, together with Exxon Mobil and the Dutch government. The chance that Shell will invest in order to adapt its Dutch refinery to the new situation is therefore higher than average.
- Nerefco (capacity of around 20.5 million tons) is a relatively simple refinery that, due to a limited capacity for deep conversion, produces a fairly large amount of heavy residue products. For this reason, Nerefco will have to invest substantially to enable it to process its comparatively high production of heavy residue flows itself. The chance that the Nerefco will adjust is to be deemed average.
- Total (capacity of approximately 7.9 million tons) has a hydrocracker for processing vacuum gas oil and would only have to invest in the processing of residual oil. Due to the relatively small flow of residual oil, investment costs are rather high. The chance that Total refinery will invest in the necessary changes is considered to be average.
- The Kuwait refinery (capacity of about 3.8 million tons) is not complex but does already have a vacuum distillation unit. Kuwait recently has made an attempt to sell the refinery (ANP-AFX, 2006). The small scale however makes investments rather expensive. The chance that the current owner is prepared to make extra investments is regarded as less than average.

If no investments are made in the processing capacity of residual oil, the industry's competitiveness will decline in the long term, particularly if there is a return to a situation with overcapacity and the margins for the refineries start diminishing again.

Models calculations on extra crude oil demand, CO_2 emissions and costs
The ECN refinery model SERUM was used to calculate the changes in the refining sector that the implementation of the Intertanko proposal would bring about with regard to the additional demand for crude oil and CO_2 emissions. The calculations indicate that the replacement of 8 million tons of bunker oil in the Netherlands with distillate fuel containing 0.5% sulphur would be associated with an increase in CO_2 emissions by about 3.5 million tons and additional energy consumption of about 1 million tons. This extra emission would mean a 2% rise in the total CO_2 emissions in the Netherlands.

The current Kyoto agreements for CO_2 emissions run until 2012, whereas the first mentioned implementation of the Intertanko proposal refers to the period 2012-2015. Implementation of the Intertanko proposal would therefore primarily affect a subsequent post-Kyoto international climate regime about which little is yet known.

The model calculations also reveal that desulphurisation of bunker oil (the alternative for distillate shipping fuel) would emit about 1.9 million additional tons of CO_2. Desulphurisation of bunker oil would require about 0.7 million tons of extra oil equivalent to energy, and the distillate requirement would be in the range of 0.9–1.2 million tons of oil equivalent.

Extrapolation of the calculations for the Netherlands to the European scale indicates an extra 22 million tons of CO_2 emissions. This figure is lower than the additional 35 million tons of CO_2 that would be emitted according to the European Petroleum Industry Association (EUROPIA). Assuming a worldwide distillate demand of 200 million tons, the global increase in CO_2 emissions would total approximately 90 million tons.

EUROPIA claims that production of an additional 50 million tons of distillate in Europe would require an investment of € 30 billion. Assuming the ECN calculations of the Netherlands situation to be applicable to all of Europe, the resulting investment requirement is calculated to be € 9 billion (with a disinvestment margin running up to € 12 billion).

If the refineries would decide to convert their residual oil in distillate and other products, this would require substantial investment. Other oil companies would also make similar investments, which ultimately would translate into pricing changes for various products. As is the case in other markets, investment is in most cases recoverable from revenue.

Economics of the Bunker fuel market
About 1500 employees are directly involved in the bunkering industry. Rotterdam has grown into one of the three most important players on the bunker market, due to (1) the bunker production at local refineries, (2) the deepwater harbour enabling the biggest ships to port, and (3) a favourable geographical position for bunker imports from Russia and the Baltic states. Given these advantages, bunker fuels can be offered in the Netherlands at a lower price than at other important bunker ports. The bunker market in Rotterdam would suffer a decline if the value of oil exports for the bunker market were to drop, and the same would hold true if some of the refineries were to decide to stop production of fuels for ocean shipping.

The Netherlands produced around 9 million tons of residual fuels in 2005 and imported approximately 20 million tons. Of this, around 15 million tons was bunkered by sea-going vessels, around 12 million exported (to Singapore and other locations), and the remaining 2 million tons used for domestic consumption. The economic GE scenario reveals that the bunkering of ship fuel in the Netherlands will grow from 600 PJ in 2005 to approximately 1060 PJ in 2030, an increase of 3% per year. The Rotterdam bunker market processes both domestic and imported refinery residues. The residues are used to blend shipping bunker fuels, which are both sold to ships and exported to other harbours. If a prohibition of residual fuels in shipping comes into force, the natural position favoured by inexpensive HFO imported from Russia will disappear, although transit of this product will continue. Rotterdam will not necessarily be able to develop a similar position in import, export and bunkering of distilled shipping fuels. On balance, there is a reasonable chance that the bunker sector, where about 1500 people are employed, would decrease. Since the storage sector also processes crude oil and other products, the decline over the entire sector will be smaller.

Additional remarks
At present, the difference between available refinery capacity and the demand for oil production is smaller than it has been over the past 25 years. Although the coming years will see substantial investment in additional refining capacity, it is highly unlikely that in the short term sufficient distillates can be produced to supply all sea-going vessels in addition to current sales. What is more, there would also be a surplus in oil products if HFO continues to be used.

The pace of implementing the Intertanko proposal could greatly affect pricing on the oil-market, the oil products market and the market for sea transport. It is likely that an abrupt implementation would inevitably involve severe market disturbances with high peak prices. Negative impacts might include shortages and price perturbations for certain oil products, as well as shortages in the engineering and construction capacity for refining facilities. Gradual introduction over about 6 years, preceded by a preparation phase for the refineries of approximately 6 years, could limit the negative effects.

1. Introduction

1.1 Purpose of the study

The Ministry of Transport, Public Works and Water Management requested the Energy Research Centre of the Netherlands (ECN) to conduct a quick scan of the economic consequences resulting from a prohibition on the use of residual fuels in maritime navigation, such as proposed by the International Association of Independent Tanker Owners (Intertanko). In particular, this scan provides a view/estimate of the economic impact on Dutch petroleum companies, the bunker market for ocean-going vessels in Rotterdam and possible effects on other stakeholders in the Netherlands. The quick scan is intended to provide independent support for the Dutch position in the discussions on air pollution to be held by the International Maritime Organisation (IMO, a United Nations Agency) in 2007 and 2008. A consideration of the wider context lies outside the scope of this report.

1.2 Background

Environmental proposals for the marine industry are being discussed in the framework of the IMO. These deliberations are occurring in connection with the revision of Annex VI of the 'International Convention for the Prevention of Pollution from Ships' (MARPOL). At present, the possibilities of tightening existing air quality standards are being explored by the IMO 'Subcommittee on Bulk, Liquids and Gases (BLG) - Working Group on Air Pollution'. This work group prepares proposals submitted for the consideration of the IMO 'Marine Environment Protection Committee' (MEPC). Among other items, a proposal has been tabled by Intertanko to prohibit the use of residual fuel in shipping and to switch to distilled fuel all around the world. The effects of this proposal on the environment and the maritime industry are being discussed at length by stakeholders within the IMO framework; they do not therefore constitute the purpose of this report. However, the proposal also has consequences for Dutch petroleum companies, the bunker market in Rotterdam and other implicated parties.

The extent of the impact is still unclear at present. Petroleum companies hold critical views and emphasise that costly and lengthy investments would be required to convert to the new situation. Dutch petroleum companies insist that, for them, the production and sale of residual fuel oil is an essential element of their business operations, and the elimination of it would result in a significant loss. Other experts are emphasising that substantial investments in more extensive refining techniques are already planned and that the complete refining of fuels (deep conversion) will be an unavoidable future trend. An additional request from the Ministry of Transport, Public Works and Water Management concerns the possible economic consequences on the strong position of Rotterdam as a bunker port for sea-going ships. The Ministry requires an independent study in order to obtain an objective view of the economic fallout for Dutch petroleum companies and possible third parties.

1.3 Structure of the report

This report presents our findings concerning the effects of a prohibition on the use of residual fuels in shipping. Our study is based on: literature, mathematical models, a workshop involving the industry and the ECN's years of experience with policy studies concerning the oil refining industry in the Netherlands. Chapter 2 provides information about the goals of, and background to, a ban on residual fuel in marine transport. A brief sketch will also be made of the various types of shipping fuels and the corresponding prices. Subsequently, Chapters 3 and 4 will describe the expected economic effects for both the refining industry and the bunker market in the Netherlands. The chapter will also present comparisons in either sector between the future expectations of the existing policy and the scenario involving a residual fuel ban. Chapter 5 contains an overview of other economic repercussions. The most important conclusions of this study are summarised in Chapter 6. The appendices (A through F) include: the sulphur requirements for ship fuels (A), details about further refining capacity in the Netherlands (B), degree of utilisation for the refining capacity (C), a report on a workshop held with the industry (D), as well as the written responses to the conclusions of this workshop from Intertanko (E) and from Acid Rain, a Swedish NGO (F).

2. The Intertanko proposal and ship fuels

2.1 MARPOL ANNEX VI and the Intertanko proposal

The objectives of the IMO are to promote safety in ship transport and reduce the environmental pollution of ships. The IMO MARPOL convention is the most important international agreement intended to limit the environmental impact of shipping both during normal operations and as a result of accidents. The MARPOL treaty combines two international agreements from 1973 and 1978, both of which have been updated over the years by a series of amendments ('Annexes'). Annex VI was adopted in 1997 as a countermeasure to the air pollution from maritime vessels. This Annex came into effect on 19 May 2005. See Figure 2.1 for a graphic representation (Mortensen 2007).

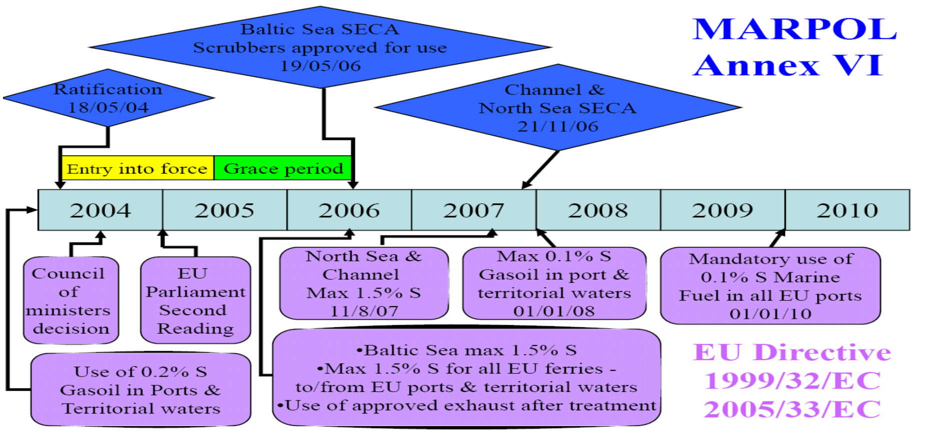

Figure 2.1 *Overview of IMO/EU regulation and implementation*

Annex VI prescribes a worldwide limitation on maximum sulphur content of 4.5% in order to reduce acidification and health problems due to SO_x emissions from marine transport. Annex VI also makes it possible to designate special areas in which sulphur-oxide emissions are to be restricted (SECAs: SO_x Emission Control Areas). The fuel used in a SECA may only have 1.5% sulphur content by mass. As an alternative, ships are also permitted to install exhaust gas scrubbing systems that reduce the emission of SO_x to the equivalent of fuel with 1.5% sulphur.[2]

The Baltic Sea has SECA status since 19 May 2006, and the English Channel and the North Sea will also be given such designation on 21 November 2007. Other SECAs will likely follow, see Figure 2.2 (Mortensen, 2007).

[2] A gas scrubber was installed by Krystallon on a ferry in 2005 (www.krystallon.com). The cost-effectiveness of such technology depends on several factors, including the size of the installation, the price difference between high and low-sulphur fuel, and the operating time. The latter is important because such a system is more cost effective the more that navigation involves travel through SECAs. According to Wärtsilä, it is technically possible to install gas scrubbers on most ships (Henriksson 2006).

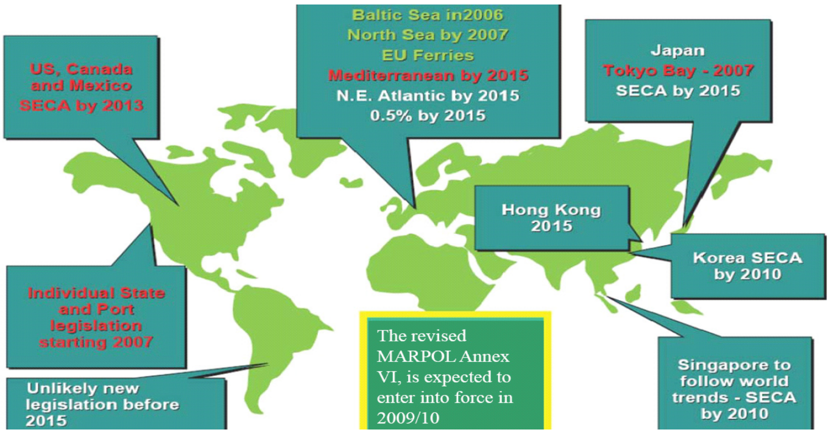

Figure 2.2 *Possible future expansion of SECAs worldwide*

Prior to the meeting to review Annex VI in November 2006, Intertanko submitted a proposal (Intertanko 2006b) to convert all ships to distillate fuels by sometime in 2010 (see Section 2.2 on fuels). At a later stage, 2010 was changed to 2012 due to concerns about the fuel supply. The essence of the Intertanko proposal to the IMO Working Group on Revisions of the MARPOL Annex VI is summarised in Table 2.1.

Table 2.1 *Intertanko proposal*

Date	Proposal	Maximum sulphur content
Around 2012	Only distilled fuel	1% S
2015	Idem	0.5% S

* The 2012 implementation date will be examined and discussed further because it may be insufficient time for the necessary oil-industry investments.

In a presentation, Intertanko provided the following explanation of the proposal (Intertanko 2006b) as summarised in Table 2.1 (Intertanko, 2006a):

- Intertanko is asking the IMO to consider distillate (gas oil) as an alternative to HFO (heavy fuel oil).
- Distillate is roughly twice as expensive as HFO, but some other costs would disappear.
- In addition to the benefits for air quality, the use of distillate as a fuel has other advantages over HFO, in the area of operational security and the safety associated with it, for example.
- A further analysis must be made of the advantages and disadvantages.

Intertanko indicates that fuel costs will certainly be higher but that the use of distillate fuel will lead to lower fuel consumption as well as lower emissions of heavy metals, particulate matter and SO_2, less waste/sediment from fuel purification on board and no waste production from exhaust gas scrubbers, the alternative to lowering sulphur content in fuel.

In addition, ships navigating SECAs require less investment in: extra tanks and pipelines (for different quality fuels), different types of lubricant, fuel processing systems and gas scrubbers, as well as any other exhaust gas cleaning systems meant to counteract the discharge of dust and SO_2. The predictability of the fuel qualities is also improved for engine manufacturers, and Intertanko expects that the costs for engine maintenance will decrease (as a result of more consistent fuel quality) and that safety will increase (as a result of greater operational security).

Three options were outlined in the IMO work group on air emissions in 2006:

A. Continue current state of affairs.
B. Reduce the maximum content of sulphur in SECAs to 1% sometime in 2010 and 0.5% in 2015. If required, the maximum sulphur content in all bunker oil used as marine fuel could also be reduced.
C. The Intertanko proposal: New engines would have to run on distillate with maximum 0.5% sulphur beginning in 2015 (the latter has already been adapted, and this proposal is now being suggested for all engines).

Other options/proposals have now also been put forward.

The present report is primarily concerned with the economic effects of the Intertanko proposal on:

- Dutch petroleum companies,
- the maritime bunker market in Rotterdam,
- other possible stakeholders in the Netherlands.

2.2 Marine fuel

Two types of fuel are used in the shipping industry: Heavy Fuel Oil (HFO) and distillates, the latter further divisible into Marine Diesel Oil (MDO) and the lighter Marine Gas Oil (MGO; for prices, see Table 4.3).

HFO largely consists of the *residue* that remains from the refining process after the light products have been separated from crude oil by means of distillation. HFO is therefore a residual oil product and contains a high concentration of impurities, such as sulphur and (heavy) metals. To modify the viscosity and other fuel qualities, HFO is diluted with so-called 'cutter stock', which is composed of a very divergent series of refining products. HFO is the most widely used name for the category of 'heavy' marine fuel. The following alternatives are also common: residual fuel oil, bunker fuel, bunker C, fuel oil No 6, industrial fuel oil, marine fuel oil and black oil (CONCAWE, 1998). Heavy fuels with comparable properties are also employed in mid-size and large energy plants, as well as in industrial boilers and furnaces (but not any more in the Netherlands).

The HFO used in international shipping is, under MARPOL Annex VI, permitted to have a maximum sulphur content of 4.5%. On average, sulphur content is about 2.7%. No cutter stock is added to MDO, a much 'lighter' and therefore less viscous product, so that the composition is more straightforward. This distillate also contains fewer impurities, and fewer pollutants are therefore emitted. Marine gas oil (MGO) alone is used in inland navigation. This type of distillate is of better quality than the diesel oil used in shipping (MDO) and has a sulphur content of 0.2%, which will be lowered to 0.1% as of 1 January 2008. MGO comes closest to the diesel used in the road transport sector.

Comparable to the octane number (anti-knock rating) of petrol,[3] the cetane number for diesel fuels is an important quality parameter. The cetane number is an indicator of the speed with which the fuel for a diesel motor will self-ignite. A lower cetane number indicates a more delayed process of self-ignition. Lower quality fuel is used in shipping in particular (lower cetane number, therefore lower speed of self-ignition). Since ship diesels generally operate with lower numbers of revolutions and higher compressions, the combustion delay associated with a lower cetane number is not a drawback in their case (Wikipedia 2007).

[3] $Euro_{95}$ stands for petrol with an octane number of 95.

3. Effects on the refining industry

The central question concerns the effects that implementing the Intertanko proposal would have on the refining industry in the Netherlands. This can be further specified into three questions:

- What is to be done with the residue that remains after secondary (vacuum) distillation and is currently used as fuel for the shipping industry?
- How is the increased demand for distillates to be satisfied?
- By what date are the necessary changes to be implemented?

3.1 Refining process

A refining diagram is presented as Figure 3.3. Crude oil enters the atmospheric distillation process, where it is heated. Lighter products, such as petrol and diesel fuel, evaporate because they have a lower boiling point and are, in this way, separated from the heavy products. The heavy residue (atmospheric residue) can then be: (1) used directly as heavy fuel oil or (2) distilled a second time under low pressure (vacuum distillation). During vacuum distillation, a part of the residue will then be evaporated (vacuum gas oil) and another part will remain in the bottom of the tower (vacuum residue). Atmospheric residue and vacuum residue are the raw materials for HFO, otherwise known as bunker oil. Various qualities of marine fuel can be made by blending different residues and possibly adding some gas oil. A step that is sometimes used to reduce viscosity is the visbreaker. Marine diesel, the distillate that Intertanko proposes as a substitute for HFO, can be made from gas oil by means of the product flow indicated in Figure 3.3. Gas oil is also used to make diesel and home heating oil. NB: Gas oil is not to be confused with gasoline (which is a synonym for petrol).

3.1.1 Changes required to refine HFO

Figure 3.4 shows the same diagram as Figure 3.3 but modified so that all HFO is further refined into lighter fuel. This means, first of all, that more investments must be made in vacuum distillation. Money must also be invested in the reprocessing of the vacuum gas oil by, among other techniques, increasing the capacity of hydrocrackers in which good quality diesel fuel is made by adding hydrogen. There has been a great deal of investment in hydrocrackers in Europe. Catalytic crackers (otherwise known as ‘catcrackers’) are used to make petrol from (vacuum) gas oil. A part of the vacuum gas oil can also be used directly as distillate fuel for ocean-going vessels with and without any intervening processing steps.

It is also possible to convert vacuum residues, characterised by a high carbon/hydrogen ratio, into lighter products. This involves processes in which heavy residues are transformed by: (1) separating out carbon, as done in the flexicoker procedure at Exxon Mobil, or (2) adding hydrogen, as is the case in the hycon procedure at Shell. Both procedures not only produce distillate/gas oil but also other products, such as kerosene and petrol. The reconstruction/expansion of the refining sector to facilitate the complete processing of residual oil (deep conversion) would always generate other products in addition to distilled marine fuel.

In the hycon process, residues from vacuum distillation with high sulphur and heavy-metal content are largely converted into distillates. A residual oil flow continues to exist, one to which hydrogen can be added in the hycon process. The heavy metals are removed in the first step and remain on the catalyst. An important ingredient in the process is the constant replacement of the catalyst (see Figure 3.1; source: Moulijn and Makkee, 2003). The first hycon unit in the world was launched at Shell Pernis in 1989. After overcoming various start-up problems involving the installation and materials, the system has now been operating effectively for about a decade (Scheffer et al., 1998).

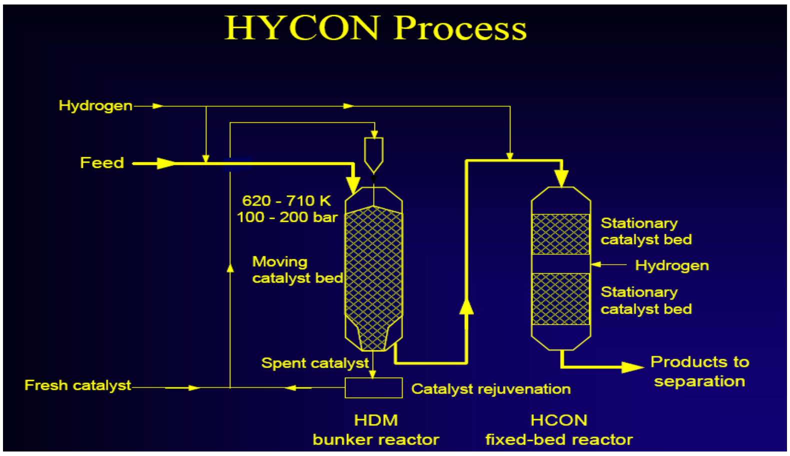

Figure 3.1 *Schematic diagram of the hycon process*

Flexicoking is a procedure especially developed to convert heavy oil fractions into lighter ones by extracting carbon. The input material for the flexicoker is the residue from vacuum distillation, the heaviest oil fraction in the refinery. This is converted in flexicoker installations at high temperature into 70% light oil products and cokes.

A flexicoker does not therefore produce any liquid residue. The heavy metals remain behind in a remnant product made up of cokes, which are subsequently transformed into a low-caloric gas used for heating various steps in the manufacturing process. The very small quantity of ash that remains from the coke finds its way to the cement industry (Moulijn and Makkee, 2003).

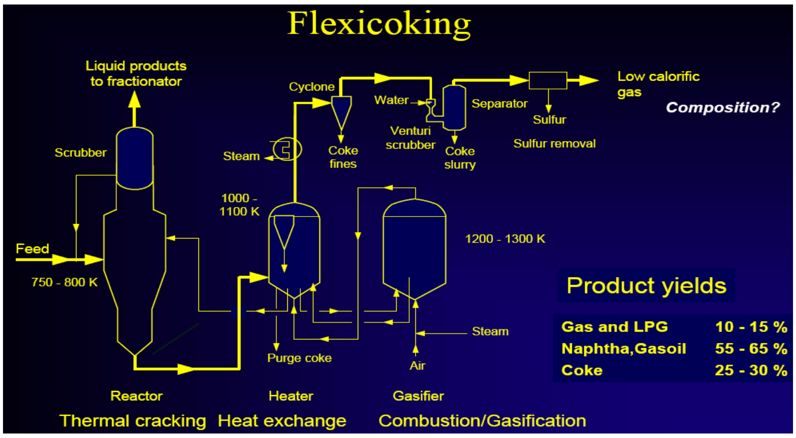

Figure 3.2 *Schematic representation of the flexicoking process*

Since there are other applications for HFO outside shipping (e.g. fuel for energy plants as well as large industrial boilers and furnaces), a complete conversion to such an HFO free configuration as the one shown in Figure 3.4 will never occur. In the Netherlands, the switch should be relatively large because heavy fuel oil has nearly no uses any longer in this country outside sales to the shipping industry and because the market for heavy fuel oil in surrounding countries is also limited.

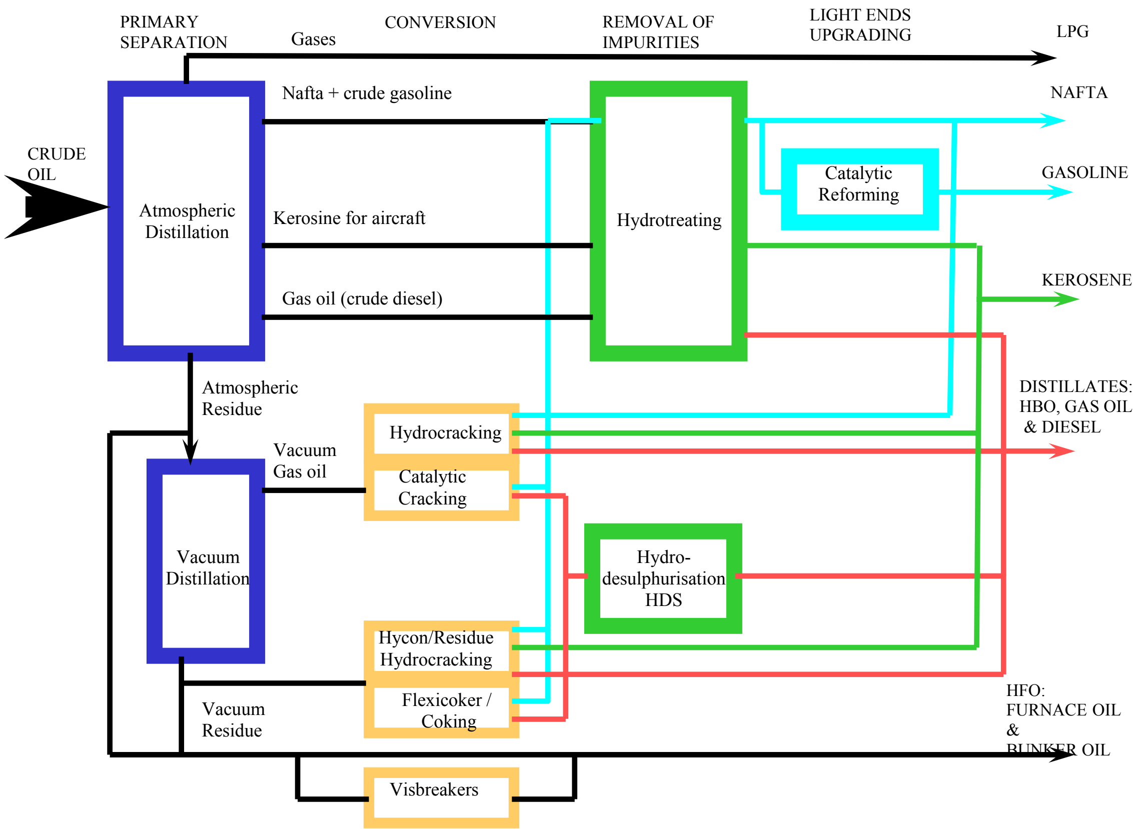

Figure 3.3 *Diagram of the refining process with HFO production*

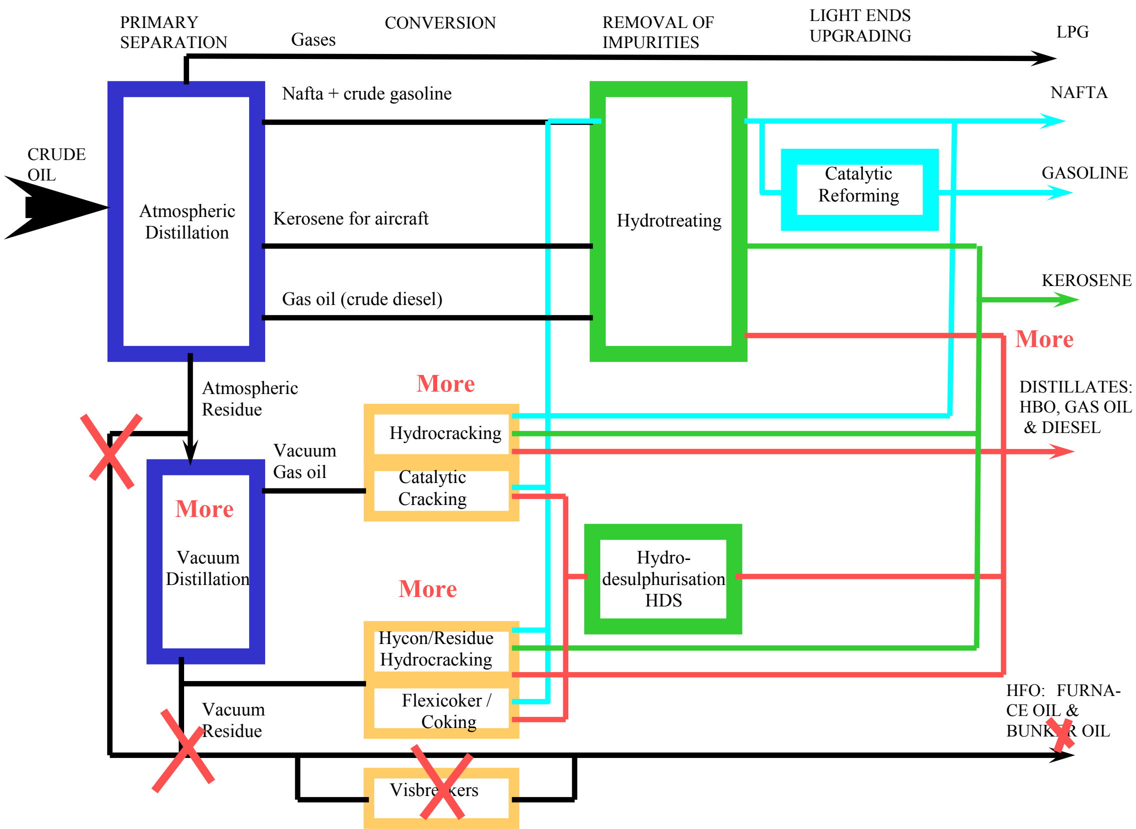

Figure 3.4 *Diagram of the refining process without HFO production*

3.2 International developments in residue processing

There are various possible ways of processing HFO residues (see Section 3.1.1). The first is to break the petroleum chains into smaller pieces, removing the excess carbon (in cokers and flexicokers). The second is, after breaking the chains into shorter pieces, to attach hydrogen to the open end (in a residue hydrocracker). Both produce lighter products, such as petrol and diesel. The first also yields petroleum cokes or a low-caloric gas, while the second requires a great deal of hydrogen. A third method is to gasify the HFO and to make chemical products, hydrogen and/or energy from the synthetic gas.

3.2.1 Cokers and flexicokers

Based on data from the Oil & Gas Journal, an investigation was made into the progress being made in developing the capacity to convert HFO. This is also called 'deep conversion' capacity. To begin with, Table 3.1 provides a survey of flexicokers, all built between 1980 and 1990 (Rooijmans, 2003).[4] The corresponding capacities are taken from the Oil & Gas Journal (2006). Assuming that 1 barrel per capacity day (bpcd) roughly agrees with an effective processing capacity of 47 tons/year, the capacities are also converted into million tons per year. (The unit bpcd indicates the number of barrels of oil that can be processed on average each day, a figure that takes factors into account such as maintenance etc. - the unit of a barrel is equal to 159 litres.)

The total processing capacity of flexicokers and comparable technology is indicated in Table 3.2. Total possible throughput in 2007 is 206 million tons. Table 3.2 reveals that processing capacity has increased by approximately 30 million tons since 2000 (17%). In the same period, the crude-oil processing capacity in refineries (the primary capacity) has only increased by 4.5 % from 81.5 million bpcd in 2000 to 85.2 million bpcd in 2007. Consequently, a trend exists in which the growth in deep conversion is more rapid than the growth in primary capacity. The world's entire deep-conversion capacity currently amounts to approximately 6% of the total primary processing capacity.

Table 3.1 *Flexicokers built between 1980–1990*

Location	Country	Company	Capacity [bpcd]	Throughput [million tons/yr]
Rotterdam	NL	Exxon Mobil	41,000 (3)	1.9
Baytown	USA-Tx	Exxon Mobil	44,500 (2), 39,000 (3)	2.1 / 1.8
Martinez	USA-Ca	Shell	26,800 (2), 21,600 (3)	1.2 / 1
TOA	Japan	State-owned	24,000 (1)	1.2
Amuay	Venezuela	State-owned	87,300 (2)	4.2
Elefsis	*Greece*	*HELPE*	*2,0000 (announced)*	*1*

Note: (1): fluid coking, (2): delayed coking and (3): other; see Oil & Gas Journal (2006) and references therein.

[4] The USA has 61 coking units (8 fluid coking units, 50 delayed coking units and 3 other units); Japan has two other coking units with capacities of 24,000 (3) and 22,000 (2) bpcd; Venezuela has 1 other coking unit with a capacity of 57,000 (3) bpcd.

Table 3.2 *Worldwide coking capacity as of 1 January, with additional details about 2007*

[in 1000 bpcd]	2000	2001	2002	2003	2004	2005	2006	2007	*Number*
Coking, total	3,745	3,826	3,876	4,150	4,206	4,440	4,367	4,389	146
Increase		+81	+50	+274	+56	+234	-73	+22	
Distribution									
Fluid coking								38	17
Delayed coking								3,380	106
Other								299	16
Unspecified								267	7

The average investment in a flexicoker (including environmental measures) is 3,000-4,000 $\$_{2003}$/bpsd (barrels per stream day; see list of abbreviations; source: Hydrocarbon Processing, 2004). This is for a capacity of 2 million tons, valued between $ 120 to 190 million.

3.2.2 Residue hydrocrackers

Another method to process residual oil is not to remove carbon in cokers, but to add hydrogen. Shell's hycon is an example of such residue hydrocrackers (see Section 3.1.1). Table 3.3 provides a survey of the various installations in use (Oil & Gas Journal, 2006). According to the Oil & Gas Journal, capacity for a throughput of 16.4 million tons was available as of 1 January 2000. In 2007, this has become 22.7 million tons, corresponding to an increase of 6.3 million tons (+ 38%). The current worldwide hycon capacity, amounting to 23 million tons per year, is small in comparison with the flexicoker capacity at approximately 206 million tons per year.

The typical investment in a hycon with a throughput of 1.8 million tons per year is from 200 to 300 million dollars. The higher figure includes an integrated hydrocracker (source: Hydrocarbon Processing 2004).

Table 3.3 *Worldwide residue hydrocracker (hycon) capacity as of 1 January 2007*

Country	Capacity [bpcd]	Throughput in million tons/y
Canada	3600 (c)	0.16
Croatia	12264 (m)	0.57
Germany	29900 (c)	1.4
Iraq	5000	0.24
Italy	23400	1.1
Japan	22500 (c)	1.1
Malaysia	36000	1.7
Mexico	18500	0.87
Netherlands (Shell Pernis)	25400 (c)	1.2
Poland	33500	1.6
Slovakia	23000 (c)	1.1
South Korea	60000 (c)/ 27000 (c)	2.8 / 1.3
Thailand	24613 (c)	1.1
USA	18000 (c)/ 45000/ 57000 (c)/ 29500 (c)	0.85/3.1/2.7/ 1.4
Total	494177	23.2

Note (c): conventional (high pressure) hydrocracking (>100 bar), (m): mild to moderate hydrocracking (<100 bar).

3.2.3 Gasifiers

Another option is to gasify the HFO in order to produce syngas, which can be used for the production of chemicals, electricity and hydrogen. In 2004, coal was the primary substance that was being gasified worldwide (49% of the capacity in 22 installations), followed by oil (37% of the capacity in 57 stations, amounting to 16,400 MW_{th}). 9% of gasifying capacity involved gas being gasified in order to make chemical products and clean motor vehicle fuels. Finally, smaller percentages were used for petrocokes (3%) and biomass/waste (2%). Strong growth was expected in 2005, particularly for coal (41%) and gas (43%). For oil, this was 8%. The 16,400 MW_{th} from 2004 is equivalent to 44,000 tons per day or 16 million tons of HFO and other oil products per year. In Europe, the installations involved are located in the Netherlands, Italy and Germany. Current capacity is at least 16.2 million tons, assuming that the increase between 2000 and 2007 in projects inventoried by the ECN is about 4.4 million tons. (Sources: NETL, 2005; McGehee, 2006; Zuideveld, 2003).

3.2.4 Overall picture

It can be concluded that the world residual processing capacity has risen over the past seven years by 36 million tons (19%), while primary capacity over the same period increased by 5% (see Table 3.4).[5] Including the processing of residual oil by gasification, the increase is approximately 41 million tons or 20%. Relatively speaking, residual processing capacity is increasing four times faster than primary capacity. If the expansion of residual conversion capacity continues to grow at the same rate as the 41-million-ton increase in capacity accomplished over the past 7 years, it would take almost 35 year to achieve an increase of 200 tons per year.

Table 3.4 *Summary overview of world capacity in million tons, along with the % increase*

	1 January 2000	1 January 2007	Increase 2000-2007	
Primary refining capacity	3,750	3,920	170	5%
Specific to vacuum conversion				
Cokers and flexicokers	176	206	30	17%
Residue hydrocrackers	16.4	22.7	6.3	38%
Subtotal vacuum conversion	192.4	228.7	36.3	19%
Gasifying	ca. 11.8	ca.16.2	ca. 4.4	ca. 37%
Total	204	245	41	20%

Table 3.4 reveals that the world increase in primary processing capacity of 5% over the last seven years corresponds to approximately 170 million tons conversion capacity. In the case of primary capacity too, the entire increase involves complex installations along with their associated systems. Technically, it therefore appears possible to expand capacity for deep conversion of residual fuel[6] by 200 million tons in about seven years. The issue will therefore primarily be whether expansion of deep conversion capacity can be achieved *in addition to* the autonomous activities involved in primary capacity expansion.

3.3 Refining capacity in the Netherlands

3.3.1 Six Dutch refineries

Table 3.5 provides a survey of the Dutch refinery capacity (Netherlands Petroleum Industry Association; VNPI) (Port of Rotterdam Authority, 2007). Of the 66 million tons of refining capacity, 58 million are located in the Rotterdam port area (see Figure 3.5; source: Port of Rotterdam Authority). As of 1 January 2005, the worldwide refining capacity was 82 million barrels per day (Oil & Gas Journal, 2006; BP gives a higher figure on its site: 85.7 million barrels per day). The Dutch share amounted to approximately 1.6%. The VNPI expects 3 % annual growth until

[5] With annual growth in the demand for oil of 1.5%/y (see 5.1) and an increase in primary capacity of 0.7%, any surplus in refining capacity would quickly be absorbed.

[6] Residual fuel is assumed to resemble the composition in the Netherlands, containing vacuum residues, atmospheric residues, and some distillates for blending purposes (see Paragraph 3.3.4 and 3.3.5).

2010/2012.[7] Disregarding an announcement of limited changes, there are no plans for large scale investments known to ECN. Given that such company information is considered strategic, plans are generally only announced when they have to be made known as part of a request for a permit, for example.

Among the mentioned refineries, Exxon Mobil possesses a flexicoker installation in which residual oil from its Rotterdam refinery and from Antwerp (Belgium) is converted into lighter products. This process also produces a great deal of heat, residual gas and cokes. Due to this flexicoker (listed in Table 3.5 under thermal operations), this refinery does not produce any residual fuel and will therefore not be (directly) affected by the Intertanko proposal. The Exxon Mobil refinery therefore demonstrates that, under certain (market) conditions, it is both technically and economically possible to entirely refine crude oil into light products. The Koch refinery does not produce any residual fuel as well and, consequently, will also not be directly affected by the Intertanko proposal. However, this is because the Koch installation does not process crude oil but natural gas condensate.

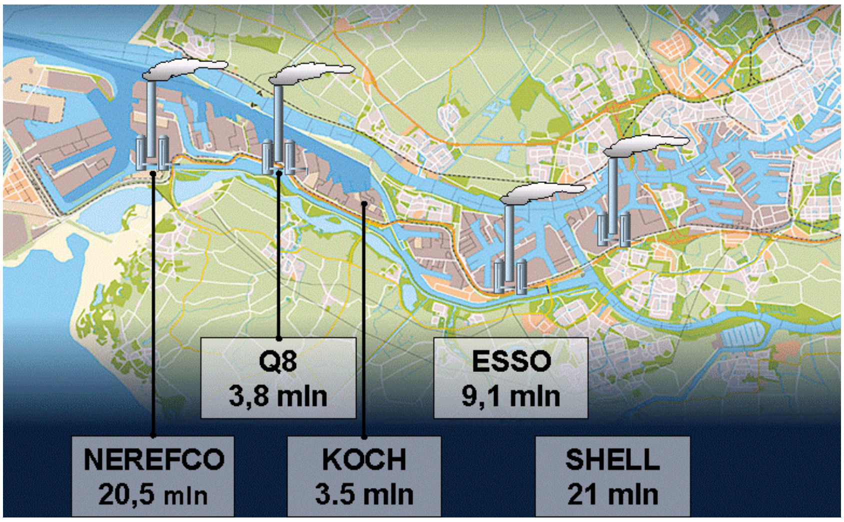

Figure 3.5 *Location of the five refineries in the Rotterdam port area*

Table 3.5 *Refining capacity in the Netherlands in 2004 (thousand barrels per day)*

Location	Owner	Crude	Vacuum distillation	Thermal operations	Cat-cracking	Cat-reforming	Hydro-fining	Hydro-treating	Hydro-cracking
Pernis	Shell	418	140	46	48	42	23	233	55
Europoort	Nerefco	400	88	36.7	58.9	31.4	91	176.5	0
Rotterdam	Exxon M.	195	90	40	n.a.	30	n.a.	130	60
Vlissingen	Total	158	59.5	n.a.	n.a.	26.3	n.a.	48	50
Rotterdam	Kuwait	86	41.5	17.5	n.a.	22.6	n.a.	73.5	
Europoort	Koch	75	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Table 3.6 shows current employment at the refineries in 2006. They directly account for 3,240 jobs (Port of Rotterdam Authority, 2007; Total: www.trn.nl). However, numerous employees of third parties are also working at these sites. Total indicates that around 120 individuals from other companies work at its facilities every day. Based on this information, it can be concluded that the entire directly-employed work force likely consists of an additional 1,000 individuals. This means that somewhere between 4,000 and 4,500 employees are active at the refineries.

7 This can be deduced from the increase in CO_2-emissions indicated on the XLS sheet 'Emissies van NO_x, SO_2 en CO_2 door Nederlandse raffinaderijen' (Emissions of NO_x, SO_2 and CO_2 from Dutch refineries) on the VNPI website.

Table 3.6 *Direct employment at Dutch refineries*

Owner	Number of direct employees
Shell	1,458
Nerefco	534
Exxon Mobil	580
Total	340 (and 120 from other companies)
Kuwait	305
Koch	25

3.3.2 Refining capacity is geared to volume of 'regional demand'

In Europe, there is both a shortage of kerosene, which is imported from the Middle East, and a shortage of diesel fuel, which is imported from Russia. A surplus of petrol is exported to the US. The shipment of products is, in most cases, more expensive than the transportation of crude petroleum because smaller ships are used. For this reason, primary capacity and throughput in refineries are partly determined by local demand.

In Europe, bio-fuels are on the upswing. In principle, this will decrease the growth in demand for petroleum-based fuels in our region. This will also curtail the readiness to invest in new capacity. If refineries nevertheless invest in capacity expansion, the result will likely be a surplus of capacity, making it less attractive for others to do the same. Guaranteed regional sales across the entire spectrum of light products (including petrol) will make expansion into strong growth markets, such a Southeast Asia, more appealing to refining companies than enlargement of their facilities in the Netherlands. Conversely, refineries will, to a large extent, be able to focus on maximising production of marine fuels and other diesel fractions for which there is a large demand in Europe. This will, however, require additional investment in such items as hydrocracking capacity and possible divestment of the existing capacity in catcrackers. [8]

[8] A solution supplementing the implementation of the Intertanko proposal with a better alignment to regional demand (increasing diesel fuel requirement) and supply (petrol surplus) would involve making the use of petrol in personal vehicles more attractive by reducing the taxes on it. This would, however, lead to higher CO_2 emissions from personal vehicle transportation due to the lower efficiency of petrol engines in comparison with diesel engines.

3.3.3 Previous large changes at Dutch refineries

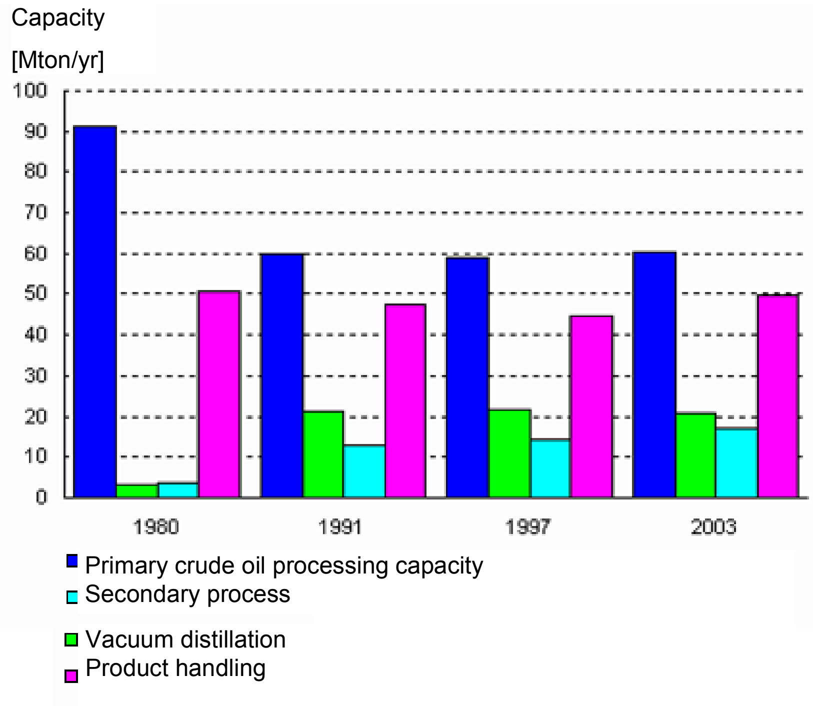

Figure 3.6 *Change in Dutch refinery capacity (1980 - 2003)*

Many large changes have occurred in the Dutch oil refining industry, especially in the period from 1980 to 1990 (see Figure 6; source: energie.nl). In 1980, oil was distilled and heavy residues were simply sold as fuel oil or bunker oil. In the 90s, the residues were partly separated in vacuum distillation. Crackers were used to transform the light portion into petrol and diesel. The heavy component went to sea ships. In the mid 1980s, the Netherlands began to crack the heavy residues as well, initially in a hycon at Shell and a flexicoker at Exxon Mobil (see Section 3.1.1).[9] There are now more flexicokers in existence. Shell has also had a gasifier for residues producing hydrogen and energy since 2003. To make high quality diesel fuel from vacuum gas oil, the gas oil is further refined in a hydrocracker (comes under the heading of 'secondary processes' in the legend of Figure 3.6). Simultaneous desulphurisation occurs during the hydrocracking process.

3.3.4 Bunker oil in Dutch refinery production

In Figure 3.7, the importance of bunker oil in Dutch refinery production is expressed in millions of tons of gross production.[10] The Netherlands does no longer have any industry or electrical energy plants that use fuel oil. Industry primarily uses gas, while energy plants burn gas or coal. The refineries do not therefore have a domestic market on which to sell heavy fuel oil and therefore mainly concentrate on the market for bunker oil. Bunker oil is actually a type of 'residual product'. It is sold at a lower price than the crude oil from which it is made (see Section 2.2).

[9] These investments were connected with a gentlemen's agreement in which it was agreed that Exxon Mobil and Shell as participants along with the Kingdom of the Netherlands in the Gasunie would make substantial investment in the Netherlands.

[10] This is not all made from crude oil. Refineries also purchase semi-refined petroleum products as well as oil in order to improve the quality of their production.

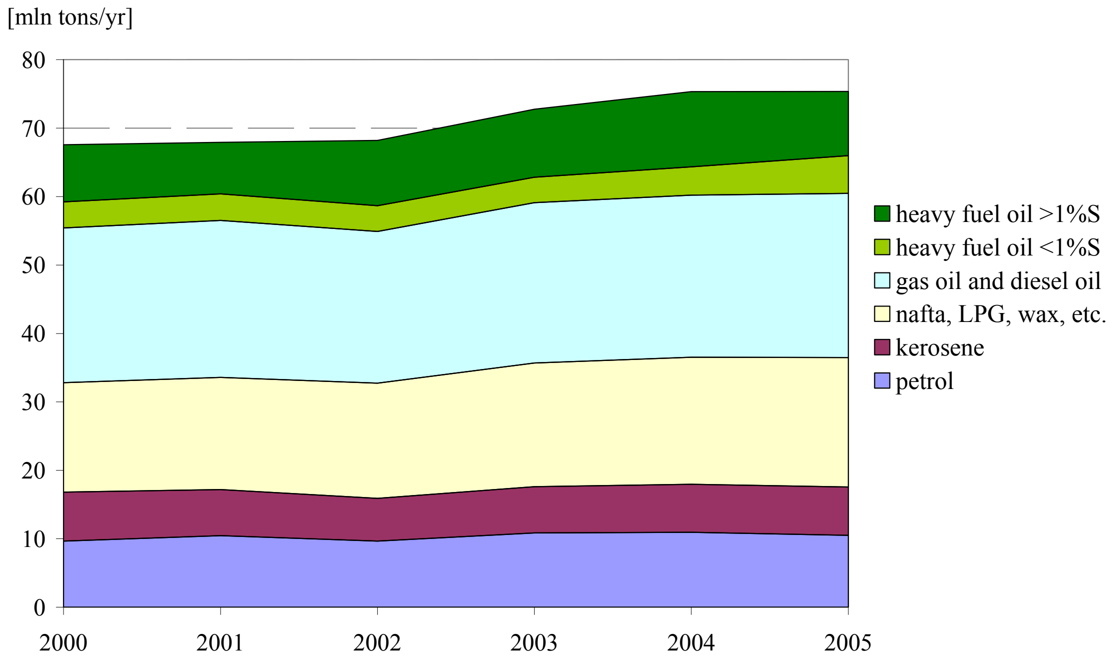

Figure 3.7 *Gross production of Dutch refineries*

Table 3.7 displays the data from Figure 4.3 in percentages. The quantity of residual fuel produced by refineries in the Netherlands in recent years has amounted to about 10 million tons a year. In this regard, it must be noted that the refineries have also purchased heavy oil in order to bring their own residual oil up to market quality (especially for the bunker market). Any loss of sales for HFO bunker oil will not necessarily mean that the refineries will have 10 million tons of residue left over. This figure will be a few million less. Likely, the production of residual fuel in the Netherlands will remain around 8 million tons per year, although this forecast can only be a rough estimate because statistics do not make any distinction between bunker oil for sea-going vessels and heavy fuel oil for fuelling energy plants, furnaces and steam boilers.

Table 3.7 *Gross production from Dutch refineries (percentages)*

[%]	petrol	kerosene	nafta, LPG, wax, etc.	gas oil and diesel oil	fuel oil <1%S	fuel oil >1%S
2000	14	11	24	33	6	12.4
2001	15	10	24	34	6	11.1
2002	14	9	25	32	5	14.0
2003	15	9	25	32	5	13.6
2004	15	9	25	31	6	14.6
2005	14	9	25	32	7	12.4

For future developments, see Section 3.4.

3.3.5 Proposed solutions for surplus residual fuel

For full conversion of the total amount of residual fuel produced in the Netherlands (the residues from atmospheric and vacuum distillation), the first step might be to expand vacuum distillation so that the entire residue from atmospheric distillation is processed. A substantial expansion of capacity in vacuum distillation is possible (especially in the case of the Nerefco refinery), and this could reduce the total quantity of (vacuum) residue in the Netherlands to 5 million tons. Increased vacuum distillation would also create about 3 million tons of vacuum gas oil that can (probably) be refined into heavy distillate for the maritime industry. The vacuum gas oil can also be processed into high-grade road fuel using catalytic crackers and hydrocrackers.

In the Netherlands, there are now three options available for processing the residual oil from vacuum distillation (see Table 3.8).

Table 3.8 *Processing options already in use*

	[million tons/yr]	
Flexicoker Exxon Mobil	2.1	Makes light products, heating and residual gas
Hycon Shell	1.3	Makes light products, requires hydrogen
Gasifier Shell	0.5	Makes residual gas, energy and hydrogen

Example:
To process the 5 million tons of vacuum residues remaining after the above-mentioned maximum expansion of vacuum distillation capacity, two or three flexicokers would have to be built with a total processing capacity of approximately 5 million tons per year. The investment in the existing flexicoker at Exxon Mobil, with a processing capacity of approximately 2.1 million tons of vacuum gas oil per year, amounted in 1985 to around 2.5 billion guilders (now about € 1.5 billion). This price also includes all other costs involved in renovating and constructing extra facilities, such as a vacuum distillation unit, product handling systems and a hydrogen plant. Based on these investments in the past, facilitating the complete processing of the residues in the Netherlands by constructing flexicokers would, if renovation work is more or less done at the same time, require an investment of approximately € 3.5 billion.

The European Petroleum Industry Association (Suenson, 2007) states that a great deal of investment is required for the worldwide production of 200 million tons of marine distillate. For Europe, this would involve the construction of about 50 million tons of 'deep conversion' processing capacity, a total investment of roughly € 30 billion. This estimate is based on the construction of 50 new processing units. The flexicoker is globally viewed as the most applicable technology for deep conversion. Downscaled to the capacity of the Exxon Mobil flexicoker in the Netherlands (2.1 billion tons per year) and disregarding any possible scaling factors, this would require an investment of about € 1.26 billion. The Oil & Gas Journal (2006) provides a figure for investment in flexicoker capacity that is nearly an order in magnitude lower, specifically € 115-180 million for a capacity of 2.1 million tons. However, this amount only covers the costs of one part of the required changes.

To provide an indication of the time required for a project, the management decision at Shell about the construction of a flexicoker was probably made in 1980 (the initial costs estimates date from that year). In 1981, the project was contracted out to an engineering firm (to make the detail design, etc.). Construction started in 1983 and the project was completed in 1986. Such a complex implementation process therefore demanded a completion time of about seven years. According to estimates in 1985, the project was to provide permanent employment for 250 people.

It should be clear that there is only limited capacity and expertise in the world capable of accomplishing this type of project and manufacturing the required equipment (for certain large and specific components, there are only a small number of manufacturers in the entire world). Viewing the situation in the Netherlands, it might perhaps be possible to undertake such a project every 1 ½ years (unfortunately, we have not managed to have this assessment verified in the sector). This means that, once the decision has been definitively made to undertake three large refinery renovations, their completion would only occur between seven years (for the first) and eleven years (for the third) from the decision date. Problems involving permit acquisition could easily extend the period by a number of years. A longer implementation period lowers the costs, and a few years delay provides the opportunity to undertake development work on more efficient options.

Other proposed solutions for processing residue flows that are not further elaborated in this quick scan might be:
- Gasifying residue for the sake of electricity generation;
- Selling residue to other refineries;
- Selling residue as industrial fuel or fuel for energy plants in developing countries;
- No net capacity expansion but shifting fuel residues between markets and sectors.

3.3.6 Further analysis of difficulties affecting the rate of construction/renovation

Under contract to the Department of Energy (EIA, 2007), a study was made of the major overhaul of refineries. During a maintenance period lasting 20 to 60 days, the number of employees at a refinery (around 500) is temporarily enlarged by 1,000 to 1,500 people. Major overhauls occur around every 4 to 5 years. The report indicates that the preparation for a major overhaul required two years, or even more if large changes are to be implemented. We are therefore talking about a period of 2½ to 3 years. It frequently takes 2 or more years to design and manufacture new reactor vessels, compressors and turbines. Cranes and other equipment must also be reserved sufficiently in advance. Not everything can be planned, as the actual work on a major overhaul takes on average an extra 5 days. Sometimes, there are also malfunctions requiring immediate repair.

Companies that provide temporary employees have an important role to play. A study about major overhauls at FCC installations reveals that maintenance options are currently restricted due to a lack of personnel. No available personnel means no overhaul. Scarcity of skilled, temporary employees is therefore a relevant factor.

The length of time that a refinery would have to discontinue operations in order to achieve the necessary expansion is not precisely known at ECN. The absolute minimum time, in which the new installation can be constructed beside the operational one and only the connections need to be realised, is however still 2½ months (loss of 20% of annual production). In more complex situations, this time can extend up to 1 year. If 40% of European refineries have to be modified in 1 year, this would mean a capacity loss of 8 to 40%. With a 5-year switchover period, the margin becomes 2 to 8%. Consideration should be given to combining renovation with current maintenance and to the fact that it is unnecessary to make all the changes precisely during the stated period.

The following example illustrates these effects. During the situation concerning Hurricane Rita, prices in the US went up extremely rapidly, while only 5% of production capacity was directly affected. It must however also be noted that changes known in advance have different effects on the market. In regions where a large amount of maintenance is being performed and many refineries are off line, the result is increased importing of products and less of crude oil.[11] A limited amount of inventory can even be built up. The problem in this case is that the change must be implemented worldwide.

It is possible to conclude that the availability of expert personnel will represent a bottleneck that will cause investment to be spread over several years. It is not clear if a period of five years would be sufficient in this regard. The current scarcity in refining capacity is another factor necessitating the switchover to be drawn out over time. A rapid conversion would require so much capacity to be taken offline that it would have significant consequences on the price of oil products.

[11] http://www.coking.com/forum/m.asp?m=869.

3.3.7 Possible reactions from Dutch refineries

It is difficult to draw conclusions that apply to each individual refinery. Decisions about investment are made by these companies' international boards of directors. Below is an estimate of the possible operational changes at the six largest refineries in response to a potential prohibition on the use of HFO in the shipping industry.

- The Exxon Mobil refinery (capacity of around 9.1 million tons/yr) does not have to modify its refining process because of the above-described flexicoker that already converts residual fuel into lighter products.

- The relatively small Koch refinery (capacity of around 3.5 million tons/yr) does not have to modify its refining process because it does not use crude oil as raw material but natural gas condensate, a base material that does produce any heavy residue. There is however a movement at Koch to begin processing crude petroleum.

- The Shell refinery (capacity of approximately 21 million tons/yr) is a complex refinery that has already implemented process steps to reduce the proportion of HFO in production. Together with Great Britain, the Netherlands is the ‘home base’ for Shell. Shell also participates with Exxon Mobil and the Dutch government in the Gasunie. The chance that Shell will invest in its Dutch refinery in order to adapt to the new situation is therefore higher than average.

- Nerefco is a large refinery (capacity of around 20.5 million tons) from which one of the partners is going to withdraw. As a result, Nerefco will become wholly owned by BP. The refinery possesses a catalytic cracking facility for the processing of vacuum gas oil. Nerefco is a relatively simple refinery that, due to a limited capacity in ‘deep conversion’, produces a relatively large quantity of heavy residue. Therefore, Nerefco will have to make substantial investment in order to process its own heavy residue flows. This does not only involve reprocessing residues from the vacuum installation by constructing a flexicoker or hycon processing capacity. Because Nerefco currently only further refines a portion of the residues from atmospheric distillation in vacuum distillation, an expansion of vacuum distillation capacity is also required, as well as refining capacity for the additionally produced vacuum gas oil. The chance that the Nerefco refinery will invest in the necessary modifications is considered to be average.

- Total, a somewhat smaller refinery in Vlissingen (capacity of around 7.9 million tons), has a hydrocracker for the processing of vacuum gas oil. The Total refinery is therefore more complex than the Nerefco refinery. Total only needs to invest in the processing of residual oil. Because Total's refinery produces less HFO than the Nerefco refinery, its investment costs are however relatively high. The chance that the Total refinery will invest in the necessary modifications is considered to be average.

- The Kuwait refinery is still a degree smaller than Total (capacity of around 3.8 million tons/yr) and is less complex, but it already has, for example, a vacuum distillation unit. Kuwait has recently made attempts to sell the refinery (ANP-AFX, 2006). The chance that the current owner is ready to make extra investments is therefore considered to be less than average. In addition, investment becomes relatively more expensive as the scale of the installation become smaller.

If no investment is made in HFO processing, the competitive position will deteriorate over time, especially if a situation of overcapacity should recur.

3.4 Model calculations

ECN possesses a refinery model (SERUM) with which to calculate changes in the Dutch oil refining sector (Oostvoorn, 1998; Kok, 1997).[12] This model was used to calculate the effects of the Intertanko proposal on the Netherlands in relation to a reference scenario. The model gives a good impression of the direction and a usable indication of the possible size of the effects. The model is, however, limited to the extent that individual companies are not modelled separately.

3.4.1 Future development in demand for bunker oil

Table 3.9 contains the findings from the study 'Welfare, Prosperity and Quality of the Living Environment' (WLO), (Janssen et al., 2006) concerning the development of the production demand of refineries, according to the so-called Global Economy (GE) scenario (see Section 4.1.1 for a brief description). Net production is involved here. Products that the refineries purchase in this regard (such as oil for blending with marine fuels) are, in this calculation, deducted from gross production. This development is, however, depicted against a background in which the share of bio-fuels in the Netherlands initially remains limited to 2%. The EU objective for the proportion of bio-fuels in transport has now been raised to 5.75% in 2010 and 10% in 2020.

Table 3.9 *Net production of refineries in the GE scenario (WLO)*

[million tons of oil]	2000	2005	2010	2015	2020	2025	2030
LPG	1.2	1.1	1.0	1.0	1.1	1.2	1.3
Petrol	11.2	10.9	11.3	11.7	14.1	18.0	19.6
Nafta	4.4	5.3	5.9	6.6	6.5	6.5	6.5
Kerosene	5.8	6.1	7.4	8.6	11.9	14.8	15.4
Car diesel	13.0	12.9	13.5	14.0	16.9	20.2	21.5
Public transport gas oil	7.5	7.3	7.6	7.7	7.8	7.8	7.8
Heavy fuel oil/bunker fuel	9.2	10.1	10.0	11.0	12.5	13.5	14.0
Asphalt	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Lubricant and wax	0.8	0.7	0.7	0.7	0.7	0.7	0.7
Net total production	53.7	54.9	57.8	61.8	72.0	83.1	87.3

Figure 3.8 shows how physical CO_2 emissions in the sector will also change. The development in emissions beginning in 2000 runs reasonably parallel to refinery production. Until 2010, there will be a somewhat stronger rise in emissions resulting from the extra energy needed to make cleaner fuels for motor vehicles. In the indicated GE scenario, investment in the expansion of refinery capacity will be made around 2020, resulting in an increase in throughput.

[12] The developed LP model (Linear Programming Model) named SERUM (Static ESC Refinery Utility Model) can calculate the consequences of various changes that refineries are facing, such as changes in product demand, product specifications and emission requirements. The model, which was developed under contract to the Netherlands Ministry of Economic Affairs, describes the processing of a mix of three types of crude oil (Brent Blend, Iranian Light and Arabian Heavy) into final products such as petrol, diesel and heavy fuel oil.

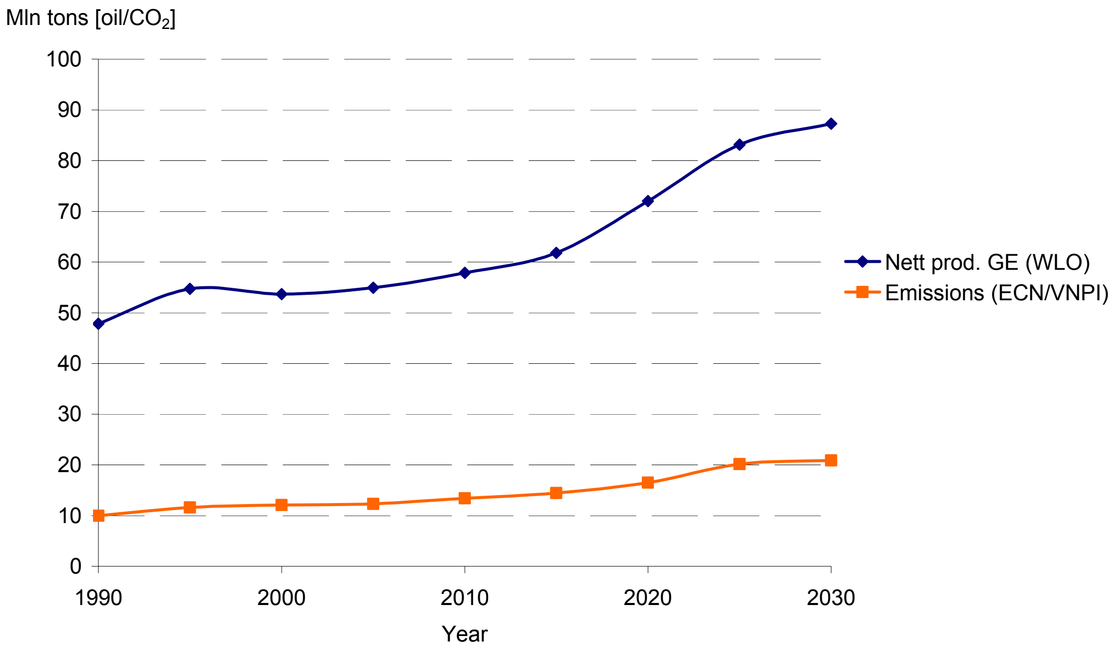

Figure 3.8 *Growing oil processing (blue) and CO_2 emissions (orange) for the WLO GE-scenario*

Production of clean road fuels (10 ppm diesel and petrol) and HFO with 1.5% sulphur for SECAs is already included in these calculations.

3.4.2 Model calculations

To calculate the effects of the Intertanko proposal on increased crude oil demand and CO_2 emissions using this model, the new fuel qualities prescribed by the Intertanko proposal need to be included in the refinery model. The proposed requirements for distillate fuels resemble what the 'International Council on Combustion Engines (CIMAC)' names DB, with a viscosity of 11 cSt at 40°C. There is still a heavier distillate (DC with a maximum viscosity of 14), and there are also two lighter distillates (DX and DA with respective maximum viscosities of 5.5 and 6.0). The ECN model contains the most important quality requirements for current oil products. The model uses an index to calculate viscosity, making it possible to take it further into account in terms of volume shares, the usual practice for this type of model. The viscosity from the Intertanko proposal (Intertanko, 2006b) of 11 cSt at 40° C is translated into 7 cSt at 130°F for this purpose. The other requirements can be used directly in the model (see Table 3.10).

Table 3.10 *Quality requirements in the SERUM model*

Requirements	Bunker fuel	Distillate (Intertanko)	Distillate in model
Specific gravity	0.99	0.9	0.9
Viscosity	0.7 index	11 cSt at 40° C	0.431 index (7 cSt at 130° F)
Carbon residue	22%	0.3%	0.3%
Sulphur	3%	1%	1%

Two sets of calculations were conducted for 2015 using the above-mentioned GE scenario of the WLO (Janssen et al., 2006). The standard calculation is preformed using an oil price of 22.7 \$/barrel (180 €$_{2000}$/ton). The GE scenario also has a high oil price variant of 36.2 \$/barrel or 290 €$_{2000}$/ton. The high oil price scenario is also computed as a sensitivity analysis. Taking the exchange rate between the euro and the dollar into account, as well as inflation since 2000, the high oil price variant comes closest to the currently high oil prices in €$_{2007}$/ton. To obtain a good idea about the consequences of additional crude oil demand and CO_2 emissions, calculations include a gradual tightening of sulphur requirements. The results are displayed in Table 3.11 and Table 3.12.

Table 3.11 *Effect of the sulphur and distillate requirements on additional oil demand and CO_2 emissions in the GE scenario for 2015*

Sulphur content of bunker fuel	3% & 1.5% SECAs	1.5%	1%	0.5%	Difference between 0.5% and 3% S
Emissions [Mtons CO_2]					
Only sulphur (GE)	13.4	14.0	14.7	15.3	1.9
Distillate (GE)			16.8	17.1	3.7
Only sulphur (GE HP)	14.3	15.0	15.5	16.2	1.9
Distillate (GE HP)			17.5	17.7	3.4
Energy supply [million tons of oil eq]					
Only sulphur (GE)	67.3	67.5	67.7	68.0	0.7
Distillate (GE)			68.5	68.5	1.2
Only sulphur (GE HP)	67.7	67.9	67.7	68.4	0.7
Distillate (GE HP)			68.5	68.6	0.9

In these standard scenario calculations, the oil price is at a relatively low level (22.7 dollars/barrel [180 €$_{2000}$/ton]). Despite the low oil price, in the GE scenario demonstrates that it remains profitable in 2015 to build somewhat more residual conversion capacity, given the projected shifts in demand to oil products. However, if there is no expansion, there will hardly be any increase in production costs, capital expenses will be lower and there will be more investments in the importing of oil and other fuels. Consequently, there is a balance for oil companies between investing in their own refinery capacity and purchasing more expensive crude oil. The calculation results, however, show a considerable margin in this respect.

At a certain point, the model is limited in the possibility of adequately reprocessing heavy oil, and a part of it is then ‘discarded’. The reason for this threshold is that, despite North Sea oil being shipped in, there are no further possibilities for processing residues into sufficiently light products in the most usual version of the model. The parameters in the model for both the hycon and flexicoker are set for the processing of heavier residues than those from North Sea oil (Brent Blend). To resolve this, in the model a coker is ‘activated’ for which parameters were available for processing the residue in question. With this adjustment, the model is however being used outside its normal limits.

In the GE scenario of 2015, it is assumed that around 3 million of the 11 million tons of residual oil can be sold as heavy fuel oil and 8 million tons in the form of bunker oil. It is these 8 million tons that have to be desulphurised or replaced by distillate. Table 3.11 reveals that the desulphurisation of bunker oil delivers around 1.9 Mtons of extra CO_2 emissions and the making of desulphurised distillate (0.5% sulphur) around 3.4–3.7 Mtons. Notably, the distillate requirements are such that, in the refinery structure used, sulphur content automatically returns to around 0.8%. Mathematical models for the distillate fuel requirement and a sulphur content higher than 0.8% (e.g. 1%, 1.5% or 3%) also generate the same solution. Table 3.11 shows that the desulphurisation of bunker oil requires approximately 0.7 million additional tons of oil equivalent of energy and the distillate requirement approximately 0.9–0.12 million tons of oil equivalent.

If consideration is given to the fact that the combustion of 1 million tons of crude oil yields about 3.1 million tons of CO_2, the relationship between energy input and CO_2 emission is clear. The differences that are subsequently discernible involve, to an important degree, a shift in the purchase of natural gas. The more that requirements to the model are increased, the greater the (price) pressure in the model on a switch to HFO combustion, instead of natural gas.

Based on the calculations, it can be concluded that the replacement of 8 million tons of bunker oil by distillate is linked with increased CO_2 emissions of approximately 3.5 Mtons and additional energy consumption of around 1 million tons of oil.

The European Petroleum Industry Association (EUROPIA) reports that a worldwide required quantity of distillate amounting to 200 million tons, of which 50 million tons are needed in Europe, produces an increased CO_2 emissions of 35 million tons. Extrapolating the European distillate demand of 50 million tons from the situation in the Netherlands, the ECN calculations indicate additional CO_2 emissions of (50 ∗ (3.5⁄8) =) 22 million tons, therefore a lower amount than the 35 million ton figure provided by EUROPIA. Assuming a worldwide distillate demand of 200 million tons, the global increase in CO_2 emissions would total approximately 90 million tons.

The costs for the refineries, according to the calculations in Table 3.11, are shown in Table 3.12. The first line for ‘GE 2015’ and ‘GE 2015 with high oil price’ reveals that the annual capital expenses for the production of 8 million tons of distillate fuel increase by about 120–130 million (1150 minus alternatively 1020 and 1030). Using the annuity factor in the model, this is the equivalent of approximately € 1,500 million in extra investment. The figure can be higher if a correction is first made for investments in facilities that are no longer required. This could cause investment to increase somewhat (maximum € 500 million, the model only indicates the costs of facilities that are used and not of facilities that are likely still available but not included in the mathematical model). This € 1.5 (or perhaps 2) billion is therefore lower than the € 3.5 billion designated for flexicokers (capacity of 5 million tons/yr) in Section 3.3.5.

The European Petroleum Industry Association (EUROPIA) claims that production of an additional 50 million tons of distillate in Europe would require an investment of € 30 billion. Assuming the ECN calculations of the Netherlands situation to be applicable to all of Europe, the resulting investment requirement is calculated to be (50∗(1.5⁄8)=) € 9 billion (with a disinvestment margin up to € 12 billion). The difference is not explained by the fact that ECN is still using $euros_{2000}$ in its calculations.

Taking into account the necessary uncertainty in the ECN model, it can be cautiously concluded that the EUROPIA figures are not impossible but appear to be on the high side.

Table 3.12 *Effect of sulphur and distillate requirements for marine fuel on Dutch refinery costs (in million €/yr)*

Sulphur content of bunker fuel	3% & 1.5% SECAs	1.50%	1%	0.50%	distillate 1%	distillate 0.5%
GE 2015						
Capital expenses	1,020	1,050	1,120	1,080	1,140	1,150
Annual fixed costs	270	270	270	290	290	300
Variable costs	130	140	170	140	140	130
Purchase raw materials	13,830	1,400	14,010	14,040	14,160	14,180
Total costs	15,250	15,450	15,580	15,550	15,730	15,760
GE 2015 with high oil price						
Capital expenses	1,030	1,090	1,100	1,140	1,140	1,150
Annual fixed costs	270	280	290	300	290	300
Variable costs	130	150	150	150	140	140
Purchase raw materials	20,630	20,690	20,760	20,840	21,150	21,170
Total costs	22,060	22,220	22,310	22,430	22,720	22,760

Appendix B further details the capacities of the various types of installation in the model calculations. There is a tendency to use more deep conversion capacity due to the increased throughput in the GE scenario, the increasing average heaviness of crude oil and the reduction of the HFO share in sales. To outline the uncertainties, the appendix also includes another scenario (SE) in which, at a certain moment, the demand for oil begins to decline again due to large savings in energy consumption. In this model, deep conversion capacity increases much less and, at a certain moment, even begins to decline.

It is not the case that the worldwide tendency to invest more in deep conversion automatically leads to a shift from HFO to distillate in the shipping industry. The more HFO production decreases in comparison to demand, the higher the price will go. This makes it less interesting for other refineries to invest in HFO processing as well. There will always be a difference in price between HFO and distillate because the refining of HFO into lighter products requires substantial investment and incurs necessary energy costs. The price difference is so large that, in the business as usual perspective, the use of HFO for ship propulsion will always remain attractive to a significant number of ship owners.

4. The bunker market

4.1 Bunker volumes

Figure 4.1 shows the market for bunker oil in the Netherlands and clearly indicates an increase in bunker sales. The sale of fuel oil with a sulphur content under 1% remained very limited until 2005 (the thin dark-blue line above 'gas oil and diesel oil' in Figure 4.1) but then increased substantially since the establishment of the first SECAs in 2006. The sale of marine diesel (to inland shipping as well) remains more or less constant in the Netherlands ('gas oil and diesel oil' in the legend of Figure 4.1. Aircraft bunkers are not indicated in the diagram, although they increased to 3.5 million tons in 2005.

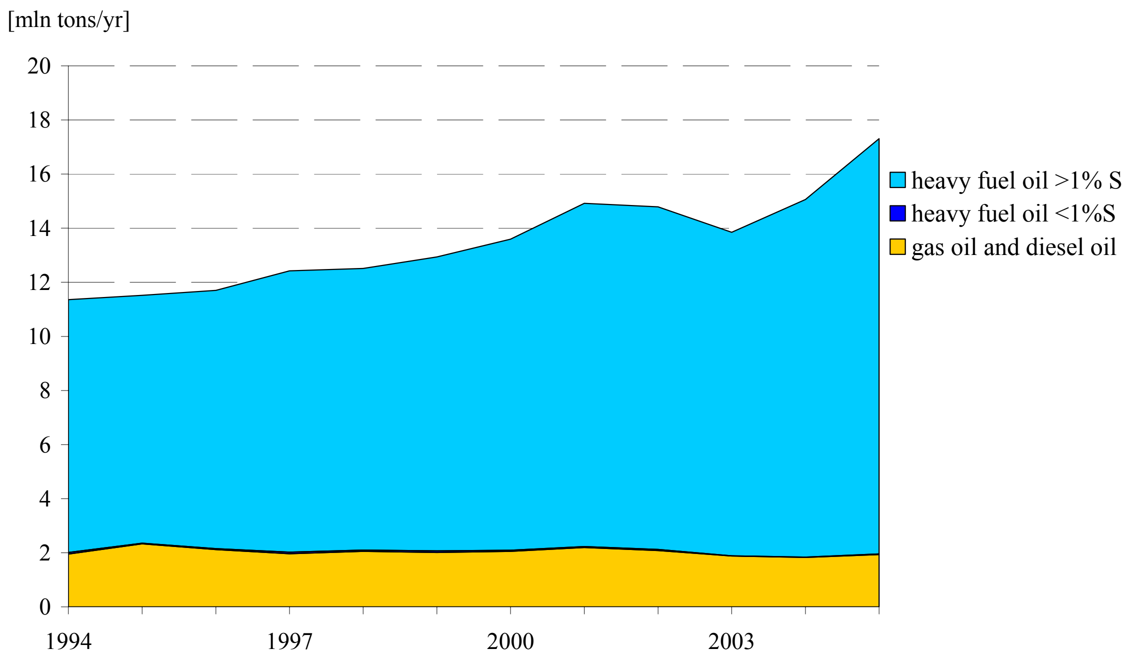

Figure 4.1 *Past bunkering of oil in the Netherlands*

The Dutch bunker market is depicted in detail in Figure 4.2. The diagram indicates the balance between production and import on the one hand (expressed in negative figures) and the terms of export and consumption on the other (expressed in positive figures). The negative numbers at the bottom of Figure 4.2 indicate that domestic (gross) production is hovering around 10 million tons/yr and that imports are mostly from Russia and Estonia (see Figure 4.3). Domestic consumption primarily represents the quantity of heavy oil that the refineries purchase themselves (to an important extent in order to use for their own bunker production, but heavy oil is also purchased for processing in distillation towers and crackers). The strong increase in imports is partly offset by exports to Singapore. These exports are attractive because the bunker oil price in Rotterdam is, on average, in the order of 10% lower than the Singapore price (see Table 4.3). These shipments primarily involve the transportation of 'Russian' oil (see Appendix D). Also of note in Figure 4.3 are the relatively large exports to Belgium. The extent of bunkering in Antwerp has risen in recent years and now amounts to roughly half the bunkering in the Netherlands. Additionally, the Exxon Mobil refinery in Rotterdam processes heavy oil from the Exxon Mobil refinery in Antwerp.

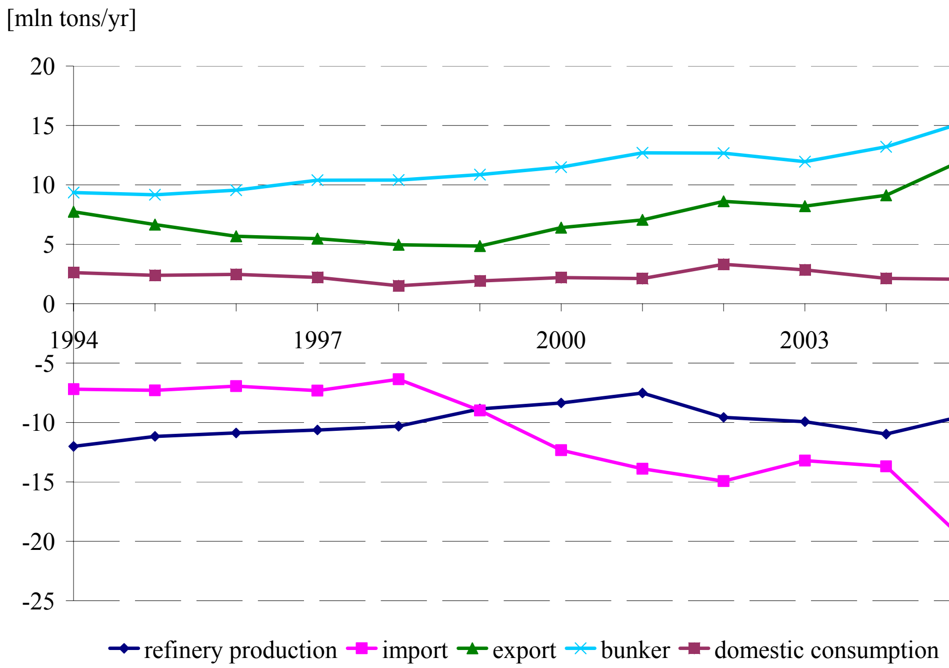

Figure 4.2 *Dutch market for heavy fuel oil and bunker oil (balance); the total from refinery production and import is equal to the total of bunkers, export and domestic consumption*

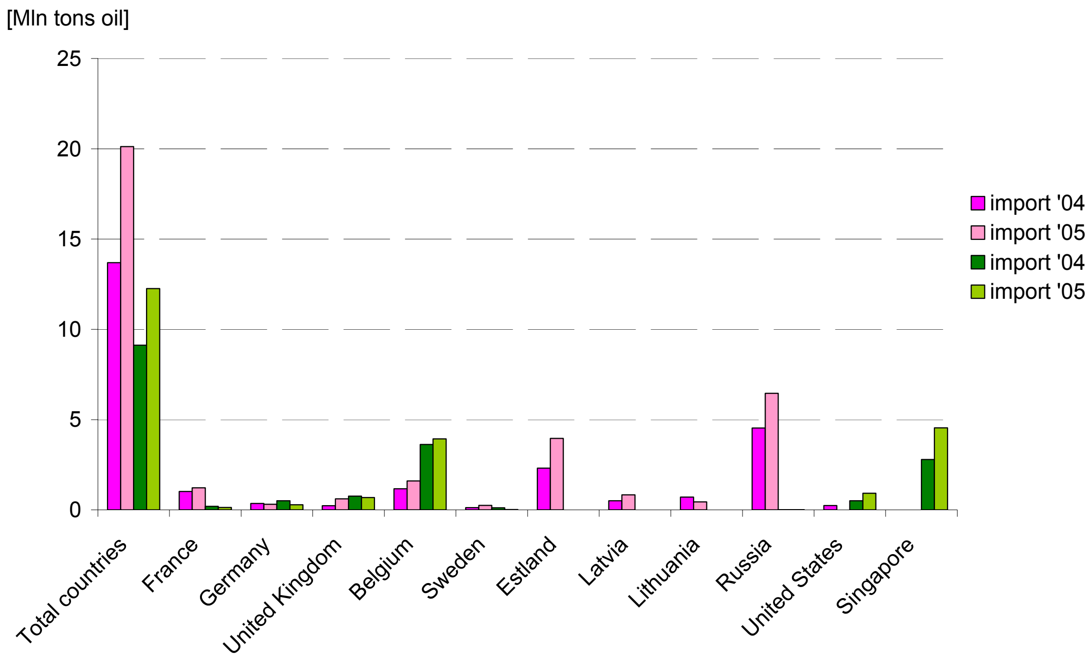

Figure 4.3 *Import and export of heavy oil per country (> 0.2 million tons)*

Figure 4.2 and Figure 4.3 reveal that the import of 20 million tons of bunker in 2005 together with a production of 8 million tons of bunker by Dutch refineries is in equilibrium with an export of 12.5 million tons and the 15.5 million tons of bunkering for ships.

4.1.1 Future development in demand for bunker oil

Figure 4.4 and Table 4.1 present the historical figures and future expectations concerning sales of bunker fuel, such as currently used in the Netherlands (see, for example, Hoen, 2006). To consider the future, use is made of two economic scenarios composed by the Netherlands Bureau for Economic Policy Analysis (CPB), namely the 'Global Economy' (GE) and the 'Strong Europe' (SE). The SE scenario forecasts moderate growth and strong public responsibility, and the GE scenario foresees high growth and a strong orientation on private responsibility. Although both scenarios are used in policy documents, it is especially the GE scenario that is most commonly used as a reference scenario.

With regard to future expectations, growth in ship bunkers is based on growth in the fuel consumption of ships, both in port and on the Netherlands Continental Plate (NCP). Viewed historically, such consumption correlates reasonably well with bunker demand (Hoen, 2006). The analysis indicating a rising bunker market suggest, however, that the relationship is more of a simultaneous development than one involving a causal relationship.

For the sake of completeness, domestic sales to inland shipping and the fishery are included, although these flows are very small in comparison with sales for ocean shipping. Further subdivision of the various types of marine fuel is not incorporated in future scenarios.

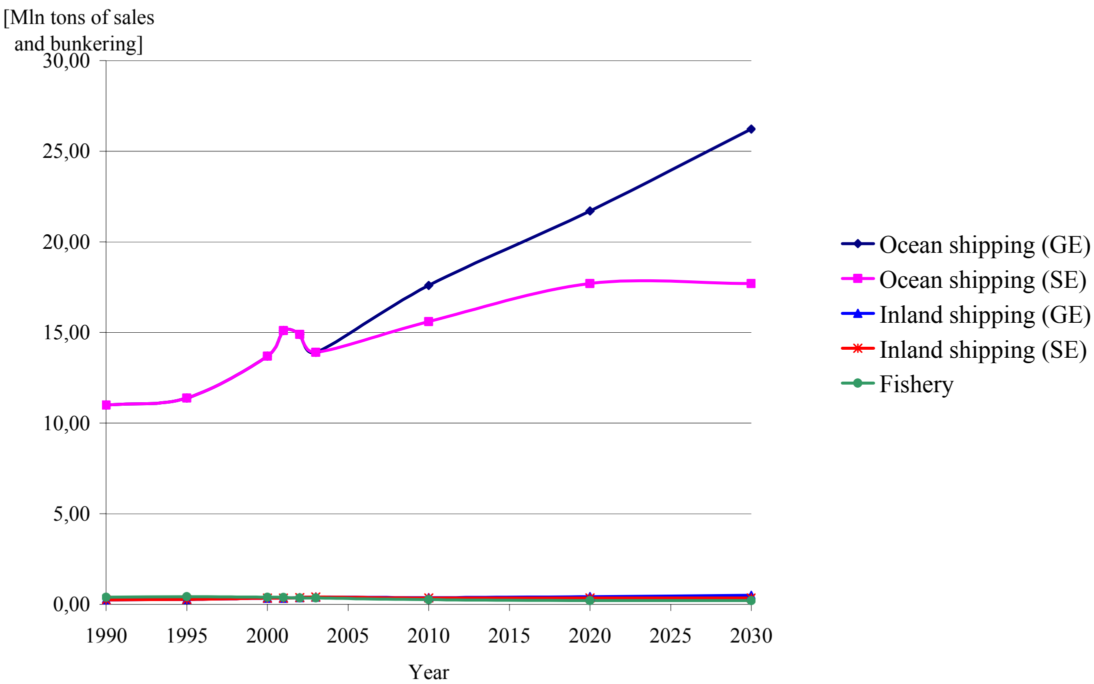

Figure 4.4 *Historical and future development in the demand for bunker fuels*

Table 4.1 *Historical and future development in demand for bunker oil*

	1990	1995	2000	2001	2002	2003	2010	2020	2030
Ocean shipping (GE)	11.00	11.38	13.70	15.10	14.90	13.90	17.60	21.70	26.23
Ocean shipping (SE)	11.00	11.38	13.70	15.10	14.90	13.90	15.60	17.70	17.70
Inland shipping (GE)	0.24	0.27	0.34	0.34	0.37	0.40	0.37	0.42	0.49
Inland shipping (SE)	0.25	0.27	0.34	0.34	0.37	0.41	0.35	0.35	0.35
Fishery	0.39	0.42	0.40	0.39	0.35	0.35	0.26	0.21	0.21

4.2 Scope and vulnerability

The strong increase in bunker oil demand in the Netherlands comes primarily from container shipping. These ships are the most prominent bunkerers on the Dutch market. There are additionally other products supplied to ships, such as lubricant. About 1,500 employees are directly involved in oil bunkering (Port of Rotterdam Authority, 2007).

Examining the entire array of bunkering activity (including marine diesel), the Netherlands supplied about 5% of the world marine bunker demand in 2000, amounting to approximately 13 million tons. In 2005, bunkering in Rotterdam rose to about 15.5 million tons.

Table 4.2 *Worldwide bunker market*

Million tons of oil (2000)	World	EU region
Total	252	51
EU flags	66	24
To and from EU ports	51	
In ports	10	3

With 1.6% of the refinery capacity in the world and 5% of the world's ocean-shipping bunkering, the Port of Rotterdam will be relatively strongly affected by the implementation of the Intertanko proposal.

Rotterdam has grown into one of the three most important players on the bunker market due to: (1) the bunker production at local refineries, (2) the large deepwater harbour enabling the biggest ships to port, and (3) a favourable geographical position for bunker imports from Russia and the Baltic states. Given these advantages, bunker fuels can be offered in the Netherlands at a structurally lower price than at other important bunker ports (see Table 4.3). The bunker market in Rotterdam would suffer a decline if the value of oil exports for the bunker market drops, and the same would hold true if some of the refineries were to decide to stop production of fuels for ocean shipping. The advantage of refuelling in the Netherlands would, in that case, disappear, especially for ships that also moor in Middle-Eastern or Far-Eastern ports.

Table 4.3 *Average bunker oil prices [$/ton] on 1 March 2007 (source: bunkerworld.com)*

Quality	IFO380 (HFO)	IFO180 (HFO)	MDO (marine diesel; not road diesel)	MGO (Marine gas oil)
Fujairah	314	323	585	591
Houston	273	286	531	
Rotterdam	*266*	*285*	*487*	*539*
Singapore	296	308	535	541

In the period of 1998-2002, oil prices were substantially lower. The 5-year average prices over the period 1998-2002 were 100 $/ton for HFO and around 180 $/ton for MDO/MGO.

4.3 Storage companies

Storage and transfer of oil is, in terms of tonnage, the most important product in the Port of Rotterdam. There are a large number of storage companies active in the port (see Table 4.4; Sources: Votob, Vopak; Port of Rotterdam Authority, 2007). These companies not only store liquid products but also improve bunker oil quality to a suitable level (see Section 2.2).

Table 4.4 *Tank storage companies and capacity*

VOTAB members	[1000 m^3]
Koole Tankstorage Pernis BV	300
LBC Rotterdam BV	80
Oiltanking	1,075
Odfjell Terminals (Rotterdam)	1,500
Petroplus	190
Vopak	6,544
Europoint Terminals Netherlands BV	1,250
Subtotal	10,939
Oil companies	11,885
Total	22,824

4.3.1 Importance of storage

The position of the Netherlands in the tank-storage field can also be illustrated using the throughput of liquid products, as represented in Table 4.5 (CRA, 2004). With regard to crude oil, it should be noted that Rotterdam, Wilhelmshaven and Le Havre are the only ports that can serve the large tankers of 175,000 to 440,000 tons from the Middle East. In other ports, crude oil is imported from the North Sea using smaller tankers (90,000 tons) and other means.

The role of storage and transfer is very important for the world trade in bulk products. Chemical plants and refineries require a continuous flow of raw materials and produce a continuous flow of products. Conversely, the supply and removal of raw materials and products on ships is precisely not continuous; large quantities are delivered and taken away at one time. In particular, the less frequent links have a strongly graduated capacity. The tanks in Rotterdam provide the necessary buffer in this transportation system, one that gradually collects products for tankers in the course of weeks or that unloads tanker cargo in the course of weeks (onto smaller ships or with pipelines).

The position of Rotterdam regarding the export of HFO to the Far East is clear in this regard. Oil products are delivered to the port from places such as Russia and collected there. An enormous quantity of bunker can then be shipped all at once on a mammoth tanker. There are few alternatives for this process.

Table 4.5 *Throughput of liquid goods in West European ports for 2003*

	Crude oil		Oil products		Other bulk liquid products	
	Throughput in 2003 [million tons]	Market share [%]	Throughput in 2003 [million tons]	Market share [%]	Throughput in 2003 [million tons]	Market share [%]
Rotterdam	99.8	55	27.5	29	25.2	60
Antwerp	6.9	4	21.2	22	7.1	17
Amsterdam	0	0	11.6	12	2	5
Wilhelmshaven	27.9	15	8.6	9	0.3	1
Le Havre	35.2	19	7.7	8	1.7	4
Dunkirk	6.8	4	5.5	6	0.9	2
Hamburg	4.1	2	5.3	6	2.2	5
Zeebrugge	0	0	4.7	5	0.2	0
Bremen	0	0	1.9	2	0	0
Gent	0	0	0.8	1	2.2	5
Total	180.7	100	94.8	100	41.8	100

5. Other economic effects

5.1 Effect of converting from HFO to distillate on the crude oil market

Based on 1 million tons of extra consumption for the deep conversion of 8 million tons of residual oil in the Netherlands, the worldwide conversion of 200 million tons would require an increase in oil consumption of 25 million tons. In relation to the world consumption in 2005 of 3,840 million tons (of which 700 million tons in the EU 25), world demand for oil could consequently increase by 0.65%.

EUROPIA (Suenson, 2007) indicates additional CO_2 emissions in Europe of 35 Mtons. Subtracting the reduction from ships due to better fuel quality, CO_2 emissions on balance for Europe will be 20 Mtons. The EU demand for distillate fuel needed for shipping will, as a result of the conversion, increase by about 50 million tons, a factor 4 lower than the world demand of roughly 200 million tons. Worldwide, CO_2 emissions will therefore be around 4 times as high, which is to say about 80 Mtons, or an increase in the demand for oil of approximately 45 million tons (1.2%). If all ocean-going ships are also able to obtain the associated efficiency gains, this increase in the world demand for oil will fall to about 27 million tons (0.7%).

The direct effect on the world oil demand depends on the period in which the switchover is to take place (see Table 5.1). Examining the developments in the oil price, there is no clear relationship between the increase in demand or increase in the demand for oil minus oil production and an increasing oil price. On two occasions when there was a large surplus of oil production (1986 and 1997), the price fell. Over the past 15 years, there has been 1 year with an increase in demand amounting to 3.9% and two years with demand increases of 2.6% (these were, however, also years in which production grew strongly).

Table 5.1 *Increase in the world demand for oil in % per year as a function of the number of years to complete the conversion, given a growth in the world oil demand of 1.5%/yr*

[%]	1 year	5 years	10 years
Base	1.5	1.5	1.5
0.65% (ECN calculation)	2.2	1.63	1.56
Max 1.2% (Suenson, 2007)	2.7	1.7	1.6

A 1-year conversion can be expected to have an effect on world oil prices in the order of 2 \$/barrel (with a large margin). If the process is spread over several years, little can be said because the oil price will likely be determined by the balance between (the growth in) supply and (the growth in) demand.

5.2 CO_2 market

The refining of HFO into distillate will result in increased energy consumption by the refineries and, correspondingly, increased emissions of CO_2. In the practice of allocating emission allowances employed in the Netherlands and other EU countries, companies are granted emission allowances on the basis of historical emissions. Legally, it is possible to be allotted an extra share of the CO_2 market if a sector consumes additional energy in connection with environmental measures.[13]

Ultimately, higher emissions from refineries will lead to a larger allocation of allowances to the oil refining sector. Total emissions from the EU are limited to the agreed Kyoto levels until 2012. Additional emissions will have to be resolved by reducing others elsewhere. On balance, the price will rise on the CO_2 market. All commercial enterprises will be subject to the advantages and disadvantages of this occurrence, but the greatest possible amount of the extra costs will ultimately be passed on to customers.

For the period following the current Kyoto agreement, there are two possibilities. The higher CO_2 price will have an effect on the willingness to make further reductions and a less far-reaching reduction will be agreed. Another possibility is that the desired reduction will in fact be maintained, which will mean that future demand for CO_2 emission rights will also be higher. This will ultimately increase the costs of achieving a certain reduction in the EU.

The increase estimated for the Netherlands of 3 to 4 Mtons of CO_2 discharge in Section 3.4.2 will mean an increase of the emissions on the current trading system of nearly 4% (as well as 2% higher emissions in the Netherlands). In negotiating the next climate regime after 2012 (the so-called post-Kyoto period), the Netherlands could strive for a higher ceiling in order to prevent or limit the additional emission reduction for other Dutch companies. Although very many countries will be subject to the same consequences, the effects in the Netherlands will be relatively high.

In this respect, it should be remarked that not even the main features of the successor to the European emission trading scheme in the post Kyoto period are known. If the emissions for large companies and electrical energy plants are to be allocated or auctioned Europe-wide, there is hardly any immediate importance for the Netherlands to request more or less CO_2 emission provisions for its facilities.

If it is deemed desirable to absorb the extra emissions inside the Netherlands, this could be arranged by providing additional CO_2 storage or by promoting sustainable energy. Insofar as such possibilities are available, a condition that strongly depends on future happenings in this area, annual costs of offsetting an emission increase of 4 Mtons/yr will be in the order of € 200 to 400 million.

5.3 Additional sulphur and petroleum cokes

The conversion of HFO into lighter products will generate two residual flows: extra sulphur from the desulphurisation installations and petroleum cokes from the cokers (flexicokers make this substance into a gas; see Section 3.1.1). For petroleum cokes that can be used as fuel or raw material, there is a market that might be able to absorb an increase in production. Sulphur is a substance that occurs in nature and is used for products varying form sulphuric acid to car tires. At present, there is already a surplus of sulphur due to the large production in the refineries, and new markets are being sought (TSI, 2004). According to TSI, production in 2004 amounted to 65 million tons, 90% of which was a by-product. The Intertanko proposal could add an additional 5 million tons of sulphur to this surplus.

[13] In the Criteria for the National Allocation Plans for CO_2 Emission Rights, it states: “The plan must be in agreement with other legislative instruments such as Community policy instruments. Consideration should be given to the inevitable increase in emissions as a result of new legal requirements.”

6. Conclusions

The core conclusions of this Quick Scan into the economic consequences of a ban on the use of residual fuel in shipping are given in the 'bullets' below, and are briefly explained in the next sections.

- The Dutch refinery industry annually produces about 8 million tons of refinery residues, the main component of the presently used shipping fuel. It is technically possible to convert all residues into lighter products, although this process will cause an additional energy use of about one million tons of crude oil and a related CO_2 emission of about 3.5 million tons. A fast introduction would lead to market disruptions and peak prices. These effects could be limited by a gradual introduction over about 6 years, preceded by a preparation phase for the refineries of approximately 6 years. The investment costs for the Netherlands are estimated at about € 1.5 tot 2 billion.

- The Rotterdam bunker market processes both domestic and imported refinery residues. The residues are used to blend shipping bunker fuels, which are both sold to ships and exported to other harbours. Rotterdam will not necessarily be able to develop a similar position in import, export and bunkering of distilled shipping fuels. On balance, there is a reasonable chance that the bunker sector, where about 1500 people are employed, would decrease.

Processing capacity and volume flows

The current primary refining capacity is 3,400 million barrels per year worldwide, of which 1.6% occurs in the Netherlands. The global capacity for deep conversion is about 206 million tons per year, corresponding to about 6% of the total primary refining capacity. The additional refining of all the residual fuel currently used for ship propulsion would require a doubling of the present global capacity for deep conversion. This capacity has grown in recent years almost 4 times faster than primary processing capacity, a development that is mostly due to crude oil becoming heavier, as well as the comparatively strong increase in demand for relatively light products. Current increase in deep conversion capacity is therefore independent of any transition from residual ship fuel to distillates.

If this expansion in capacity continues at the same rate as the past 7 years, it would then take almost 35 years before the desired supplementary annual processing capacity for 200 million tons of residual ship fuel[14] is reached. Worldwide, the *primary* conversion capacity has increased by about 170 million tons over the last seven years to reach its current level of 3,400 million barrels per year. Technically, it might also be possible to expand capacity for deep conversion by 200 million tons in roughly seven years. The main question is therefore whether deep conversion can be increased *concurrently* with the autonomous activities involving expansion of primary conversion. Potential difficulties involve the availability of technical knowledge and production capacity for the construction of new deep conversion installations, as well as the production decreases due to temporary stoppages in refineries in order to incorporate the new installations.

Furthermore, refinery capacity is, as far as possible, geared to regional demand for various types of fuel produced in the refining process. This can provide refineries with a reason to prefer expansion into growth markets such as Southeast Asia, where future sales of the entire spectrum of refinery products are very secure.

Economics of the refining industry

At present, approximately 3,240 people work in refineries located in the Netherlands. Including personnel from contracting companies, the number rises to 4,000-5,000 employees.

[14] Residual shipping fuel is assumed to resemble the composition in the Netherlands, containing vacuum residues, atmospheric residues, and some distillates for blending purposes (see § 3.3.4, 3.3.5).

The Netherlands no longer have any industry or electrical energy plants that 'run' on heavy fuel oil. Dutch refineries therefore do not have any alternative domestic market on which to sell heavy fuel oil and that is why they mainly concentrate on the market for bunker fuels for shipping.

The investments for further refining of the residues in the Netherlands are estimated at approximately € 1.5 to 2 billion, on the basis of the ECN refining model. The investments for additional deep conversion capacity as reported in literature vary substantially, depending on the extent to which costs have been included for: (1) fitting the installations in the refinery, (2) additional processing of the intermediate products, and (3) distinguishing between new constructions and retrofit. Based on past actual investment, the installation of the necessary flexicoker capacity would now require an investment of approximately € 3.5 billion, at least if renovations are done more or less at the same time. The Oil & Gas Journal indicates an investment that is substantially lower, around 0.3-0.4 billion for the same capacity. This, however, is a 'basic' price for the flexicokers, one that still needs to be increased by the (high) costs of installation and modification for the refinery, as well as the substantial additional investments in capacity expansion of the installations in which the raw products from the flexicokers have to be processed.

An assessment of the willingness to invest in deep conversion capacity of the 6 largest refineries in the Netherlands, in response to any potential prohibition of the HFO use in sea-going shipping paints the following picture:

- The Exxon Mobile refinery (capacity of approximately 9.1 million tons) will not need to adjust its capacity because it already converts all its residual fuel into lighter products.
- The comparatively small Koch refinery (capacity of around 3.5 million tons) also does not have to make any changes as the raw material that it processes, natural gas condensate, does not produce any heavy residues.
- The Shell refinery (capacity of about 21 million tons) is a complex refinery that already has processing steps to reduce the proportion of residual fuel oil in production. The Netherlands, along with the UK, is 'home base' for Shell. The company also participates in the Gasunie, together with Exxon Mobil and the Dutch government. The chance that Shell will invest in order to adapt its Dutch refinery to the new situation is therefore higher than average.
- Nerefco (capacity of around 20.5 million tons) is a relatively simple refinery that, due to a limited capacity for deep conversion, produces a fairly large amount of heavy residue products. For this reason, Nerefco will have to invest substantially to enable it to process its comparatively high production of heavy residue flows itself. The chance that the Nerefco will adjust is to be deemed average.
- Total (capacity of approximately 7.9 million tons) has a hydrocracker for processing vacuum gas oil and would only have to invest in the processing of residual oil. Due to the relatively small flow of residual oil, investment costs are rather high. The chance that Total refinery will invest in the necessary changes is considered to be average.
- The Kuwait refinery (capacity of about 3.8 million tons) is not complex but does already have a vacuum distillation unit. Kuwait recently has made an attempt to sell the refinery (ANP-AFX, 2006). The small scale however makes investments rather expensive. The chance that the current owner is prepared to make extra investments is regarded as less than average.

If no investments are made in the processing capacity of residual oil, the industry's competitiveness will decline in the long term, particularly if there is a return to a situation with overcapacity and the margins for the refineries start diminishing again.

Models calculations on extra crude oil demand, CO_2 emissions and costs
The ECN refinery model SERUM was used to calculate the changes in the refining sector that the implementation of the Intertanko proposal would bring about with regard to the additional demand for crude oil and CO_2 emissions. The calculations indicate that the replacement of 8 million tons of bunker oil in the Netherlands with distillate fuel containing 0.5% sulphur would be associated with an increase in CO_2 emissions by about 3.5 million tons and additional energy consumption of about 1 million tons. This extra emission would mean a 2% rise in the total CO_2 emissions in the Netherlands.

The current Kyoto agreements for CO_2 emissions run until 2012, whereas the first mentioned implementation of the Intertanko proposal refers to the period 2012-2015. Implementation of the Intertanko proposal would therefore primarily affect a subsequent post-Kyoto international climate regime about which little is yet known.

The model calculations also reveal that desulphurisation of bunker oil (the alternative for distillate shipping fuel) would emit about 1.9 million additional tons of CO_2. Desulphurisation of bunker oil would require about 0.7 million tons of extra oil equivalent to energy, and the distillate requirement would be in the range of 0.9–1.2 million tons of oil equivalent.

Extrapolation of the calculations for the Netherlands to the European scale indicates an extra 22 million tons of CO_2 emissions. This figure is lower than the additional 35 million tons of CO_2 that would be emitted according to the European Petroleum Industry Association (EUROPIA). Assuming a worldwide distillate demand of 200 million tons, the global increase in CO_2 emissions would total approximately 90 million tons.

EUROPIA claims that production of an additional 50 million tons of distillate in Europe would require an investment of € 30 billion. Assuming the ECN calculations of the Netherlands situation to be applicable to all of Europe, the resulting investment requirement is calculated to be € 9 billion (with a disinvestment margin running up to € 12 billion).

If the refineries would decide to convert their residual oil in distillate and other products, this would require substantial investment. Other oil companies would also make similar investments, which ultimately would translate into pricing changes for various products. As is the case in other markets, investment is in most cases recoverable from revenue.

Economics of the Bunker fuel market
About 1500 employees are directly involved in the bunkering industry. Rotterdam has grown into one of the three most important players on the bunker market, due to (1) the bunker production at local refineries, (2) the deepwater harbour enabling the biggest ships to port, and (3) a favourable geographical position for bunker imports from Russia and the Baltic states. Given these advantages, bunker fuels can be offered in the Netherlands at a lower price than at other important bunker ports. The bunker market in Rotterdam would suffer a decline if the value of oil exports for the bunker market were to drop, and the same would hold true if some of the refineries were to decide to stop production of fuels for ocean shipping.

The Netherlands produced around 9 million tons of residual fuels in 2005 and imported approximately 20 million tons. Of this, around 15 million tons was bunkered by sea-going vessels, around 12 million exported (to Singapore and other locations), and the remaining 2 million tons used for domestic consumption. The economic GE scenario reveals that the bunkering of ship fuel in the Netherlands will grow from 600 PJ in 2005 to approximately 1060 PJ in 2030, an increase of 3% per year. The Rotterdam bunker market processes both domestic and imported refinery residues. The residues are used to blend shipping bunker fuels, which are both sold to ships and exported to other harbours. If a prohibition of residual fuels in shipping comes into force, the natural position favoured by inexpensive HFO imported from Russia will disappear, although transit of this product will continue. Rotterdam will not necessarily be able to develop a similar position in import, export and bunkering of distilled shipping fuels. On balance, there is a reasonable chance that the bunker sector, where about 1500 people are employed, would decrease. Since the storage sector also processes crude oil and other products, the decline over the entire sector will be smaller.

Additional remarks
At present, the difference between available refinery capacity and the demand for oil production is smaller than it has been over the past 25 years. Although the coming years will see substantial investment in additional refining capacity, it is highly unlikely that in the short term sufficient distillates can be produced to supply all sea-going vessels in addition to current sales. What is more, there would also be a surplus in oil products if HFO continues to be used.

The pace of implementing the Intertanko proposal could greatly affect pricing on the oil-market, the oil products market and the market for sea transport. It is likely that an abrupt implementation would inevitably involve severe market disturbances with high peak prices. Negative impacts might include shortages and price perturbations for certain oil products, as well as shortages in the engineering and construction capacity for refining facilities. Gradual introduction over about 6 years, preceded by a preparation phase for the refineries of approximately 6 years, could limit the negative effects.

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http://www.trn.nl/ (Total refinery)

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Abbreviations

BLG	IMO Sub-Committee on Bulk, Liquids and Gases
Bpcd	Barrels per capacity day; number of barrels of oil that can be processed on average per day, taking maintenance etc. into account
Bpsd	Barrels per stream day; capacity in barrels of oil per day
Europia	European Petroleum Industry Association
HFO	Heavy fuel oil (heavy fuel oil and bunker oil for ocean-going vessels)
IMO	International Maritime Organization
MARPOL	International Convention for the Prevention of Pollution from Ships
MDO	Marine diesel oil (heavy diesel oil for ships' diesel engines)
MEPC	Marine Environment Protection Committee
MGO	Marine gas oil (to some extent comparable to domestic fuel oil and diesel)
SECAs	SO_x Emission Control Areas
VNPI	Netherlands Petroleum Industry Association

Appendix A Current sulphur requirements

Table A.1 *Current sulphur requirements*

	Where	Max weight % S	Legislation
HFO	Land area	1% (to a poss. 3%) from 1-1-2003 or with waste gas desulphurisation 1%	(EC, 1999)
Gas oil	Land area	0.2 from 1 July 2002 and 0.1% from 1 January 2008	(EC, 1999)
HFO	Baltic Sea/North Sea	1.5% from 11 August 2006 and 11 August 2007, resp.	(EC, 2005)
Ship's diesel	Sale in EU	1.5% 11 August 2006	(EC, 2005)
All shipping fuels	Inland shipping, ships on berth in the port	0.1 from 1 January 2010	(EC, 2005)
Gas oil for shipping sector	Sale in EU	0.1% from 1 January 2010	(EC, 2005)
Fuel passenger ships	On regular service from/to EU ports	1.5% from 11 August 2006	(EC, 2005)
All	Fuel in SECA area; Baltic Sea/North Sea	1.5% from 19 May 2006, and 21 November 2007 resp.	Marpol Annex VI
All	All shipping fuels	4.5% from 19 May 2005	Marpol Annex VI

Appendix B Details of future refining capacities

This appendix examines the development of the refining capacities of the various systems resulting from the model calculations. Table B.1 and Figure B.2 display the development calculated in the GE scenario (CPB/MNP/RPB/ECN, 2006). Here, the year 2000 is a simulation in which the capacities available at that moment and the actual processed types of crude oil are the determining factors. For the year 2005 and subsequent years, the model has more freedom of choice. In the GE scenario, the oil throughput increases through time but the demand for HFO increases less quickly. On balance, this assumption results in an increasing demand for processing capacity for HFO.

Table B.1 *Development of the refining capacity in the GE scenario*

Requisite capacity [million tons/yr]	2000	2005	2010	2015	2020	2025	2030
Atmospheric distillation	66.9	63.2	66.6	71.3	83.4	96.7	101.4
Product reprocessing	46.5	47.0	54.1	57.9	70.1	83.2	86.9
Vacuum distillation	29.9	20.8	21.9	24.3	29.5	37.2	39.5
Reprocessing vacuum gas oil	16.2	10.8	12.2	12.2	13.8	17.3	19.0
Processing HFO	4.1	5.0	5.6	6.0	6.6	7.8	8.1

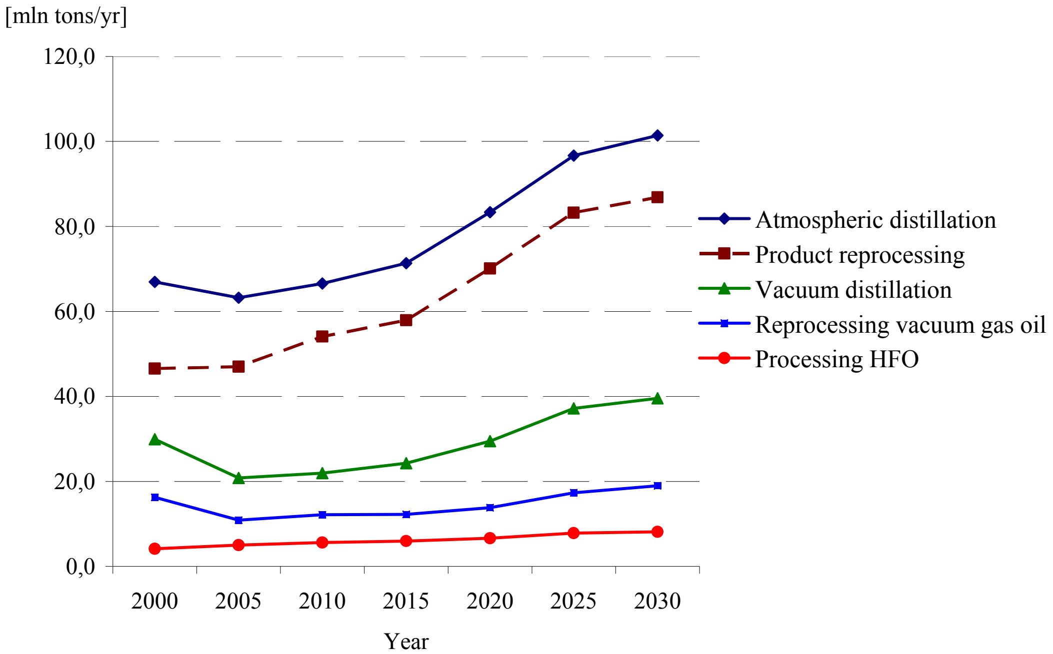


Figure B.1 *Possible development of the refining capacity in the GE scenario*

Another development is also possible. Take for example the SE scenario, in which a strong policy in the area of CO_2 reduction is assumed and in which economic growth is lower. Here, hardly any growth in HFO processing is visible. See Table B.2 and Figure B.2.

Table B.2 *Development of the refining capacity in the SE scenario*

Requisite capacity [million tons/yr]	2000	2005	2010	2015	2020	2025	2030
Atmospheric distillation	66.9	62.8	66.0	67.5	70.9	69.3	66.2
Product reprocessing	46.5	47.2	54.4	57.7	60.2	58.8	55.8
Vacuum distillation	29.9	21.1	22.1	24.1	25.9	25.2	23.6
Reprocessing vacuum gas oil	16.2	10.8	12.3	12.7	13.8	13.3	12.4
Processing HFO	4.1	4.4	5.5	5.7	5.6	5.3	4.9

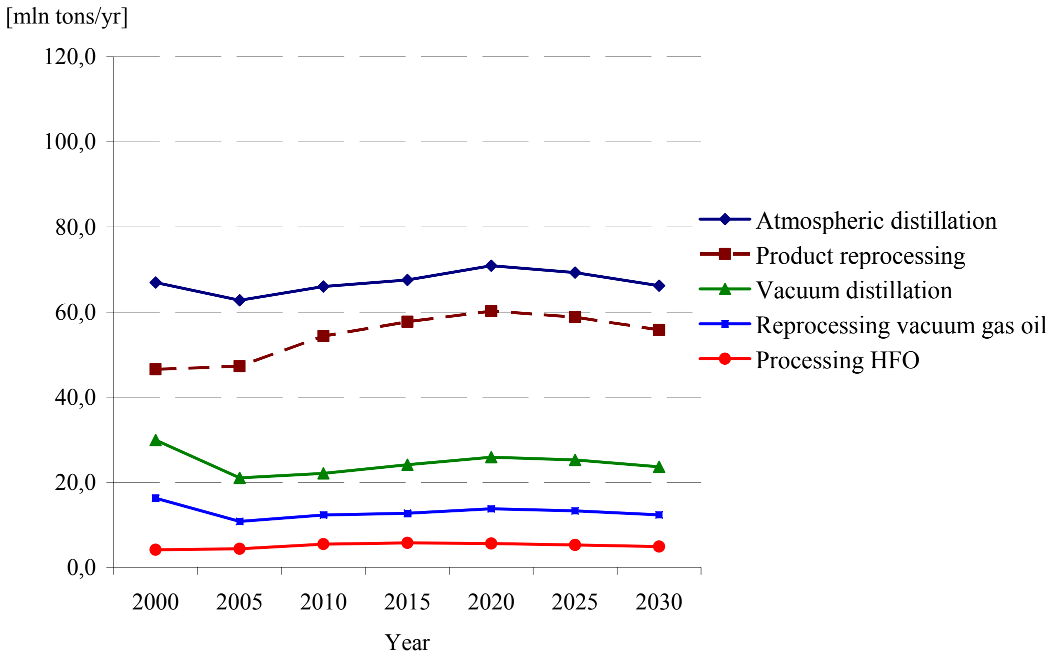


Figure B.2 *Possible development of the refining capacity in the SE scenario*

Table B.1 displays the capacities from the calculations. This involves the capacities for desulphurisation of the HFO and the two variants for distillate (1% sulphur and 0.5% sulphur). The table shows that the capacity for processing the HFO (9.9 to 10.3 million tons) that normally goes to ocean-going vessels, into distillate is higher than would be reached in the GE scenario in 2030 (8.1 million tons). It is therefore not true that in the long term all the HFO in the scenarios would automatically be processed into lighter products.

Table B.3 *Variants on GE 2015 with HFO desulphurisation and 100% distillate*

Requisite capacity [million tons/yr]	GE 2015	3% and SECA	HFO 1.5%	HFO 1%	HFO 0.5%	Distillate 1%	Distillate 0.5%
Atmospheric distillation	71.3	70.6	70.8	71.3	71.3	72.9	72.9
Product reprocessing	57.9	58.8	60.8	62.6	63.4	56.1	58.7
Vacuum distillation	24.3	24.5	24.4	26.1	29.0	32.8	32.6
Reprocessing vacuum gas oil	12.2	12.4	11.4	11.3	10.8	12.7	12.6
Processing HFO	6.0	4.0	5.1	5.9	7.7	9.9	10.3

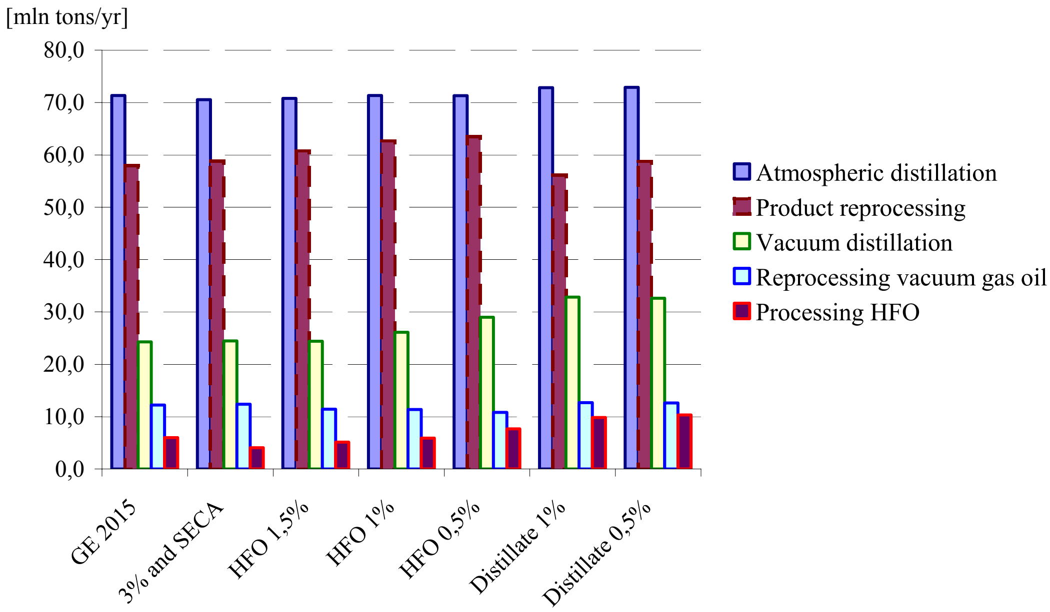


Figure B.3 *Variants of GE 2015 with HFO desulphurisation and 100% distillate*

The capacities are graphically displayed in Figure B.3. Here, the processing of HFO includes Flexicoking, Coking, Hycon and gasification. The product reprocessing in the distillate variant sometimes seems to be somewhat lower here. Among other things, this is caused by a shift - not visible in the figure - in the reprocessing of vacuum gas oil from catcrackers to hydrocrackers.

Appendix C Utilisation factor of refining capacity

Another question that must be answered is whether the extra distillate cannot be produced with the current refining capacity. This does not take into account the surplus of other products, particularly HFO, which is then produced. Figure C.1 displays the utilisation factor of the refining capacity (source: www.bp.com, except for the Netherlands). This is the actual throughput divided by the maximum capacity. In the maximum capacity used here, the fact that refineries shut down for maintenance for a number of weeks every year has already been taken into account. It seems as if there is extra production space, but it is limited. This is because the actual throughput is limited by malfunctions in the systems and by necessary structural alterations and renovations (outside normal maintenance). Moreover, there may be other systems (intended for reprocessing the products) in the refinery that restrict the capacity in the case of the crudes being used. The use of semi-manufactured goods can also restrict the capacity for processing crude oil. The stretched capacity in North America for example, came to light during Hurricane Katrina. At the time, part of the refining capacity (9 units) was non-operational for a week and petrol prices rose dramatically by 1/3.

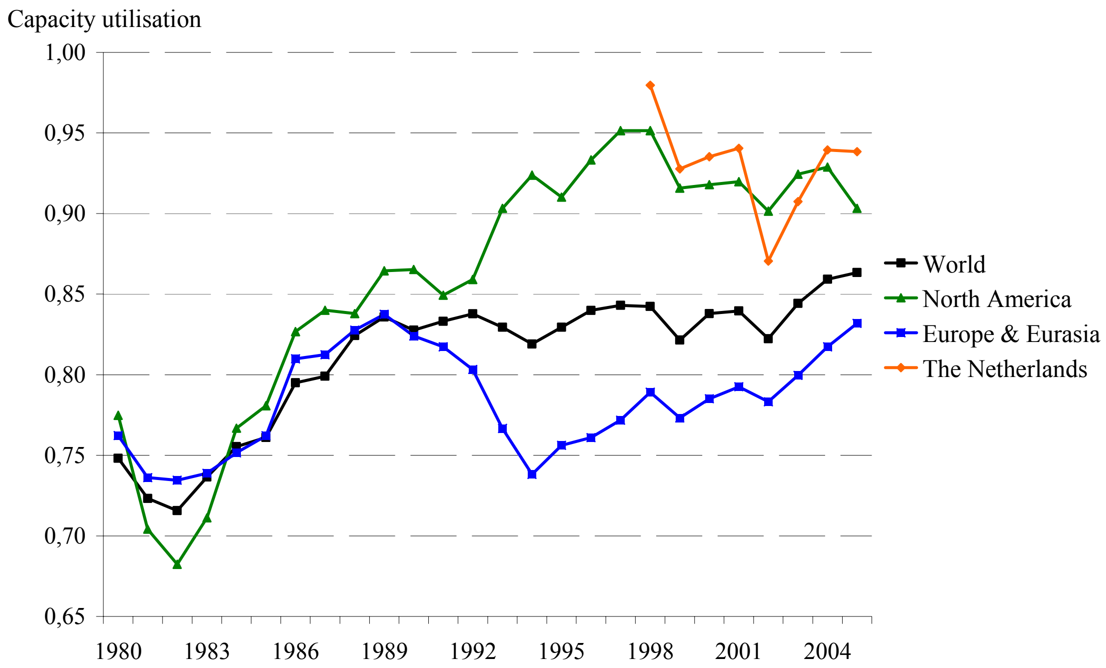
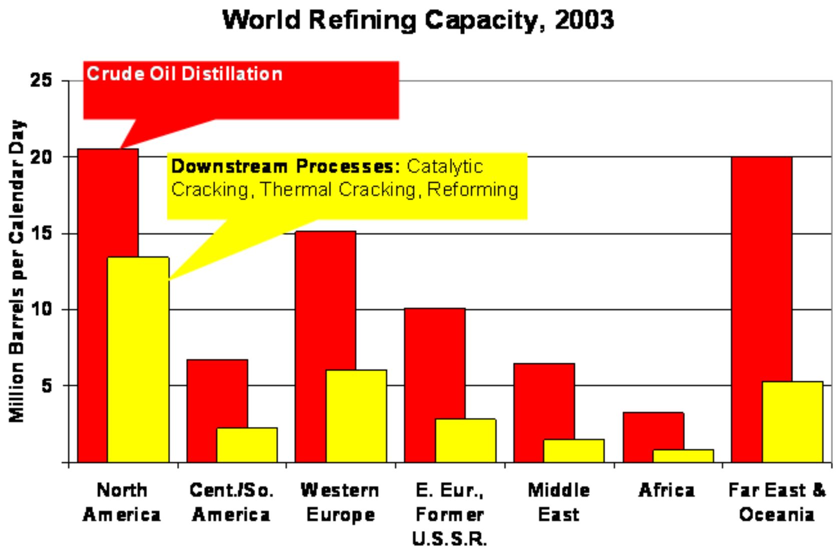


Figure C.1 *Utilisation factor refining capacity*

In the past years, the Dutch refineries have exhibited a less high utilisation factor than the US. This is due to maintenance, individual incidents (malfunctions) and considerable investments in desulphurisation (that also result in extra standstill). As for the distribution of refining capacities, 24% can be found in North America, 29% in Europe and Eurasia and 1.4% in the Netherlands. In 2005 (the last year in the figure), the global refining capacity, compared to throughput, has been tighter than it ever was in the past 25 years. In 2006, the refining capacity was expanded by more than 2.3%; in 2007, around 0.9% is expected and in the years afterwards around 1.8%/yr (Mueller, 2007).



This figure shows the relationship between the atmospheric distillation (the maximum of crude oil) and the capacity to reprocess products to make them lighter or better. In North America, this is very high because a lot of petrol is used there. The figure in the former USSR countries is lower than in Europe. Because of the low capacity in the former USSR countries for processing atmospheric residue, that residue is transported to markets for bunker fuel. Rotterdam is the first major bunker port encountered by ships sailing south from the Baltic. In Rotterdam, this oil is used to increase the quality of any very heavy residues. Ultimately, a substantial share of the Russian oil, which may or may not be mixed with other residues, is transported on very large tankships to bunker ports in the Far East (including Singapore). Rotterdam is therefore an important storage and transfer port for this oil. Because this reprocessing capacity requires a great deal of capital, which is currently limited in Russia (and the former USSR states), it can be expected that a significant share of this residual oil flow will probably still be transported through Rotterdam even after implementation of the Intertanko proposal.

Appendix D Report Workshop 28 February 2007

On 28 February 2007, a workshop was organised in the NOVOTEL in Rotterdam. In addition to the project team, the following people attended the workshop:
- Ing. D.W. Anink (KVNR - Royal Association of Dutch Shippers)
- Erik de Vries (NOVE - the Dutch Organisation for the Energy Sector)
- Ronald A. Backers (Port of Rotterdam Authority)
- Martin Smits (Argos Ceebunkers B.V.)
- Eric van Neerbos (Vopak)
- Martin Mærsk Suenson (EUROPIA - European Petroleum Industry Association) at the request of VNPI (The Netherlands Petroleum Industry Association).

During the workshop, three presentations were given; these presentations are discussed below, followed by various comments - including those made during the presentations. In this report, the comments were processed from a draft version by the following participants/interested parties: Ronald Backers, Maurits Prinssen; Martin Suenson, David Anink and Martin Smits.

The viewpoints put forward by the participants/interested parties in question do not necessarily correspond with the ideas of the project team. We also submitted the conclusions of the workshop for commentary to Mr Rauta, Technical Director of Intertanko, and to Acid Rain, a Swedish NGO that has specialised for years in monitoring emissions in the shipping sector (see the appendices below).

Introduction by ECN

An introductory presentation was given to define the question and explain the structure of the workshop. The focus of the workshop is on the economic effects for the Netherlands, with the following starting point: Suppose that the Intertanko proposal is implemented, what are the economic consequences particularly for the refining sector, the bunker market and any other actors?

Intertanko's proposal
Intertanko asked IMO to start using distillate worldwide instead of HFO (heavy fuel oil). Distillate is twice as expensive, however, but savings can be made on other costs. In addition, the use of distillate has other advantages, but further research is required into the advantages and disadvantages. The proposal is to switch in 2012 to distillate with 1% sulphur and in 2015 to 0.5% sulphur.

The workshop has three main subjects, indicated below by the letters A, B and C.

A Economic analysis of the current refining sector and bunker market and the future if the existing policy is pursued.
Specific questions on this subject include:
- Scale in €/$, added value and employment.
- The sale of bunker fuels in NL, the types, prices and trading parties.
- Production through refinery in the Netherlands and the import of fuels.
- The influence of the 'pipeline policy' and trends such as the rising demand for diesel.
- The factors that determine NL's current strong position in bunker fuels.
- Investments already planned, particularly the capacity for extra distillate.
- The position of the Netherlands in relation to other countries.

B Implementation of the Intertanko proposal: Required adaptation of the Dutch refining sector
Specific questions on this subject include:
- Adjustments in processes and systems: the influence on the product flows, energy use and emissions (ECN works with the SERUM refining model).
- Economic effects and employment, taking account of alternative sales opportunities.
- The occurrence of side effects, such as extra CO_2 emissions.
- The position of the Netherlands in relation to other countries.

C Possible reactions of the Dutch bunker oil market to shifts in the refining sector
Specific questions on this subject include:
- Costs, supply and sale of heavy fuel oil.
- The position of the Netherlands in relation to other countries and possible shifts of the trading and production capacity to other countries.
- The consequences, in a positive or negative sense, for third parties such as dealers and/or storage companies etc.; alternatives.
- Additional effects for the port of Rotterdam, such as space required for extra refining capacity and storage.

It should be emphasised that with point A the focus is particularly on the position of the Netherlands in relation to the other countries. Will the Netherlands (under C) lose its strong position and are there consequences for storage or is there a demand for extra space? During the workshop, only limited time is available for possible alternative solutions.

Presentation by Martin Mærsk Suenson of Europia

Mr Suenson starts by saying that he has no detailed information about the actual investments and investment plans of the members.

In his presentation, Mr Suenson says that the demand for low-sulphur fuel for the current SECAs is mainly covered by means of shifts in the selection of crude and by keeping flows with a low sulphur content separate. The adjustments by the refineries could therefore be realised relatively easily and quickly. However, the Intertanko proposal involves large volumes of low-sulphur residual fuel, very low sulphur contents and distillates rather than HFO. This cannot be realised through shifts or limited investments but requires large structural investments in the refineries.

It is not the case that there is capacity available to just start making the extra distillate, although you could easily come to this conclusion based on overviews of the capacity utilisation of refineries. It is indeed true that there is a difference between capacity and throughput. However, this is because maintenance also has to be carried out and because it is not only the (primary) capacity that limits the throughput but also the refining steps that follow it (limitations in secondary capacity). A utilisation factor of 90% is already very good.

Suenson uses a diagram to illustrate two possible ways of improving the bunker fuels. The first is the desulphurisation of this fuel. That produces a HFO with a lower sulphur content. The other option is to convert HFO into lighter products; this creates not only distillates/diesel but also other products such as kerosene, petrol and LPG.

If only diesel may be used in ships instead of HFO, this means an additional worldwide demand for 200 million tons/yr of distillate. To put this into perspective, with the average worldwide refining structure, 600 million tons of crude oil is required to manufacture 200 million tons of distillates. This is more than Saudi-Arabia's annual production. For Europe, it means 50 million extra tons of distillate. At present, because its own production is too low, Europe is already importing 33 million tons of distillate (from Russia, amongst others).

Possible ways of meeting the extra demand:
- Import more (but this provides few prospects because the switch is happening worldwide). Replace distillate used in other markets (for example, replace domestic fuel oil with something else).
- Invest in refineries. For Europe (EU-25), that would involve building around 50 refinery complexes (costing € 30 billion). This adaptation would take more than 20 years and the new refining situation would ultimately cause extra emissions of 35 million tons CO_2/yr (20 million tons if corrections are made for possible efficiency yield in ships using distillate instead of HFO and the lower carbon content). The level of the CO_2 emissions of the EU refineries are now at 175 Mton. A 'normal' refinery's own consumption would increase from 7.5% to 10.5% of the throughput.
- A refinery can ignore the bunker market and try to sell HFO on other markets. For example, use HFO in boilers and power stations with waste gas treatment systems.

The reaction of the sector will be a mix of these options.

The consequences can only be commented upon in terms of quality. The following consequences will very probably occur:
- The supply situation of oil (products) will become uncertain.
- The costs of shipping fuel will double. Fuel is an important cost item, so it can result in a modal shift (a shift from the shipping sector to another means of transport).
- Other products will also increase in price, such as diesel, kerosene and domestic fuel oil.
- Europe will become more dependent on oil imports.
- The price of gas and imports of gas will increase.

Conclusions
- Large-scale changes in the market for shipping fuels.
- It will disrupt the market for these fuels and cause uncertainty.
- Changes in the refineries can only take place gradually and will take 20 to 30 years.
- The delivery of shipping fuels must follow this pattern and can therefore only be adapted gradually.
- During the transition period, there will be ships sailing on distillate and ships sailing on HFO.
- This process requires good planning and management because there will be market disruptions unless international measures can be taken to compensate for the price difference between HFO and distillates.
- Other energy markets will also feel the effects.

Lastly, Mr Suenson discusses the cost effectiveness of the reduction. If the emissions in the Mediterranean and the Atlantic are compared to the North Sea and the Baltic Sea, the emissions are 2½ times higher but the effect on acidification is a factor of 10 lower. It is important to look not only at the size of the emissions but also at the consequences for the environment.

Presentation by Ronald A. Backers, Port of Rotterdam Authority
Oil is the largest transhipment product in tons for the port of Rotterdam, followed by coal Roughly one-third of crude oil comes from the North Sea, one-third from the Middle East and one-third from Russia (and the former Soviet republics). The share of Russian oil has risen sharply since 2002/2003.

Of the 3.8 billion tons of oil that were consumed worldwide in 2005, 0.7 billion tons went to Europe and 102 million tons of that went through Rotterdam. In Rotterdam, there are 6 terminals for crude oil with a total capacity of 12.7 million m^3 and 5 refineries that can process 57.9

million tons of oil. In Northwest Europe, 12% fuel oil, 14% gas oil and 22% diesel is manufactured from crude.

The transhipment of oil products in Rotterdam has also risen substantially to around 42 million tons in 2005 (27.3 million tons of incoming product and 14.8 million tons outgoing). Of this, more than 50% was HFO, 16% was gas oil (a combination of both diesel and gas oil) and 14% was naphtha. In addition, there were 12.5 million tons of bunkering (which is becoming increasingly heavier); there were 48 million tons of oil products produced in the refineries and 49 million tons were transported to the hinterland by inland shipping, trail, pipeline and road transport. The Rotterdam port focuses mainly on the export of oil products. In 2006, the throughput of oil products rose by as much as 7% compared to the above situation for 2005. Transhipments amounted to almost 46 million tons, of which 29.7 million tons were incoming and 16.1 million tons were outgoing.

As much as 75% of imports and production are exported. With 31,000 ships calling at the port every year, Rotterdam is one of the largest bunker markets in the world. Bulk carriers and Container ships in Rotterdam ship relatively large amounts on each visit. The latter are responsible for the bulk of the HFO bunkering. Given the expansion plans of the port of Rotterdam, particularly in the area of container transport, bunkering could be 3 times higher in 30 years time.

The giant tankers (Very Large Crude Carriers and sometimes even Ultra Large Crude Carriers) make an important contribution to the fuel oil trade through Rotterdam. These vessels transport fuel oil to other ports in large bulk. A significant number of these ships first deliver crude oil in Rotterdam. In 2005, 58% of the HFO was shipped to Singapore. It is safe to say that Rotterdam plays an important role as a collection point in the export chain of Russian oil products. For tax reasons, Russian oil companies prefer to sell products rather than crude oil.

Crude oil is stored at the following locations: MOT 4.1 million m^3, Nerefco 1.3, Shell 2.1, TEAM 2.8, MET 1.4 and Vopak 1.0 million m^3. Nerefco, ETT/Vitol, Vopak, STR, Odfjell and Argos are active in the HFO cluster.

Reactions during the workshop

Emission requirements

Mention is made of the EU directives that regulate the sulphur content of fuels for ocean-going vessels: EC/1992/32 and EC/2005/33. Inland shipping vessels and quayside ships are already switching to 0.1% sulphur. In the SECA areas and for passenger ships, the standard is now 1.5%.

De Vries says that doing nothing is not an option. The sulphur norm will drop to 1% and then to 0.5%. If IMO does nothing, the EU will definitely do something. Or, to put it another way, he expects a sulphur reduction whatever happens. Suenson says that nothing has been decided yet. Prinssen: If IMO does nothing, the EU will definitely do something. What is the source of this information, or is it somebody's opinion?

Various areas are named as potential SECAs (or other locally-oriented zones with a lower sulphur content). In the US there is a 200-mile zone around the coast in which only 0.1% sulphur may be used. Prinssen: In the US there is a 200-mile zone around the coast in which only 0.1% sulphur may be used: Where has this information come from? I think the information about California is true, but this statement doesn't tally with my perception. A 24-mile zone in California for 0.1% S is mentioned. In addition, a possible worldwide reduction in the maximum sulphur content from 4.5 to 3% is mentioned.

Problems with low-sulphur fuel

There are problems with the low-sulphur fuel, however. Distillate fuel is thinner. According to Anink, the safety of engines is guaranteed when up to 1.5% sulphur is used. A level of 0.1% can cause problems with the engine, such as deposits on the cylinder head and problems with the lubricants.

Anink, after the workshop: Sailing on low-sulphur fuel is no problem. Problems come about when ships are accustomed to sailing on high-sulphur fuel and then have to switch to very low sulphur fuel. That will cause problems with the cylinder lubrication.

Someone comments that the low-sulphur HFO for the SECAs wasn't sold until just 1 week before the commencement date of the ban. Dealers did not purchase it sooner because there was no demand for it. Nowadays, a switch is much easier for a SECA area thanks to automation: just press a button, after which the whole switchover process is set in motion. Depending on the fuel system, the tank capacity, etc., the switchover must be activated approximately a day in advance. Anink: In order for a ship to be properly capable of quickly switching to low-sulphur fuel, it must actually be equipped with a double set day and settling tank. This also avoids the risks that occur when various types of fuel must be mixed.

Price differences of HFO versus distillate

Martin Smits comments that in 2006 bunker oil cost approximately 290 $/ton and distillates 575$/ton. The doubling of the price indicated by Intertanko is consistent with the current situation. Bunker oil is often referred to by its viscosity. Qualities of 700, 500 and 380 cst (centistokes) are usually quoted. If 380 cst costs 290 $/ton and distillate 575 $/ton, the price difference is 285 $/ton. However, this is with the MDO (DMB) norm and not the diesel norm for road transport.

An annual bunkering of 13 million tons (the amount of HFO in Rotterdam) therefore involves almost € 4 billion in extra costs.

Ronald Backers: The price differences between HFO and distillate: at the moment, distillate is indeed twice as expensive. However, it is very uncertain whether this will continue if the demand for distillate increases by 200 million tons and the demand for HFO decreases by 200 million. My gut feeling is that this won't happen, that distillate will be more expensive and the difference will therefore be greater.

Refinery process

The prescription of very low-sulphur HFO was also proposed. However, this is very like making distillate fuel. So the refineries must choose between manufacturing 0.5% S fuel oil or further refining to the quality of road transport diesel that can earn more on a stable market. The desulphurisation of HFO requires major investments. It is possible that some refineries may now take some back and try to sell the fuel oil on the industrial market instead of reprocessing it themselves.

Ronald Backers: HFO desulphurisation and the manufacture of distillate are two completely different processes in a refinery, although they may be similar in terms of the size of the investments. So from an economic perspective it is important that a refinery looks at the difference between the investment and the income from the products.

Is this cost-effective for improving the environment?

The EU has introduced the CAFE norm (Clean Air For Europe) for air quality. What is important is the location of the regions with dense populations, the sensitivity of the soil for acidification, and the predominant wind direction. Only then is it possible to look at the best option for improving the air quality. According to Suenson, there is no proof yet that a switch to low-sulphur distillate fuel also leads to better air quality. The distance between the point of emission and the region to be improved is too great for that. In the logic of Annex VI of the Marpol Treaty, cost effectiveness plays an important role. Is this route now being abandoned? Suenson says that providing the whole world with clean fuel is an expensive way of improving the air quality. Local measures are generally more cost-effective.

Remarks about Intertanko's argumentation

A quote: "Since 1945, we have been the garbage incinerator of the petrochemical industry". It is clear that Intertanko has an image problem. Increasingly stricter requirements are on the way and the sector wants to work on a green image.

- Intertanko says it is difficult to sail on different qualities of fuel.

With the current SECAs, the problems are limited.

- Reducing measures on board.

Intertanko claims that it is resolving all the problems in one operation, but this is not the case. It may indeed be true for desulphurisation on board, but certainly not for particulate matter. Nothing is being done about the most harmful part, the whole small particles. Moreover, it is emerging that exactly in the port area, when switching between half and full power, soot particles that accumulated earlier in the exhaust system are blown out in one go. HFO produces larger particles than diesel and they may be less harmful. Suenson comments that you must make a distinction between primary particulate matter and secondary particulate matter (that can be formed, for example, from sulphate particles and nitrates in the air). Prinssen: "Paragraph underneath: the relationship between sulphur and particulate matter has not yet been properly researched. In my opinion, a perception/observation is being described that is possibly not consistent with the studies being conducted. The Ministry of Transport, Public Works and Water management/the Directorate General for Transport and Aviation commissioned TNO to research the emission factors of ocean-going vessels. The results of this research could be included in this argumentation."

- Fewer occurrences of malfunctions on board.

Martin Smits comments that more blackouts (when the engines come to a standstill) occur in ships sailing on distillate than in ships sailing on HFO. KVNR cannot support this. Only the system according to which ships are nowadays sailing on one type of fuel has increased operational safety. It then does not matter on which type of fuel the ship is sailing. Chances of blackouts are only increased by the switch. The reason for this is that when distillate from various producers is mixed in tanks it causes problems. Nowadays there are also ships that centrifuge/filter the distillate just like HFO. The advantage of distillate is that the fuel does not need to be kept warm, but that happens anyway due to the residual heat of the engine, so this does not cost any extra fuel.

If the costs are charged on to the owner, there is no problem for the shipper. Later it is remarked that with tanker operators the party that delivers the freight regularly also delivers the fuel. In that case, therefore, the tanker sector itself will suffer no inconvenience from a change of fuel).

Somebody wonders whether the Intertanko proposal was discussed in detail beforehand with the members. Anink says that the KNVR is in favour of doing things differently to Intertanko.

The current trend is actually for ships to switch from distillate to HFO

Every shipping company can now already choose to install an engine in its ship that runs on diesel or HFO. There are no restrictions. With this proposal, the shipping industry is being compelled to make a switch that requires major investments. At present new ships are being built in which both the main engine and the auxiliary engine run on HFO. In addition, many ships are being converted from diesel to HFO. There is also a trend involving the use of engines that run on increasingly heavier qualities of HFO (700 cst). Various examples are cited.
Prinssen: Engines are actually being designed so that they can run on HFO. If other fuel is used in them, the performance can be lower.

Ships that have little space for the installation of an extensive fuel cleaning system - for example fishing vessels- are sailing on distillate as standard. Remark Smits: “very large fishing vessels are sailing on HFO.”

Transport costs

Smits says that the plan itself must be looked at from A to Z and therefore not just the ships. As far as shipping is concerned, worldwide trade can be damaged, particularly the ‘low cost’ cargoes (transport for low transport fees, such as the transport of potatoes to Mozambique, for example). Here, the higher transport costs can cause a decline in trade. A 140-metre ship consumes roughly 35 tons of fuel a day, corresponding to a cost item of approximately 10,000 €/day.

The share of fuel in the transport sector is 30-40% for normal shipping. For very large ships over long distances, this can increase to 60%. If required, KNVR is willing to provide extra data on this.
It is suggested that ships can start sailing slower in order to conserve fuel. For example, switching from 25 to 20 knots (48 -> 38 km/h) produces a 30-35% reduction in fuel consumption. At present, shippers are discussing this issue with their customers. What proportion do the savings in fuel costs bear on the extra travelling time? Anink: Sailing slower means that more ships would have to be used.

Conversion of refineries

Someone remarks that the speed of a switch from HFO to distillates is not only limited by engineering capacity (design), but also capacity problems in the production of special parts, such as the requisite cylinders in the reactors. There are not very many manufacturers of cylinders worldwide. In addition, a limited number of manufacturers supply the valves in the large pipes.

There is a discussion about where investments will be made in refineries. Will this be in the Middle East or in Europe? In Europe, there will be a high CO_2 bill, and at a certain moment there will be no more room to manoeuvre. Someone mentions a refinery that was relocated from Europe to Asia. At the moment, new refineries are primarily being built in Southeast Asia. Suenson says that for the past 15 years investment in Europe has mainly been defensive. Only investments necessary from an environmental perspective were made.
Ronald Backers: Conversion refineries, 2nd paragraph, on the refinery that was relocated. This isn’t accurate; it probably refers to the Nerefco refinery in Pernis that was supposed to be relocated. In the end it didn’t happen and the refinery was demolished.
As well as this, I would also state more frankly that the chance of investments in Europe into large scale adjustments is lower than the chance of it happening somewhere else.
Prinssen: CO_2 emission trade: for more information on this, see the last proposal of EC (Jos Delbeke).

Somebody remarks that the CO_2 emissions will also rise.

Qualities on the bunker market

There is some discussion about the share of distillate in shipping fuels, which is much less than the 50% specified by Intertanko. The heaviest HFO that is produced has a viscosity of 500-700 centistokes. In the past, this was cut back to 350 centistokes by mixing distillate. However, the newer container ships can easily sail on 700 centistokes and they even use this in their auxiliary engines. (Added by Ronald Backers after the workshop: According to some market parties, the amount of 500 centistokes in Rotterdam is as much as 40% of the bunkers sold, partly because these bunkers are a few dollars per ton cheaper).

The following remarks are made for the three fuels:
HFO: is often brought up to standard (lower viscosity) by adding distillate;
MDO: quality requirements create space to add some HFO ;

MGO: as far as its properties are concerned, is more like diesel for road transport.

Oil market

Europe has a shortage of distillate and a surplus of petrol. We get our distillate from Russia and the former Soviet states. We import kerosene from the Middle East and Korea.

Ronald Backers, after the workshop; what it came down to is this:
"At the moment, Rotterdam occupies an important position in the export of Russian oil products, particularly fuel oil and gas oil. For these products, Rotterdam is a logical storage location. Some of these products are then transported further in this trading market, together with oil products produced in Rotterdam and products from other regions. For example, a lot of fuel oil is sent from the Rotterdam storage location to Singapore/China. The bunker market is another market: due to the import of Russian fuel oil, Rotterdam is one of the cheapest bunker ports in the world, and this is combined with the possibility of purchasing a wide range of blending materials in Rotterdam. These two markets are in fact separate from each other, but they influence each other all the same.
When switching to distillate, the important question is whether Rotterdam can maintain its position. There is a shortage of distillate in Europe and a surplus in the Middle East and India and also in Russia. That means that distillate is already coming to Rotterdam from those regions. Some of that is ordinary auto diesel (which has nothing to do with fuel for shipping). If its import is necessary on a large scale due to the increased demand for distillate, we have to ask ourselves what will happen. It will cause considerable market disruption. We do not think it is logical anyway to first bring the distillate to Rotterdam for use in the bunker market, all the more so because the major users of bunkers (the container ships between Asia and Europe) sail along the Middle East and India. Because of this, there is definitely a chance of Rotterdam losing its position as a large bunker port.
The question is also: what will Rotterdam's position be on the trading market? That partly depends on what the Russian refineries, for example, are going to do in terms of investments."

Products are transported for the 'balancing' of the refineries. Refineries try to gear themselves as much as possible to the local/regional market. Shortages and surpluses are transported to and from the refineries. It is more expensive to transport refined products than crude. This is because crude can be transported in larger ships. If you want to ship petrol, for example, you have to have separate tanks for $Euro_{95}$ and $Euro_{98}$. The price differences between Russia and Singapore must be looked at. These reflect the transport costs, but in the short term they are the market prices. The price in Rotterdam is also determined by the price in Singapore and the transport costs.

If the EU has a shortage of distillates, what is then the use of transporting distillates to the EU and bunkering them here if the ships are docking in India anyway?

As well as this, in Europe HFO cannot be used everywhere on land (for example, in power stations) because of the maximum limit of 1% sulphur. In the Philippines or in Africa, for example, these limits do not exist. Depending on the price, some refineries will therefore decide to further crack HFO.

According to Anink, the chain of Russia, Rotterdam, China (Singapore) will remain active for the time being, as long as Russia does not have the necessary processing capacity. It takes a lot of capital to do your own processing. Rotterdam is in an advantageous position because it is the first large port that ships from Russia and the former Soviet republics sail along on their way to the south. Rotterdam is therefore strategically located. The system has grown along with market developments. In short, Rotterdam is now a market trading platform.

Production in the North Sea will drop in the next 15 years. And it is exactly there that a relatively light crude is produced.

Furthermore, someone remarks that bunkering in Antwerp is now half that of the Netherlands (6 million tons).

Storage
There is some discussion about the number of people working in the bunker oil sector. The figure of around 1,500 people specified by Port of Rotterdam Authority would seem to be the most realistic. The figure of 4,000 people that was also mentioned probably also includes activities associated with other products.

Substantial investments are being made in the bunker fuels sector. For one storage company alone, an amount of € 250 million in investments in storage/and loading/unloading locations over the past 5 years is being mentioned. Ronald Backers, after the workshop: "The figure of € 250 million refers to the entire bunker 'system' in Rotterdam, therefore jetties, pipelines, measurement systems, new bunker barges, and so on. So it is not just one storage company that has invested this amount." Tank storage companies can increase throughput even more. The question is whether the investments will be recovered if the bunker market declines. Another aspect that plays a role here is that bunker oil storage capacity requires expensive heating systems. These costly systems are not necessary for the storage of distillate fuels. Remark by Smits, after the workshop: "In addition substantial investments are made in double hull bunker supply vessels, for transport of HFO from the storage terminal to the ocean-going vessels".

In the tank depot, there is large-scale blending of HFO. Approximately 40% of the residual oil can be used directly by container ships; approximately 60% must first be made lighter (lower viscosity) by adding distillate.

Alternatives
As other options, Suenson mentions the use of biofuels or the cleaning of exhaust gases on ships. A general rule is that a law should not prescribe any technology. If it is cheaper to clean the exhaust gases on board, that solution may not be excluded in advance. Scrubbers are systems connected behind the engine to remove sulphur compounds from the waste gas, particularly SO_2. The number of scrubbers operating on ships is currently limited. Work is ongoing on two projects.

The participants have no explicit ideas about how the situation will develop over thirty years ("The oil has to run out sometime.").

Summary of viewpoints contributed to the workshop
With respect to the economic research question, the various viewpoints can be summarised as follows:

- For the Rotterdam bunker oil market, it is generally expected that the switchover will have a negative effect (the chance of a negative effect is greater than the chance of a positive effect). Between 1,500 and 4,000 people work in this sector. Moreover, substantial investments are being made in systems and supply vessels that are aimed at the current market for HFO.

- For the refining sector, it is generally expected to have both a negative and a positive effect. There is a realistic chance that refineries will 'drop out'. In principle, it is cheaper just to remove the sulphur, but this already costs so much in investments that the sector will then want to go further and also start producing (diesel) for road transport (more stable and more well-known market). The necessary adjustments will take at least 20 years. During this period, the necessary distillates will only become available gradually, which means that there will be competition unless compensation measures are introduced internationally.

Prinssen:
- Some effects have not been researched or are not worked out in the proposal.
- There is no estimate for the economic consequences for the bunker market, for Rotterdam if it loses its bunker position or for the refining industry and the shippers.

Other viewpoints:

- The Intertanko proposal is not thoroughly underpinned. Some of the effects that are claimed are doubtful. This includes the reduction of dust emissions (there are also particulate matter emissions linked to gas oil/distillates, and these are expected to be smaller particles) and the number of malfunctions that cause engines to break down when there are fuel problems.

- Furthermore, the question is whether a transition to low-sulphur distillate fuel is a cost-effective measure. In many places, the measure produces no appreciable environmental advantage, particularly in the case of emissions in the open sea, far from land. It is more cost-effective to take measures that are specifically aimed at the vulnerable locations.

Ronald Backers, Eric van Neerbos: I would be more forceful when describing the conclusion that the switchover to distillate will have a negative effect for Rotterdam.

Appendix E Reaction of Acid Rain (NGO in Sweden) to the conclusions of the workshop

Explicit referral is made to the reaction of Sweden on the IMO proposal BLG 11/5/19 dated 16 February 2007

- The Intertanko Proposal lacks a thorough foundation, and certain claimed effects are doubtful.

Comment: In my view, this type of sweeping statements tells more about those who criticise than about what they criticise...

- It concerns, among others, the emission reduction of the particulate matters, as there are also such emissions by using gas oil, and even smaller particles are expected in that case.

Comment: As the critics claims that the Intertanko Proposal "lacks a thorough foundation", it would be interesting to know the foundation for their statement that implies that PM total emissions would remain, and that there would be a transition towards smaller particles. I'm certainly not an exhaust expert, but to me it appears logic that a 'cleaner' fuel (e.g. with less ash content) will result in less PM emissions. Emission measurements on board ships have confirmed this (see for example: "Exhaust emissions from ships at berth", by D.A. Cooper, published in Atmospheric Environment (2003)).

- Also the number of blackouts due to the fuel-related problems is expected to be more when sailing on gas oil.

Comment: This is certainly news to me. Again, it would be interesting to know the foundation for this statement. It would appear logic that using (one) cleaner, well-defined fuel would reduce the risk of fuel-related engine problems, as compared to using several (usually much dirtier and sometimes blended) types of fuel. It is my understanding that usage of gas oil (instead of residual oils) will reduce the exposure to mechanical wear and therefore also potential breakdowns.

- The question is, whether the Intertanko Proposal is a cost-effective measure. The measure does not lead to any considerable environmental benefit in many places, especially by emission in open sea, far from the land. It would be better to take measures, which are directed specifically to vulnerable locations.

Comment: The vast majority (about 80%) of shipping - and thus also of the associated emissions - takes place near (within approximately 200 nautical miles, or 320 kilometres) the coast, and only about 20% are in areas away from the coast (Sources: "Study of greenhouse gas emissions from ships" by IMO (2000), and "Global nitrogen and sulphur emissions inventories for ocean-going ships" by J. Corbett et al (1999)).
As there are several other advantages (apart from the emission reductions as such) of moving to one well-defined type of distillate fuel globally (some of those additional advantages are mentioned in the Swedish submission to IMO, document BLG 11/5/19, enclosed), the combined positive effects speaks in favour of

the Intertanko Proposal. To the extent possible, you need to consider <u>all</u> the pros and cons of a proposal when evaluating it.

Implementation of the Intertanko Proposal does not exclude the possibility to take additional measures "directed specifically to vulnerable locations", such as the wider use of shore-side electricity in ports in cities.

Moreover, as the residence time for sulphur dioxide, secondary sulphate aerosols, and fine particles (PM) usually is between one and ten days, typical travel distance of these pollutants may be up to about 1000 kilometres or more, so reducing ship emissions also further away from land would most likely also bring some health and environmental benefits.

- The share of distillates in the shipping fuels is much less than 50%, as is presented by Intertanko (referred to Mr. Ranheim's presentation). The heaviest HFO produced, has a viscosity of 500-700 centistokes. Formerly, the viscosity was reduced down to 350 centistokes by blending with distillates. However, the newer container ships can sail on 700 centistokes, and this is even used in their auxiliary motors.

Comment: This is outside my area of knowledge - I suggest you approach Intertanko directly to let them better explain the basis for their calculations. Without a fair comparison between the apparently different ways of calculating, you are not likely to be able to come to a fair conclusion...

- In principle, it is cheaper to remove the sulphur, but this requires such a high investment, that the sector will go further to produce diesel (road transportation fuel), as this is a more stable and a better known market.

Comment: Interestingly, the ICCT recently recommended that in the long term, fuel standards for marine fuels should be harmonised with standards for on-road fuels (i.e. reducing sulphur levels down to 10-15 ppm). See "Air pollution and greenhouse gas emissions from ocean-going ships" by the ICCT (2007) (www.theicct.org). But as a step before that, the ICCT recommends a uniform global fuel sulphur standard of 0.5 per cent.

- A reasonable transition period for the required adjustments would take more than 20 years.

Comment: Before being able to comment on this statement, I would need some facts and calculations showing how this figure of 20 years was arrived at. It appears highly unfair to require 'foundation' only from Intertanko, but not from the stakeholders that criticise Intertanko's proposal by making their own unfounded claims...

Christer Ågren

Appendix F Intertanko's reaction to the conclusions of the workshop

INTERTANKO
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Mr. Hamid Mozaffarian
Energy Research Centre of the Netherlands (ECN).

13 April 2007
Our Ref.: DR-30167/10154

Dear Sir,

INTERTANKO proposal to the IMP Working Group on revision of the Marpol Annex VI

This message is in response to your e-mail of 23rd March 2007 and it consists of two parts:

Response to the question you raise and marked by text in red
Additional information on data and assessments made by INTERTANKO with regard to the critical issues raised in response to our submission to IMO in November 2006.

With regard to the second point above, I would like to advise upfront that any assessment of the INTERTANKO submission to IMO needs to be done in comparison with all other alternative solutions for the revision of the MARPOL Annex VI which IMO has for consideration. The comparison should be done on the same criteria: availability, environmental impact and costs.

1. Response to specific questions from the Energy research Centre of the Netherlands (ECN).

'The Intertanko Proposal lacks a thorough foundation, and certain claimed effects are doubtful. It concerns, among others, the emission reduction of the particulate matters, as there are also such emissions by using gas oil, and even smaller particles are expected in that case. Also the number of blackouts due to the fuel-related problems is expected to be more when sailing on gas oil.'

The above statement, particularly the first sentence is obviously not well thought. Basically, ships are equipped with Diesel Engines and thus it is more than natural that these engines can safely run on Marine Diesel Oils (MDO).

The statement above puts a spin in what INTERTANKO suggested. Basically, in switching to MDO, one eliminates the source of PMs of medium and high sizes, including PAH and heavy metals which are not present in MDO but present only in residual fuels. If continuing to use residual fuels, the containment of PM emissions has to be done through a series of filters of different densities/sizes that need to be continuously washed/cleaned to avoid clogging. If ships use MDO, the technical and practical solutions are much simpler and the PM emissions reduction more efficient.

The last sentence in the statement above is completely wrong. Historically, ships have switched from residual fuels to MDO when approaching the coast lines. They did this to avoid engine troubles because of the residual fuels. So, by switching to MDO, ships will minimise or even eliminate the black outs due to fuels. MDO is cleaner and it has strict quality specifications. Fuel test laboratories have always issued warnings on fuels off specifications for residual fuels and not for MDO.

As advised, one should consider whether other alternatives are better than MDO on these criteria. We understand that you do not have experience in operating ships and thus can ensure you that use of MDO is much reliable and less prone to problems than in operating scrubbers, installations that are still to be tested and assessed. As stated by oil companies, it seems that the use of Low Sulphur Residuals will not be an option because a large increase in demand will require high investments and thus high prices, close to the MDO prices.

'The question is, whether the Intertanko Proposal is a cost-effective measure. The measure does not lead to any considerable environmental benefit in many places, especially by emission in open sea, far from the land. It would be better to take measures, which are directed specifically to vulnerable locations.'

The environmental global benefit is undisputable by using cleaner fuels like the MDO. There are even cleaner fuels for use, like Marine Gas Oil but we suggested maybe a radical change to what we believe is realistic and efficient to be applied to ALL existing ships' engines. As with regard to the efficiency of the INTERTANKO proposal that can be only assessed in line with the IMO and Governments' expectations and decisions. However, please note that our suggestion is based on the aim of significant reduction of air emissions from ships and a long term, foreseeable and predictable regulatory regime.

'The share of distillates in the shipping fuels is much less than 50%, as is presented by Intertanko (referred to Mr. Ranheim's presentation). The heaviest HFO produced, has a viscosity of 500-700 centistokes. Formerly, the viscosity was reduced down to 350 centistokes by blending with distillates. However, the newer container ships can sail on 700 centistokes, and this is even used in their auxiliary motors.'

I noted there is disagreement with our assessment on the share of distillate used to make up the residual fuels. We would appreciate to learn of a better estimate from those who have better expertise. I agree that 50/50 is not the usual make up. Let us assume that the make up is 20% distillates and 80% residues, which in our view is under the average. According to the INTERTANKO Suggestion, this amount of 80% residues needs to be replaced by MDO. This additional amount of MDO is still around 10%

of the current total amount of medium and heavy distillates produced by refineries. We do not say it is easy but we only say it is possible over a certain period of time.

We noted that ships are pushed to use 500 cSt and now you acknowledge the use of 700 cSt fuels. These residual fuels will emit even a larger number and a larger size variety of PMs and thus more pollution. Such residual fuels will pose serious problems to ship engines in coping with efficient systems to reduce NO_x emissions to the level Governments intend to require.

We do not actually understand the point which was made in the text above: is anyone proposing that ships should have engines that run on residues alone? Is anyone suggesting that ships should become the refineries' incinerators?

'In principle, it is cheaper to remove the sulphur, but this requires such a high investment, that the sector will go further to produce diesel (road transportation fuel), as this is a more stable and a better known market.'

According to the CONCAWE Study (report no.2/2006), de-sulphurisation on residual fuels is not cheap. At a sulphur content of 0.5% in fuels, as Governments consider to require (at least for SECAs), this operation makes the low sulphur residuals as expensive as the MDO.

The last part of the statement above is difficult to understand. The market for MDO will be extremely stable and significant for the amounts to be supplied, should MDO be mandated by regulators.

'A reasonable transition period for the required adjustments would take more than 20 years.''''''

We agree that a transition period is required. We disagree that it would take 20 years. However, has anyone assessed how much time is needed to equip all commercial ships with at least 3 or 4 scrubbers/ship? We made some assessments which are provided below.

2. Data and assessments made by INTERTANKO with regard to the critical issues raised in response to our submission to IMO last November

<u>Availability</u> - This section assesses the availability of the currently alternative solutions for lowering SOx and PM emissions.

<u>MDO</u>

The question of availability of MDO is principally relevant only if:

- ships will be required to use only this type of fuel on a global basis or if the extent of SECAs and other regional requirements will require use of low sulphur fuels (e.g. max. 0.5% or even 1.0%). and
- there would be strict limitation on PM emissions

INTERTANKO takes the extreme case scenario with all ships using MDO only, on a global basis. To assess the need for demand of additional MDO, one needs to find out:

1. the total amount of MDO to be supplied
2. the capacity of refineries to produce medium distillates

3. how much increase would this additional MDO supply be from the total refinery production of medium distillates?

1. Total amount of additional MDO supply - According to professional assessments made by M.A.N. (Horst Koehler, NO_x emissions from ocean going ships: calculation and evaluation, Proceedings of ICES03, 2003 Spring Technical Conference of the ASME Internal Combustion Engine Division, Salzburg, Austria, May 2003):

MARINE FUEL CONSUMPTION =	281 mill. t/year
DISTILLATES =	90 mill. t/year
RESIDUAL FUELS =	191 mill. t/year

However, the 191 MT of residual fuels are blends between distillates and residuals. The content of distillates in the residual fuels is variable, depending on the type of crude oils blended prior to the distillation process and the density and viscosity of residues remaining after distillation and which would be dedicated to produce residual fuels.

There are different expert views on the actual make up of residual fuels. Therefore, the table below gives a wider perspective. The table below considers a large variety of MDO/Resids ratio, on a conservative approach as a make up of the residual fuels delivered to ships.

2. The World Refinery Production capacity for medium distillates - According to BP Quantify Energy - BP Statistical Review of World Energy of June 2006.

The world crude oil refining throughput = 4.4 bill t/year (12 mil. t/day)

According to IPIECA paper to IMO (IMO document BLG 11/5/14, February 2007),

33% of it represents heavy distillate production = 1.45 bill. t/year

Table below gives the INTERTANKO assessment of the added MDO production in each case scenario of a make up ratio between MDO and resids.

MDO/Resids ratio	MDO [t/yr]	Resids [t/yr]	Medium Distillate Production [t/yr]	**MDO additional supply [%]**
40/60	76	115	1,450	**8.0**
30/70	57	134	1,450	**9.0**
20/80	38	153	1,450	**10.5**
10/90	19	182	1,450	**12.6**

The bold figures represent the increase of additional MDO to be supplied as a percentage of the current refinery capacity of medium distillate production. These are all lower than the data given by IPIECA (e.g. 200 t/yr). [Apparently, IPIECA seems to assume that the entire amount of residual fuels currently used by ships need to be replaced by MDO which would obviously be incorrect since the distillates blended into these are already produced.]

No matter the actual ratio between the MDO and Resids that make up the residual fuels, the table indicates that the additional supply of MDO is not an unrealistic increase even though not an easy task. The principal issue therefore is more one of timing and availability.

INTERTANKO believes that the data provided by IPIECA to IMO (IMO document BLG 11/5/14, February 2007) is not presented in a balanced manner and it does not give the reader a proper system of reference to properly understand the level of the increase and possibilities to provide the additional MDO.

Based on data published by the oil industry itself, INTERTANKO can assess that the additional MDO required will NOT be obtained by a large amount of new units. To the contrary, INTERTANKO has reasons to believe that a large part of the additional MDO (which we estimate to 120 mill t/year to 140 mill t/year) could be provided by the current refinery capacity and by the new capacities that are already under construction or the capacities that are under expansion. Some relevant data to support the INTERTANKO views is as follows:

- the projects for new units/substantial conversions already underway (reported as 9 million barrels/day - as assessed in 2006 - of new or expanded primary-distillation capacity) (Petroleum Economist, Profits boom on strong demand, September 2006)
- the new distillation capacity, mostly targeted for completion by 2011, represents an increase of 10.4% over the world's end-2005 capacity (Petroleum Economist, Profits boom on strong demand, September 2006)
- some foresee even larger expansions (e.g. IEA forecasted a rise by close to 14% over the end-2005 capacity) which even created concerns of over-expansion in case China's economical growth slows down (Petroleum Economist, Profits boom on strong demand, September 2006)
- re-distribution of current stream productions (e.g. ADO mixed with 10% - 15% bio-component = more capacity for producing MDO)
- efficiency of conversion
- better utilisation of production capacities; the 2005 average utilisation of refinery capacity was (Petroleum Economist, Profits boom on strong demand, September 2006):
    - World wide - 86.3%
    - EU - 92.4%
    - Asia-Pacific - 91.5%
    - North America - 89.4%

INTERTANKO recognises the refinery capacity is stretched and one could never get close to a 100% utilisation but the increase capacity reported, combined with a better utilisation by 1% or 2% on a world wide basis and a better re-utilisation of the production streams could supply much of the additional MDO without any of the additional costs and investments predicted by IPIECA (IMO document BLG 11/5/14, February 2007).

<u>Low Sulphur residuals</u>

According to CONCAWE (The Oil Companies European Association for Environment, Health and Safety in Refining and Distribution) (*Techno-economic analysis of the impact of the reduction of sulphur content of residual marine fuels in Europe, Report no.2/06, June* 2006), the amount of low sulphur residuals is limited and a significant increase for supply will only be obtained through de-sulphurisation of residual fuels. This is not a trivial task and will require high investments and upgrades to refineries, the type of upgrades that currently are not under consideration. The CONCAWE report goes as far as stating that in case of limiting the sulphur cap in current SECAs and additional SECAs at 0.5%, the price of low sulphur residual fuels can be comparable with the price of the heating oil/distillates which will then make ship owners opt for MDO and eventually make the initial investment for de-sulphurisation economically unattractive.

Examples (direct quotations) from the CONCAWE report are relevant (emphasis added):

European refineries have no real incentive to produce LS RMFO unless the premiums are such that its price would resemble distillates

Commercially speaking, refineries would have a clear incentive for further conversion of its entire residual streams to distillate products compared to residue desulphurisation to produce more LS RMFO

Ship owners may just as well resort to burning MDO to meet the 1.5% sulphur cap

INTERTANKO would conclude that, if in 10 years ahead the legislation will require extensive use of fuels with very low sulphur content, the low sulphur residuals will not be an option.

Scrubbers

The scrubbing technology is not new as it is applied to tankers' inert gas systems. However, application of scrubbing technology to main and auxiliary engines is different and more challenging. There are scrubbers installed on a few existing ships, particularly on ferries operating in the Baltic Sea. We are however unaware of the efficiency and reliability of such scrubbers. There is little data provided and the fact that SeAT has initiated a specific project to design and test scrubbers for ships may indicate that the existing scrubbers are not working properly.

Another important element is that the scrubber technology developed by SeAT will only work with sea water and currently is inefficient with fresh water or with water with reduced salinity. As a result of this, Wärtsila has set up a new project to develop scrubbers that would use caustic soda as the prime medium. We have no information on any detail of this technology.

The question is however, would scrubbers be available and how much time will it take to phase in such a demand? To make the assessment, one needs to make a few assumptions:

how many scrubbers will be needed?
how much time will it take to install them/ship?
number of shipyards that can do the job
how much time will be needed to phase-in a scrubber solution?

1. How many scrubbers will be needed - According to Fairplay database, the number of commercial ships that could be subjected by MARPOL Annex VI limitations on low sulphur and low PM emissions are 46,340. Each ship will need one scrubber for the main engine and possibly one scrubber for each auxiliary engine. Although the current test onboard Pride of Kent runs with one scrubber/auxiliary engine, there are views that one could reduce the number of scrubbers that would treat the exhaust emissions from the auxiliaries. Roughly, we could say there would be between 3 and 5 scrubbers/ship. Thus, the potential number of scrubbers to be supplied to all these ships is of some 140,000 and 230,000. Even if only half or one-third of the fleet will need to be supplied with scrubbers (taking only the case of 3 scrubbers/ship), the numbers (70,500 and 47,000 respectively) are impressive.

2. How much time will it take to install 3 to 5 scrubbers/existing ship - Not known but various views estimate between 30 days and 45 days. However, expert opinion (i.e. designers who looked into project for such retrofitting estimate it may take as much as 90 days).

3. Number of shipyards that can do the job - If we limit the assessment to ships of 30,000 dwt and above, there are not too many ship repair yards to do the job. Roughly one could estimate between 50 and 100.

4. How long will it take to retrofit scrubbers to the existing fleet - Assuming that 10,000 and 15,000 ships over 30,000 dwt will be expected to retrofit scrubbers, the time needed will be:

10,000 ships x 30 days/ship / 365 days/year / 100 ship repair yards = **8+ years**

15,000 ships x 30 days/ship / 365 days/year / 100 ship repair yards = **12.5 years**

Note that we took a conservative view and the time for retrofitting on a limited number of existing ships is extremely long provided that ship repair yards work for all this period every single day, including week-ends. Assuming a 45 days retrofitting time for each ship, the phase-in retrofitting period will be 12 years and 15.5 years respectively.

OVERALL CONCLUSIONS:

1. Oil companies have lately recognised that if required by regulations, they will be able to supply the necessary amount of additional MDO. The only element which counts is time. Although they predict at least 10 years, the official reports on investments in expansion and construction on new distillation units plus better utilisation of the existing capacities and change on the current production streams indicate oil companies could make MDO available in sufficient amounts sometime between 2012 and 2015 if IMO indicates that MDO will be mandated by that time.

2. The low sulphur residual fuels are most likely not a solution in case of a higher demand for use of low sulphur fuels by ships. They would cover a smaller part of the demand. However, residual fuels, even with low sulphur still do not adequately address the requirements for lower PM emissions as MDO does.

3. Scrubbers, yet not in production in series. Tests are yet to be performed on main engines. Test results on auxiliaries still to be revealed. The option to use scrubbers would require a long time for retrofitting in all ships that would cross SECAs. This does not take into account the significant demand in manufacturing large numbers of scrubbers in a short period of time. It also does not address the materials to be used for the pipes and other fittings of the installation after treatment. Due to the high acidity, we understand that these elements are for the time being made of titanium. A large number of scrubbers would require a large amount of such special materials of which availability is not known to us.

Environmental Impact - CO_2 emissions

MDO

There has been a campaign on alleged increase of CO_2 emissions in case of a request to supplement MDO supply. From the outset, INTERTANKO would say that all these allegations are not properly founded but, just made to oppose the idea of using MDO by ships.

There is no proof that additional supply of MDO will result in 15% increase of CO_2 emissions from refineries (IMO document BLG 11/5/14, February 2007). To the contrary, the exclusive use of MDO by all ships will be the alternative that would have the lowest impact, IF any, in additional CO_2 emissions as compared with the other alternatives.

We have only incomplete data but, can state that de-sulphurisation of residual fuels will produce more CO_2 than adding up to 10% more MDO supply of the total refinery production capacity for heavy distillates. Taking into account the new projects for improving the distilling capacity world wide given in the section before (Petroleum Economist, Profits boom on strong demand, September 2006), one can assume that in theory there would be a marginal possible CO_2 additional emissions by adding MDO.

Moreover, the use of MDO by ships is the only alternative that would actually reduce the fuel consumption from operating ships with at least 4%. This too was challenged but, it can be also reflected by the data provided by IPIECA. In brief, the CO_2 emissions are accounted as a direct measure of the mass of fuel consumed by an engine. On one hand, due to its lower density, the same volume of MDO as compared with HFO is some 10% lower by mass. On the other hand, due to the fact that the calorific value is measured in energy produced/mass, the MDO needed to maintain the same power output, will not be 10% but only 4% lower by mass as compared with the mass of HFO that would be used for the same trip and the same speed. (calorific value of MDO is 42 MJ/kg: calorific value of HFO is 38 MJ/kg). In conclusion, to keep the same power output as using HFO, a diesel engine will use less MDO by mass than when using HFO by some 4%. This will mean at least a 4% reduction of CO_2 emissions.

Low Sulphur Residual Fuels

Significant supply of Low Sulphur Residual Fuels will be provided by de-sulphurisation of residual fuels. This implies indeed conversion of refinery units and the de-sulphurisation such as hydro de-sulphurisation (HDS) which will result in a by-product such as hydrogen sulphide (H_2S) which is lethal and will need to be burned. In a nutshell, the process of obtaining significant amounts of low sulphur residuals will produce significant additional CO_2 emissions with no deductible reduction for ship operations as in case of using MDO.

Scrubbers

In case of scrubbers, the additional CO_2 emissions from manufacturing 40,000 - 70,000 scrubbers need to be seriously considered. In addition, there would be additional CO_2 emissions from energy used to operate the large pumps (up to 2 MW and 3 MW) needed to supply of large water flow required by these systems.

OVERALL CONCLUSION

A rough environmental assessment based on potential additional CO_2 emissions from alternative solutions shows:

a) HFO with scrubbers = highest CO_2 impact
b) De-sulphurisation of HFO (to 1% or 0.5%) = second highest CO_2 impact
c) low sulphur distillate (0.5%) = marginal CO_2 impact

Cost Assessment

There is limited information available to assess the capital and the running costs of scrubbers and SCRs. However, INTRTANKO has made a cost assessment based on the best information which has been made available by manufacturers. Some of the cost assessments and the source of the information are given as follows:

Scrubbers - Krystallon indicates that the capital cost of a scrubber is calculated on price differential and a payback time of 3.5 years for an average fuel consumption of a tanker.

SCRs - Sources like Haldor Topsøe and Munters gave capital costs as function of the installed power as follows:

for 15 MW - USD500,000
for 30 MW - USD850,000 - USD900,000

The running costs/urea consumption was given as between USD200/tonne and USD285/tonne.

According to these cost estimates, INTERTANKO made a rough assessment of costs to ship owners by using scrubbers and SCRs (Selective Catalytic Converters). The fleet size, the average of the main engine power and the average of auxiliaries' power were taken from the Fairplay database. The usage of main engine and auxiliaries was made by INTERTANKO.

ASSUMPTIONS		
Fleet size:	46,340 ships	
Average main engine size:	5.6 MW	
Three auxiliaries:	750 kW/each	
Main engine usage:	300 days/year	
Auxiliary usage:	365 days/year	
CAPITAL COST ONLY		
Scrubber main engine:	US$40 billions	
Scrubber aux. (3):	US$20 billions	
SCR main engine:	US$13 billions	
SCR aux. (3):	US$5 billions	
TOTAL		US$78 billions
TOTAL (50% of fleet to install)		US$39 billions

According to IPIECA, the costs to refineries to provide the needed MDO was estimated to some US$38 billions

However,
IPIECA prices based on 200 mill tons MDO
Reality is lower than that 120 - 140 mill tons MDO (60% - 70%)
Price for refineries most likely 23 - 27 bill USD if we accept the 38 bill USD given by IPIECA was correct
There would be a similar cost level for ship owners if only 28% to 36% of the commercial fleet will be retrofitted

However, according to BP, the capital costs for scrubbers in new buildings, as given above are some 60% to 70% of the costs of retrofitting the same in existing ships.

The capital cost provided above is based on cost expectation indicated by manufacturers who did not commit a price. If scrubbers are a solution and they would be the alternative most ships will look for, one could anticipate a shortage of available units with the consequent price increases as per the demand-supply.

Use of MDO will only require simpler, low cost modifications like modification of fuel pumps, injection system in engines and boilers, etc which can be done in a few days with no need to dry-dock.

Note to be taken that the cost estimates above did not include:

expenses for each ship to dry-dock and spend a month in retrofitting the installations
cost of operating scrubbers (running some 10,000 t to 20,000 t of water per day - Krystallon data: 45 t/hr/MW; waste disposal of some 50 kg to 100 kg/day of hazardous waste - Krystallon data: 5 Kg/day/MW) (see Appendix 1)
eventual losses when scrubbers will not work in SECAs - Krystallon had problems with the monitoring equipment, the quantum cascade laser technology used to measure the SOx, CO_2, NO_x and PM levels. According to BP (ref. 8) these problems were resolved but we do not know whether this QCL probe is going to become a similar sensitive monitoring system that ships have experienced with the Oil Counter Meter.
the "cost" of waste in residual fuels taking into account the sludge which is part of the originally paid fuel (the extent of oil sludge generation from a purifier is approximately 0.7% of the bunkers consumed (figures from DNVPS and FOBAS); this means that the total oily sludge generation from bunkers per annum is 1,337,000 tonnes (based on the 191million tonnes used per annum globally); taken at a current price for HFO of USD250/t, the ship owners pay some USD335 mill/year for the amount of component of the residual fuels that would turn as sludge and that would cost further to be disposed of)

OVERALL CONCLUSION:

It is not easy to make a cost comparison between the current alternative solutions because:

there is very little information on the costs of the abatement technologies still under development;
there is no indication what would be their actual price in case the demand will go far beyond the supply (no data on the production capability from different and very few manufacturers);
it is difficult to predict the costs for ships for running these after-treatment installation and the costs to segregate and dispose the solid waste;
it is not easy to predict the price difference between MDO and HFO few years ahead.

It is however easy to conclude that no matter the outcome of the IMO revision of MARPOL Annex VI, the costs for ship owners will be significant.

One can predict that use of MDO only will be among the more expensive solutions but there are serious doubts that the difference would be as high as predicted by some.

Final comments

The INTERTANKO approach to consider use of MDO as the dedicated fuel for ships is based on a concept of creating a stable and predictable regulatory regime. It would probably be difficult to believe that in 10 years from now, ships running along the EU coasts and in bays, estuaries and fjords will be allowed to use residual fuels, even with low sulphur content. Use of scrubbers might then be an alternative but would coastal states accept whether the waste generated by scrubbers is processed or discharged in coastal waters? However, if ships engaged in coastal trade will use scrubbers, then what would be the problem to strip the sulphur from fuels at refineries on shore? Are ships better plants to treat fuels than refineries? Last but not least, high reduction of NO_x emissions would ultimately require use of low sulphur MDO because any of the current methodology to reduce NO_x emissions gets more complicated, with fuel penalties and more difficult to operate if ships burn residual fuels.

Comparison between the three alternatives shows that in practical terms the MDO is the simplest and fastest solution that can be obtained and it is the only solution that can realistically be applicable in a short period of time to ALL ships.

Additional conclusions could also be drawn:

- if refiners cannot supply 10% more MDO, a product that has been produced for several decades and used by ships for a long period of time, it would be highly unrealistic to expect a new product like scrubbers to become an efficient solution;
- operational efficiency of scrubbers onboard ships in bad weather is not yet demonstrated; it would be more efficient to provide MDO by use of known technology from less than 700 refineries world wide than to equip 20,000 - 40,000 commercial ships with complete new technologies and demand all these ships to operate a new equipment and to handle a significant amount of waste.

Concluding, we are positive to the fact that the INTERTANKO paper to IMO has finally generated an open and more transparent discussion on alternative solutions and their practicalities for reducing air emissions from ships.

Should you have more information, please do not hesitate to contact us.

Yours sincerely,
INTERTANKO