



The 0.1% sulphur in fuel requirement as from 1 January 2015 in SECAs

- An assessment of available impact studies and
alternative means of compliance

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Part 1: Introduction

1. Background

In October 2008 the International Maritime Organization (IMO) adopted a set of amendments to Annex VI of the MARPOL Convention which, among other things, strengthened the requirements on the permitted sulphur levels in ships' fuels. The amendments provide for a progressive reduction of the sulphur content of marine fuels as follows: from 1 January 2012 the global sulphur cap will be reduced, first to 3.50% (from the current 4.50%) and then, subject to a feasibility review to be completed no later than 2018, progressively to 0.50 % from 1 January 2020 (or in 2025 at the latest). In 'Sulphur Emission Control Areas' (SECAs), requirements are more stringent.¹ As from 1 July 2010, the maximum sulphur limit has been reduced to 1.00%, (from 1.50%), while from 1 January 2015, the limit will be further reduced to 0.10%.

It is mainly this last requirement, the 0.10% limit within SECAs, which has caused concern within the EU to date. A series of studies have recently been performed by various organizations to assess the implications of the new sulphur in fuel standards for the shipping industry and other stakeholders in general and for short sea shipping in particular. The focus on the 0.1% requirement within SECAs is explained by the fact that the only existing SECAs are located within the EU and that short sea shipping accounts for an important share in the transport logistic chain of the countries bordering these areas. It should be noted, though, that existing EU law (Directive 2005/33/EC) already requires ships, with certain exceptions, whilst in EU ports to use fuel with maximum 0.1 % while at berth if they do not use shore-side electricity. This requirement has been in force since 1 January 2010.

At a meeting between the European Commission and the Directors of the EU Member States' national maritime administrations in Brussels on 26 April 2010, EMSA was requested to provide a summary of the findings of the available studies and to identify potential measures (technical and other) that could mitigate the negative effects of the new MARPOL requirements. The present report responds to that request. It consists of two main parts: part 2 summarises the available studies and their results and assesses whether it is possible to find common conclusions of the impacts the new requirement on shipping within the EU. Part 3 introduces and assesses various technical alternatives that are available for operators that do not wish to switch to more expensive low sulphur fuel. Some main conclusions are finally offered in Part 4.

¹ There are currently two SECAs, both located in EU waters: the Baltic Sea and the North Sea including the English Channel. A third SECA has been adopted more recently covering parts of the (Atlantic, Gulf of Mexico and the Pacific Coast) coastal waters of the United States and Canada. The North American ECA will take effect as from 1 August 2011.

Part 2: Assessment of studies

2.1 General

This part of the report provides an overview of the main elements from the available studies on the impact of the revised MARPOL Annex VI. Seven studies and one more general assessment of the studies were available at the time of finalizing this report (October 2010). The full titles and references of the studies are listed in Annex 1.

Four of the studies have been performed by or on behalf of EU Member States located within SECAs: by Finland, in a study made by the Centre for Maritime Studies at the University of Turku in 2009 (hereinafter referred to as 'the Finnish study'), by Sweden in a study undertaken by the Swedish maritime administration in 2009 ('the Swedish study'); by the United Kingdom, in a study by ENTEC in 2009 ('the UK study') and by Germany in a study made by Institute of Shipping Economics and Logistics in 2010 ('the German Study'). The Finnish study mainly analyses the effects of the increased fuel costs due to the 0.1% requirement within SECAs for the Finnish industry while the Swedish, UK and German studies analyse the increased fuel costs and their potential impact on shipping in relation to other modes of transport. The German study has in addition assessed the additional effects on the ports concerned.

One study has been commissioned by a shipping organisation, the European Community Ship-owner Association (ECSA) and was performed by the Institute of Transport and Maritime Management (ITMMA) at the University of Antwerp in 2010 ('the ECSA study'). This study has assessed the potential modal shift from shipping to road and rail on specific shipping routes as a consequence of the new stricter sulphur in fuel requirements. In addition, a group of Northern shipowner associations have commissioned an assessment of the different studies that have been undertaken on this topic. The assessment of studies was performed by ENTEC in 2010 and has been endorsed by the wider membership of ECSA and the ICS. It is referred to as 'the joint ship-owner assessment'. That assessment was based on six studies available at the time (not including the COMPASS study, which is included in this report).

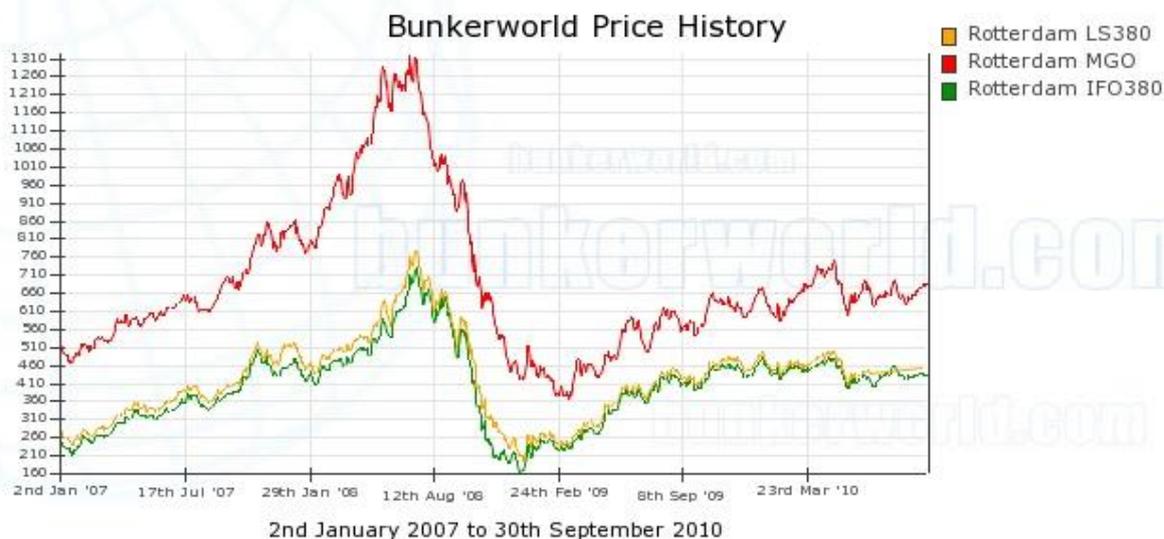
The three remaining studies have been commissioned by the European Commission. The first one is a cost benefit analysis to support the impact assessment accompanying the revision of Directive 1999/32/EC on the Sulphur Content of certain Liquid Fuels (performed by the AEA in 2009 and referred to as 'the AEA study'). The second study, which assesses the impact of the Annex VI requirements on short sea shipping, was finalized in 2010 and was commissioned by DG TREN (now DG MOVE). It was performed by SKEMA and is referred to as 'the SKEMA study' below). Finally, the COMPASS study, commissioned by DG Environment, has studied the competitiveness of European short-sea freight shipping compared with road and rail transport. It was undertaken by Transport & Mobility Leuven in 2010 and is referred to as 'the COMPASS study').

Most studies have centred on the same two key issues, i.e.: what economic effects will the 0.1% sulphur limit within ECAs have by 1 January 2015, and what consequences will those effects have on transport patterns? This report only focuses on the impact of the 0.1% sulphur requirement applicable within SECAs as from 1 January 2015, as this is widely accepted in the studies as being the most challenging requirement for now. A common assumption in the studies is that the 0.1% requirement will mainly be met by the use of distillates in place of residual (heavy fuel) oil² and that the fuel expected to be used is marine gas oil (MGO). The subsequent global requirement of maximum 0.5% sulphur in fuel as from 2020 (or later) will not be addressed in this report.

² The UK study assumes in one of their scenarios that 90% of the vessels will switch fuel while 10% will use wet scrubbers.

2.2 What are the economic effects of the 0.1% sulphur limit within ECAs by 1 January 2015?

The most obvious effect of the requirement to lower the permitted sulphur level in marine fuels to 0.1% in 2015 is an increased fuel price. This consequence, which is acknowledged in all studies, is not a big surprise given that low sulphur fuel (MGO) already today is more expensive (some 70-80%) than heavy fuel oil, mainly due to the fact that it is a distillate product and to the costs involved in the desulphurization process. Graph 1 below summarises the price difference between MGO and (high and low sulphur) oils over the past few years.



Graph 1: Price history in USD/tonne (source: Bunkerworld)

The seven studies are not entirely consistent in their view on how the increased demand for MGO will affect its price. While some (notably the ECSA study) emphasizes the added needs for desulphurization, implying additional costs, the COMPASS study notes that the demand increase for this type of fuel could result in a decrease of the relative price as a result of economies of scale.³ The UK study also notes that by the time the global cap of 0.5% enters into force (in 2020 or later) the increased cost for the refining industry might well be passed directly to ship operators through an additional fuel premium.⁴ At this time, however, the price differential between the global sulphur limit and that applying in SECAs will be reduced.

A main problem that has been highlighted in all studies is the difficulty to predict the trends of fuel price more generally in the future. Bunker prices fluctuate constantly due to market forces and the price of crude oil. On top of this the difference between HFO and MGO is not constant. The ECSA study shows that the price difference between IFO 380 (heavy fuel oil) and MGO (0.1%) has fluctuated between 30 and 250% over time while the moving annual is between 52 and 155% with a long term average of 93%.⁵ According to the Finnish study the price difference between heavy oil (1.5%) and light fuel oil (0.1%) was 73-85% on average during 2006-2008, while the price difference between the 1.0% (which is the requirement that applies since 1 July 2010) and 0.1% was 51-62%.⁶

All studies have made some form of estimates on the amount or percentage of the fuel price increase and they have all used different baseline prices. Table 1 below seeks to summarise the results in terms of the estimated price of MGO.

³ COMPASS study, p. 67.

⁴ UK study, p. 55

⁵ ECSA Study p. 18.

⁶ From table 3.1 at p. 12 of the Finnish study.

Study	Expected price for MGO (0,1 % S) per ton in USD in 2015	Conversion to EUR ⁷	Expected differential per ton between 1.5% S and 0.1% S, if indicated
ECSA	Low: 500 USD Medium: 750 USD High: 1000 USD ⁸	379 568 758	80% ⁹
Sweden	Low: 662 USD ¹⁰ Medium: 1158 USD High: 1650 USD	502 877 1250	
Finland	470-500 EURO ¹¹ (historic price) (633-673 USD)	470-500	73-85% (historic price difference 1,5% to 0,1 % S) The historic price difference between 1,0 % and 0,1% S has been 51-62%
UK	Scenario 1: 545 USD Scenario 2: 727 USD ¹²	413 551	Scenario 1: 92 and 42% Scenario 2: 119 and 59% ¹³
SKEMA	656 EURO (883 USD)	656	
COMPASS	656 EURO (883 USD)	656	65%
AEA	No comparable values provided		No comparable values provided.
Germany	Low: 850 USD High: 1300 USD	644 985	70-86% (price difference 1,5% to 0,1% S) 57-75% (price difference 1,0% to 0,1% S)

Table 1: Summary of cost estimates for MGO in 2015

All studies thus estimate that the fuel price for the maritime traffic within SECAs will rise by 2015, but there are significant differences as to how big the increase will be. The table above suggests that in normal circumstances (i.e. low or medium scenarios) the price for MGO in 2015 would be somewhere between 600-900 USD. While the figure is not dramatically different from the current price of MGO, it is significantly higher than the costs of trading with the fuels that are allowed today. Based on the table, it seems that the shift from heavy fuels to MGO will imply an increased fuel price by around 65-80%, compared to the 1.5% limit, for ships trading within ECAs. All studies, however, emphasize the uncertainty involved in these calculations.

The SKEMA, COMPASS and the German studies have based their estimates on that made by Purvin & Gertz in 2009.¹⁴ However, for reasons which are not explained, the figures in the studies exceed (by some 20-25% per cent, depending on the exchange rate) the ones on which they are said to be based. The German study has further increased the estimate on the basis of the development during 2010. In the studies the fuel prices are presented in the form of a table:

⁷ To simplify comparison, all prices have been converted here to EUR irrespective of the currency used in the study. The conversion rate used for this purpose is that of 10 December 2010, i.e. 1 EUR = 1.32 USD.

⁸ The ECSA study has used historic values of the price for MGO and has on this basis set estimate values for the medium term.

⁹ According to the ECSA study the long term averages indicate a cost difference between 70-90 %. The study has chosen 80% in all three scenarios as a percept price difference for the purpose of the study.

¹⁰ Based on the price for different fuel types in Oct/Nov 2008.

¹¹ Average price for light fuel oils (0.1%) in 2006-2008.

¹² The is the calculated price for MGO at 2015, scenario 1 being that 90 % of the vessels switches to MGO and 10 % use wet scrubbers and scenario 2 being that all vessels switch fuel.

¹³ The difference in premium in the same scenario is due to the fact that the UK Study chose to use two values for the baseline value of 1.5% fuel, depending on whether it is a blend on IFO 380 (3%S) and 1 % S LSFO or a blend of MGO and IFO380(3S).

¹⁴ Purvin & Gertz: 'The impact on the EU Refining Industry & Market of IMO Specification Changes & Other Measures to Reduce the Sulphur Content of Certain Fuels', 2009.

Fuel Sulphur Content	€/Ton		
	1.50%	1.00%	0.10%
2009	€166.56	€178.72	€425.80
2010	€281.75	€293.91	€492.11
2015	€399.60	€411.76	€656.24
2020	€424.74	€434.34	€705.83
2025	€466.38		€752.99

Table 2: price estimates by SKEMA, COMPASS

Apart from the German study, which is the most recent one, the studies have mainly analysed the difference between 1.5% requirement and 0.1%.¹⁵ Based on the figures presented in table 2, one may calculate not only the price differences between the 1.5% requirement and 0.1%, but also the difference between the latter and the 1.0% limit which is currently in force and therefore seems more appropriate as a reference figure.

Year	Price difference 1,5 to 0.1 % S	Price difference 1,0 to 0.1 % S
2010	74,66 %	67,4 %
2015	64,22 %	59,37 %
2020	66,17 %	62,50 %

Table 3: Calculated price difference between different types of fuel

The figures in table 3 could also be compared with the price difference in the recent past, which in the Finnish study is reflected as an average over the years 2006-2008, found to be 73-85% between 1.5% and 0.1% S, while the price difference between the 1,0 % S and MGO has been 51-62%.¹⁶ On this basis it seems tempting to assume that the new requirements will not dramatically affect the *difference* in price between 1.5%, 1.0 and 0.1 % S fuel compared to the recent past. What is affected is mainly the *absolute* price, which will go up in all categories. As is noted in the German study the actual fuel prices have been somewhat higher in 2010 than predicted in table 2 for all fuel options¹⁷. On the other hand, the price *difference* between 1.0% and 0.1% fuel has been lower than predicted, around 52% in early December 2010.¹⁸

It may also be noted that the studies, when assessing the economic impact of the new requirements within SECAs, usually assume that ships undertake a complete shift from 1.5% fuel to MGO. That approach may not sufficiently take into account that there is already a requirement to use 1.0% in SECAs and that a maximum of 0.1% sulphur in fuel is already required while at berth in any EU port. The ECSA study also notes that a significant number of ships in the intra-Baltic trade already use fuel of lesser than the (then) maximum of 1.5%.¹⁹

¹⁵ The German study was performed after the entry into force of the 1.0% requirement within SECAs and has accordingly compared the present requirement 1.0% to 0.1%, but also to the global requirement 0.5 %.

¹⁶ Table 3.1 in the Finnish Study – Estimated price differentials for low sulphur fuel grades in relation to the fuel grade currently in use. See also figure 1 above.

¹⁷ German study, pp. 3-11.

¹⁸ The relevant prices as per early December were: MGO 760 USD: 1.0% fuel 500 USD.

¹⁹ Tables 4.2 and 4.3 in the ECSA study. In the intra-Baltic trade only 61% of the ships used 1.5% and in the Sound/Kattegat area this number is down to 35%. 9% of the ships were already using the 0.1% sulphur in the latter region.

2.3 What consequences do the increased fuel costs have on transport patterns in the EU?

2.3.1. General

Six of the studies have paid more particular attention to the implications of the increased fuel prices with respect to different ship types and routes.

- 1.** The COMPASS study aimed at analyzing the effect on short sea shipping and the risk for modal shift to land-based transport modes. 252 origin-destinations pairs were studied, chosen on the basis that they were part of freight corridors where a modal shift may take place and where there was a real potential for a drop in cargo volumes.
- 2.** The ECSA study used a set of 30 origin-destination pairs centred on four short sea routes within SECAs. It studied the impact of the increased fuel costs for shipping compared to competing road and rail transport.
- 3.** The Finnish study focused on the impact of the fuel prices for the Finnish exports and imports. In this study the potential modal shift is not addressed.
- 4.** The Swedish study used some of the reference material from the Finnish study, but also analysed the effect that the increased fuel prices for shipping would have on transport patterns to and from Sweden.
- 5.** The SKEMA study looked at the effect for short sea shipping within the present SECAs based on 10 competing services operating in four corridors.
- 6.** The German study assessed the effect for eight different corridors for RoRo shipping and five corridors for container shipping to and from Germany.

In view of their purpose, it is natural that the studies mainly assess the effect of the increased fuel costs for shipping on the total transport costs. In this sense the potential for modal shifts is assessed in purely monetary terms. It is well accepted, however, that a transport buyer's choice of the mode of transportation also depends on several other important factors such as flexibility, reliability, speed etc.²⁰

It was already concluded above that the fuel costs for shipping in SECAs will substantially increase from 2015 and this, in turn, will increase the transport costs. According to the Finnish study, the increased fuel costs will most probably channelled to the sea freight charges. However, the Swedish study suggests that it would be difficult to channel the cost increase to the transport buyer, as industries within ECAs are competing with industries in regions that are not ECAs and do not have corresponding fuel requirements. The latter suggestion is also supported in the ECSA study where it is stated that due to the competition with road transport the shipping sector will find it difficult to charge their customers for the fuel cost increase. The ECSA study also highlights the risks with the other option: if the increased fuel price is absorbed by the ship operators it would negatively affect the financial basis and attractiveness of the short sea shipping business and the lower margins would risk undermining innovation in the industry and could prolong the operating lifespan of (older) short sea vessels. Yet for the purpose of their calculation for potential modal shifts, the studies widely assume that the increased fuel price will channelled in the form of freight charges.

²⁰ COMPASS p. 12, SKEMA p. 39,

2.3.2. Effect on different ship types and segments

Not all ships will be similarly affected by the increased fuel prices. Unsurprisingly it is expected that the more fuel intensive types of ships will be harder hit than other ships. All studies further accept that the impact depends on the share of fuel costs out of the overall transport cost for the specific ship type. It is accordingly concluded that ship categories like general cargo ships and container vessels will be particularly affected by an increased fuel price. According to the COMPASS study, fuel represents 47% of the daily costs (including all costs such as fuel, capital investment, interest, manning, gross margin, repairs, maintenance etc.) for LoLo (container) ships²¹ while the corresponding share for a Ro-Ro ship is estimated at 32%.²² The Finnish study similarly suggests a high fuel cost percentage for container vessels (54%) as compared to conventional dry cargo vessels (38%), dry bulk vessels (40%) or tankers (33%). For Ro-Ro ships the share is estimated at 36% and for car passenger ferries 30%. The ECSA study indicates a similar result but is calculated on the basis of speed rather than ship types.²³

The impact also depends on the route concerned. The SKEMA study estimates that the LoLo shipping for the selected routes risks to experience a shift away from maritime transport in favour of road, and this is supported by the COMPASS study assessing that up to 10% of the routes where a LoLo is used might be affected while the corresponding number for Ro-Ropax is only 1%. The COMPASS study, however, suggests that even the LoLo vessels will remain competitive over relatively short distances (0-500 km). As the distance of the sea leg increases, the LoLo segment is expected to suffer a 14–15% reduction in cargo volumes.

The SKEMA study also found that the mode utilisation (i.e. the degree to which a resource is fully utilised during a voyage) had a significant impact on the overall route costs and hence the differential in competitiveness between modelled routes. This was also supported in the COMPASS study in which they even estimated that short sea shipping might lose market shares to deep sea vessels with larger volumes, which are used for longer routes but which could be making extra port calls. The study however emphasises that other aspects than explicit costs such as flexibility, opportunity costs and load factors will probably temper this effect.

The COMPASS study estimates that the most affected commodity types will be metal and agricultural products, while the impact will be smaller for foodstuff, building materials and chemicals. The ECSA study, on its part, shows that the forest industry will be strongly affected with an anticipated increase of 25 to 35% per tonne freight, implying a final price increase for the paper product ranging from 0.4% to 2.6%. The ECSA study concludes that it may be difficult to pass on this increase to the final customer in a global market.

2.3.3. Effect on different ship routes

In its study ECSA analysed four short sea traffic areas²⁴ and 30 origin/destination routes, all of which are facing a potential competition from road haulage. The outcome suggests that the length of the sea leg significantly affects the prospects of a modal shift. At the low cost scenario (MGO price USD 500) the expected freight rate increases will be in the order of 15-25% with an overall average of nearly 18%. Rate increases are expected to be highest on the longer and medium long routes. The corresponding volume losses, according to the ECSA study, are expected to be 14.5%. The routes covering medium-range distances (400-750 km) are likely to be hit the strongest with expected volume losses of 21% on average. The long-distance routes

²¹ Lo/Lo (lift on - lift off) is defined in the study as a medium - long range ship serving container ports with carrying capacity between 500 and 750 TEUs.

²² COMPASS study, p. 65

²³ The ECSA study shows differences in HFO compared to MGO and depending on routes and length. The highest share is 64% and is found on a long-intra Baltic journey with a fast ship (25 kn) while the lowest share for MGO is 14.7% is found on a medium long journey between the UK and the Baltic States.

²⁴ Germany/Denmark to Sweden; English Channel; West Europe to the Baltic States and West Europe to Scandinavia (Sweden/Norway)

seem to be less affected. The study has also studied at a high price scenario (MGO price at USD 1000) where the anticipated volume losses were more than 50%.

The ECSA study also indicates that the longer the sea leg is in the total distance of the transport, the more will the use of MGO impact the total transport price for the truck/short sea option. The study mentions the example of Rotterdam-Oslo where the price increase associated with a shift to MGO amounts to 11-12% in the high fuel price scenario (MGO price USD 1000) when using the Ghent-Gothenburg short sea link. When using shorter short sea links (Travemünde-Trelleborg or Putgarten-Rödby) the transport price increase is estimated at between 1.1 and 3.4%.

The study also concludes that there will be changes in the relative competitiveness of the short sea/truck option versus the 'truck only' option. In the high scenario, on the ferry routes from Germany/Denmark-Sweden, short sea shipping remains highly competitive, being around 21% less expensive than the truck only option. For shorter routes which include a road haulage segment the competitive advantage slightly decreases when considering the switch to MGO. For example, on the route Putgarten-Rödby the cost difference (which is not in favour of short sea shipping even today) is expected to decrease from -5 to -7%.

The ECSA study also concludes that the shipping routes transiting the English Channel will be severely impacted. Following a shift to MGO the combined truck/short sea solution will have a price disadvantage of between -32-0% compared to the truck/rail combination. According to the study this increase suggests a modal shift from short sea services on the Calais-Dover link to rail services through the Channel Tunnel. However, this conclusion only applies in the case of the high fuel price scenario (where MGO is priced at USD 1000), whereas all the English Channel routes still remain competitive in the low price scenario (USD 500). The Rotterdam-Harwich routes show the most competitive profile on all routes considered and remains 8% cheaper than the 'truck only' option even in the high fuel price scenario.

The ECSA study also concludes that the transport connections between Western Europe and the Baltic States are expected to be heavily impacted. Routes like Amsterdam-Kaunas and Dieppe-Kaunas are shown to decrease significantly in the high scenario, but other routes, like Hamburg-Tallinn, would still remain competitive. The short sea connections between the Benelux/Western Germany and Scandinavia (Sweden and Norway in particular) would face rather limited competition from road haulage, though the competitive advantage for shipping would be reduced. More certain, according to the study, is that the use of MGO will trigger a shift from long-distance to short-distance sea links; hence the Travemünde-Trelleborg route would clearly overtake the Ghent-Gothenburg route to become the cheapest solution between Rotterdam and Stockholm.

A more detailed study of the figures presented in the ECSA study (tables 4.15 and 4.16) suggests that the general tendency in the high scenario is that the links that have had competitiveness problems even with the high-sulphur option would still have (even more) problems with the new requirements in place. Conversely, the links that have been competitive will remain competitive, even if the margins would be shrinking. In the low cost scenario (MGO price 500 USD) the picture is not the same. None of the links would lose to a 'truck only' option and only two would not be competitive (two links from The Netherlands and Belgium to Lithuania) one of which was not competitive in the high-sulphur option either. The remaining routes would remain competitive although less clearly so than in the high-sulphur option.

The study on routes made in the COMPASS study is based on a different selection of routes. Here the general tendency seems to be that the longer routes to and from Finland will be more affected than other routes and especially the so-called LoLo vessels. The same goes for the longer journey analyzed from Northern Sweden to the UK, some lines Norway to the UK and Stockholm-Belgium. The findings in the SKEMA study similarly point towards such effects for LoLo ships on the routes Vilnius-Dortmund, Gothenburg-Dortmund and Dortmund-Manchester.

This would seem to support the conclusion of the ECSA study that middle long journeys will generally be more affected than shorter journeys and especially those with a long sea leg. The findings in the SKEMA and German studies also support the conclusion that traffic to the Baltic States will be affected. Another conclusion that can be drawn is that not all lost traffic for the medium long shipping routes will be lost to rail or road transport. Some will be lost to other short sea shipping routes involving a shorter sea leg. This conclusion is also confirmed in the German Study.²⁵

The SKEMA study found that even for Ro-Ro shipping there will be a shift to road, but this finding does not seem to be supported in the other studies. The ECSA study suggested that the Ro-Ro routes would still generally be competitive, partly due to the consideration – which is also supported in the Finnish study – that the higher investment costs for a Ro-Ro ship, compared to a general cargo ship, mean that share of fuel costs of the total cost will be lower.

The Swedish report suggested that a modal shift is probable, in different proportions according to the different scenarios considered. The decline in tonne-km for shipping ranges from two to ten per cent, depending on scenarios, in favour of rail and road transportation. The German study, on the other hand, predicted an overall decrease in volumes by 22% in their high-price scenario (MGO price: USD 1300). This is – among other things – due to a predicted shift in market shares towards Southern ports, such as the Adriatic.

The studies also made the distinction between ships transiting through the SECA as part of longer voyages and ships which are usually operating exclusively within SECAs. The latter category will obviously be most affected, and as underlined in the ECSA study even relatively small traffic losses (e.g. 10 to 20%) can trigger a vicious cycle that lead to the implosion of the short sea sub market.

Overall, the various studies offer differing conclusions as to whether a modal shift is imminent, which may in part, but not entirely, be explained by the difference in routes selected for their analyses. While the Swedish, German and ECSA studies (mainly) in their high price scenario foresee a substantial shift from short sea shipping to land-based modes, the COMPASS study acknowledges that there will be a cost increase and a change in transport volumes, but concludes that “it is not expected that changes in entry/exit points or shifts in modal balance (SSS to land) will take place.” Another conclusion by the COMPASS study is that the European imports and exports are not likely to have more than negligible cost increases to the end user given the marginal cost increase of maritime and the marginal share of maritime transport cost in end user prices.²⁶

2.3.4. Availability of low sulphur fuel

The availability of low sulphur fuel has been looked at in most studies. It represents another parameter that is hard to predict. However, the Finnish, Swedish and the UK studies estimate that there will be sufficient quantities of low sulphur fuel available by 2015 when the 0.1% requirement enters into force.²⁷ Several of the studies expect that by the time the global level of 0.5% comes into force (possibly by 2020) the oil industry will have to increase its refining capacity considerably to meet the rise in demand for light fuel grades.

²⁵ The German study, pp. 1-3.

²⁶ COMPASS study p. 97.

²⁷ The Finnish study concludes that it has been difficult to predict the availability of low-sulphur fuels but recognized that the any problem will not be due to the increased demand in SECAs areas.

2.3.5 Benefits to society

In the heat of the discussions of the impact of the new fuel requirements over the past few years, the purpose of the new rules may sometimes be forgotten. The underlying objective of the new requirements in Annex VI is of course to minimize the environmental and health risks related to air pollution from ships, notably emissions of sulphur oxides (SO_x) and particulate matter, which contribute to acidification and eutrophication as well as a range of other environmental and health impacts, in particular for people living in port cities and coastal communities.²⁸ The impact assessment accompanying the European Commission's 'Thematic Strategy on Air Pollution' in 2005 indicated that, unless further action is taken, emission of SO₂ and NO_x from the maritime sector could exceed total European emissions from land-based sources by 2020. While land-based industries, including transport, have had a series of fuel quality requirements implemented in the past decades, resulting in significantly stricter rules than the revised MARPOL Annex VI, shipping had until 2008 made a very limited contribution to the efforts to improve air quality in Europe and beyond. In view of this, it was commonly accepted to be not only appropriate, but also cost-effective to shift the regulatory attention from land to shipping and its contribution to air pollution.²⁹

The benefits to society provided by the stricter requirements have been noted in most of the studies, but only four of them (UK, AEA, ECSA and the Swedish study) seek to quantify those benefits in more concrete terms, in terms of health, environmental or other benefits. All studies have used different scenarios as a basis for their calculation; the case examined below is the broadest one in which the sulphur requirements are fully implemented by all ships and only through a switch from 1.5% sulphur fuel to MGO (i.e. without using other fuels or abatement technologies).

The most complete picture when it comes to assessing **health benefits** is provided by the AEA study. The benefit assessment model used in that study is well-known in the EU and has also been used in the framework of the Commission's Acidification Strategy, the Ozone Directive, the National Emission Ceiling Directive and in the Gothenburg Protocol to the UN Convention on Long-Range Transboundary Air Pollution. Based on its calculations the AEA study estimates that the net health benefits to society of the new rules (ranging from EUR 8 to 16 Billion) will be far greater in 2015 than the costs of the new measures (estimated at EUR 3.7 Billion in the highest estimate). By 2020 the net health benefits will have increased to 10-23 Billion.³⁰ The UK study also indicated a high annual health benefit in the UK (£309-622 Million), which had been calculated in terms of avoided life years lost, reduction in respiratory and cardiovascular hospital admission etc.

Apart from the health benefits, some of the studies also indicate positive **environmental** effects, as acidity and nutrient nitrogen deposition are expected to decrease through the new requirements. In the AEA study the reduction in acidification is expected at -25% in SECA areas while eutrophication is estimated to be reduced by -3% in 2015. The UK Study uses 2020 as for their calculation. Some important benefits have been identified due to the reduction of particles (PM 10-PM 2.5) which are estimated to reduce by 65-77% compared to the 'do nothing' option (where the new revised Annex VI is not implemented). The Swedish study also points at the benefits of reduced particulates emissions, of which the larger particles in particular impacts the local environment, and expects the reductions to be up to 80-85%.

Other environmental benefits from a shift from high sulphur fuel to MGO referred to in the UK study include that distillates have less hazardous components than residual fuels, the environmental consequences are less damaging for distillates in case of a bunker fuel oil spill and that the use of distillates reduces the onboard production of oily waste which in turn may reduce the problems related to operational discharges of oily waste by ships. Outside the realm

²⁸ UK study p.1

²⁹ See e.g. the AEA Study p. 3 and the UK study p. 2

³⁰ AEA Study p. 2.

of environmental benefits, it is also noted that a series of other monetary benefits are likely to result from the new rules. The UK study estimates that savings in the form of less damage to buildings (including monuments and buildings of special interest to preserve) and materials will amount to £ 6.32 Millions per year in the UK alone.

The UK study also provides for a **carbon assessment** of the new sulphur in fuel requirements. The 'all vessels fuel switch' by 2020 is the most CO₂ efficient scenario with a total estimated reduction of 1.467.000t of CO₂, valued to £38M.³¹ Conversely, the 'all vessels use wet scrubbers' scenario is the least CO₂ efficient, providing for an *increase* of 593.000t of CO₂ by 2020, representing an additional cost of £14M to the society. CO₂ emissions from refineries process to produce of distillates fuels and emissions linked with the scrubber's production have not been integrated in the estimation.³²

In conclusion, it seems clear that the health, environmental and other benefits of the new sulphur in fuel requirements in SECAs will be significant. In fact, any study that has included an assessment of the benefits has concluded that these outweigh the associated societal costs. As has been illustrated in the joint ship-owner assessment, the benefits will also be geographically distributed. Clearly the greatest benefits will be felt in Member States bordering SECAs, and in densely trafficked and populated areas in particular, notably the North Sea region.³³ The assessment concludes that at least without the modal shift (which has not been taken into account in the AEA study), the monetised benefits of the new sulphur in fuel requirements are expected to be greater than the costs for Europe as a whole.

2.4 Conclusion

It seems clear that the implementation of the 0.1% sulphur in fuel requirement in SECAs as from 2015 will imply extra costs for shipping. The range of the cost increase varies according the MGO price estimation used in the different studies, the most common estimates of the predicted fuel price in 2015 lie around USD 600-900 per ton. The proportional difference in price between high sulphur fuel and MGO is not expected to undergo significant changes.

The increased fuel cost – if materialised as a corresponding increase in sea freight charges - will have some effects on the shipping patterns within short sea shipping in the SECA areas. Some studies have highlighted the risk of a shift towards road transport – mainly for certain routes to and from the Baltic States and for the English Channel and mainly when applying a highest fuel price scenario. Medium distance routes have also been found to be harder affected than shorter and longer routes. This route segment is more likely to face increased competition from routes which includes a shorter sea leg (i.e. longer road and/or rail transport in either end, but not to a 'truck only' option). It also seems that the utilisation factor will have a significant impact on the competitiveness, implying that routes which already have a low degree of utilisation will be more affected. General cargo ships and container ships are considered to be more sensitive to a higher fuel price than are Ro-Ro vessels; and low value goods, such as metal and forest products, are considered to be particularly vulnerable cargoes. Yet, it nevertheless seems that if the price for MGO will stay within the low or medium ranges foreseen, existing short sea shipping routes will remain competitive after 2015 if they were competitive already when using HFO. Even if competitive, however, it seems inevitable that the increased fuel price will negatively affect the profit margins for the shipping sector within ECAs, again with the fuel intensive segments being most affected.

³¹ All prices are based on 2009 figures.

³² UK study p. 49.

³³ See figure 4.4 of the joint ship-owners' assessment, summarising the results of the AEA study in terms of monetised benefits on a country-by-country basis.

In the broader picture it does not seem to be disputed that the wider benefits for the society of the new fuel requirements by far exceed the costs of their implementation. Those effects will be felt all over Europe, but particular benefits are expected for States bordering the SECA areas with the densely populated States around the North Sea having a particular advantage in this respect.

Part 3: Alternatives

3 Scrubbing technology

3.1 Introduction

There are some options available for ship operators who wish to meet the new revised Annex VI sulphur requirements by other means than by switching to MGO. The 0.1% requirement could either be met by using high sulphur fuel together with abatement technology to achieve 'equivalent' levels of emissions or by changing to fuels which have limited or no sulphur content. At the current stage of technological development, the first option largely means installing one or more 'scrubbers' on the ship to reduce the sulphur from the exhaust gases, while the options for alternative fuel mostly consist of liquefied natural gas (LNG) and, to a lesser extent, bio-fuels. These options will be briefly presented in this part of the report. The present chapter provides more detailed information on the scrubber technology while the option of alternative fuels is further explored in chapter 4.

3.2 Background

Scrubbing has been used on shore with success to reduce SO_x emissions of industrial plants since the 1930s. The basic principle is to bring a fluid with capacity to absorb SO_x and neutralise the effluent in contact with the exhaust gas. The absorbed SO₂ is converted by reaction with alkali material in the liquid to SO₄. The sulphur contained product then leaves the scrubber with the effluent and the de-sulphurised exhaust gas is sent out through the funnel. The waste, also known as sludge, is stored on board to be delivered to a reception facility on shore.

Sea water – thanks to its natural alkalinity – has been successfully used to scrub exhaust gas from boilers on oil tankers since the 1960s and is now widely used for cleaning the exhaust gases from the tanker's boiler plant providing a clean inert gas and preventing gas/air mixtures explosion. All oil tankers are fitted with inert gas systems and most use sea water scrubbing for this purpose.

Since the 1990s this technology has been adapted to be used to clean exhaust gas from the (auxiliary and main) engines. Several projects for using scrubbers to reduce SO_x emissions from ships have been carried out and where tests and trials results have been made available, a SO_x cleaning efficiency of more than 90% is reported.³⁴ Depending of the chosen configuration, each engine (main and auxiliary) can require its own dedicated Exhaust Gas Cleaning System (EGCS) unit. Constraints related to space and costs have lead to the development of integrated EGCS where a single unit for main and auxiliary engines is sufficient. In a more basic configuration, the EGCS can also be only linked with the main engine taking into consideration that auxiliary engines sometimes use lighter fuels that do not require scrubbing of exhaust gases.

The technology for scrubbers has developed significantly in the past few years and some classification societies (including DNV and GL) have already certified certain equipment based on successful trials.³⁵ Questions related to noise, stability, wash-water quality and impact on the environment, sludge toxicity have been addressed by the manufacturers. Based on the information available, both fresh and sea water scrubbers now seem have proven their suitability for maritime application and are, according to their manufacturers, ready for installation and use.

³⁴ Source: Greenhouse Gas Emissions for Shipping and Implementation Guidance for the Marine Fuel Sulphur Directive (Marintek, Germanischer Lloyd, DNV and CE Delft), Study prepared for DG ENV, December 2006.

³⁵ See e.g. Public test report, Exhaust Gas Scrubber installed onboard MT "Suula", Wärtsilä, June 2010

3.3 The legal framework

Regulation 4 of the revised MARPOL Annex VI allows, with the approval of the Administration, the use of an alternative compliance method at least as effective in terms of emission reductions as the standards set forth in Regulation 14 of the Annex which regulates the sulphur content of marine fuels to be used in certain sea area. Moreover, the Guidelines for on board exhaust gas cleaning systems (EGCS) (MEPC.184(59)) provide the framework for the development of this equipment.

These guidelines specify the requirements for the testing, survey certification and verification of exhaust gas cleaning systems to ensure they provide effective emission reductions. Two alternative schemes are offered for demonstrating compliance with the guidelines: scheme A builds on type approval and certification of the exhaust gas cleaning system while scheme B is based on continuous monitoring of the SO_x emissions. Under scheme A, an EGCS must obtain a SECA Compliance Certificate (SCC). This document implies that an EGCS must be supplied with a technical manual and that emission and wash water measurements are performed. Under scheme B, the monitoring system should be approved by the administration, and able to produce results to be used to demonstrate compliance. SO_x and CO₂ should be measured. Under both schemes a SECA compliance plan approved by the flag State Administration is required for detailing how compliance is achieved and demonstrated. An onboard monitoring manual is also compulsory under the two schemes.

At EU level, Directive 2005/33/EC on marine fuels and its article 4c on trials and use of new emission abatement technologies introduced a specific regime for abatement technologies to be tested and used on board ships flying the flag of an EU Member State. It is based on the international rules and regulations, but is narrower in scope in that it only recognizes scheme B.

3.4 Available scrubbing technologies

Four technologies are known to be used and ready for commercial application: 1) seawater scrubbing (or 'open scrubber')³⁶; 2) the freshwater scrubber ('closed-loop scrubber'),³⁷ 3) a combination of the two (the hybrid technology);³⁸ and finally 4) the CSNO_x system, which targets not only sulphur oxides but also nitrogen oxides and CO₂.

Sea water scrubbing

The seawater scrubbing is based on the natural alkaline characteristic of seawater, it is used to neutralise the acidic exhaust gases. Further to the absorption of the SO_x molecules by the seawater, the water is then discharged back into the sea after extracting and storing the relevant sludge from scrubbing. The resulting sludge must be stored on board prior to final delivery to a shore reception facility.

The seawater scrubbing technology is suitable for new buildings and retrofit installations. It can be applied to all types and brands of diesel engines and oil fired boilers. Based on available information, sea water scrubber units are available for the full engines power range, from 500kW to 78MW. On the emission reduction performance side, the sea water scrubber proves to be very effective. Tests and trials conducted on board the *Pride of Kent* (ferry) and on board the *Zaandam* (cruise vessel) indicate a 99% SO_x removal and a removal of particulate matter by 50 to 70% when used on HFO with 3.5% sulphur content.³⁹

³⁶ Developed and commercialised by Hamworthy and Wärtsilä

³⁷ Developed and commercialised by Wärtsilä

³⁸ Developed and commercialised by Aalborg

³⁹ Information provided by Hamworthy during a meeting organised by DG MOVE and the European Marine Equipment Council (EMEC) in Brussels (June 2010). This model has been developed under scheme B of the IMO Guidelines and is hence based on a continuous monitoring of the system and no certification is needed.

For competition reasons it is difficult to obtain reliable cost and price information for scrubbers. It is known that the monitoring equipment constitutes a large part of the cost and that the total cost largely depends on the number of stacks. In general, installation costs will also vary greatly with the configuration, vessel design and shipyard in charge of the installation. The prices provided in the table below are for guidance only.

	Cruise ferry (about 40 MW)	Cargo ship (about 20 MW)
New build	3 M €	2,1 M €
Retrofit	3,5 M €	2,4 M €

Table 4: Indicative investment cost of seawater scrubber

In addition to the investment costs, the operation of scrubbers increases fuel consumption. It is commonly estimated that the operation of scrubbers gives rise to an overall increase of fuel consumption of some 1-3%.

A system based on seawater scrubbing is already available on the market. Hamworthy/Krystallon, who manufactures and sells the product, estimates that some 20 ship-sets could be delivered in 2011.⁴⁰ More than 100 ship-sets per year could be made available by 2015.

Freshwater scrubbing

The principle of the fresh water scrubbing is a variation of the technology which requires the addition of caustic soda (NaOH) to react with and absorb the sulphurous emission gases. Its main benefit is that it opens the possibility to use the scrubbing technology in sea areas where the natural alkalinity of the sea water is not sufficient to react on its own with sulphuric products. Like for the seawater scrubber, the resulting sludge must be stored on board prior to final delivery to a shore reception facility.

The freshwater scrubbing technology may be applied to all types and brands of diesel engines and oil fired boilers. Like the seawater scrubber it is suitable for both new buildings and retrofit installations.

The performance has been checked during tests and trials, the guaranteed SO_x-reduction is 97.15 %, offering ships SO_x-emissions equivalent with 0.1 % sulphur in the fuel when using fuel with 3.5 % sulphur. Other air pollutants are also reduced but in a less significant proportion. The NO_x-reduction is approximately 3 to 7 % and PM-reduction from 30 to 60 %.

The table below provides a cost indication for a marine closed-loop fresh water exhaust gas scrubber system. The figures are for guidance only.

	Cruise ferry (about 40 MW)	Cargo ship (about 20 MW)
New build	About 2.4 M €	About 1.9 M €
Retrofit	About 3.4 M €	About 2.4 M €

Table 5: Indicative investment cost for a freshwater scrubber.

Following the conclusion of the trial period and of the tests conducted on board the M/T Suula during two years, the manufacturer Wärtsilä in its final report on the project, indicated that the freshwater scrubber for marine exhaust gas is now ready for commercial application.

⁴⁰ There are increasing signs that operators are already finding scrubbers interesting. For example, the Italian owner Ignazio Messina & C was recently reported to have ordered seawater scrubbers from for four 45000 dwt ro-ro ships under construction. Each of the vessels will be fitted with five scrubbers (two per auxiliary engines and one for the auxiliary boiler). Provision has also been made for future installation for main engine installations. Source: Fairplay, 24 June 2010, volume 369-page 27.

The hybrid system

This technology is based on a combination of the two type of technology as described previously. The versatility of the equipment provides flexible solution to switch between sea water and fresh water.

The technology has been installed on board the *Tor Ficaria* in July 2009 to scrub emissions from the 21 MW main engines. It is still under extensive tests, but the manufacturer Aalborg reports SOx emissions cleaning performance of 98 to 100%. For particulate matter, an 80% performance is reported.

The table below provides elements of cost for ship-owners of a marine, hybrid, exhaust gas scrubber system. These estimates include project management, documentation, components and installation. However the figures are for guidance only.

	Cruise ferry (about 40 MW)	Cargo ship (about 20 MW)
New build	About 3.8 M €	About 2,6 M €
Retrofit	About 4.3 M €	About 3,0 M €

Table 6: Indicative investment cost for hybrid scrubber.

The manufacturer indicated that a number of case studies are being conducted with different shipowners. It is reported that the hybrid scrubber should be commercially ready and available in 2011.

The CSNOx System

A fourth and completely different technology is represented by the CSNOx system which is being developed by Ecospec, based in Singapore, and targets three air pollutants (SOx, NOx and CO2) and as such is the first of its kind.⁴¹

Little information has been provided on the functioning or cost of this technology. It is also based on the use of seawater. The seawater goes through a succession of steps, it is enriched to remove the SO2 and through the use of ultra low frequency it is conditioned to improve the water absorption capability. The pH value of the water is raised and finally the treated seawater is pumped into a tower to remove the CO2 and NOx. The CSNOx system has been tested on a trading Aframax tanker. The American Bureau of Shipping (ABS) issued a statement of fact verifying the removal of 99% of SO2, 77% of CO2 and 66% of NOx emissions during the tests. The wash water quality met all IMO requirements.

A partnership with the Royal Caribbean Cruise Lines was agreed in June 2010, which entails that a CSNOx system will be installed on the Royal Caribbean's *Independence of the Seas* for a test period. The trials are expected to be completed in the spring of 2011.

3.5 Environmental impacts and other technical considerations

The first environmental impact to be noted is that the powering of the scrubbers will require more fuel and hence will contribute to more CO2 emissions. This applies for all types of traditional scrubbers and as was noted above it is commonly estimated the fuel consumption increase is around 1 to 3%.

A second environmental impact relates to the quality of the wash water from sea water scrubbers. The IMO has developed guidelines in order to establish minimum standard for a set of substances the Ph, Polycyclic aromatic hydrocarbons (PAH) content, turbidity and nitrate content. The guidelines were finalised and adopted by IMO in July 2009⁴² and subsequently

⁴¹ See www.ecospec.com. It may be noted that the CSNOX technology received the "Technology of the Year" award at the Green Ship Technology Conference 2010 in Copenhagen

⁴² Revised Guidelines for Exhaust Gas Cleaning Systems, Resolution MEPC.184 (59).

reviewed by the Joint Group of Experts for Scientific Aspects of the Marine Environmental Protection (GESAMP). The group recommended, among other things, to strengthen monitoring programme by imposing continuous monitoring. GESAMP also underlined the need for IMO to consider the potential contribution to ocean acidification of the large scale application of SO₂ capture from ships and the discharge of sulphurous/sulphuric acid containing effluents.⁴³ It was also agreed that the wash water discharge criteria should be revised in the future as more data becomes available on the contents of discharge and its effects. No specific date for a review was so far agreed but France has recently, through a submission at the 61st session of IMO's Marine Environment Protection Committee, proposed to structure the data gathering exercise. The matter will now be looked at by the BLG Sub-Committee and should be finalized in 2011.

The amount of generated sludge by scrubbers is approximately of 0.1 to 0.4 kg/MWh, which represents less than 10% of the "normal" sludge production. Tests and analyses carried out on freshwater scrubbers indicate that the properties and treatment of the sludge from scrubbers is very similar to other engine room sludge. This has also been confirmed by operators of waste reception facilities in Finland and Sweden.

A number of other issues relating to stability, noise and space limitations have been raised during the development of the ECGS. These concerns have now reportedly been addressed by the various manufacturers.⁴⁴ The space limitation may be an obstacle for certain smaller size vessels in the case of retrofitting. Even there, however, a redesign of the funnel after the scrubber unit installation offers a potential solution.

⁴³ MEPC59/24 Report of the 59th MEPC session, p. 29

⁴⁴ See for example the Public test report –Exhaust Gas scrubber installed onboard M/T *Suula* - Wärtsilä – June 2010

4 Alternative fuels

4.1 General

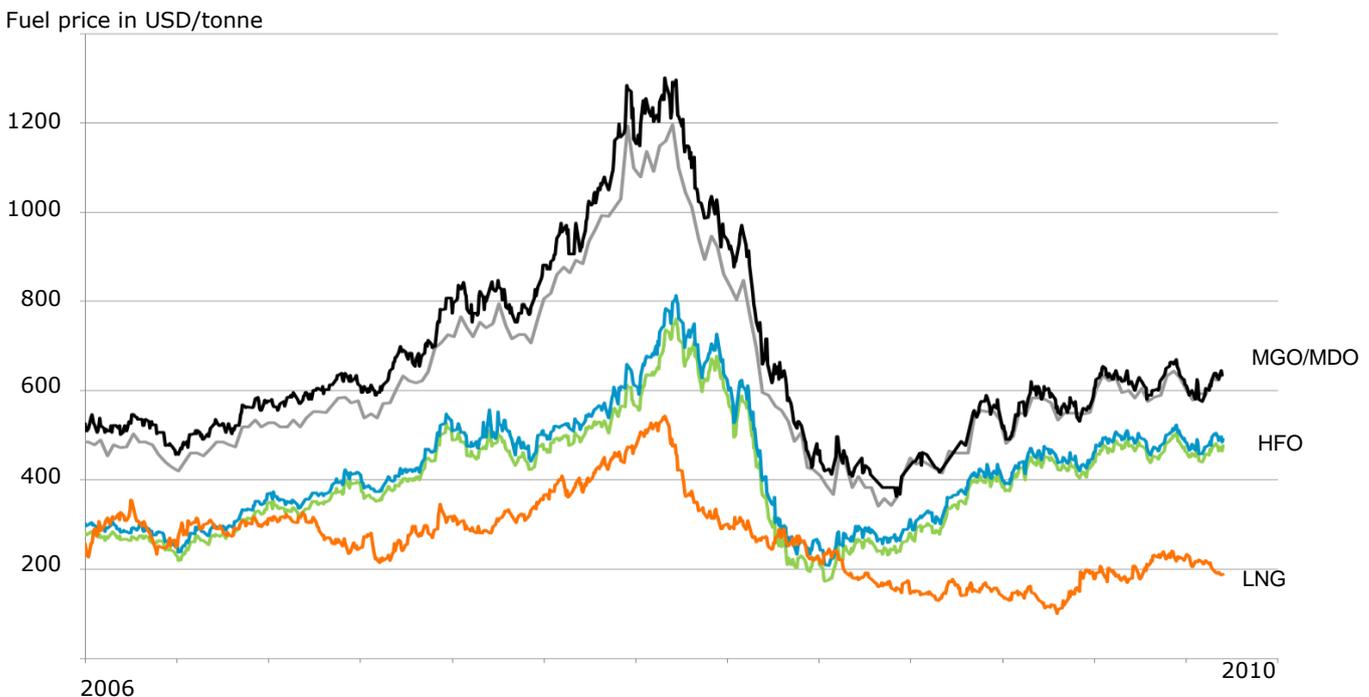
Apart from the use of MGOs or technologies of 'equivalence' SOx emissions from shipping could also be cut by switching to alternative fuels, liquefied natural gas (LNG) or bio-fuels, or even by installing nuclear reactors on board commercial ships. This chapter provides a brief overview of the state of play and maturity of the available alternatives (sections 4.2-4.4) and identifies certain possibilities for financial support for the industry and governments who would be interested in promoting alternative fuels (section 4.5).

4.2 LNG as fuel for ships

4.2.1 General

Natural gas is a fossil fuel found in sub terrain reservoirs and produced in special gas fields or in parallel with oil production. The proven gas reserves in the world are already larger than the oil reserves and new reserves are continuously being found. The global resource situation for natural gas is thus better than for oil in terms of reserves-to-production ratio. The main producers of natural gas are Russia, Iran and Qatar. Natural gas can either be liquefied (LNG) or compressed (CNG), but the latter has so far been of limited interest for shipping.

As is illustrated in graph 2 below LNG prices has fluctuated less than any of the other marine fuels in the relevant period. It remains far cheaper than MGO, significantly less than half of the MGO price at the peak price moment (June-September 2008) and even cheaper than HFO for most of the period. The current low price of gas is due to partly to the global economic downturn and its resultant reduction of natural gas demand, and partly to an increase in natural gas production, notably shale gas. For the future, it is commonly expected that the price of LNG will gradually be delinked from the more volatile price of oil.



Graph 2: Bunker fuel prices fluctuations between October 2006 and March 2009 (sources: Wärtsilä, www.lngoneworld.com, www.bunkerworld.com)

The use of LNG to propel ships represents a real 'green' alternative when it comes to air emissions. It provides a basically complete reduction of sulphur dioxides and particulate matter and some 90% reduction of NOx. For greenhouse gases, LNG's reduced carbon factor signifies a reduction of some 20% in CO2 emission compared to refined oil products. The figure includes a certain emission of non-combusted methane, the so-called 'methane slip', which engine manufacturers are currently seeking to reduce. Other advantages of LNG include that no sludge is produced and that there is no visible smoke.

Operating on LNG does not affect the speed or otherwise the operational qualities of the ship, though it does involve some additional technical and operational complexities, which necessitate special training for the crew members.

Tightened environmental requirements for ships, in combination with favourable economic conditions has resulted in significant interest in the use of LNG as ships' fuel in the past few years. Currently some 30 LNG-powered ships (in addition to LNG tankers which are not considered here) are in operation, most of which are based in Norway. The range of ship types varies and includes Ro-Ro ferries, supply vessels and coast guard vessels. Two LNG Ro-Ro vessels have been ordered and will be delivered in 2011. The Government of Norway has been a driving force behind this development and the Norwegian NOx Fund has stimulated interest in this technology and also co-funded many of the installations. Wärtsilä, Rolls Royce Marine, Mitsubishi and MAN are the leading manufacturers of gas or dual fuel engines for ships. European based countries are also pioneers in most of the relevant technologies and equipment related to LNG propelled ships.

4.2.2 Selected considerations

Market for ships

Not all ships are suitable for LNG propulsion. In view of a more limited range than oil-based fuels, LNG is mostly suitable for ships in coastal trades (short sea shipping) and in view of the limited shore infrastructure available to fuel this type of ships, the concept is particularly apt for ships engaged in regular trade, in the shorter term at least.⁴⁵ Certain shipping segments (such as port service vessels, Ro-Ro, Ro-Pax ferries and high speed craft) have accordingly been highlighted as being particularly interesting in this respect.

According to a 2008 study, a total of 182 Ro-Ro and Ro-Pax ships are operating on regular lines in the Baltic Sea – North Sea region, a third of which are more than 20 years old and soon to be replaced.⁴⁶ This situation, which at least partly coincides with the introduction of the 0.1% sulphur in fuel requirement, has been considered to represent an interesting opportunity for accelerating the introduction of LNG technology in this part of Europe. At least two projects involving LNG-fuelled ferries within the SECA area have been announced in the latter half of 2010.⁴⁷

⁴⁵ LNG is not necessarily limited to short sea shipping, however. Already, certain classification societies and owners are discussing installing LNG engines in ocean-going container ships.

⁴⁶ Source: The MAGALOG project (Marine Gas Fuel Logistics), co-financed by the EU under the Intelligent Energy program (DG TREN) and conducted in 2007/2008 until December 2008). The project analysed the potential use of liquefied natural gas (LNG) as a fuel for ships and the establishment of LNG supply chains in the Baltic Sea region.

⁴⁷ The Finnish ferry operator Viking Line and STX Finland Oy have announced that they have signed a preliminary agreement for the construction of an environmentally friendly new generation cruise ferry for Viking Line for the route Turku-Stockholm. The cruise ferry is about 210 metres in length with a gross tonnage of 57 000 and max speed of 23 knots. The ship will be built at Turku shipyard for delivery in the beginning of 2013. The final agreement still depends on the approval by the European Commission of the planned environmental subsidies by the Finnish Government.

Fjord Line has through its Danish subsidiary applied for a direct co-funding from the EU (TEN-T) to upgrade its two new ferries to be able to run on LNG on a dual-fuel concept. Each of the vessels will have capacity for 1.500 passengers and up to 600 vehicles, and offer daily sailings on the service between Bergen, Stavanger and Hirtshals, and the service between Kristiansand and Hirtshals. The aim is to have the ferries in service from autumn/winter 2012.

The first high-speed passenger Ro-Ro ship powered by LNG has also been announced recently. The ship is designed by Incat and is a 99 metre high speed ferry, with capacity for over 1000 passengers and 153 cars, and is being built at the Incat Tasmania shipyard at Prince of Wales Bay in Hobart for delivery in 2012. So far the owner and route involved have not been revealed.

The ship side

A main challenge for conversion to LNG is that this type of fuel entails different fuel tank requirements. The fuel tank has to be pressurised and is usually in a cylinder format, which takes more space than conventional fuel tanks. It is estimated that up to 3-5 times more space is consumed for LNG fuel storage than for oil. For containerships some 2-4% of the cargo carrying capacity has to be sacrificed to provide space for the fuel tanks, which can be placed in containers. There is some on-going research indicating a possibility for squarely shaped LNG tanks in the future.

The engines themselves require less intervention. LNG engines are of similar size as diesel engines and some of the existing engines can already be purchased with 'LNG kits'. Dual fuel engines also exist.

The extra investment needed for a new ship generally lies between €1 and 8 Million, depending on the size and the complexity of the installation. A broader market of manufacturers of LNG engines, fuel tanks etc. is expected to reduce the prices in the future.

Given the technical requirements the option to shift for LNG is normally more suitable for newbuildings. However, there are certain recent examples involving retrofitting or large-scale conversion of existing ships. The M/V *Bit Viking*, a chemical tanker built in 2007 will be soon converted and fitted with a dual fuel engines, allowing the ship to operate for a period of 12 days on gas fuel. The gas tanks (2x500m³) which are placed on deck will bring an additional weight of 400 tons to the ship; necessary structure strength enhancement will be done by Wärtsilä under the supervision of the Germanischer Lloyd. Another recent example is retrofitting the 2006-built *Maersk Drury*, a 5,044 TEU deep sea container vessel to use LNG in two auxiliary engines and one auxiliary boiler.⁴⁸

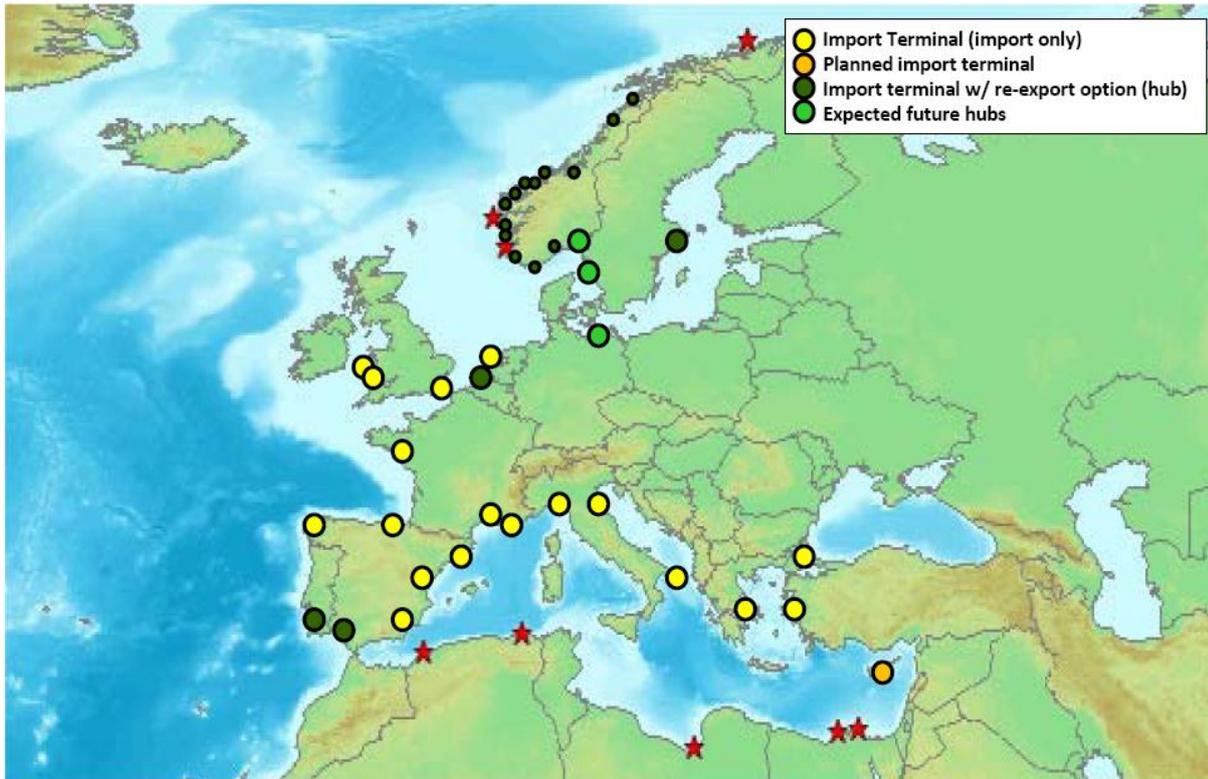
The European Commission's Directorate-General for Research and Development is currently co-operating with MAN DIESEL in a project called HELIOS that could provide new solutions for the retrofitting of dual fuel engines in ships currently serving on diesel. The project represents a new generation of high pressure gas injection engines operating on compressed natural gas (CNG) and/or liquefied natural gas (LNG). It is stated that the needed modifications in components are limited and do not necessitate removing or reinstalling the ship's engine.

The shore side

A main challenge for making LNG a viable alternative to conventional fuels is to ensure that this type of fuel is available for ships. The problem is not primarily related to lack of LNG in ports; as picture 1 below illustrates, a number of LNG terminals exist around the continent and more are planned.⁴⁹

⁴⁸ Additional LNG storage will be added using specially designed containers accommodated on deck in normal cargo spaces. LNG containers will be delivered and loaded in the same way as other cargo carrying boxes. The loss of cargo carrying capacity is limited (30 container slots), equivalent to less than 1% of the ship's capacity. The estimated cost of the project is estimated to about \$5m-\$6m. Lloyds List, 09.09.2010

⁴⁹ In addition to the plans indicated in the map, there are plans to establish LNG hubs in Estonia (to start in 2012-2014), Lithuania (2010-2013), Poland (Swinoujscie 2014) and Germany (Wilhelmshaven 2014). In addition, some Nordic ports have specifically announced their intention to be LNG bunkering ports (Sweden: Oxelösund and Gävle in 2012; Finland: Turku/Naantali 2013).



Picture 1: network of main LNG ports in Europe (source: Germanischer Lloyd)

The more immediate problem for ship operators is that LNG is not generally available for bunkering to ships, not even in the import terminals. The storage, handling and distribution of LNG is directed at the land-based uses and outside Norway there are currently very few places which provide the infrastructure necessary for bunkering ships. As the Norwegian experience suggests, however, the challenge is not primarily of a technical nature: it is quite feasible to bunker LNG on ships, either by fixed installations, tank trucks or even by ship-to-ship transfers by small tankers or bunker barges. But in the absence of a commercial interest there has not been much investment in this type of infrastructure until now. However, a number of projects for developing the LNG bunkering infrastructure for ships are currently underway in Northern Europe and around the Baltic Sea and North Sea in particular. The possibilities explored include both the use of bunker barges in ports and fixed installations, including the setting up of a small scale LNG production plant for ships bunkering.

The issue of LNG infrastructure has been thoroughly analysed in a recent Danish study, which concluded that part of the ferry sector is well-suited to conversion to natural gas in Denmark.⁵⁰ According to the study it appears beneficial to target the installation of LNG/CNG storage and refilling plant to the most consuming routes/ports, i.e. ferry ports with a consumption of more than 20,000 tons per year. A number of key barriers for the introduction of LNG are identified, including the lack of filling stations, lack of safety regulation for ship-to-ship transfers and for bunkering while passenger are on-board. Like an earlier Swedish study on the topic,⁵¹ the Danish study considers that political intervention may be necessary to reduce the uncertainty

⁵⁰ Natural gas for ship propulsion in Denmark – Possibilities for using LNG and CNG on ferry and cargo routes, 2010. The study was performed by LITEHAUZ ApS in association with Incentive Partners ApS, Technical University of Denmark, Det Norske Veritas and Ramboll Oil and Gas and was conducted for 'Partnerskap for Renere Skibsfart' (a partnership between the Danish Environmental Protection Agency and the Danish Shipowners' Association) and DONG Energy.

⁵¹ LNG för fartygsdrift – performed by SWECO supported by the Swedish Ship-owner Association as well as The Swedish Gasassociation, November 2009.

relating to port infrastructure for LNG, and thereby reduce one of the key concerns of private operators considering LNG.

Administrative challenges

A legal framework for gas fuelled ships is currently under preparation at IMO. The interim Guidelines on safety for gas-fuelled installations in ships, which are largely based on the national standards elaborated in Norway, have been finalised and adopted in 2009. These Guidelines are already used on a voluntary basis by a number of EU Member States. The second step will be the development and finalisation of the International Code of Safety for Gas-fuelled Ships (IGF Code) by 2014. The IGF Code addresses not only natural gas fuel, but also other gas types, such as butane, hydrogen, and propane, and the intention is to make the Code mandatory through its inclusion in the SOLAS Convention by 2014.

However, the IMO rules do not cover bunkering on land, installations in ports or the actual bunkering operations by ships and barges. These matters are still subject to national and local rules and authorities which may vary largely and may represent significant barriers to rapid progress in development. Several ports, including some of the main European ports, and certain other sectors of the industry are currently preparing their own rules for the LNG bunker facilities and bunkering process.⁵² The need for a harmonised approach has been highlighted in several recent studies on LNG, including the ones referred to above.

4.3 Other alternative fuels

4.3.1 Bio-fuels

As bio-fuels are also sulphur-free, their use would also contribute to remove the SO_x emissions from shipping. Bio-fuels have not been used commercially on board ships, but a number of projects are currently looking at the potential.⁵³ Other related projects have demonstrated that existing engines can be modified to operate on biofuels.⁵⁴

The consortium in charge of the IMO's update study on greenhouse gases concluded that the potential of bio-fuel (in the context of reducing CO₂ emissions) is limited in the short to medium term, in particular as they are currently more expensive than oil-derived products (including MDO/MGO).⁵⁵ Nevertheless, the second generation of biofuels, produced out of biomass like wood and algae, could further increase the production and reduce the price. Combined with potential future regulations on greenhouse gas reductions, the use of bio-fuels such as pyrolysis-oils or lignin could well represent part of solution for the longer term.

According to Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources, Member States should aim to diversify the mix of energy from renewable sources in all transport sectors. The

⁵² A joint industry project, called the Gothenburg STS-project, has recently developed a 'LNG ship to ship bunkering procedure', published in 2010. The project is a technology development project carried out by Swedish Marine Technology Forum, FKAB Marine Design, Linde Cryo AB, DNV, LNG GOT and White Smoke AB. See <http://www.lnggot.com/2010/documentation-and-project-report%E2%80%9Dlng-ship-to-ship-bunkering-procedure%E2%80%9D/>.

⁵³ E.g a project ran by the National Oceanic and Atmospheric Administration (NOAA) in the Great Lakes Region in the US, where a research vessel has been operating only bio-fuels and other bio-lubricants. (see www.glerl.noaa.gov). Tests to use bio fuels are currently carried out on a large container vessel on the Maersk Kalmar (Science a step closer to biofuel for ships (May 2010) www.maersk.com) In a recent experiment involving the Danish Ro-Ro ferry *Bitten Clausen* one of the two diesel engines will be run on bio-fuels made from waste from a nearby slaughterhouse (Svensk Sjöfartstidning, 23 September 2010).

⁵⁴ The aviation sector also follows closely the development of this type of fuels and several successful tests have been conducted in past few years (<http://www.airnewzealand.co.nz/biofuel-test>).

⁵⁵ Second IMO GHG study 2009, O. Buhaug and al, pp. 50-51. The study also noted that the net benefits on CO₂ emissions varies between different types of bio-fuels and that not all biofuels have a CO₂ benefit.

Commission should present a report to the European Parliament and the Council by 1 June 2015 outlining the potential for increasing the use of energy from renewable sources in each transport sector.

4.3.2 Nuclear fuel

The current pressures on reducing of all types of air pollution from shipping have also regenerated interest in the use of nuclear-powered engines in commercial ships. Recent information or statements of high profile shipping actors⁵⁶ have shown an increasing interest into nuclear technology. This technology has been used since many years on board navy ships, but nuclear powered ships have also been used for commercial purposes. The German cargo ship *Otto Hahn* operated successfully under nuclear power between 1968 and 1979 and a number of ice-breakers also use this technology.

Thanks to this background there is already an existing legal framework for this type of ships. Chapter VIII of the SOLAS Convention provides basic requirements for nuclear-powered ships and refers to the more detailed and comprehensive Code of Safety for Nuclear Merchant Ships which was adopted by the IMO Assembly in 1981.

A research consortium with British, Greek and American industry interest has recently agreed to explore a marine application of small modular nuclear reactors (SMRs).⁵⁷ The research project aims to produce a concept design of a nuclear powered tanker, with a SMRs of more than 68 megawatt used as a "plug-in nuclear battery".

4.4 Availability of funding

Another aspect which may be of relevance when considering alternative approaches to reducing emissions relates to funding possibilities for innovative projects. The EU includes a variety of support mechanisms or programs that could potentially be used to facilitate a switch towards less polluting technologies. Apart from the sizeable budget for research and development, which will not be studied further here, at least the following possibilities are available for co-funding interesting pioneering projects.

The two main types of funding available for promoting maritime transport are: firstly, the **Marco Polo** project which is used to co finance projects proposed by private companies, mostly in the field of short sea shipping; and secondly, the Trans-European Networks (TEN-T) which under its '**Motorways of the Seas**' (MoS) programme co-finances studies and infrastructure projects proposed by Member States. In 2010, € 85 Million will be made available under the MoS programme and in 2011 the proposed budget is € 130 Million. The first project promoting the use of LNG to power ships, a Danish proposal to improve the bunkering infrastructure in the port of Hirtshals and address the related administrative challenges, has been proposed for approval in the 2010 call.

In addition, the Community **Guidelines on state aid for environmental protection** adopted on 1 April 2008⁵⁸ already allow, under certain conditions, for aid for the acquisition of new vessels complying with adopted EU standards, when such acquisition occurs before the entry

⁵⁶ See e.g. Lloyd's List 30 April 2010, in which Germanischer Lloyd's executive board member Mr Hermann Klein is reported to be convinced that there will be nuclear-driven container vessels in the future. It may also be noted that Lloyd's Register reactivated its work on this type of propulsion for commercial ships in 2007.

⁵⁷ The consortium includes, among others, Lloyd's Register, Hyperion Power Generation, BMT Nigel Gee and Enterprise Shipping and Trading.

⁵⁸ Community Guidelines on State aid for environmental protection (2008/C 82/01).

into force of the new standards. However, once these standards are mandatory, the rules will not apply retroactively to the already purchased vessels. Nevertheless, the aid amount covers only the difference between the cost of the more environmentally-friendly vessel and the cost of a technically comparable vessel that provides a lower degree of environmental performance.

Subsidies for the retro-fitting of the existing fleet could be accepted, provided that the conditions foreseen by the guidelines are met. The so-called Block Exemption Regulations for State aid⁵⁹ include the possibilities for environment. Also, the framework State aid to shipbuilding⁶⁰ contains some possibilities for State aid to the shipbuilding sector. In particular, it allows under certain conditions for aid granted for innovation in existing shipbuilding, ship repair or ship conversion yards up to a maximum of 20% of the innovation costs.

Finally, the European Investment Bank (EIB)⁶¹ in 2008 introduced a **Clean Transport facility**, which could significantly help the sector introduce innovation.

4.5 Estimated payback time

As has been described above the two most likely options to avoid the use of MGO, in the short term, would be either to use high sulphur fuel together with a scrubber solution or to change fuel altogether by switching to liquefied natural gas (LNG). Both these options would require new technology to be installed on board and thereby involve an investment cost. The estimated pay-back time for the investment will naturally vary depending on the type and size of the ship and its trading area. However, for illustration purposes a comparison is made below on the estimated costs and benefits for a medium-large ferry (40MW engine power), for which the assumed average capital investment cost for scrubbers would be EUR 3 million and for LNG EUR 5 million. In the example below, estimates on the size, average total installed power, specific fuel consumption, average sailing time etc. are based on IMO's second study on greenhouse gas emissions from 2009. On this basis, the estimated fuel consumption of the ship is around 30,000 tonnes per year. The fuel prices used for the calculation are based on graph 2 for 2010, i.e. HFO USD 450 USD/tonne and MGO 600 USD/tonne. However, for LNG it is well established that the fuel is not currently available for ships at the world market price. A surcharge of 50 USD/tonne has therefore been added to the 200 USD/tonne figure of graph 2 to cover the costs of a future bunker distribution system. Assuming that the ship would otherwise be exclusively operating on MGO, and that the fuel prices remain at the levels referred to above, the annual fuel costs and pay-back time for the different options would be as follows:⁶²

Annual Fuel Cost			
	MGO	HFO	LNG
M USD	18	13.5	7.5
M EUR ⁶³	13	10	5.5

Table 7: Annual fuel cost in Euro and USD for a cruise ferry (40MW total installed power)

⁵⁹ Commission Regulation (EC) No 800/2008 of 6 August 2008 declaring certain categories of aid compatible with the common market in application of Article 87 and 88 of the Treaty.

⁶⁰ Communication from the Commission concerning the prolongation of the Framework on State aid to shipbuilding" - adopted by the Commission on 3 July 2008

⁶¹ The EIB has lent more than €120bn to the transport sector over the past decade. Out of the total, about a quarter has been for rail infrastructure and tolling stock; 20 % for urban transport; 36% for road investments; 15% for airports, aircraft, and air traffic management systems; and about 4% for maritime transport (ports and vessels).The average EIB lending for shipbuilding and maritime infrastructure has been to the order of €500m-€550m/year.

⁶² The calculation does not take into account the additional operating costs of the scrubber.

⁶³ The conversion has been made on the basis of the exchange rate of 21 October 2010, i.e. 1 EUR to 1.39 USD.

Total Annual Fuel consumption of approx. 30,000 tonnes		
	MGO vs HFO&Scrubbers	MGO vs LNG
Annual Fuel Saving Cost (M EUR)	3.3	7.7
Avg. Investment Cost (M EUR)	3	5
Estimated Payback Time (years)	0.9	0.6

Table 8: Estimated payback time (years) for a cruise ferry (40MW total installed power)

This very rough estimate indicates a very short payback time for either investment in these particular circumstances, with an advantage for LNG.⁶⁴

The pay-back time would obviously increase with smaller fuel consumption or with less time spent in SECAs. In separate estimates for scrubbers, it has been assumed in the SKEMA and UK studies that the payback time for a seawater scrubber (after 2015) would be less than five years.⁶⁵

4.6 Concluding remarks

All options will be considered by operators to choose the most suitable and potentially the least costly option for each vessel. Some uncertainties about the availability and the technical readiness with regard to scrubbers have been found in some of the studies considered in Part 2.⁶⁶ However, the brief review made in chapter 3 above indicated that technical alternatives already seem to be available. Several types of Exhaust Gas Cleaning Systems (EGCS) are ready or will be ready for commercial release in 2011 and seem to be sufficiently effective for the forthcoming SECA requirements. This technology might therefore constitute an attractive and cost effective alternative solution to the use of low sulphur fuels. Capital and operational costs are relatively limited, retro-fittings are feasible and the payback period is relatively short. The sludge disposal would not add significant costs, as the sludge from scrubbers is treated in the same way as the more traditional oily sludge.⁶⁷

Another option which has proven to be workable and recently has become of increasing interest to ship operators is to switch fuel from oil to natural gas. The attractiveness of this option is illustrated by the fact that several operators are currently considering shifting to LNG for market price reasons alone. The benefits in comparison to MGO are striking but even in relation to HFO, LNG is - and is likely to remain - competitive. The investment costs for these two main options (scrubbers or LNG) are not necessarily very different, but probably in most cases to the advantage of scrubbers, which also seem to be a more suitable option for retro-fitting and for ocean-going ships. On the other hand, recent developments in the LNG field indicate important advances in both those areas and LNG entails the additional economic advantage that this option does not involve higher operational (running) costs. Both alternatives have a relatively short pay-back time with the current market prices, but this calculation is highly dependent on

⁶⁴ See also the more cautious estimate by the Danish LNG study referred to above, which was based on a 444 USD/tonne price of LNG.

⁶⁵ See the SKEMA study and the UK Study referred to in Part 2 of this report. The studies also note that the payback time for seawater scrubbers would shorten significantly in 2020 (or later) when the global requirement to use of 0.5% sulphur content enters into force.

⁶⁶ See in particular the SKEMA study, the joint ship-owner assessment and the German Study.

⁶⁷ The UK study.

the fuel consumption and the trading area of the ship. For both alternatives, investment costs may be expected to decrease in the future as more equipment manufacturers enter the market.

LNG has considerably broader environmental benefits than the use of (traditional) scrubbers, in that it also significantly reduces other types of emissions which are going to be subject to stringent regulation in the near future, such as NO_x and CO₂, and it produces no sludge. Recent pilot projects have illustrated that technical solutions are generally available for making a shift to LNG feasible for ships, but that a series of mostly non-technical hurdles are still to be overcome to make the option attractive on a wider scale. The most significant challenge is to have the necessary infrastructure in place in (key) ports to permit bunkering of LNG in ports. For this type of initiatives there seem to be interesting possibilities for EU co-funding under the TEN-T Motorways of the Seas programme.

In the longer term, the potential of biofuels to propel ships should not be disregarded and should be further studied in the near future.

For any option further administrative clarity would seem necessary to support the availability of alternatives. When it comes to scrubbers legal certainty is needed on the recognition of the IMO wash water standards within the EU and there may be reasons to consider whether to accept the scheme A alternative in the IMO Guidelines. For LNG, the underlying administrative framework is completely lacking. This is being addressed in IMO as far as ships are concerned, but the bunkering facilities will still depend on a variety of national, regional or local rules and permits, which may need to be adapted to facilitate a switch towards new types of fuel.

Part 4: Conclusions

5 Overall conclusions

The aim of this report is to assess the available studies on the impact of the revised Annex VI and to study whether there are alternative ways to comply with the stricter fuel requirements in SECA areas. The studies are based on different perspectives and different parameters. The most important parameter for any conclusion to be drawn is the estimated fuel price for low sulphur fuel (MGO). This parameter varies substantially in the studies and thereby the conclusions. That said, the following general conclusion may be drawn:

- Whether or not a ship-owner chooses to meet the new stricter sulphur requirements by shifting to low sulphur fuel or if they chose alternative methods, the owner will have increased costs due to the new regulations, either in form of increased operational cost due to higher fuel costs or investment cost in new technology.
- The increased costs will either be borne by the ship-owners or – more probably – channelled to the buyers of maritime transport services. In case the increase will be charged on the transport buyer it will affect the volumes of transport goods in the short sea shipping segment.
- With regard to the risk of shift from the short sea shipping to other transport modes it has been found that there are certain risks for that, but only within certain limited routes and under certain (high-end) fuel price scenarios. The routes that are likely to be hit hardest by competition from a truck or rail only option are the ones that have a real competition from these options (notably between the three Baltic States and Central Europe and in the English Channel). Routes at risk of losing shares have mostly been found to lose to other shipping routes with a shorter sea-leg and a longer road and rail option in between. Medium long routes are more likely to be affected than short and long routes. These assumptions are all due the predicted price for MGO. If the fuel price for low sulphur fuel will stay around 600-900 USD per ton, which most studies seem to foresee, the studies suggest that short sea shipping will remain competitive towards others modes even if volumes will be lost. If the fuel price for MGO reaches levels around USD 1000 per ton the effects will be more severe but even then still many short sea shipping routes will remain competitive.
- The benefits for the society in form of health and environmental benefits through better air quality have been found to be considerably higher than the costs involved in implementing the new requirements. The countries that are within SECAs will also be the ones particularly benefiting from the new requirements in this respect.
- There are alternative ways to comply with the stricter fuel quality standards. To mitigate the economic effects of the new requirements ship owners may opt for alternative technologies, such as scrubbers, or alternative fuel, such as LNG. Both options have proven their workability and availability as alternatives in the past few years. The range of benefits, including environmental benefits, is broader in case of a switch of fuel to LNG, which reduces both CO₂ and NO_x emissions, but for certain ships scrubbers will remain a more suitable alternative. The cost comparison between the various alternatives is depending on future development of fuel prices but both variants have been found to be highly interesting from an economic point of view and to be available in time for the new requirements. The estimated payback time for both options seems to be short. However, additional measures are needed to promote alternative measures. For scrubbers, certain legal clarification at EU level would seem helpful, while for LNG, further work is needed to develop the necessary infrastructure and administrative framework in ports, including the bunkering of ships.

ANNEX

List of studies considered

AEA (2009) – Cost Benefit Analysis to Support the Impact Assessment accompanying the revision of Directive 1999/32/EC on the Sulphur Content of certain Liquids Fuels, prepared for the EU Commission. Referred to as AEA study.

COMPASS (2010) – The COMPetitiveness of EuropeAN Short sea freight Shipping compared with road and rail transport, performed by Transport & Mobility Leuven, supported by EU Commission through DG ENV. Referred to as COMPASS study.

ECSA (2010) – Analysis of the Consequences of Low Sulphur Fuel Requirements, performed by University of Antwerpen, Institute of Transport and Maritime Management Antwerpen (ITMMA). Referred to as ECSA study.

German Shipowners' Association and Association of German Seaport Operators (2010) – Reducing the sulphur content of shipping fuels further to 0.1 % in the North Sea and Baltic Sea in 2015: Consequencs for shipping in this area, performed by Institute of Shipping Economics and Logistics. Referred to as German Study.

Maritime Coast Guard Agency (2009) – Impact Assessment for the revised Annex VI of MARPOL, performed by ENTEC. Referred to as UK study.

Ministry of Transport and communications Finland (2009), Sulphur content in ships bunker fuel in 2015, A Study on the impacts of the new IMO regulation on transportation costs, performed by the University of Turku, The Centre for Maritime Studies. Referred to as Finland study.

Shipowner association of Belgium, Finland, Germany, Holland, Sweden and UK and endorsed by the wider membership of ECSA and ICS (2010) – Study to Review Assessments Undertaken of The Revised MARPOL Annex VI Regulations, performed by ENTEC. Referred to as the joint ship-owner study.

SKEMA (2010) – Task 2 and 3 Impact Study on the future requirements of Annex VI of the MARPOL Convention on Short Sea Shipping, supported by DG TREN at the time. Referred to as SKEMA study.

Swedish Maritime Administration (2009), Consequences of the IMO's new marine fuel sulphur regulations, performed by The Swedish Maritime Administration. Referred to as Sweden study.