PREVENTION OF AIR POLLUTION FROM SHIPS

Study to review assessments undertaken of the revised MARPOL Annex VI regulations

Submitted by the International Chamber of Shipping (ICS)

SUMMARY

Executive summary: This document provides a study of the potential impact of the revised MARPOL Annex VI regulations in the North Sea and Baltic Sea areas. In particular, the study reviews impact studies on the implementation of 0.1% sulphur requirement within ECAs in 2015.

Strategic direction: 7.3

High-level action: 7.3.1

Planned output: 7.3.1.1

Action to be taken: Paragraph 6

Related document: Resolution MEPC.176(58)

Introduction

1 The Committee's attention is drawn to an ENTEC study that summarizes the potential impacts on shipping and the environment through the implementation of the revised MARPOL Annex VI regulations in the North Sea and Baltic Sea areas. The study concludes that there is a possibility of a modal transport shift away from shipping in the region with the consequence of harmful impact on the environment.

Background

2 Following the adoption of the revised MARPOL Annex VI that requires a reduction in the maximum sulphur content in fuels in Emission Control Areas (ECAs) to 0.1% (effective on and after 1 January 2015) a number of studies have been undertaken that provide analysis of the potential impact to shipping in the North Sea and Baltic Sea ECAs. It is to be noted that no formal impact assessment had been performed prior to adoption of the 0.1% sulphur fuel requirement in the revised MARPOL Annex VI.

3 A group of ICS Northern European Member shipowners' associations have become increasingly concerned with the potential harm to short sea shipping that may result from the implementation of the 0.1% sulphur fuel requirement. The various regional impact studies...
that have subsequently become available have all highlighted the possibility that the higher fuel costs associated with low sulphur fuels have a potential, through cost effect on freight transport prices, to cause a modal shift from shipping to land transportation. Such modal transport shift would also have the consequence of increased negative impact to the environment. As a result of the shipping concerns, a study by "ENTEC" was commissioned to collate and compare the key inputs, approaches and outputs of each of the six main studies with the aim of presenting a consolidated summary. The six regional studies reviewed are identified in page v of the executive summary provided at the introduction to the ENTEC study.

4 The ENTEC study is attached at annex to this document. The study can also be obtained at the ICS homepage <http://www.marisec.org> by clicking on the "ENTEC" link.

5 Although the ENTEC study purely addresses the situation in the Baltic and North Sea, it would appear that the general conclusions may well apply in other ECA cases. The availability of compliant fuel has been highlighted as a potential problem.

**Action requested of the Committee**

6 The Committee is invited to note the information provided.

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ANNEX

ENTEC – STUDY TO REVIEW ASSESSMENTS UNDERTAKEN OF THE REVISED MARPOL ANNEX VI REGULATIONS
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Executive Summary

Summary of Outcomes

This report has been commissioned by a number of North European shipowner associations and endorsed by the wider membership of the European Community Shipowners’ Associations and the International Chamber of Shipping. Its purpose is to draw together the conclusions of six independent reports about the potential impacts of the revised MARPOL Annex VI Regulations on Sulphur Emissions on the maritime sector. By doing so, the intention is to produce a single series of conclusions which can be readily understood by all interested parties.

The following conclusions can be drawn from this study:

i. The additional fuel cost of shifting to 0.1% Sulphur (S) Marine Gas Oil (MGO) from 1.5% S Heavy Fuel Oil (HFO) in 2015 is expected to be in the range of €155-310 per metric tonne of fuel with an average of the quoted values from all of the studies of approximately €230 per tonne. This represents an average increase in fuel costs per tonne of around 80%. Some concerns have been raised regarding the availability of 0.1% S content fuel in sufficient quantities from 2015 and, as well as the direct impacts of this on MGO, possible knock-on effects on the market for and cost of diesel for land based sources.

ii. Total compliance costs assuming fuel switching only have been estimated to be €3.0-3.6 billion in 2015. The costs of alternative compliance mechanisms such as seawater scrubbers are expected to be approximately 20-50% of the total cost of switching fuels. However, there are a number of uncertainties related to the availability and reliability of such technologies which are expected to limit any significant take up by 2015.

iii. Of those studies concerning themselves with modal shift, it is clear that the revised regulations will lead to some shift away from short sea shipping to road and rail freight. This shift is expected to be between 3-50% in volume and varies significantly between different routes and fuel price projections.

iv. In terms of total external costs (environmental, health and social costs to society), most studies have considered the benefits of ships switching to 0.1% S content fuel from 2015 but not the potential impacts if any modal shift to land-based transport were to occur. Without modal shift, monetised benefits are expected to be greater than costs for Europe as a whole (although some Member State studies show conflicting results). However, in some cases modal shift may reverse the situation in that total external costs may in fact increase (i.e. a disbenefit).
Policy Context

In April 2008, IMO’s Marine Environment Protection Committee (MEPC) approved proposed amendments to the MARPOL Annex VI Regulations to reduce harmful emissions from ships. MEPC unanimously adopted the amendments to Annex VI and the NOx Technical Code in October 2008. These amendments set more stringent limits on SOx and NOx emissions from ship exhausts than the existing Annex VI.

The revised MARPOL Annex VI Regulations entered into force on 1st July 2010. Some of the key provisions include:

- A reduction in the global limit of sulphur content in fuel to 3.5% by mass (from the current 4.5%) effective from 1st January 2012; then to 0.5%, effective from 1st January 2020, subject to a feasibility review to be completed no later than 2018);
- A reduction in sulphur limits for fuels in SOx Emission Control Areas (SECAs) to 1%, beginning on 1st July 2010 (from the previous 1.5%); being further reduced to 0.1% from 1st January 2015;
- As with the existing MARPOL Annex VI, the revised regulations allow for the use of suitable abatement equipment as an alternative to the fuel switching requirements described above on the basis that equivalent SOx emissions are achieved on a continuous basis; and
- Tiered reductions in NOx emissions from marine engines (with the most stringent controls on ‘Tier III’ engines, i.e. those installed on ships constructed on or after 1st January 2016, operating in NOx ECAs).

The revised Annex VI also allows for Emission Control Areas (ECAs) to be designated to limit emissions of SOx, particulate matter or NOx, or all three pollutants.

This Report

The shipping industry in Northern Europe (i.e. operating in the SECAs) as well as harbour authorities and local industry around the Baltic Sea have raised concerns about the potential impacts of the revised MARPOL Annex VI Regulations on the sector. In particular, there are concerns related to rising fuel costs associated with switching to 0.1% S fuel in the SECAs from 2015 and potential knock-on effects on freight transportation prices. The industry has also expressed the view that no formal impact assessment was undertaken prior to the adoption of the 0.1% S fuel requirement in the revised regulations.

The purpose of this report is to present a summary of a review of a series of studies looking at the impacts of revisions to IMO’s MARPOL Annex VI Regulations. The six studies reviewed are as follows:

- University of Turku Centre for Maritime Studies (2009): Sulphur content in ships bunker fuel in 2015 – A study on the impacts of the new IMO regulations on transportation costs (prepared for the Ministry of Transport and Communications Finland). [hereafter referred to as “Finland (2009)”]
- Swedish Maritime Administration (2009): Consequences of the IMO’s new marine sulphur fuel regulations. [hereafter referred to as “Sweden (2009)”]


The original intention was to review a German study looking at the revised MARPOL Annex VI Regulations but this was not available within the timescales of the work. Details of the scope and objectives of the study are provided in Appendix A.

Overview of Reports

Section 2 (page 6) of this report provides a summary of the review of each of the studies listed above. To ensure a consistent and thorough review of each study and ease of comparison of the outputs of the review, a review template based around a number of key criteria was applied (see Appendix B). The detailed reviews of each of the studies against the template are provided in Appendices C-H. Whilst all six of the studies are focussed on the potential impacts of the revised MARPOL Annex VI Regulations, they vary considerably in terms of focus, scope and approach. Table 2.1 (page 6) and Table 2.2 (page 7) provide a summary of the aims and objectives of each study and the scope and focus of analysis, respectively. Figure 2.1 (page 7) provides an overview of the geographical scope of each of the studies to help visualise how they overlap.

The overall conclusions presented above in the section “Summary of Outcomes” have been drawn through summarising each of the studies listed above. The following subsections provide further details behind these conclusions.

Key Assumptions

Section 3 (page 11) of this report presents a summary and comparison of the key assumptions that have been applied in each of the studies. The focus is on those assumptions which are likely to have a significant impact on the overall outputs and conclusions of each study. These include:

- The business as usual scenario i.e. what is the assumed starting point for the analysis? [page 11]

Almost all of the reports assume the use of 1.5% S HFO by all vessels in SECAs as the baseline. It is unclear in many of the reports how/if the 0.1% S requirement for vessels at berth has been taken into
account. Omitting this from the baseline could lead to an overestimation of impacts (both costs and benefits).

- **Shipping sector response i.e. how is the sector assumed to achieve compliance with the revised regulations in 2015? [page 12]**

  Each of the six studies considers a range of different responses (scenarios) including 100% fuel switching (considered most likely), 100% uptake of scrubbers and variations in between (e.g. 90:10 in favour of fuel switching).

- **Availability and costs of low sulphur fuels, now and in the future. [page 12]**

  There is a consensus across all of the studies that the stricter sulphur limits will force ships to use distillates in place of residual oil, but that future availability of distillates is difficult to forecast. One of the most critical, and perhaps most uncertain, assumptions is around fuel prices, as this has the greatest influence on the conclusions of each of study. A number of studies have projected fuel prices to 2015 and beyond whereas others have simply applied current prices. The figure below demonstrates the recent variation in the cost of 0.1% S MGO as well as the range of projected values from each study (NB: most studies consider a range of fuel price scenarios to reflect uncertainty in future fuel prices).
Note 1: Trend in historical MGO price summarised from detailed time series of sale prices in Finland (2009) and Sweden (2009).

- Availability, reliability and costs of scrubbers, now and in the future. [page 18]

  The reports concur that the most common type of scrubbing for marine applications is sea water scrubbing (SWS) with an abatement efficiency of 90-95% for SO₂. The limitations and/or uncertainties associated with the use of scrubbers have been considered in a number of studies, for example in relation to concerns over availability by 2015. As with fuel costs there is high uncertainty regarding scrubber costs due to the small number of scrubbers currently in operation.

- Approach taken to investigating modal shift. [Section 3.6, page 21]

  Four of the six studies reviewed have considered modal shift in detail. Table 3.3 (page 21) summarises the approaches taken.

- Approach taken to estimate emission reductions and associated health and/or environmental benefits. [page 22]
All but one of the six studies (ECb (2010)) considers the health and/or environmental benefits associated with switching to a lower sulphur fuel or installing scrubbers. However, only UK (2009) and ECa (2010) have actually quantified these impacts (ECa (2010) quantifies health impacts only). These impacts have then been monetised (where possible) through the application of appropriate monetised values. Sweden (2009) and ECSA (2010) have monetised the health and environmental impacts associated with reductions in emissions through the application of damage cost functions i.e. applying a monetary value in € per tonne of pollutant emission reduced.

Key Findings and Conclusions

Section 4 (page 24) provides a summary and comparison of the key findings and conclusions of each study with consideration of the assumptions that have been applied. This includes costs (page 24), benefits (page 26) and modal shift (page 30). The section focuses on the outputs from each study for the most likely scenario (i.e. shipping response) and a range of values are presented to reflect the variation in fuel prices.

Costs & Benefits [assuming no modal shift]

Only ECa (2010) has quantified the costs and benefits associated with the revised regulations at a European level. Three country-specific studies have been undertaken which have considered costs (all) and benefits (UK and Sweden only) either for ships operating in a certain geographical area (UK) or those travelling to and from a particular country (Finland and Sweden). These are presented in Sections 4.2 and 4.3 (page 24 onwards).

The figure below summarises the monetised health benefits calculated in ECa (2010) relative to the total costs for compliance in 2015 for the whole of Europe. The costs and benefits presented in the figure are additional to the baseline i.e. they represent the incremental impacts associated with the revised regulations. As the figure shows, the monetised health benefits outweigh the costs under all scenarios i.e. even when adjusted to take account of a potentially higher price premium for 0.1% sulphur fuel. The wide variation in the cost estimations at a European (and Member State) level reflects the significant uncertainty with respect to the response of the shipping sector to the revised regulations and, in particular, fluctuations in fuel prices, now and in the future.
Figure 2  Summary of net annual costs and monetised health benefits from ECa (2010) for 2015 [assuming no modal shift]

Note 1: Costs have been adjusted to take account of range of fuel price premia and a 90:10 split between fuel switching and scrubbers applied. Further details are provided in Section 4.2.

Note 2: Figures include the estimated health impacts associated with PM and ozone exposure. The range of benefits presented is based on differing approaches to valuing mortality.

In addition to the monetised health impacts, the report also quantifies (but does not monetise) some of the potential environmental impacts associated with a reduction in shipping emissions including reductions in sulphur (8% in 2015) and nitrogen (2% in 2015) deposition and reductions in acidification (25% in 2015) and eutrophication (3% in 2015).

In contrast to ECa (2010), the monetised benefits estimated in Sweden (2009) and UK (2009) are significantly lower than the calculated compliance costs. However, these estimates are expected to be underestimates for the reasons outlined in Section 4.3 (page 29).

It should be noted that, whilst only ECa (2010) gives a comprehensive assessment of costs and benefits for the whole of Europe where the costs are directly comparable to the benefits, the study does not consider the potential for modal shift as a result of increasing shipping costs. In addition, there does not appear to have been any consideration of the possible indirect impacts of the revised regulations on refinery emissions (air pollutants and greenhouse gases) as a result of increased demand for lower sulphur fuels. This may result in an overestimation of the potential emission reductions and associated health and environmental benefits.
Modal Shift

Four of the six studies reviewed have considered modal shift to some extent:

- Finland (2009) considers the potential knock-on impacts of increased shipping fuel prices on freight costs for Finnish industry but does not quantify what this may mean in terms of modal shift.

- Sweden (2009) takes the analysis a step further and looks at the impacts of increased fuel costs on shipping and estimates potential transfer of freight from road to rail.

- Both ECSA (2010) and ECb (2010) consider modal shift at a finer resolution by investigating the likely impacts of increased fuel costs for a selection of competing freight routes (road, rail and sea) in the SECA.

Table 4.1 (page 30) summarises the key outputs and conclusions regarding modal shift for each of the studies. The figure below provides a summary of the expected increases in shipping freight costs as a percentage relative to the current situation. As the figure demonstrates the implementation of the revised regulations is expected to have a significant impact on freight charges for shipping operating within the SECA.

**Figure 3** Potential increases in shipping freight charges as a result of revised regulations

Note 1: Increases expected to be significantly higher for fast sea services (up to 40%).
Whilst each study has a slightly different focus and/or approach to considering modal shift, it is clear that the implementation of the revised regulations (assuming all vessels switch fuels1) is expected to lead to some shift away from short sea shipping (freight) to road and rail freight; for some routes this shift away from shipping may be as little as a 3% loss in volume or as much as 50%. The extent to which this takes place depends on a number of route-specific factors such as level of competition and availability of alternative routes as well as the projected fuel costs. In some cases a shift to a land-based only route is expected, whilst in others a shift is estimated to take place to routes with a greater proportion of distance via land. These impacts should be considered against the European Union’s Marco Polo programme which aims to shift freight transport from the road to sea, rail and inland waterways.

An interesting observation from ECSA (2010) is that the gain in marginal external costs (i.e. the valuation of congestion, accidents, environmental and associated health impacts and infrastructure) due to switching to 0.1% S fuel will deteriorate if one assumes a modal shift of 20% away from shipping to road and/or rail on selected routes (relative to a reference scenario of ships using 1% S HFO2). If a modal shift of 10% away from shipping occurs then external costs are expected to increase in 26% of the cases assessed in the study. With no modal shift, external costs decrease by approximately 15% overall. The study notes that no modal shift is expected to occur if 0.5% sulphur fuel were required in place of 0.1% as it does not require a change in fuel type and therefore no significant cost increases are expected. With this in mind, external costs are expected to decrease in all cases modelled (i.e. positive benefit) when switching to 0.5% sulphur fuel (approximately 5%). It should be noted that the external costs associated with shipping emissions may be underestimated due to the relatively low valuation applied in the calculations for emissions of PM in the North Sea. However, the potential implications of modal shift on total external costs is an important issue which has not been considered in any of the other studies and needs to be kept in mind when considering the overall picture.

Very limited consideration has been given to the value of any modal shift in terms of lost profit from the shipping industry. Sweden (2009) has considered possible impacts on the passenger ferry market concluding that operators may be able to pass on any additional costs to passengers via increased ticket costs. In addition, ECSA (2010) includes a short discussion of the possible impacts of increased costs, reduced profitability and modal shift on short sea shipping; this indicates that even relatively small losses in volume for short sea services could have significant impacts on the financial position of operators (page 30).

1 The majority of studies dealing with modal shift only consider fuel switching for compliance in 2015. However, ECB (2010) has modelled a scenario for each of the selected routes where all ships are assumed to install scrubbers and continue using higher sulphur fuels rather than switching to 0.1% sulphur fuel. For this scenario, market share for the shipping sector is maintained and in some cases increased relative to land based transport. However, it should be noted that a 100% shift to scrubbers is unlikely, particularly in the short term.

2 The outcome might be different if comparing against the current MARPOL Annex VI requirements of 1.5% S HFO in SEACs.
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Appendix G TNO, IVL, AEA, EMRC (2009): Cost benefit analysis to support the impact assessment accompanying the revision of Directive 1999/32/EC on the sulphur content of certain liquid fuels
Appendix H SKEMA (2010): Impact study of the future requirements of Annex VI of the MARPOL Convention on Short Sea Shipping
1. Introduction

1.1 This report

The purpose of this report is to provide the international shipping industry with a summary of a review undertaken of a series of studies looking at the impacts of revisions to IMO’s MARPOL Annex VI Regulations. The six studies reviewed are as follows:

- University of Turku Centre for Maritime Studies (2009): Sulphur content in ships bunker fuel in 2015 – A study on the impacts of the new IMO regulations on transportation costs (prepared for the Ministry of Transport and Communications Finland). [hereafter referred to as “Finland (2009)”]
- Swedish Maritime Administration (2009): Consequences of the IMO’s new marine sulphur fuel regulations. [hereafter referred to as “Sweden (2009)”]

The original intention was to review a German study looking at the revised MARPOL Annex VI Regulations but this was not available within the timescales of the work (details of the aims and objectives of this study are provided in Appendix A). Therefore, it was agreed that this would be substituted with the report prepared for the Commission on the impacts on short sea shipping (see final bullet point above).

It should be noted that the information presented in this report is based on that contained within each of the reports listed above. It has not been feasible or realistic to review the accuracy of the modelling and calculations undertaken in each study.
1.2 **Policy context**

1.2.1 **Existing MARPOL Annex VI Regulations**

The International Maritime Organization (IMO) Regulations for the Prevention of Air Pollution from Ships were adopted in the 1997 Protocol to MARPOL 73/78 and are included in Annex VI of the Convention, which entered into force in May 2005. MARPOL Annex VI sets limits on SOx and NOx emissions from ship exhausts. It includes a global cap of 4.5% by mass on the sulphur content of fuel oil and also set provisions allowing for special Sulphur Emission Control Areas (SOx ECAs, ‘SECAs’) where either the sulphur content of fuel oil used on board ships must not exceed 1.5% m/m, or ships must fit technologies to achieve equivalent SOx emissions. Limits on emissions of NOx from diesel engines are also set. The Baltic Sea is designated as a SECA in the Protocol and the North Sea was adopted as a SECA in July 2005 (the North Sea SECA entered into force on 21st November 2006, to be fully implemented 12 months later, on 22nd November 2007).

1.2.2 **Sulphur Content of Marine Fuels Directive**

The SCMF Directive\(^3\) entered into force on 6th July 2005, amending the existing Sulphur Content of Liquid Fuels Directive (SCLFD)\(^4\). The SCMFD is linked to MARPOL Annex VI and sets the maximum permissible sulphur content of marine fuels used in SECAs. The main elements of the Directive include:

i) A 1.5% sulphur limit for fuels used by all ships in the SECAs of the Baltic Sea, from 11\(^{th}\) August 2006, and the North Sea and English Channel, from either 11\(^{th}\) August 2007 or 12 months after the entry into force of the International Maritime Organisation designation, whichever is the earlier;

ii) A 1.5% sulphur limit for fuels used by passenger vessels on regular services between EU ports, from 11\(^{th}\) August 2006; and

iii) A 0.1% sulphur limit\(^5\) on fuel used by inland waterway vessels and by seagoing ships at berth in EU ports, from 1\(^{st}\) January 2010.

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\(^5\) The 0.1% sulphur limit on fuels used by inland waterway vessels and ships at berth does not apply to:

a) Ships due to be at berth for less than two hours according to published timetables.

b) Inland waterway vessels that carry a certificate proving conformity with the International Convention for the Safety of Life at Sea, 1974, as amended, while those vessels are at sea.
As an alternative to the use of low sulphur marine fuels to comply with Articles 4a and 4b of the Directive, Member States can ‘... allow ships to use an approved emission abatement technology, provided that these ships continuously achieve emission reductions which are at least equivalent to those which would be achieved through the limits on sulphur in fuel specified in [the] Directive’ (Article 4c, paragraph 4).

In addition to the requirements described above, the European Parliament negotiated a review of the Directive in 2008 requiring the Commission to consider a second phase sulphur limit of 0.5% in fuel (dependent upon progress at the International Maritime Organisation). The Commission is also required to consider the designation of additional SECAs and alternative or complementary measures. This review has been delayed.

1.2.3 Revised MARPOL Annex VI Regulations

In April 2008,IMO’s Marine Environment Protection Committee (MEPC) approved proposed amendments to the MARPOL Annex VI Regulations to reduce harmful emissions from ships. MEPC unanimously adopted the amendments to Annex VI and the NOx Technical Code\(^6\) when it met for its 58th session (from 6 to 10 October 2008)\(^7\). These amendments set more stringent limits on SO\(_x\) and NO\(_x\) emissions from ship exhausts than the existing Annex VI.

The revised MARPOL Annex VI Regulations will enter into force on 1st July 2010, under the tacit acceptance amendment procedure. Some of the key provisions include:

- A reduction in the global limit of sulphur content in fuel to 3.5% by mass (from the current 4.5%) effective from 1st January 2012; then to 0.5%, effective from 1st January 2020 subject to a feasibility review to be completed no later than 2018);

- A reduction in sulphur limits for fuels in SO\(_x\) ECAs to 1%, beginning on 1 July 2010 (from the current 1.5%); being further reduced to 0.1%, effective from 1st January 2015;

- As with the existing MARPOL Annex VI, the revised regulations allow for the use of suitable abatement equipment as an alternative to the fuel switching requirements described above on the basis that equivalent SO\(_x\) emissions are achieved on a continuous basis; and

  c) Ships which switch off all engines and use shoreside electricity while at berth in ports.

\(^6\) The NO\(_x\) Technical Code was first adopted at the same time as the original Annex VI was added to MARPOL 73/78. The aim of the NO\(_x\) Technical Code was to establish mandatory procedures for the testing, survey and certification of marine diesel engines, in order to enable engine manufacturers, ship-owners and Administrations to ensure that all applicable marine diesel engines comply with the regulation.

\(^7\) http://www.imo.org/Newsroom/mainframe.asp?topic_id=1709&doc_id=10262
• Tiered reductions in NO\textsubscript{x} emissions from marine engines (with the most stringent controls on "Tier III" engines, i.e. those installed on ships constructed on or after 1\textsuperscript{st} January 2016, operating in Emission Control Areas).

The time-limited sulphur content limits are represented graphically in Figure 1.1 below.

**Figure 1.1 Revised MARPOL Annex VI - Fuel Sulphur Limits**

![Graph showing fuel sulphur content limits](image)

The revised Annex VI will also allow for Emission Control Areas (ECAs) to be designated to limit emissions of SOx, particulate matter or NOx, or all three pollutant species, from ships subject to a proposal from a Party or Parties to the Annex which would be considered for adoption by the IMO if supported by a demonstrated need to prevent, reduce and control one or all three of those types of emissions from ships.

1.3 **Aims & objectives**

The shipping industry in Northern Europe (i.e. operating in the SECAs) as well as harbour authorities and local industry around the Baltic Sea have raised concerns about the potential impacts of the revised MARPOL Annex VI Regulations on the sector. In particular, there are concerns related to rising fuel costs associated with switching to 0.1% sulphur fuel in the SECAs from 2015 and potential knock on effects on freight transportation prices. Industry has also expressed the view that no formal impact assessment was undertaken prior to the adoption of the 0.1% S fuel requirement in the revised regulations.
The aims and objectives of this study were twofold:

1. To undertake a review of each of the six reports listed above against a series of criteria.

2. To collate and compare the key inputs, approaches and outputs of each study with the aim of presenting a consolidated summary of the key impacts expected.

1.4 Structure of report

This report is structured as follows:

- Section 2 provides an overview of the scope of each study.
- Section 3 presents a summary and comparison of the key assumptions applied e.g. fuel costs; and
- Section 4 summarises the key findings and conclusions.
2. Overview of Reports

2.1 Overview

This section provides a summary of the assessment of each of the studies listed in the previous section. To ensure a consistent and thorough review of each of the six studies and ease of comparison of the outputs of the review, an assessment template was developed and used (see Appendix B). The template was based around a number of key criteria to ensure that a suitable summary and understanding of each study may be developed. The assessments of each of the studies against the template are provided in the following appendices:

- Appendix C – UK (2009);
- Appendix D – Finland (2009);
- Appendix E – Sweden (2009);
- Appendix F – ECSA (2010);
- Appendix G – ECa (2010); and

2.2 Summary of assessment

2.2.1 Aims and objectives of each study

Whilst all six of the studies are focussed on the potential impacts of the revised MARPOL Annex VI Regulations, they vary considerably in terms of focus, scope and approach. The tables below provide a summary of the aims and objectives as well as the scope and focus of each study. Further details are provided in each of the report assessments in Appendices C-H.

<table>
<thead>
<tr>
<th>Study</th>
<th>Aims &amp; Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK (2009)</td>
<td>Impact Assessment for the revised Annex VI of MARPOL</td>
</tr>
<tr>
<td></td>
<td>The report was intended to provide information to help in understanding the likely impacts of the revised MARPOL Annex VI Regulations adopted in 2008. The report includes an assessment of the possible compliance costs and health and environmental benefits of implementing the regulations for the UK.</td>
</tr>
<tr>
<td></td>
<td>The report was to be used in support of an Impact Assessment as well as for consulting with relevant stakeholders to implement the amendments of the revised MARPOL Annex VI Regulations.</td>
</tr>
<tr>
<td>Finland (2009)</td>
<td>Sulphur content in ships bunker fuel in 2015 – A study on the impacts of the new IMO regulations on transportation costs</td>
</tr>
<tr>
<td></td>
<td>The report intends to assess the impacts of the revised MARPOL Annex VI regulations on fuel costs to maritime traffic between Finland and continental Europe and freight traffic transportation costs in the SECA area. In addition, the report aims to assess the impacts of these costs on a range of import and export sectors in Finland.</td>
</tr>
</tbody>
</table>
Aims & Objectives

Sweden (2009)  Consequences of the IMO’s new marine sulphur fuel regulations
The aim of the study was to investigate the consequences for Swedish Trade and Industry of the revised MARPOL Annex VI Regulations. To do this 18 public authorities and business organisations were consulted. The key objectives of the study were as follows:
• The investigation of availability and pricing of low sulphur fuel;
• Evaluate modal shift from shipping to other forms of transport;
• Propose measures to facilitate the implementation of the regulations; and
• Draw up proposals for voluntary initiatives that can facilitate the application of the regulations for ship owners

ECSA (2010)  Analysis of the Consequences of Low Sulphur Fuel Requirements
The report analyses the impact on the ECAs of the new fuel quality requirements of the revised MARPOL Annex VI. The revised Annex VI enters into force on 1 July 2010. The new regulations mean that the limit value for sulphur in the ECAs (Baltic Sea, North Sea/English Channel) is lowered to 0.1% by weight in 2015 and globally to 0.5% by weight in the year 2020 or, depending on fuel supply, at the latest by the year 2025. The report aims to assess the concerns of the shipping lines over: serious disruption of the commercial dynamics of shipping in the ECAs, increases in vessel operating costs, lower competitiveness for shipping compared to other modes of transport and a potential modal shift from sea to road. The report aims at analysing the potential impact of the new low sulphur requirements on shipping in the ECAs, with an emphasis on short sea shipping.
The report particularly focuses on three questions:
• What is the expected impact of the new requirements of IMO on costs and prices of short sea traffic in the ECAs?
• What is the expected impact of the new requirements of IMO on the modal split in the ECAs?
• What is the expected impact of the new requirements of IMO on external costs?

ECa (2010)  Cost benefit analysis to support the impact assessment accompanying the revision of Directive 1999/32/EC on the sulphur content of certain liquid fuels
This report aims to inform the European Commission’s review of Directive 1999/32/EC relating to a reduction in the sulphur content of certain liquid fuels by determining the effects of:
• Revisions of MARPOL Annex VI and the Technical Code on Control of Emissions of Nitrogen Oxides from Marine Diesel Engines;
• Possible designation of additional SOx ECAs;
• Possible designation of NOx ECAs; and
• Agreement by the European institutions on the Climate and Energy Package.

ECb (2010)  Impact study of the future requirements of Annex VI of the MARPOL Convention on Short Sea Shipping
The overall aim of this study was to assess the sectoral, economic and environmental impacts associated with the use of low sulphur fuels on short sea shipping. This was to be achieved through the following tasks:
• Estimation of the costs (operational and capital) associated with the use of low sulphur fuels;
• Evaluation of the economic impacts of installing sulphur abatement equipment;
• Investigation of impacts of additional costs on competitiveness of sea versus road transport including an estimation of impacts on modal balance; and
• Estimation of emission impacts for a range of scenarios.

Scope of each study
The figure below provides an overview of the geographical scope of each of the studies to help visualise how they overlap.
Figure 2.1 Geographical scope of each study

**Sweden (2009)**
- **Geographic:** Focus is on impacts on SE trade & industry - transport to & from Sweden as well as transit traffic to FI through SE, & access to N SE through NO ports that are not within a SECA.
- **Temporal:** May to May 2015.
- **Shipment movements/types:** Impacts on both passenger vessels & freight vessels considered. Modal shift considered for freight traffic only.

**Finland (2009)**
- **Geographic:** Vessels calling at FI ports in 2007.
- **Temporal:** No projections for vessel numbers/types or fuel consumption. All calculations based on 2004-2009 data.
- **Shipment movements/types:** Cost estimations based on vessels that paid waterway charges to FI in 2007.

**ECa (2010)**
- **Geographic:** Europe: EU-27 & Baltic, Black, Mediterranean & N Seas & NE Atlantic.
- **Temporal:** Baseline year 2000 with BAU baseline projected to 2015 & 2020.
- **Shipment movements/types:** Ex-tomis model used to split fuel consumption by vessel type & engine size.

**UK (2009)**
- **Geographic:** UK waters (200 nautical miles from coastline) & further E to ensure complete coverage of N Sea.
- **Temporal:** Baseline year of data is 2007, with projections for 2010, 2015 & 2020.
- **Shipment movements/types:** All movements within geographic boundary of study area.

**ECSA (2009)**
- **Geographic:** Focus is on 30 origin-destination pairs centred around four short sea routes within the ECAs: DE/DK to SE, Channel, W Europe to Baltic States & W Europe to Scandinavia.
- **Temporal:** 2015.
- **Shipment movements/types:** Short sea shipping only.
The table below provides an overview of the scope of each study in terms of the impacts they have considered.

### Table 2.2 Overview of scope and focus of each study

<table>
<thead>
<tr>
<th>Study</th>
<th>Costs</th>
<th>Emissions (Note 1)</th>
<th>Environmental</th>
<th>Health</th>
<th>Modal Shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK (2009)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>(Quantitative: fuel, scrubbers &amp; administrative costs)</td>
<td>(SO2, NOx, CO2, PM &amp; VOCs – modelling at 5x5 km2 resolution)</td>
<td>(Critical load exceedences - quantified but not monetised)</td>
<td>(Quantified &amp; monetised)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Qualitative: costs to UK refineries)</td>
<td></td>
<td>(Building &amp; materials damage – monetised)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finland (2009)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>(Fuel costs only)</td>
<td>(Impacts on shipping emissions discussed but not quantified)</td>
<td>(Impacts on environment discussed but not quantified)</td>
<td>(Impacts on health discussed but not quantified)</td>
<td>(Estimates of % increases on freight transportation costs – by freight type &amp; sector)</td>
</tr>
<tr>
<td>Sweden (2009)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>(Fuel costs only)</td>
<td>(SO2 quantified. PM and SO2 results from another study quoted but not related to data in study)</td>
<td>(Monetised values for SO2 presented based on damage cost functions)</td>
<td>(Monetised values for SO2 presented based on damage cost functions)</td>
<td></td>
</tr>
<tr>
<td>ECSA (2010)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>(Fuel costs only)</td>
<td>(SO2, PM, NOx, CO, VOCs &amp; CO2 estimated for 5 short sea vessels on 5 short sea routes)</td>
<td>(Monetised values presented based on damage cost functions)</td>
<td>(Monetised values presented based on damage cost functions)</td>
<td></td>
</tr>
<tr>
<td>ECa (2010)</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>(Fuel, NOx control &amp; scrubber costs quantified)</td>
<td>(SO2, PM, NOx, VOCs)</td>
<td></td>
<td>(Quantified &amp; monetised)</td>
<td></td>
</tr>
<tr>
<td>Study</td>
<td>Costs</td>
<td>Emissions (Note 1)</td>
<td>Environmental</td>
<td>Health</td>
<td>Modal Shift</td>
</tr>
<tr>
<td>------------</td>
<td>---------------------------------</td>
<td>----------------------------------------------------------</td>
<td>----------------</td>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>ECb (2010)</td>
<td>✓</td>
<td>✓ (Reductions in SO₂ emissions per unit – i.e. per trailer – estimated for selection of routes &amp; years)</td>
<td>X</td>
<td>X</td>
<td>✓</td>
</tr>
</tbody>
</table>

Note 1: Only UK (2009) attempts to quantify the potential increase in CO₂ emissions from refineries as a result of increased production of low sulphur fuels.
3. Key Assumptions

3.1 Overview

This section aims to present a summary and comparison of the key assumptions that have been applied in each of the studies. The focus is on those assumptions which are likely to have a significant impact on the overall outputs and conclusions of each study. These include:

- The business as usual scenario i.e. what is the assumed starting point for the analysis?
- Shipping sector response i.e. how is the sector assumed to achieve compliance with the revised regulations in 2015?
- Availability and costs of low sulphur fuels, now and in the future.
- Availability, reliability and costs of scrubbers, now and in the future.
- Approach taken to investigating modal shift.
- Approach taken to estimate emission reductions and associated health and/or environmental benefits.

3.2 Business as usual scenario

It is important to consider what each study has assumed in terms of the starting point for any analysis. In particular, any differences in terms of Business-As-Usual fuel types and S levels would be a cause of differences in the costs and benefits of Revised MARPOL Annex VI. In theory, the starting %S figures should be as per the existing MARPOL Annex VI and Sulphur Content of Marine Fuels Directive i.e. 1.5% S for all vessels in SECAs and for passenger ferries on regular services between EU ports and 0.1% at berth.

It appears that all of the reports have assumed the use of 1.5% S HFO by all vessels in SECAs as the baseline for analysis. Only ECSA (2010) uses a slightly different assumption (1% HFO) when assessing the likely impacts of the revised regulations on external costs. For all other parts of the analysis in this report, the starting point is 1.5% S HFO. What is unclear for a number of the reports is how/if the 0.1% S requirement for vessels at berth has been taken into account. This could lead to an overestimation of impacts (both costs and benefits) if it is not taken into account.
3.3 Shipping sector response

The revised MARPOL Annex VI regulations will require ships operating in the SECA to switch to distillate fuels with a sulphur content of less than 0.1% from 2015 onwards or to use abatement equipment such as seawater scrubbers to reduce emissions by an equivalent amount.

Each of the six studies considers a range of different responses (scenarios). UK (2009) considers that in 2020 10% of vessels will continue to use high sulphur fuels but fit scrubbers for compliance and the remaining 90% will switch to distillate fuels. The assumption of a 90:10 split between fuel switching and scrubbers is based on an IMO publication. The majority of studies, however, assume that all vessels will switch fuels. ECa (2010) and ECB (2010) include both scrubbers and fuel switching in their analyses, but assume either 100% fuel switching to low sulphur fuel or 100% scrubber fitting and nothing in the range between.

Each of the studies has also considered the impacts of different fuel prices to take into account the uncertainty in predicting future prices.

3.4 Fuels

3.4.1 Availability

Whilst the introduction of the 1% S limit in SOx ECAs in 2010 can be met with 1% S content HFO, the introduction of the 0.1% S limit in SOx ECAs in 2015 will require a shift away from heavy fuel oil. The reports agree that few crude oils in the world are of low enough sulphur content to produce a heavy fuel oil with sulphur content less than 0.5%. There is a consensus that the stricter sulphur limits will force ships to use distillates in place of residual oil.

It is difficult to estimate the availability of low-sulphur fuels in the future. Studies agree that availability of distillates depend on a multitude of factors: supply, demand, geopolitical developments and development of alternative fuels; making forecasting future availability difficult. The three Member State reports (Finland, Sweden and UK) conclude that the introduction of stricter sulphur limits in SOx ECAs areas in 2010 will not represent a problem for local refineries. Sweden (2009) and UK (2009) both conclude that the introduction of the 0.1% S limit in SOx ECAs in 2015 will result in ships switching to marine gas oil. Both reports concur that this will increase demand for diesel / gasoil in North West Europe. At the present time, Europe has a surplus of a gasoline and a deficit of diesel which is compensated by a surplus of diesel in the USA. Recent hikes in oil prices in the USA have pushed up demand for diesel which affects supply and pricing in Europe. Furthermore, possible establishment

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8 IMO (2007), Revision of MARPOL ANNEX VI and the NOx Technical code, Input from the four subgroups and individual experts to the final report of the Informal Cross Government/Industry Scientific Group of Experts Note by the Secretariat, Subcommittee on bulk liquids and gases, 12th session, Agenda item 6, 28 December 2007 http://www.endseurope.com/docs/80213b.pdf
of ECAs in USA and Canada will further increase demand for low-sulphur fuels. Sweden (2009) remarks that the US EPA expects there to be sufficient refinery capacity to meet demand. UK (2009) concludes that the marine fuel demand in SOx ECAs constitutes only a very small share of global fuel consumption, and would not be enough to drive big investments such as hydrocracking.

At the global scale, the studies largely agree that the world-wide limit of 0.5% S in 2020 will lead to a global switch to distillates in the maritime transport sector which will require the oil industry to change its refining capacity considerably. Finland (2009) includes projection of demand of different fuels until 2025 which shows the increasing demand for distillates (26% of fuel demand in 2010 and 93% in 2025). Sweden (2009) expects the implementation of restrictions to result in a shift to distillates (MDO and MGO) by 2015. In terms of meeting this demand, ECSA (2010) assumes that 1% S HFO, 0.5% S MDO and 0.1% S MGO will be available in the future whilst ECa (2010) does not consider whether the global refining industry would be able to supply sufficient low sulphur fuels. ECa (2010) expects low sulphur oil to be residual fuel that has been desulphurised or MDO formed from a mixture of residual oil and distillates. Sweden (2009) and UK (2009) assess possible options for refineries:

- Desulphurise residues – costly and results in additional CO2 emissions. Sweden (2009) notes that onboard desulphurisation may be an option for some vessels.

- Convert residual streams to distillate products – costly and complex but distillate products are inherently more valuable than residues.

- Adjust the product yield from the crude oil to market needs, e.g. increase the proportion of lighter fractions during distillation.

- Optimise HFO stream separation and mixing to obtain low-sulphur bunker fuel - the scope for this is limited as residual fuel blending is more likely an option for compliance with the 1% S limit in SOx ECAs in 2010.

- Process more low-sulphur crude oils – limited scope to this option. ECb (2010) notes that average crude sulphur content is expected to increase from current 1.2% to 1.4% by 2020 which is likely to lead to an increase in average sulphur content of HFO (p10).

- Export surplus of high-sulphur bunker – studies agree this will only be possible for a limited period as increasing geographic areas introduce more stringent limits. Sweden (2009) notes that land based power stations may become a consumer of some residues (although this may be limited in the EU as the maximum allowable sulphur content for heavy fuel oil used by land-based sources is 1% as specified in the Sulphur Content of Liquid Fuels Directive).

Both reports conclude that exporting surplus of high-sulphur heavy distillates is a feasible option in the short-term but will become limited after 2015. Converting residual streams to distillate products is a longer-term option. Sweden (2009) concludes that coker units despite significant investment costs have a short repayment period of 4-5 years, making this method feasible. UK (2009) refers to a study by CONCAWE (2006) predicting better economic prospects for this option than desulphurisation. It is not clear from the studies how the increased demand for distillates will be met.
3.4.2 Costs

One of the most critical, and perhaps most uncertain, assumption that has the greatest influence on the modelling and conclusions of each of the studies is fuel prices, and in particular the fuel price premium associated with 0.1% sulphur fuel (relative to HFO).

Approach

The table below provides a summary of the approaches taken for each study with respect to fuel prices.

Table 3.1 Comparison of approaches taken by each study with respect to fuel prices

<table>
<thead>
<tr>
<th>Study</th>
<th>Approach and assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Cost of fuel switching modelled by use of fuel price premia. Price premia are related to three crude oil price scenarios: $60/ barrel; $80/barrel and $150/barrel.</td>
</tr>
<tr>
<td></td>
<td>• Modelling includes fuel consumption savings as a result of switch to distillates and are estimated at around 4.5% of fuel consumption. Considers additional costs such as modifications/ adjustments on fuel pumps. Estimates provided but not incorporated.</td>
</tr>
<tr>
<td>Finland (2009)</td>
<td>• No projections, information based on current fuel price and fuel consumption</td>
</tr>
<tr>
<td></td>
<td>• Cost of fuel switching modelled by use of fuel price premia. Estimated price differentials based on three-year (2006-2008) average for fuel prices given by Finnish Oil and Gas Federation for Fuels. This information used to provide estimates of fuel costs per day and TEU</td>
</tr>
<tr>
<td></td>
<td>• No projections for vessel numbers or fuel consumption. Fuel consumption based on ships operating in 2007 (calculated using existing studies e.g. HELCOM ShipNODep project)</td>
</tr>
<tr>
<td></td>
<td>• Only takes account cost of using fuel needed for SECAs – 0.1% S. Does not take into account savings in fuel costs that could be possible using higher sulphur fuels in conjunction with abatement equipment</td>
</tr>
<tr>
<td>Sweden (2009)</td>
<td>• Fuel price projections for 2015</td>
</tr>
<tr>
<td></td>
<td>• Price projections based on IEA crude oil forecast price of $100/barrel</td>
</tr>
<tr>
<td></td>
<td>• Presents fuel prices for each fuel grade by sulphur based on average fuel prices during October and November 2008 in Rotterdam. Assumes constant price premium between HFO and MGO based on the price differential in October/November 2008 ($297/t) (see p32 of report)</td>
</tr>
<tr>
<td></td>
<td>• Weighted mean fuel prices calculated based on proportion of port arrivals of each vessel type (and sulphur content) using data from Swedish Maritime Administration for 2008 (p32)</td>
</tr>
<tr>
<td></td>
<td>• Assumes fuel consumption for all ships to be 190g/kWh (p37)</td>
</tr>
<tr>
<td></td>
<td>• Projections consider increasing demand for middle distillate fraction</td>
</tr>
</tbody>
</table>
### Study Approach and assumptions

<table>
<thead>
<tr>
<th>Study</th>
<th>Approach and assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECSA (2010)</td>
<td>• Fuel price projections for 2015 • Estimates fuel prices for 1.5% S HFO, 0.5% S MDO and 0.1% S MGO for 3 scenarios where 0.1% S MGO is assumed to cost $500/t, $750/t and $1,000/t. The price differential between HFO and MDO is set at 80% in the scenarios based on current (BAU) situation • Considers increased fuel efficiency due to the higher energy density of distillates • Impact of reduced maintenance costs and modification costs for switching to distillates not considered. • Total fuel costs calculated using fuel price projections and average fuel consumption per km (t/km) based on short sea journeys in ECAs.</td>
</tr>
<tr>
<td>ECa (2010)</td>
<td>• Fuel price projections for 2020 • Projections based on Purvin and Gertz (2009)⁹ • Assumes that costs to adapt to different fuels are relatively small (p 37)</td>
</tr>
<tr>
<td>ECb (2010)</td>
<td>• Fuel price projections for 2025 • Projections based on Purvin and Gertz (2009)⁹ • Fuel consumption estimates based on assumed speed, fuel consumption, engine size, fuel type and voyage duration for particular vessel (p56). No projections of fuel consumption</td>
</tr>
</tbody>
</table>

### Projected MGO (0.1% sulphur) price

UK (2009), Finland (2009), Sweden (2009) and ECb (2010) state assumed MGO prices for 2015 (and other years for some studies). In UK (2009), both low and high price scenarios are used: in the low scenario, the price of MGO increases 8.5% from 2010 to 2015, whilst in the high scenario the price increases by 43%. ECb (2010) forecasts a 33% increase over the same time period. Both Sweden (2009) and Finland (2009) include a historical context of MGO prices before 2009, and both studies agree with one another that large fluctuations in MGO price can occur over short periods, as occurred during 2008. Such significant fluctuations in fuel prices over a short period of time demonstrate the difficulty of forecasting future fuel prices with any certainty.

All the figures – both past and projected – for MGO prices used in the studies are summarised below in Figure 3.1.

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⁹ Purvin and Gertz (2009) Impacts on the EU Refining Industry and Markets of IMO Specification Changes and Other Measures to Reduce the Sulphur Content of Certain Fuels
Figure 3.1  Historical MGO price (as reported in Sweden (2009) and Finland (2009)) and projected MGO prices used in the studies over time (€/tonne, 0.1% sulphur)

Note 1: Trend in historical MGO price summarised from detailed time series of fuel sales prices in Finland (2009) and Sweden (2009).

Impact of fuel sulphur content on fuel price

All six studies include assumptions regarding the price of different fuels at certain different fuel sulphur contents – the fuel sulphur contents considered are 0.1%, 0.5%, 1.0% and 1.5%. Many studies – UK (2009), Finland (2009), ECSA (2010) and ECa (2010) – separate fuel prices into low, mid or high scenarios. All the price assumptions (converted where necessary to €/tonne) are plotted as a function of fuel sulphur content in Figure 3.2. It is important to note that the assumptions are for different years: Finland (2009) uses 2009 prices, ECa (2010) has 2020 price projections and the remaining studies are using 2015 price projections. The figure clearly demonstrates the increase in fuel price with the decrease in fuel sulphur content.
Figure 3.2 Assumed fuel prices (€/tonne) as a function of fuel sulphur content (%)

Note: the assumed fuel prices in the above figure relate to different years, as included in the legend. Also, not all studies have data available to plot, such that for example the 0.1% S fuel price assumptions of ECSA (2010) and ECb (2010) are single points unconnected by lines, which gives them at first sight comparatively less emphasis.

Price premium of 0.1% and 0.5% S fuels over 1.5% S fuel

A key input assumption for most studies is the price premium of lower S fuel (0.1% or 0.5%) over fuel with a S content of 1.5% in order to estimate additional cost impacts. To reflect anticipated fuel prices changes over time, the studies often assume that the price premia vary by year. Figure 3.3 shows the average price premia that the studies employ on the price premium of fuels with sulphur content of 0.1% and 0.5% over fuel with sulphur content of 1.5%, separately for years 2010, 2015 and 2020 (and an average for all years). The error bars indicate the minimum and maximum values from the six studies for each of the years.
Figure 3.3  Average price premium of lower sulphur fuels (0.1% MGO and 0.5% MDO/LSFO) over 1.5% HFO

3.5  Scrubbers

3.5.1  Availability and Reliability

MARPOL Annex VI allows the after-treatment of exhaust gases as an alternative to low sulphur fuel on the basis that an equivalent reduction in emissions is achieved. There are three principle types of sulphur scrubber suitable for ships: open (sea-water), closed (freshwater) and dry scrubber. The reports concur that the most common type of scrubbing for marine applications is sea water scrubbing (SWS). The reports agree that it is technically feasible for operators to install SWS in order to comply with the SOx limit and that they can remove 90-95 % of SO2.

The Swedish and Finnish reports both acknowledge the limitations of using SWS in the Baltic Sea. Ocean alkalinity is usually constant and high. However, alkalinity in the Baltic Sea is lower than normal because of the minimal exchange of water through the Danish straits. At low alkalinity SWS can still operate, but it can lead to lower cleaning efficiency (requiring greater volumes of sea water and/or additional reagent) and low effluent pH figures. The Swedish report notes that closed fresh water scrubbers may be more appropriate/acceptable but they are more expensive than open systems, can create work environment safety problems and require facilities in ports for handling sludge. The UK reports notes that the technology is less well developed than the use of sea water alone. To date, ships sailing in the Baltic Sea have not made use of scrubbers. ECa (2010) and ECb (2010) recommend that further studies are undertaken for brackish and river water.
The UK and Finnish reports both remark that there are currently few manufacturers in the scrubber market. According to UK (2009) this may be linked to limited demand. Limited production capacity may also impose a restraint on the uptake of this technology. The UK report concludes that as demand increases, production capacity will increase, however manufacturers are unlikely to invest in sufficient capacity to meet all demand before 2020. However it is not expected that demand will substantially increase in the near future and may only increase from 2015 onwards. The UK report states that industry does not consider likely a high % uptake of SWS. In addition, ECSA (2010) considers scrubbing to be an immature technology and does not expect it to play an important role in 2015.

The reports agree that for the commercial implementation of marine scrubbers to become viable, there are a number of challenges to be faced:

- **Ecological concerns of sludge disposal** – there is concern that sending seawater back into the ocean with S-containing wastewater is harmful to the marine ecosystem. There are IMO regulations on wash water criteria approved under Method B of IMO Annex VI Regulation 14. Criteria include pH, PAH, turbidity, nitrates, additives.

- **Environmental concerns of sludge disposal** - there are already some regulations stipulating performance, verification, and certification issues for SOx scrubbers. IMO Resolution MEPC.130(53) requires a SECA Compliance Plan (SCP) describing methodology for compliance by each ship using scrubbers rather than low-sulphur fuel.

- **Availability of space on vessels** – reports concur that retrofitting SWS in existing ships would be difficult and costly as the sludge cleaning equipment occupies a significant amount of space onboard which is not readily available (although this needs to be considered against the costs of low S fuel).

- **Design of new ships** – the Finnish report argues that installation would be easier in new ships where necessary space could be designed at the planning stage.

- **Interaction with other abatement measures such as selective catalytic reduction (SCR)**. SCR can be used along with SWS, if the SWS system is connected after the SCR system as there could be issues of high back pressure on the engine. Note that this would only be an issue for new vessels covered by the tightest NOx controls.

- **Fuel consumption penalty** associated with the operation of the unit.

- **New Technology** – uncertainty over costs and technology.

The UK report finds that industry experts note that the amount of sludge produced is overstated and that the amount of sludge from in-vessel fuel treatment systems is higher than that from SWS. They also find that experts do not consider that the disposal of sludge should be an environmental concern. ECa (2010) assumes that compliance with sulphur limits can be achieved with the use of scrubbers with high sulphur fuel (2.94%). The scenarios in the study separately consider scrubbers in existing and new vessels and between closed and open scrubbing systems.
None of the reports examines issues of reliability of scrubbing in any great detail primarily as it is a relatively new technology with limited applications. In the instance that the scrubber system fails whilst the ship is at sea the vessel would be forced to change over to an alternative fuel of the appropriate level of sulphur content for the area in which the vessel is operating. Alternatively, the vessel would be off service until the scrubber fault was rectified. It should be noted that not all vessels have sufficient tank segregation to carry fuels of up to three different levels of sulphur content. ECa (2010) states that there is limited data on the performance of marine scrubbers and it is important to conduct more trials.

### 3.5.2 Costs

As with fuel costs there is high uncertainty regarding scrubber costs due to the small number of scrubbers currently in operation and the application of available cost data (in terms of € per installed kW) to different engine sizes. As would be expected, the reports concur that scrubber costs will be higher for retrofit systems than for new systems and that closed systems are more costly than open ones. UK (2009), ECa (2010) and ECB (2010) are the only studies that include scrubber costs in their analyses; these are summarised in the table below.

<table>
<thead>
<tr>
<th>Study</th>
<th>Key Assumptions</th>
<th>New Build Capex (€/kW)</th>
<th>Retrofit Capex (€/kW) (Note 1)</th>
<th>Abatement Efficiencies</th>
<th>O+M Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK (2009)</td>
<td>• Focuses on SWS (2009 prices)</td>
<td>122</td>
<td>156</td>
<td>SO\textsubscript{2} up to 95%, PM up to 80%</td>
<td>Per year: small: 3%; medium: 2%; large: 1%</td>
</tr>
<tr>
<td></td>
<td>• Assumed capital costs of installing scrubbers to main engine only (separate costs given for combined installation to main and auxiliary engine)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Expected lifetime: 25 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Fuel consumption penalty: 1.5%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Sensitivity scenario has been considered whereby scrubber costs reduce by 50% due to increased commercialisation.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECB (2010)</td>
<td>• Separately considers prices for open/ closed scrubber systems (2005 prices)</td>
<td>100-200</td>
<td>200-400</td>
<td>Assumes abatement up to 97%</td>
<td>k€/vessel (15MW): 28 (incl sludge disposal costs of €0.12/ litre)</td>
</tr>
<tr>
<td></td>
<td>• For closed systems, purchase of NaOH and fresh water are taken into consideration. NaOH cost: €0.5/litre 50% NaOH</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>• For SWS maintenance costs and fuel penalty are taken into account.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Expected lifetime: 15 years for new, 12.5 for retrofit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Fuel consumption penalty: 2%</td>
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</tbody>
</table>
Creating the environment for business

<table>
<thead>
<tr>
<th>Study</th>
<th>Key Assumptions</th>
<th>New Build Capex (€/kW)</th>
<th>Retrofit Capex (€/kW) (Note 1)</th>
<th>Abatement Efficiencies</th>
<th>O+M Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECB (2010)</td>
<td>• Focuses on SWS (2009 prices)</td>
<td>118</td>
<td>168</td>
<td>Range based on scrubbers from different manufacturers: SO₂ 93-100%; PM 50-85%</td>
<td>€/MWh: small 0.8; medium 0.5; large: 0.3</td>
</tr>
</tbody>
</table>

Note 1: Based on discussions with industry, the retrofitting of a scrubber will require an off service period of up to 28 days which is considerably longer than routine dry-docking and refits of the same vessels. Operators therefore have to factor in the additional loss of revenue due to the time off service. These additional costs do not appear to have been taken into account in the figures quoted above.

3.6 Modal Shift

Four of the six studies reviewed have considered modal shift in any detail. ECSA (2010) and ECB (2010) have considered the potential impacts of the revised MARPOL Annex VI Regulations on Short-Sea Shipping (SSS) along a selection of routes in the SECA. Sweden (2009) focuses on possible modal shifts in freight transit to and from Sweden whereas Finland (2009) only considers increases in freight transportation costs with some commentary on possible implications. The table below summarises the approaches taken.

Table 3.3 Comparison of approaches taken to assessing modal shift

<table>
<thead>
<tr>
<th>Study</th>
<th>Approach and assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finland (2009)</td>
<td>• Study considers possible impacts of increasing fuel costs on transportation costs for selected sectors. Modal shift is discussed in the report but has not been quantified.</td>
</tr>
</tbody>
</table>
| Sweden (2009)  | • Modal shift due to projected marine fuel price rises is considered through the use of a freight model. The model assesses shifts to road and to rail freight.  
• Impacts assessed using a cost minimisation model that takes into account transport costs, transhipment costs, order administration costs, storage costs and the tied-up capital costs of goods in storage and during transport.  
• The model selects alternative route choices and alternative mode choices, including each vehicle type within a mode. |
Study | Approach and assumptions
--- | ---
**ECSA (2010)** | - Two approaches were taken for assessing modal shift due to increased fuel costs:
  - a stated-preference technique has been applied by presenting the results of a survey among leading short sea operators in the ECAs. The survey aimed at assessing the perception of short sea operators on the potential volume losses and modal shift impacts linked to the implementation of strict low sulphur fuel requirements under different scenarios regarding fuel price evolutions;
  - a detailed cost analysis was undertaken to assess modal competition between the short sea/truck option and the truck only option on 30 origin-destination routes linked to the ECAs; volume losses due to modal shift were not estimated.
- The study focuses on 30 origin-destination pairs centred around four short sea routes: Germany/Denmark to Sweden, English Channel, West Europe to Baltic States and West Europe to Scandinavia (Sweden / Norway).
- The effect of modal shifts of 10%, 20% and 30% on ‘external costs’ (i.e. damage costs of air pollutants) were evaluated for each of the routes considered.

**ECb (2010)** | - Two transportation models have been used to assess possible impacts on modal shift for the RoRo (“NECL Model”, 10 competing routes operating on four corridors) and LoLo (“TAPAS Model”, 5 competing routes operating along a single corridor) SSS industry for a selection of routes in the Baltic and North Seas.
- For both models, input data includes estimates of unit price impacts of MARPOL Annex VI for SSS as well as potential impacts of implementing the Eurovignette infrastructural and environmental tolls (i.e. proposed amendments to Directive 1999/62/EC on the charging of heavy goods vehicles for the use of certain infrastructure).
- It has been assumed that the transport of goods by SSS must be approximately 15% cheaper than the road alternative in order to be equitable i.e. approximately 50% of the cargo will travel via SSS and 50% by road. This was applied to each scenario to estimate the potential change in route selection.

### 3.7 Benefits

All but one of the six studies (ECb) considers the health and/or environmental benefits associated with switching to a lower sulphur fuel or installing scrubbers. However, only UK (2009) and ECa (2010) have actually quantified these benefits (ECa quantifies health impacts only) through the use of the “impact pathway approach” i.e. where geographically disaggregated emissions and air quality modelling is undertaken to estimate exposure and exposure response factors applied to estimate impacts. These impacts have then been monetised (where possible) through the application of appropriate monetised values.

Sweden (2009) and ECSA (2010) have monetised the health and environmental impacts associated with reductions in emissions through the application of damage cost functions i.e. applying a monetary value in € per tonne of pollutant emission reduced. Reductions in emissions have first been estimated and then multiplied by appropriate functions. Sweden (2009) assumes a benefit (to Sweden) of approximately €2,600 per tonne of SO₂ reduced from ships. No equivalent figure has been presented for PM although reference is made to figures from the European Commission’s Clean Air For Europe (CAFE) programme; €12,000-35,000 (Baltic Sea) and €28,900-80,000 (North Sea) per tonne of PM reduced. ECSA (2010) takes a different approach in that marginal external costs have been estimated for a range of routes on a per trip basis. These take into account environmental and health impacts (road...
and shipping) as well as accident, congestion and infrastructure (road only) costs. The following valuations have been applied for the shipping emissions component of the above (i.e. health and environmental impacts): 

- For SO\(_2\): €2,678 (Baltic Sea) to €6,620 (North Sea) per tonne.
- For PM: €26,050 (Baltic Sea) to €8,210 (North Sea) per tonne.

Whilst the value for SO\(_2\) for the Baltic Sea is similar to that applied in Sweden (2009), the values for PM for the North Sea are considerably lower than those developed in the CAFE programme.

It is not possible to derive an equivalent damage cost function for UK (2009) or ECa (2010) as the quantified and monetised benefits relate to multiple pollutants e.g. SO\(_2\) and PM.

The location of the emissions (or reductions) will influence the exposure of the population and associated impacts. In addition, it is important to note that different countries and the EU value health impacts in different ways (approach and valuation of impacts). For example, the UK study considers all ships within a 200 mile distance of the coast for emissions and costs purposes but environmental and health benefits are only estimated for the UK due to the nature of the study i.e. they are underestimates as reductions in emissions in this area will also benefit other neighbouring countries.

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10 Valuations for other pollutants have also been included in the report i.e. CO, VOCs, NOx, CO\(_2\), N\(_2\)O. Note, valuations for road emissions are higher than those for shipping reflecting the fact that these emissions are released on land much closer to the population.

11 AEA Technology (2005): “Damages per tonne emission of PM\(_{2.5}\), NH\(_3\), SO\(_2\), NO\(_x\) and VOCs from each EU25 Member State (excluding Cyprus) and surrounding seas”, final report for the European Commission, March 2005. Report available from: http://www.cafe-cba.org/assets/marginal_damage_03-05.pdf
4. Key Findings and Conclusions

4.1 Overview

This section provides a summary and comparison of the key findings and conclusions of each study with consideration of the assumptions that have been applied (as described in the previous section). This includes costs, benefits and modal shift. This section focuses on the outputs from each study for the most likely scenario (i.e. shipping response) and a range of values are presented to reflect the variation in fuel prices.

4.2 Costs

The figure below provides a summary of the costs estimated in ECa (2010) for Europe for achieving compliance with the revised MARPOL Annex VI Regulations (note, these figures exclude the costs associated with achieving the Tier I and II NOx standards). These costs have also been presented disaggregated by sea area in the report indicating that there will be a 30:70 split between the Baltic and North Sea.

![Summary of ECa (2010) costs (2005 prices, additional to baseline)](image)

Note 1: Costs have been adjusted to take account of range of fuel price premia and a 90:10 split between fuel switching and scrubbers applied. Further details provided in text below.

The costs for fuel switching presented above are based on a price premium of approximately €190-230 per tonne in 2020 for 0.1% S content compared to 1.5%. However, if a price premium of €111 or €480 per tonne was used (low

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and high values from Finland, 2009\textsuperscript{12}), total costs for the fuel switching scenario would be approximately 40% lower or 115% higher, respectively (i.e. approximately €1.8-7.8 billion in 2015). In addition, ECa (2010) assumes 100% scrubbing or 100% fuel switching whereas the reality is likely to lie somewhere between the two scenarios. UK (2009) has assumed a 90:10 split in favour of fuel switching. If this split were to be applied to the ECa (2010) data then costs would be approximately €2.8-3.5 billion in 2015 (or €1.7-7.2 billion if applying the low and high fuel price premia values from Finland (2009)).

Only ECa (2010) has quantified the costs associated with the revised regulations at a European level. As discussed in the previous section, three country specific studies have been undertaken which have considered costs either for ships operating in a certain geographical area (UK) or those travelling to and from a particular country (Finland and Sweden). The total additional compliance costs estimated in each study are presented in the figure below.

**Figure 4.2 Summary of costs estimated in Finland (2009), Sweden (2009) and UK (2009) (2009 prices, additional to baseline)**

![Cost Summary Chart](image)

Note 1: Ships calling at Finnish ports. Low value relates to price differential of €111 per tonne for minimum fuel consumption scenario. High value relates to price differential of €480 per tonne for maximum fuel consumption scenario.

Note 2: Ships calling at Swedish ports. Low and high values equate to varying assumptions about operation hours and fuel consumption in the SECA.

\textsuperscript{12} These represent the highest price differentials applied in either of the studies. They are spot prices for March 2009 (low value) and May 2008 (high value) which have been applied in the Finnish study in order to illustrate the significant variation in fuel prices (and premia) from year to year. An expert estimate is stated as €214 per tonne which is in the lower half of the range.
Note 3: Ships operating within 200 miles of UK coastline. Costs based on expected impacts in 2020 with lower value based on 100% SWS uptake and upper value assuming 10% SWS uptake with the remainder switching fuels. UK (2009) also considered a sensitivity whereby scrubber costs reduced by 50% due to increased take up.

The wide variation in the cost estimations at both a European and Member State level reflects the significant uncertainty with respect to the response of the shipping sector to the revised regulations and, in particular, fluctuations in fuel prices, now and in the future.

It should be noted that whilst some of the studies have discussed the possible implications for the refining sector as a result of increased demand for low sulphur fuels, no quantification has been undertaken of the likely impacts. It could be argued that the fuel price premium between 1.5% S HFO and 0.1% S MDO already factors in the additional costs for refineries. The scale of any impacts will depend on the overall response of the shipping sector to the revised regulations both within the SECA as well as worldwide when the 0.5% limit comes into force. The latter is expected to have the biggest impact on refineries.

To try and reduce the overall impacts associated with the switch to 0.1% sulphur fuel, Sweden (2009) has identified a number of possible options that could be taken to mitigate the impacts of the revised regulations including:

- Transport subsidies for ports;
- Increased funding for research and development;
- Investment grants;
- Reduced fairway charges;
- Fully internalise environmental impacts for all modes of transport;
- Tax-free shoreside electrical supply to ships; and
- International collaboration between Baltic Sea countries.

4.3 Benefits [assuming no modal shift]

Almost all of the studies reviewed have considered the potential impacts of the revised regulations on emissions from shipping. ECSA (2010) and ECb (2010) have considered this on a route basis; this is discussed in more detail in the following section on modal shift. ECa (2010), Sweden (2009) and UK (2009) have all considered total emission impacts in the relative study area/shipping type and quantified associated health and environmental impacts (Sweden only considers monetised health benefits):

- UK (2009): for a central case NOx emissions are projected to reduce by 8% in 2020, SO2 emissions by 88%, CO2 emissions by 3%, PM10 emissions by 67% and fuel consumption by 3%.
- Sweden (2009): SO2 emissions from ships calling at Swedish ports expected to reduce by approximately 80kt (92% reduction in emissions in the SECA).
- ECa (2010): SO₂ emissions in the SECAs are expected to reduce by approximately 466kt in 2015, a reduction of approximately 93% from the baseline.

The figure below summarises the monetised health benefits calculated in ECa (2010) relative to the costs. The costs and benefits presented in the figure are additional to the baseline i.e. they represent the incremental impacts associated with the revised regulations. As the figure shows, the monetised health benefits outweigh the costs under all scenarios i.e. even when adjusted to take account of a potentially higher price premium for 0.1% sulphur fuel.

**Figure 4.3 Summary of net annual costs and monetised health benefits from ECa (2010) for 2015 [assuming no modal shift]**

Note 1: Costs have been adjusted to take account of range of fuel price premia and a 90:10 split between fuel switching and scrubbers applied. Further details are provided in Section 4.2 above.

Note 2: Figures include the estimated health impacts associated with PM and ozone exposure. The range of benefits presented is based on differing approaches to valuing mortality.

Note 3: 2005 prices.

The report presents monetised benefits on a country by country basis; these are summarised in the figure below. As would be expected, the greatest benefits are expected to be realised in those Member States with coastline in the SECAs (North Sea and Channel, in particular) and relatively high population density i.e. UK, France, Germany and the Netherlands.
In addition to the monetised health impacts presented in the figures above, the report also quantifies (but does not monetise) some of the potential environmental impacts associated with a reduction in shipping emissions including:

- Reductions in sulphur (8% in 2015) and nitrogen (2% in 2015) deposition; and
- Reductions in acidification (25% in 2015) and eutrophication (3% in 2015).

The figure below presents a summary of the potential monetised benefits that have been estimated in Sweden (2009) and UK (2009) relative to the compliance costs. These benefits estimates are expected to be underestimates for the reasons outlined in the notes to the figure (see notes 2 and 4).
Figure 4.5  Summary of net costs and monetised health benefits from Sweden (2009) and UK (2009) [assuming no modal shift]

Note 1: Ships calling at Swedish ports. Low and high values equate to varying assumptions about operational hours and fuel consumption in the SECA.

Note 2: Benefits estimates only take into account reductions in emissions of SO2 and not PM; it is unclear if secondary particulates have been taken into account in the value for SO2. The study does include a rough estimate of the potential benefits associated with reduced PM emissions for the whole of the SECAs based on estimates from a previous report for the European Commission\textsuperscript{13} using a damage cost function taken from the Commission’s CAFE Programme. This is estimated to be approximately €1.8-5.1 billion in 2015.

Note 3: Ships operating within 200 miles of UK coastline. Costs are based on expected impacts in 2020 with the lower value based on 100% SWS uptake and the upper value assuming 10% SWS uptake with the remainder switching fuels. UK (2009) also considered a sensitivity whereby scrubber costs reduced by 50% due to increased take up.

Note 4: Due to the scope of the study the benefits estimates are underestimated in that benefits to other countries (i.e. non-UK) due to reduced emissions in the study area are not taken into account e.g. reducing emissions from ships in the English Channel will have benefits for France as well as the UK. In addition, the benefits valuation does not take into account expected reductions in critical load exceedences for acidification and eutrophication for all ecosystems in the UK (approximately 1-2% reduction).

Overall only ECa (2010) gives a comprehensive assessment of costs and benefits for the whole of Europe where the costs are directly comparable to the benefits. This shows that the monetised benefits far outweigh the costs even

when comparing against the highest fuel price premia. However, it should be noted that this study does not consider the potential for modal shift as a result of increasing shipping costs. This is discussed in more detail in the following section.

In addition, as with the cost estimations, there does not appear to have been any consideration of the possible indirect impacts of the revised regulations on refinery emissions (air pollutants and greenhouse gases) as a result of increased demand for lower sulphur fuels. This will result in an overestimation of the potential emission reductions and associated health and environmental benefits.

4.4 Modal shift

As outlined in Section 3.6, four of the six studies reviewed have considered modal shift to some extent:

- Finland (2009) considers the potential knock-on impacts of increased shipping fuel prices on freight costs for Finnish industry but does not quantify what this may mean in terms of modal shift.
- Sweden (2009) takes the analysis a step further and looks at the impacts of increased fuel costs on shipping and estimates potential transfer of freight from road to rail.
- Both ECSA (2010) and ECB (2010) consider modal shift at a finer resolution by investigating the likely impacts of increased fuel costs for a selection of competing freight routes (road, rail and sea) in the SECA.

The table below provides a summary of some of the key conclusions from each of the above studies.

<table>
<thead>
<tr>
<th>Study</th>
<th>Key Conclusions</th>
</tr>
</thead>
</table>
| Finland (2009)   | • The total estimated additional freight costs that Finnish industry will incur as a result of increased shipping fuel costs is estimated to be approximately €0.4 billion. The main industries likely to be affected include the forestry, metal and chemicals sectors.  
• This does not take into account any additional costs that long-haul carriers may incur if they also had to use low sulphur fuels outside of SECA for technical reasons or potential fuel savings associated with the use of higher sulphur fuels in conjunction with scrubbers.  
• Research in the study (expert interviews) indicates that additional costs will eventually be incorporated into sea freight costs with rises in freight charges estimated to be 28-51% depending on the type of freight. |
| Sweden (2009)    | • Fuel costs are expected to increase by approximately 50-55% from 2015 but may be higher for vessels only transporting goods between ports within SECA. This is expected to increase overall shipping transport costs by approximately 20-28% which is expected to be incorporated in freight charges.  
• There is a high risk of transfer of freight from sea to both road and rail in Sweden.  
• The results indicate a decline in shipping of between 2% and 10% depending on the projected price of fuel with consequent increases in road haulage traffic of between 2% and 6% and rail freight traffic increases of between 0% and 8%.  
• There is only a marginal shift from sea to air freight. |
### Study Key Conclusions

<table>
<thead>
<tr>
<th>Study</th>
<th>Key Conclusions</th>
</tr>
</thead>
</table>
| ECSA (2010) | As described in Table 2.1 this study carried out an assessment against three main questions. The key findings against each of these are presented below:  
  a) **What is the expected impact of the new requirements of IMO on costs and prices of short sea traffic in the ECAs?**  
     - The switch from HFO to MGO under different fuel price scenarios was found to increase shipping costs (fuel and vessel costs) by 19-31%.  
     - Freight rates were estimated to increase (pass through of increased shipping costs) due to the switch to MGO (0.1%) by an average of 12-20% under different fuel price scenarios; for fast sea services the figures are much higher (25-40%).  
  b) **What is the expected impact of the new requirements of IMO on the modal split in the ECAs?**  
     - The results from the stated preference survey of short sea operators found that respondents expected the freight rate to increases in the order of 15% to 25%. The routes covering medium-range distances (400-750Km) are likely to be the most affected, with volume losses of 21% on average.  
     - The main conclusion of the detailed cost analysis of total transport costs under the alternative routing options is that under both scenarios, the switch to MGO is expected to generate shifts from sea to road due to the change in ratios between truck prices and truck/short sea prices.  
  c) **What is the expected impact of the new requirements of IMO on external costs?**  
     - On average, total external costs per trip reduce by 5% when switching to 0.5% HFO and by about 15% when switching to 0.1% MDO.  
     - If no modal shift is assumed, the external costs for truck-ship routes reduce under the 0.5% HFO scenario and again under the 0.1% MDO scenario. The relative scale in the reduction of external costs is dependent on the length of the sea voyage relative to the total journey length and the vessel utilisation assumed. The results show that for the majority of origin-destinations assessed the truck only option has lower external costs than the ship-truck option under the reference scenario (i.e. when ships are using 1% HFO); the difference in external costs between the options reduces and in some cases reverses due to the introduction of lower sulphur fuels for ships (i.e. 0.1% or 0.5%).  
     - If a 10% modal shift was assumed to occur, the reduction in external costs under the 0.1% MGO scenario became an increase relative to the reference scenario in 26% of the cases analysed. Where a 20% modal shift is assumed, external costs are higher than under the reference scenario for most cases. The analysis shows that if a sulphur limit of 0.5% was imposed and this led to no modal shift, the external costs would be lower than under the 0.1% sulphur limit scenario where 20% modal shift is assumed.  
   
  It should be noted that the valuation applied in this study for PM emissions in the North Sea is considerably lower (by a factor of approximately 4-10) than the range quoted in Sweden (2009) which was developed as part of the Commission’s CAFE Programme i.e. €8,000 versus a range of €29,000-80,000. Therefore, the external costs associated with shipping may be underestimated in this study. |
| ECB (2010) | Two transportation models have been used to assess the possible impacts of MARPOL on modal shift for the RoRo (“NECL Model”) and LoLo (“TAPAS Model”) short-sea shipping industry in the Baltic and North Seas. Modal choice decisions have been modelled for a range of scenarios and established competing sea/road routes.  
  - **TAPAS Model:** The outputs of the modelling indicate that for each scenario a single route is selected on the basis of the optimal transport solution for the product and transport demand of the customer. The results indicate that as fuel costs for shipping increase with more stringent requirements on sulphur content of fuels a route based on a greater share of transport by road is selected. This is particularly apparent from 2015 onwards when the lowest sulphur requirements apply.  
  - **NECL Model:** The average percentage change in costs from a base case for a range of scenarios and groups of routes was estimated (up to 20% for certain routes/scenarios). This was then applied to estimate changes in market share of each route. With MARPOL (assuming fuel switching only) an increase in market share of predominantly road transport routes is anticipated at the expense of routes more dependent on shipping (up to 60% reduction in base case cargo volumes for some routes). Market share is only maintained (and in some instances improved) for the scenario which assumes that high sulphur fuels will continue to be used with seawater scrubbers.  
   
  The study highlights that whilst the routes themselves are actual routes, there are limitations in trying to compare the impacts of MARPOL on shipping and assuming road transport stays constant as the two modes are interdependent on  

14 See Section 3.7 or Appendix E for a summary of what has been included in the external cost estimations from ECSA (2010).
The figure below provides a summary of the expected increases in shipping freight costs as a percentage relative to the current situation.

**Figure 4.6  Potential increases in shipping freight charges as a result of revised regulations**

![Graph showing potential increases in shipping freight charges](image)

**Note 1:** Increases expected to be significantly higher for fast sea services (up to 40%).

As the figure above demonstrates the implementation of the revised regulations is expected to have a significant impact on freight charges for shipping operating within the SECA's, in some cases they are expected to increase by up to 50% (container freight, Finland (2009)).

Whilst each study has a slightly different focus and/or approach to considering modal shift, it is clear that the implementation of the revised regulations (assuming all vessels switch fuels) will lead to some shift away from short sea shipping (freight) to road and rail freight; for some routes this shift away from shipping may be as little as 3% loss in volume (ECSA (2010) – low fuel price scenario: MGO $200 per tonne) or much as 50% (ECSA (2010))

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15 The majority of studies dealing with modal shift only consider fuel switching as a possible or realistic option for compliance with the revised regulations in 2015. However, ECb (2010) has modelled a scenario for each of the selected routes where all ships are assumed to install scrubbers and continue using higher sulphur fuels rather than switching to 0.1% sulphur fuel. For this scenario, market share for the shipping sector is maintained and in some cases increased relative to land based transport. However, it should be noted that a 100% shift to scrubbers is unlikely, particularly in the short term.
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– high fuel price scenario: MGO $1,000 per tonne). The extent to which this takes place depends on a number of route specific factors such as level of competition and availability of alternative routes as well as the projected fuel costs. In some cases a shift to a land-based only route is expected, in others a shift is estimated to take place to routes with a greater proportion of distance via land. These impacts should be considered against the European Union’s Marco Polo programme which aims to shift freight transport from the road to sea, rail and inland waterways16.

An interesting observation from ECSA (2010) is that the gain in marginal external costs (i.e. the valuation of congestion, accidents, environmental and associated health impacts and infrastructure) due to switching to 0.1% S fuel will deteriorate if one assumes a modal shift of 20% away from shipping to road and/or rail on selected routes (relative to a reference scenario of ships using 1% S HFO). If a modal shift of 10% away from shipping occurs then external costs are expected to increase in 26% of the cases assessed in the study. With no modal shift, external costs decrease by approximately 15% overall. The study notes that no modal shift is expected to occur if 0.5% sulphur fuel were required in place of 0.1% as it does not require a change in fuel type and therefore no significant cost increases are expected. With this in mind, external costs are expected to decrease in all cases modelled (i.e. positive benefit) when switching to 0.5% sulphur fuel (approximately 5%). The figure below – reproduced from ECSA (2010) – illustrates this point for a selected route (Dortmund-Gothenburg). The second bar (“SSS – Ref”) is the reference scenario assuming that ships are using 1% S HFO. All bars to the right of this summarise the results for the different scenarios assuming differing levels of modal shift (0-30%) and different assumptions on the level of fuel switching (0.1% or 0.5% S).

16 http://ec.europa.eu/transport/marcopolo/home/home_en.htm
As discussed in the summary for ECSA (2010) in Table 4.1, the valuation used for PM emissions from shipping in the North Sea which has been factored into the external cost calculations is low relative to other sources quoted in Sweden (2009). Therefore, the external costs associated with shipping emissions may be underestimated. However, the potential implications of modal shift on total external costs is an important issue which has not been considered in any of the other studies and needs to be kept in mind when considering the overall picture. In addition, a reference scenario assuming 1% S HFO has been used for comparing scenarios against. The situation might be different if comparing against the current MARPOL Annex VI requirements of 1.5% S HFO in SECA.s.

Finally, whilst a number of studies have considered potential impacts on shipping fuel costs and knock on effects on freight charges as well as associated impacts on modal shift, very limited consideration has been given to the value of any modal shift in terms of lost profit from the shipping industry. Sweden (2009) has considered possible impacts on the passenger ferry market concluding that they may be able to pass on any additional costs to passengers via increased ticket costs. ECSA (2010) includes a short discussion of the possible impacts of increased costs, reduced profitability and modal shift on short sea shipping:

“The logistics industry is sensitive to price changes. The observed shifts in price differences incurred when introducing MGO (0.1%) as a base fuel in the ECAs would undoubtedly lead to changes in the modal split at the expense of short sea services. We also indicated that on some routes shifts from long-distance to short-distance short sea routes are to be expected. Traffic losses for short sea services force short sea operators to reduce capacity, to downsize vessels deployed (leading to less economies of scale) and to limit frequency of their services. Lower frequencies and higher operational costs linked to smaller vessels further reduce the attractiveness /
competitiveness of the short sea option. If traffic losses reach a level no longer allowing the short sea operator to guarantee a minimum service frequency then a complete closure of the line is a probable outcome. In other words, even relatively small traffic losses (e.g. 10% to 20% less cargo) for existing short sea services can trigger a vicious cycle of capacity reduction and lower frequencies ultimately leading to a poorer position for short sea services and thus an unattractive market environment for investors. Vicious cycles characterized by the downsizing of short sea activities and the closures of lines can lead to an overall implosion of a short sea sub-market, leaving room to the ‘truck only’ option or short sea services on short or ultra-short distances to fill the gap in the market.”

4.5  **Summary**

In summarising each of the above studies, it is possible to draw the following conclusions:

i. The additional fuel cost of shifting to 0.1% S MGO from 1.5% S HFO in 2015 is expected to be in the range of €155-310 per metric tonne of fuel with an average of the quoted values from all of the studies of approximately €230 per tonne. This represents an average increase in fuel costs per tonne of around 80%. Some concerns have been raised regarding the availability of 0.1% S content fuel in sufficient quantities from 2015 and, as well as the direct impacts of this on MGO, possible knock-on effects on the market for and cost of diesel for land based sources.

ii. Total compliance costs assuming fuel switching only have been estimated to be €3.0-3.6 billion in 2015. The costs of alternative compliance mechanisms such as seawater scrubbers are expected to be approximately 20-50% of the total cost of switching fuels. However, there are a number of uncertainties related to the availability and reliability of such technologies which are expected to limit any significant take up by 2015.

iii. Of those studies concerning themselves with modal shift, it is clear that the revised regulations will lead to some shift away from short sea shipping to road and rail freight. This shift is expected to be between 3-50% in volume and varies significantly between different routes and fuel price projections.

iv. In terms of total external costs (environmental, health and social costs to society), most studies have considered the benefits of ships switching to 0.1% S content fuel from 2015 but not the potential impacts if any modal shift to land-based transport were to occur. Without modal shift, monetised benefits are expected to be greater than costs for Europe as a whole (although some Member State studies show conflicting results). However, in some cases modal shift may reverse the situation in that total external costs may in fact increase (i.e. a disbenefit).
Appendix A
Summary of Terms of Reference – Study commissioned by German Shipowners’ Association and German Seaports’ Association to analyse the impacts of new sulphur regulation of the revised MARPOL VI

The following information has been provided by Matthias Plötzke, German Shipowners’ Association (personal communication, 6th July 2010).

The study shall analyse the effects of the new sulphur limits applicable in SECA from 2015 with particular focus on the impacts of cost increases on short sea shipping and the potential for modal shift. The focus is on entire transport chains including sea transport with particular relevance for Germany. The study aims to address the following questions:

1. Which scenarios are probable with respect to the development of crude oil prices and the interconnected price development of distillate fuels (here: MGO)? At the least, trend prognoses will be appreciated. Existing studies of third parties may be involved.

2. Which prognoses can be made regarding the sufficient availability of distillate fuels (also MGO) in Germany respectively in Europe? Existing studies of third parties may be involved.

3. Which are the corridors most likely to be affected by modal shift to the detriment of commercial shipping? To which extent may modal shift that embraces entire origin-destination-transports including pre- and on-carriage be expected?

4. What are the expected impacts on the RoRo / RoPax sectors by the likely price increases? In this context ultra-short, short, medium-range and long-distance traffic shall be differentiated with a view to the varying ratio of fuel costs to overall costs. What extent may be derived from a modal shift – also between the different transport parts with the shifting in between road- and sea shares of the overall distance?

5. What are the concrete effects of the forecast price increase on feeder traffic? The effects shall be studied on the basis of selected typical transport routes. Which extent of a transport shifting may be derived?
6. Which effects can be identified for German North Sea and Baltic Sea ports? Will changes in cargo volume and transhipment cargo (percentages) be realised? The focus of this part of the analysis will be primarily on high-value cargo.

7. Will the requirements of MARPOL Annex VI result in an impairment of the inner-European competitiveness of German seaports from 2015? A trend prognosis shall be conducted to identify in which way and which European origin and destination areas as well as cargo and transhipment volume of German seaports will be affected by a possible shifting to ports outside of SECAs on the European coast of the Atlantic and in Southern Europe.

8. What effects will a re-shifting have on the utilization of the German road transport infrastructure network?
Appendix B
Review Criteria

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<td>→ Other impacts e.g. modal shift</td>
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Appendix C

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quantitative assessment focussed on the ship operators. The impacts of the full implementation of all requirements of the revised MARPOL Annex VI regulations are assessed against a reference scenario (a ‘do nothing’ scenario) which assumes the status quo of the existing MARPOL regulations and the Sulphur Content of Liquid Fuels Directive.

The quantitative assessment of impacts on ship operators is undertaken by compliance assessment at a vessel movement basis. The study utilises a detailed database of all vessel movements within a set geographic scope, which includes the fuel consumption and emissions (SO₂, NOx, CO₂, PM, VOC) associated with the movement. The database lists the fuel type used by each vessel movement (which takes into account whether the routing of that movement is within or goes via a SOx ECA). The compliance assessment in each scenario applies the relevant compliance routes identified for each incumbent fuel type, which adjusts the fuel consumption and emission estimates accordingly.

- The impacts on emissions are quantitatively assessed.
- The costs of compliance for ship operators (associated with NOx emission standards, fuel switching and fitting scrubbers) are quantitatively assessed. The costs to UK refining industry, for competent authorities and to wider society are assessed qualitatively.
- The benefits related to reduction in SO₂, NOx and PM emissions is assessed. The environmental benefits to the UK are assessed quantitatively (but not monetised) in terms of critical load exceedances for both acid deposition and nitrogen deposition, and qualitatively in terms of other impacts. The health benefits to the UK have been quantified (and monetised) in terms of reductions in acute mortality, chronic mortality, respiratory hospital admissions and cardiovascular hospital admissions. The benefits from reduced building and material damage through reduction in acid deposition, ozone and deposition of airborne particles were also monetised.
- Other benefits to industry have been assessed qualitatively.

### Approaches for developing assumptions / scenarios on decisions for abatement vs. fuel switching

Three scenarios have been developed for compliance options to reflect the uncertainty associated with the shipping industry’s response for complying with the revised MARPOL Annex VI:

- The central scenario (scenario 1) assumes that, in 2020, 10% of vessels currently using Residual Oil (RO) fit scrubbers and the remainder switch to distillate fuels. Prior to 2020 it has been assumed that the preferred option for the shipping industry would be fuel switching.
- Scenario 2 assumes that all vessels switch to low sulphur RO or distillate fuels (depending on the sulphur requirements) for all years.
- Scenario 3 assumes that all vessels will switch fuels to comply until 2015. During the period 2015-2020, only new vessels will install scrubbers and in 2020 both new and existing vessels will adopt scrubbers for compliance. This scenario does not take into account potential barriers to implementation such as the space requirements of the technology, limited production capacity in the scrubbers market or aesthetic considerations.

### Approaches for developing assumptions / scenarios on modal shift

N/A

### Key assumptions

<table>
<thead>
<tr>
<th>Fuel types &amp; their availability</th>
<th>Separates RO from marine diesel oil (MDO) and marine gas oil (MGO).</th>
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<tr>
<td><strong>Current</strong></td>
<td>The 2007 current fuel consumption estimates assume that vessels are using RO with 2.7% S, RO with 1.5% S, or MGO with 0.2% S, with different assumptions for each vessel type. For main engines used outside of SOx ECAs it is assumed that RO is used by all vessel categories except passenger (assumed to use MDO, with an exception for certain vessels), and smaller fishing and smaller other vessels (both assumed to use MGO). For main engines used within SOx ECAs it is assumed that MDO is used by all vessel categories except smaller fishing and smaller other vessels (both assumed to use MGO);</td>
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<tr>
<td><strong>Projections</strong></td>
<td>Assumes sulphur content of RO to remain at 2.7%, but that RO with 1.5% sulphur would be available under the ‘do nothing’ scenario in 2010, and that RO with 1% sulphur would be available as a compliance option in</td>
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2010.

- MDO blend at 0.5% S assumed to be available in 2020.
- MGO assumed to have sulphur content of 0.1% from 2010.

**Availability**

Liquefied Natural Gas (LNG) and biofuels are considered but discarded. Switching to LNG (as a potential option for LNG tankers and ferries) is not considered a compliance option because of the small scale of potential uptake of LNG and the short/medium term barriers to implementation. Switching to biofuels is also not considered a likely compliance option because of the already limited capacity to supply biofuels to meet road transport requirements.

Assesses impact on UK refining industry: refineries will see increased demand from the maritime sector for low sulphur fuels and a corresponding reduction in demand for higher sulphur fuels.

- Does not expect the 1% S limit in SOx ECAs in 2010 to lead to significant capacity problems for UK refineries;
- Expects the 0.1% S limit in SOx ECAs in 2015 to increase demand for diesel / gas oil in NW Europe, but not enough to trigger large refinery investments (e.g. hydrocracking);
- Expects the worldwide 0.5% S limit in 2020 to lead to a global switch to distillates in the maritime transport sector, which will have significant impacts for the refining industry. The report lists the options available to refineries.
- Impacts not taken into account in final figures (costs or emissions).

**Fuel consumption (current & projected)**

**Current (2007)**

- Total fuel consumed was estimated with a bottom-up methodology in Entec (2008)\(^{17}\);
- Assumes the provisions of the SCMF Directive regarding SOx ECAs are met for the full calendar year;
- Assumes that all vessels switch to distillates when entering a SOx ECA.

**Projected (2010, 2015, 2020)**

- Assumes an annual growth factor of 1% in fuel consumption (on an energy basis, i.e. takes into account the higher energy density of distillates) for projections from 2007 (pg 17, 26, and 44).

**Fuel price trends**

- The cost of fuel switching is modelled by the use of fuel price premia. The price premia are related to the crude oil price scenarios – three crude scenarios are used to reflect the uncertainty surrounding future fuel prices, all of which assume $50/barrel in 2009: (i) $60/barrel in 2020, (ii) $80/barrel in 2020 and (iii) $150/barrel in 2020.
- A number of data sources were used to derive the assumptions for fuel price premia including existing literature, interviews with fuel price experts and shipping stakeholder comments, and projections on basis of IEA historic prices.
- The price premia used are listed in the report’s appendix A.
- Considers costs beyond fuel premia may be incurred if additional tanks and piping are necessary and if modifications / adjustments on fuel pumps, fuel injection systems, lubrication systems and fuel tanks are required. Estimates provided, but not incorporated as some costs may occur under business as usual.

**Fleet composition (current & projected)**

- Disaggregates vessels into eight categories: bulk carrier, container, general cargo, passenger, ro-ro cargo, tanker, fishing and other.
- Projects vessel numbers separately from assumed growth in fuel consumption, but consistently with fuel consumption. This is derived from figures taken from IMO (2008)\(^{18}\), the 2007 baseline vessel numbers are multiplied by the ratio of the IMO reported annual average increase in vessel numbers to the IMO’s annual average increase in CO\(_2\) (based on scenario B1). This method does not take into consideration future changes in the proportion of different sizes and types of vessels in the fleet. Vessel fleet baseline and projections are presented (pg 18).

**Fleet movements (current & projected)**

**Current**

- Vessel movements have place of departure and arrival recorded in the LMIU database. The vessel routes, which determine not only the location of the emissions, but also whether the vessel enters a SOx ECA and

---


Abatement equipment, especially sea water scrubbing (uptake, efficiencies, costs etc.) – including assumptions on availability of different types of equipment (current & projected)

Projected
• Ship movements and routings in projected years are assumed to be as per 2007.
• Assumes compliance with S limits can be achieved with the use of sea water scrubbing (SWS) with RO (rather than MDO).
• Scenario A assumes no SWS, scenario B assumes a 90/10 split between fuel switching and the use of scrubbers; scenario C assumes no fuel switching, i.e. 100% uptake of SWS for new vessels from 2015 and for all vessels from 2020.
• Costs: Assumed capital costs of installing scrubbers to main engine only (separate costs are given for combined application to main and auxiliary engine) are £122/kW installed power for new vessels and £156/kW for retrofit to existing vessels. Capital costs of scrubbers annualised over 25 years, at a 3.5% discount rate. Operational costs assumed to be (mostly down to fuel consumption penalty of 1.5%) 2% of new vessels’ capital expenses, which apply for both new and retrofit vessels.
• Separate costs for each vessel type were used, based on the relationship between vessel size (GT) and engine size (kW).

Legislative assumptions
The business as usual situation assumed to include the existing MARPOL Annex VI Regulations and the Sulphur Content of Liquid Fuels Directive (1999/32/EC).

NOX impacts of the revised MARPOL Annex VI Regulations
• Assumes that for most vessels, the necessary emission reductions to meet Tier I and II NOx standards will be met under the ‘do nothing’ scenario, i.e. that engine manufacturers should be able to meet the new NOx emission standards easily, if they are not doing this already.
• Assumes that NOX Tier III standards do not apply (as no NOX ECA designated), such that end of pipe technology, such as selective catalytic reduction, is not necessary to comply.

SO2 impacts of the revised MARPOL Annex VI Regulations
• A global cap of 3.5% m/m on the sulphur content of fuel oil on and after 1 January 2012.
• A global cap of 0.5% m/m on the sulphur content of fuel oil on and after 1 January 2020.
• A cap for all vessels operating within a SOx ECA of 1% S on and after 1 July 2010.
• A cap for all vessels operating within a SOx ECA of 0.1% S on and after 1 January 2015.

Other impacts of the revised MARPOL Annex VI Regulations
• Other requirements of the revised Annex VI not related to fuel sulphur content or NOx emissions from engines are identified in Regulations 15 and 18, but these are not considered to have major impacts

Outputs
Summary of outputs of study including:
→ Costs and sensitivity to assumptions (if discussed)
→ Benefits and sensitivity to assumptions (if discussed)
→ Other impacts e.g. modal shift
→ Key conclusions

Emissions results
For the central case of scenario 1, compared to baseline for 2020, NOx emissions are projected to reduce by 8%, SO2 emissions by 88%, CO2 emissions by 3%, PM10 emissions by 67% and fuel consumption by 3% [pg 54].

Costs
• Compliance costs to shipping industry (annualised): £1.6 - 3.6bn. Sensitivity analysis for a 50% decrease in the price of seawater scrubbers changes annualised compliance costs to £0.9 - 3.6bn.
• The administrative costs are not considered to be significant when compared with the total costs of compliance;
• The world-wide limit of 0.5% S in 2020 is expected to lead to a global switch to distillates, which may have significant impacts for the refining industry. It is expected that the increase in costs associated with this switch to distillates may be passed directly to the ship-owner through a fuel premium.
• The cost of goods transported by sea and the price of passenger fares could increase as ship operators pass costs through to consumers. However, no substantive impacts are expected on the wider society as the additional cost of goods would be shared by the UK economy as a whole.

Environmental benefits
• Annual benefits from CO2 emission reductions: Scenario 1: £33m, Scenario 2: £38m, Scenario 3: -£14m (i.e. increased emissions),
• Reduction in critical load exceedances for all ecosystems: acid deposition – reduction from 42% to 39.6%; nitrogen deposition – reduction from 49.1% to 48.4%; reductions in ocean acidification (not quantified).

Health benefits
• Annual benefit of £309-622m from avoided life years lost, reductions in respiratory and cardiovascular hospital admissions;
• Additional benefits include: 300 fewer Accident and Emergency visits; 1,500 fewer GP consultations for asthma; 2,500 fewer GP consultations for respiratory illness; predicted decrease in symptomatic days in individuals with asthma is approximately 5%, and reduction of around 6,000 to 12,000 in the number of new cases of chronic bronchitis in a year.

Reduced building and material damage
• Annual benefit of ~£6m

Key conclusion: Although the monetised costs outweigh monetised benefits, the following points should be taken into account:
• Monetised benefits to the UK are expected to be underestimates as they do not include ecosystem impacts and some additional health benefits (reductions in accident and emergency visits; GP consultations; symptomatic days in individuals with asthma; cases of chronic bronchitis).
• Monetised benefits to the UK also do not include health and environmental benefits to the UK from vessels outside the study area.
• Total benefits are expected to be underestimates as they do not include health and environmental benefits to any other Member States from reductions in emissions for all vessels in the study area. Benefits to other Member States could be significant particularly due to the direction of the wind.
Appendix D
Finnish Ministry of Transport and Communications (2009): Sulphur content in ships bunker fuel in 2015 – A study on the impacts of the new IMO regulations on transportation costs

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<tr>
<td>Fuel types &amp; their availability</td>
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<tr>
<td>• Study uses prices provided by the Finnish Oil and Gas Federation for Fuels currently available at current prices. Prices are provided for Heavy Fuel Oil (HFO) (1.5%) €271 per tonne, HFO (1%) €290-330 per tonne, HFO (0.5%) €305-350 per tonne, Light Fuel Oil (LFO) (0.1%) €470-500 per tonne.</td>
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<tr>
<td>• No price is provided for LFO with 0.5% sulphur as it is still unknown to suppliers, however a price for LFO with 0.1% sulphur content is available as it is to all intents and purposes, gas oil (MGO) (pg 11 and 12).</td>
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Projected
- The study assumes that HFO will be abandoned when sulphur restrictions drop to below 1%.
- Assumes there will be a switch from HFO to LFO with a sulphur content of <0.1% (MGO) by 2015

### Fuel availability

The problem of availability is discussed however there are no real conclusions due to the number of variables involved.

- Figures are provided to illustrate the current demand for heavy fuels of different sulphur contents and names of refineries currently supplying heavy fuel oil with a sulphur content of less than 0.5% (pg16)
- The report states that the oil industry will have to increase its refining capacity in order to meet the demand for MGO fuel. (pg 16, 17 and 18)

### Fuel consumption (current & projected)

#### Current

- Fuel consumption is hypothetical and calculated using formulae (pg23) and information from the HELCOM ShipNODeP project, which provided estimates for ship consumption from every ship that paid waterway charges in Finland in 2007.
- Variables for fuel consumption were chosen to create maximum, minimum and “average” (expert opinion). The variable chosen in order to provide this range of fuel consumption appears to be the travel time alone, however further clarity on this and the formulae used in the calculations will be sought.
- Totals for fuel consumption from Finnish imports and exports in 2007 was calculated and was in the range of 1.8-2.6 million tonnes in 2007.
- For ships sailing under the Finnish flag, fuel consumption in 2007 was calculated at 0.46-0.57 million tonnes.

#### Projected

No projections were included and the information was based on current fuel price and fuel consumption based on ships operating in 2007.

### Fuel price trends

- Price increases are based on the relative prices of fuel with different sulphur contents as given by the Finnish Oil and Gas Federation for Fuels. There are no projections of fuel prices and comparisons of the costs of fuel of different sulphur content are used to calculate additional costs of meeting regulations.
- The report also states that the price may be influenced by the growing market for low sulphur fuels in US due to the imposing of sulphur emissions restrictions. (pg12).
- The study only takes into account the cost of using fuel needed for SECAs – 0.1% sulphur (pg28 and 29).
- The report does not take into account savings in fuel costs that could be possible using higher sulphur fuels in conjunction with abatement equipment.

### Fleet composition (current & projected)

The fleet composition is provided by a list of ships which paid waterway charges to Finland in 2007 which was supplied by the Finnish Maritime Administration (pg21).

- Numbers and vessel types are reported in table 5.1 and comprise passenger vessels, cruise ships, high speed craft, roll-on roll-off ships, bulk carriers, other dry bulk carriers, tankers, other vessels.
- The fleet is also broken down into ships that crossed the North Sea and ships sailing under the Finnish Flag.
- There are no projections of fleet composition covered by the report.

### Fleet movements (current & projected)

Estimates of the fleet's movements may be included in Helsinki’s Commission ShipNODeP project referenced as the source of each ship’s fuel consumption. Further information is being sought to clarify the report estimates into current fleet movements.

### Abatement equipment, especially sea water scrubbing (uptake, efficiencies, costs etc.) – including assumptions on availability of different types of equipment (current & projected)

The report states that sea water scrubbers used in the Baltic require more sea water as the Baltic contains fresher sea water (pg19). It states that scrubbers are expensive as sludge cleaning equipment occupies space. The use of abatement equipment is not considered within the calculations as an alternative to switching to low sulphur fuels.

### Legislative assumptions

The report assumes that the sulphur contents of fuel will be required to be reduced from 4.5% to 3.5% in Jan 2012, and to 0.5% in Jan 2020. In SECAs the limits will be reduced from 1.5% to 1% from 1 July 2010 and to 0.1% from 1 Jan 2015. The report does not consider the NOx impacts of the regulations.
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| **Summary of approach used (key steps)** | Estimates of fuel costs for low sulphur fuels (pg12) have been gathered. A maximum – (€229 per tonne), minimum (€199 per tonne) and “average” (€214 per tonne) price differential between HFO 1.5% sulphur and MGO has been estimated by the Finnish Oil and Gas Federation to give scenario 1, scenario 2 and “average” (based on expert judgement), respectively.  
  This information is used to provide estimates of fuel costs per day and per TEU for different vessel types (pg 13, 14 and 15) for fuels of various sulphur contents.  
  The number of each type of ship entering Finnish waters is taken from the waterway charges (2007).  
  Fuel consumption of each type of vessel is calculated based on information from HELCOM ShipNODep project, three formulae which vary travel time to produce maximum (scenario 1), minimum (scenario 2) and “average” (expert judgement) fuel costs for both MGO (<0.1% sulphur) and HFO (1.5% sulphur) (pg 22-23).  
  This information is split into different industries using information from the National Board of Customs Foreign Trade Statistics. The additional costs to various industries is provided in order to assess impact on the economy. |

| Top down / bottom up | The study is developed with a bottom up approach, calculating hypothetical fuel consumption for individual ships. |
| Granularity (if modelled) | N/A |

| Approaches for developing assumptions / scenarios on decisions for abatement vs fuel switching | The report assumes that HFO will have to be abandoned when the requirements for sulphur content for fuel is less than 1%. No fuel price is available for a LFO of a sulphur content of 0.5% so a LFO with a sulphur content of 0.1% is used, which will be the sulphur limited required in SECA’s in 2015. |
| Approaches for developing assumptions / scenarios on modal shift (e.g. elasticities) | N/A |

<table>
<thead>
<tr>
<th>Outputs</th>
<th>Costs</th>
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</table>
| **Summary of outputs of study including:** | Additional costs based on a maximum (scenario 1), minimum (scenario 2) and “average” (expert judgement) are calculated based on hypothetical fuel cost difference and fuel consumption per vessel type.  
  Final conclusions include the additional costs to vessels paying fairway dues to Finland if they were to switch from HFO to LFO (0.1%):  
  1) at €111 per tonne (price differential on 9th March 2009) the additional costs would be €190-273 million (minimum fuel price/consumption scenario)  
  2) at €480 per tonne (price differential in May 2008) the additional costs would be €823-1,182 million (maximum fuel price/consumption scenario) (pg35)  
  A total estimated additional cost to Finnish industry of switching fuels is quoted as between these figures at €430 million (pg31). This is disaggregated by industry in the report.  
  This does not take into account any additional costs that long-haul carriers may incur if they also had to use low sulphur fuels outside of SECA’s for technical reasons or potential fuel savings associated with the use of higher sulphur fuels in conjunction with scrubbers.  
  Research in the study (expert interviews) indicates that additional costs will eventually be incorporated into sea freight costs. |
| → Costs and sensitivity to assumptions (if discussed) | Environmental & Health Impacts  
  The environmental and health impacts of switching to lower sulphur fuels are discussed in the report but not quantified (pg 32 and 33) |
| → Benefits and sensitivity to assumptions (if discussed) | |
| → Other impacts e.g. modal shift | |
| → Key conclusions | |
Appendix E
Swedish Maritime Administration (2009): Consequences of IMO’s new Marine Fuel Sulphur Regulations

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Swedish Maritime Administration. Authors are Thomas Ljungström, Jörgen Leyendecker and Stefan Lemieszewski.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author(s)</td>
<td>Commissioned by Swedish Government</td>
</tr>
<tr>
<td>Date and status of report</td>
<td>Final Report, May 2009</td>
</tr>
</tbody>
</table>
| Aims and objectives | To study the consequences for Swedish Trade and Industry of the new IMO regulations concerning the content of sulphur in marine fuel. To do this 18 public authorities and business organisations were consulted. The study aims to report:  
• The development of availability and pricing of low sulphur fuel;  
• Evaluate modal shift from shipping to other forms of transport;  
• Propose measures to facilitate the implementation of the regulations; and  
• Draw up proposals for voluntary initiatives that can facilitate the application of the regulations for ship owners. |

Scope

| Geographic | The mandate of the report is to assess the impacts on Swedish trade and industry of the revisions to MARPOL Annex VI. In the freight model of modal shift, transport to and from Sweden is considered (with a focus on Northern Europe), as well as transit traffic to Finland through Sweden, and access to northern Sweden through Norwegian ports that are not within a SECA. |
| Temporal | The focus of the study is assessing impacts in 2015 and the availability of fuels in this period, due to the uncertainty over the prescription of a maximum fuel sulphur content in SECAs in 2020 of 0.1%. |
| Vessel types / movements | Impacts on both passenger vessels and freight vessels are considered. The model for modal shift considers freight traffic only. The study considers separately the consequences for both Swedish registered vessels (of gross tonnage exceeding 200GT) and vessels calling at Swedish ports. |
| Modal shift | Modal shift due to projected marine fuel price rises is considered through the use of a freight model. The model assesses shifts to road and to rail freight. The model is a cost minimisation model (working on an annual basis) that takes into account transport costs, transhipment costs, order administration costs, storage costs and the tied-up capital costs of goods in storage and during transport. The model selects alternative route choices and alternative mode choices, including each vehicle type within a mode. (pg 34)  
The model takes account of infrastructure restrictions applicable to the defined vehicle types in the form of, for example, deep water for ships, maximum permitted weight for trucks and axle load for trains. In terms of harbour capacity and track capacity (in the number of freight trains), no assumptions are made in terms of restrictions. (pg 35) |

Approach

| Summary of approach used (key steps) | Due to Sweden’s geographic situation (entire coastline is within the Baltic Sea SOx ECA) this report assesses the impact in 2015 of needing to switch to fuel with a maximum sulphur content of 0.1%.  
The report includes an assessment of the feasibility of production of sufficient fuel at the specified sulphur content, |
and concludes sufficient availability of low sulphur fuel, albeit at increased cost. The fuel route assumed to be taken is switching to MGO with a sulphur content of <0.1% at a price of $662/tonne.

The impacts of requiring 0.1% S fuel in SECAs in 2015, and the associated costs of this are assessed through the following:

- A quantitative assessment is made as to transferral of sea-based freight to land-based freight through the use of a multi-modal freight transport model.
- A quantitative valuation of additional costs and benefits is made for three specific industries: the timber industry (pulp sawn products and linerboard), steel industry and the passenger ferry industry. The cost impacts are presented in terms of the estimated increase in percentage terms that product prices / ticket prices would need to change in order to cover the additional transportation costs of rising fuel prices. The socioeconomic benefit is calculated from the reduction in SO2 emissions using a figure of SEK 25/kgSO2. 19
- The study also calculates the additional fuel costs in 2015 to Swedish registered vessels with a tonnage over 200. Two scenarios were considered, based on vessels operating entirely within the SECA with <0.1% sulphur content MGO and operating two thirds of the time in the SECA and one third outside the SECA using maximum permissible sulphur content fuel. The most realistic scenario is identified as between the two and a corresponding result is reported.
- The additional fuel costs to vessels calling at Swedish ports in 2008 and the SO2 emission reductions and their value are also investigated. Three scenarios were investigated – the two scenarios used to investigate Swedish registered vessels and a third scenario with ferry traffic operating entirely within the SECA and other traffic operating one third of the time in the SECA and two thirds of their time out with the SECA. The third scenario was deemed most likely to be realistic.
- An assessment of the safety and technical consequences for ship operation on entering / leaving an ECA (p67).
- An assessment of the additional demands placed on public authorities and other organisations.

**Top down / bottom up**

**The Cost to Industry**

The impacts to the steel industry (p56) are estimated on the basis of bottom-up analysis for one major representative steel company. The timber industry costs are top-down. The impact on the ferry industry is also estimated on the basis of data for one ferry route between Stockholm and Finland.

**Freight Model of Modal Shift**

It is unclear from the report whether the freight model assesses the impacts on a per-vessel or movement basis.

**Granularity (if modelled)**

N/A: no dispersion modelling undertaken.

**Approaches for developing assumptions / scenarios on decisions for abatement vs fuel switching**

Abatement technology is not incorporated into the investigations carried out within the study; only fuel switching to 0.1% MGO is used to price additional costs and to investigate modal shift.

Scrubbers are assessed (pg 24) but it is recognised that the use of seawater scrubbers may not be possible in the brackish waters of the Baltic Sea due to sensitivity to acidification and the very large water volumes required to neutralise the flue gas acidity. The use of freshwater scrubbers that utilise NaOH would be possible to accept, but there is concern that the waste output produced by these systems is too hazardous in that it introduces additional problems with handling and provision of port services.

**Approaches for developing assumptions / scenarios on modal shift (e.g. elasticities)**

A freight model developed by the four Swedish transport administration agencies and SIKA is used to assess modal shift. The model makes the following assumptions (page 34):

- **Cargo groups.** The logistics model covers 34 freight categories. Analysis is generalised except for some types of forest industry products and metal products. It does not specifically cover all the different types of goods and the different patterns for incoming and departing transports.
- **Demand for freight transportation.** The demand for freight transport to and from Sweden (expressed in tonnes) between each pair of shipment and receiving areas is assumed to be fixed i.e. neither the goods volume nor the shipper/receiver geographical pattern is affected by increased or decreased transport costs. Demand for freight transport by specific transport types does vary according to the aggregated logistics costs.
- **Vehicle and Ship types.** 33 vehicle types are covered, including 5 road vehicle types, 8 rail freight types, 19 maritime vessel types and one air freight type.
- **Infrastructure limitations are considered:** e.g. deep water for ships, maximum permitted weight for trucks and axle load for trains. However, no assumptions are made for harbour capacity and rail track capacity. The degree of detail in assumed transport infrastructure decreases as the distance from Sweden increases both

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19 ASEK4-valuation; SIKA (Swedish Institute for Transport and Communications) PM 2008:3.
Creating the environment for business

<table>
<thead>
<tr>
<th>Key assumptions</th>
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<tr>
<td><strong>Fuel types &amp; their availability</strong></td>
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| According to the Swedish Petroleum Institute (SPI) and Preem AB, the oil industry will be able to process sufficient low-sulphur fuel by 2015 in order to meet shipping’s requirement within the SECA. The implementation of the restrictions is expected to lead to a shift to distillates e.g. marine diesel oil (MDO) and marine gas oil (MGO) by 2015 (pg 28).

The study assesses different methods by which the oil refinery industry could make low sulphur fuel available:
1) Optimising heavy fuel oil stream separation and mixing in order to obtain low-sulphur bunker, however this method is not capable of producing 0.1% sulphur content fuel.
2) Processing more low-sulphur crude oils – will likely involve the mixing of high and low sulphur oils and is a realistic alternative to develop low-sulphur fuel until 2015.
3) Desulphurising heavy fuel oil – Swedish Refining industry operators Preem judges that the output to desulphurise heavy fuel to 0.1% will require too much investment; however the production of middle distillates (including MDO and MGO) will require less investment. Desulphurising fuel does however increase refinery CO2 emissions.
4) Converting heavy fuel oil to vehicle fuel – Preem judges that using coker units to refine heavy oil into lighter ship and vehicle fuel will be economically viable after 2015.
5) Exporting surplus of high-sulphur bunker – limited due to possible further restrictions, however land based power stations may become a consumer of some residues (pg 20 -23).

<table>
<thead>
<tr>
<th>Fuel consumption (current &amp; projected)</th>
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<tr>
<td><strong>Freight Model of Modal Shift</strong></td>
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<tr>
<td>The freight model of modal shift assumes fuel consumption for all ships to be 190 g/kWh [p 37], which results in variation in the quantity of fuel consumed per day among the 21 vessel types used in the model: from 2.5t/day for the smallest Other Ferry category (&lt;1,000GT) to 200t/day for the largest Container Ship category (&gt;80,000GT) (p38).</td>
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<tr>
<th>The Cost to Industry</th>
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<tr>
<td>The fuel consumption estimates from which the costs to industry are derived are based on the assumption that ships operate for 6,000 hours a year at an engine power output of 75%. This fuel consumption assumption was also used to calculate additional costs to Swedish registered vessels and vessels calling at Swedish ports.</td>
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<tr>
<th>Projected Fuel Consumption</th>
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<tr>
<td>In the assessment of cost consequences for vessels calling at Swedish ports, it is assumed that all such vessels have total bunker fuel consumption of 16.6Mt (pg 61-62). Two scenarios were assessed in terms of the split of this fuel consumption between SECAs (i.e. MGO) and outside SECAs: (i) all the vessels operated exclusively within a SECA; and (ii) all passenger vessels operated exclusively within SECAs whilst freight and other vessels spent twice as many hours operating within SECAs as hours spent operating outside SECAs (leading to a 70:30 split in tonnes of fuel consumed inside:outside SECAs).</td>
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<tr>
<th>Fuel price trends</th>
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<tr>
<td>The report acknowledges that crude oil prices depend on a range of different factors, including supply, demand, development of alternative fuels, energy efficiency improvements and geopolitical developments (pg 26). Furthermore, the availability and price of distillates is expected to be influenced by demands from land-based transport (pg 29). The fuel price projections for 2015 are based on an IEA crude oil forecast price of $100/barrel. The fuel prices assumed for each fuel grade by sulphur content are presented in the report (pg 33). They are taken as average values of fuel prices during October and November 2008 in Rotterdam. The study assumes a price premium of MGO over HFO (LS380) of $297/tonne, which is the price differential from October/November 2008 (pg 28).</td>
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Weighted mean fuel prices that take into account the proportion of ships arriving at Swedish ports that use each sulphur content are thus derived and reproduced below. These do not take into account actual fuel consumption.
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by each vessel type, and so are more influenced by short-sea movements/port callings. These figures are used to evaluate in the modal switching model the probability of a transfer from maritime to other transport modes.

RoRo $385/t; passenger ships $590/t; other ships $486/t; container ships $365/t.

Projected Fuel Prices

The report includes projection of demand of different fuels until 2020 (pg 29), which shows how the increasing demand for the middle distillate fraction and the increasing ratio of distillates to gasoline. Important factors identified are the demand for diesel and the development of ECAs in the US.

Freight Model of Modal Shift

In the freight model of modal shift, three different scenarios of fuel price trends are used to assess the impacts of restrictions on the sulphur content against a base case scenario in which fuel prices in 2015 remain as for 2008/9:

- Scenario 1 assumes 0.1% MGO will be required to be used – at a price of $662/t. The scenario takes into account the fact that some vessels already use low sulphur fuel oil under business as usual.
- Scenario 2 is an upward adjustment of scenario 1 fuel costs of 75% to $1,158/t. This % increase reflects the crude oil price rise projected by the IEA, plus a small additional increase due to increased competition for fuel between trucks and shipping.
- Scenario 3 is a larger increase in fuel costs, to illustrate the effects of a higher crude oil price. In this scenario a +150% increase in MGO price to $1,650/t has been assumed.

Fleet composition (current & projected)

The study does not utilise a bottom-up database of fleet movements or vessel types. The fuel prices have been determined through application of weighting by numbers of port arrivals of each vessel type (and fuel sulphur content). The Swedish Maritime Administration provided a list of the number of arrivals at Swedish ports in 2008, split by vessel type and fuel type (pg 32). The number of arrivals were split among the vessel types by the following distribution: bulk carriers (1%), dry cargo ship (11%), passenger ship (77%), RoRo (3%), Tanker (5%), Tug (0.006%), Container ship (2%) and other vessels (1%).

The freight model of modal shift does state the 21 vessel types that are used (these comprise container ships, RoRo ships, passenger ships, rail ferries, other ferries and other vessels), but does not state the baseline mix of each vessel type.

There is no projected change in the future composition of the fleet.

The additional costs for Swedish registered vessels associated with the switch to MGO in 2015 is outlined on page 59 for each vessel type, where vessels are split into the following types: work vessels, PCTC vessels, tugs, container roll on, chemical tankers, dredgers, oil/chemical tankers, oil tankers, passenger ships, general cargo/RoRo, general cargo, and other.

Fleet movements (current & projected)

Freight Model of Modal Shift

- It is unclear in the report where the source of information for the fleet’s current movements for the model is sourced.
- The results of the freight model of modal shift provide some possible indications of trends of fleet movements based on the increased cost of fuel. Some domestic traffic is expected to transfer to road, whilst some international traffic is expected to transfer to rail (pg 49). The cost increases makes it advantageous to wholly avoid the SOx ECA for goods destined for northern Sweden by re-routing vessels to northern Norway followed by a transfer by road. The scenarios modelling higher fuel prices (scenarios 2 and 3) extend the effects of modal shift from northern Europe to include those to/from the Mediterranean.

The Cost to Industry

- The assessment of impacts on industry does not assess alternative fleet movements; it looks only at the additional costs given the existing fleet movements (pg 51-58).

Abatement equipment, especially sea water scrubbing (uptake, efficiencies, costs etc.) – including assumptions on availability of different types of equipment (current & projected)

The option to use abatement equipment instead of fuel switching was not incorporated into calculations of modal shift or the increased costs to industry (see approach section above).

Legislative assumptions

The report assumes vessels operate with maximum permitted sulphur content according to the revised MARPOL Annex VI Regulations:

- A reduction in the cap for all vessels operating within a SOx ECA to 0.1% S on and after 1 January 2015.
- A reduction in the global cap to 0.5% m/m on and after 1 January 2020, or depending on fuel supply, at the
latest by the year 2025. This assumption is less important in this report, as its focus is on vessel movements within SOx ECAs in 2015.

The report also assumes that, in accordance with Directive 1999/32/EC on the reduction in the sulphur content of certain liquid fuels, marine gas oil used in the territorial waters of EU member states may not have a sulphur content exceeding 0.1% by volume, and that the sulphur content of any marine fuels used from January 2010 in EU Member State ports may not exceed 0.1% by weight (pg 10 and 11).

Outputs

Summary of outputs of study including:

→ Costs and sensitivity to assumptions (if discussed)
→ Benefits and sensitivity to assumptions (if discussed)
→ Other impacts e.g. modal shift
→ Key conclusions

The focus of the outputs of the study are assuming a need to switch to MGO with sulphur content <0.1% in 2015.

Modal Shift

The results of the freight model of modal shift are:

• There is a high risk of transfer of freight from sea to both road and rail in Sweden.
• The results indicate a decline in shipping of between 2% and 10% depending on the projected price of fuel (scenario 1, -2%; scenario 2, -7%; scenario 3, -10%), with consequent increases in road haulage traffic of between 2% and 6% (scenario 1, +1-2%; scenario 2, +2%; scenario 3, +6%) and rail freight traffic increases of between 0% and 8% (scenario 1, marginal change; scenario 2, +8%; scenario 3, +5%).
• There is only a marginal shift from sea to air freight.
• The geographical distributions of the modelled shifts for each mode are shown on pages 42 to 48, and in Annex 1. The main changes are:
  − The main switch is to road in Sweden via the Oresund Bridge instead of the Port of Gothenburg, and to railway outside of Sweden.
  − Within shipping there the results show a switch from the east to the west coast to avoid the SOx ECA.
  − There are expected to be fewer transfers occurring in northern Sweden, with transfers occurring in southern and central Sweden with longer connecting journeys on land. The socio economic costs of this shift have not been included within the model.

Additional costs and benefits

• Forestry industry – a rough estimate of additional cost to the entire industry is SEK1.3 billion. The increased costs of marine transport are expected to lead to an increase in product prices of 0.4-2.6% in these industries (products considered: sawn wooden products, printing paper and linerboard), equivalent to SEK 20-100/tonne depending on the product. The benefits of SO2 emission reductions have been estimated for three producers alongside their costs: a newsprint producer may bear fuel cost increases of SEK 15m, with socioeconomic benefit of SEK 3.1m; a liner producer may bear fuel cost increases of SEK 39m, with socioeconomic benefit of SEK 7.3m; and a pulp producer may bear fuel cost increases of SEK 25m, with socioeconomic benefit of SEK 4.7m. Cost-benefit ratios are in all three cases about 5:1.
• Steel industry – additional costs to industry are calculated to be about SEK 32 million annually, increasing fuel costs by 66%. The annual socioeconomic benefit of the consequent reduction in 170t SO2 emissions is calculated as SEK 8.5 million.
• Ferry industry – using an example of a ferry line between Stockholm and Finland which already uses low sulphur fuel, the increased costs of fuel are just over 30% or almost SEK 41 million. This is likely to lead to an increased cost to the customer of around SEK 20.50 per passenger. The socioeconomic benefit of the associated reduction in SO2 emissions of 110 tonnes is calculated as SEK 5.5 million. For a ferry route which currently operates using 1.5% S fuel, the increased fuel costs may be closer to SEK 75m, equivalent to a need to raise customer ticket prices by SEK 37.50 per passenger.
• Overall, the projected fuel cost increases that would need to be borne by the shipping industry are 50-55%. For vessels that mostly transport cargoes between ports within the SOx ECA(s), the increase in the fuel costs may be higher at around 70%. Some examples show that bunker fuel costs comprise between 40 and 50% of the total operating costs of a ship, such that the use of more expensive, low sulphur MGO will increase shipping costs by an average of 20-28%.
• The additional cost to Swedish registered vessels is estimated to be around SEK 3.8 billion.
• The total projected additional costs in 2015 for the vessels that called at Swedish ports during 2008 are estimated to be approximately SEK 13 billion (p63). The consequent reduction in SO2 emissions of approximately 80 kilotonnes corresponds to a socioeconomic benefit of SEK 4 billion.
• The increases in costs are unlikely to be transferred to purchases as Sweden is competing in a global market where other countries have varying demands on sulphur content. The costs are likely to reduce profit margins so as to remain competitive.
Safety and technical consequences for ship operation entering / leaving an ECA

- The report identifies safety problems with switching between HFO and distillates whilst operating. There is a need to switch fuels under controlled conditions and under low load. There is also a risk of boiler explosions that needs to be mitigated.
- The study reports that manufacturers should be able to supply replacement parts, boilers could be adapted and training given to overcome these issues.

Mitigation Measures

To ensure that there is not the shift to road haulage or loss of revenue by business that rely on Swedish shipping, a number of mitigation measures are suggested:

- Subsidies;
- Increased funding and development of alternative fuels;
- Reduced fairway charges;
- Fully internalise the environmental effects of all modes of transport;
- Tax-free shore-side electrical supplies; and
- International collaboration at an EU level.
Appendix F
European Community Shipowners’ Association (2010): Analysis of the Consequences of Low Sulphur Fuel Requirements

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<tr>
<th>Purpose</th>
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<tbody>
<tr>
<td>Author(s)</td>
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<tr>
<td>Commissioned by</td>
</tr>
<tr>
<td>Date and status of report</td>
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</tbody>
</table>
| Aims and objectives | The report analyses the impact on the Emission Control Areas (ECAs) new fuel quality requirements of the revised MARPOL Annex VI Regulations. The revised Annex VI enters into force on 1 July 2010. The new regulations mean that the limit value for sulphur in the ECAs (Baltic Sea, North Sea/English Channel) is lowered to 0.1% by weight in 2015 and globally to 0.5% by weight in the year 2020 or, depending on fuel supply, at the latest by the year 2025. The report aims to evaluate the concerns of the shipping lines over: serious disruption of the commercial dynamics of shipping in the ECAs, increases in vessel operating costs, lower competitiveness for shipping compared to other modes of transport and a potential modal shift from sea to road. The report aims at analysing the potential impact of the new low sulphur requirements on shipping in the ECAs, with an emphasis on short sea shipping (pg 13). The report particularly focuses on three questions:
• What is the expected impact of the new requirements of IMO on costs and prices of short sea traffic in the ECAs?
• What is the expected impact of the new requirements of IMO on the modal split in the ECAs?
• What is the expected impact of the new requirements of IMO on external costs? |

<table>
<thead>
<tr>
<th>Scope</th>
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| Geographic | The study considers origin-destination pairs within the ECAs: Baltic Sea, North Sea and the English Channel and surrounding land areas. The impact on a distortion in competition between North and South Europe are not considered as short sea services in these markets are expected to be less subject to competition from trucking (pg 13). The study focuses on 30 origin-destination pairs centred around four short sea routes (pg 4):
  - Germany/Denmark to Sweden, English Channel, West Europe to Baltic States and West Europe to Scandinavia (Sweden / Norway). |
| Temporal | 2015 |
| Vessel types / movements | The study specifically focuses on short sea and ropax (roll-on-roll-off passenger ferry/ship) services. The impacts on container, bulk, feeder and other vessels are not considered (pg 13). |
| Modal shift | The report considers the impact of the regulations on modal shift from truck-sea routes to truck-only routes. The impact of modal shift in terms of volume is estimated through a stated preference survey of ship operators; the process the ship operators underwent to arrive at their estimates is not explained. The impact of lower sulphur requirements on freight rates, which will influence modal shift were evaluated using: a stated-preference survey of ship operators and a detailed cost analysis of the alternative routes (pg 13). However, these estimates were not used to predict modal shift. The effect of modal shifts of 10%, 20% and 30% on ‘external costs’ (i.e. health, environmental, congestion, accident and infrastructure impacts) are evaluated for each of the routes considered (pg 14 / pg 66 – 69). |
The study assesses the impact of MARPOL Annex VI requirements for maximum sulphur limits in fuel for shipping within SECA's, with an emphasis on short sea shipping. The report is sub-divided into three assessments; the approach to each of these assessments is set out below:

**What is the expected impact of the new requirements of IMO on costs and prices of short sea traffic in the ECAs?**

- The report estimates the effect of the regulations on freight rates by estimating the effect on fuel costs for short sea vessels due to increased fuel prices. Firstly, the historical difference in fuel prices (price premia) between the current (BAU) situation (1.5% HFO) and other fuels (0.5% MDO and 0.1% MGO) are averaged to estimate what the future fuel price premia will be. Future fuel prices were estimated using this fuel price premia for three fuel price scenarios (pg 21). It also considers the effect of several other factors on fuel price (see below). In this element of the analysis, three fuel price scenarios were considered, with MGO (0.1%) priced at: $500 (low), $750 (base), $1,000 (high).

- The impact of increased fuel prices on the fuel costs was estimated using the fuel price estimates and average fuel consumption per kilometre (t/km) data for traditional short sea and ropax vessels operating at an average commercial speed of 18.5 knots (pg 18). The average fuel consumption (t/km) was estimated by comparing data from two major operators in the short sea business with sectors spread over the ECAs. Sailing distance was found to have no impact on the average fuel consumption (t/km). Any differences in fuel consumption were deemed to be attributable to the unit capacity of the vessel, the engine type, vessel age and weather conditions on the liner service; these differences were not taken into account when estimating the cost increases.

- Total fuel costs were calculated for the three fuel price scenarios assuming that the average fuel consumption was: 0.06 t/km or 0.09 t/km for short sea vessels travelling at 18.5 knots and 0.18 t/km for fast sea short vessel travelling at 27 knots. In order to give context to these estimates in fuel costs, the fuel cost increases were compared with total operating costs of short sea vessels. The other elements in total operating costs are termed vessel costs, which include: vessel capital costs, daily running costs, bunker costs, port charges and administrative costs. The current share of fuel costs in total operating costs was estimated from a sample of 15 short sea operators in the ECAs. The survey aimed at assessing the perception of short sea operators on the potential volume losses and modal shift impacts linked to the implementation of strict low sulphur fuel requirements under different scenarios regarding fuel price evolutions. A questionnaire was sent to relevant lines with operations in the ECAs (pg 31).

- The questionnaire requested information on operational parameters (routes, number of trips, number and type of vessels), fuel consumption within the ECAs (by type of fuel) and transport performance (number of passengers, volume of freight, total tonne-Km). The respondents were asked to indicate what effect (quantitatively where possible) the use of MGO would have on freight rates and volume losses for the following fuel price scenarios: $200, $500 and $1,000 per tonne of MGO (pg 31). The survey included data on 64 individual short sea services, which carried 40m passengers, 5.31m freight units and 2m TEU in 2008.

- The second approach encompasses a detailed cost analysis to assess modal competition between the short sea/truck option and the ‘truck only’ option on thirty origin-destination routes linked to the ECAs. The ‘truck only’ option means that a truck is used all the way from origin to destination without including a short sea section: only truck transport.

**What is the expected impact of the new requirements of IMO on the modal split in the ECAs?**

Two approaches were taken to assessing this question (pg 13-31-36):

1. In a first approach, a stated-preference technique is used by presenting the results of a survey among leading short sea operators in the ECAs. The survey aimed at assessing the perception of short sea operators on the potential volume losses and modal shift impacts linked to the implementation of strict low sulphur fuel requirements under different scenarios regarding fuel price evolutions. A questionnaire was sent to relevant lines with operations in the ECAs (pg 31).

- The second approach encompasses a detailed cost analysis to assess modal competition between the short sea/truck option and the ‘truck only’ option on thirty origin-destination routes linked to the ECAs. The ‘truck only’ option means that a truck is used all the way from origin to destination without including a short sea section: only for the Dover-Calais there is a combination with rail in the Channel Tunnel. The aim is to identify to what extent the low sulphur fuel requirements will affect the modal split on each of the O-D routes. Based on the aggregated results, a more comprehensive picture can be drawn on expected modal shifts.

Finally, the impact of fuel cost increases on freight rates for truck / trailer combinations were estimated. It was assumed that the sea operator charges its customers to recuperate the additional fuel costs linked to the use of MGO. To estimate freight rates, data was collected on the average utilisation of vessels operating on the 17 lines analysed and the average utilisation rate was calculated for ultra-short (<50Km), short (50 – 125 Km), medium long routes (125 – 400 Km) and long routes (>400Km). These average utilisation figures were used along with the increases in total operating costs to estimate increases in freight rates for the routes covered under the fuel price scenarios (pg 26 – 28).

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**Appendix F**

2 of 6

July 2010
systems were not applied. The cost functions for the road and sea elements were then combined for each of the routes studied to give cost estimates of the total journey. Five scenarios were studied: the ‘truck-only’ option, total minimum price for combined road and sea (1.5% HFO), total maximum price for combined road and sea (1.5% HFO), total minimum price for combined road and sea (0.1% MGO) and total maximum price for combined road and sea (0.1% HFO). The cost differences between the alternative shipping options were then compared for these scenarios; no estimates of modal shift were made however.

What is the expected impact of the new requirements of IMO on external costs?

The marginal external costs evaluated were climate change and the costs of air quality affecting human health and causing environmental damage; these are assumed to be directly related to the fuel use. The external costs are directly evaluated for 5 short sea vessels for 5 short sea routes: Germany/Denmark to Sweden, English Channel, Western Europe to Baltic States and Western Europe to Scandinavia. The external costs for shipping were calculated for three scenarios (pg 56): HFO with 1% of sulphur content, HFO (0.5%) and MGO (0.1%). The external costs were calculated using the EMOSS model, which determines the use of energy and from this the use of fuel and associated emissions for shipping. The emission factors are taken from a Dutch study and are dependent on the type of motor, building year, fuel used and the power loading. Data for representative vessels on the expected routes are taken from Lloyd’s MIU database.

In order to calculate the marginal environmental costs, total emissions were multiplied by with the marginal damage cost functions (Tremove Maritime (see Table A2 of Annex 1)) to give a marginal external cost per ship per trip (pg 61).

The marginal external costs of trucks were also evaluated within the GRACE project. For each country, the marginal external costs were averaged for the truck fleet of that country; thus the method takes into account the impact of newer, less polluting trucks within the fleet. The costs for each route were then calculated by using the country specific marginal external cost figure and multiplying by the distance travelled through this country (see Table 5.6 on page 63). The marginal external costs for electric trains carrying freight through the channel tunnel were calculated based on TM Leuven and the GRACE project.

To estimate the marginal external costs per truck (pg 64) assumptions were made on the ships capacity, average utilisation rate of ships and the proportion of emissions attributable to passengers. The marginal external costs were then estimated for trucks travelling between each origin-destination, for the truck only option and the short sea / truck option; in this analysis, no modal shift was assumed.

Finally (pg 66), the effects of a modal shift on external costs was evaluated by comparing the total external costs for each origin destination pair for:

- the reference scenario (1% HFO);
- a simulation (0.5% HFO) with no modal shift; and
- a simulation (0.1% MD) with: no modal shift, 10%, 20% and 30% modal shift.

The total external costs were then compared for each origin-destination under each of these scenarios. It should be noted that the method of calculating external costs assumed that the same number of sea journeys would be undertaken regardless of the demand; external costs attributable to vessels was the same under all assumptions of modal shift.

Top down / bottom up
The approach taken was bottom up for the majority of elements of analysis.

Granularity (if modelled)
The impacts on freight rates and external costs were estimated for each of the origin-destination pairs.

Approaches for
developing assumptions / scenarios on decisions for abatement vs fuel switching
It was assumed that all vessels would switch fuels in order to comply with Annex VI. No uptake of sea water scrubbing, or any other abatement activity was considered.

Approaches for
developing assumptions / scenarios on modal shift
Two approaches for assessing modal shift due to increased fuel costs:

- a stated preference survey of ship operators, which collated their opinions on freight rate increases and volume losses under three fuel price scenarios;
- a detailed cost analysis was undertaken to assess modal competition between the short sea/truck option and the truck only option on 30 origin-destination routes linked to the ECAs (pg 36); volume losses due to modal shift were not estimated.

For further details see the approach section.

The impact of (assumed) modal shift on total external costs were estimated; see methodology for option c.
### Key assumptions

| Fuel types & their availability | Current (2009) | In the current situation, it was assumed that all vessels would consume 1.5% HFO in a and b, and all vessels would consume 1% HFO in c.  

#### Projections

Assumed that 1% HFO, 0.5% MDO and 0.1% MGO would be available at all points in time considered. The availability of other fuels was not considered.  

Whether the global refining industry would be able to supply sufficient low sulphur fuels was not considered explicitly. |
| Fuel consumption (current & projected) | Current (2009) | Total fuel consumed was estimated using a bottom-up methodology. In parts a and b of the analysis, vessel specific characteristics (engine, size etc.) were not considered, but in part c the typical vessel characteristics for each route were considered when evaluating the emissions.  

#### Projections (2015)

No change in the number of journeys undertaken was assumed in any part of the analysis. It was assumed that the vessels on the routes considered would consume the same mass of fuel regardless of fuel type. |
| Fuel price trends | a) **What is the expected impact of the new requirements of IMO on costs and prices of short sea traffic in the ECAs?** |
| | The report estimates fuel prices for 1.5% HFO, 0.5% MDO and 0.1% MGO for three price scenarios, where 0.1% MGO is assumed to cost: $500/t (low), $750/t (base) and $1,000/t (high/upper limit) (pg 2). The differences between the current fuel (1.5% HFO) and the other fuels are estimated by analysing the historical price differences between these fuels and the following factors (pg 19):  

- The ability of the global refining industry to produce the required volume of distillates and the effect of the capital investments necessary to produce these distillates on price;  

- The impact on oil price increases on the bunker costs for shipping is more direct than for trucking, as a large part of the diesel price for trucks consists of taxes;  

- Faster evolution of fuel efficiency in trucking than shipping, due to the difference in amortisation time;  

- The benefit to shippers from burning distillates; reduced engine wear, reduced sludge disposal costs and increased fuel efficiency due to the higher energy density of distillates;  

- The impact of alternative measures, such as sea water scrubbing on operating costs.  

The price difference between HFO and MGO is set at 80% in the three scenarios, meaning that MGO will be 80% more expensive than HFO. The fuel prices assumed in the three scenarios were €193-386 per tonne for HFO (1.5%) and €348-695 per tonne for MGO (0.1%).  

The impact of reduced maintenance costs and the modification costs for switching to distillates are not considered in the report.  

b) **What is the expected impact of the new requirements of IMO on the modal split in the ECAs?**  

For the stated preference survey of short sea operators and the detailed cost analysis in this section of the report, 3 fuel price scenarios were considered, where MGO was assumed to be $200, $500 and $1,000 per tonne of MGO (pg 31). |
| Fleet composition (current & projected) | Described in the method, as different data sets were used in different parts of the analysis. |
| Fleet movements (current & projected) | Described in the method, as different data sets were used in different parts of the analysis. |
| Abatement equipment, especially sea water scrubbing (uptake, efficiencies, costs etc.) – including assumptions on availability of different types of equipment (current & projected) | The availability of sea water scrubbing was not considered in the analysis. Only fuel switching was considered as an option for compliance with the regulations. |
### Legislative assumptions

Only the sulphur related limits of MARPOL Annex VI Regulations and the Sulphur Content of Liquid Fuels Directive (1999/32/EC) were considered in the analysis. As all of the routes considered were within SECAs, the sulphur limits considered were:

- 1% HFO (reference scenario);
- 0.1% MDO (2015 onwards); and
- 0.5% HFO (if this were to be implemented within SECAs instead of 0.1%)

### Outputs

#### Summary of outputs of study including:

- Costs and sensitivity to assumptions (if discussed)
- Benefits and sensitivity to assumptions (if discussed)
- Other impacts e.g. modal shift
- Key conclusions

<table>
<thead>
<tr>
<th>Key conclusions</th>
<th>a) What is the expected impact of the new requirements of IMO on costs and prices of short sea traffic in the ECAs?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The switch from HFO to MGO under the base and high fuel price scenarios was found to increase shipping costs (fuel and vessel costs) by 25.5% and 30.6% respectively (18.5 knots). Freight rates were estimated to increase due to the switch to MGO (0.1%) by an average of: 11.5%, 15.9% and 19.7% under the low, base and high fuel price scenarios; for fast sea services the figures are much higher.</td>
</tr>
</tbody>
</table>

b) What is the expected impact of the new requirements of IMO on the modal split in the ECAs?

The results from the stated preference survey of short sea operators found that respondents expected the freight rate to increase in the order of 15% to 25%, with an overall average increase of nearly 18% under the $500 / t MGO scenario (pg 35); the routes covering medium-range distances (400-750Km) are likely to be the most affected, with volume losses of 21% on average. Under the high fuel price scenario ($1,000 / t MGO), a freight rate increase of 60%, with a resultant volume losses of more than 50% are expected. Under the low fuel price scenario ($200 / t MGO), the impact was expected to be marginal.

The main results of the detailed cost analysis of total transport costs under the alternative routing options are presented in detail in Tables 4.11 and 4.12 on pg 50. The main results on the relative competitiveness position of the short-sea truck routes versus truck only options are presented in table 4.13 and 4.14 (pg 53); tables 4.15 and 4.16 (pg 54) summarise the main findings. The main conclusion is that under both scenarios, the switch to MGO is expected to generate shifts from sea to road due to the change in ratios between the truck prices and the truck/short sea prices.

A comparison of the results of the survey and the freight rate estimation undertaken in Task 1 are presented in Table 4.6 (pg 36).

c) What is the expected impact of the new requirements of IMO on external costs?

#### External costs from shipping

The results from the external cost calculations are presented in tables 5.1 and 5.2 on page 60 and 61. The switch to lower sulphur fuels results in lower sulphur emissions; the impact is relatively larger for long distance routes as the influence of emissions at berth are lower (0.1% fuel in all scenarios). CO₂ emissions were found to decrease under the MGO scenario but remain constant under the 0.5% HFO scenario. Figure 5.3 (pg 62) shows the marginal environmental costs for VOCs, PM₁₀, SO₂, NOₓ, CO₂ and CO emissions per ship, per trip under the three scenarios; figures are in thousands of Euros. The most important pollutants in terms of marginal external costs are PM, NOₓ and SO₂. On average, total external costs per trip reduce by 5% when switching to 0.5% HFO and by about 15% when switching to 0.1% MDO.

#### Total external costs (rail, road and shipping) when no modal shift is assumed

The marginal external costs for each origin-destination using either the truck only option or the short sea / truck option were then compared under the three fuel price scenarios; the results are presented in Table 5.8 (pg 65). Because no modal shift is assumed, the external costs for truck-ship routes reduce under the 0.5% HFO scenario and again under the 0.1% MDO scenario. The relative scale in the reduction of external costs is dependent on the length of the sea voyage relative to the total journey length and the vessel utilisation assumed. The results show that for the majority of origin-destinations assessed the truck only option has lower external costs than the ship-truck option (1% HFO); the difference in external costs between the options reduces and in some cases reverses due to the introduction of lower sulphur fuels.

#### Total external costs (rail, road and shipping) when modal shift is assumed

In the final part of the analysis, the total estimated external costs (land and sea) under a number of scenarios (pg 68, 69) were estimated:

- the reference scenario (1% HFO);
- a simulation (0.5% HFO) with no modal shift; and
- a simulation (0.1% MD) with: no modal shift, 10%, 20% and 30% modal shift.
Results of this analysis may be found in Annex 2 (pg 80). The analysis found that where a 10% modal shift was assumed to occur, the reduction in external costs under the 0.1% MGO scenario (compared to reference scenario) become an increase relative to the reference scenario in 26% of the cases analysed. Where a 20% modal shift is assumed, external costs are higher than under the reference scenario for most cases. The analysis shows that if a sulphur limit of 0.5% was imposed and this led to no modal shift, the external costs would be lower than under the 0.1% sulphur limit scenario where 20% modal shift is assumed.

It should be noted that the method of calculating external costs assumed that the same number of sea journeys would be undertaken regardless of the demand and the external costs from vessels was the same under all assumptions of modal shift.
Appendix G
TNO, IVL, AEA, EMRC (2009): Cost benefit analysis to support the impact assessment accompanying the revision of Directive 1999/32/EC on the sulphur content of certain liquid fuels

### Purpose

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>TNO, IVL, AEA, EMRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commissioned by</td>
<td>European Commission</td>
</tr>
<tr>
<td>Date and status of report</td>
<td>Final report, December 2009</td>
</tr>
</tbody>
</table>
| Aims and objectives | To inform the European Commission’s review of Directive 1999/32/EC relating to a reduction in the sulphur content of certain liquid fuels by determining the effects of:  
  - the revisions of MARPOL Annex VI and the Technical Code on Control of Emissions of Nitrogen Oxides from Marine Diesel Engines;  
  - the possible designation of additional SOx ECAs;  
  - the possible designation of NOx ECAs; and  
  - the agreement by the European institutions on the Climate and Energy Package. |

### Scope

| Geographic | Europe: the EU-27 and the European Seas of the Baltic Sea, the Black Sea, the Mediterranean Sea, the North East Atlantic and the North Sea. Health benefits are also considered for Switzerland, Croatia, Norway and Turkey. |
| Temporal | The baseline is the year 2000, and a business-as-usual baseline is projected to 2015 and 2020. Policy scenarios are analysed in projections to 2015 and 2020. |
| Vessel types / movements | The Ex-tremis model is used to split the fuel consumption by vessel type and engine size. (pg 8)  
  - Ex-tremis does not cover traffic in European seas generated by non-EU countries in Europe. It is assumed that evolution of the non-EU fleet follows the EU fleet, such that the distribution of vessel types (e.g. bulk carrier), and engine classes (e.g. medium speed diesel) are applied to the regional fuel consumption of international shipping in 2010, 2015 and 2020. |
| Modal shift | This report does not consider any modal shifts away from marine shipping as a consequence of increased shipping prices following costs for introducing emission abatement and/or using lower sulphur fuels. (pg 35) |

### Approach

| Summary of approach used (key steps) | Baseline scenario (2000 and projected)  
  - The baseline of emissions for land-based sources and from the combustion of national maritime fuel consumption |
is derived from the GAINS model developed by IIASA (package NEC6/C&E) (pg 8). The baseline of emissions for international shipping is derived from fuel consumption reported on page 6 in Cofala et al (2007)\(^\text{20}\) which in turn bases fuel consumption estimates on Entec (2005)\(^\text{21}\). The fuel consumption data as reported in Cofala et al. has the Ex-tremis modal baseline scenario superimposed in order to provide a more disaggregated split of fuel consumption (splits by engine type (main and auxiliary), vessel category, fuel used by main engine, and main engine speed). Growth rates to project the baseline to future years (2010, 2015 and 2020) are taken from the Ex-tremis model (Chiffi et al., 2007), rather than from Cofala et al..

Emissions are derived from the fuel consumption estimates through the use of emission factors. The emission factors (appendix 1) are available to the same level of disaggregation as the fuel consumption split, i.e. by main engine speed and by main engine fuel type (Tables 2 and 3 in appendix 1). For remaining fuel consumption by auxiliary engines, general emission factors are used (Table 1, appendix 1).

The sum total of emissions is distributed geographically by sea area according to the split given by Entec (2005). (pg 9)

**Define and develop policy scenarios**

Five scenarios for sea-based emissions were developed and are compared below for their key differences in assumptions. It is intended that the comparison between scenarios yields the relative benefits of individual policy measures:

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Year(s)</th>
<th>Fuel S content outside SOx ECAs</th>
<th>Additional SOx ECAs (all include the Baltic and North Sea / English Channel)</th>
<th>Fuel S content in SOx ECAs</th>
<th>NOx ECAs (tier III standards from 2016)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>2015, 2020</td>
<td>2.7% - 1.45%</td>
<td>-</td>
<td>1.45%</td>
<td>None</td>
</tr>
<tr>
<td>SEA1</td>
<td>2015, 2020</td>
<td>2.94% - 0.1%</td>
<td>Baltic Sea, North Sea / English Channel, Mediterranean</td>
<td>0.1%</td>
<td>Baltic Sea, North Sea / English Channel, Mediterranean</td>
</tr>
<tr>
<td>SEA2</td>
<td>2015</td>
<td>2.94%</td>
<td>Mediterranean</td>
<td>0.1%</td>
<td>N/A</td>
</tr>
<tr>
<td>SEA3</td>
<td>2015, 2020</td>
<td>2.94%</td>
<td>Mediterranean, Black Sea</td>
<td>0.1%</td>
<td>Baltic Sea, North Sea / English Channel, Mediterranean</td>
</tr>
<tr>
<td>SEA4</td>
<td>2020</td>
<td>0.5%</td>
<td>Mediterranean</td>
<td>0.1%</td>
<td>Baltic Sea, North Sea / English Channel, Mediterranean</td>
</tr>
<tr>
<td>SEA5</td>
<td>2020</td>
<td>0.5%</td>
<td>Mediterranean, Black Sea</td>
<td>0.1%</td>
<td>Baltic Sea, North Sea / English Channel, Mediterranean</td>
</tr>
</tbody>
</table>

Points to note about the scenarios: the modelling of fuel sulphur content within SECAs as 0.1%, is as per the revised MARPOL Annex VI. For permissible maximum fuel sulphur contents outside of SECAs, the revision of


Annex VI states this to be 0.5% from 2020 (i.e. as per scenarios SEA4 and SEA5), subject to feasibility study. The limit otherwise imposed is 3.5% (i.e. which is not subject to a feasibility study).

Two additional scenarios covering the effects on land-based emissions of other, non-maritime aspects of Directive 1999/32/EC on the reduction of sulphur content of certain liquid fuels have also been considered but are not included in this report.

**Dispersion modelling of emissions to determine atmospheric concentrations, which are used to derive exposure, impacts and benefits of both the baseline and scenarios**

The emissions data derived for the baseline and scenarios were used to estimate the atmospheric dispersion of ship emissions, and their effect on the European distribution of sulphur and nitrogen deposition, and on ground-level ozone and particulate matter concentrations, using the LOTOS-EUROS model (Schaap et al., 2005).

The estimated effects of the changes in shipping emissions on air pollutant concentrations have been assessed through changes in exposure as health benefits, which have also been monetised. The health benefits assessment model used is ALPHA2.

**Assess costs of scenario compliance and compare them to the monetised benefits**

Costs considered are the fuel cost changes associated with lower sulphur contents, the costs of fitting scrubbers and the costs of introducing NOx control technologies.

<table>
<thead>
<tr>
<th>Top down / bottom up</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Top-down: the land-based emission sources are derived from GAINS, and those from international shipping are derived from fuel consumption estimates from Entec (with adjustments made). (pg 8)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Granularity (if modelled)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>The domain of the LOTOS-EUROS model used for the dispersion modelling runs from 10° West till 60° East and from 35° North till 70° North; it covers the whole of Europe (Iceland excluded) with a horizontal resolution of 0.5° longitude x 0.25° latitude (~30x28 km², depending on latitude). In vertical direction it extends to 2-3 km above the surface resolved in four layers: a planetary boundary layer with a fixed surface layer of 25 metre height, and two reservoir layers on top of the planetary boundary layer. (pg 14)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Approaches for developing assumptions / scenarios on decisions for abatement vs fuel switching</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No decisions are made on whether scrubbers or fuel switching should be undertaken. Costs for both outcomes are presented, and in all cases the study finds that installing scrubbers is cheaper than fuel switching, often by a factor of 2 (pg 44). In both cases – that of installing scrubbers and fuel switching – a range with low and high estimates is presented. As such, the final comparison of costs with benefits takes a range with lower bound as the lower estimate for fitting a scrubber and with upper bound as the high estimate for using low sulphur fuels. (pg 52)</td>
<td></td>
</tr>
</tbody>
</table>

| Approaches for developing assumptions / scenarios on modal shift (e.g. elasticities) | N/A |

### Key assumptions

| Fuel types & their availability | The baseline assumes the sulphur content of HFO to be 2.7% outside of SOx ECAs and 1.45% inside SOx ECAs. (pg 8) |
|---------------------------------| Assumes that the fuel used to meet the 0.1% fuel sulphur limit in SECAs will be marine gas oil or “similar to it”. Assumes that fuel with a sulphur content of 0.5% can either be residual fuel that has been de-sulphurised or marine diesel formulated from a mixture of residual oil and distillates. However, consultation with authors suggests that HFO desulphurised to 0.1% S is also assumed. (pg 35) |
| Fuel consumption (current & projected) | The average annual growth rate of HFO consumption is 2.7% and the average annual decline of distillates consumption is 0.5%. (pg 8) |
| Fuel price trends | It is recognised that the main parameters influencing the costs of fuel relate to sulphur content of crude oils as well as the necessary investments in refinery capacities. It is assumed that there are relatively small costs for vessels to adapt to different fuels. (pg 37) The fuel costs used in this report are based on the fuel price projections in Purvin & Gertz (2009), and are listed in the table below as costs per PJ of heat value: |
Table 7.2: Fuel costs in 2020, adapted from Purvin & Gertz, 2009 and corresponding SOX associated abatement costs.

<table>
<thead>
<tr>
<th>Option (%S in fuel)</th>
<th>Low cost / tonne</th>
<th>High cost / tonne</th>
<th>Low cost [€/ton SOX]</th>
<th>High cost [€/ton SOX]</th>
<th>Low SOX abatement cost [€/ton SOX]</th>
<th>Low SOX abatement cost [€/ton SOX]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel shift (2.94 – 1.0)</td>
<td>20</td>
<td>20</td>
<td>359</td>
<td>359</td>
<td>510</td>
<td>510</td>
</tr>
<tr>
<td>Fuel shift (2.94 – 1)</td>
<td>30</td>
<td>30</td>
<td>538</td>
<td>538</td>
<td>568</td>
<td>568</td>
</tr>
<tr>
<td>Fuel shift (2.94 – 0.5)</td>
<td>120</td>
<td>120</td>
<td>2,152</td>
<td>3,049</td>
<td>1,806</td>
<td>2,559</td>
</tr>
<tr>
<td>Fuel shift (2.94 – 0.1)</td>
<td>280</td>
<td>280</td>
<td>4,510</td>
<td>5,370</td>
<td>3,621</td>
<td>4,268</td>
</tr>
<tr>
<td>Fuel shift (0.0 – 0.1)</td>
<td>160</td>
<td>160</td>
<td>2,753</td>
<td>2,753</td>
<td>14,692</td>
<td>14,692</td>
</tr>
</tbody>
</table>

The fuel cost for heavy fuel with 2.94 % sulphur content is projected to be € 430 / tonne in Purvin & Gertz 2009. The fuel costs per tonne are converted to costs per PJ by considering the specific heat value of the fuel and the conversion rate between euro and dollar.

Fleet composition (current & projected)
No detailed information.

Fleet movements (current & projected)
No detailed information.

Abatement equipment, especially sea water scrubbing (uptake, efficiencies, costs etc.) – including assumptions on availability of different types of equipment (current & projected)

Scrubbers for SOX
- Separately considers costs for retrofit / new vessel installation. Retrofits assumed lifetime of 12.5 years, whilst new vessel scrubbers are assumed to have lifetimes of 15 years. (pg 40). Investment costs are from engine manufacturers.
- Separately considers prices for open / closed scrubber systems. For closed (freshwater) systems, costs for maintenance, purchase of NaOH and fresh water are taken into consideration, and it is recognised that the amount of fresh water and NaOH used depend on the sulphur content of the fuel. The assumed cost of NaOH is €0.5 / litre 50% NaOH. For open (seawater) systems, maintenance costs and fuel penalty are taken into account.
  - Assumes fuel penalty to be 2%. (pg 38)
  - Costs include sludge disposal. The cost is relatively small and could decrease following construction of new sludge disposal facilities and higher rates of usage of these facilities.
  - Assumes scrubber to operate 4,000 hours per year at sea. (pg 38)
  - Assumes abatement up to 97% (implied, pg 39).
- The unit costs per vessel are converted to unit costs per PJ fuel by assuming a specified number of operating hours (h) and an average engine size (kW) for each size category (small, medium, large) of vessel and converting between kWh and PJ. It is not clear what load factors (if any) are used to produce the total cost estimates. Total fuel consumption (P/J) per sea is used to derive total cost estimates.
  - Costs per tonne abated are derived figures from the outcomes, rather than those which are applied to derive total costs.
  - Cost ranges (low to high) are derived from retrofit/new and open/closed systems and range from €500-2,680 (new) to €885-4,290 (retrofit) per tonne of SO2 abated.

NOx abatement
- Considers that SCR is the likely route to compliance with tier III, but that it may be possible to use exhaust gas recirculation (EGR) in combination with water injection.
  - Assumes urea price to be €0.2 / litre. (p38)
  - Assumes a fuel penalty of 2% on EGR systems.
  - Tier I, Tier II and Tier III (SCR) are assumed to have the same cost regardless of sulphur content of the fuel.
  - SCR requires the use of low sulphur inflow gases as the sulphur content poisons the catalyst. However, the costs associated with ensuring that SO2 abatement is achieved in parallel with the NOX abatement are not included in these estimates.
  - Costs per tonne of NOX abated assumed in the analysis range from €8 (retrofit, tier I, basic IEM) to €600.

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22 Sometimes referred to as water in fuel (WIF), which can take the form of humid air motors, direct water injection, or water emulsion.
Legislative assumptions

The report states that the baseline does not include some of the impacts of MAPROL Annex VI (the 1997 protocol, not the revisions) which means that the Tier I requirement for new engines installed on or after 1/1/2000 are not taken into account in the baseline. (pg 8)

In the scenarios (pg 43), for diesel engines with power output $>5,000$ kW and a per cylinder displacement $\geq 90$ litres are upgraded as follows:

- Tier I standards for 30% of the ships constructed between 1/1/1990 and 1/1/2000;
- Tier I standards for ships constructed between 1/1/2000 and 1/1/2011;
- Tier II standards for ships constructed on or after 1/1/2011; and
- Tier III standards for ships constructed on or after 1/1/2016 and sailing in the Baltic Sea, North Sea/English Channel and/or the Mediterranean Sea (only applicable to the 2020 scenarios)

The Ex-tremis model includes an assumption on the age distribution of the world merchant fleet by vessel type for 2005. This study assumes this 2005 age distribution can also be applied in 2010, 2015 and 2020.

Outputs

The baseline emissions estimated in the study are presented below:

<table>
<thead>
<tr>
<th>Sea area</th>
<th>2000</th>
<th>2020</th>
<th>2010</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SO$_2$</td>
<td>NO$_x$</td>
<td>NMVOC</td>
<td>PTotal</td>
</tr>
<tr>
<td>North Sea</td>
<td>417</td>
<td>664</td>
<td>23</td>
<td>22</td>
</tr>
<tr>
<td>Black Sea</td>
<td>53</td>
<td>83</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Mediterranean</td>
<td>1024</td>
<td>1593</td>
<td>56</td>
<td>118</td>
</tr>
<tr>
<td>Baltic Sea</td>
<td>177</td>
<td>283</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>NE Atlantic</td>
<td>472</td>
<td>742</td>
<td>26</td>
<td>56</td>
</tr>
<tr>
<td>Total</td>
<td>2144</td>
<td>3955</td>
<td>118</td>
<td>212</td>
</tr>
</tbody>
</table>

The estimated health benefits for the EU-27 due to reduced exposure to particulates and ozone were valued to be (in €bn):

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SEA1</td>
<td>8 to 16</td>
<td>10 to 23</td>
</tr>
<tr>
<td>SEA2</td>
<td>11 to 24</td>
<td>14 to 32</td>
</tr>
<tr>
<td>SEA3</td>
<td>11 to 25</td>
<td>15 to 34</td>
</tr>
<tr>
<td>SEA4</td>
<td>-</td>
<td>16 to 36</td>
</tr>
<tr>
<td>SEA5</td>
<td>-</td>
<td>16 to 36</td>
</tr>
</tbody>
</table>

Additionally, the health benefits for Croatia, Norway, Switzerland and Turkey were assessed; these were found to be small for all except Turkey.

Costs

The additional costs for each scenario compared to the baseline are presented separately for SO$_2$ scrubbers and fuel switching, and additional costs for NO$_x$ compliance. These are shown in the table below. The results show that SO$_2$ abatement controls dominate the costs; the costs of NO$_x$ abatement are an order of magnitude less (with the partial exception of SEA1). They also show that the extent of variation in the NO$_x$ control cost estimates is small compared to variation in the SO$_2$ control costs. And finally they also show that, despite a significant level of variation in costs for the two SO$_2$ control options, there is no overlap in their ranges.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Cost component</th>
<th>SO$_2$ abatement option</th>
<th>2015 cost (€m)</th>
<th>2020 cost (€m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEA1</td>
<td>SO$_2$</td>
<td>Scrubbing</td>
<td>563 – 1,883</td>
<td>404 – 1,810</td>
</tr>
<tr>
<td></td>
<td>Fuel switching</td>
<td></td>
<td>3,024 – 3,622</td>
<td>3,279 – 3,957</td>
</tr>
<tr>
<td>NO$_x$</td>
<td>-</td>
<td></td>
<td>76</td>
<td>452 – 645</td>
</tr>
</tbody>
</table>
A comparison of costs and benefits in this analysis shows that benefits exceed costs for all scenarios modelled.

Table 8.2 Summary of costs and quantified benefits in the EU27 for the 2020 scenarios (£billions)

<table>
<thead>
<tr>
<th></th>
<th>SEA1</th>
<th>SEA2</th>
<th>SEA3</th>
<th>SEA4</th>
<th>SEA5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs</td>
<td>low</td>
<td>0.9</td>
<td>2.0</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>high</td>
<td>4.6</td>
<td>12</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>Benefits</td>
<td>low</td>
<td>10</td>
<td>14</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>high</td>
<td>23</td>
<td>32</td>
<td>34</td>
<td>36</td>
</tr>
</tbody>
</table>

This conclusion is subject to the following caveats:

- the ranges shown are indicative – they do not account for all of the uncertainties that could affect the analysis, particularly on the side of the benefits estimation;
- the benefits do not include quantified benefits to ecosystems, crops and the built environment (including cultural heritage), whose inclusion would add to the benefits; and
- the benefits include only the health benefits, which are sensitive to the benefits of reduced mortality using the lower bound (Value of Life Year - VOLY) approach (p52).

The uncertainty assessment made (p53-58) concluded that for the cost ranges considered most reliable (the average or best cases, rather than the worst cases) the probability of benefit exceeding cost can be described as very likely / virtually certain, irrespective of the approach taken to mortality valuation. With one slight exception (SEA5 with mortality valued using the VOLY) the probability of benefits exceeding costs can be described as likely, very likely or virtually certain even for the worst case assumptions on cost.
## Appendix H

SKEM (2010): Impact study of the future requirements of Annex VI of the MARPOL Convention on Short Sea Shipping

### Purpose

**Author(s)**  
SKEMA Consortium (NECL, UGOT, BIT/Vectura & AUEB)

**Commissioned by**  
European Commission

**Date and status of report**  
Draft Final report, April 2010

**Aims and objectives**  
To assess the sectoral, economic and environmental impacts associated with the use of low sulphur fuels. To be achieved through the following tasks:
- Estimation of the costs (operational and capital) associated with the use of low sulphur fuels;
- Evaluation of the economic impacts of installing sulphur abatement equipment as well as impacts on emissions;
- Investigation of impacts of additional costs on competitiveness of sea versus road transport including an estimation of impacts on modal balance;
- Estimation of overall emission impacts for a range of scenarios.

### Scope

**Geographic**  
Baltic and North Seas.

**Temporal**  

**Vessel types / movements**  
Study has utilised two models to assess impacts of MARPOL on roll-on roll-off (RoRo) and lift-on lift-off (LoLo) short sea shipping in the study area (see above).

**Modal shift**  
The main focus of the study is on impacts of MARPOL on Short Sea Shipping (SSS) in the study area. Two models have been applied to estimate. Modal choice decisions have been modelled for a range of scenarios and established sea/road routes. Analysis is limited to sea and road transport only i.e. does not consider use of inland waterways or rail transport.

### Approach

**Summary of approach used (key steps)**  
Two transportation models have been used to assess the possible impacts of MARPOL on modal shift for the RoRo (“NECL Model”) and LoLo (“TAPAS Model”) SSS industry in the Baltic and North Seas. For both models, input data includes estimates of unit price impacts of MARPOL Annex VI for SSS as well as potential impacts of implementing the Eurovignette infrastructural and environmental tolls (i.e. proposed amendments to Directive 1999/62/EC on the charging of heavy goods vehicles for the use of certain infrastructure). Further details of each model including the routes and scenarios modelled are described below.

**NECL Model**  
The NECL model simulates the costs and duration of transporting a trailer on RoRo vessels on an East-West corridor defined in an earlier report (“Task 1”). The model was applied to estimate the potential cost impacts of MARPOL and emissions on a unit basis (i.e. per trailer) for each of the scenarios considered (see below).
In total, ten competing routes operating on four corridors were considered in the modelling. The figure below summarises the relative proportion of kilometres for each route travelled by road (black) and sea (blue):

A list of key model inputs is provided in Appendix B to the report (pg 55). The source of these inputs is unclear (to be clarified with the authors).

**TAPAS Model**

The TAPAS model (Transportation And Production Agent-based Simulator) simulates the decisions affecting modal choice on the transport of TEUs of average value of €20k and weight 11ton on LoLo vessels on an East-West corridor defined in an earlier report ("Task 1").

"The TAPAS model is a simulation tool for microlevel simulation of the production and the transportation of products. It is based on agent technology where the decision makers which appear in transport chains are modelled as software agents and their interactions are modelled according to an interaction protocol. The types of agents which are included in TAPAS are customer, transport chain coordinator, transport buyer, transport planner, product buyer, and production planner.

The agents try to meet a consumer demand by transport and product ordering, selection of which transport and production resources as well as which infrastructure that should be used, and how the resources and infrastructure should be used. When the agents have agreed on how the production and transportation should be performed, the overall transport and production solution is simulated which gives performance indicators in terms of economical, logistical, and environmental performance, see Davidsson (2008) for more information.

The TAPAS model simulates one consumer and one supplier at a time. Therefore the agents are not supplied with a modal choice decision but a route choice (routes 1-5) decision. The percentage modal share per route, however, does represent a modal preference. Due to the modelling of an individual supplier and an individual consumer the route choice is mutually exclusive. Therefore if under certain conditions the agents will select route-2 all of the freight will travel on this route. This is acceptable as the volume of TEUs transported between the supplier and the consumer is limited to approximately 5 TEUs per week. (pg 29)

Five alternative routes between Klaipeda and Harwich were modelled in the study using this model. These routes are competing services operating on the same transport corridor.

Only the potential impacts of switching to lower sulphur fuels were modelled using TAPAS i.e. the potential use of
Creating the environment for business

| abatement technology was not considered. |
| Top down / bottom up | Modelling is based on theoretical units (TEU or trailers) being transported via a series of routes with varying splits of transport by road and sea. |
| Granularity (if modelled) | N/A |
| Approaches for developing assumptions / scenarios on decisions for abatement vs fuel switching | No decisions are made on whether scrubbers or fuel switching should be undertaken. One of the scenarios modelled with the NECL model (S4 – see above) assumes that the ships considered continue to use high sulphur fuels but apply seawater scrubbers instead. |
| Approaches for developing assumptions / scenarios on modal shift (e.g. elasticities) | Unit cost impacts of MARPOL and proposed amendments to HGV road user charging were estimated for each scenario and route. The average percentage change in costs was then estimated relative to a base case (i.e. no MARPOL). Section 5.5.5. (pg 39) of the report outlines the approach taken for estimating the potential for modal shift. It has been assumed that the transport of goods by SSS must be approximately 15% cheaper than the road alternative in order to be equitable i.e. approximately 50% of the cargo will travel via SSS and 50% by road. This was applied to each scenario to estimate the potential change in route selection. |

### Key assumptions

| Fuel types & their availability | The potential availability of low sulphur fuels is discussed in Section 3.1 of the report (pg 9). However, no conclusions are made as to whether or not availability will be an issue in the future. It is assumed that a marine distillate fuel would be required to meet the 2015 MARPOL limit of 0.1% sulphur and this is expected to be MGO/MDO. |
| Fuel consumption (current & projected) | Fuel consumption for a particular route has been estimated for an example ship based on an assumed speed, fuel consumption, engine size, fuel type and voyage duration (Appendix C, pg 56). The source of these data is unclear (to be clarified with the authors). No projections appear to have been developed. |
| Fuel price trends | Fuel prices are based on those developed by Purvin & Gertz (2009) in a recent study for the Commission (“Impacts on the EU refining industry and markets of IMO specification changes and other measures to reduce the sulphur content of certain fuels”) extrapolated to 2025. | €/Ton |
| Fuel Sulphur Content | 1.50% | 1.00% | 0.10% |
| 2009 | €156.55 | €178.72 | €428.80 |
| 2010 | €281.75 | €293.91 | €492.11 |
| 2015 | €399.60 | €411.76 | €656.24 |
| 2020 | €424.74 | €434.34 | €706.83 |
| 2025 | €466.38 | €475.99 | |

| Fleet composition (current & projected) | Not considered in this study. |
| Fleet movements (current & projected) | Not considered in this study – modelling is based on specified routes along certain transportation corridors. |
| Abatement equipment, especially sea water scrubbing (uptake, efficiencies, costs etc.) – including assumptions on availability of different types of equipment (current & projected) | Section 4 of the report (pg 17) provides a discussion of the possible impacts of installing sulphur abating technologies. Whilst other techniques are discussed, the study focuses primarily on sea water scrubbers. Cost data is primarily based on an earlier Entec (2005) report for the Commission: €168/kW (retrofit) and €118/kW (new build) installed. A 10% reduction to these costs was applied in the modelling due to new manufacturers of scrubbers entering the market. Other key assumptions include the following: |
|  | • Assumed lifetime of 15 years. |
|  | • Maintenance costs equivalent to 3, 2 and 1% of capital costs for small, medium and large vessels, respectively. |
Abatement efficiencies presented for a range of available scrubbers from different manufacturers: SO2 93-100%, PM 50-85%.

Legislative assumptions

The legislative assumptions applied in the study are summarised in the table below:

<table>
<thead>
<tr>
<th>When</th>
<th>Ship Type</th>
<th>Area</th>
<th>%</th>
<th>Act</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.8.2006</td>
<td>All</td>
<td>Baltic ECA</td>
<td>1.5</td>
<td>MARPOL</td>
</tr>
<tr>
<td>11.8.2006</td>
<td>All</td>
<td>Baltic ECA</td>
<td>1.5</td>
<td>EU</td>
</tr>
<tr>
<td>11.8.2007</td>
<td>Passenger ships</td>
<td>All EU</td>
<td>1.5</td>
<td>EU</td>
</tr>
<tr>
<td>22.11.2007</td>
<td>All</td>
<td>North Sea + English Channel ECA</td>
<td>1.5</td>
<td>EU</td>
</tr>
<tr>
<td>1.1.2010</td>
<td>All</td>
<td>All EU Ports</td>
<td>0.1</td>
<td>EU</td>
</tr>
<tr>
<td>1.7.2010</td>
<td>All</td>
<td>SOx ECAs</td>
<td>1.0</td>
<td>MARPOL</td>
</tr>
<tr>
<td>1.1.2010</td>
<td>Inland waterway vessels</td>
<td>All EU inland waterways</td>
<td>0.1</td>
<td>EU</td>
</tr>
<tr>
<td>1.1.2011</td>
<td>Inland waterway vessels</td>
<td>All EU inland waterways</td>
<td>0.001</td>
<td>EU</td>
</tr>
<tr>
<td>1.1.2012</td>
<td>16 Greek ferries</td>
<td>Greek ports</td>
<td>0.1</td>
<td>EU</td>
</tr>
<tr>
<td>1.1.2012</td>
<td>All</td>
<td>Globally</td>
<td>3.5</td>
<td>MARPOL</td>
</tr>
<tr>
<td>1.1.2015</td>
<td>All</td>
<td>ECAs</td>
<td>0.1</td>
<td>MARPOL</td>
</tr>
<tr>
<td>1.1.2020</td>
<td>All</td>
<td>Globally</td>
<td>0.5</td>
<td>MARPOL</td>
</tr>
</tbody>
</table>

Modelling Outputs: TAPAS

The outputs of the modelling indicate that for each scenario a single route is selected on the basis of the optimal transport solution for the product and transport demand of the customer. The table below summarises the route selected for each of the temporal scenarios (pg 36):

<table>
<thead>
<tr>
<th>Year</th>
<th>Route Selected</th>
<th>Vla</th>
<th>% Sea Share per Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>5</td>
<td>Esbjerg</td>
<td>&gt;90%</td>
</tr>
<tr>
<td>2010</td>
<td>2</td>
<td>Cuxhaven</td>
<td>&gt;70%</td>
</tr>
<tr>
<td>2016</td>
<td>1</td>
<td>Rotterdam</td>
<td>&gt;10%</td>
</tr>
<tr>
<td>2025</td>
<td>1</td>
<td>Rotterdam</td>
<td>&gt;10%</td>
</tr>
</tbody>
</table>

The results indicate that as fuel costs for shipping increase with more stringent requirements on sulphur content of fuels a route based on a greater share of transport by road is selected. This is particularly apparent from 2015 onwards when the lowest sulphur requirements apply.

Modelling Outputs: NECL

The average percentage change in costs from a base case (BC) for each of the six scenarios and groups of routes has been estimated (pg 37) and is presented below.
In addition, the impacts of these changes in costs on market share of each route have been estimated (pg 40).

- **Routes 1-4**: with MARPOL (assuming fuel switching only) an 8% increase in market share for route 1 (predominantly road transport route) is anticipated primarily at the expense of route 3 which is predicted to lose 5% of total market share (this represents 64% of its base case cargo volumes). Market share is maintained for scenario 4 which assumes that high sulphur fuels will continue to be used with seawater scrubbers.

- **Routes 5-6**: with MARPOL (assuming fuel switching only) a 10% increase in market share for the road based route is anticipated. A similar pattern is observed for the seawater scrubbers scenario (S4) as before.

- **Routes 7-8**: similar pattern as above.
Conclusions

Both sets of modelling indicate that the implementation of the MARPOL requirements are expected to lead to a shift away from SSS to road transport for the routes considered. However, this is only foreseen for fuel switching i.e. the use of seawater scrubbers appears to maintain the current market share and in some cases improve the overall share for SSS.

The study highlights that whilst the routes themselves are actual routes, there are limitations in trying to compare the impacts of MARPOL on shipping and assuming road transport stays constant as the two modes are interdependent on each other.