

# **Sulphur content in ships bunker fuel in 2015**

**A study on the impacts of the new IMO  
regulations on transportation costs**





Authors (from body; name, chairman and secretary of the body) <b>Juha Kalli, Tapio Karvonen and</b>		Type of publication <b>Report</b>	
Teemu Makkonen, University of Turku,		Assigned by <b>Ministry of Transport and Communications</b>	
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Name of the publication <b>Sulphur content in ships bunker fuel in 2015</b> <b>A study on the impacts of the new IMO regulations and transportation costs</b>			
Abstract <p>On 10 October 2008 the Marine Environment Protection Committee of the International Maritime Organisation, IMO, unanimously adopted the revised Annex VI, Prevention of Air Pollution from Ships, to the MARPOL 73/78 Convention. The Annex sets limits on nitrogen oxide and sulphur oxide emissions from ship exhausts. Low sulphur fuel also reduces particulate emissions from ships. The new Annex will enter into force on 1 July 2010. The highest sulphur content allowed in ship fuel will reduce globally as of 1 January 2012 from 4.5% to 3.5% and as of 1 January 2020 to 0.5%. Sulphur content allowed in Sulphur Emission Control Areas (SECA) that currently include the Baltic Sea, the North Sea and the English Channel will decrease as of 1 July 2010 from 1.5% to 1.0% and as of 1 January 2015 to 0.1%. The use of exhaust gas cleaning systems will continue to be allowed, which means that vessels equipped with scrubbers may also run on types of fuel that are currently in use.</p> <p>According to an IMO expert study, the use of heavy fuel oils will largely have to be abandoned once the sulphur content limit in fuel decreases to less than 1%. Transfer to low sulphur and thus cleaner fuels (marine diesel and marine gas oil) will increase fuel costs considerably, because it is more expensive to produce cleaner fuels than heavy fuels. Fuel price forecasts should be treated with caution because there are so many variables affecting the price.</p> <p>A calculation model presented in the study estimates the fuel consumption of vessels in Finland's foreign trade transport to be 1.8 million to 2.6 million tonnes a year. With many uncertainties involved, it is difficult to estimate how the fuel price will develop. The two fuel consumption scenarios in the study suggest that additional costs would amount to between 200 million and 1.18 billion euros. After the entry into force of the new IMO regulations in SECA areas in the beginning of 2015, the growing fuel costs will increase sea freight charges.</p> <p>The savings in fuel costs due to the possible use of a scrubber adaptable to Baltic Sea conditions has been considered in the calculations. The calculations do not, however, take account of the impact of the new SECA areas. The USA and Canada will establish a SECA area outside their coastal areas. The Commission of the European Union is also exploring the possibilities to establish SECA areas outside EU Member States' coastal areas in the Mediterranean and the Black Sea. The increasing demand for low sulphur fuel will increase the market and thus influence the price formation.</p>			
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## ABSTRACT

On 10 October 2008 the Marine Environment Protection Committee (MEPC) of the International Maritime Organisation (IMO) unanimously adopted the revised Annex VI to MARPOL 73/78 (International Convention for the Prevention of Pollution from Ships), which places restrictions on nitrogen and sulphur oxides emissions from ship traffic. Lowering the sulphur content in fuels will also be a way to reduce emissions of particulate matter from shipping. The new Annex enters into force on 1 July 2010. The sulphur content of fuel will fall in the special areas (SECA = Sulphur Emission Control Area), which are the Baltic Sea, the North Sea and the English Channel, from 1.5% to 1% from 1 July 2010, and to 0.1% from 1 January 2015. Globally, the highest permitted sulphur content of fuel will fall, as from 1 January 2012, from 4.5% to 3.5%, and to 0.5% from 1 January 2020. The use of sulphur scrubbers will still be allowed, so that the fuel grades currently in use on vessels fitted with them can also be used.

For a long time now, large car and passenger ferries on the Baltic Sea have been using heavy fuel oil with a sulphur content of no more than 0.5%. However, there is not enough of it as things are now – and the situation may not change in the future either – to meet the needs of all marine traffic in the Baltic, North Sea and English Channel. A report by the IMO states that approximately 0.5% of the fuel currently used by global maritime traffic is heavy fuel oil with a sulphur content of less than 0.5%. According to the report, the use of heavy fuel oil grades will mainly need to be abandoned when the sulphur content limit for fuel is less than 1%, necessitating a switch to light fuel grades. Accordingly, it is also difficult to estimate the price that heavy fuel oil with a maximum sulphur content of 0.5% might be in the future.

A switch to fuel with a maximum sulphur content of 0.1% will in practice mean that vessels will have to use gas oil (MGO) as fuel, which is a lot more expensive than heavy fuel oils, owing to the way it is manufactured. It has proven difficult to estimate the availability of low sulphur fuels. Estimates received suggest that the problems will not be owing to the demands on SECA areas, at least not yet, but to the fact that when light fuels start to be used worldwide, the oil industry will have to increase its refining capacity considerably to meet the rise in demand for light fuel grades.

One should always exercise caution when predicting future prices for fuels, as there are so many variables involved. Besides, price trends are not so much based on facts as all the various expectations and beliefs concerning the future. Uncertainty and the massive fluctuations in fuel prices we have witnessed have led us in this report to give fuel prices that are not based on any precise value but a probable range of variation on the basis of estimates by the member companies of the Finnish Oil and Gas Federation.

The expert views received from shipping companies and Confederation of Finnish Industries associations suggest that rising fuel costs will, in time, be incorporated in their entirety in sea freight costs. As a result, sea freight charges will increase considerably when the stringent regulations on maximum sulphur content take effect. Rising freight costs will particularly affect sectors that depend very much on exports and/or imports.

The total fuel consumption for ships bound for Finland has been estimated on the basis of two scenarios for consumption in 2007, where maximum consumption is 2.6 million tonnes (scenario 1) and minimum consumption is 1.8 million tonnes (scenario 2). The estimate is that if vessels bound for Finland were to switch from heavy to light fuel - in this case gas oil with a maximum sulphur content of 0.1% - the following additional costs would be incurred, given the differential in prices for fuel grades:

- 1) at 111 euros per tonne the maximum would be 273 million euros and the minimum 190 million euros
- 2) at 480 euros per tonne the maximum would be 1.182 million euros and the minimum 823 million euros

The calculations do not take account of the savings in fuel costs through the possible use of sulphur scrubbers, adapted to deal with the conditions in the Baltic Sea.

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Appendix 1: Outlook for Marine Bunkers and Fuel Oil to 2025. Sourcing Lower Sulphur Products

## 1 INTRODUCTION

On 10 October 2008 the Marine Environment Protection Committee (MEPC) of the International Maritime Organisation (IMO) unanimously adopted the revised MARPOL 73/78 (International Convention for the Prevention of Pollution from Ships) Annex VI on air pollution from ships. The aim of the IMO is to reduce emissions from ships by a switch from heavy fuel oils to light fuel oils. The new rules would place restrictions on nitrogen and sulphur oxides (NO<sub>x</sub> and SO<sub>x</sub>) emissions from ship traffic into the atmosphere and as fallout into the sea. Lowering the sulphur content in fuels is also a way to reduce emissions of particulate matter from shipping. The regulations would help reduce the harmful effects of emissions on human health and the marine environment, and would increase navigational safety.

The new Annex enters into force on 1 July 2010, in accordance with the 'tacit acceptance procedure of the MARPOL 73/78 Convention.

The sulphur content of fuel will fall in the special areas (SECA), which are the Baltic Sea, the North Sea and the English Channel (figure 1), from 1.5% to 1% from 1 July 2010, and to 0.1% from 1 January 2015. Globally, the highest permitted sulphur content of fuel will fall, as from 1 January 2012, from 4.5% to 3.5%, and to 0.5% from 1 January 2020. The use of sulphur scrubbers will still be allowed, so that the fuel grades currently in use on vessels fitted with them can also be used.

The European Union will also see a regulation take effect on 1 January 2010 which states that if a vessel is in a port for more than two hours it has to use a fuel with a sulphur content of no more than 0.1% while it is there.

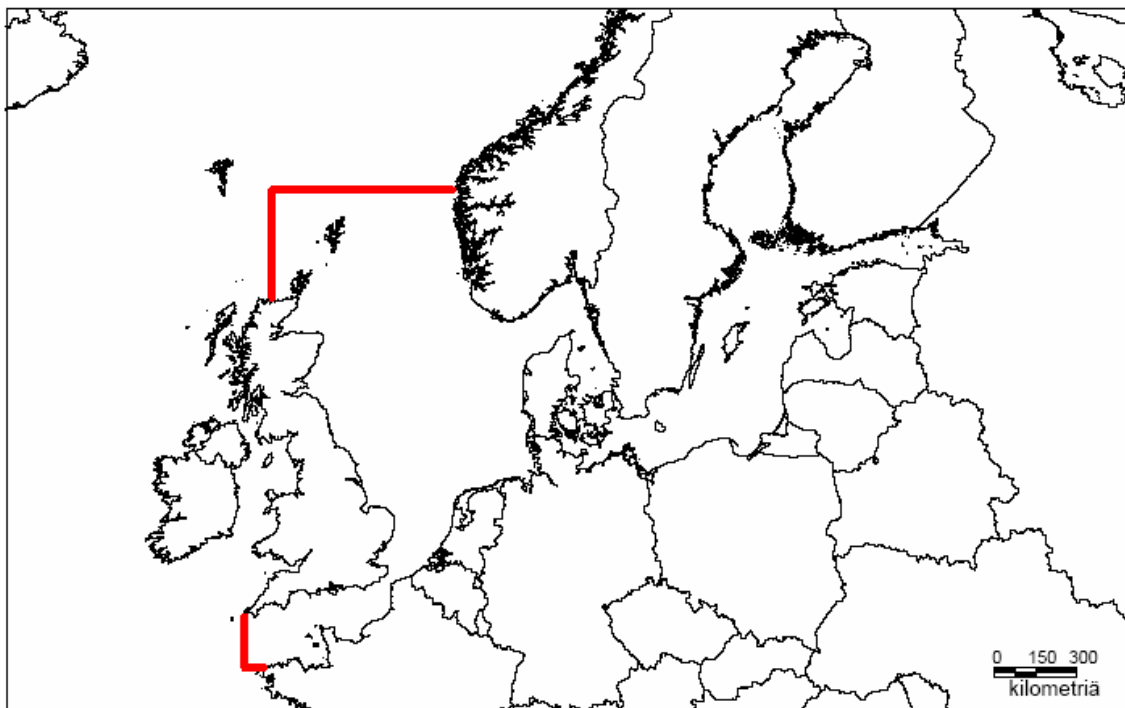


Figure 1.1. The SECA special area (Baltic Sea, North Sea [latitude 62° north and longitude 4° west] and the English Channel [longitude 5° west]).

In addition, the IMO's MEPC 58 meeting endorsed the three Tier rules for NO<sub>x</sub> emission limits (Tiers 1-3) In addition to the existing Tier 1, there will be a Tier 2 standard for new engines (in effect from 2011; around 20% lower than Tier 1) and the Tier 3 emission limits (in effect from 2016; around 80% less than Tier 1). The Tier 3 standard is to be applied in the special Emission Control Areas established and would mean, using current technology, the introduction of the catalyst system, for example. The Tier 2 standard can be attained through improved engine technology. HELCOM is at present looking into the possibility of creating an NO<sub>x</sub> special area in the Baltic Sea.

The IMO's MEPC is presently preparing draft measures to limit greenhouse gases from shipping. The Committee is to continue its discussion of the matter at its meeting in July 2009.

The principle aim of this report is to assess the effect of the regulations on the sulphur content of fuel used by ships under the revised Annex VI of the MARPOL 73/78 Convention on the fuel costs to maritime traffic between Finland and continental Europe and freight traffic transportation costs in the SECA area, and also to assess the impacts of these costs on the various import and export sectors in Finland.

The report was produced by the Centre for Maritime Studies at the University of Turku. It was the work of special researcher Mr. Tapio Karvonen, acting as project manager, and researchers Me. Juha Kalli and Mr. Teemu Makkonen. The report was commissioned and sponsored by the Finnish Ministry of Transport and Communications. Mrs. Lolan Margaretha Eriksson, Ministerial Counsellor at the Ministry, acted as Chairperson of the Steering Committee. The other members were Mr. Jorma Kämäräinen, Senior Maritime Inspector, Mr. Markus Helavuori, Maritime Inspector at the Finnish Maritime Administration, Mrs. Tiina Haapasalo, Senior Adviser at the Confederation of Finnish Industries, and Mr. Bernt Bergman and Mr. Tero Jokilehto, both Senior Advisers at the Finnish Shipowners' Association.

## 2 DAY-TO-DAY RUNNING COSTS OF THE VARIOUS VESSEL TYPES

Figure 2.1 gives the relative distribution of the day-to-day running costs by vessel type of vessels operating between Finland and other countries and sailing under the Finnish or a foreign<sup>1</sup> flag, according to the Finnish Vessel Costs Survey 2006. Cost factors are proportionately tied to vessel type and size. Seven vessel types are examined: container, container feeder<sup>2</sup>, conventional dry cargo, dry bulk and ro-ro vessels, car and passenger ferries and tankers. The comparisons given here were made by vessel type according to the mean value for their draught categories<sup>3</sup>. It will be seen from the diagram that fuel costs account for the largest share of the vessel costs for all vessel types now, and especially container vessels (fuel prices as at 2006: container vessels 54%, conventional dry cargo vessels 38%, dry bulk vessels 40%, tankers 33 %, ro-ro vessels 36%, and car and passenger ferries 30%)<sup>4</sup>.

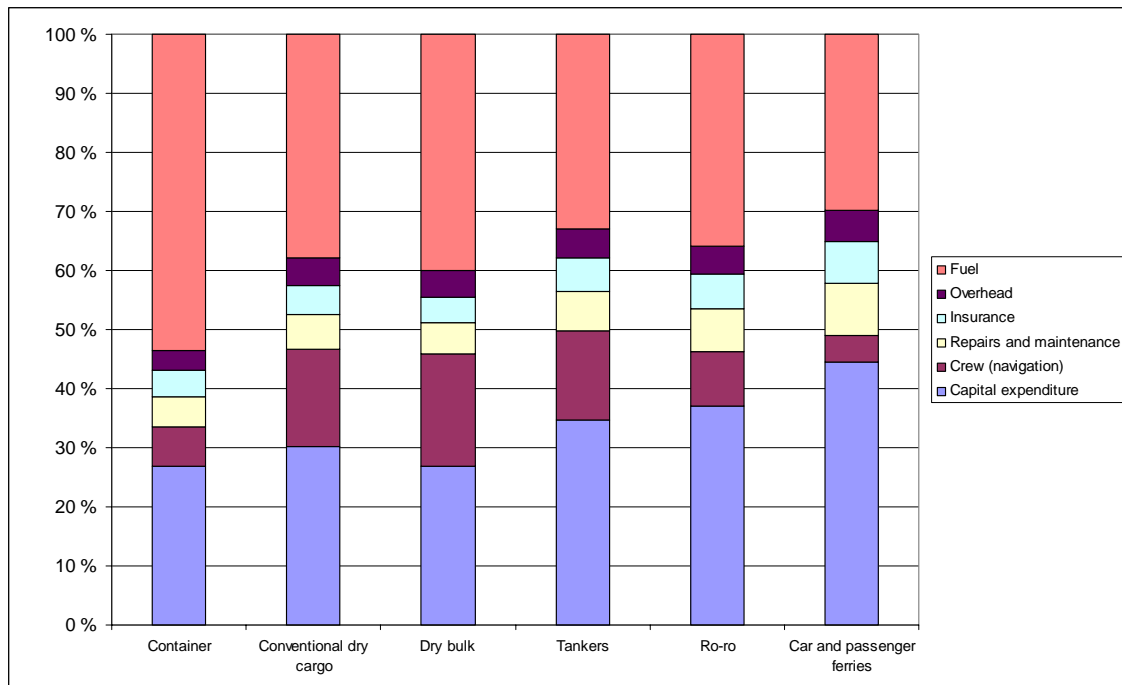


Figure 2.1. Distribution of costs by vessel type on average for vessels operating between Finland and other countries and sailing under the Finnish or a foreign flag (Karvonen et al 2006).

<sup>1</sup> The structure of day-to-day running costs of foreign vessels is assessed in the survey (Karvonen et al 2006) with principle reference to the main flag states for vessels entering Finnish ports.

<sup>2</sup> A typical container vessel for feeder traffic in operation in Finnish waters (draught 9 m, container capacity approximately 1,000 TEU).

<sup>3</sup> Because the calculations do not use a weighted mean value, the figures do not reflect an average vessel but the mean values for draught categories.

<sup>4</sup> With regard to container vessels, it should be noted that the calculation is based on sample data, including that for large container vessels that do not enter Finnish ports. The share of fuel costs is not so great for feeder container vessels typically sailing in Finnish waters. It is closer to those for conventional dry cargo vessels.



Changes in the price of fuel affect the relative cost structure. If it rises, fuel and vessel running costs increase and the relative share of fuel costs as a component of day-to-day costs also goes up. It should be noted with regard to vessel costs that the fuel costs contained in them have been calculated in general with reference to the vessel's engine power. In reality, vessels with the same engine power can consume very different amounts of fuel. The speeds of vessels also affect consumption, which has an impact on fuel costs: consumption at lower speeds is less, and fuel costs are also lower as a result. But vessels on scheduled routes cannot normally reduce their speed without it affecting the viability of the entire transport chain.

The Vessel Costs Survey 2006 and the additions made to it (Karvonen 2007) can help us to identify the average total costs and fuel costs<sup>5</sup> for the different vessel types both overall and per transported unit (Tables 2.1 and 2.2). Car and passenger ferries have by far the highest operational and fuel costs. The running costs for ro-ro ships are clearly higher than other cargo ship types when costs are examined for each transported unit (see Karvonen et al 2006).

*Table 2.1. Average fuel and operating costs for container vessels<sup>6</sup>*

Vessel type	Fuel costs € per travel day	Vessel costs € per travel day	Fuel costs €/TEU per travel day	Vessel costs €/TEU per travel day
Container vessels	24,199	35,983	15.63	23.24
Container feeder vessels	15,081	23,184	12.73	19.56

*Table 2.2. Average fuel and operating costs for vessel types*

Vessel type	Fuel costs € per travel day	Vessel costs € per travel day	Fuel costs €/t per travel day	Vessel costs €/t per travel day
Conventional dry cargo ves- sels	6,425	12,320	0.67	1.29
Dry bulk vessels	10,357	19,033	0.29	0.53
Tankers	10,093	21,615	0.40	0.86
Ro-ro vessels	14,587	29,255	1.70	3.41
Car and passenger ferries	41,166	95,407		

<sup>5</sup> To eliminate the distorting effect of huge fuel price fluctuations for short periods of time, the calculations have made use of a three year (2006-2008) average of 370 USD/t = 271 €/t, i.e. at the average dollar exchange rate for the same period (1 USD = 0,732 €) (Scandinavian Shipping Gazette 2009; Bank of Finland 2009).

<sup>6</sup> With container vessels the transported unit referred to is not the number of tonnes but TEUs, because that reflects the reduction in vessel costs in relation to the amount of transported goods on container vessels more satisfactorily than a calculation based on the number of tonnes, as the economies of scale are very obvious (Karvonen 2007).

### **3 EFFECT OF THE ESTIMATED FUEL PRICE RISE ON THE CHANGE TO THE DAY-TO-DAY RUNNING COSTS OF VESSELS**

#### **3.1 Ship fuels**

Ships generally run on heavy fuel oil (HFO/IFO). In auxiliary engines distillates are usually used like marine diesel oil (MDO) or marine gas oil (MGO, with a maximum sulphur content of 0.1%). Both of these have a lower sulphur content than heavy fuel oil. MDO and MGO are also collectively known as light fuel oil. These distilled fuels are more expensive than heavy fuel. For the purposes of this report, shipping companies were asked in what proportion they used heavy fuel and distilled fuel grades in their vessels. The answers received showed that 95% of the fuel used was heavy fuel oil and 5% MDO or MGO. This information was used in the cost calculations presented later in this report.

It is possible to achieve a low sulphur content in fuel in two ways:

- 1) heavy fuel oil can be made from crude oil, which naturally contains less sulphur
  - or
  - 2) high sulphur and low sulphur fuel are mixed together
- Fuel containing less than 1.5% sulphur, which is used at present in the Baltic Sea, the North Sea and the English Channel, is normally high sulphur fuel which has been mixed with a slightly lower sulphur content fuel, to keep the sulphur content under the 1.5% mark. In 2010 the sulphur content limit will drop to 1.0%, which will in practice mean having to change the mixing proportions, resulting in a greater need for low sulphur fuel. Mixing different fuel grades, however, could lead to increasing engine problems due to poorer quality fuel, as the new blends might be unstable.

#### **3.2 Fuel prices**

By 2015 the maximum sulphur content limit will fall to 0.1% in the SECA areas. Then it will be technically impossible to mix fuel grades, and ships will have to switch to gas oil (MGO), which would be the only option among the fuel grades presently available. Because of the way it is manufactured, MGO is far more expensive than heavy fuel oils. Furthermore, as the demand for it increases, it will also presumably go up in price.

As has been said, the prices of fuel grades containing less sulphur are higher than that for the fuel grade more commonly in use at the moment (heavy fuel oil with a sulphur content of 1.5%). This will cause a rise in the fuel costs of vessels. The change to fuel costs was assessed by asking member companies of the Finnish Oil and Gas Federation (ÖKKL) for their estimates for price increases for ship fuels (Table 3.1). The prices given are at current levels. The fuel grades concerned are:

- 1) heavy fuel oils (sulphur content 1.0 % and 0.5 %)
- 2) light fuel oil (sulphur content 0.1 %) <sup>7</sup>.

One should always exercise caution when predicting future prices for fuels, as there are so many variables involved. Besides, price trends are not so much based on facts as all the various expectations and beliefs concerning the future. It may be that only a few refineries will specialise in the manufacture of lower sulphur fuels. If future demand should exceed supply, price differentials may be even greater than the estimates here. Furthermore, if prices go up, sulphur levels might also be lowered by mixing middle distillates with a quantity of heavy fuel, which will also affect future fuel prices. Uncertainty and the massive fluctuations in fuel prices (Figure 3.1) we have witnessed have led us in this report to give fuel prices that are not based on any precise value but a probable range of variation on the basis of estimates by the member companies of the Finnish Oil and Gas Federation (Table 3.1). For the sake of comparison, we can say that the average price for heavy fuel oil presently used globally (sulphur content 2.6–2.7%) at the start of 2009 (24.12.2008–25.2.2009) in Rotterdam was around 173 euros a tonne (Petromedia Ltd. 2009; Bank of Finland 2009).

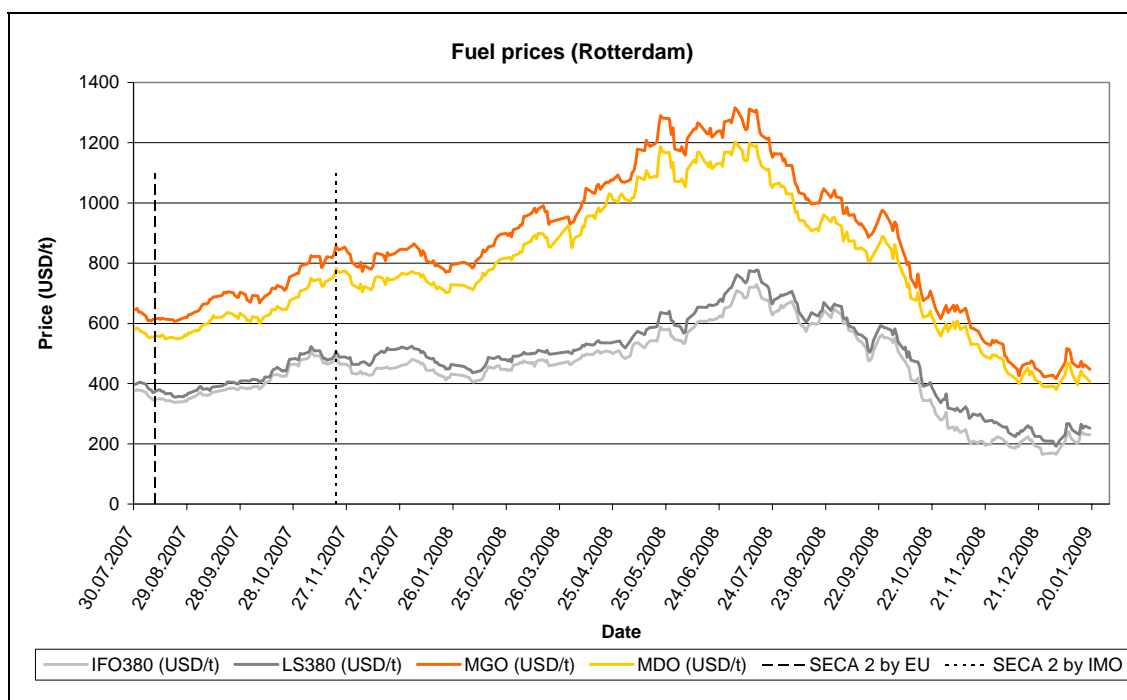


Figure 3.1. Recent fluctuations in the price of fuel (see Appendix). In the diagram LS (Low Sulphur) is heavy fuel oil used in the SECA areas (meets the current 1.5 % requirement for sulphur content). MDO and MGO are light fuel oils, of which MGO is the only one that contains less than 0.1% sulphur (MDO is also available in Finland; it has a sulphur content of less than 0.1%). IFO (intermediate fuel oil) is heavy fuel oil that may contain 4.5% sulphur. 380 is the fuel's viscosity.

<sup>7</sup> ÖKKL member companies were also asked for estimates of the price and availability of light fuel oil (sulphur content 0.5%), but this fuel grade is still unknown to suppliers of fuel. Light fuel oil with a maximum sulphur content of 0.1% is, to all intents and purposes, gas oil.

Table 3.1. Estimated price differentials<sup>8</sup> for low sulphur fuel grades in relation to the fuel grade currently in use (maximum sulphur contents in brackets)

Fuel grade	Price € per tonne	Differential € per tonne	Differential expressed as a percentage
Current heavy fuel oil (1.5%)	271		
Heavy fuel oil (1%)	290–330	+19–59	7–22 %
Heavy fuel oil (0.5%)	305–350	+34–79	13–29 %
Light fuel oil (0.1 %)	470–500	+199–229	73–85 %

The estimated fuel prices help calculate the new fuel and vessel costs for the various vessel types (Tables 3.2 and 3.3). Fuel costs will rise and their share of overall vessel costs will increase. It is worth noting that the switch from heavy fuel oil to light fuel oil will at the same time give rise to a very substantial rise in costs. Light fuel costs will be considerably higher in all vessel types as compared to heavy fuel if the price estimates for fuel grades used in this survey prove correct.

This will also affect global navigation when the global switch to fuel with 0.5% sulphur content in 2020 or no later than 2025 takes place. According to a report by the IMO (2008), the use of heavy fuel oil grades will mainly need to be abandoned when the sulphur content limit for fuel is less than 1%, necessitating a switch to light fuel grades. An alternative, however, is the use of sulphur scrubbers, which would allow the use of current fuel grades.

The USA and Canada will present a proposal to the IMO in 2009 to have their sea areas, which extend 200 nautical miles from their coastlines, designated as special areas with regard to the sulphur content regulations in the new Annex VI to the MARPOL Convention. In this report it has not yet been possible to take account of the change to the demand and availability of low sulphur fuel this would cause.

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<sup>8</sup> Given here is the three-year (2006-2008) average for fuel prices and the changes estimated with reference to that, and not the price for any single day.

Table 3.2. Effect of the minimum and maximum estimated price rise for fuel (See Table 3.1) on the day-to-day running costs of container vessels.

Vessel type	Fuel costs € per travel day	Percentage increase	Vessel costs € per travel day	Percentage increase	Fuel costs €/TEU per travel day	Percentage increase	Vessel costs €/TEU per travel day	Percentage increase
Container vessels	24,200		36,000		15.62		23.24	
- Heavy fuel oil 1%	25,900-29,400	7 - 22 %	37,700-41,200	5 - 15 %	16.64 - 18.78	6 - 20 %	24.21 - 26.29	4 - 13 %
- Heavy fuel oil 0.5 %	27,200-31,200	12 - 29 %	39,000-43,000	8 - 20 %	17.44 - 19.84	12 - 27 %	24.99 - 27.33	8 - 18 %
- Light fuel oil 0.1 %	41,900-44,600	73 - 84 %	53,700-56,400	49 - 57 %	26.20 - 27.78	68 - 78 %	33.56 - 35.12	44 - 51 %
Container feeder vessels	15,081		23,184		12.73		19.56	
- Heavy fuel oil 1%	16,100-18,400	7 - 22 %	24,200-26,500	5 - 14 %	13.61 - 15.49	7 - 22 %	20.45 - 22.32	5 - 14 %
- Heavy fuel oil 0.5 %	17,000-19,500	12 - 29 %	25,100-27,600	8 - 19 %	14.31 - 16.42	12 - 29 %	21.15 - 23.26	8 - 19 %
- Light fuel oil 0.1 %	26,100-27,800	73 - 84 %	34,200-35,900	48 - 55 %	22.06 - 23.46	73 - 84 %	28.89 - 30.30	48 - 55 %

Table 3.3. Effect of the minimum and maximum estimated price rise for fuel (See Table 3.1) on the day-to-day running costs of vessels.

Vessel type	Fuel costs € per travel day	Percentage increase	Vessel costs € per travel day	Percentage increase	Fuel costs €/TEU per travel day	Percentage increase	Vessel costs €/TEU per travel day	Percentage increase
Conventional dry cargo vessels	6,400		12,300		0.67		1.29	
- Heavy fuel oil 1%	6,900-7,800	7 - 22 %	12,800-13,700	4 - 11 %	0.72 - 0.81	7 - 21 %	1.33 - 1.42	3 - 10 %
- Heavy fuel oil 0.5 %	7,200-8,300	12 - 29 %	13,100-14,200	7 - 15 %	0.75 - 0.86	12 - 27 %	1.37 - 1.47	6 - 14 %
- Light fuel oil 0.1 %	11,100-11,800	73 - 84 %	17,000-17,700	38 - 44 %	1.14 - 1.20	69 - 79 %	1.74 - 1.80	35 - 40 %
Dry bulk vessels	10,400		19,000		0.29		0.53	
- Heavy fuel oil 1%	11,100-12,600	7 - 22 %	19,800-21,300	4 - 12 %	0.31 - 0.35	7 - 21 %	0.55 - 0.59	4 - 11 %
- Heavy fuel oil 0.5 %	11,600-13,000	12 - 29 %	20,300-22,000	7 - 16 %	0.33 - 0.37	12 - 27 %	0.57 - 0.65	7 - 15 %
- Light fuel oil 0.1 %	17,900-8,600	73 - 84 %	26,600-30,100	40 - 46 %	0.50 - 0.70	72 - 83 %	0.74 - 0.77	39 - 44 %
Tankers	10,100		21,700		0.40		0.86	
- Heavy fuel oil 1%	10,800-12,300	7 - 22 %	22,300-23,800	3 - 10 %	0.43 - 0.48	6 - 20 %	0.88 - 0.93	3 - 8 %

- Heavy fuel oil 0.5 %	11,400-13,000	12 - 29 %	22,900-24,500	6 - 14 %	0.45 - 0.51	11 - 26 %	0.90 - 0.95	5 - 11 %
- Light fuel oil 0.1 %	17,500-18,600	73 - 84 %	29,000-30,100	34 - 39 %	0.66 - 0.70	65 - 74 %	1.10 - 1.13	28 - 32 %
Ro-ro vessels	14,600		29,300		1.70		3.41	
- Heavy fuel oil 1%	15,600-17,800	7 - 22 %	30,300-32,400	3 - 11 %	1.82 - 2.06	7 - 21 %	3.53 - 3.77	3 - 10 %
- Heavy fuel oil 0.5 %	16,400-8,800	12 - 29 %	31,100-33,500	6 - 14 %	1.91 - 2.19	12 - 29 %	3.62 - 3.89	6 - 14 %
- Light fuel oil 0.1 %	25,300-26,900	73 - 84 %	39,900-41,600	37 - 42 %	2.92 - 3.11	72 - 83 %	4.62 - 4.80	35 - 41 %
Car and passenger ferries	41,200		95,400					
- Heavy fuel oil 1%	44,000-50,100	7 - 22 %	98,300-104,300	3 - 9 %				
- Heavy fuel oil 0.5 %	46,300-53,100	12 - 29 %	100,500-107,400	5 - 13 %				
- Light fuel oil 0.1 %	71,300-75,900	73 - 84 %	125,600-130,100	32 - 36 %				

### 3.3 Fuel availability

Member companies of the Finnish Oil and Gas Federation (ÖKKL) were also asked to assess the future availability of the fuel grades examined, after the new legal instruments pertaining to sulphur oxides emissions enter into force. Individual shipping companies were also asked about the current and future availability of fuel grades. However, neither the ÖKKL members nor the shipping companies were able to estimate future availability with any degree of certainty, as there were so many factors to consider, such as demand, price, the general situation with regard to shipping, etc.

For a long time now, large car and passenger ferries on the Baltic Sea have been using heavy fuel oil with a sulphur content of no more than 0.5%. However, there is not enough of it as things are now – and the situation may not change in the future either – to meet the needs of all maritime traffic in the Baltic, North Sea and English Channel. A report by the IMO states that approximately 0.5% of the fuel currently used by global marine traffic is heavy fuel oil with a sulphur content of less than 0.5% (Figure 3.2). According to the report, the use of heavy fuel oil grades will mainly need to be abandoned, as the sulphur content limit for fuel is less than 1%, necessitating a switch to light fuel grades. Accordingly, it is also difficult to estimate the future price of heavy fuel oil with a maximum sulphur content of 0.5%.

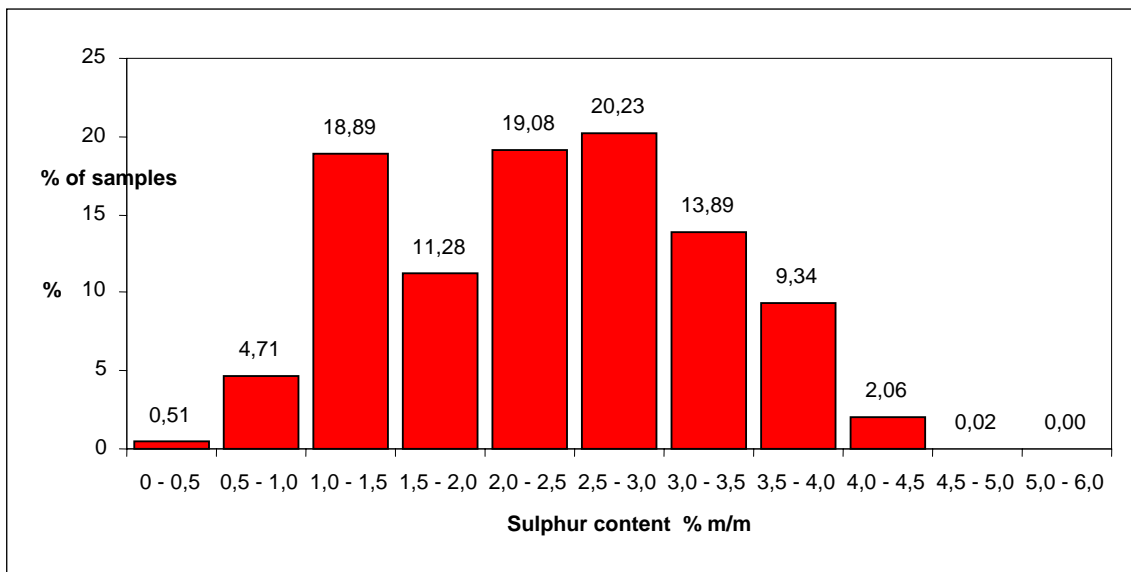


Figure 3.2. The sulphur content of heavy fuel grades used by ships (global marine traffic; 196,925 samples) (IMO 2009)

Heavy fuel oil containing less than 0.5% sulphur is obtained from crude oil with a sulphur content that is clearly less than 0.5%. Heavy fuel oil is distillation residue oil, which remains when grades of light fuel oil have been produced from crude oil. Most of the sulphur remains in the heavy fuel oil, so sulphur-rich crude cannot possibly be used to produce heavy fuel oil containing less than 0.5% sulphur. In practice, of the grades of crude oil shown in figure 3.3 below, heavy fuel oil containing less than 0.5% can only possibly be obtained from Daqing (China), Bonny Lt. (Nigeria), Brent (UK) and WT (USA).



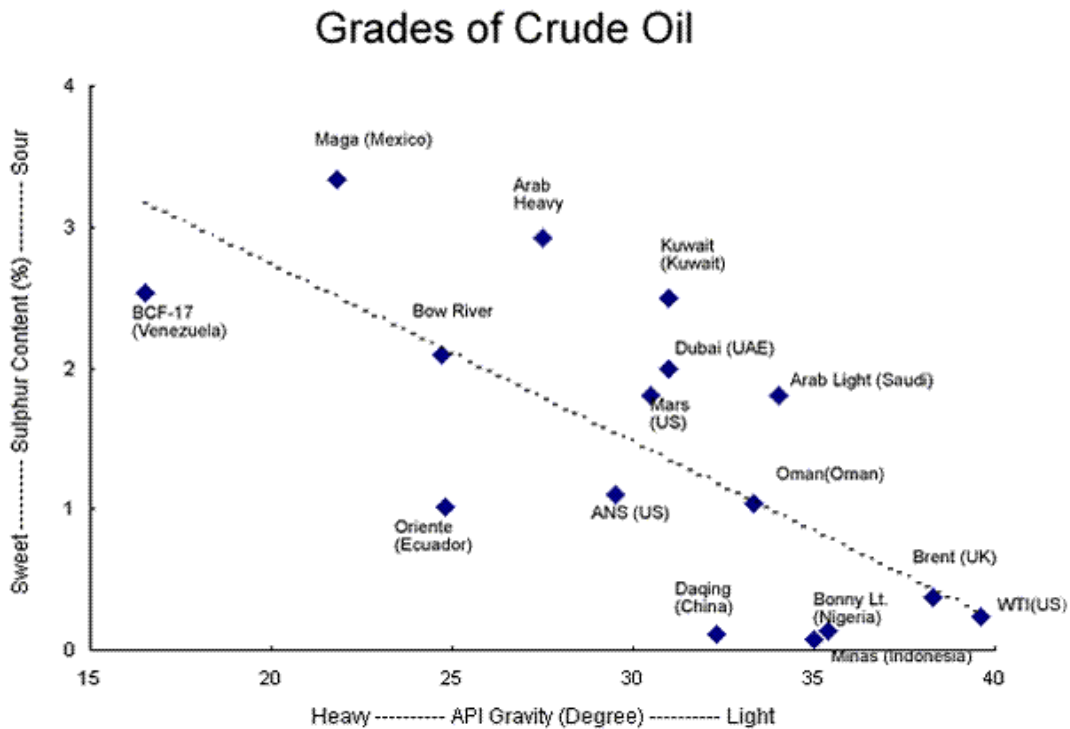


Figure 3.3. The sulphur content of some grades of crude oil. Source: <http://www.fxstreet.com/education/related-markets/oil-basis-grades-of-crude-oil/2008-12-10.html>

In practice, it is not possible to extract sulphur from heavy fuel oil using current methods, because the metallic impurities in heavy fuel oil, such as vanadium and nickel, despite their very low content on the whole, prevent the use of the sulphur extraction systems employed for the lighter fractions in the oil refinement process for the removal of sulphur in heavy fuel oil, as they poison the sulphur extraction catalysts. For that reason, low-sulphur heavy fuel oil is only normally produced from low sulphur crude oil (source: Fortum Oyj, Raskaan polttoöljyn käyttöopas (*Heavy Fuel Oil Guide*), 2002, chapter 1.4.1).

A switch to fuel with a maximum sulphur content of 0.1% will in practice mean that vessels will have to use gas oil (MGO) as fuel, which is a lot more expensive than heavy fuel oils, owing to the way it is manufactured. Similarly, the switch to 0.5% fuel will also in practice mean using diesel oil, or light fuel oil, containing 0.5% sulphur (Figure 3.4).

It has proven difficult to estimate the availability of low-sulphur fuels. Estimates received suggest that the problems will not be owing to the demands on SECA areas, at least not yet, but to the fact that when light fuels start to be used worldwide, the oil industry will have to increase its refining capacity considerably to meet the rise in demand for light fuel grades.

The legal instruments pertaining to sulphur content in the special areas that differ from global requirements have also led to the concern that it would be difficult for vessels

arriving from outside these areas to operate their services for technical reasons connected with their engines and that the volume of direct, long-haul traffic would fall.

It is difficult to estimate future prices for fuels and predict what grades will be available.

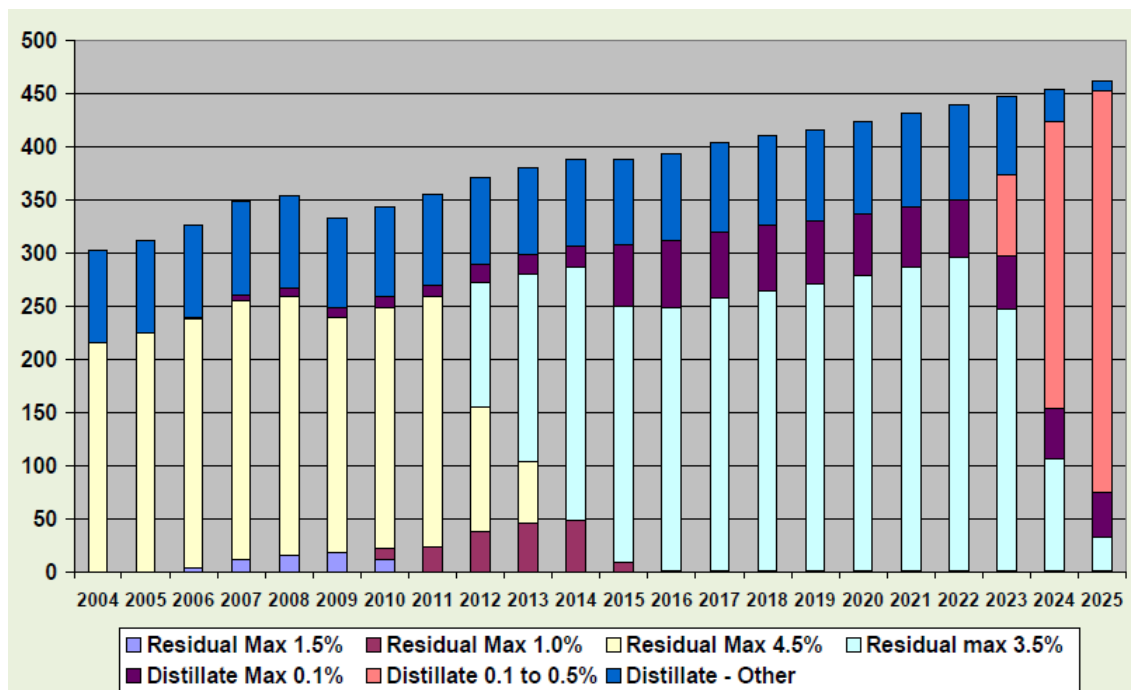


Figure 3.4. Forecast for the trend in the demand for fuel oil grades (see Appendix 2).

#### 4 INVESTMENT IN AND USE AND TOTAL COSTS OF SULPHUR SCRUBBERS

Annex VI of the MARPOL 73/78 Convention allows the after-treatment of exhaust gases as an alternative to low sulphur fuel. There is plenty of experience of removing sulphur from exhaust gas when it comes to energy plants on land, but up till now very little in connection with the equipment installed in ships.

Cleaning the sulphur from ship exhaust is an option, the good sense and economics of which will grow in importance as the price differential between high sulphur (sulphur content over 1.5%) and low sulphur (sulphur content, e.g. 0.5% and 0.1%) increases. It should be remembered that, if a sulphur scrubber is used, it will be possible to use fuel with over 1.5% sulphur content even in the Baltic Sea, so increasing the price differential. It may also be assumed that the price differential will grow in the future as the demand for low sulphur fuel oil increases.

Hitherto, ships sailing in the Baltic Sea have not made use of sulphur scrubbers, but the first equipment suited to the Baltic is being trialled on M/T Suula in an auxiliary engine. In this report we were unable to produce any calculations of the benefits of the equipment in terms of savings in fuel costs.

There are at present basically two types of sulphur scrubber suitable for ships: the seawater scrubber and the freshwater scrubber. In both cases, the extracted sulphur is conducted into the sea.

The seawater scrubber's principle of operation is to pass the exhaust gas through seawater. The seawater absorbs the sulphur compounds (and any other impurities, such as particulate matter and heavy metals). The effectiveness of this method relies on the seawater's alkalinity, and so in waters low in salt, such as the Baltic, a lot more seawater has to be used than in the oceans. The sulphur washed out of the exhaust is conducted into the sea along with the wash water.

The freshwater scrubber's (see Appendix) ability to clean and to neutralise sulphur oxides relies on maintaining the water's pH, using a lye solution. The wash water's pH in a closed loop is kept close to neutral throughout the process and the quality of the seawater does not affect the effectiveness of the cleaning operation. During the process the sulphur's oxides are neutralised and converted into harmless sulphates, which fall into the sea with the wash water. The pH of the cleaned wash water that falls into the sea is neutral and thus barely differs from the pH of seawater.

Sulphur scrubber wash waters are pumped into the sea through separate purification plants, where the oil (hydrocarbons) and other impurities are separated. The separated sludge is similar to that from the engine room and can thus be left in the port. Ports will therefore have to prepare to receive sulphur scrubber waste from ships.

Uncleaned sulphur scrubber wash water might pose an environmental risk, in the form, say, of heavy metals, oil, nitrous compounds and the pH of wash water, which can differ significantly from that of seawater. Wash water may have an adverse impact on the environment, particularly in ports and harbours, river deltas, other narrow and shallow waterways and channels, and in archipelagos, especially if the use of sulphur scrubbers

becomes common. On the other hand, sulphur scrubbers remove harmful compounds from exhaust, which would otherwise pass through the atmosphere and end up polluting the environment with no controlled capture system in place. To minimise the risk to the environment, the IMO has specified criteria for the quality of wash water falling into the sea and for continued monitoring.

A sulphur scrubber can be installed in existing ships and new ones on certain conditions. The greatest challenge is probably the cleaning efficiency of the unit and its size, which is in proportion to how efficient it is. The need for space for the cleaning equipment on board ship might in some cases make it a doubtful investment in terms of the ship's earnings potential. Installing the equipment in existing vessels would naturally be a much more complex task than with new ships, where the necessary spatial solutions could be reckoned with at the planning stage.

For the purposes of this report, representatives of Wärtsilä were interviewed, and they supplied the information appended to it. There are only a few manufacturers of sulphur scrubbers and no more exact survey of the number of suppliers was conducted in this study.

## 5 AN ESTIMATE OF TOTAL COSTS TO FINNISH MARINE TRAFFIC

On the basis of the costs of fuel and sulphur scrubbers, an estimate can be made of the additional costs of the various options to Finland's foreign traffic by multiplying the rise in the price of fuel by the volume of fuel required to meet Finnish marine transport needs.

This survey makes use of the list of ships supplied by the Finnish Maritime Administration (1, 437 in all) that paid waterway charges to Finland in 2007. The vessels are examined more closely in Table 5.1, which divides them according to type. A separate estimate of fuel consumption for each ship was made for the year 2007, with reference to the estimates produced for the Baltic Sea area by the Helsinki Commission's (HELCOM's) ShipNODep project. In the project, the fuel consumption for every ship operating in the Baltic Sea was estimated separately for both the main engines and auxiliary engines.

A total of 1.081 of the ships paying fairway dues to Finland called at ports in the North Sea in 2007. This is evident from the statistical data from the HELCOM AIS server. The North Sea is also a SECA area, so the fuel consumption for the ship in question has to be added to the amount of fuel used by the ship in the Baltic Sea.

*Table 5.1. Breakdown of the vessels that paid fairway dues to Finland in 2007*

Ship type	Number
Passenger vessel (including car and passenger ferries)	34
Cruise ship	61
High speed craft	7
Roll-on roll-off ship	151
Bulk carrier	86
Other dry bulk carriers	793
Tanker	266
Other vessels	39
Total	1.437
Ships that crossed the North Sea	1.081
Ships sailing under the Finnish flag	108

The hypothetical values used in calculating fuel consumption are set out in Table 5.2. The average travel time and the ship's engine data (see Formula 3) are used to estimate the amount of fuel consumed in the North Sea. The average power consumption for the vessels is 80% of the total engine power.

Scenario 1 is a calculation method where the variables have been chosen so that the result obtained is the highest estimate for fuel consumption (maximum scenario). In scenario 2 the variables have been chosen so that the estimated fuel consumption obtained is the 'minimum estimate'. The "average" (expert opinion) scenario has been used to establish the best estimate given in the results for the additional costs due to sulphur legislation. The variables used in the calculation for the different scenarios are set out in Table 5.2. On the basis of scenarios 1 and 2 the maximum and minimum fuel

consumption in the SECA area is obtained. The actual fuel consumption is assumed to lie somewhere between these.

Table 5.2. Hypothetical values used in calculating fuel consumption. The values in Table 3.1 have been used as the price estimates

	Price of fuel (euros)		
	Scenario 1	Scenario 2	Average (expert's estimate)
Price of gas oil (MGO)	500	470	485
Price of heavy fuel oil (LS380 1.5 %-S)	271	271	271
Price differential between heavy fuel oil (LS380 1.5 %-S) and MGO (see Table 3.1)	229	199	214
Travel time in the North Sea (days)	10	2	4
Travel time in the Baltic Sea ( $t_{\text{Baltic}}$ , days)	10	4	7

It should be remembered, however, that it is not possible to estimate the additional cost to Finland in respect of the total fuel cost (for the vessels in question): instead, what needs to be calculated is the share of fuel consumption by one single ship in connection with Finnish imports and exports. In this survey we have worked on the assumption that the ships should be given a factor of K (see Formula 1), which determines the share of fuel consumption to be allocated to Finland. The basic assumption is one for all ships that came to Finland more than 30 times or whose total consumption in the Baltic Sea is less than 100 tonnes per one trip to Finland in 2007. In other cases fuel consumption is calculated as in Formula 2.

$$\text{Formula 1: } K = \text{NumberofvisitsstoFinland} * \frac{P_{\text{eng}} * 0.8 * S * t_{\text{Baltic}}}{\text{Consumption}_{\text{Baltic}}}$$

Where:

K = allocation factor to calculate share of total fuel consumption of significance for Finland for the ship in question

$P_{\text{eng}}$  = total engine power for ship

S = consumption factor of 180 g/kWh

$t_{\text{Baltic}}$  = the time a ship needs to get to a Finnish port from the Danish Straits and back

$\text{Consumption}_{\text{Baltic}}$  = the ShipNODep project's estimated consumption for a given ship in the Baltic Sea area in 2007

Formula 2:

Ship X's share of fuel allocated to Finland

$$K * (\text{Consumption}_{\text{Baltic}} + \text{Consumption}_{\text{North Sea}})$$

Formula 3:

$$\text{Consumption}_{\text{North Sea}} = \text{Number of trips in North Sea} * P_{\text{eng}} * 0.8 * t_{\text{North Sea}}$$

The number of trips in the North Sea is restricted, being no more than the number of trips to Finland

Formula 1 is used to establish factors for ships visiting Finland fewer than 30 times, which ensures the overall allocation of consumption is sufficiently accurate. Table 5.3 gives estimates for fuel consumption and the additional costs for the different scenarios, if it is assumed that vessels will switch from heavy fuel oil to light fuel oil (i.e. gas oil [MGO]).

Table 5.3. Estimated fuel consumption and additional costs for the different scenarios. The additional cost estimates are based on the hypothetical values for the price of fuel in Table 5.2.

<b>Scenario 1</b>	<b>All ships paying fairway dues to Finland</b>		<b>Ships sailing under the Finnish flag</b>	
Ship types	fuel consumption (tonnes)	estimate of additional cost in euros	fuel consumption (tonnes)	estimate of additional cost in euros
Passenger vessel	452,776	98,501,422	226,527	49,280,984
Cruise ship	173,831	37,817,042	472	102,757
High speed craft	25,625	5,574,797	0	0
Roll-on roll-off ship	751,849	163,564,714	175,135	38,100,713
Bulk carrier	56,865	12,370,966	28,654	6,233,611
Other dry bulk carriers	798,854	173,790,727	55,608	12,097,558
Tanker	308,217	67,052,621	57,271	12,459,414
Other vessels	24,945	5,426,775	23,468	5,105,523
<b>Total</b>	<b>2,592,963</b>	<b>564,099,065</b>	<b>567,137</b>	<b>123,380,560</b>
<b>Scenario 1</b>	<b>All ships paying fairway dues to Finland</b>		<b>Ships sailing under the Finnish flag</b>	
Ship types	fuel consumption (tonnes)	estimate of additional cost in euros	fuel consumption (tonnes)	estimate of additional cost in euros
Passenger vessel	452,201	85,488,639	225,952	42,716,293
Cruise ship	76,366	14,437,076	248	46,958
High speed craft	25,625	4,844,475	0	0
Roll-on roll-off ship	572,659	108,261,126	126,914	23,993,129
Bulk carrier	35,727	6,754,101	23,144	4,375,381
Other dry bulk carriers	475,975	89,983,032	38,676	7,311,668
Tanker	144,078	27,237,894	27,033	5,110,562
Other vessels	22,429	4,240,264	21,946	4,148,829
<b>Total</b>	<b>1,805,060</b>	<b>341,246,607</b>	<b>463,913</b>	<b>87,702,821</b>
<b>Average estimate (by expert)</b>	<b>All ships paying fairway dues to Finland</b>		<b>Ships sailing under the Finnish flag</b>	
Ship types	fuel consumption (tonnes)	estimate of additional cost in euros	fuel consumption (tonnes)	estimate of additional cost in euros
Passenger vessel	452,345	91,961,721	226,096	45,965,329
Cruise ship	118,843	24,160,839	304	61,880
High speed craft	25,625	5,209,636	0	0
Roll-on roll-off ship	629,915	128,061,628	144,490	29,374,856
Bulk carrier	43,478	8,839,005	24,725	5,026,628
Other dry bulk carriers	608,468	123,701,500	44,153	8,976,256
Tanker	213,596	43,424,048	38,563	7,839,935
Other vessels	23,300	4,736,964	22,457	4,565,605
<b>Total</b>	<b>2,115,570</b>	<b>430,095,340</b>	<b>500,789</b>	<b>101,810,489</b>



Figures 5.1 and 5.2 give the fuel consumption for the different vessel types. Depending on the calculation method used, total fuel consumption for ship traffic connected with Finnish imports and exports in 2007 was between 1.8 and 2.6 million tonnes. Of this, ships sailing under the Finnish flag accounted for 0.46–0.57 million tonnes. Fuel consumption is given in Table 5.3 above.

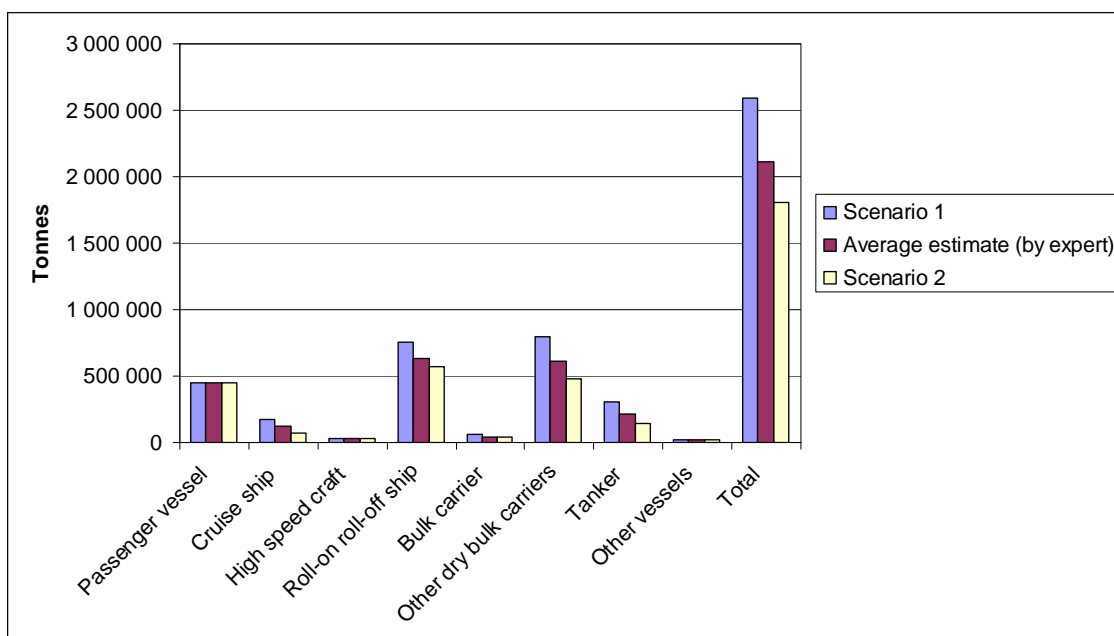


Figure 5.1. Fuel consumption for ships paying fairway dues to Finland by vessel type

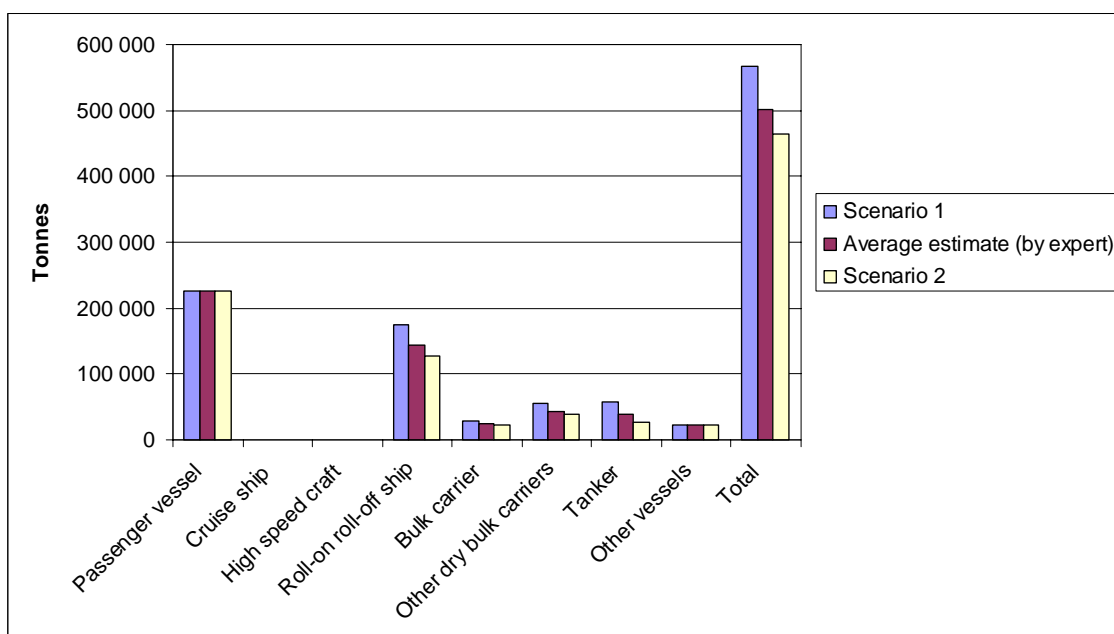


Figure 5.2. Fuel consumption for ships sailing under the Finnish flag paying fairway dues to Finland by vessel type

The additional costs to the different vessel types are illustrated in Figures 5.3 and 5.4. The estimates for additional costs take account of the impact on costs when fuel grades change from heavy fuel oil with a 1.5% sulphur content to light fuel oil with a 0.1% content. The additional cost estimates for the different scenarios are based on the hypothetical value of fuel in Table 5.2.

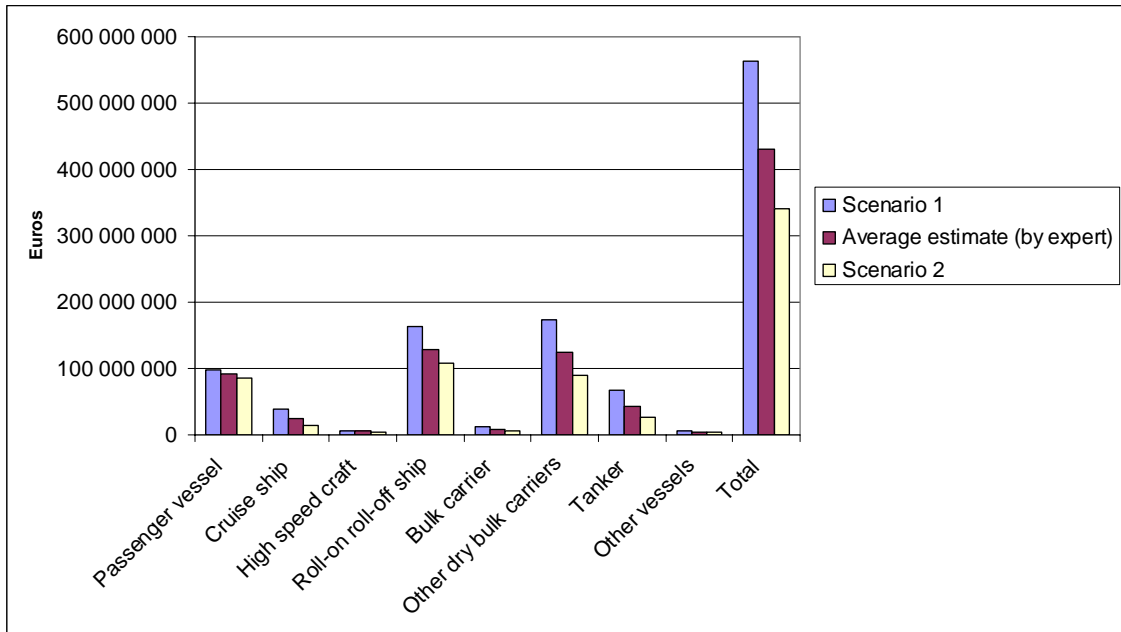


Figure 5.3. Estimated additional cost to ships paying fairway dues to Finland for switching from heavy fuel oil to gas oil by vessel type; the restrictions are to take effect in stages after 2015

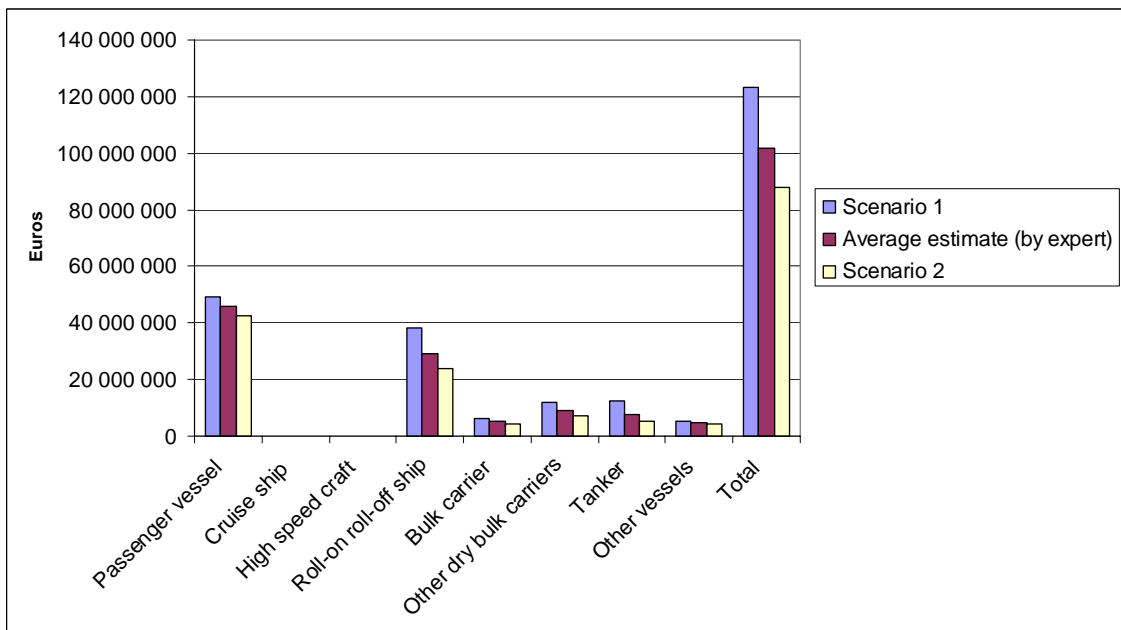


Figure 5.4. Estimated additional cost to Finnish ships paying fairway dues to Finland for switching from heavy fuel oil to gas oil by vessel type; the restrictions are to take effect in stages after 2015

Figures 5.5-5.8 illustrate the impacts of the price difference between heavy fuel oil and gas oil on additional costs. The additional cost estimates for the different scenarios are based on the hypothetical values for the price of fuel in Table 5.2.

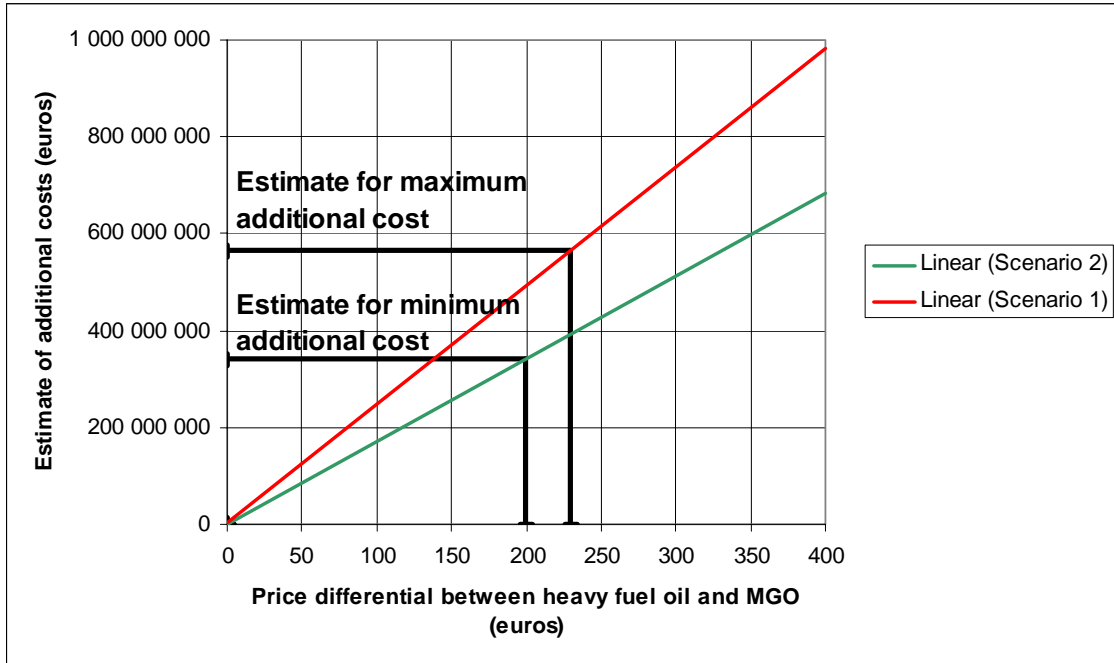


Figure 5.5. Effect of the price differential on additional costs to ships paying fairway dues to Finland and switching from heavy fuel oil to gas oil

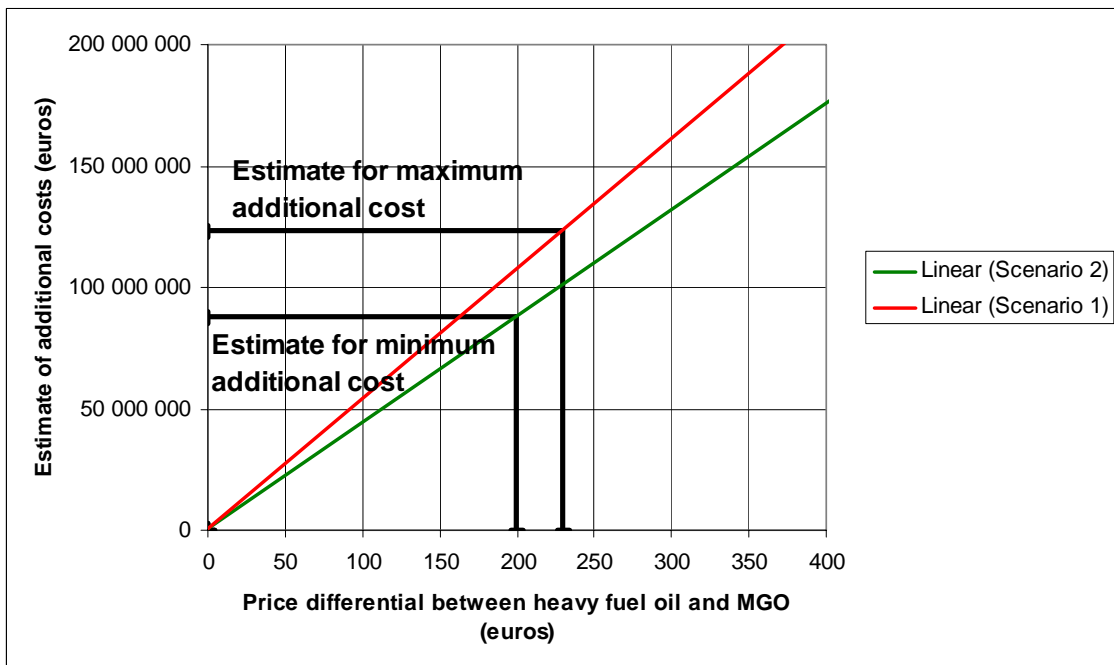


Figure 5.6. Effect of the price differential on additional costs to Finnish ships paying fairway dues to Finland and switching from heavy fuel oil to gas oil

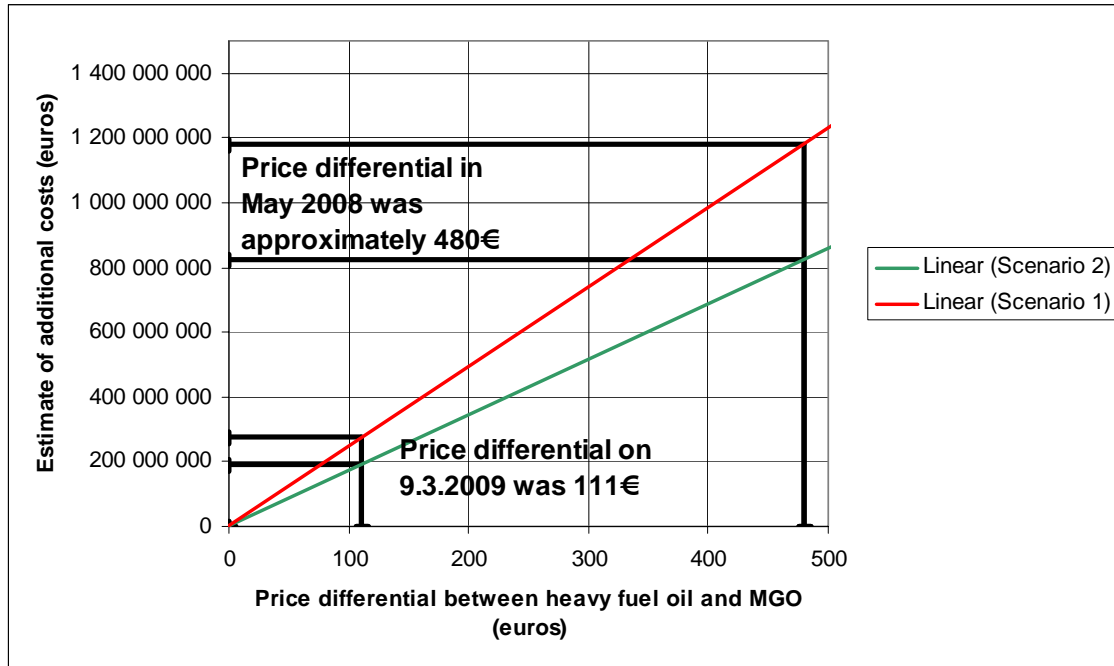


Figure 5.7. Estimated additional cost at the current price differential level (9.3.2009) and at that for May 2008, when the differential was at its highest

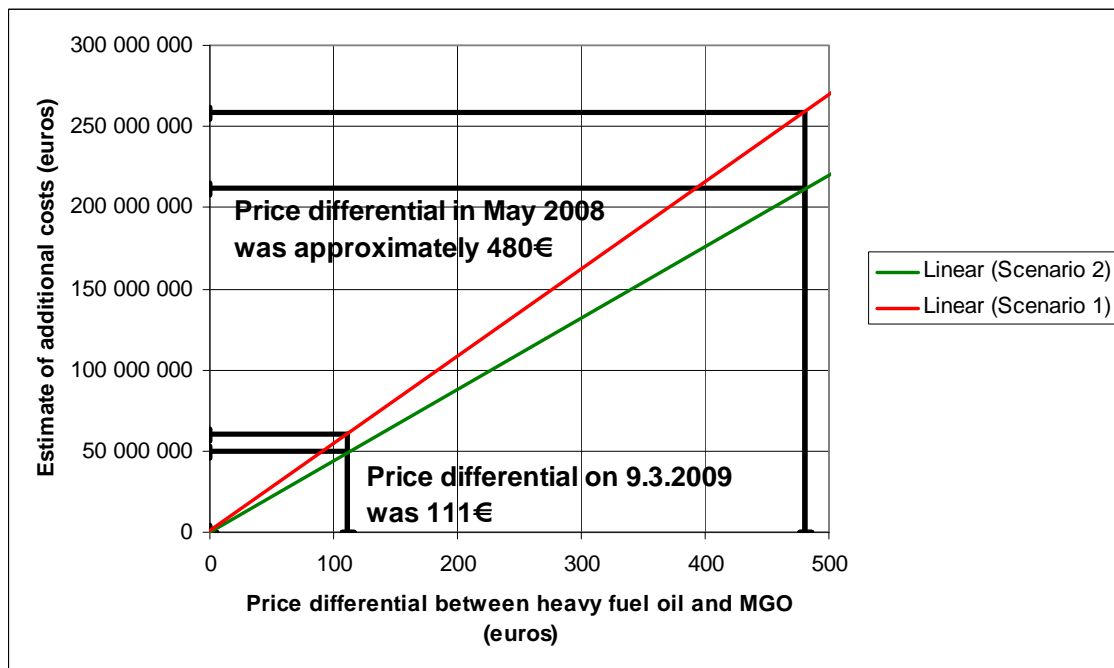


Figure 5.8 Estimated additional cost at the current price differential level (9.3.2009) and at that for May 2008, when the differential was at its highest (ships sailing under the Finnish flag)

These calculations do not take account of how much the additional costs will affect traffic bound for areas outside the SECA areas if the fuel switch on a vessel is not possible for certain reasons and if it also has to use more expensive low-sulphur fuel outside the SECA areas. Neither do they take account of any alternative scenario, whereby long-haul carriers might be reloaded in a European port outside the SECA areas and which allows entry of vessels using sulphur-rich fuel. And, furthermore, the calculations do

not take account of the savings in fuel costs though the possible use of sulphur scrubbers, adapted to deal with the conditions in the Baltic Sea.

## 6 EFFECT OF THE ESTIMATED PRICE RISE IN FUEL ON FREIGHT CHARGES AND ON CERTAIN SECTORS

A vessel's charter party contract determines who pays for the fuel it uses (Table 6.1). If the vessel is in the service of the shipping company that owns it, the shipping company pays all the costs, including fuel. A shipping company that has entered into a time charter agreement leases the vessel to a charterer at a certain price for a given period of time. The time charterer pays the operational costs of the service, including fuel costs, and the shipping company pays the day-to-day running costs. A voyage charter agreement concerns the transportation of cargo from a port of loading to a port of discharge, and in this case the shipping company pays not just the day-to-day running costs but also the transportation costs, including fuel. With a bareboat charter agreement, the shipping company is only responsible for the vessel's capital outlay as well as certain insurance premiums, and all other costs are the responsibility of the charterer (Karhunen et al 2004.)

*Table 6.1. Responsibility for fuel costs in charter agreements.*

<b>Charter agreement type</b>	<b>Responsible for fuel costs</b>
Time charter	Charterer
Voyage charter	Shipping company
Bareboat charter agreement (vessel hire)	Charterer

Freight charges here are being examined from the perspective of transportation costs. The expert views obtained from shipping companies and the Confederation of Finnish Industries associations suggest that rising fuel costs will, at least in time, be incorporated in their entirety in sea freight charges.<sup>9</sup> Table 6.2 gives examples of by how much transportation costs<sup>10</sup> for certain types of freight will rise as a percentage per transported tonne or per TEU. Freight charges for bulk cargo transported on container ships and dry bulk carriers can expect to see the greatest percentage increase. It is worth noting that this estimate suggests that the effect on the rise in freight charges of the switch from heavy fuel oil to light is major. This will have a particularly adverse impact on export sectors located far away from the main markets. Shipping companies have also expressed the concern that excessively high fuel prices might lead to a modal switch to other transport modes.

For example, around 49% of container traffic (excluding traffic in transit [total = 59%]) in Finnish waters is traffic between Finland and countries outside Europe (in container tonnes 23% and in container exports 70%) (Venäläinen 2008: 7–9). Containers are mainly imported on ocean-going vessels into ports in continental Europe, such as Rotterdam and Hamburg, where they are reloaded onto container feeder vessels for transportation to Finland. Similar transport chains are employed for exports, but going in the other direction.

<sup>9</sup> Despite trying to do so in a short space of time, no one could describe in detail how much fuel costs would account for the various freight charges associated with different types of freight

<sup>10</sup> The example freight types are divided according to transportation vessel type, so here the focus of investigation is the estimated increase in vessel costs per tonne/TEU (cf. Tables 3.2 and 3.3)

Table 6.2. Effects of the estimated price rise in fuel on freight charges (percentage increase on current levels).

Freight type	Sulphur content		
	1.0 %	0.5 %	0.1 %
Container	4–13 %	8–18 %	44–51 %
Paper reel	3–10 %	6–14 %	35–40 %
Lorry	3–10 %	6–14 %	35–41 %
Private car	3–10 %	6–14 %	35–41 %
Oil	3–8 %	5–11 %	28–32 %
Freight tonne on bulk carriers	4–11 %	7–15 %	39–44 %
Timber	3–10 %	6–14 %	35–40 %
Steel products	3–10 %	6–14 %	35–40 %

Next we examine the effects of the estimated price rise in fuel separately for various sectors. The estimated additional costs to Finnish industry (reckoned here to be around 430 million euros) have been broken down by sector and the percentage in tonnes for exports and imports are given for each sector (Table 6.3)<sup>11</sup>. Imports account for 58% of all transportation and exports for 42% (Finnish Maritime Administration 2007), which has been taken into account in calculating the sector's share of total maritime traffic. It would seem that costs would go up in the forest and metal industries especially. The large share 'other services' have of overall tonnage is explained by the fact that here electricity, gas and water supply are being included in the sector.

Table 6.3. Estimated share of the tonnage of Finland's foreign trade in terms of maritime traffic expressed as a percentage by sector and estimated additional costs due to the estimated rise in the price of fuel calculated on the basis of this distribution

Sector	Exports	Imports	Total	Estimated additional cost
Agriculture	0.0 %	0.7 %	0.41 %	1,763,994
Forestry	0.0 %	0.0 %	0.00 %	382
Mining	4.7 %	0.0 %	2.02 %	8,668,913
Construction	0.9 %	8.1 %	5.02 %	21,581,213
Forest industry	51.5 %	9.5 %	27.64 %	118,890,562
Metal industry	9.1 %	18.4 %	14.36 %	61,776,307
Technology industry	0.4 %	0.4 %	0.43 %	1,838,810
Chemical industry	24.1 %	6.8 %	14.22 %	61,169,232
Food industry	3.1 %	2.1 %	2.51 %	10,812,674
Other industry	3.7 %	2.3 %	2.89 %	12,416,636
Commerce and trade	2.3 %	6.9 %	4.92 %	21,153,124
Other services	0.2 %	44.9 %	25.58 %	110,023,494
<b>Total</b>	<b>100 %</b>	<b>100 %</b>	<b>100 %</b>	<b>430,095,340</b>

<sup>11</sup>The percentage shares the sectors have were calculated by dividing the amounts for tonnes or euros in 2007 for types of goods in National Board of Customs foreign trade statistics (SITC 3) for a given sector or certain sectors on the basis of expert opinions.

## 7 ENVIRONMENTAL IMPACT AND EFFECTS ON HUMAN HEALTH OF THE SULPHUR CONTENT OF FUEL

### 7.1 Sulphur dioxide

Sulphur is everywhere in the atmosphere, the most common sulphur compounds being H<sub>2</sub>S, CH<sub>3</sub>SCH<sub>3</sub>, CS<sub>2</sub>, OCS and SO<sub>2</sub>. Of these, it is sulphur dioxide (SO<sub>2</sub>), obtained in the fuel combustion process in energy production and in industrial processes, that is not only harmful to human health but is also an important nutrient. Sulphur emission levels have been falling in Finland, and this is observed everywhere in the country in the shape of lower sulphur dioxide content of the air and decreased sulphur fallout, both at background stations and traffic and industrial monitoring stations in cities.

Currently the sulphur dioxide content can typically rise locally and for a short time when there is industrial disruption or malfunction. But in recent years sulphur dioxide levels in Finland have remained under the limit values imposed to protect health.

Gaseous SO<sub>2</sub> oxidises in the atmosphere to become sulphuric acid and sulphates, mainly via a hydroxyl radical, at a rate that is the equivalent of an average lifetime of around a week. Aqueous phase oxidation, e.g. in a cloud, is a much faster process. SO<sub>2</sub> very effectively passes out of the atmosphere through a process of dry and wet deposition, so it also has a local fallout range, unlike NO<sub>2</sub>, which mainly passes out of the atmosphere only after it has converted into nitric acid or nitrates in atmospheric chemical reactions. The average lifetime of SO<sub>2</sub> in the atmosphere is two days, while the lifetime of sulphate that results in the oxidation process is around five days. An important sulphur compound in the marine environment is dimethyl sulphide (DMS, CH<sub>3</sub>SCH<sub>3</sub>) produced from plant plankton, whose chemical lifetime in the marine environment is several days (Hongisto 2009).

### 7.2 Fine particles

Fine particles get into the atmosphere during the combustion of fuel, for example. Particles with a diameter of less than 2.5 micrometres (µm) are the particles that typically result from the combustion reaction in a diesel engine. Fine particles (PM<sub>2.5</sub>) are some of the particles we inhale and they can be carried for up to thousands of kilometres, depending on the circumstances. When monitoring air quality, it is necessary to pay attention to the ever smaller sizes of particle, because smaller particles penetrate deep into the respiratory tracts as we breathe. According to a study by Corbett (Corbett et al, 2007), fine particulate emissions from shipping are the cause of premature death in 62,000–64,000 people around the world each year.

Lowering the sulphur content of fuel linearly affects the mass volume of particles, as does lowering its ash content (Figure 7.1). The new regulations under MARPOL 73/78 Annex VI will dramatically reduce particulate emissions, although they will not as yet actually limit fine particulate emissions. To be able to set emission limits for fine particles from diesel engines, and if we want to install the same type of particulate traps as there are in cars now, the fuel should be light fuel oil with a sulphur content of less than 0.05%. The sulphur and ash content of fuel needs to be low if the particulate trap's oxi-



dation catalyst is to work properly (Hellén 2009). The IMO has not yet been prepared to go to such low sulphur content levels, but things may well change in the future.

It has been estimated that particulate emissions for diesel engines are reduced by 60%-90% mass, if the fuel grade changes from heavy fuel oil to diesel oil (MDO) (IMO 2007). In Figure 7.1 we can see how the combustion of heavy fuel oils produces far more particles than light fuel grades. More details on the environmental impact of MARPOL 73/78 Annex VI are to be found in the document BLG 12/INF.10/IMO 2007 (available from the Finnish Maritime Administration).

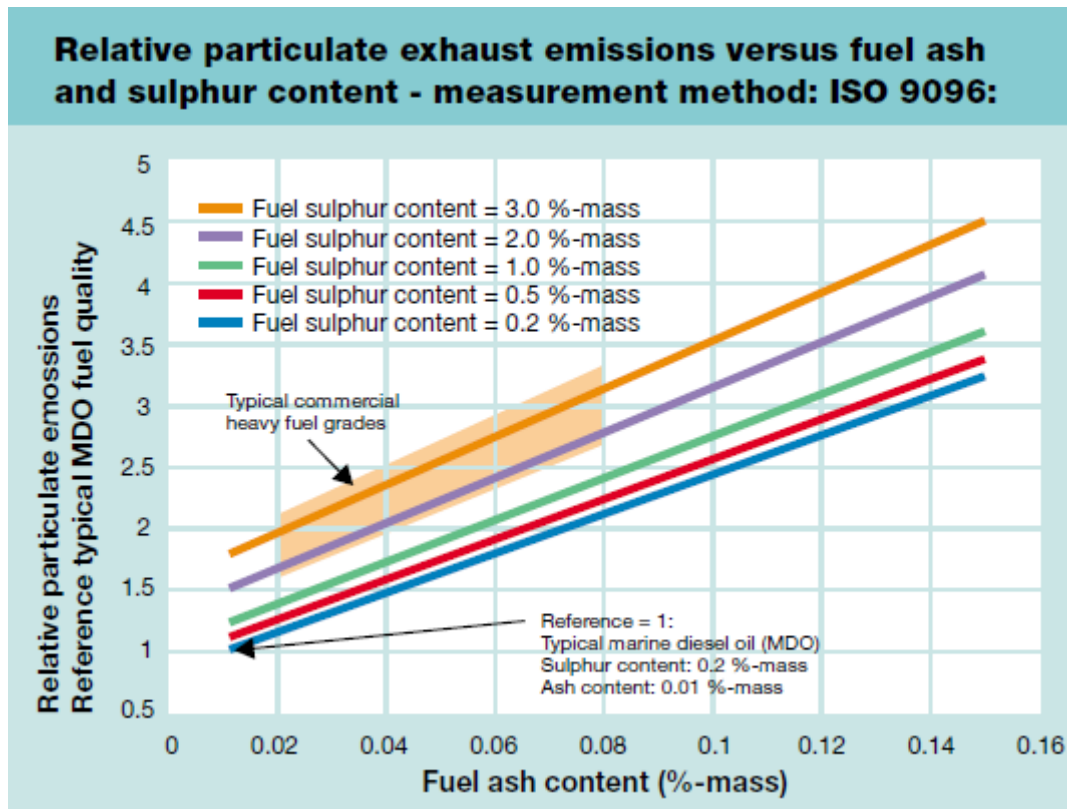
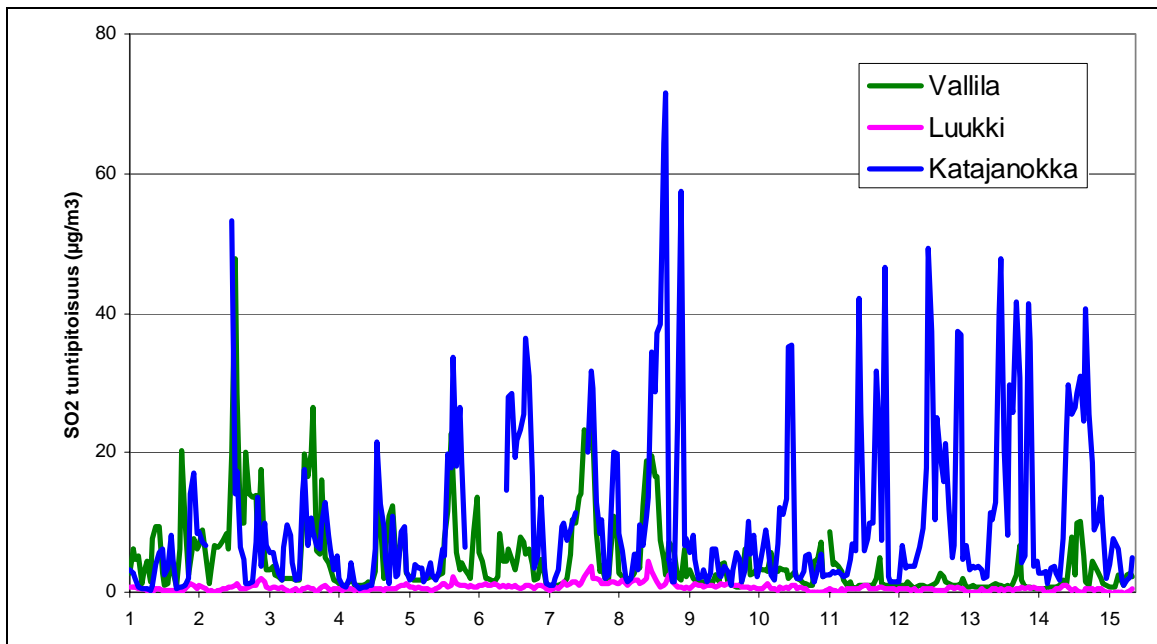


Figure 0.1 The effect of sulphur and ash content on particle volume (Hellén 2003)

### 7.3 The effect on air quality of lowering the sulphur content of fuel used in ships

The Helsinki Metropolitan Area Council has taken measurements of the air quality to examine the effect of emissions from power stations. Power stations on land partly use the same type of - and even exactly the same - diesel engines as in ships, and so they tried to use existing data to assess the environmental impact of sulphur fallout from ship fuel. Discussions with experts have led us to the conclusion that it is very difficult to compare power stations with ships. Power station chimneys can be approximately 70 metres high, and the temperature and flow rate of exhaust gases determine, along with other factors, the extent to which the compounds spread. The comparison is also made all the harder by a general lack of information. Data on the volume and grades of fuel used in power stations in particular is an important factor but is difficult to come by. For that reason, more resources are needed to interpret the yearly emission reports. These reports nevertheless reveal how the volume of sulphur oxides and particles has fallen with more stringent legislation.

Recent measurements taken in Katajanokka (harbour) and the port area of Helsinki show that sulphur emissions from ships can clearly be observed. Rising values are observed when the wind blows exhaust gas in the direction of the measurement point. A comparison with the results of the monitoring stations at Vallila and Luukki is given in Figure 7.2. But even at their maximum, the peaks do not reach harmful levels. The sulphur emissions from ships by the quayside in the dock area will fall when the EU regulation enters into force in 2010. Then all ships entering EU ports will have to use fuel with a maximum sulphur content of 0.1% if they are moored there for more than two hours. Furthermore, the increasing use of shore-side electricity will cut the emissions from ships in the port area.



**Hourly SO<sub>2</sub> content (µg/m<sup>3</sup>)**

*Figure 0.2. Hourly SO<sub>2</sub> content measured at Katajanokka in early 2009 compared to the monitoring stations at Luukki and Vallila.*

## 8 CONCLUSIONS

According to the expert estimates of the member companies of the Finnish Oil and Gas Federation, prices for low sulphur (light) fuel grades are and will be higher than the price for heavy fuel oil currently being used. This being the case, the fuel and vessel running costs for ships operating in the current special areas, i.e. the Baltic Sea, the North Sea and the English Channel, will rise considerably as the provisions on sulphur content of 0,1 % in the revised MARPOL 73/78 (International Convention for the Prevention of Pollution from Ships) Annex VI enter into force in 2015. This will also affect global navigation when the global switch to fuel with 0.5% sulphur content in 2020 or no later than 2025 takes place. The switch to light fuel oil (diesel or gas oil) will result in a very significant rise in costs as compared to those for heavy fuel oil now in use.

It has proven difficult to assess the availability of fuel. At present, fuel availability should not be a great problem, as the growing demand will create a supply. The USA and Canada will present a proposal to the IMO/MEPC in July 2009 to have the sea areas of these countries, which extend 200 nautical miles from their coastlines, designated as special areas with regard to the new sulphur content regulations. When light fuels start to be used worldwide, the oil industry will have to increase its refining capacity considerably to meet the rise in demand for light fuel grades.

The results of interviews with experts suggest that increased fuel costs will, in time, be incorporated in their entirety in sea freight costs, which means that sea freight costs will increase considerably when the tighter regulations on sulphur content take effect in 2015. Rising freight costs will particularly affect export- and/or import-oriented sectors, such as the metal and forest industries.

The total fuel consumption for ships bound for Finland has been estimated on the basis of two scenarios for consumption in 2007, where maximum consumption is 2.6 million tonnes (scenario 1) and minimum consumption is 1.8 million tonnes (scenario 2). The estimate is that if vessels bound for Finland were to switch from heavy to light fuel - in this case gas oil with a maximum sulphur content of 0.1% - the following additional costs would be incurred given the differential in prices for fuel grades:

- 3) at 111 euros per tonne the maximum would be 273 million euros and the minimum 190 million euros
- 4) at 480 euros per tonne the maximum would be 1.182 million euros and the minimum 823 million euros

These calculations do not take account of how much the additional costs would be if long-haul carriers (bound for destinations outside the SECA areas) also had to use low-sulphur fuel outside the SECA areas for technical reasons. Neither do they take account of the savings in fuel costs through the possible use of sulphur scrubbers, adapted to deal with the conditions in the Baltic Sea.

The calculations made in this report are of a type that can serve as a good basis and starting point in the future when the figures are being updated in the light of new information, estimates and assessments.

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## APPENDIX 1

### Outlook for Marine Bunkers and Fuel Oil to 2025 Sourcing Lower Sulphur Products

#### Available NOW

*Increasing pressure from governments to address the issue of sulphur levels in ships' bunkers has led IMO to agree in October 2008 to a severe cut, phased in over the next 12 to 17 years. This change in bunker quality specification will have profound implications for both the bunker and refining industries since it could imply a widespread switch to burning middle distillates in ships' engines.*

Marine and Energy Consulting Ltd and EMC have co-operated to complete this report, which follows on from our previous two bunker studies and provides a detailed assessment of the potential economic and operational implications of these radical new proposals, not only on the bunker market, but also for refining investments, product price differentials and products trade. It also examines the extent to which technology could soften the impact through economically viable abatement systems, such as on-board scrubbers and engine design modifications.

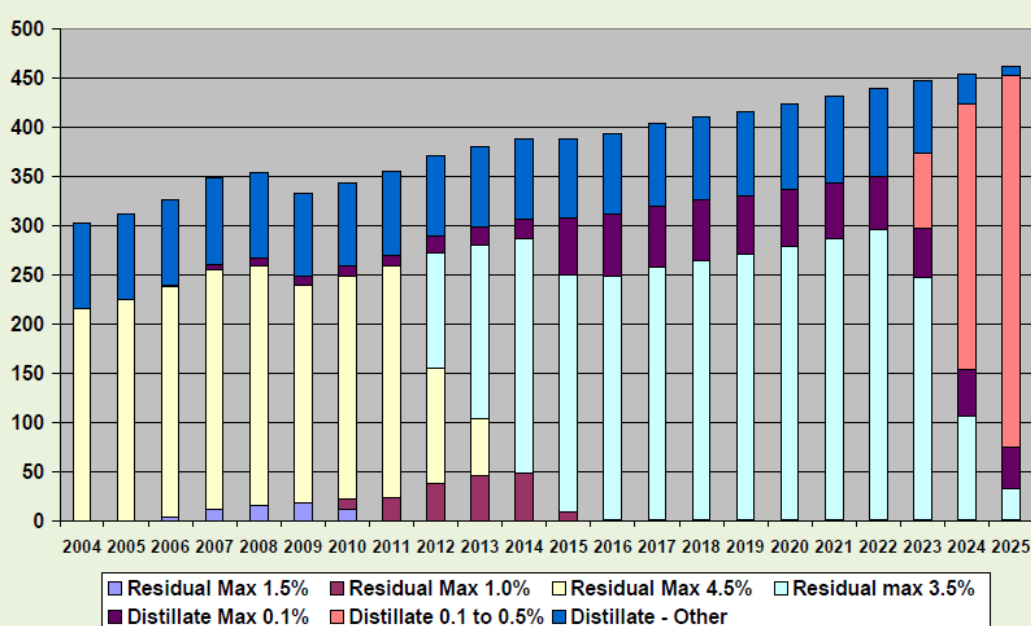
The study provides detailed input to planning and operational issues for all aspects of the interface between the supply and consumption of residual and distillate fuels as bunkers and inland.

#### **Specific topics covered in the study include:**

- Proposed future marine emission legislation including possible new Emission Control Areas
- Detailed forecast of the world fleet and its bunker consumption by type and location
- Price projections for low and high sulphur fuel oil and distillate bunkers and the impact on future bunker fuel costs relative to crude oil
- Comparative technical specifications and viability of vessel abatement systems
- A forecast of the prospective world fuel oil demand for, and supply of, low sulphur and high sulphur distillates and fuel oil for inland and marine bunker consumption by main geographical regions
- Considerations as to how the international refining industry will react to the proposed IMO changes, in particular in the context of potential restructuring in the industry
- An evaluation of the feasibility of a switch from residual fuel oil to distillate as bunker fuel in terms of refining investments so as to implement the IMO recommendations within the specified time frame
- Future sourcing of low sulphur residual and distillate fuels

This detailed study examines issues of vital interest to:

- *ship owners*
- *ship charterers*
- *refiners*
- *traders*
- *fuel oil consumers*
- *oil storage operators*
- *engine and lubricating oil manufacturers*
- *legislators*
- *enforcement agencies and*
- *technology providers*



**Fee Information**

The study is due for completion in November 2008 at a cost per hard copy of £6,500 to new subscribers and £5,250 to previous subscribers.

**The authors:**

**Marine and Energy Consulting Ltd** - expert advisers on bunker fuels issues; the firm works closely with suppliers, consumers and legislators such as the EU Commission on new bunker fuels and emission legislation.

Email contact: [RMeech@RobinMeech.com](mailto:RMeech@RobinMeech.com)

**EMC – Energy Market Consultants (UK) Ltd** – the FACTS Global Energy Group’s London Office, which specializes in forecasting and analyzing international oil and energy market and refining sector developments.

Email contact: [emc@FGEnergyMC.com](mailto:emc@FGEnergyMC.com)

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