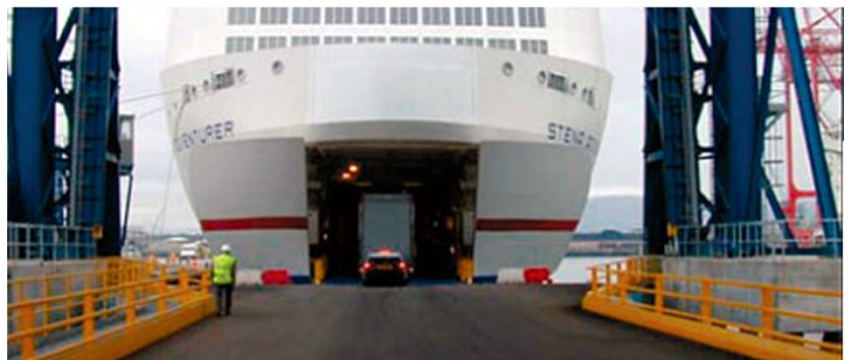


UK Chamber of Shipping

Impact on Jobs and the Economy of Meeting the Requirements of MARPOL Annex VI

Final Report



AMEC Environment & Infrastructure UK Limited

March 2013

Copyright and Non-Disclosure Notice

The contents and layout of this report are subject to copyright owned by AMEC (©AMEC Environment & Infrastructure UK Limited 2013), save to the extent that copyright has been legally assigned by us to another party or is used by AMEC under licence. To the extent that we own the copyright in this report, it may not be copied or used without our prior written agreement for any purpose other than the purpose indicated in this report.

The methodology (if any) contained in this report is provided to you in confidence and must not be disclosed or copied to third parties without the prior written agreement of AMEC. Disclosure of that information may constitute an actionable breach of confidence or may otherwise prejudice our commercial interests. Any third party who obtains access to this report by any means will, in any event, be subject to the Third Party Disclaimer set out below.

Third-Party Disclaimer

Any disclosure of this report to a third party is subject to this disclaimer. The report was prepared by AMEC at the instruction of, and for use by, our client named on the front of the report. It does not in any way constitute advice to any third party who is able to access it by any means. AMEC excludes to the fullest extent lawfully permitted all liability whatsoever for any loss or damage howsoever arising from reliance on the contents of this report. We do not however exclude our liability (if any) for personal injury or death resulting from our negligence, for fraud or any other matter in relation to which we cannot legally exclude liability.

Document Revisions

No.	Details	Date
1	Draft report for comment	13/02/2013
2	Draft report v2 for comment	21/02/2013
3	Draft Final	01/03/2013
4	Final	0803/2013

Report for

David Balston, Director Safety and Environment
UK Chamber of Shipping
30 Park Street
London
SE1 9EQ


Main Contributors

Evan Williams
David Tyrer
Jeremy Brutus
Colin Carter

Issued by


.....
Evan Williams

Approved by


.....
Ben Grebot

**AMEC Environment & Infrastructure
UK Limited**

6/7 Newton Terrace, Glasgow G3 7PJ, United Kingdom
Tel +44 (0) 141 222 1200
Fax +44 (0) 141 222 1210

Doc Reg No. 33509/C000/rr002i4

r:\projects\33509 ppaq shipping economic assessment\c
client\reporting1\draft final\for final report\rr002i4 uk chamber of
shipping.docx

UK Chamber of Shipping

Impact on Jobs and the Economy of Meeting the Requirements of MARPOL Annex VI

Final Report

AMEC Environment & Infrastructure
UK Limited

March 2013



ISO 9001 - FS 13881
ISO 14001 - EMS 69090

In accordance with an environmentally responsible approach,
this document is printed on recycled paper produced from 100%
post-consumer waste, or on ECF (elemental chlorine free) paper

Executive Summary

This report identifies significant impacts on the UK short sea shipping industry in meeting the requirements of Marpol annexe VI.

In addition to direct costs to operators, the report identifies modal shift and threats to the viability of routes with consequent knock on effects for jobs in the port and ferry industry.

Review of options for meeting the requirements

The report contains a technical review of three possible means of achieving the required standards; retrofit scrubbing systems, retrofit conversion to LNG and use of lower sulphur fuel (in place of heavy fuel oil).

Retrofitting LNG was found, in practice, to be unsuitable for much of the UK fleet given the age and configuration of the existing ships. Whilst there is some potential for new ships to take up this option the limited availability of bunkering facilities, space at port and fuel infrastructure render this option unviable for the foreseeable future.(Section 1.3)

This report shows that scrubbing has the potential to be a viable technology in the future. However a review of the current state of development, and operators direct experience of trialling systems, does not provide sufficient confidence that the investments required would result in the emission reductions required to ensure compliance. (Section 2.3).

Given the technical and practical unavailability of LNG and scrubbers in the immediate future the only viable means of meeting the requirements of MARPOL Annex VI will be through switching to lower sulphur fuel.

Analysis of the economic impacts of fuel switching

The consequences of using lower sulphur fuel within the ECA from 2015 are that there will be significant increases in costs associated with fuel purchases of between an additional \$275 and \$350 per tonne of fuel used. (Section 2)

Due to the current financial position of most operators on these routes it is assumed that the full cost of fuel price increases will be passed on directly as increased ticket prices.

The direct impacts of increased costs on the shipping industry in the UK could be considerable leading to increases in fuel costs faced by operators in the Western Channel and North Sea of more than £300 million. The effect on ticket prices charged (simply to recover these additional costs) on North Sea routes would require price increases of between 5 and 21% (Table3.3) and on Western Channel routes of between 8 and 29% (Table 3.2) (section 3.4).

Limited UK and EU refinery capacity for middle distillate fuels are likely to have knock on effects in terms of fuel imports, and as highlighted by a recent Swedish study (Sweco 2012) this could impact on the price faced by road diesel users. An increase in the costs of road fuel diesel as estimated in the Sweco study (Box 1) would increase the costs faced by road diesel users by more than £700 Million per year.

Increased ticket prices on longer sea routes will result in haulage operators switching from longer sea routes to shorter sea routes which require longer road journeys. This “modal shift” away from ferries to road journeys will lead to reduced viability of some routes threatening thousands of jobs as well as an increase in congestion and other detrimental affects.

Depending upon the costs faced by hauliers for road Km travelled and the scale of increases in tariffs the expected modal shift for the North Sea and Western Channel is modelled to be between 6 and 16% of all freight traffic with the switching being most noticeable for routes near to Dover Calais which is the shortest available cross channel route.

Our analysis suggests that modal shift will threaten the viability of routes in the North Sea Western Channel. (section 4) The loss of viability of routes and port operations has the potential to displace thousands of (good quality) jobs (Section 4). Overall, as many as 2,000 full time, part time and contract positions are likely to be at risk in the UK and on the continent, in maritime engineering, navigation, catering, customer service, cleaning and administrative occupations from those routes that are potentially unviable or would be threatened from the traffic reductions identified. The analysis further indicates that modal shift will affect between 1.3-3.6 Million tonnes of freight leading to between 1.5-10 million additional road kilometres. This is expected to lead to increased congestion on the roads and local environmental problems. A conservative estimate of the scale of harm to the UK from externalities of “modal shift” is that it results in an addition burden of approximately £3.75 Million in external costs (Section 4).

A one to one relationship between price increase and loss in quantity demanded is predicted for the leisure market. . This would suggest that a 10% increase in price would lead to a reduction of 10% in market volumes.

Contents

1.	Introduction	1
1.1	Purpose of this Report	1
1.2	Report Structure	1
1.3	Policy context	1
1.3.1	Existing MARPOL Annex VI Regulations	1
1.3.2	Sulphur Content of Marine Fuels Directive	2
1.3.3	Revised MARPOL Annex VI Regulations	3
1.3.4	Revised Sulphur Content of Marine Fuels Directive (2012)	4
2.	Review of options for meeting the requirements	5
2.1	Introduction	5
2.2	Option 1: Fuel switching from 1% to 0.1% Sulphur fuel	5
2.3	Option 2: Feasibility of adopting abatement technology	8
2.3.1	Technical options (Scrubbers)	8
2.3.2	Consultation Responses	10
2.3.3	Technical Assessment of Scrubber Technology	14
2.3.4	Cost estimates	16
2.3.5	Conclusions	17
2.4	Option 3: Alternative Fuel (LNG)	17
2.4.1	Consultation Responses	17
2.4.2	Technical Assessments	18
2.4.3	Conclusions	18
2.5	Option 4: Methanol	19
2.6	Option 5: Use of Exemptions	19
2.7	2.7 Conclusion	19
3.	Analysis of the economic impact of switching to 0.1% Sulphur fuel	20
3.1	Overview	20
3.2	Costs associated with fuel switching	21
3.2.1	Previous studies on price impacts	21
3.2.2	Uncertainties and assumptions	22
3.2.3	Price difference forecasts	23
3.2.4	Conclusions	25

3.3	Effect of increased demand for middle distillate fuels on European refineries and fuel imports	25
3.3.1	Current trends	25
3.3.2	Impacts on refineries of increased distillate demand from shipping	26
3.3.3	Conclusion	27
3.4	Impact on ticket prices	27
3.4.1	Introduction	27
3.4.2	Overview of Approach and Key Assumptions	28
3.5	Impact on customer behaviour and modal shift	31
3.5.1	Introduction	31
3.5.2	Approach	32
3.5.3	Tariff increases	33
3.5.4	Market Structure	36
3.5.5	North Sea freight routes	38
3.5.6	Key Assumptions in the estimates	41
3.5.7	Estimates of modal shift impacts on market and on routes	43
3.5.8	Comments on results	47
3.6	Impact of Identified Modal Shift	48
3.6.1	Externalities	48
3.6.2	Other impacts	52
3.6.3	Conclusion	52
4.	Wider Economic Effects and Route Viability	53
4.1	Introduction	53
4.2	Route viability - effects of fuel switching	53
4.3	Wider economic effects	55
4.3.1	Employment	56
4.3.2	Effects on hauliers and on trade	57
4.4	Externalities	57
4.4.1	Conclusions	58
5.	Summary and Conclusions	59
5.1	Purpose of this Report	59
5.2	Report Structure	59
5.3	Options for meeting the requirements	59
5.4	Approach take in the study	60
5.5	Increases in fuel costs	60

5.6	Increases in ticket prices	61
5.6.1	Effects of fuel switching on ticket prices – Western Channel Routes	61
5.6.2	Effects of fuel switching on ticket prices – North Sea and Container Routes	61
5.7	Modal shift	61
5.7.1	Switching behaviour by area	61
5.7.2	North Sea	61
5.8	Impact of Identified Modal Shift	63
5.9	Route viability - effects of fuel switching	63
5.9.1	North Sea routes	63
5.9.2	Western Channel routes	64
5.10	Wider economic effects	65
5.10.1	Shipping operator employment	65
5.10.2	Port based employment	65
5.10.3	Effects on hauliers and on trade	65
6.	References	66
Table 2.1	Specifications of the most common marine fuels	7
Table 2.2	Scrubber status and experiences (January 2013)	10
Table 2.3	Comparison of scrubber costs and assumptions (from Entec 2011 review)	16
Table 2.4	Costs estimates from industry consultation (January 2013)	17
Table 3.1	Approach to estimating ticket price increase	29
Table 3.2	Estimated Ticket Price increases - Western Channel Routes	30
Table 3.3	Estimated Ticket Price increases – North Sea and Container Routes	30
Table 3.4	Tariff Increases (freight)	34
Table 3.5	UK- Continent Freight Market Volumes on Reference routes	37
Table 3.6	Switching on North Sea routes by Port	41
Table 3.7	North Sea - Modal Shift estimates (freight)	43
Table 3.8	Western Channel - Modal Shift estimates (freight)	44
Table 3.9	North Sea and Western Channel - Modal Shift estimates (freight)	45
Table 3.10	Upper estimates for modal shift for routes (freight)	47
Table 3.11	2015 marginal external costs for passenger cars, Great Britain weighted average across road types	50
Table 3.12	Passenger Car Unit (PCU) factors	50
Table 3.13	2015 Marginal greenhouse gas costs associated with lorries	51
Table 3.14	2015 marginal and total external costs following modal shift (2010 prices)	51
Table 4.1	Economic implications of lower traffic volumes – Western Channel	54
Table 4.2	Economic implications of lower traffic volumes – North Sea and Container Routes	54
Table 4.1	Job numbers	56
Table 5.1	North Sea - Modal Shift estimates (freight) (Page 44)	62
Table 5.2	Western Channel - Modal Shift estimates (freight) (page 45)	62
Table 5.3	Economic implications of lower traffic volumes – North Sea and Container Routes (Page 58)	64
Table 5.4	Economic implications of lower traffic volumes – Western Channel (page 57)	65
Figure 1.1	Baltic and North Sea SECA	2
Figure 1.2	Revised MARPOL Annex VI - Fuel Sulphur Limits	4
Figure 3.1	Analytical approach	20
Figure 3.2	Assumed fuel prices (€/tonne) as a function of fuel sulphur content (%)	24
Figure 3.3	Net European Trade Flows of Oil Products, 2009 estimate	26
Figure 3.4	Distances and Tonnage Westbound (freight)	40

1. Introduction

1.1 Purpose of this Report

This report has been prepared for the UK Chamber of Shipping, on behalf of several North Sea and Western Channel shipping operators, to establish the economic effect of compliance with the requirements of MARPOL Annex VI regulations, which sets sulphur limits for fuels in SO_x Emission Control Area (SECA) currently 1%, since 1 July 2010; being further reduced to 0.1%, effective from 1st January 2015.

The report has considered three potential options by which shipping operators' services within the SECA can comply with the requirements. First, by switching fuel from Heavy Fuel Oil (HFO) to a Low Sulphur Fuel (LSF). Second by installing ship exhaust scrubber systems and third by using alternative fuels, such as liquefied natural gas (LNG). There are substantial commercial and practical problems associated with the implementation of all three of these options in order to comply with the 2015 deadline.

1.2 Report Structure

The report is structured as follows:

- Section 2 reviews the three potential options in greater detail and establishes the costs and practical issues associated with their implementation in order to comply with the requirements of the regulation;
- Section 3 examines the impacts expected to arise from fuel switching from HFO to LSF. The analysis is undertaken in a series of steps. First the costs of switching fuel are estimated and subsequently the effect this will have on ticket prices. Potential impacts on route switching and modal shift are then considered;
- Section 4 investigates the wider economic and route viability impacts of meeting the requirements identifying the scale of risk to the industry and to the wider economy and
- Summary and conclusions are set out in Section 5.

1.3 Policy context

1.3.1 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 SO_x and NO_x 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 (SO_x 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 SO_x emissions. Limits on

emissions of NO_x 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).

Figure 1.1 Baltic and North Sea SECA



Source: ECG, Sulphur content in marine fuels, 2011, p7.

1.3.2 Sulphur Content of Marine Fuels Directive

The SCMF Directive¹ entered into force on 6th July 2005, amending the existing Sulphur Content of Liquid Fuels Directive (SCLFD)². The SCMF Directive 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 11th August 2006, and the North Sea and English Channel, from either 11th August 2007 or 12 months after the entry into force of the International Maritime Organisation designation, whichever is the earlier;

¹ Directive 2005/33/EC of the European Parliament and of the Council of 6 July 2005 amending Directive 1999/32/EC as regards the sulphur content of marine fuels.

² Council Directive 1999/32/EC of 26 April 1999 relating to a reduction in the sulphur content of certain liquid fuels and amending Directive 93/12/EEC. OJ L 121, 11/05/1999 p.13-18.

- ii) A 1.5% sulphur limit for fuels used by passenger vessels on regular services between EU ports, from 11th August 2006; and
- iii) A 0.1% sulphur limit³ on fuel used by inland waterway vessels and by seagoing ships at berth in EU ports, from 1st January 2010.

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).

1.3.3 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 NO_x Technical Code when it met for its 58th session (from 6 to 10 October 2008)⁴. 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 entered 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; 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
- Tiered reductions in NO_x 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 Emission Control Areas).

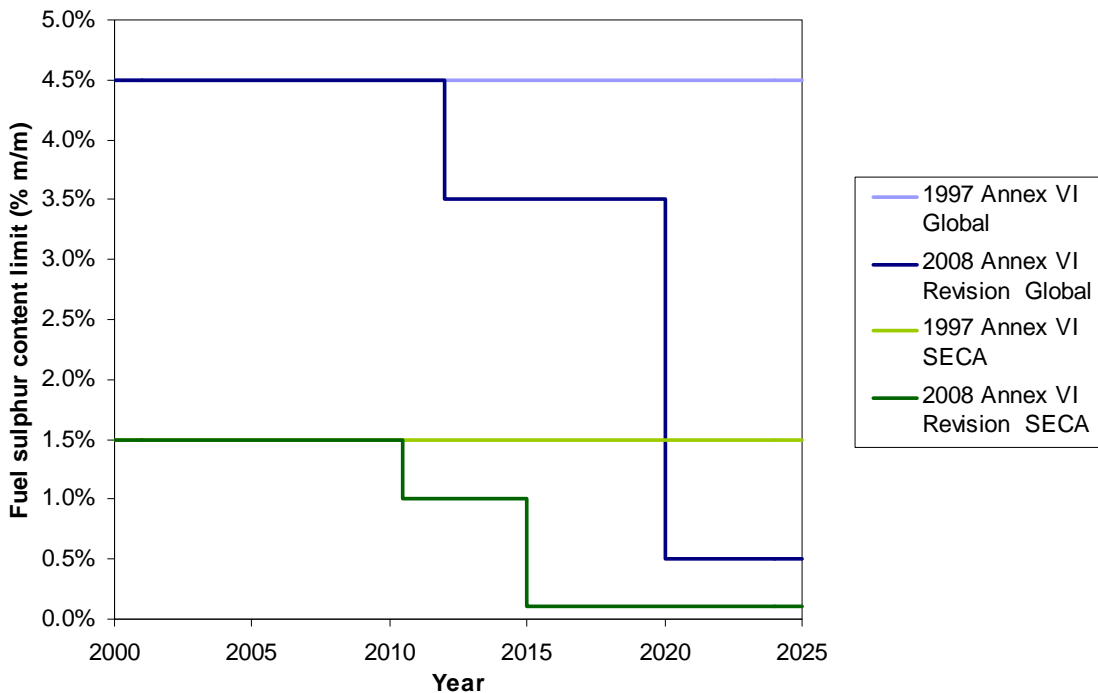
³ The 0.1% sulphur limit on fuels used by inland waterway vessels and ships at berth does not apply to:

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

⁴ http://www.imo.org/Newsroom/mainframe.asp?topic_id=1709&doc_id=10262

The time-limited sulphur content limits are represented graphically in Figure 1.2 below.

Figure 1.2 Revised MARPOL Annex VI - Fuel Sulphur Limits



The revised Annex VI will also allow for Emission Control Areas (ECAs) to be designated to limit emissions of SO_x, particulate matter or NO_x, 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.

1.3.4 Revised Sulphur Content of Marine Fuels Directive (2012)

The revised SCMF Directive⁵ entered into force on 21st November 2012, amending the existing Sulphur Content of Liquid Fuels Directive (SCLFD)⁶. The revised SCMF Directive is linked to MARPOL Annex VI and sets the maximum permissible sulphur content of marine fuels used in SECAs and in EU Waters outside of SECAs.

⁵ Directive 2012/33/EU Of The European Parliament And Of The Council of 21 November 2012

⁶ Council Directive 1999/32/EC of 26 April 1999 relating to a reduction in the sulphur content of certain liquid fuels and amending Directive 93/12/EEC. OJ L 121, 11/05/1999 p.13-18.

2. Review of options for meeting the requirements

2.1 Introduction

This chapter examines the technical feasibility and associated impacts of three options to comply with the requirements of MARPOL Annex VI. Consultation with the operators and the UK Chamber of Shipping as well as a review of relevant literature indicates there are three realistic options open to operators for long term compliance with the requirements of the legislation. These are:

- **Option One: Fuel switching from ‘Heavy Fuel Oil (HFO), to Low Sulphur Fuel (LSF).** This option is technically feasible, with limited up-front investment costs (except for change of designation and use of some fuel tanks from HFO to LSF involving tank cleaning of those tanks). However, significant operational costs are likely to be incurred by operators, arising from the price differential between HFO and LSF; the latter being significantly more expensive. These increased operational costs are likely to be passed on, in the form of increased ticket prices to passengers and freight/container customers, given operating margins on the routes analysed. The potential effects arising from such an increase is the subject of chapter three and is not considered in detail here.

A consequential and wider issue relates to the impact of an associated increase in the demand for middle distillate fuel, and the ability of European refineries to meet this demand. In the event of supply constraints, import volumes from outside of Europe are likely to increase. Prices for all users of such fuels, including road users, are also likely to be affected.

- **Option Two: Retrofit of a scrubbing system to ships.** The consensus from the shipping operators that have been consulted as part of the study is that the currently available abatement technology is not sufficiently proven for ship owners to switch with confidence and demonstrate compliance *within the time period required by the legislation (i.e. by January 2015)*. This section collates operators experience with the technology to date and reviews publicly available information on the current status of the technology.
- **Option Three: Use of Liquefied Natural Gas (LNG) as an alternative fuel.** Alternative fuels may be applicable in some circumstances and the potential use of LNG has been assessed. Its use poses particular problems where existing ships would need to be retrofitted (which is understood to be unsuitable for much of the UK fleet) and is more appropriate for new build ships. This is an immature market and a lack of appropriate infrastructure or supply chain as well as uncertainty over prices means that this option therefore remains a concern for the industry.

A fourth option of switching to Methanol as a fuel and a fifth the use of exemptions are also briefly discussed.

2.2 Option 1: Fuel switching from 1% to 0.1% Sulphur fuel

Under Option 1, ship operators meet the MARPOL Annex VI sulphur emissions requirements by switching from current fuels (with 1% sulphur in SECAs since 2010) to low sulphur fuels (0.1% sulphur in SECAs from 2015).

Broadly, this means switching from fuels that are primarily constituted of residual oil to fuels that are primarily constituted of distillate oil. The specifications of the most common marine fuels are given in

Table 2.1.

This illustrates that, in general, reducing marine fuel content involves a shift away from residual to distillate oils. Currently, the only fuels that meet the 0.1%S requirements are particular grades of marine gas oil (MGO), all of which consist of 100% distillate.

This is expected to have a range of impacts on the shipping industry, especially for those operators sailing in SECAs, as well as on refineries and refined oil product markets more generally:

- **Impacts on shipping operators:** The main impacts on shipping operators are:
 - A requirement to change the designation and use of some fuel tanks from HFO to LSF involving tank cleaning of tanks that have been used for HFO storage over a number of years, so as to avoid blockage of filters and guard against the likelihood of machinery failures;
 - increase in fuel costs while sailing in SECAs, illustrated in see Section 4.2.3;
 - potential downstream market impacts linked to the ability of shipping operators to pass on these increased cost to their customers, via increased ticket prices;
 - potential impacts on vessel and route viability linked to these market impacts; and
 - potential losses of seafarer, shipping and ports jobs.
- **Impacts on refineries:** The main impacts on refineries are linked to the increase in demand on distillate oils, combined with a decrease in demand for fuel oils. The European distillate production capacity is currently unable to meet domestic demand for diesel and gasoil, and Europe as a whole is a net importer of these products. Under Option 1, the main choice facing refineries would be:
 - Substantial investment to convert residual oils into distillate oils; or
 - No change, which would necessitate an increase in diesel/gasoil imports, along with a corresponding increase in fuel oil exports.
- **Impacts on wider refined oil product markets:** The increase in demand for distillates is likely to lead to an increase in the price of diesel, which would have potentially important consequences for road users and the economy as a whole. (see Box 1).

Table 2.1 Specifications of the most common marine fuels

Industrial name	ISO name	Composition	ISO Specification sulphur weight %	Actual sulphur weight %	Price, \$/tonne (**)
Intermediate Fuel Oil 380 (IFO 380)	RMG380, RMH380	98% residual oil 2% distillate oil (*)	Statutory requirements (3.5% outside SECAs)	2.67% world average (*)	644.50
Intermediate Fuel Oil 180 (IFO 180)	RME180, RMF180	88% residual oil 12% distillate oil (*)	Statutory requirements (3.5% SECAs)	2.67% world average (*)	668.00
Low sulphur intermediate fuel oil (LS 380)	n/a	Not given	Not given	On market meeting 1% specification	693.50
Low sulphur intermediate fuel oil (LS 180)	n/a	Not given	Not given	On market meeting 1% specification	717.00
Marine Diesel Oil (MDO)	DMB	Distillate oil with trace of residual oil	2%	0.65% world average (*)	-
Marine Gas Oil (MGO)	DMA	100% distillate oil	1.5%	0.38% world average (*) On market meeting 0.1% specification	1,005 (0.1%S)
Marine Gas Oil (MGO)	DMX	100% distillate oil	1%	On market meeting 0.1% specification	1,005 (0.1%S)
Low Sulphur Marine Gas Oil (LSMGO)	n/a	100% distillate oil	Not given	On market meeting 0.1% specification	1,005

(*) Information published in 2007. Current values are probably different, reflecting regulatory changes since then.

(**) Prices from bunkerworld.com for 11 February 2013 at Rotterdam.

Source: ICCT (2007), based on Vis 2003, BP 2004, Exxon Mobil Marine 2006, CARB 2005. Updated in line with information on bunkerworld.com and ISO 8217 standards as published by Chevron.

This study focuses primarily on the impacts on shipping operators, according to a methodology and structure that is presented in Section 3. Impacts on refinery investment choices are briefly considered in Section 3.2.2 in order to assess how their reactions and investment decisions might affect shipping fuel prices. The predicted impacts on the European balance of trade in refined oil products are summarised in Section 3.3.

The wider market impacts on downstream users of refined oil products (e.g. on diesel prices for road transport users) are not assessed in detail in this report. However, the analysis of this impact in Sweden by Sweco (2012) is summarised in Box 1 which illustrates the potential scale of impact in the UK.

Box 1 Increased demand from shipping has the potential to increase prices for all users of diesel

The expected increase in demand for middle distillate oils, combined with supply side constraints at the European level, has the potential to increase fuel prices for all users.

This is particularly relevant for users of diesel road vehicles, since marine gas oil is very similar to road transport diesel. However, any price increase in road diesel would ultimately affect consumer travel choices, and would therefore have indirect impacts for all fuel users.

Sweco (2012) attempt to quantify the impacts of a potential switch to 0.1%S shipping fuel on road diesel prices in Sweden. Starting from their calculation that the expected price premium for low sulphur fuels in SECAs should be above \$350 per tonne in 2015, they equate this to a 4% pre-tax increase in the price of road diesel relative to the baseline price. They then calculate this to be equivalent to an increase of 0.8 SEK per litre of post-tax road diesel in 2015, or roughly €0.072.

Applying a similar analysis, assuming a 4% increase in the price of pre-tax diesel and using 2011 average UK diesel prices and tax rates yields an expected increase in road diesel post-tax pump prices of 2.8 pence per litre. The actual 2015 values are likely be higher than this, due to inflation.

Road diesel	2011 average	Data source
Pre-rise pump price (pence/litre)	138.81	DECC
Duty rate (pence per litre)	58.18	DECC
VAT rate (%)	19.95*%	DECC
Implied pre-tax price (pence per litre)	57.54	Calculation
Post-rise pre-tax price (pence per litre)	59.84	Calculation
Post-rise post-tax price (pence per litre)	141.57	Calculation
Pump price difference (pence per litre)	2.76	Calculation

According to HMRC⁷, around 26,000 million litres of diesel were consumed in the UK in 2011, meaning that such an increase in the diesel pump price would be equivalent to an overall additional cost to road diesel consumers in the region of **£720 million**.

* VAT rate changed to 20% from 17.5% during the period

2.3 Option 2: Feasibility of adopting abatement technology

2.3.1 Technical options (Scrubbers)

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 suitable sulphur scrubber. It is important to note that the evidence reviewed suggests that this approach does offer a potentially feasible option for some operators to comply with the SO_x limit for some of their fleet; and that systems can remove 90-95 % of SO₂.⁸ This evidence should be compared with the experience of operators who have both installed test bed prototype and full scale scrubber systems and those in negotiations with potential suppliers of the technology. In those instances where scrubbers have been installed, the evidence suggests that important design and operational

⁷ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65772/5953-dukes-2012-chapter-3-energy.pdf

⁸ Entec, 2010. Study to review assessment undertaken of the revised MARPOL Annex VI regulations. Study prepared for the ship-owner associations of Belgium, Finland, Germany, Holland, Sweden and UK and endorsed by the wider membership of ECSA and ICS.

lessons are still being learnt. Clearly the technology is continuing to develop and remains a likely long term solution. Given the lead in time required for the development, installation and testing of the systems, investment decisions for 2015 compliance would need to be made imminently. On that basis, this section provides an overview of the options, the implications of their use and draws on recent operator experience in using or procuring the technology.

Wet scrubbers

Wet scrubbers are typically located near to the funnel and mix water with the exhaust gas, reducing its sulphur content. They require a scrubber chamber, washwater treatment and sludge tanks, emissions monitoring systems, various pipes, pump and cooling equipment. Reheaters, used to increase exhaust gas temperatures, may also be necessary on certain ships.

Wet scrubbers are available as 'open loop' or 'closed loop' systems. The former pump seawater into the ship, which is then mixed with the exhaust fumes inside the scrubber system to reduce sulphur emissions. The seawater is then treated inside the ship and pumped out to sea. A SO_x removal rate of 98% would be required to ensure emissions from 3.5% sulphur content fuel would be equivalent to the use of 0.1% fuel, after scrubbing. Open loop systems typically weigh between 30 to 55 tonnes (excluding washwater and treatment systems) and consume between 1% and 2% of engine power⁹. Depending on the type of ship and how many scrubbers are fitted the water within the scrubber system could be as much as 250 tonnes, which can cause some vessels stability issues

Similarly, wet scrubber 'closed loop' systems scrub the exhaust gasses using use fresh water, treated with sodium hydroxide (NaOH), which removes SO_x as sodium sulphate. The used water then passes into a process tank, is cleaned and recirculated inside the system. Closed loop systems typically weight between 30 to 55 tonnes (excluding washwater and treatment systems and the required holding tanks) and consume between 0.5% and 1% of engine power. However, it is understood that not many 'closed loop' systems have been taken to market due to the extra cost involved over and above 'open loop' scrubbers. 'Hybrid' models (with both open and closed loop capability) are also available, and could typically be used as 'closed loop' in the Baltic Sea or in ports of high environmental sensitivity such as Gothenburg and as 'open loop' scrubbers in the North Sea. It is understood a hybrid system normally only has sufficient capacity to maintain the wash water on board for 2 -3 days.

Dry scrubbers.

Dry scrubbers use chemicals (typically calcium hydroxide granules that absorb exhaust gas particles) rather than water to scrub the exhaust fumes. These granules require storage on board, (both before and after use as they are not dissolved in the process) as well as appropriate delivery and storage infrastructure at port. The reaction is exothermic (heat releasing) so dry scrubbers are located before (i.e. beneath) waste heat recovery or selective catalytic reduction systems. These units typically weigh some 250 – 300 tonnes (including circa 150 – 200 tonnes of granules stored on board) and consume between 0.15% and 0.2% of engine power. The granules will need to be exchanged for fresh supplies every 10 – 14 days which presents a logistics challenge during port turnarounds. Additionally, these dry scrubbers will typically reduce the vessel's deadweight once retro-fitted and will likely use valuable cargo space so that up to 5 cargo units are required to be excluded. A cargo ship has recently had a dry

⁹ Lloyds Register, June 2012. Understanding exhaust gas treatment systems. Guidance for ship-owners and operators.

scrubber system retro-fitted to it and has added 3 – 4 large containers in front of the vessel’s accommodation as storage space for the granules. This may be possible on cargo freight ships, but this retro fit would not be possible on large RoRo passenger vessels nor would complement the vessel’s design. As such this operator told us they do not believe dry scrubbers are feasible for passenger vessels or passenger ferries.

2.3.2 Consultation Responses

As of January 2013, two of five operators consulted as part of the study, have installed scrubber technology; a full scale wet scrubber followed by test bed platform installation in one case and a full scale wet scrubber in the other. The remaining three operators highlighted commercial (cost and contractual), technical and practical concerns.. These are briefly summarised below Table 2.2.

Table 2.2 Scrubber status and experiences (January 2013)

Current Position/Operator	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5
Summary of status	No installations to date. Extensive discussion with potential suppliers. Offers for installation received.	No installations to date. Extensive discussion with potential suppliers. Offers for installation received.	Installation of full scale wet scrubber system installed 2003 which was unsuccessful and decommissioned in 2005. Full scale system covered 4 main engines and 4 generators. Installation of a test bed prototype wet scrubber fitted to one generator in December 2005 and removed in March 2012.	No data available	Installation of one full scale wet scrubber system (2009 - ongoing). Fire in scrubber whilst in dry dock (2009). First live test; discovered corrosion to pipe work requiring replacement (2010). Second fire in scrubber whilst in dry dock (2011). Melting of metal filing from exhaust damper failure; melting of plastic covering (2012). A System was operational only 73% of the time(January 2013).

Source: Consultations between the consultants and operators’.

Installation Experience

Feedback from operators that have installed scrubbers to date, have highlighted some operational issues, summarised below.

- Loss of revenue associated with installation: scrubber installations were not possible within standard maintenance windows. These take place every other year and take between two and three weeks, during which time the ship is out of service. These installations took between four and eight weeks, resulting in an additional time out of service of between two to six weeks out of service, resulting in some £300,000- £5,000,000 lost revenue depending on vessel type and trade.

- Length of time from installation to full commissioning. An open loop system was commissioned six months to one year after installation; a closed loop system some two and half years after installation¹⁰.
- Ongoing modification requirements, post installation. One of the five operators consulted noted, one full scale scrubber had been installed, "...its utilisation has been 73%, or some 8,300 running hours, during which time two fires have occurred whilst the ship was in dock.." These fires were caused by the use of plastic covering and coated steel piping on parts of the scrubber system. The operator is confident that these lessons have been learnt and these problems will not re-occur. Other more basic scrubber maintenance has been possible within standard maintenance windows, and has related mainly to pumps, valves, and a plate heat exchanger.
- The other operator consulted confirmed the installation of a full scale wet scrubbers in a system installed 2003 which was unsuccessful and decommissioned in 2005. This system was actually installed whilst the vessel was undergoing a 3 month major conversion but the operator estimates it would have taken six to eight weeks off service to fit. The four main engine scrubbers did not operate successfully and although the operator persevered with the scrubbers of the generator system, the scrubbing efficiency did not come close to design specification or the 0.1% sulphur requirement. As such the operator de-commissioned the system in 2005.
- The same operator then installed a test bed prototype wet scrubber on a generator in December 2005 which was finally removed from the vessel in March 2012. During this period the prototype scrubber had operated for a total of 35,000 hours and when operational met the 0.1% sulphur requirement. However, there were issues about the reliability of the system, lack of continuous running, and its maintenance requiring intervention by the crew and/or the manufacturer.
- A number of developments had been demonstrated by this second operator, notably the use of continuous monitoring of emissions at the funnel (IMO Scheme B) and the standards for sludge handling and washwater criteria which had later been agreed at IMO. It was acknowledged that the lessons learnt had been incorporated into the latest generation of scrubbers and this operator welcomed the development of multi-engine scrubbers, as an option which may be of benefit for multi-engine vessels.

Barriers to investment

Given confidentiality concerns, it is inappropriate to examine the issues each operator has encountered separately. There are, however, a number of common themes, as follows. It is important to note that these are the operators' opinions, which are based on their dealings with potential suppliers to date.

- Uncertainty over technical performance: In principle, the operators consider that both wet and/or dry scrubber technologies are potentially viable, but the risk of non compliance is, in their view, currently still too high. Insufficient technical detail has been received from the scrubber suppliers. In particular further technical details are needed on the:
 - Performance of the scrubber systems under different engine loads, at different exhaust temperatures and at various periods between maintenance schedules?

¹⁰ If take up of scrubbers increases then the commissioning period can be expected to reduce due to learning effects as the installers and operators become more familiar with the new technology.

- Performance effects of using fuels containing differing sulphur content?
- Frequency of nozzle plugging and effects of this on scrubber performance?
- Reaction speed of the scrubber in response to sudden change in engine load?
- Weight and dimensions of the scrubber system and auxiliary systems (and differences in weight between in use and idle)?
- Implications for existing sea water systems (for example flow speed variation, cavitations, erosion, connection on sea water crossover or on sea chests)?
- Impacts on exhaust gas boilers, for example do they cause backpressure, diminution of gaps flow, temperature increases, turbocharger speed or surging?
- Maximum or optimal durations of operation for closed loop and details of system reaction to extended periods in closed loop running?
- Effects of technology combinations, for example can the scrubber system be used alongside selective catalytic reduction (SCR) technology, and the effects of this on future SCR maintenance?
- Implications of future NO_x regulations and assessments as to whether further retrofit or upgrades are required?
- Operators have concerns about financial liabilities associated with their use and have been unable to accurately forecast the capital, operational and maintenance costs (including installation time) associated with the scrubber systems. Problematical areas include:
 - Space requirements of the systems and whether this may result in a loss of revenue generating space?
 - Forecasting additional power needs and costs. Operator assessments have indicated that the electrical power needs may require almost exclusive use of one of the auxiliary engines?
 - If dry scrubbing systems are used, the port facilities that will be required to dispose of chemical products. Operators have estimated the chemical consumption and costs, and estimate that around 40 tonnes may be required per week, pumped aboard using special equipment.
 - If wet scrubbing systems are used, fresh water consumption, storage and disposal needs are unclear.
 - Maintenance costs and expected operational lifetimes of equipment.
- Caveats and exclusions in suppliers' contractual offers, or scope of works. In a number of specific areas, operators perceive that these have either required them to take a disproportionate level of commercial risk, or prevented them from sufficiently understanding their commercial risk.
 - Installation of the scrubber systems have been the ship owner's responsibility. Limited technical guidance or specifications have been provided, which could be passed on to the shipyard, to aid the installation process.

- Insufficient clarity has been provided on, for example, delivery time and duration of installation; the requested contractual time allowances for supplier repairs and performance failure have been, in the operator's view, substantial and are likely to have operational implications. Insufficient guarantees of functionality have been received, and these have predominantly been for test systems only.
- Contractual stipulations for performance guarantees have not, in the operator's view, been satisfactory.
- Further technical detail has been contingent on performing an initial test study.
- Inability to install the system within the standard maintenance windows or during major refit period (typically the latter are of two to three week duration, every two years). Operators have estimated that installation will occupy all of this time and a further 4-5 weeks (alongside other work) to allow the shipyard to complete installation, with approximately three further days testing at sea.
- Operators who have approached shipyards to discuss installation have received what they consider to be insufficiently firm offers, due to their inexperience with the technology.
- Deadweight and age of vessel. On ships that are older than 20 years, operators do not consider that the revenue generating potential of the ship justifies expenditure that would be required to install a scrubber. It is likely that such ships would therefore be sold. In addition, the weight of the scrubber system, may affect the deadweight of the vessel and hence the volume of freight/passengers carried.
- The Europe wide recession is further limiting operators' ability to raise suitable finance.

A proposal to reduce the current pH 6.5 limit for wash-water discharges when ships operate in the open sea was recently discussed at the 17th meeting of the IMO's Sub-Committee on Bulk Liquids and Gases (BLG 17) (4 to 8 February 2013). Denmark presented a paper to BLG 17 suggesting achieving the pH 6.5 limit set in the 2009 guidelines is not possible for seawater scrubbers operating in open loop mode, and said research showed that pH 3 in washwater at sea presented no environmental threat. There are diverging views over whether the pH values of the discharge water from open loop scrubbers operating at full power in open sea comply with the wash water criteria. Therefore the BLG Chairman concluded that it is important to find out if current scrubbers exist which can meet the pH 6.5 discharge limit when operating in open loop mode before a change in regulation can be considered by the Marine Environment Protection Committee (MEPC). This uncertainty over the performance of open loop scrubbers and the likelihood of future changes to wash water criteria regulations is a further cause for hesitation in operators' investment decisions. Furthermore, if a failure to adjust the pH limit does rule out several currently available systems from the market this would further restrict short term supply of suitable scrubber technologies.

2.3.3 Technical Assessment of Scrubber Technology

Entec 2010. Study to Review Assessments Undertaken of the Revised MARPOL Annex V1 Regulations.

Entec (now AMEC) prepared a review of six studies¹¹ which examined the effect of revisions to IMO's MARPOL Annex VI regulation, in June 2010. This included an assessment of scrubber technology and usage at the time, which is summarised below. These studies have been prepared for a number of EU member state governments and are hereafter referred to by the nationality of that government.

As noted above, the most common type of scrubbing options for marine applications is sea water scrubbing (SWS) or open loop wet scrubbing systems. The Sweden (2009) and Finland (2009) reports acknowledge the limitations of using sea water scrubbing (SWS) in the Baltic Sea, for example, where alkalinity is lower than normal because of the minimal exchange of water through the Danish straits (it is usually constant and high). 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. Sweden (2009) notes that closed fresh water scrubbers may be more appropriate/acceptable, but are more expensive than open systems, can create work environment safety problems and require facilities in ports for handling sludge. The UK (2009) report notes that this technology is less well developed than the use of sea water (open loop) 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.

Both UK and Finland (2009) remark that there are currently few manufacturers in the scrubber market, likely to be linked to limited demand (UK 2009) and production capacity. The UK report concludes that as demand increases, so too will production capacity, however manufacturers are unlikely to invest in sufficient capacity to meet all demand before 2020. 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 percentage uptake

¹¹ The six studies reviewed and the references assigned dot these are as follows:

- Entec (2009): Impact Assessment for the revised Annex VI of MARPOL (prepared for the Maritime & Coastguard Agency, UK). [hereafter referred to as "**UK (2009)**"]
- 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)**"]
- ITMMA University of Antwerp & TM Leuven (2010): Analysis of the Consequences of Low Sulphur Fuel Requirements (prepared for the European Community Shipowners' Associations). [hereafter referred to as "**ECSA (2010)**"]
- AEA Technology, TNO, IVL & EMRC (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 (prepared for the European Commission). [hereafter referred to as "**ECa (2010)**"]
- SKEMA (draft April 2010): Impact study of the future requirements of Annex VI of the MARPOL Convention on Short Sea Shipping (prepared for the European Commission). [hereafter referred to as "**ECb (2010)**"]

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 concur 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 SO_x 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) and clearly depends on ship design/size;
- 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 system¹² however, issues of high back pressure on the engine could arise. Note that this would only be an issue for new vessels covered by the tightest NO_x controls;
- Fuel consumption penalty associated with the operation of the unit; and
- New Technology – uncertainty over costs and technology.

The UK (2009) 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%).

None of the reports examines issues of reliability of scrubbing systems in detail, primarily as it is a relatively new technology with limited applications and hence empirical data. In instances where scrubber systems fail whilst the ship is at sea, the vessel would be forced to change over to an alternative fuel with appropriate 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

¹² Such a configuration is unlikely as the catalyst in the SCR will be poisoned if the exhaust gas has a high sulphur content, therefore SWS is more likely to be fitted before SCR to mitigate this. The exhaust may need to be reheated after the SWS to meet the operating criteria of the SCR unit.

different levels of sulphur content. ECa (2010) state that there is limited data on the performance of marine scrubbers and it is important to conduct more trials.

2.3.4 Cost estimates

The 2011 study reviewed costs associated with the installation of and use of scrubbers. The findings have been summarised here. 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. The reports concur that scrubber costs will be considerably 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) include information on scrubber costs in their analyses, supplemented with more recent costs estimates, taken from consultation with several operators in January 2013 (Table 2.3 and Table 2.4).

Table 2.3 Comparison of scrubber costs and assumptions (from Entec 2011 review)

Study	Key Assumptions	New Build Capex (€/kW)	Retrofit Capex (€/kW) (Note 1)	Abatement Efficiencies	O+M Costs
UK (2009)	<ul style="list-style-type: none"> Focuses on SWS (2009 prices) Assumed capital costs of installing scrubbers to main engine only (separate costs given for combined installation to main and auxiliary engine) Expected lifetime: 25 years Fuel consumption penalty: 1.5% Sensitivity scenario has been considered whereby scrubber costs reduce by 50% due to increased commercialisation. 	122	156	SO _x up to 95% reduction. PM up to 80%	Per year: small: 3%; medium: 2%; large: 1%
ECa (2010)	<ul style="list-style-type: none"> Separately considers prices for open/ closed scrubber systems (2005 prices) For closed systems, purchase of NaOH and fresh water are taken into consideration. NaOH cost: €0.5/litre 50% NaOH For SWS maintenance costs and fuel penalty are taken into account. Expected lifetime: 15 years for new, 12.5 for retrofit Fuel consumption penalty: 2% 	100-200	200-400	Assumes abatement up to 97%	k€/vessel (15MW): 28 (incl sludge disposal costs of €0.12/ litre)
ECb (2010)	<ul style="list-style-type: none"> Focuses on SWS (2009 prices) Cost data based on Entec (2005) report for the European Commission with 10% reduction applied to account for new manufacturers of scrubbers entering the market. Expected lifetime: 15 years 	118	168	Range based on scrubbers from different manufacturers: SO ₂ 93-100%; PM 50-85%	€/MWh: small 0.8; medium 0.5; large: 0.3

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.

Table 2.4 Costs estimates from industry consultation (January 2013)

Current Position/Operator	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	UK Chamber of Shipping/Average
Capital Cost Estimates (per unit)	£6 million	£6 million*	Confidential	No data received	£9 million	£7 million
Operational Cost Estimates (per installed unit, per year)	£500,000	£700,000*	Confidential	No data received.	£3 million**	£1 million

Source: Confidential consultations between the consultants and operators'. *Based on an average, operational costs are estimates from the operator. **Broad estimates based on lost revenue incurred from ship being out of service during installation and power requirements. Note: where data has been provided in Euros, these have been converted to pound sterling using exchange rate at December 2011.

2.3.5 Conclusions

Exhaust gas scrubbers are an emerging technology for shipping. A number of barriers to investment are still to be over-come before take up is likely to become widespread. The consensus from the shipping operators that have been consulted as part of the study is that the currently available abatement technology is not sufficiently proven for ship owners to switch with confidence and demonstrate compliance *within the time period required by the legislation*. As such this would appear to be an unrealistic option for achieving compliance by 2015.

2.4 Option 3: Alternative Fuel (LNG)

The use of liquefied natural gas (LNG) is a third potential option for MARPOL Annex VI compliance. LNG is naturally sufficiently low in sulphur that it is understood that its use would meet the requirements. Use of LNG would require some engine modification and upgrading of fuel tanks on board ship. In addition port operators would need to provide storage facilities and fuelling facilities at port.

2.4.1 Consultation Responses

As with scrubbers, consultation with the operators has highlighted a number of viability concerns, summarised below;

- Uncertainty over future LNG fuel prices. There is concern that as LNG becomes established as a shipping fuel, prices will be pegged to the price of LSF and therefore increase quickly and hence any cost saving brought about by using LNG rather than purchasing scrubbing equipment or using LSF may be temporary.
- Costs of retrofitting existing ships are considered prohibitively expensive. Estimates have been provided of between €12- €16 million (£10-£13 million) for retrofit of ship with one main engine and four auxiliary engines, meaning that LNG has not been seriously considered for existing ships. Costs for dual fuel use are also considered to be prohibitively high. The associated costs of transportation and storage are also unclear.

- Concerns about supply capability and resilience. The operators' view is that LNG suppliers have not/will not establish the infrastructure required to support its widespread use, until demand increases. There are three basic options for transportation and bunkering of LNG:
 1. Transportation by road and direct filling at port from a LNG tanker. This is relatively easy to establish, but it is not practicable or cost effective for quantities required greater than 20 tonnes.
 2. Transfer LNG from a terminal to ship, via a pipeline and loading arm. The infrastructure required is complicated and expensive and cannot be carried out in all harbours (reflecting the requirements of the Seveso¹³ regulation). This is more suitable for larger volumes (up to 1,300 m³ or more).
 3. Ship to ship (i.e. via a seaborne LNG tanker/barge, residing at port). This is considered the most practicable long term option. However, this requires a sufficient volume of LNG traffic, more than currently exists. Operators expressed concern about the upfront costs of commissioning barges and setting up the infrastructure and were concerned that these costs would fall largely on them. For operators sailing into ports with higher volumes and more users, costs may be more widely spread.
- The product is cryogenic and flammable, for ports that are in close proximity to urban areas; challenges are expected regarding permitting for the transportation and storage of LNG.
- One operator is designing the technical scope of a new vessel that will be able to run on LNG, alongside an MGO/LSF. The capital costs of the ship is likely to be substantially greater than both the cost of conventional (HFO/MO(LSF)) and scrubber fitted equivalents. The ship will not be delivered until after 2015 and is at research and development stage only.

2.4.2 Technical Assessments

Entec 2010. Study to Review Assessments Undertaken of the Revised MARPOL Annex V1 Regulations.

Of the six MARPOL impact studies reviewed, one (UK 2009) reviewed Liquefied Natural Gas (LNG) as a potential option for MARPOL Annex VI compliance. The report concludes switching to LNG is not considered a compliance option because of the small scale of potential uptake of LNG and the short/medium term barriers to implementation.

2.4.3 Conclusions

LNG is a more expensive option compared to scrubber technology or switching to LSF, but better from an environmental standpoint and would result in co-benefits from reduced greenhouse gas emissions. The greatest short term technical challenge is the delivery and provision of LNG in suitable quantities rather than the technical feasibility (although costs are high and depend on the configuration of the affected ship).

LNG may become competitive, in the mid to long term, if suitable infrastructure is in place (LNG terminal or ship to ship). LNG could become the most appropriate choice beyond 2020, where sulphur limits will be 0.5% outside

¹³ Council Directive 96/82/EC on the control of major-accident hazards –(Seveso II Directive)

<http://ec.europa.eu/environment/seveso/index.htm>

ECA, although this depends on the price and availability of HFO. The European Commission is proposing that LNG refuelling stations be installed in all maritime and inland parts of the trans-European (TEN-T) core network by 2020 (2025 for inland ports), a total of 139 ports which account for about 10% of all EU ports. However, consensus is that it is not viable for existing vessels to be retrofitted to use LNG. Therefore, this LNG strategy supported by the Commissions will not lead to significant numbers of LNG vessels until ship-owners commence building new ships as part of a fleet renewal plan. As such it is not considered a viable option for existing vessels to comply with the 2015 0.1% Sulphur requirements in the Baltic/North Sea/Channel SECA

2.5 Option 4: Methanol

The use of Methanol as a fuel is currently being explored by some operators although retrofitting / conversion from HFO would be required with a high associated cost. The potential benefits of methanol as a fuel are said to include lower emissions of particulates and NOx. In addition, the increasing interest in methanol as a road transport fuel may soon lead to an opportunity for the shipping industry. However, Methanol is not currently widely available and it is perhaps too early in the R&D cycle to be considered suitable as a significant option for the industry at present. Given the short timescales between now and January 2015 methanol is unlikely to represent a significant means of meeting the new regulations right away but may of course develop as an alternative to switching to low sulphur fuels in the future. Methanol is beyond the scope of this report and has not been explored further.

2.6 Option 5: Use of Exemptions

The UK Chamber of Shipping favours the “implementation of tightly controlled route and time specific exemptions” once the 0.1% Sulphur requirement in SECAs comes into force in January 2015. The UK Chamber believe such exemptions offer the most realistic option to protect important UK trade routes, UK jobs, UK companies and the environment whilst preventing a predictable modal back shift from sea to land.

2.7 Conclusion

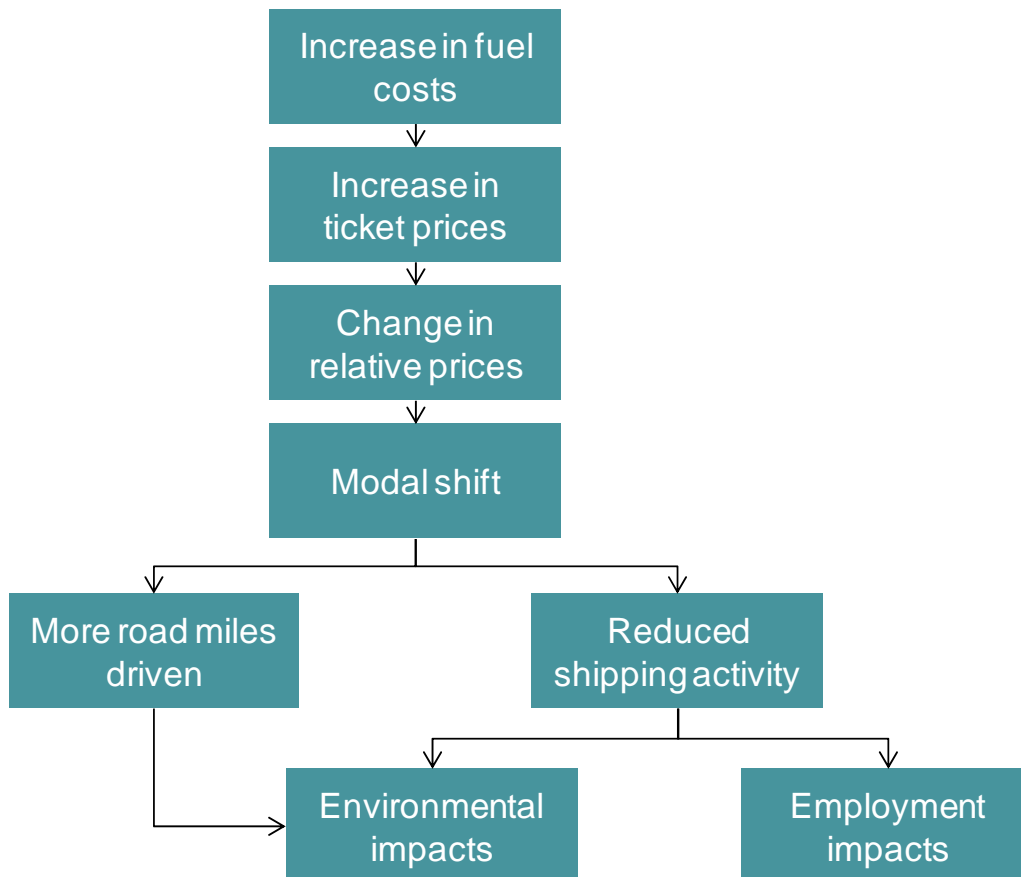
Given the technical and practical unavailability of LNG and scrubbers in the immediate future the only viable means of meeting the requirements of MARPOL Annex VI will be through switching to lower sulphur fuel.

3. Analysis of the economic impact of switching to 0.1% Sulphur fuel

3.1 Overview

This section explores the economic and environmental impacts of the fuel switching option set out in the previous chapter. First, the anticipated costs associated with fuel switching are established. This is based on a review of available information on the costs associated with different types of fuel. Second, the effect of increased demand for middle distillate fuels on European refineries and fuel imports is considered, which has the potential to increase the cost of such fuels. Third, we consider the effect on fuel costs borne by operators on particular shipping routes and how this is expected to manifest in increased ticket prices for freight and passengers. Fourth, we consider how these ticket price increases can be expected to affect haulier (and to a lesser extent passenger) route choice and the extent to which modal shift may occur between longer sea routes to shorter seas routes, with the associated increase in road miles travelled in both the UK and on the continent from this traffic. Fifth, economic and environmental externalities associated with these road miles are considered.

Figure 3.1 Analytical approach



3.2 Costs associated with fuel switching

3.2.1 Previous studies on price impacts

There have been a number of studies attempting to forecast the marine fuel price impacts of the MARPOL Annex VI Regulations. A comprehensive review of these is provided by Entec (2010), which summarises the following:

- Entec (2009): Impact Assessment for the revised Annex VI of MARPOL (prepared for the Maritime & Coastguard Agency, UK). [hereafter referred to as “**UK (2009)**”];
- 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)**”];
- ITMMA University of Antwerp & TM Leuven (2010): Analysis of the Consequences of Low Sulphur Fuel Requirements (prepared for the European Community Ship owners’ Associations). [hereafter referred to as “**ECSA (2010)**”];
- AEA Technology, TNO, IVL & EMRC (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 (prepared for the European Commission). [hereafter referred to as “**ECa (2010)**”]; and
- SKEMA (draft April 2010): Impact study of the future requirements of Annex VI of the MARPOL Convention on Short Sea Shipping (prepared for the European Commission). [hereafter referred to as “**ECb (2010)**”].

These can also be supplemented by more recent studies, published since the Entec (2010) review. These include:

- Bartholomew & Panagiotopoulos (2011): Options for lower-sulphur marine fuels (prepared for digitalrefining.com);
- Purvin & Gertz (2011): Supply and pricing of low sulphur fuels (prepared for the Interferry 36th Annual Conference, Barcelona, 3-6 October 2011); and
- Sweco (2012): Consequences of the Sulphur Directive (October 2012).

All the studies above recognise the difficulty in forecasting such price changes. This goes beyond the difficulty inherent in price forecasting in general, as it depends critically on the behaviours and investment decisions of both shipping operators and refineries.

The key considerations for these actors are briefly described below, in order to present a context in which the price forecasts found in the literature can be presented and interpreted. These are then used to select working figures for this study.

3.2.2 Uncertainties and assumptions

Shipping Operators

For shipping operators, the key uncertainty is as to whether to install scrubbers or not. The advantages of scrubbers are that SECA sulphur emissions requirements could be met by using cheaper high sulphur marine fuel oil such as IFO 180 or IFO 380 (HFO). However, this would require significant capital investment (the cost of installation and taking the ship out of service is of the order of 6M Euro) and scrubbing remains a technology with limited track record and reliability issues to overcome in practice.

So far, all the studies reviewed assume that shipping operators will not install scrubbers in the near-term. For example, Sweco (2012) assume that most shipping lines will delay installing scrubber technology until there are more certainty over the performance of scrubbers and clearer indicators of the cost difference between the use of low sulphur fuel and the installation of scrubbers to achieve the same reduction of SO₂ emissions.

Therefore, a near-universal expectation is that marine sulphur emissions limits in SECAs from 2015 will be met via a switch to 0.1%S fuels.

Despite this, it remains recognised that, should the price differential between 1% S MFOs and 0.1%S distillates be large enough, and as scrubbing technology becomes more technically and economically viable, an increasing proportion of ship operators may eventually install scrubbers. This is particularly the case given that installing scrubbers on new ships is a lot cheaper than retrofitting them onto existing ones (Bartholomew & Panagiotopoulos, 2011). As such, the proportion of ships with scrubbers installed would be expected to naturally increase in time as older ships are retired and replaced by newer ones.

Refiners

For refineries, the key uncertainty is as to how they might meet the increased demand for 0.1%S marine fuel. Broadly, there are two ways in which this can be achieved;

- The first option, used traditionally, involves refineries reducing the sulphur content of MFO by blending it with increasing proportions of low sulphur distillates
- Bartholomew & Panagiotopoulos (2011) relate the rule of thumb that current intermediate fuel oil (IFO) is a blend of 75% MFO with 25% distillate. They expect that meeting new 0.1%S requirements will lead to these proportions being reversed, i.e. that distillates will replace the great majority of MFO in marine fuel. This rule of thumb is in line with other assessments, such as that by ICCT (2007), presented in
- The second option involves converting heavier residual oil (resid) into 0.1%S fuel useable in ships. This can be achieved by desulphurisation of resid to produce low sulphur MFO; or by converting resid into lighter distillate grades using techniques such as coking or hydrocracking. This has two main advantages over blending in that it (i) does not reduce the overall supply of distillate, for which there is a relative shortage that stands to be further exacerbated by ships switching to 0.1%S fuels; and (ii) utilises the heavier residual oil, for which there is an over-supply that also stands to be increased by such a switch. However, both desulphurisation and coking/hydrocracking would require many

refineries to undertake significant capital investments. These have been estimated by Purvin & Gertz (in Sweco, 2012) to be in the range of \$0.5-1 billion per refinery, with a lead-time of 3-4 years. Similarly, Deloitte (2010) have estimated these costs to be in the range £440-770 million per refinery. It is worth noting that some analysts do not consider cokers to be a fully commercially mature technology (Sweco, 2012).

In this context, the preferred option for refineries would be for ships to install scrubbers and keep using high sulphur MFO. This would allow them to avoid the significant capital investment costs while maintaining their customer base for heavier residual oils. For this reason, it might be expected that refineries will be reluctant to invest in desulphurisation or coking/hydrocracking technologies until the regulatory and market conditions have stabilised and that shipping operators' responses are known, especially regarding the uptake of on-board scrubbers (Sweco, 2012, Purvin & Gertz, 2009).

Working assumptions

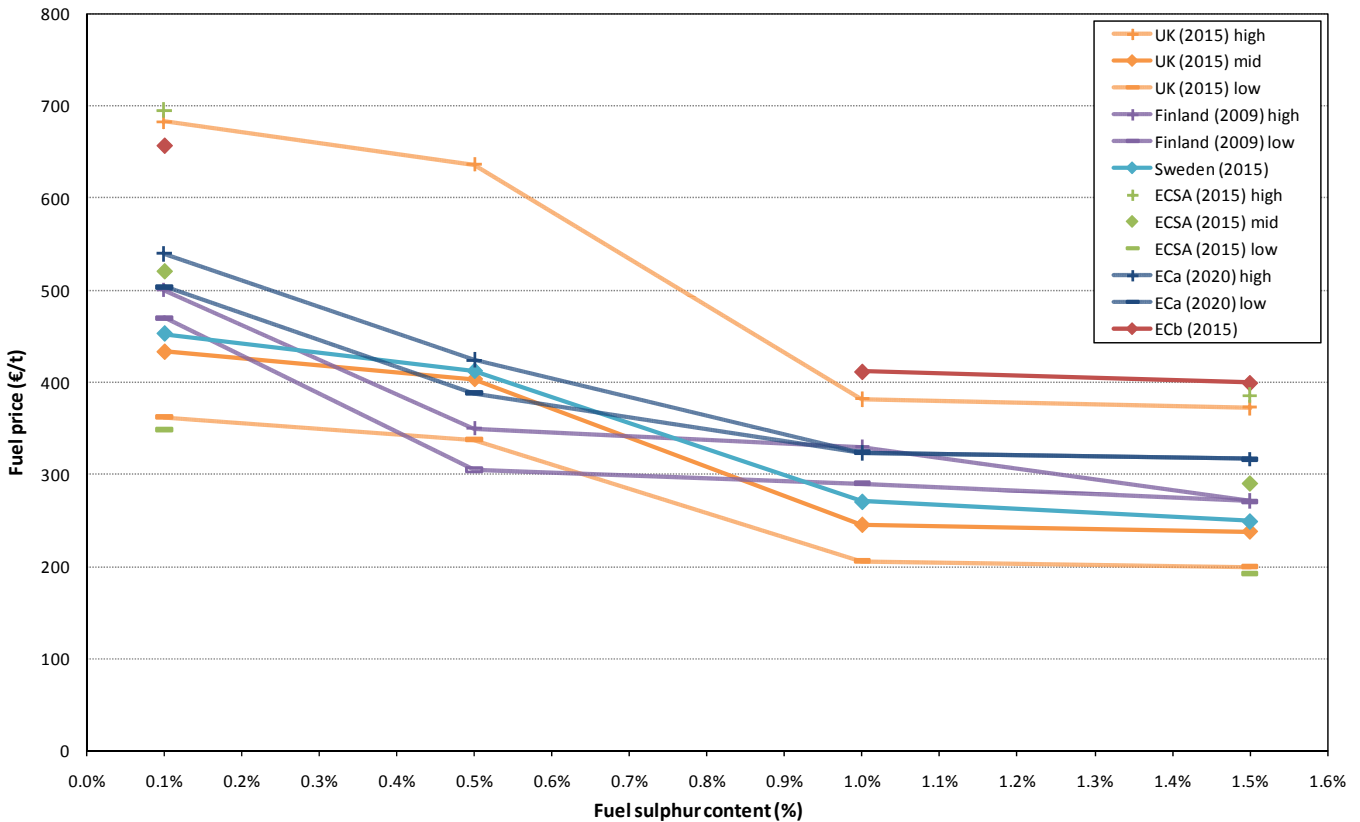
In line with the ship operator and refinery considerations presented above, our main working assumption is that both shipping operators and refineries will delay any substantial investments (in scrubbers and hydrocracking respectively) until there is greater certainty regarding the relative fuel prices between 1% S marine fuel and 0.1% S marine fuel (as well as confidence that scrubbers are reliable enough to achieve compliance). More specifically, our assumptions for 2015 are:

- Shipping volumes remain at 2011 levels;
- All shipping operators in the EU SECAs meet MARPOL Annex VI regulations by switching to distillate-grade fuel (low sulphur MGO), i.e. there is no immediate uptake of scrubbers or LNG;
- EU refineries do not undertake any immediate investments in resid desulphurisation, coking or hydrocracking; and
- Any increase in distillate demand for shipping that cannot be met by EU refineries is imported (see Section 3.3.2 below).

3.2.3 Price difference forecasts

All of the studies presented above provide some forecasts for the difference in price between low and high sulphur marine fuel, although the exact definitions sometimes differ, according to the exact sulphur content. Entec (2010) uses the price data and forecasts in the studies it summarises to produce a graph of fuel prices as a function of sulphur content, as presented in Figure 3.2. This graph presents an expected differential between 0.1%S fuel and 1%S marine fuel for 2015 in a broad range of €150-300 per tonne.

Figure 3.2 Assumed fuel prices (€/tonne) as a function of fuel sulphur content (%)



Source: Entec (2010)

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.

The more recent studies also present some predicted values for such price differentials:

- Sweco (2012) estimate that the price premium for low sulphur fuels (mainly diesel) in the SECAs (i.e. the difference between 0.1%S and 1%S fuel) will rise from a “current” value of \$290 per tonne to “more than” \$350 per tonne in 2015;
- Bartholomew & Panagiotopoulos (2011) predict a price spread between 0.1%S distillate marine fuel and 1%S fuel oil of \$24 per barrel. This is roughly equivalent to \$320 per tonne¹⁴; and
- Purvin & Gertz (2011) predict a price differential between North West Europe gasoil and 1%S fuel oil of about \$275 per tonne in 2015.

¹⁴ This assumes 0.1%S distillate density of 890 kg/m³, 1%S MFO density of 920 kg/m³ (both from ISO 8217 fuel standards for 2010), and a 1%S MFO price of \$660 per tonne (from consultation).

3.2.4 Conclusions

The range of values in the three most recent studies is therefore **\$275-350 per tonne**, with an average of **\$315 per tonne**, which is consistent with the literature and consistent with current price differentials experienced by operators. It is therefore the range and expected value adopted in this study.

3.3 Effect of increased demand for middle distillate fuels on European refineries and fuel imports

3.3.1 Current trends

The oil extraction and refining market is a global one, with traded products making up around 20% for gasoline products and 50% of heavy fuel oil. The trade in refined oil products is important in balancing regional/national refinery supply with demand. Countries where refining capacity is small or otherwise unable to match local demand rely upon trade flows to meet these¹⁵.

In recent years, Europe has been a net importer of kerosene and diesel/gasoil and a net exporter of gasoline and heavy fuel oil. This reflects European demand for gasoil/diesel increasing strongly between 1996 and 2006, with demand for gasoline declining¹⁶. Sweco (2012) report that the diesel deficit in Europe amounted to 30-40 million tonnes per year in early 2012 (equivalent to 300-400 TWh). This has resulted in increased imported gasoil products (particularly from Russia and the former Soviet Republics) whilst surplus gasoline has been exported to the US, where demand has grown strongly. Similarly, gasoline demand is expected to grow strongly in Africa and the Middle East, some of which will be met by European refineries. However, these exports are likely to face increasing competition from other exporters, reflecting increases to Middle Eastern and Indian refining capacity. In terms of gasoil/diesel, European imports are expected to continue to increase.

For heavy fuel oil, Europe has recently been a net exporter, reflecting a surplus in production relative to domestic demand. This has been primarily driven by a move away from heavy fuel oil in the power generation sector, especially following on from the introduction of the Large Combustion Plants Directive¹⁷ (LCPD). Similarly, industrial users of heavy fuel oil have been switching to alternatives such as natural gas. It is thought the majority of European heavy fuel oil surplus has been exported to Asia (Purvin & Gertz, 2009).

These patterns and expected trends are presented in Figure 3.3, from Purvin & Gertz (2009). Overall, the recent pattern is expected to continue up to 2020, with the exception of heavy fuel oil, for which Europe is expected to shift from being a slight net exporter, to a slight net importer, reflecting announced refinery investments to reduce

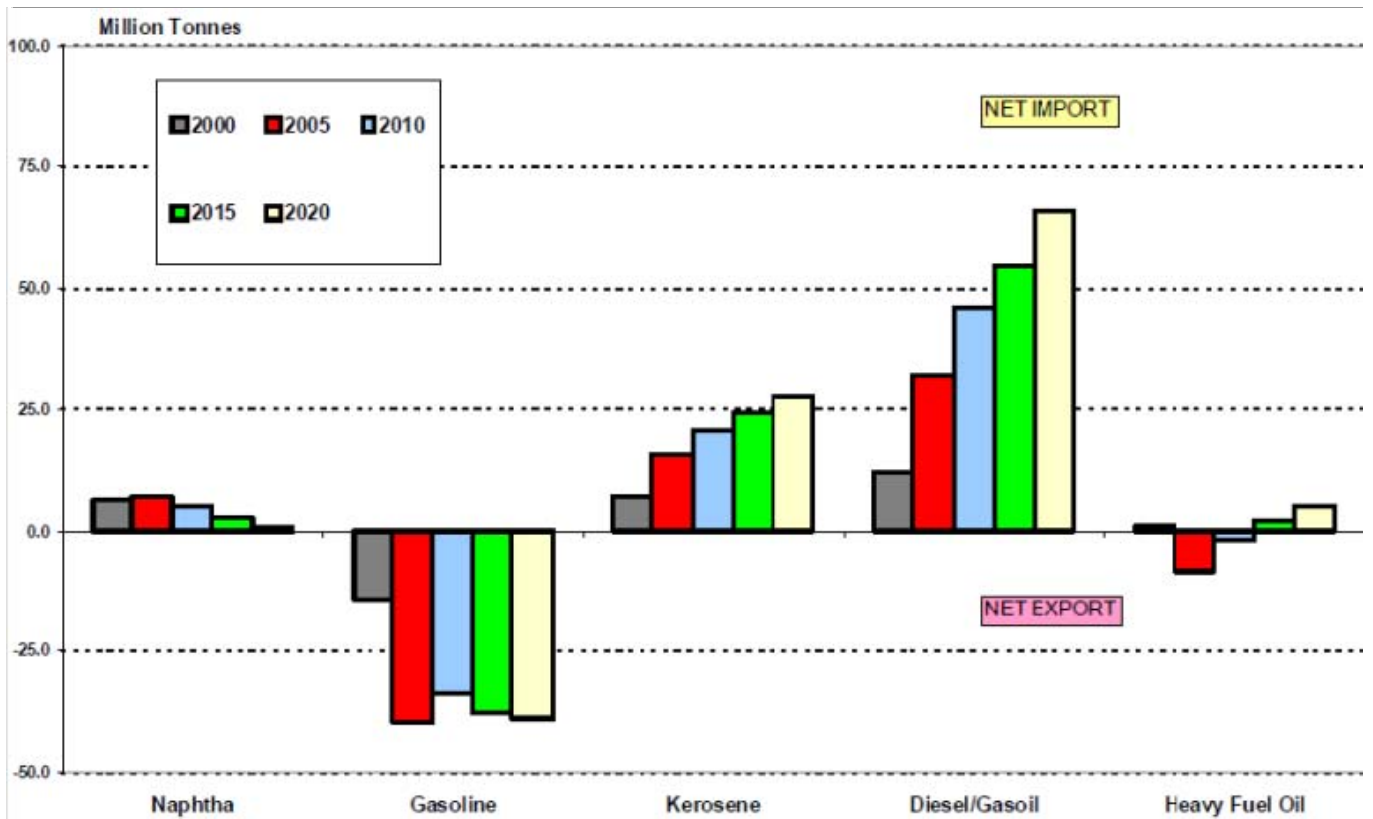
¹⁵ Study on oil and oil refining, Purvin and Gertz Inc. 2008.
http://ec.europa.eu/energy/observatory/oil/doc/refining/2008_01_study_oil_refining_oil_markets.pdf

¹⁶ Figure A-1-1. Study on oil and oil refining, Purvin and Gertz Inc. 2008.
http://ec.europa.eu/energy/observatory/oil/doc/refining/2008_01_study_oil_refining_oil_markets.pdf

¹⁷ Directive 2001/80/EC on the limitation of emissions of certain pollutants into the air from large combustion plants.

heavy fuel oil production with a view to balancing European supply and demand. Most importantly, the gap between European demand and production of diesel and gasoil is expected to widen, thus driving greater net imports of middle distillate grades of fuels. It is important to note that these are baseline expected trends, i.e. *before* any shift in shipping fuel use.

Figure 3.3 Net European Trade Flows of Oil Products, 2009 estimate



Reproduced from: (Purvin & Gertz, 2009:42).

In the longer term, major investments in refining capacity are expected in China, the Middle East and India, which is expected to have substantial implications for European refiners as the quantum of exported products will increase, putting downward pressure on prices (albeit from a currently very high level). This may disincentives investment in plant and capacity; increasing the likelihood that products will be imported from elsewhere.

3.3.2 Impacts on refineries of increased distillate demand from shipping

As presented in Section 3.2.2, it is expected that refineries will be reluctant to invest in desulphurisation or coking/hydrocracking technologies until the regulatory and market conditions have stabilised and that shipping operators’ responses are known, especially regarding the uptake of on-board scrubbers (Sweco, 2012, Purvin & Gertz, 2009).

3.3.3 Conclusion

It is expected that the entirety of increased demand for distillates will be met from imports, thus exacerbating the current trend in that direction. Similarly, the reduced demand for MFO this implies is expected to result in more exports of heavy fuel oil from Europe. This alone may be sufficient to bring Europe from being an expected net importer of heavy fuel oil in 2015-2020 (Figure 3.3), back to being a net exporter.

3.4 Impact on ticket prices

3.4.1 Introduction

This section explores the impact of the increase in fuel prices on the ticket prices charged to RoRo freight traffic, unaccompanied trailers (UT), container shipping and passengers. The approach has assumed that 100% of any fuel price increase would be passed on to customers. This is based on discussions with the operators. In addition, a data proforma was agreed with five operators, who subsequently provided a range of information on western channel and North Sea routes. This included information on categories of freight and passengers carried, fuel use, fuel prices, revenues, operating margins, number of trips and distances travelled and current ticket prices. This information has formed the basis of the analysis presented here.

All data is based on 2011¹⁸ as at the time of data collection, this was the last full year for which data was available. It is presented in pound sterling, using exchange rates prevailing at December 2011, where applicable. All but three of these routes relate to trips taking place entirely within the SECA. The analysis assumes that where journeys take place beyond the SECA boundary, operators will switch from using LSF to HFO, and therefore not incur additional fuel costs. The information has been made available on the basis that commercially confidential data would not be presented in the final report; hence the results are anonymised and in summary form. Moreover, whilst operators have provided standard information, it has been derived in slightly different ways. These differences are explained in footnotes to the text.

The selected routes comprise a total of nineteen RoRo, RoPAX and container services operating from thirteen ports in England and Scotland and to France, Spain, Sweden, Denmark, Germany, Holland, Belgium and Poland. The routes analysed relate to some 4.6 million kilometres travelled at sea, from a total of 38 ships making some 1,200 journeys and using 1.6 million tonnes of HFO, alongside some 10,300 tonnes of MGO (LSF). In total, some 3.3 million passengers, 500,000 lorries, 100,000 unaccompanied trailers (UT) and 110,000 containers¹⁹ were carried on the routes analysed.

¹⁸ In a small number of instances, data was provided for financial rather than calendar years. For the purposes of the assessment, data for '2011-2012' has been treated the same as data for '2011' as the data has been used to estimate typical costs and volumes carried in a twelve month period.

¹⁹ All information was based on 2011 data.

3.4.2 Overview of Approach and Key Assumptions

The data which was received from the operators has been collated and analysed in a series of steps, which are explained below.

Information on existing operations and costs

- Fuel costs: data was provided on the total fuel use (tonnes), per ship, per route for 2011 broken down by usage of both Heavy Fuel Oil (HFO) and Marine Gas Oil (Low Sulphur Fuel (LSF)). In addition, information on the prices paid for these fuels, again in 2011, were given (typically annual average fuel prices, per tonne). These figures were multiplied to provide a total annual fuel cost, per ship, per route. Details of existing total revenues, annual numbers of sailings were also provided, per ship and route.
- Freight volumes and passengers carried: operators provided details of the total number of passengers, lorries, unaccompanied trailers and containers carried by route, ship and year.
- Ticket prices: 2011 ticket price data was provided, for passengers, lorries, UTs and containers.²⁰

Estimating future costs associated with MARPOL Annex VI compliance

- Estimating future fuel costs: the additional cost per tonne that operators are expected to pay for LSF under the three price scenarios (that the price will increase by \$275, \$315 or \$375 described above has been added to the price that operators paid for HFO, per tonne in 2011. No allowance has been made for substantial differences in fuel efficiency or calorific value. This revised fuel price is then multiplied by the total quantum of HFO fuel used, per ship and route to provide an estimated annual fuel bill, assuming the MARPOL Annex VI restrictions are in place. This is then subtracted from the 2011 fuel bill to indicate the total 'revenue gap' that would need to be recouped from ticket sales, if existing operating margins are to be maintained. The total HFO fuel bill for 2011 was £160 million; the total future fuel bill, assuming the current configuration of ships and distances remain unchanged, would be some £230 million; resulting in a revenue gap of some £70 million²¹.
- Apportioning increased fuel costs to freight and passengers carried (details of the approach used and a hypothetical example are provided below and in Table 3.1):

²⁰ This information has been provided in slightly different ways, depending on the data collections methods of the respective operators. For one operator, 2011 average passenger ticket prices were derived by total revenue generated from passengers, divided by the number carried. Another operator provided revenue generated from Lorries, per 'Lane-metre' (i.e. per metre of used garage space). In this instance, ticket prices were estimated by applying a revenue per lane metre, multiplied by an estimated average lorry length. The average used was 16.5 metres (i.e. the average maximum length of an articulated lorry, which was considered appropriate, given the routes under consideration. Other categories considered, but not used, were rigid vehicles and 'road trains' (i.e. a lorry and trailer). Source: 'UK regulation: Road Vehicles (Construction and Use) Regulations 1986 (SI 1986/1078)' available from <http://www.worcestershire.gov.uk/cms/pdf/2009-Oversize-&-Weight-limits.pdf>.

²¹ Note, numbers rounded.

- Total ticket revenues generated from passengers, lorry, UTs and containers were identified by multiplying average prices by the number carried, in each category²² (For example, route 1 may generate £400,000 from 10,000 passengers each paying £40 per trip).
- The proportion of total revenue accounted for by each of these categories (for example on route 1, 20% of total revenue is accounted for by passengers, the remainder by lorries) was then applied to the total additional fuel cost, to identify the annual revenue gap that would need to be recouped, from each category of customer (for example the fuel price increase is estimated to result in an additional cost per year of £290,000, hence 20% of this amount, £58,000, would need to be recouped from the 10,000 passengers on that route, through ticket sales).
- This provides an amount that would need to be recouped, per passenger, which is then added to the 2011 ticket price to provide a future ticket price. The two figures are compared; the percentage increase, per category and route are set out in Table 3.2 and Table 3.3²³.

Table 3.1 Approach to estimating ticket price increase

<p><i>Relevant ticket revenue = average prices * units carried (e.g. number of passengers).</i></p> <p><i>Proportion of total to be recouped by unit type (e.g. passenger) = Relevant ticket revenue / total ticket revenue</i></p> <p><i>Revenue to be recouped from unit type (e.g. passengers) = total costs associated with fuel switching (Note 1) * proportion of total revenue to be recouped by unit type</i></p> <p><i>Cost to recoup per unit type = Revenue to be recouped from unit type / units carried</i></p> <p><i>'Future' ticket price = Cost to recoup per unit type + 2011 ticket price</i></p> <p><i>Percentage increase in ticket price = new price - the old cost per ticket / old ticket price.</i></p>
--

Note 1 see 'fuel costs' paragraph above.

Three scenarios have been presented, based on a 'low', 'central' and 'high' estimate of future LSF price increases, set out in the previous chapter. The approach assumes that current use volumes of HFO will switch entirely to LSF and that this LSF will cost between \$275 or £176 (low scenario); \$315 or £202 (central scenario); and \$350 or £225 (high scenario) more per tonne than current prices paid for HFO. The price increases have only been applied to the volumes of HFO used; current usage of LSF (used in port for manoeuvring or powering on board systems whilst in dock) has not been included in the estimates of additional fuel costs.

Effects of fuel switching on ticket prices – Western Channel Routes

The results of the analysis for Western Channel Routes are shown below. It suggests that ticket prices, per passenger, would increase between an average of 9% and 12%, with small differences between routes in the price increase expected. Ticket prices for lorries and unaccompanied trailers are expected to increase between 12% and 16%, with larger differences between routes. Containers are not carried on the Western Channel routes analysed.

²² Note, in terms of passenger prices, the data presented below shows the percentage increase in the price paid per passenger (not per car) the percentage increase paid per car/family would be greater than set out here.

²³ Note that where a number of different ships were used on particular routes in 2011, an average has been taken.

Table 3.2 Estimated Ticket Price increases - Western Channel Routes

Route	Passenger (PAX)			Lorry			Unaccompanied Trailer (UT)		
	Low	Central	High	Low	Central	High	Low	Central	High
WC 1	10%	12%	13%	10%	12%	13%	10%	12%	13%
WC 2	n/a	n/a	n/a	21%	25%	29%	21%	25%	29%
WC 3	8%	10%	12%	8%	10%	12%	8%	10%	12%
WC 4	9%	10%	12%	9%	10%	12%	9%	10%	12%
Western Channel Average	9%	11%	12%	12%	14%	16%	12%	14%	16%

Source: AMEC, based on operator data. *Note n/a denotes data unavailable or missing.

Effects of fuel switching on ticket prices – North Sea and Container Routes

The same approach has been taken to estimating ticket price increases on North Sea and container routes. The shaded cells denote routes where the relevant unit type is not carried, or data was not provided²⁴. In this sector there is greater variance between distances, volumes and ship types, which is reflected in wider percentage increases between routes. Overall, passenger prices are expected to increase by between 10% and 13%. For lorries ticket prices are expected to rise by between 11% and 14%; for unaccompanied trailers by between 9% and 13% and containers between 7% and 10%.

Table 3.3 Estimated Ticket Price increases – North Sea and Container Routes

Route	Passenger (PAX)			Lorry			Unaccompanied Trailer (UT)			Containers		
	Low	Central	High	Low	Central	High	Low	Central	High	Low	Central	High
NS 1				9%	11%	12%						
NS 2	13%	15%	17%	13%	15%	17%						
NS 3				15%	17%	19%						
NS 4				14%	17%	18%						
NS 5				9%	10%	12%						

²⁴ As above, one operator provided revenue and price information for Lorries in terms of Lane-metres (i.e. the amount of revenue generated by one lanemetre). This figure has been used to estimate total revenue on that route, and average ticket prices per lorry, based on an assumed average lorry length. The operator provided passenger ticket prices directly. The two figures have been added to provide total ticket revenue. The subsequent approach to estimating ticket price increases on the routes operated by this company is the same as set out above, i.e. identify proportions of ticket revenue generated by each category of passenger, apply this proportion to total fuel costs that would need to be recouped; identify the cost per passenger or lorry, then add this to existing 2011 ticket price and establish a percentage difference.

Route	Passenger (PAX)			Lorry			Unaccompanied Trailer (UT)			Containers		
NS 6				17%	19%	21%						
NS 7	16%	18%	20%	16%	18%	20%						
NS 8										5%	6%	7%
NS 9										7%	8%	9%
NS 10										6%	7%	8%
NS 11	7%	8%	10%	7%	8%	10%	12%	15%	17%	12%	15%	17%
NS 12	5%	7%	8%	5%	7%	8%	5%	7%	8%	5%	7%	8%
NS 13	8%	10%	11%	9%	10%	11%						
NS 14				10%	11%	12%						
NS 15				9%	11%	12%				9%	11%	12%
North Sea Average	10%	12%	13%	11%	13%	14%	9%	11%	13%	7%	9%	10%

Source: AMEC, based on operator data.

3.5 Impact on customer behaviour and modal shift

3.5.1 Introduction

This section explores the extent to which the ticket price increases set out in the previous chapter are likely to affect the route decisions of freight and passengers and lead to a modal shift from longer sea routes, to shorter sea routes with the associated additional road miles travelled. Passengers in particular may also have the option not to travel. This chapter explores the extent to which this modal shift is likely to occur and the economic and environmental impact of this.

Such modal shifts are only expected to occur where the costs of travelling to the relevant port are less than the expected ticket price increase. We assume that hauliers (i.e. freight traffic) are more price sensitive, given the commercial pressures, and are more likely to reallocate their traffic. This, in turn, supposes that the current distribution of traffic volumes on the Western Channel and North Sea routes are financially and operationally optimal. Hauliers' decisions are therefore represented by a comparison of the ticket price increase with the cost of driving additional road miles to access short sea ferry services.

Changes in the distribution of traffic are likely to result in a number of potential knock on impacts. These include adverse impacts for viability of ferry services and their frequency, with associated impacts to port revenues and employment. Reductions in traffic may also have further effects on ticket prices and on competition between operators on routes, which are clearly dynamic. Freight hauliers who do not switch routes will however still have to bear the additional costs of travel, which may affect the viability or configuration of haulage operations or the prices charged. Passengers are expected to be less price sensitive and we understand many, particularly those

travelling on the western channel routes, own property in France or Spain, however price increases may well affect frequency of travel, travel in peak seasons and short breaks.

3.5.2 Approach

From an economic perspective, the increase in ferry company fuel costs can be characterised as a shock to a market in equilibrium. This shock to supply costs leads to price changes which then affect demand. Eventually a new equilibrium develops reflecting two impacts, firstly an overall rise in prices leading to a change in overall level of the market - the total goods or passengers carried - and secondly, a change in demand for different routes according to movements in relative prices between them.

For analysis, these two effects can be treated independently. The overall market effect is often seen as the most important in this and similar cases as it affects the total size of the sector, whereas the movement in relative prices affects only the balance between different parts of it. In principle, such a shock may exhibit these two effects in different proportions with the possibility of either no change in the overall market or no change in the movement between routes. The likelihood of these outcomes depends on the alternatives available and price sensitivity of the different customer groups.

At the level of the overall market, the main issue is whether current users have alternatives which mean that they no longer make use of ferry services. A good example of this is in the leisure market where a more expensive cross-channel break by car may be replaced by a visit by air to a European city. For freight, the effect at the level of the overall market is less important as freight costs are a relatively small proportion of the final price paid by the consumer for all goods except certain bulk commodities. However, hauliers are likely to be very sensitive to the relative costs of different routes as their choices are constrained by few factors other than price. For example, final consumers typically will not care which route was taken and only some goods, such as hazardous cargoes need specific handling and shipping facilities only available on some routes. In simple terms, the freight market is therefore very sensitive to the structure of prices but less to the overall level while the leisure market is less sensitive to price structures but more to the overall price levels.

The freight market consisting predominantly of trucks and trailers and leisure market were understood as different market sectors and could be analysed independently. Freight is the primary market by volume and value to ferry operators, and the analysis focuses on this market first.

The analysis focuses on the relative attractiveness of key routes in the Northern and Western sections of the market when tariffs increase. These routes are Harwich-Holland and Portsmouth-Caen respectively. Changes to these routes provide the evidence that can be related to routes with lower traffic densities (such as the routes through Poole and Tilbury).

The availability of specific data was substantially greater for the North Sea than for the Western Channel and this conditioned our approach. A detailed route by route haulage analysis was undertaken for the North Sea crossing and this was used as an example to estimate the impacts on the Western channel.

3.5.3 Tariff increases

Fuel costs are a cost that is relatively simple to apportion across a shipping fleet as, following basic economic and accounting theory, all the fuel costs of a ship on a route should be paid for by customers using that route because all these costs would be avoidable if customers did not travel. Any rise in fuel costs will therefore result in a corresponding rise in tariffs for each customer class based on their current tariff as already described. In summary, the result is that the increase is of a similar proportion in percentage terms for all customer classes and both freight and passengers will see the same percentage increase in the headline price of a ticket.

In assessing their response to high prices, leisure customers may compare this new price of a ticket with their alternatives, for example the costs of alternative ferry routes and costs of alternative holidays. Freight customers will simply look at the impact on the relative costs of different routes between the endpoints of their haulage contract.

For a haulier, alternative freight routes will differ according to a number of factors that affect their final choice including security and reliability of service, both of which come ahead of price in a recent report (Malmqvist 2013). Differences in security levels between ports has not been highlighted in the evidence collected for this analysis while reliability of service in terms of its frequency is understood as having a potential impact, though short sea crossings which may substitute from the longer crossing may also have better service frequency from the perspective of a haulier.

Non-price factors are likely to be of different levels of importance to individual hauliers depending on their cargos and customers and so may not always lead to a financial benefit. The impact of tariff increases will however directly affect all hauliers financially. Choosing a different route is a simple method of mitigating such increases and there are no additional costs in changing route which makes it relatively easy for hauliers to switch. We understand even long term contracts for bulk purchases of crossings are not longer than a year and frequently less.

Hence, in the freight market for UK-continent crossings, price is the dominant decision variable. The access to a more frequent service may add a small additional impact. This frequency effect would be enhanced if switching is sufficient to reduce demand and so the number of ferry sailings on the route being switched away from and further if it increases the number of sailings on routes that hauliers switch to. Both these might happen if ferry operators were to move a ship operating on the Hoek van Holland-Harwich crossing to Dover-Calais in response to hauliers also moving to the short sea crossing.

For hauliers, no new route is expected to have a smaller road distance and moving away from an existing route is assumed to require additional road miles. From a purely financial perspective, the decision to drive an additional distance will depend on the saving in ferry tariffs that could be achieved. Equally, the level of tariff increase determines the distance they would be prepared to drive which in turn depends on the haulier's cost per kilometre.

The table below shows the tariff increases calculated for each of the routes of interest to this study and in the right hand columns the equivalent driving distances. For example, the tariff increase for a haulier using the Portsmouth-Caen route in the low fuel price scenario would be £33. The equivalent distance they would be prepared to drive is 38km if each km is costed at the total costs of running a truck and 86km if each km is costed to include just the fuel and other operating costs. Even leaving aside the non-price factors, this example shows the wide range in the

propensity to switch resulting from the cost models that hauliers are actually using. The economic analysis of this issue would best be related to the use of the truck over the long term. Hauliers using the truck extensively for cross-channel work would find that they would need to recognise some of the non-fuel costs in their decisions, or they might find that the saving in tariffs was insufficient to account for wear and tear (depreciation) and other non-mileage related costs. However a truck that is used only intermittently for cross-channel work might find that the few additional kilometres will not affect noticeably affect wear and tear, the cost of which are largely covered by other work. Older trucks which for example have been fully depreciated will have costs somewhere in between these upper and lower limits.

This leads to possibly counter-intuitive result. Trucks which are used regularly, even if old, may not find the additional distances worthwhile when costed at the cost of fuel only as the regularity of use does have other appreciable costs such as wear and tear which may reduce truck life. These trucks will therefore not drive the maximum distances shown in the table below to avoid the tariff increase. However, trucks used less regularly have a greater incentive to profit from what for them is an infrequent event. As the first group are the more regular users, they make up the bulk of the traffic and so qualitatively there may be an overall reduction in the switching that might otherwise be expected.

Table 3.4 Tariff Increases (freight)

	Volumes	Sea Distances	Tariff increases as equivalent road km(all road costs)		Tariff increases as equivalent road km(operating costs only)	
			(1) Low fuel price	(2) High fuel price	(1) Low fuel price	(2) High fuel price
	units	Km	km	Km	Km	km
Dover - Calais	113038	43	-	-	-	-
Portsmouth – Caen	22242	181	38	49	86	110
Poole – Cherbourg	7153	122	38	52	86	117
Plymouth – Roscoff	5889	187	19	38	43	85
Portsmouth – Bilbao	95935	1,000	193	247	433	555
Gothenburg-Immingham	15764	922	158	201	355	452
Esbjerg-Harwich	68730	633	111	141	249	316
Esbjerg-Immingham	22366	609	100	127	224	285
Cuxhaven-Immingham	104121	624	105	134	237	302

	Volumes	Sea Distances	Tariff increases as equivalent road km(all road costs)		Tariff increases as equivalent road km(operating costs only)	
Vlaadingen-Immingham	7904	369	52	66	117	149
Zeebrugge-Rosyth	23151	733	122	155	275	350
Amsterdam-Newcastle	43480	500	176	224	396	504
Hull-Zeebrugge	95417	372	22	32	50	73
Hull-Europort (Rotterdam)	142000	368	22	32	50	71
Hoek van Holland-Harwich	79000	204	36	46	81	104
Hoek van Holland-Killingholme	60300	367	48	61	108	137
Rotterdam/Europort-Harwich	18700	204	27	34	60	77
Tilbury – Zeebrugge	113038		36	46	81	104

Source: Road distance summaries from IRN; Tilbury-Zeebrugge tariffs explicitly set to match Hoek van Holland - Harwich

This table is important to the analysis of routes as it provides a method of identifying the maximum additional driving distances that might apply for different routes and hence defines a limiting case for possible switching away from a particular route. If the total additional driving distance using a new route through a different port is greater than this maximum, it is not in a haulier's interests to switch away from the current route. As a further simplification, if the additional distance required is greater than the maximum driving distance in the table (555km), then no further consideration is required to confirm that a switch will not occur.

Using this approach, some switching scenarios can be investigated immediately.

The increase for the routes using Hull is less than the increase for Harwich and Killingholme routes and, based on this alone, traffic through Hull traffic will not switch to either Harwich or Killingholme. Traffic using Hull will also not switch to the Short Sea crossings as the distance from Hull to Dover is greater than the 555km maximum distance. This simplified analysis is supported by the fact that the price increase for the Hull routes over the short sea routes is equivalent to a maximum of 73km, insufficient to reach Killingholme or Dover.

On the Harwich routes the greatest additional cost a haulier would be exposed to is £40. The Tilbury-Zeebrugge route is a probable alternative for some hauliers but a switch from Harwich routes to Tilbury routes is not expected as they have the same sea distances and shipping tariffs are expected to rise almost identically, though tariff rises have not been calculated explicitly for the Tilbury route.

The only plausible main switching dynamic for North Sea routes is away from Harwich or Tilbury to routes using short sea crossings, and the maximum saving available to a haulier is £40.

When expressed in terms of road distance this would be equivalent to the costs of driving 104km for a haulier seeking to cover only mileage costs (principally fuel). It would fall to 46km for a haulier with a cost model where all vehicle costs were covered. In the scenario with lower shipping fuel costs and correspondingly lower tariff increases, the equivalent road distances are correspondingly reduced, but are of a similar order of magnitude - 36km and 81km.

Therefore, on the North Sea under all scenarios of shipping fuel costs and haulier cost models, the range of possible distances that a haulier would consider driving are between 36km at the low end and 104km at the high. In particular, no haulier would switch if they had to drive further than an additional 104km.

Dover-Calais prices also increase as a result of the shipping fuel increases, this increase has been calculated to be approximately £6/trip although we did not have the same level of detail behind that calculation as was available for the other routes should the real price effect be greater the relative advantage of Dover-Calais would correspondingly reduce and in these circumstances the upper limit for road distances is reduced which marginally reduces the impacts.

3.5.4 Market Structure

Geographically, the cross-channel market divides fundamentally into two; the section to the west of the Dover straits and the section to the North of the straits. In each of these sections, the reference price has been taken to be the Dover-Calais price. This provides the benchmark route with the shortest sea crossing and, by implication, often the longest distance travelled on land. The volumes of traffic in the freight market on reference routes²⁵ are shown in Table 3.5

As a result of the geography, when shipping ticket prices increase, there is an incentive for road traffic to divert to the Dover straits where costs are lower due to the shorter sea crossing. Traffic increases on the short sea routes (Dover-Calais, Dover- Dunkerque, Folkestone-Coquelles (via Eurotunnel)) and away from the main western routes (predominantly Portsmouth-Caen) and the North Sea routes (Harwich-Holland, Tilbury-Zeebrugge, and the more Northern ports to the Netherlands).

²⁵ These reference routes are used to correspond to the haulage endpoint data analysis.

Table 3.5 UK- Continent Freight Market Volumes on Reference routes

	Market Western Channel and North Sea				
	Total Freight Units	(Cab and Trailer)	Trailer	Sub total	%
Dover/Calais (P&O)	1,067,597	1,031,459	36,158		
Dover-Calais (Sea France)	533,367	530,911	2,456		
Dover/Dunkerque (DFDS)	468,267	462,247	6,020		
				2,069,231	49%
Eurotunnel	1,263,322	1,263,322			
				1,263,322	30%
Newhaven/Dieppe(Transmanche Ferries)	37,364	34,764	2,600		
Portsmouth Le Havre (LD Lines)	24,867	24,014	853		
Portsmouth-Caen (Brittany)	110,311	89,637	20,674		
Portsmouth-Cherbourg (Brittany)	2,368	2,060	308		
Portsmouth-St. Malo (Brittany)	13,423	11,584	1,839		
Portsmouth-Bilbao (P&O/BF)	8,986	6,449	2,537		
Portsmouth-Santander (Brittany)	8,196	5,651	2,343		
Poole-Cherbourg (Brittany)	22,263	19,901	2,313		
Poole-St Malo (Brittany)	-	-	-		
Poole-Santander (Brittany)	11,956	9,741	2,215		
Plymouth-Roscoff (Brittany)	7,016	6,060	956		
Plymouth-Santander (Brittany)	1,160	1,108	52		
Plymouth-St Malo (Brittany)	143	136	7		
				248,053	6%
Teesport/Rotterdam (P&O Ferries)	47,431	1,392	46,039		
Teesport/Zeebrugge (P&O Ferries)	102,729	2,007	100,722		
Hull/Rotterdam (P&O Ferries)	128,489	46,063	82,426		
Hull/Zeebrugge (P&O Ferries)	72,938	10,384	62,554		
Killingholme/Hook of Holland (Stena Line)	78,773	42,045	36,728		
Harwich/Hook of Holland (Stena Line)	142,346	91,610	50,736		
Harwich/Rotterdam (Stena Line)	67,267	6,846	60,421		
				639,973	15%
		Total market		4,220,579	100%

Source: summaries from IRN; operator submissions to this project

3.5.5 North Sea freight routes

Haulage data was provided which covered current patterns of traffic from a major logistics operator. It comprises data for specific haulage routes and includes:

- The UK endpoint (UK town);
- Continental endpoint (country);
- Crossing used;
- Tonnage shipped;
- Number of journeys; and
- UK and continental road distances.

The information relates to 2012 and relates to freight journeys across the North Sea, rather than through Western Channel routes; data is provided for both westbound (i.e. Continent – UK) and eastbound (i.e. UK-Continent) directions. The data can be understood as a sample of the North Sea market and makes up approximately 10% of the traffic on the Harwich, Hull, Immingham-Netherlands and Tilbury routes. It is for unaccompanied trailers only and excludes traffic from one operator.

The total traffic tonnages eastbound reported by this operator are 28% less than westbound though this may result from hauliers' different choice of operator for westbound and eastbound trips. However the structure of traffic within the respective totals is also different. Eastbound traffic shows a greater tonnage on a fewer number of haulage routes. Westbound traffic has a greater number of haulage routes and a more diverse set of UK endpoints. This would correspond with inbound goods being more widely distributed, while outbound goods are predominantly shipped from places where they are already concentrated (such as a production facility).

The number of end-to-end individual movements of consignments ('jobs') by this operator makes up approximately 10% of total traffic on the North Sea. As a check on its suitability as a sample of the market the relative use by this operator of the different ferry routes closely matches the relative traffic volumes by route for the corresponding routes in the North Sea market and so is a good representation of the structure of this section of the market.

Within the dataset the routes with the top 30% by tonnage of west-bound (Continent-UK) traffic routes and the top 66% by tonnage of east-bound (UK- Continent) traffic were selected for analysis and to exclude the numerous routes which carried little tonnage and to concentrate on the switching dynamic for the major end-to-end routes.

For these routes the analysis of the propensity to switch was done based on the relative difference between the route currently taken and the alternative route using the short sea crossing. Two scenarios are run to cover the range from 36km to 104km. Each is run independently and only those routes are selected where the additional distance is less than that set in that particular scenario.

The estimation of haulage route distance was based on the AA routeplanner. The approach to the calculation of distance on the UK side and the continental side was different. On the UK side, the two alternative distances were

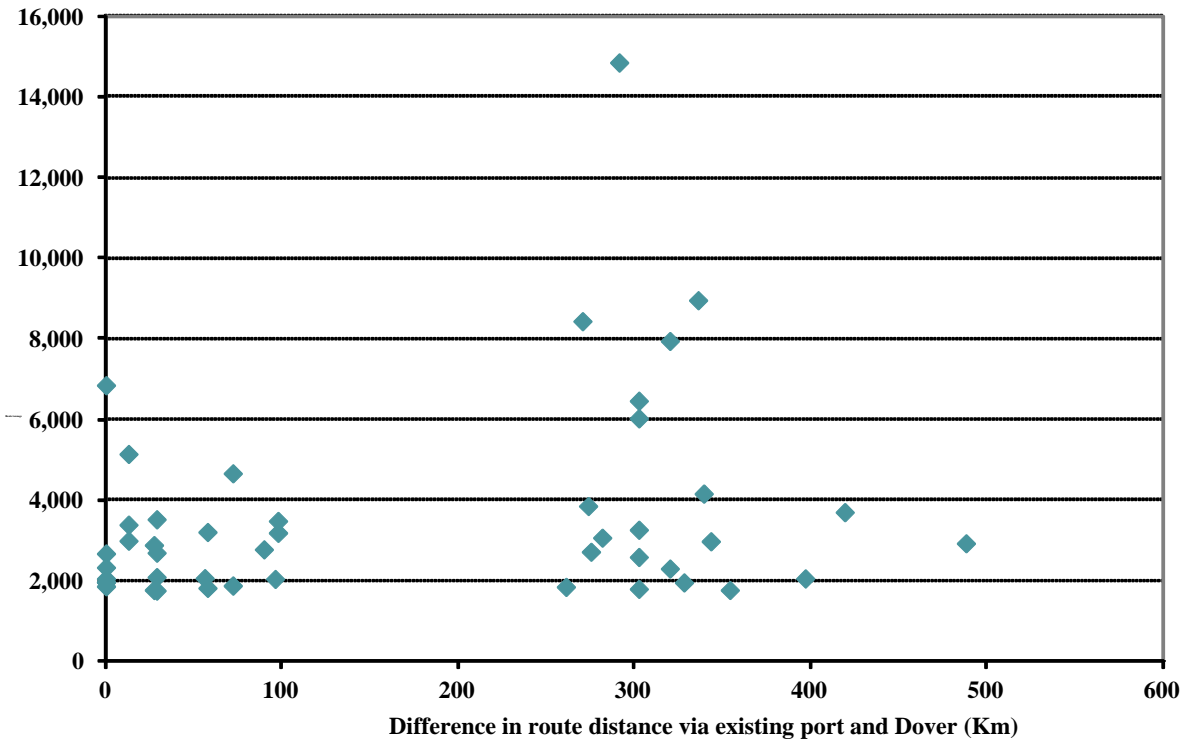
firstly from the particular town to the short sea crossing point (assumed to be Dover) and secondly from the particular town to the currently used port. On the continental side, there was assumed to be no change in distance. The rationale for this assumption was checked but in essence the logic is as follows. The relative distance to Hoek van Holland and Calais reduces with the total length of journey on the continental side and the continental leg of journeys is relatively long. The route data specified continental endpoints only in terms of their country (e.g. 'Germany') and knowledge of the particular part of each country is required to specify an assumption that is better than the assumption of 'no change in continental distance'.

Certain routes are excluded. Routes which already use the Short Sea are not considered switchable. Routes which had 'Europoort' as the port and 'The Netherlands' as the continental endpoint were assumed to be mainly transhipments. For this reason (i.e. onward shipping rather than delivery to the continent) and, as the distance between Calais and Europoort is 331km, switching to a short sea crossing would imply a distance for the continental leg which was not 'no change' but approximately 331km longer, these routes were also excluded, even though the difference in UK distances fell within the 104km limit.

Figure 3.4 illustrates the volume in terms of tonnage on westbound routes that would be affected compared with the distance between the chosen port actually used and an alternative route via Dover.

The haulage routes divide into two main groups, those with additional distances to Dover that are less than 100km and those with additional distances greater than 250km. There is no implicit reason for this, but would reflect the fact that companies expecting to ship large volumes regularly to or from the continent are located within range of a port. Those in the lower group use Harwich and have an option to use Dover. Those in the higher distance band are those which are located to use the Northern ports. Based on the analysis of tariffs, these Northern routes have no financial incentive to switch.

Figure 3.4 Distances and Tonnage Westbound (freight)



This structure of traffic indicates the potential proportion of traffic that could switch. All routes with distances less than 104km might switch. From the figure, the total tonnage that is in this category is of the order of 30% of the total (the sum of the all the tonnage to the left of the 100km point on the horizontal axis). This 30% is an upper limit of the tonnage that might switch. For a greater tonnage to switch the hauliers would need to be prepared to drive over 250km to avoid the £40 (corresponding to the 104km) tariff increase and there is no financial incentive to do this.

Route selection was undertaken separately for the Westbound and Eastbound traffic. Switching in the low scenario was 8% Westbound and 3% Eastbound, giving (when weighted by tonnage) an overall 6%. For the high scenario, both Westbound and Eastbound switching was close to 16%. These figures are percentages of the overall sample from the logistics operator. Switching percentages at individual ports, as a percentage of traffic through those ports are higher.

Switching behaviour by port

Table 3.6 shows the switching that occurs on the routes in the sample through the different ports. The differences are notable, but reflect structural patterns in the traffic. The high westbound switching propensity at Harwich reflects a more geographically distributed set of UK endpoints, and the lower propensity eastbound a greater number of UK locations which have fewer route choices.

The short distance between Tilbury and Dover giving almost all hauliers using that route a choice and when Tilbury becomes more expensive almost all would switch based on the relative prices.

Table 3.6 Switching on North Sea routes by Port

	Harwich		Tilbury	
	Low	High	Low	High
Westbound	42%	57%	0%	100%
Eastbound	14%	25%	4%	89%
West and East combine	27%	40%	3%	92%

3.5.6 Key Assumptions in the estimates

Use of the North Sea Analysis

The North Sea analysis has the advantage that it includes the endpoint data critical to assessing switching. As well as the intrinsic aspects of the dataset (such as including only unaccompanied traffic) its use in developing the estimates below will necessarily reflect the following additional aspects:

- Switching only occurs on two routes, through Harwich and Tilbury;
- Harwich and Tilbury have 53% of the unaccompanied traffic whereas for the routes in the sample overall there is 69% unaccompanied traffic. When Harwich and Tilbury are taken as proxies for either other ports or for overall markets these differences indicate a potential range to be considered;
- The influence of Europoort is important as routes there are assumed not to switch under any of the levels of tariff increases included in this study;
- There is a quite a different eastbound and westbound structure of routes and tonnages;
- There are major volumes shipped to specific locations (e.g. steel or car plant) and their switching behaviour is implicitly included in the switching estimates; in general major volumes do not switch reflecting the fact that they are already located to use a particular port; and
- The relevant market is wider than just the routes that switch, because major importers/exporters have locational choices.

Relevance of endpoint data for assessing switching

Knowledge of the endpoints of the haulage routes is critical to the assessment of switching behaviour.

The specific case of the Immingham-Cuxhaven route provides a good illustration of the general issues. The estimated tariff increase of £116 equates to a possible 302km (in the high case with high shipping fuel costs case and with lowest road haulage costs). The alternatives to the Immingham-Cuxhaven crossing are via short sea routes or Harwich-Hoek van Holland.

Cuxhaven is 481km from Hoek van Holland by road so any haulier within 179km (i.e. 481-302km) of Cuxhaven would have no financial incentive to switch crossings to the Harwich with the additional working assumption that road distances on the UK side were the same.

It is not impossible that a number of haulage routes using the Immingham-Cuxhaven crossing have their continental endpoints within 179km of Cuxhaven as a local concentration of suppliers and a market in England would be a reason to establish the route in the first place. These would not switch.

Hauliers using this crossing but having an endpoint further into the continent would have a greater incentive to switch. In abstract terms, an approximate circle of diameter of 302km can be imagined to be placed somewhere in Europe and all hauliers using this crossing and having journeys with endpoints in this circle are potential switching candidates, as for them the additional 302km of driving is a cheaper crossing option.

Without knowledge of which endpoints are using the Cuxhaven crossing, the difficulty is in knowing where to place this circle. If it is centred at Cuxhaven, then, following the argument above, no hauliers would switch. If it is instead half way between Cuxhaven and Hoek van Holland (i.e. all trips have an endpoint South of Cuxhaven) then all would switch. If it is in Poland then some would switch, the exact amount depending on the location of the endpoints.

The existence of a single circle is furthermore a simplification as there would be a circle for each UK potential endpoint and for each length of trip. That is a 500km trip from Sheffield to a specific location on the continent via Cuxhaven might be equivalent in cost with a 802km (500+302km) trip via Harwich. An 800km trip from Port Talbot would have different circle of potential switchers. Furthermore the circle is only an approximation of the shape which will depend on the geography of the road network.

In many respects, this pattern is as good as other approximations that might be made as all others will require other major assumptions. High level aggregate statistics, such as the volume of goods shipped from the UK to Europe do not help in distinguishing between specific routes at the level of detail implied by the additional road distance. Other assumptions such as an even geographic distribution of haulage endpoints could simply be arbitrary with even less ultimate justification.

Cases where endpoint data does not matter

For a very long haulage trip from e.g. Italy to Nottingham, the difference in road distance may make it worth switching as in general longer routes encourage switching as endpoints are further from a preferred port. However, despite their length, it may be clear that other long routes do not have a switching option as the geography precludes it.

Clear examples are the Portsmouth-Bilbao and Gothenburg-Immingham routes. In simple terms, the road alternative would involve driving along the coast road until meeting a possible port. In this case the distance along the coast road can be compared directly with the tariff increase and it is, for example, not worth driving from Gothenburg to Esbjerg.

3.5.7 Estimates of modal shift impacts on market and on routes

North Sea freight routes

The North Sea routes covered in the detailed analysis are the basis for the estimates. They are first scaled to represent the overall market.

The scaling methodology follows the following steps.

The detailed route analysis for the North Sea can be seen scaled up to provide an indication of the market in the North Sea (See Table 3.7). It should be noted that the percentages switching are calculated with respect to total tonnages in the logistics operator sample which are based on tonnages across the North Sea excluding DFDS. As discussed above, the percentage switching on the Harwich and Tilbury routes is shown as greater as the same tonnage switched is divided by the traffic for each of these ports alone.

Table 3.7 North Sea - Modal Shift estimates (freight)

		Shipping tariff increase	Haulier cost	Equivalent driving distance	Tonnage switched	% North Sea (non DFDS) market switching	Additional road km
		£/one way trip	£/km	Km	tonnes	%	km
Low	(low shipping fuel price, high haulage cost)	£31	£0.86	36	959,658	6%	1,130,667
High	(high shipping fuel price, low haulage cost)	£40	£0.43	104	2,663,874	16%	7,792,795

The two cases in the table reflect differences in terms of the shipping fuel price scenarios and haulier cost model.

The differences can be seen to multiply from what appears a small range of £31 to £40 to a much large difference in tonnage and in road kilometres. In general, this is due to the fact when switching occurs it diverts all tonnage on routes which may have substantial flows. These flows are further multiplied by differences in distances. Small tariff changes can therefore lead to substantial impacts on operators. However it is the impact of the hauliers' cost model that makes the most difference. Although the difference in haulage cost per km is only of a factor of 2 (from £0.43/km to £0.86/km) and this equates to a factor of 2 in distance terms, the catchment area is in principle related to the square of this difference (2*2) and so to a factor of 4. While these simple interpretations do not lead directly

to the results here which are calculated on the more specific route basis, they nevertheless underlie the structure of the results, particularly the additional road km.

Western Channel freight routes

Data on haulage end-points is not available in the same detail for these routes. Summary data includes only that the typical length of journey was 260km on the UK side and 890km on the continental side. The calculated tariff increases are very similar to the increases on the Harwich routes.

The key assumption is that the freight market will illustrate the same dynamics and structure as seen on the North Sea routes. Although not perfect, the market can be seen as a mini North sea, each having Dover-Calais as the main competitor to the longer routes through Harwich and Tilbury on the North Sea and through Portsmouth and Poole in the Western Channel. In addition, a similar maximum distance of 110km (rather than 104km on the North Sea) determines the catchment size of haulage routes that may switch. Without detailed endpoint information this is taken as the best assumption to make though subject to issues raised above. An alternative more detailed approach would require further assumptions that would otherwise compromise the overall analysis.

The aggregate market statistics indicate that traffic on all Western channel routes is 39% of that on the North Sea routes (see table 3.5 for market volumes) and this factor is used to scale the impacts on the North Sea and shown in Table 3.8.

Table 3.8 Western Channel - Modal Shift estimates (freight)

		shipping tariff increase	haulier cost	equivalent driving distance	tonnage switched	% Western Channel switching	additional road km
		£/one way trip	£/km	km	tonnes	%	km
Low	(low shipping fuel price, high haulage cost)	£33	£0.86	38	371,963	6%	438,245
High	(high shipping fuel price, low haulage cost)	£43	£0.43	110	1,032,515	16%	3,020,481

Other freight routes

No change is expected on the longer routes north of Harwich on the North Sea and west of Portsmouth in the Channel primarily as a result of the relatively short equivalent distances for the expected tariff increases compared with the existing length of sea route and of its road alternative. These longer routes are also those which implicitly have road alternatives which are parallel to coast for a large part of their distance (such as those to Bilbao and Scandinavia) and hence less likely to have customers who can switch.

The important caveat to the assessment of 'no change' relates to specific bulk commodities and a good example is forest products which are believed to make up an important proportion of the inbound cargoes on the Gothenburg-Immingham route. If this route is used to supply UK power stations near Immingham with biomass fuel it may be subject to a 'tipping point' where the increase in shipping cost is sufficient to cause the power station to switch to

an alternative supply such as biomass sources that UK power generators own in South America. A detailed analysis of margins on the two alternatives would be required to assess whether shipping cost increases would cause such a switch. In this instance, shipping tariff increases are only one factor in the uncertain future for UK biomass generation and hence the traffic on this route may be at risk for other reasons. The risk itself may not be substantially increased as a result of shipping tariff increases alone.

In this study, the detailed evidence of other prices and cargo volumes required for a tipping point analysis is not available and the assumption made is that the tariff increases would not themselves cause a change in traffic levels or a modal shift using a different port.

All UK-Continent freight markets

The changes calculated for the Western Channel and North Sea freight markets were summed and are reported below.

Table 3.9 North Sea and Western Channel - Modal Shift estimates (freight)

		shipping tariff increase	haulier cost	equivalent driving distance	tonnage switched	% market switching	additional road km
		£/one way trip	£/km	km	tonnes	%	km
Low	(low shipping fuel price, high haulage cost)	£31-33	£0.83	~35	1,331,620	6%	1,568,912
High	(high shipping fuel price, low haulage cost)	£40-43	£0.48	~110	3,696,389	16%	10,813,275

Leisure markets

A one to one relationship between price increase and loss in quantity is theoretically predicted and an observed characteristic of markets which are in balance between supply and demand and priced optimally. It is known as having an “elasticity” of -1 which means that an increase in price of 1% leads to a fall in quantity of -1%. Over time, suppliers tend to price such that optimal pricing prevails and in the absence of other information this can be used to estimate market impacts.

Evidence for the reaction of the leisure market is not available as regards route switching. Anecdotally, the leisure market falls into regular travellers with, for example, property in France and those with more discretion over their travel choices taking short breaks. The first group is unlikely to change behaviour in response to the level of tariff increases predicted in this study. The second group is expected to be more likely to take an alternative holiday than to use a different route.

Using these simple theories in the absence of other information about holiday choices, the leisure market is expected to lose market in line with optimal pricing. This would suggest that a 10% increase in price would lead to a reduction of 10% in market volumes. This is the figure that has been used in the viability assessments.

Analysis of upper impact of modal shifts for freight movements on specific routes.

The route by route analysis shown in Table 3.10 uses the preceding analysis above to assess the greatest potential impact on the main routes. To the right of Table 3.10 are results showing a ‘high high’ case for modal shift at particular ports, though these need to be set in context as collating and using the North Sea analysis in whole and in part introduces complexities of relative scaling particularly between market and route definitions. The aggregate analysis reported above is on a market basis whereas this analysis is on a route basis.

In order to clarify this process, the analysis for individual routes has been developed in stages. The first column (“base volume”) shows accompanied and unaccompanied volumes. The low and high distances that are equivalent to the tariff increase are shown in the next columns. The percentages shown in the middle of the table are the switching percentages calculated for Harwich based on the detailed North Sea analysis. This is uplifted by a further factor of 1.3²⁶ to give the column labelled volume reduction based on Harwich (adjusted). These figures in the high scenario are then further scaled up by a further 10% in the high case to reflect a ‘sailing frequency’ effect as these relatively high shifts would probably reduce the number of sailings and reduce traffic still further. In the low scenario the figures are equally scaled down by 25% in the low case to reflect a measure of inertia when the tariff changes are relatively small. The result is a ‘high high’ case for shift away from a particular route.

For the Portsmouth-Caen route the level of modal shift varies from 27% in the low case to 57%²⁷ in the high case, though these estimates are further commented on in the section below. However, the broad impacts are clear, relatively large movements on relatively few routes. Whether the inertia and frequency effects should be considered is an assumption used here but reflects a judgement.

This analysis focuses on the major routes as if there are shifts the major routes are those that will see the greatest absolute reductions.

The high-high case figures sum to a total number of trips (210,424) that is similar to that calculated for the aggregate market and Table 3.8 can therefore be seen as a breakdown of the aggregate figures by route. It is however simplified in that all impacts are allocated to Portsmouth-Caen and Poole-Cherbourg. The minor Channel routes are not considered. In summary, the aggregate estimates above should be used when considering the impact on the Western Channel and North Sea markets. The route by route impacts may use the raw Harwich figures of 27% and 40% where those routes are considered in a similar relationship to Dover-Calais as Harwich is to Dover-Calais.

²⁶ The adjustment factor reflects the difference between the 53% of unaccompanied traffic through Harwich and the 69% that unaccompanied traffic makes up as a proportion of the North Sea traffic. Without this factor the shift would be under-represented as a proportion of the market.

²⁷ Note that the reported percentages here are based on trips whereas for the aggregate statistics they are based on tonnage.

Table 3.10 Upper estimates for model shift for routes (freight)

	Base Volume	Tariff increases as equivalent road km		% Volume reduction based on Harwich		Volume reduction based on Harwich (adjusted)		Volume reduction for Viability assessment inputs			
		Low	High	Low	High	Low	High	Low	High-High	Low	High-High
	units	km	km	%	%	units	units	units	units	%	%
Portsmouth - Caen	113,038	38	110	27%	40%	40,071	58,362	29,293	64,199	26%	57%
Poole - Cherbourg	22,242	38	117	27%	40%	7,885	11,484	5,764	12,632	26%	57%
Hoek van Holland-Harwich	142,000	36	104	27%	40%	50,338	73,316	36,799	80,647	26%	57%
Rotterdam/Europoort-Harwich	60,300	27	77	27%	40%	21,376	31,133	15,626	34,247	26%	57%
Tilbury-Zeebrugge	18,700	36	104	0%	100%	-	18,700	-	18,700	0%	100%
<i>Total</i>						<i>119,670</i>	<i>192,995</i>	<i>87,482</i>	<i>210,424</i>		

All the haulage routes using Tilbury-Zeebrugge route switch and so an estimate is included in the table above.

3.5.8 Comments on results

Overall, it is suggested that less traffic may switch than implied by the combination of necessarily coarse assumptions.

The main assumption is the sensitivity of hauliers to tariff increases. The assumption in this study is that all who could benefit from switching do in fact switch. For some, the benefits may be very small. For example in the high case any haulier with a difference in distance between routes of less than 104km is assumed to switch. If the difference is in fact only 5km, they would only save 5km worth of haulage costs and may decide not to switch.

Price may not be the main factor affecting hauliers' decisions. A particular reference (Malmqvist 2013) quotes evidence showing that security and frequency are more important than price to hauliers. The tariff increases calculated here may be relatively small compared to the value of a typical haulage contract. The high volumes of accompanied traffic on the Western Channel indicates relatively high value and possibly time-sensitive cargoes. If a change in route comprises the quality of deliverables hauliers may not wish to change route despite the increase.

Prices rises will affect all hauliers equally and this will increase the ability of the haulage sector to pass these costs through to final customers. If customers are made aware of the impact of route choice (e.g. in terms of time to market) they may prefer to pay the additional charge.

A large proportion of foreign registered traffic already goes through Dover-Calais. The implication is that long-distance continental hauliers may already have 'switched' if they were going to prefer the short sea routes. The traffic using other routes may therefore already be dominated by hauliers undertaking shorter routes which are inherently less flexible over their route choice.

This study calculates switching relative to an increase in the Dover-Calais price of zero. If the relative tariff increases on the other routes are smaller, this will also reduce switching (as noted above).

Although the use of the North Sea analysis as a proxy for the Western Channel is seen as the best method, some qualitative differences may mean a reduction in switching on the Western Channel routes. For example, the additional distance to Dover for the catchment area currently served by Portsmouth-Caen is relatively large compared to the additional distances for North Sea routes.

Lastly, the freight market is assumed not to change in size. It is possible that fewer goods will be shipped, but anecdotal evidence of the ability to absorb transport costs (such as the 5% fuel increase in recent years) is the basis of this assumption. In contrast the leisure market, as discussed above may reduce in size. If the market reduced in overall size, the volume reduction on individual routes would correspondingly reduce.

3.6 Impact of Identified Modal Shift

3.6.1 Externalities

The predicted modal shift from maritime to road transport will have a range of social, economic and environmental consequences. Where these are not included in the actual prices, these consequences are known as externalities, which can be qualified, quantified and monetised according to standard methodologies.

In public policy appraisal in the UK and Europe, the main methodologies to assess the external costs of transport are, respectively:

- The Department for Transport's (DfT) Transport Analysis Guidance (TAG), especially Units 3.9.5 (DfT, 2012a) and 3.13.2 (DfT, 2012b); and
- The European Commission's (DG TREN) Handbook on estimation of external costs in the transport sector, (CE Delft, 2008).

This analysis is mainly based on DfT methodology and guidance, as it is both more recent and more directly applicable to the UK than the European Commission's guidance.

The DfT guidance (DfT, 2012a) identifies the main external costs of transport as being:

- **Congestion.** This is defined as “as time lost relative to free flow conditions” and is quantified and monetised using the National Transport Model (NTM). The marginal cost of congestion is in essence the “cost of delay of an additional vehicle kilometre”. It is first worked out for a passenger car, but can then be scaled up to other road vehicles using a standard Passenger Car Unit (PCU) factor for various vehicle types;
- **Infrastructure.** The DfT methodology for estimating the marginal external costs to infrastructure is based on Sansom et al (2001) and includes marginal infrastructure operating, maintenance and depreciation costs. The Sansom et al (2001) marginal costs have been updated in DfT (2012b) to reflect subsequent guidance;
- **Accidents.** The marginal accident costs are also based on Sansom et al (2001), updated in DfT (2012b) to reflect subsequent guidance. They are linked to the impact of additional traffic on accident risk rates, and include the full value of the estimated additional accidents;
- **Local air quality.** These costs are also based on Sansom et al (2001), updated in DfT (2012b) to reflect subsequent guidance. The Sansom et al (2001) methodology included the marginal costs associated with emissions of carbon monoxide, SO₂, NO_x, PM₁₀, hydrocarbons, benzene and 1,3-butadiene. Additionally emissions of benzo-[a]-pyrene were used as an indicator of potential impacts from PAHs;
- **Noise.** These costs are also based on Sansom et al (2001), updated in DfT (2012b) to reflect subsequent guidance. The marginal costs of noise are generally taken to include both an annoyance cost and a health cost; and
- **Greenhouse gas emissions.** These costs are also based on Sansom et al (2001), updated in DfT (2012b) to reflect subsequent guidance.

The DfT produces a spreadsheet²⁸ of marginal external costs for all these categories. These are on a per passenger car kilometre basis, in 2010 prices, assessed at five-yearly intervals from 2010 to 2035. Values are provided for different types of road, as well as weighted averages for Great Britain overall. The weighted average values for 2015 are provided in Table 3.11.

²⁸ <http://www.dft.gov.uk/webtag/documents/expert/unit3.9.5.php>

Table 3.11 2015 marginal external costs for passenger cars, Great Britain weighted average across road types

Cost type	Marginal external costs(2010 pence per passenger car km)
Congestion	13.1
Infrastructure	0.1
Accident	1.7
Local Air Quality	0.1
Noise	0.1
Greenhouse Gases	0.8

Source: DfT (2012a, 2012b)

Note: These figures are all taken forward for further quantification and monetisation of impacts, except the figure for greenhouse gases.

The marginal external cost values provided in Table 3.11 provide the starting point for this analysis of the external costs linked with the predicted modal shift (except for greenhouse gases, see below).

However, since these figures are for passenger cars only, scaling factors need to be used to quantify the marginal external costs linked with additional lorry kilometres travelled. In order to do this, vehicle marginal external costs can be expressed in terms of passenger car units (PCUs), which vary according to the specific external cost. For congestion, these are given in DfT (2012a:11), for other external costs, they can be approximated from the marginal external cost values given in Sansom et al (2001:56). The PCU factors used in this analysis are presented in Table 3.12.

Table 3.12 Passenger Car Unit (PCU) factors

Vehicle type	Congestion	Infrastructure	Accidents	Air pollution	Noise
Car	1.0	1.0	1.0	1.0	1.0
Light Goods Vehicle	1.0	1.2	0.7	3.8	1.9
Rigid Goods Vehicle	1.9	72.6	1.5	9.3	5.6
Articulated Goods Vehicle	2.9	144.8	1.1	8.5	8.4
Public Service Vehicle	2.5	100.3	4.8	17.5	7.9

Source: DfT (2012a), Sansom et al (2001:56)

This methodology is not used for the marginal external costs of greenhouse gas emissions, as these can be readily worked out directly from vehicle fuel consumption data from the Road Haulage Association (RHA, 2011), combined with monetised values of emissions from DECC (2011), as presented in Table 3.13.

Table 3.13 2015 Marginal greenhouse gas costs associated with lorries

Lorry	Average mpg	Average l/km	Average kg CO2/km	Marginal cost (2010 pence/km)
3.5t gross vehicle (diesel)	27	0.11	0.26	1.51
7.5t gross vehicle	16	0.18	0.44	2.55
13t gross vehicle	14	0.20	0.50	2.91
18t gross vehicle (2 axles)	12	0.24	0.59	3.39
26t gross rigid vehicle	9.5	0.30	0.74	4.29
32t gross rigid vehicle (tipper)	8	0.36	0.88	5.09
32/33t gross (4x2+tandem) combination	9	0.32	0.78	4.53
38t gross (4x2+tri-axle) combination	8	0.36	0.88	5.09
40t gross (4x2+tri-axle) combination	7.8	0.36	0.90	5.22
44t gross (4x2+tri-axle) combination	7.2	0.39	0.98	5.66
32.5t gross drawbar combination (2 axle tractor, 2 axle trailer)	9	0.32	0.78	4.53

Source: RHA (2011), DECC (2011)

Notes: mpg data from RHA (2011), mpg to l/km conversion factor is 0.352 from RHA (2011), 2.484 kg CO2/l diesel is 2015 value from DECC (2011), 5.772 pence per kg CO2 is central 2015 non-traded value from DECC (2011).

Combining the marginal external cost values (and conversion factors) presented in Table 3.11, Table 3.12 and Table 3.13 with the expected number of additional lorry road kilometres travelled from 2015 following the expected modal shift (6.2 million km mid-point estimate) yields the overall external costs presented in Table 3.14. It should be noted that, as no information was found on the shares of different lorry types potentially affected, it has been assumed that all lorries are articulated good vehicles (for externalities other than greenhouse gas emissions) or 32/33t gross (4x2+tandem) combination vehicles (for greenhouse gas emissions).

Table 3.14 2015 marginal and total external costs following modal shift (2010 prices)

Cost type	Vehicle assumption	Marginal external costs (2010 pence per vehicle km)	Total additional external costs following modal shift (2010 £)
Congestion	Articulated Goods Vehicle	37.99	2,350,000
Infrastructure	Articulated Goods Vehicle	14.48	896,000
Accident	Articulated Goods Vehicle	1.87	116,000
Local Air Quality	Articulated Goods Vehicle	0.85	53,000
Noise	Articulated Goods Vehicle	0.84	52,000
Greenhouse Gases	32/33t gross (4x2+tandem) combination	4.53	281,000
Total	32/33t gross (4x2+tandem) combination	60.55	3,749,000

3.6.2 Other impacts

There are a number of potential implications which could arise from the shift of a quantum of traffic on the various routes. First, the loss of traffic could affect route frequency or viability, affecting the number of employees required by the operators in board and in port. There would be a corresponding reduction in fees paid to port operators and the services provided, hence further job losses at the affected ports. Second, depending on the results of the viability analysis, some wider economic affects may arise, from increased costs borne by those hauliers whose behaviour does not change as a result of higher ticket prices. These would, presumably, be passed on down their respective supply chains. It is not clear if the overall effect would be a reduction in trade, however some loss of flexibility in the service that hauliers can offer their clients would be expected.

3.6.3 Conclusion

The direct impacts of increased costs on the shipping industry in the UK could be considerable leading to increases in fuel costs faced by operators in the Western Channel and North Sea of more than £300 million. The effect on ticket prices charged (simply to recover these additional costs) on North Sea routes would require price increases of between 5 and 21% (Table 3.3) and on Western Channel routes of between 8 and 29% (Table 3.2) (section 3.4).

4. Wider Economic Effects and Route Viability

4.1 Introduction

This section explores the potential implications for overall route viability. Route viability is assessed against two options; first the cost of installation and operation of scrubbers and second; the increased fuel costs expected from fuel switching; resulting in modal shift. The first option is shown for illustrative purposes as it is not expected that this option will be chosen in the immediate term; for the reasons set out in section 3.

For the fuel switching option, we assess the viability of routes with reduced traffic volumes. Economic impacts, in terms of lost jobs and port fees paid, are also assessed.

4.2 Route viability - effects of fuel switching

The analysis in this section focuses on the implications for the viability of certain routes with the reduced traffic volumes, estimated above; i.e. the effect on route viability if the modal shift estimated in the previous section transpires. First, the expected modal shift was estimated on each route, this draws on the earlier analysis set out in chapter 3. In terms of estimating reductions in passenger numbers, an elasticity of -1 was assumed; i.e. a 1% increase in ticket prices leads to a 1% reduction in passenger numbers. The overall reduction numbers are driven by the estimated average ticket price increase per route, which has been described above.

Overall, the analysis suggests that the following *reductions* in the numbers of passengers and freight would occur on each route (Table 4.1 and Table 4.2). These numbers were subtracted from the existing quantum of traffic on each route carried in 2011.

Route viability has been assessed based on the implications of the losses in traffic on revenue and hence the profitability of the route. First, the operating margin on each route was set out . This information indicates that some routes were not profitable in 2011, before any fuel switching has taken place. Second this information has been used to define the cost base on each route, and by extension, the implied profit and loss. Third, the reduced traffic volumes were applied to existing passenger, lorry, UT and container ticket prices to estimate overall ticket revenue, which was then compared to the baseline traffic volumes, ticket prices and ticket revenue, to derive losses in ticket revenue, per route. The figures were compared to illustrate if the route remained profitable or not. The implied profit or loss was then compared to baseline costs, to estimate the likely margin, on each route. As previously, where a number of ships were used on any one route, an average margin was taken for each ship used. On a number of routes, information on revenues was incomplete or not provided, so conclusions on these have not been made.

Table 4.1 Economic implications of lower traffic volumes – Western Channel

Route	Reduction in annual passenger number	Reduction in annual Freight (Lorry, UT and Container)	Implication with modal shift (lower traffic volumes) from costs associated with switching to low sulphur fuel	
			Loss making?	Viability
WC 1	90,775	46,746	Yes	Unlikely to be viable with estimated modal shift, 2011 ship configuration and number of sailings
WC 2	n/a	9,198	Yes	Unlikely to be viable with estimated modal shift, 2011 ship configuration and number of sailings
WC 3	38,357	0	Yes	Threatened with estimated modal shift, 2011 ship configuration and number of sailings
WC 4	5,149	0	Yes	Threatened with estimated modal shift, 2011 ship configuration and number of sailings

Source: AMEC analysis, based on operator data

Table 4.2 Economic implications of lower traffic volumes – North Sea and Container Routes

Route	Reduction in annual passenger number	Reduction in annual Freight (Lorry, UT and Container)	Implication with modal shift (lower traffic volumes) from costs associated with switching to low sulphur fuel	
			Loss making?	Viability
NS 1	0	0	No change	Likely to remain viable, with estimated modal shift, 2011 ship configuration and number of sailings
NS 2	13,485.60	0	Unknown	n/a
NS 3	0	0	Unknown	n/a
NS 4	0	0	No change	Likely to remain viable, with estimated modal shift, 2011 ship configuration and number of sailings
NS 5	0	0	No change	Likely to remain viable, with estimated modal shift, 2011 ship configuration and number of sailings
NS 6	0	0	No change	Likely to remain viable, with estimated modal shift, 2011 ship configuration and number of sailings
NS 7	101,288.70	0	Unknown	n/a
NS 8	n/a	n/a	Unknown	n/a
NS 9	n/a	n/a	Unknown	n/a
NS 10	n/a	n/a	Unknown	n/a
NS 11	28,733.76	0	Yes	Threatened, with estimated modal shift, 2011 ship configuration and number of sailings
NS 12	38,351.67	0	Yes	Threatened, with estimated modal shift, 2011 ship configuration and number of sailings

Route	Reduction in annual passenger number	Reduction in annual Freight (Lorry, UT and Container)	Implication with modal shift (lower traffic volumes) from costs associated with switching to low sulphur fuel	
			Loss making?	Viability
NS 13	50,900.00	58,722.93	Yes	Unlikely to be viable with estimated modal shift and 2011 ship configuration and number of sailings
NS 14	0	0	No change	Likely to remain viable, with estimated modal shift, 2011 ship configuration and number of sailings
NS 15	0	24,936.57	Yes	Threatened, with estimated modal shift, 2011 ship configuration and number of sailings

Source: AMEC analysis, based on operator data *Note, the UT and Container price increase are affected by the use of one ship on the route during 2011 which carried relatively low volumes of both UT's and containers.

The assessment of whether the routes are ‘threatened’ or judged ‘unlikely to be viable’ has been made with reference to a) whether the margin is negative and b) the change in the margin between the two scenarios. Where the routes have been judged as unlikely to be viable, the analysis suggests that costs are likely to exceed ticket revenue by over 20%. Routes are judged as threatened, where the *change* between costs and ticket revenues under the baseline 2011 traffic volumes and the reduced traffic volumes after modal shift is less than 5%. A number of assumptions have been made as part of the analysis, which should be noted:

- The analysis has been undertaken with reference to 2011 traffic volumes, ship configurations, fuel costs and sailing numbers; clearly these change from year to year. Potentially operational cost savings can be made by changing the ship configurations and number of sailings, although these may incur other, potentially substantial, costs;
- The analysis assumes a fixed costs base, if traffic volumes decrease significantly, certain costs are likely to decrease (i.e. staffing), potentially affecting the margins;
- We have analysed the information based on the implication on profitability on each route, in isolation, without reference to margins on other routes by the same operator. It may be possible for operators to maintain routes by cross subsidies. Whilst we have had access to information on the operating margin on each route, which suggests that some routes are not currently profitable, we are not privy to more detailed information. If cross subsidies were to be used to maintain loss making routes, the ability of operators to continue to do this would be adversely affected if traffic decreased on several routes, which, in some cases, appears to be the case; and
- Where sufficient information has been provided, on overall revenues, margins and profitability, the assessment has not been made and marked with a ‘n/a’.

4.3 Wider economic effects

There are a number of potential implications which could arise from the shift of a quantum of traffic on the various routes. First, changes to frequency or route closures would affect the number of employees required by the operators on board and in port. There would be a corresponding reduction in fees paid to port operators for the services provided, hence further job losses at the affected ports may well occur, depending on the number of

shipping routes operating from them. The next section explores potential impacts arising from the viability assessment above.

4.3.1 Employment

Operators

Overall job numbers have been provided by the operators. Some represent full time equivalent jobs, others total numbers of staff including full time, part time, contract and agency staff. Some operators have provided UK and continental port based employees, others have provided jobs in UK ports only. Overall, from those that provided data some 3,290 people are employed by the operators who took part in the study (Table 4.1) some of whom may be affected by service closures or less forewent service operations.

The table below estimates, in very broad terms, the UK and continental employees likely to be at risk, if the modal shift estimates above materialise and changing ship configurations are not practicable. 'At risk' has been defined as all those employees supported by routes considered to be threatened, or potentially unviable in their current form, where these numbers can be estimated. Amongst certain operators, some of the shore based jobs are likely to be supported by revenue from routes that have not been assessed as part of this study and although these too may well be affected, they do not form part of the assessment below.

Table 4.1 Job numbers

Operator	Ship Based	Shore Based	Jobs 'at risk'
1	Not provided	257*	A proportion of the shore based jobs, and further employees on board.
2	1,381**		Unknown
3	Not provided	Not provided	n/s
4	530**	422**	530 (and a proportion of shore based employment)
5	480**	220**	406
Total			940***

Source: Operator data. *FTE jobs. ** Total jobs, including full time part time and contract staff, UK and continent based. ***Numbers rounded.

Overall we can identify some 940 full time, part time and contract positions that are likely to be at risk in the UK from just two operators, given the employment of the five main operators included in this study the number of jobs at risk is likely to be in excess of 2,000. In addition jobs on the continent, in maritime engineering, navigation, catering, customer service, cleaning and administrative occupations from those routes that are potentially unviable or would be threatened from the traffic reductions identified could also be at risk

Port

Data on total port fees has also been provided from operators and is summarised below. The numbers represent total annual port fees paid to all ports called at on the relevant routes for 2011, unless otherwise stated. Overall the operators paid just over £50 million in fees on all of the routes assessed as part of the study. The size of the fee is based on services provided and is affected by number of sailings/dockings, but also freight volumes handled. As noted above, the reduced quantum of traffic on certain routes may affect the configuration, or number of ships used on routes, frequency of sailings or perhaps the viability of the routes as a whole. The table therefore also shows the total port fees that would be ‘at risk’ (i.e. associated with routes that are unlikely to be viable or threatened, if the estimated modal shift occurs, with 2011 ship configurations, sailings and costs). These fees represent an annual spend of around £38 million, supporting a range of direct jobs in freight handling/operatives, terminal services, towing, engineering, fuel handling and administration and supporting indirect jobs in logistics, fuel supply and marine engineering occupations.

Source: Operator data. *Note – fees paid for both routes, to UK ports only. Remaining data represents payments to both UK and overseas ports. Note: The information for WC routes are fees paid in 2012.

4.3.2 Effects on hauliers and on trade

Largely irrespective of modal shift decisions, it is likely that the costs for haulage firms are likely to increase, either through higher ticket prices, or (marginally lower) cost increases from increased road miles. These costs would either be at least partly passed on down their respective supply chains, or haulage firms would seek to reduce costs further, or both. One method of doing this would be to reduce wages paid to staff, potentially by using a greater number of drivers based outside the UK, or delaying investment in new rolling stock. It is not clear if the overall net effect would be a reduction in trade (i.e. some exporters and importers withdraw from the market or cease trading), however some loss of flexibility in the service that hauliers can offer their clients would be expected.

4.4 Externalities

This section summarises the identified potential impacts of shipping operators in SECAs switching from 1%S to 0.1%S fuel in 2015:

- Price increase for low sulphur fuel of \$275-350 per tonne, with a mid-point value of \$315 per tonne. For the 38 ships in the study this would add over £300M to the annual fuel costs;
- Assuming the related rise in fuel costs is entirely passed on, this is predicted to lead to ticket price increases:
 - On Western Channel routes, ticket price increases of 9-12% for passengers (11% mid-point), 12-16% for lorries (14% mid-point), and 12-16% for unaccompanied trailers (14% mid-point);
 - On North Sea and container routes, ticket price increases of 10-13% for passengers (12% mid-point), 11-14% for lorries (13% mid-point), 9-13% for unaccompanied trailers (11% mid-point), and 7-10% for containers (9% mid-point),
- This is expected to result in a degree of modal shift, estimated at 6-16% in the freight market;

- In the leisure market, there is expected to be an impact of the order of 10% reduction;
- Overall, between 1.6 and 10.8 million additional road kilometres are expected to be travelled by lorries (6.2 million km mid-point estimate);
- These (mid-point estimate) additional road kilometres will be associated with overall external costs in the UK of the order of £3.7 million, consisting of:
 - £2.4 million associated with additional road congestion;
 - £0.9 million associated with additional infrastructure maintenance and operational costs;
 - £0.1 million associated with additional road accidents;
 - £50,000 associated with reduced local air quality;
 - £50,000 associated with additional noise; and
 - £0.3 million associated with greenhouse gas emissions.

4.4.1 Conclusions

Increased ticket prices on longer sea routes will result in haulage operators switching from longer sea routes to shorter sea routes which require longer road journeys. This “modal shift” away from ferries to road journeys will lead to reduced viability of some routes threatening thousands of jobs as well as an increase in congestion and other detrimental affects.

Our analysis suggests that modal shift will threaten the viability of routes in the North Sea Western Channel. The loss of viability of routes and port operations has the potential to displace thousands of (good quality) jobs. Overall, as many as 2,000 full time, part time and contract positions are likely to be at risk in the UK and on the continent, in maritime engineering, navigation, catering, customer service, cleaning and administrative occupations from those routes that are potentially unviable or would be threatened from the traffic reductions identified.

5. Summary and Conclusions

5.1 Purpose of this Report

This report has been prepared for the UK Chamber of Shipping, on behalf of several North Sea and Western Channel shipping operators, to establish the economic effect of compliance with the requirements of MARPOL Annex VI regulations, which sets sulphur limits for fuels in SOx Emission Control Area (SECA) currently 1%, since 1 July 2010; being further reduced to 0.1%, effective from 1st January 2015.

5.2 Report Structure

The report is structured as follows:

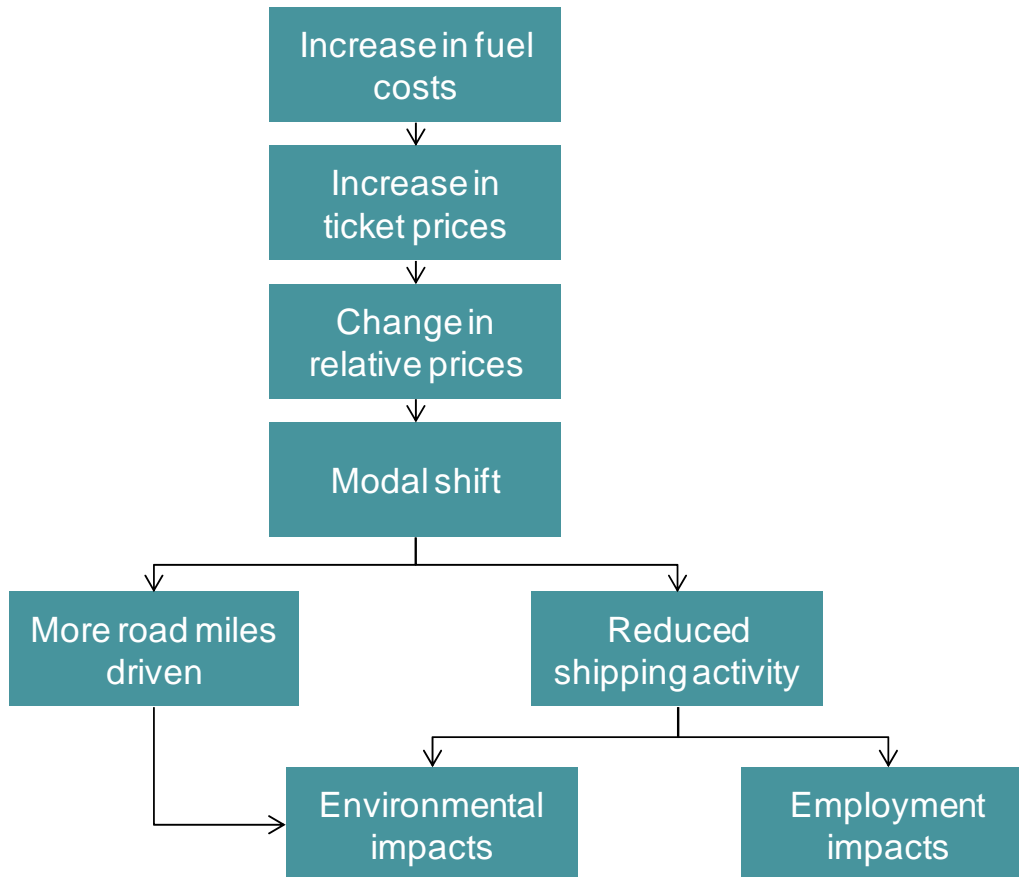
- Section 2 reviews the three potential options in greater detail and establishes the costs and practical issues associated with their implementation in order to comply with the requirements of the regulation;
- Section 3 examines the impacts expected to arise from fuel switching from HFO to LSF. The analysis is undertaken in a series of steps. First the costs of switching fuel are estimated and subsequently the effect this will have on ticket prices. Potential impacts on route switching and modal shift are then considered;
- Section 4 investigates the wider economic and route viability impacts of meeting the requirements identifying the scale of risk to the industry and to the wider economy; and
- Conclusions are set out in Section 5.

5.3 Options for meeting the requirements

- **Option One: Fuel switching from ‘Heavy Fuel Oil (HFO), to Low Sulphur Fuel (LSF).** This option is technically feasible, with limited up-front investment costs (except for change of designation and use of some fuel tanks from HFO to LSF involving tank cleaning of those tanks).
- **Option Two: Retrofit of a scrubbing system to ships.** The consensus from the shipping operators that have been consulted as part of the study is that the currently available abatement technology is not sufficiently proven for ship owners to switch with confidence and demonstrate compliance *within the time period required by the legislation.*
- **Option Three: Use of Liquefied Natural Gas (LNG) as an alternative fuel.** Alternative fuels may be applicable in some circumstances. Its use poses particular problems where existing ships would need to be retrofitted (*which is understood to be unsuitable for much of the UK fleet*) and is more *appropriate for new build.*

5.4 Approach take in the study

The analysis follows a stepwise approach as set out in this illustration.



5.5 Increases in fuel costs

- Analysis of the likely range of values for the increase in costs associated with switching from 1.0% to 0.1% Sulphur content fuel is \$275-350 per tonne, with an average of \$315 per tonne, which is the range and expected value adopted in this study. It is assumed that the full cost of fuel price increases will be passed on directly as increased ticket prices.
- Impacts on wider refined oil product markets: The increase in demand for distillates will be approximately the same as the current UK market for diesel fuel. Fuel oils are globally traded commodities and the impact of an increase in demand from across Europe is likely to lead to an increase in the price of diesel, A Swedish Study Sweco (2012) suggests an increase in fuel costs of around 2.8p per litre. Road users account for around 26,000 million litres of diesel in the UK in 2011. This means that such an increase in the diesel pump price would be equivalent to an overall additional cost to road diesel consumers in the region of £720 million. (See Box 1 in main report.).

5.6 Increases in ticket prices

In this analysis ticket prices increase in order to match the increase in operating costs associated with increases in fuel prices. The industry indicates that there is no capacity to absorb increases in costs and that margins are already tight.

5.6.1 Effects of fuel switching on ticket prices – Western Channel Routes

The results of the analysis for Western Channel Routes suggests that ticket prices, per passenger, would increase between an average of 8% and 13%, with small differences between routes in the price increase expected. Ticket prices for lorries and unaccompanied trailers are expected to increase between 8% and 29%, with larger differences between routes. Containers are not carried on the Western Channel routes analysed.

5.6.2 Effects of fuel switching on ticket prices – North Sea and Container Routes

The same approach has been taken to estimating ticket price increases on North Sea and container routes. Overall, passenger prices are expected to increase by between 5% and 20%. For lorries ticket prices are expected to rise by between 5% and 21%; for unaccompanied trailers by between 5% and 17% and containers between 5% and 17%.

5.7 Modal shift

A modal shift occurs when the relative prices of alternative modes of transport change the economic benefits of different route and transport choices. This study identifies modal shift associated with switching longer sea routes with shorter sea routes and driving more (in order to reach the new port of departure and the delivery destination at the other end. This comes about because longer sea routes imply more fuel use and increased fuel costs mean higher ticket prices which disproportionately impact longer routes.

5.7.1 Switching behaviour by area

Estimating “switching behaviour” begins with an analysis of relative price changes which are converted to an equivalent number of road miles illustrated in the following tables. The range of values presented are broad because they combine the three fuel price scenarios with two haulier cost per Km estimates.

5.7.2 North Sea

Depending upon the costs faced by hauliers for road Km travelled and the scale of increases in tariffs the expected modal shift is modelled to be between 6 and 16% of all freight traffic with the switching being most noticeable for routes near to Dover Calais which is the shortest available cross channel route.

Table 5.1 North Sea - Modal Shift estimates (freight)

		Shipping tariff increase	Haulier cost	Equivalent driving distance	Tonnage switched	% North Sea market switching	Additional road km
		£/one way trip	£/km	Km	Tonnes	%	Km
Low	(low shipping fuel price, high haulage cost)	£31	£0.86	36	959,658	6%	1,130,667
High	(high shipping fuel price, low haulage cost)	£40	£0.43	104	2,663,874	16%	7,792,795

Western Channel routes

Data on haulage end-points is not available in the same detail for these routes. Summary data includes only that the typical length of journey was 260km on the UK side and 890km on the continental side. The calculated tariff increases are very similar to the increases on the North Sea routes. As with North Sea routes the total tonnage of freight switching to shorter sea routes at the expense of increased road transport is modelled to be between 6% and 16%.

Table 5.2 Western Channel - Modal Shift estimates (freight)

		Shipping tariff increase	Haulier cost	Equivalent driving distance	Tonnage switched	% Western Channel switching	Additional road km
		£/one way trip	£/km	Km	Tonnes	%	km
Low	(low shipping fuel price, high haulage cost)	£33	£0.86	38	371,963	6%	438,245
High	(high shipping fuel price, low haulage cost)	£43	£0.43	110	1,032,515	16%	3,020,481

Leisure markets

A one to one relationship between price increase and loss in quantity demanded is predicted for the leisure market. This would suggest that a 10% increase in price would lead to a reduction of 10% in market volumes. Evidence for the reaction of the leisure market is not available as regards route switching. Anecdotally, the leisure market falls into regular travellers with, for example, property in France and those with more discretion over their travel choices taking short breaks.

The first group is unlikely to change behaviour much in the short term in response to the level of tariff increases predicted in this study, however a longer term impact might be felt in frequency of trips and second home owners, potentially seeing reductions in the value of their property. The second group is expected to be more likely to take an alternative holiday than to use a different route.

5.8 Impact of Identified Modal Shift

The predicted modal shift from maritime to road transport will have a range of social, economic and environmental consequences. Where these are not included in the actual prices, these consequences are known as externalities, which can be qualified, quantified and monetised according to standard methodologies.

Our analysis suggests that modal shift will threaten the viability of routes in the North Sea Western Channel. (section 4) The loss of viability of routes and port operations has the potential to displace thousands of (good quality) jobs (Section 4).

The analysis further indicates that modal shift will affect between 1.3-3.6 Million tonnes of freight leading to between 1.5-10 million additional road kilometres. This is expected to lead to increased congestion on the roads and local environmental problems. The DfT guidance (DfT, 2012a) identifies the main external costs of transport as being; congestion, infrastructure, accidents, local air quality. noise. greenhouse gas emissions.

5.9 Route viability - effects of fuel switching

Route viability is assessed in relation to existing margins. The impact of increased ticket prices and reduced traffic feeds through into the ship by ship cost models used by the operators. Increased fuel prices represent an increased cost and increased ticket prices multiplied by the amount of traffic represents the income. Where as a result of our analysis the gross margin switches from positive to negative these routes are identified as threatened, where the gross margin drops below -20% the route is classed as “unlikely to be viable”. Where there are several ships and multiple sailings the option to reduce capacity and maintain occupancy levels in spite of a falling volume may provide a means of securing part of the fleet and some of the routes.

5.9.1 North Sea routes

The results of modelling the costs of routes indicates one route that is unlikely to be viable post fuel switching (i.e. post implementation) and a further three are threatened. We were unable to model a number of routes in detail but of those we were able to model five were identified as likely to remain viable, and this is a reflection of the fact that for a number of these routes there are few practical alternatives.

Table 5.3 Economic implications of lower traffic volumes – North Sea and Container Routes

Route	Reduction in annual passenger number	Reduction in annual Freight (Lorry, UT and Container)	Implication with modal shift (lower traffic volumes) from costs associated with switching to low sulphur fuel	
			Loss making?	Viability
NS 1	0	0	No change	Likely to remain viable, with estimated modal shift, 2011 ship configuration and number of sailings
NS 2	13,486	0	Unknown	n/a
NS 3	0	0	Unknown	n/a
NS 4	0	0	No change	Likely to remain viable, with estimated modal shift, 2011 ship configuration and number of sailings
NS 5	0	0	No change	Likely to remain viable, with estimated modal shift, 2011 ship configuration and number of sailings
NS 6	0	0	No change	Likely to remain viable, with estimated modal shift, 2011 ship configuration and number of sailings
NS 7	101,289	0	Unknown	n/a
NS 11	28,734	0	Yes	Threatened, with estimated modal shift, 2011 ship configuration and number of sailings
NS 12	38,3512	0	Yes	Threatened, with estimated modal shift, 2011 ship configuration and number of sailings
NS 13	50,900	58,723	Yes	Unlikely to be viable with estimated modal shift and 2011 ship configuration and number of sailings
NS 14	0	0	No change	Likely to remain viable, with estimated modal shift, 2011 ship configuration and number of sailings
NS 15	0	24,937	Yes	Threatened, with estimated modal shift, 2011 ship configuration and number of sailings

Source: AMEC analysis, based on operator data *Note, the UT and Container price increase are affected by the use of one ship on the route during 2011 which carried relatively low volumes of both UT's and containers.

5.9.2 Western Channel routes

Western Channel routes were found to be vulnerable to increased relative prices. Of the four routes studied two were found to be threatened and two unlikely to remain viable in the face of different relative prices.

Table 5.4 Economic implications of lower traffic volumes – Western Channel

Route	Reduction in annual passenger number	Reduction in annual Freight (Lorry, UT and Container)	Implication with modal shift (lower traffic volumes) from costs associated with switching to low sulphur fuel	
			Loss making?	Viability
WC 1	90,775	46,746	Yes	Unlikely to be viable with estimated modal shift, 2011 ship configuration and number of sailings
WC 2	n/a	9,198	Yes	Unlikely to be viable with estimated modal shift, 2011 ship configuration and number of sailings
WC 3	38,357	0	Yes	Threatened with estimated modal shift, 2011 ship configuration and number of sailings
WC 4	5,149	0	Yes	Threatened with estimated modal shift, 2011 ship configuration and number of sailings

Source: AMEC analysis, based on operator data

5.10 Wider economic effects

5.10.1 Shipping operator employment

Overall, as many as 2,000 full time, part time and contract positions are likely to be at risk in the UK and on the continent, in maritime engineering, navigation, catering, customer service, cleaning and administrative occupations from those routes that are potentially unviable or would be threatened from the traffic reductions identified.

5.10.2 Port based employment

Data on total port fees has also been provided from operators and is summarised below. The numbers represent total annual port fees paid to all ports called at on the relevant routes for 2011, unless otherwise stated. Overall the operators paid just over £50 million in fees on all of the routes assessed as part of the study.

5.10.3 Effects on hauliers and on trade

Largely irrespective of modal shift decisions, it is likely that the costs for haulage firms are likely to increase, either through higher ticket prices, or (marginally lower) cost increases from increased road miles. These costs would either be at least partly passed on down their respective supply chains, or haulage firms would seek to reduce costs further, or both.

6. References

Bartholomew & Panagiotopoulos (2011): Options for lower-sulphur marine fuels, digital refining, PTQ Q4 2011.

CE Delft (2008): Handbook on estimation of external costs in the transport sector, Produced within the study Internalisation Measures and Policies for All external Cost of Transport (IMPACT), Version 1.1, Commissioned by the European Commission DG TREN, February 2008.

Deloitte (2010): Downstream oil – short term resilience and longer term security of supply, final report for DECC, 1 April 2010.

DECC (2011): DECC, Valuation of Energy Use and Greenhouse Gas Emissions for Appraisal and Evaluation, October 2011.

DfT (2012a): Major scheme appraisal: road decongestion benefits, Transport Analysis Guidance (TAG) Unit 3.9.5, Department for Transport, August 2012

DfT (2012b): External costs of car use in rail appraisal, Transport Analysis Guidance (TAG) Unit 3.13.2, Department for Transport, August 2012.

Entec (2010): Study to review assessments undertaken of the revised MARPOL Annex VI regulations, final report, July 2010.

ICCT (2007): Air pollution and greenhouse gas emissions from ocean-going ships: impacts, mitigation options and opportunities for managing growth, International Council on Clean Transportation, March 2007.

Malmqvist & Alden, (2013), Sulphur Regulation in the Baltic Sea.

Purvin & Gertz (2009): Study on the impacts on the EU refining industry & markets of IMO specification changes & other measures to reduce the sulphur content of certain fuels, report for DG Environment, 30 June 2009.

Purvin & Gertz (2011): Supply and pricing of low sulphur fuels, presentation to Interferry 36th annual conference, Barcelona, 3-6 October 2011.

RHA (2011): RHA Cost Tables 2011, prepared for the Road Haulage Association by DFF International Ltd.

Sansom, T., Nash, C., Mackie, P., Shires, J., & Watkiss, P. (2001) 'Surface Transport Costs & Charges: Great Britain 1998' Department of the Environment, Transport and the Regions, London.

Sweco (2012): Consequences of the Sulphur Directive, October 2012.