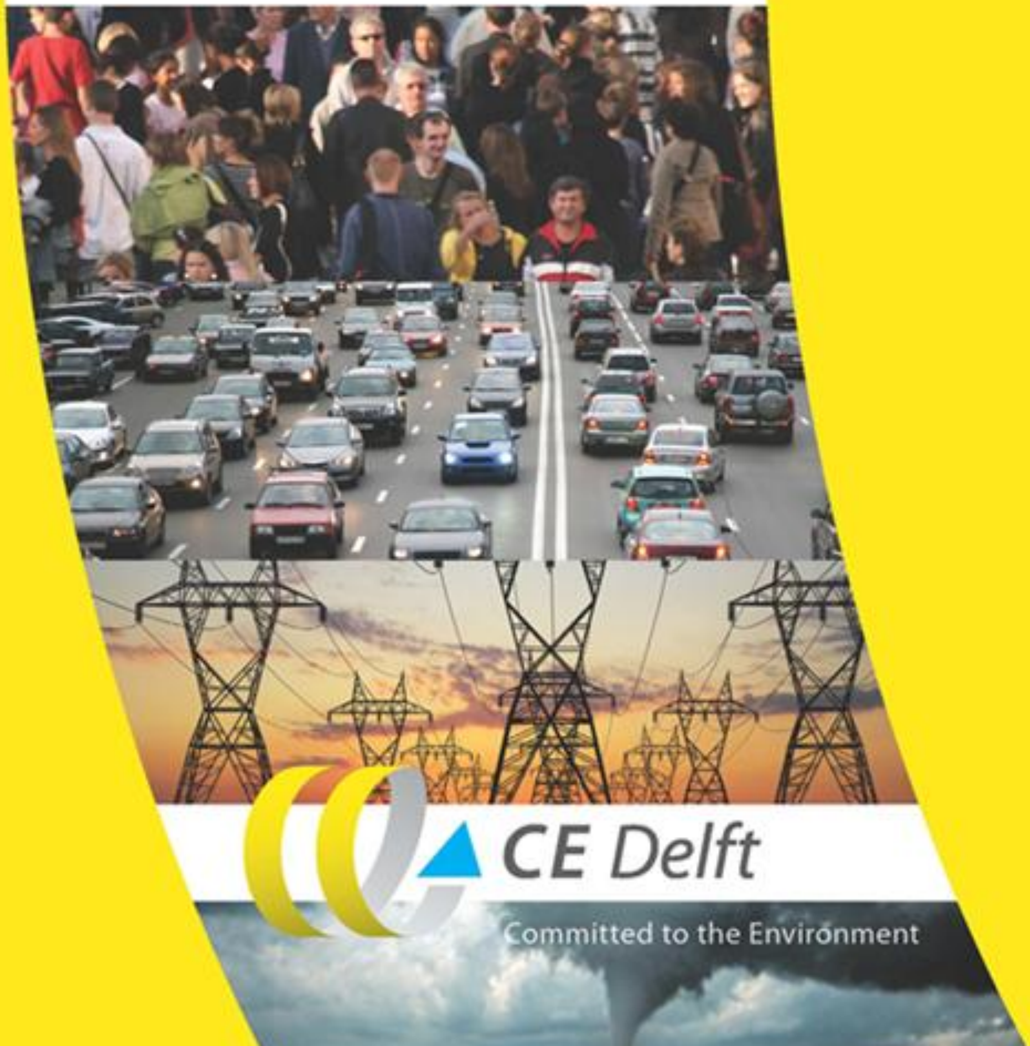
SECA Assessment: Impacts of 2015 SECA marine fuel sulphur limits

First drawings from European experiences



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SECA Assessment: Impacts of 2015 SECA marine fuel sulphur limits

First drawings from European experiences

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Summary

Introduction
International shipping is responsible for a relevant share of air pollutant emissions, especially regarding SO_2. In order to limit air pollution's negative impact for human health and the environment, Northern America and the European Union established sulphur emission control areas (SECA).
From 1 January 2015, the maximum sulphur content of marine fuels used in SECAs was reduced from 1.0% m/m to 0.1%.

In advance of and during its implementation, the reduction of the SECA fuel sulphur content led to discussions about the availability of low-sulphur fuels, price effects as well as their impact on the industry, like service or company shut downs, potential shifts towards road transport as well as the need for effective surveillance schemes for compliance and enforcement.

The objective of this study is to s ex-post assessment shows the first experiences under the 0.1%S fuel sulphur regime, focussing on air quality, socio economic benefits, impact on business and compliance and enforcement.

Air quality and socio-economic assessment
The available studies show a noticeable improvement of the air quality in port areas and along coast lines that has been measured during 2015. The specific reduction of the SO_2 concentration ranges between studies and sulphur concentration reductions of 50% and more have been reported. The actual reduction depends on the location, distance to source and the background concentration (e.g. near industry). In built areas close to busy port, the health impacts will be highest.

Using the reduction of the sulphur concentration from 1% to 0.1%, the health benefits from impact on air quality range between 4.4 and 8 billion euros, depending on the calculation methodology. The additional costs for the maritime sector of the use 0.1% MGO in the North and Baltic Sea have been quantified at 2.5 billion euros, using an estimated average price difference of $ 205. The health benefits due to lower emissions of SO_2 and PM are between 1.8 and 3.2 times higher than the costs. This shows that the benefits of the introduction of the new regulations have outweighed the costs of that policy. This statement will remain valid with future rising fuel price differences (e.g. doubling).

Fuel availability, economic impacts and modal shift
MGO availability is uncritical. While it was estimated that a fuel shortage would result in an increase of MGO price, the opposite occurred mainly as the result of reduced oil prices. Notably, the MGO price decreased more sharply than the price of HFO and automotive diesel, illustrating sufficient supply and probably oversupply of MGO. No major shifts towards road transport have been found so far for RoRo, which is the most sensitive for modal shift, and no company or even service shut-downs or decreasing cargo turnover in northern European ports, that can be clearly linked to the introduction of the 0.1%S sulphur cap.

The absence of clear shifts towards road transport is striking, because the economic position of maritime transport has worsened compared to truck transport, since the fuel price difference between the two modes decreased due to the change of the cheaper HFO to MGO. The fuel price difference reduced from 1,242 $/tonne in Q4/2014 to 900 $/tonne in S2/2015, taking end user prices (incl. excise duty) into account.

Compliance, enforcement and surveillance

The first year of 0.1% SECA regulation has shown that in ports, the largest majority of ships use a fuel that is compliant or within the accuracy margin used by European inspectorates. Between 3 and 9% of the ships are non-compliant in the Baltic Sea and North Sea respectively, according to EMSA data. Most member states use a margin of at least above 20% the legal threshold during control in ports.

Figures on the compliance on open sea are rather scarce and available data remote sensing data needs to be verified in order to be able to draw firm conclusions. The available information from Denmark illustrates a significant lowering of the fuel sulphur content on busy Danish shipping routes in 2015, but at the same time reveals the current immaturity of remote sensing with air planes. Many of the measurements show results in a grey area (below 0,3%S) which needs clarification and verification.

The number of administrative inspections is only limitedly below the required numbers, but fuel sampling needs to be intensified in 2016, in order to meet the required 30-40 fuel samples per 100 inspections.

Additional monitoring and control techniques need to be developed in order to reduce the current inaccuracies and increase the intelligence of the monitoring system. This will deliver incentives for the industry to bunker and use the required fuels. The coordination and development of surveillance activities (aerial and by ground based monitoring facilities) as well as processing and use of the collected data needs to be intensified. More knowledge, better equipment will lead to better interpretation of the assessed logbooks and will increase the effectiveness of inspections.

The increase of knowledge may lead to a reduction in error margins – up to 20% for reporting deficiencies and 50% for applying sanctions and reduce the risk of having a defector higher sulphur cap in place. Also back and forth reporting of non-compliant ships is an important precondition for increasing the effectiveness of the system.

The sanctions applied should be proportionate to the economic benefits of not complying with the regulations. The use of legal instruments (e.g. detention) should be coordinated, within the framework of varying national legal systems.

Content

1 Introduction

1.1 Background

International shipping is responsible for a significant share of air pollutant emissions in Europe (EEA, 2013). While mayor sources on land are already regulated adequately, emissions from ships are not yet completely addressed. In order to limit air pollution's negative impact for human health and the environment, Northern America and the European Union established, under cooperation with IMO, emission control areas for sulphur (SECA) and in the former case for nitrogen oxides, too (NECA).

From 1 January 2015, the maximum sulphur content of marine fuels used in SECAs has been reduced from 1.0% m/m to 0.1% m/m. Moreover, the International Maritime Organisation (IMO) is discussing a global sulphur cap of 0.5% from 2020 or 2025 at the latest.

In advance of and during its implementation, the reduction of the SECA fuel sulphur content led to discussions about the availability of low-sulphur fuels, price effects as well as their impact on the industry, like service or company shut downs, engine failures and potential shifts towards road transport. Furthermore, the need for effective surveillance schemes for compliance was stressed.

To address the issue above, NABU asked CE Delft to perform an ex-post assessment of the first experiences in Europe, which may also contribute to the discussion about lowering the fuel sulphur content of globally used fuels by 2020 or later.

1.2 Objective and project framework

The objective of this study is to present a first evaluation of the introduction of the 0.1%S cap for marine fuels in the European SECAs. The evaluation focuses on:
- air quality improvements;
- socio-economic benefits;
- economic impacts;
- modal shift impacts;
- compliance and enforcement.

One of the challenges mentioned often before the entry into force of new sulphur requirements was a potential risk of engine failures that could result in loss of propulsion and jeopardize the safety of the ship. It is widely acknowledged that no or only very few reports on loss of propulsion due to the switchover operation have been reported over the last year.

A shift to MGO is not the only option to meet the fuel sulphur cap of 0.1%. Some ferry operators decided install scrubbers in order to comply with EU sulphur regulation. Another option is the use of LNG as a fuel. Both options together represent between 100 and 200 ships at the moment, which is still a minor share of the overall fleet.

2 Air quality and socio-economic assessment

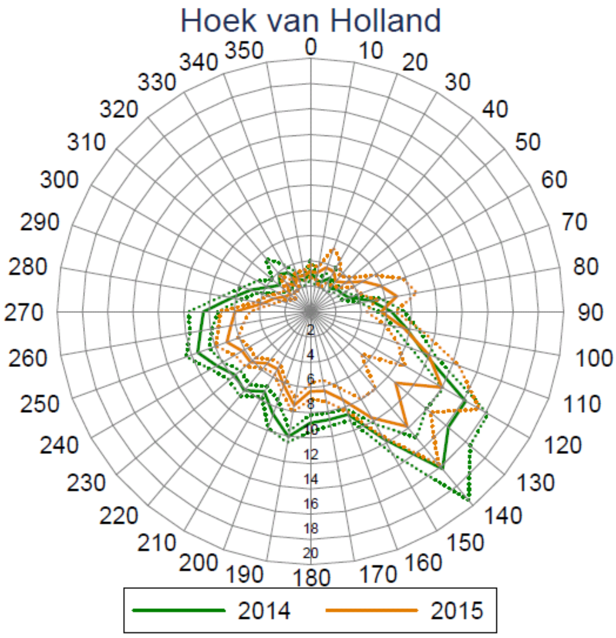
2.1 Introduction

As a consequence of the lowering of the fuel sulphur content, the emission of SO_2 and particulate matter (PM) to a lesser extent are expected to have decreased in 2015, compared to 2014. This leads to better air quality and thus less health impacts from maritime emissions. This chapter holds a preliminary ex-post assessment of reduced SO_2 emissions in the Baltic Sea and North Sea. In addition, the socio-economic benefits from lower SO_2 and PM emissions are illustrated in this chapter.

2.2 Air quality developments

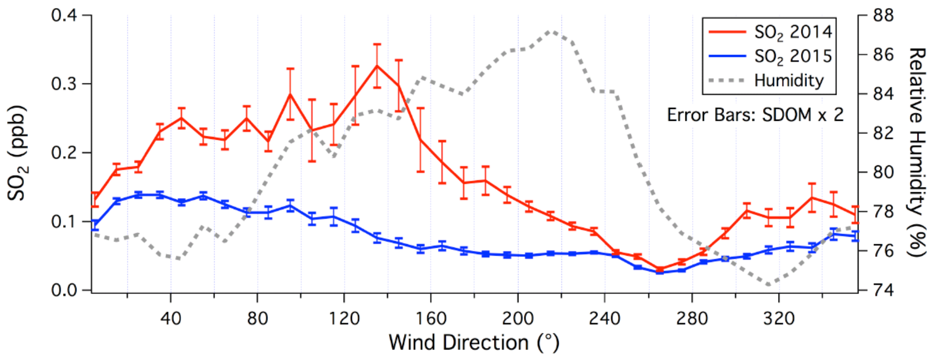
A number of studies have been commissioned so far on the assessment of SO_2 emissions after the implementation of SECAs in the North and Baltic Sea. DCMR, the environmental protection agency for the Rijnmond area Rotterdam, has performed an evaluation on the SO_2 concentrations in the first semester of 2015. The results show that the SO_2 concentrations are significantly lower in 2015 compared to 2014 levels, with differences in average SO_2 concentrations between 2.5 and 3.0 $\mu g/m^3$ (between 24 and 37% lower). The number of ship calls has not decreased and thus the decrease in SO_2 concentrations is caused by the implementation of the SECA in the North Sea (DCMR, 2015). Figure 1 shows the change in concentration for the various wind directions for the measurement station Hoek van Holland, which is located at the port entrance. 180-300° is the dominant direction for ships approaching the Port of Rotterdam. The other peak (120-150°) can be explained by the refineries in the Europoort and Botlek area.

Figure 1 SO_2 concentration changes (2.5 en 3.0 $\mu g/m^3$) for various wind directions, including 95% confidence interval (0=North; DCMR, 2015)



Comparable figures have been found for an on-coast monitoring at the Plymouth[1] coast(Yang, et al., 2016). The SO_2 concentration has been reduced threefold in 2015, starting from a situation where the average fuel sulphur content was already below the 2014 sulphur cap, which can be explained by the passenger ships on that route, see Figure 2.

Figure 2 SO_2 concentration changes for various wind directions, including 95% confidence interval (0=North)



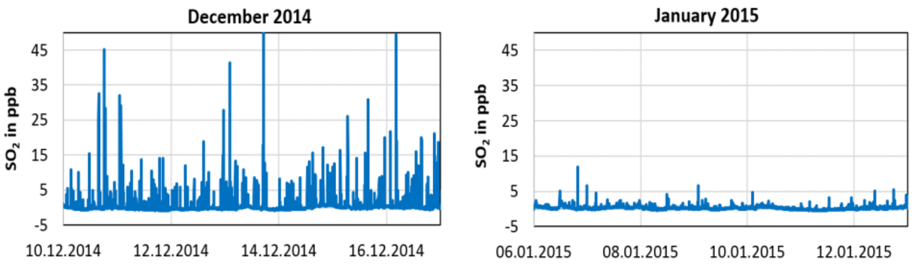
Note: Averaged SO_2 mixing ratio and relative humidity vs wind direction for year 2014 and 2015. Error bars on SO_2 indicate two standard errors. Elevated humidity marks the marine-influenced wind sector to be between about 60 and 260°.

[1] Penlee Point Atmospheric Observatory.

Also the Danish ministry of food and environment (DCE) has reported a significant decrease in sulphur concentration due to the new SECA regulations. Air pollution was measured in the Great Belt Bridge. DCE has reported that the content of sulphur in air has reduced up to 50-60% since the beginning of 2015, based on measurements at various stations (The Ministry of Environment and Food of Denmark , 2015).

Kattner et al. (2015) reports the results from an in-situ measurement station (MESMART) at German North Sea island Neuwerk shows SO_2 concentrations to go down by 50% after the SECA regulation came into effect (Figure 3).

Figure 3 **Absolute SO_2 volume mixing ratio values in December 2014 and January 2015**



Source: (Kattner, et al., 2015).

IVL has reported that at two monitoring sites in South-East Sweden, the sulphur contents in the air during late spring and early summer 2015 were 50% lower compared with average emissions for the same months in the previous three years (IVL, 2015). According to this study, the lowered level of SO_2 in the air can be linked to the introduction of marine fuels with reduced sulphur content from the beginning of 2015.

The studies show that SO_2 concentrations have decreased significantly along European coastlines in Denmark, the Netherlands, Sweden, The united Kingdom and Germany after the introduction of the 0.1%S regime. The differences found in the reduction in SO_2 concentrations can be explained by difference in shipping intensity, other sources and distance to the measurement station.

Data for PM levels were recorded by MESMART, but not assessed yet, so it is not possible to give precise information here. However, a slight improvement in PM concentrations is likely as previous studies found PM emissions to be lowered when switching from HFO to marine diesel (MGO) (Oeder, et al., 2015); AEA, 2009).

As expected NO_x concentrations were unaffected.

2.3 Socio-economic benefits of SECA policy

There are several areas where socio-economic benefits due to improved air quality occur. By far the largest benefits (>95%) occur as a consequence of decreased damages to human health[2], but also ecosystems are affected by high loads of sulphur, which leads to acidification of soils and waters.
Air pollution related health costs sum up to between 330 and 960 billion euro annually for the EU (EEA, 2015). On top come further costs resulting from air pollutants' climate impact and resulting effects. As shown before the most striking impact of the 0.1% sulphur limit is a reduction of SO_2 emissions, but also benefits from reduced PM emissions.

In order to quantify the socio-economic benefits of the SECA policy, the change in SO_2 emissions in 2014-2015 is needed. As there is only preliminary data on the sulphur concentrations in a few countries, the health benefits from the SECA are calculated in a different way.

First, the level of SO_2 emissions in the North and Baltic Sea in 2015 is quantified. For this purpose, the fuel use in these seas is taken from Kalli et al. (2013) and calculated for 2015 with the assumed annual traffic growth rate and energy efficiency change from this report. In addition, this fuel use is divided among the Baltic and North Sea assuming the division from CE Delft (2015). Second, the change in emissions of SO_2 and PM were calculated using the emission factors for these pollutants for the 1%S and 0.1%S sulphur fuel content fuels taken from AEA (2009).

The health benefits from the change in SO_2 and PM emissions are calculated using shadow prices specifically for the Baltic and North Sea taken from AEA (2005) and CEEH (2011). These shadow prices are adjusted to represent only the health effects and are corrected to prices of 2015 (Table 1).

Table 1 **Assumptions economic health benefits analysis**

Parameter	*Value*
Fuel use in North and Baltic Sea in 2015	12.5 billion tons
Division fuel use North Sea[3] vs. Baltic Sea	72-28%
SO_2 emission factor (0.1%S fuel)	0.05 kg/GJ
SO_2 emission factor (1%S fuel)	0.49 kg/GJ
Shadow prices SO_2 - North Sea - Baltic Sea	 15 €$_{2015}$/kg emission 8 €$_{2015}$/kg emission
Shadow prices PM - North Sea - Baltic Sea	 61 €$_{2015}$/kg emission 26 €$_{2015}$/kg emission

Multiplying the change in emissions with the shadow prices provides the value of health impacts caused by these pollutants. Based on this method and assumed parameters, the results for the economic benefit for health is

2 A variety of health effects are included. Examples are chronic bronchitis, restricted activity days, respiratory hospital admissions.

3 Including English Channel, Skagerrak and Kattegat.

presented in Table 2. In total, the implementation of SECA resulted in health benefits of 4.4 billion euros.

Table 2 Results health benefit analysis (in billions of €$_{2015}$)

Sea	Health benefits from decrease in SO_2 emissions	Health benefits from decrease in PM emissions	Total health impacts per sea
North Sea	2.6	1.1	3.6
Baltic Sea	0.5	0.2	0.7
Total	3.1	1.3	**4.4**

A remark on these results is that these are based on relatively old shadow prices which have been corrected to represent the price in 2015. Using the shadow prices given in CEEH (2011), the health benefits from the SECA are higher, as the (corrected) shadow price for SO_2 and PM in 2015 is € 20.4 and € 41.5/kg emission respectively. This results in health benefits from the SECA implementation of 5.8 billion euros, which is 30% higher than the CAFE shadow prices from 2005 (Table 3).

Table 3 Results health benefit analysis based on CEEH (2011)

	Billions of €$_{2015}$
Health benefits from decrease in SO_2 emissions	4.7
Health benefits from decrease in PM emissions	1.1
Total health benefits in North and Baltic Sea	**5.8**

The ex-ante benefits to society of the post 2008 policy of IMO has been studied by AEA (2009). The benefits of the introduction of lowering the fuel sulphur content and the introduction of Tier I and II emissions standards have been quantified at € 8-16 billion. However, it should be noted that the study took 1.5%S (2010 baseline) into account as baseline, instead of 1% which was applicable in the 2010-2014 period. Assuming a linear relationship between sulphur emissions and health impacts, the benefits are between 5 and 11 billion euros. It should be noted, however, that this estimate also includes benefits of the introduction of Tier I and II limits and therefore should be seen as an upper limit. However, the large majority of the benefits can be allocated to reduction of the fuel sulphur content.

2.4 Comparing costs and benefits

Our ex-post calculations are close to the lower bound of the benefits presented in AEA (2009). Comparing costs and benefits shows that the costs are significantly lower than the calculated benefits. AEA (2009) presents total costs of SECA in 2015 to be between 0.6 and 3.7 billion euro (depending on the type of abatement measure) which is about 15-85% of our calculated benefits. Using the fuel consumed in the North Sea (12.5 ktonne) and the average estimated price difference between MGO and HFO over 2015 ($ 205 per tonne), the overall additional fuel cost spent is 2.3 billion euros.

The health benefits are between 1.9 and 3.5 times higher than the costs, using benefits between benefits between 4.4 and 8 billion euros.

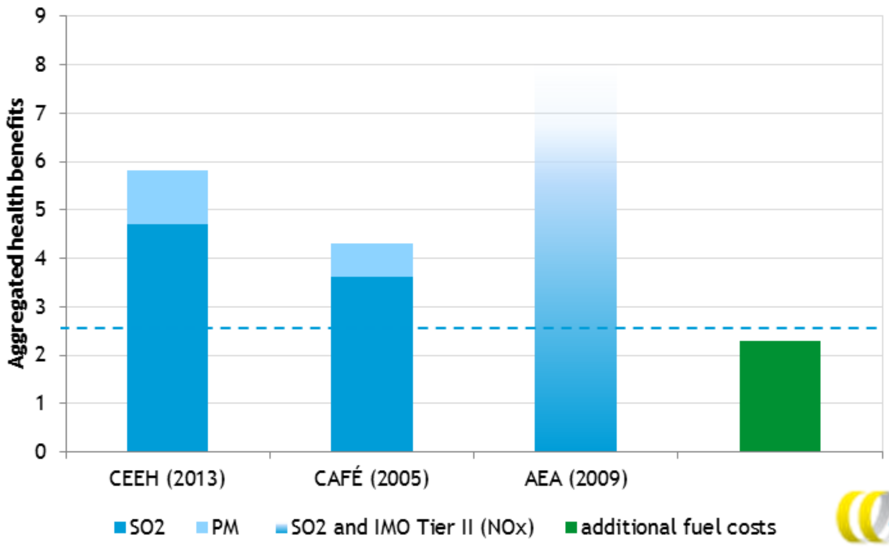
2.5 Conclusion

The available studies show a noticeable improvement of the air quality in port areas and along coast lines that has been measured during 2015, with a figure of 50% reduction cited several times. The specific reduction of the SO_2 concentration depends on the location, ship traffic, distance to source and the background concentration (e.g. near industry). In built areas close to the port, the impacts are highest.

Using the reduction of the sulphur concentration from 1 to 0.1%, the health benefits from impact on air quality range between 4.4 and 8 billion euros, depending on the calculation methodology. The additional costs of 0.1% MGO have been quantified at 2.3 billion euros, using the average estimated price difference of $ 205 over 2015 (see Section 3.3).

As shown in Figure 4 the health benefits are between 1.9 and 3.5 times higher than the costs. This shows that the benefits of the introduction of the new regulations clearly outweigh the costs of that policy, even in case of increased fuel price differences.

Figure 4 Calculated health benefits and additional fuel costs (billion euros)



3 Impact on the modal split and market

3.1 Introduction

In this chapter we provide an overview of the economic impacts of the introduction of the 0.1%S fuel requirement. First, we focus on the development of the fuel price, followed by an evaluation of the ex-ante estimated modal shift impacts will be made.

Not all ship types are expected to be similarly affected by the increased fuel prices. Unsurprisingly, the more fuel intensive types of ships will be harder hit than other ships. RoRo transport is most sensitive to modal shift, as RoRo ships can be characterised by their relatively high fuel consumption and the simplicity of shifting towards other RoRo services or to roads.

3.2 Impact of fuel price increase on transport costs

According to the COMPASS study (TML, Nautical Enterprise, 2010), fuel represented 47% of the daily costs (including all costs such as fuel, capital investment, interest, manning, gross margin, repairs, maintenance, etc.) at the time of writing. The costs breakdown (euros per day) is provided in Table 4, with a fuel price corrected for the 2015 situation.

Table 4 Cost breakdown of RoRo ship (200 veh. capacity)

Cost category	Costs (euros per day)
Manning	1,900
Insurance	443
Repairs and maintenance	1,382
Stores and lube oil	328
Administration	870
Capital repayments	7,960
Interest	6,543
Port	3,000
Fuel (200 $/tonne)	6,828
Gross margin	3,302
Overall	32,556

Source: COMPASS study (TML, Nautical Enterprise, 2010).

The additional costs of MGO consumption in the SECA represent between 128 and 244 $/tonne of fuel (Figure 6). Using these figures result in fuel cost increase of between 4,370-8,300 euros per day. This represents a cost increase of 13 to 25% of the overall costs.

The share of energy cost in total transport costs is slightly lower for road transport than for short sea shipping. The impact of a doubling of the crude oil price has a relatively higher impact on the cost of short sea shipping than on road freight transport, since fuel taxes represent a significant share of the fuel price.

Environmental policies in road transport
Not only maritime transport is faced with the costs of environmental policies. Also significant environmental technology as diesel particulate filters and selective catalytic reduction (SCR) equipment has been equipped to trucks over the last year. The costs of the latest steps (Euro V and VI) are estimated at around € 2,500 (MNP, 2008); (ICCT, 2016). Assuming a depreciation period of four years, the annual costs are around € 625. Using a travelled distance of 100,000 kilometres the average cost per kilometre would be below 0.1 cent. The typical costs of driving is between € 1.5 and € 3 per km, depending on distance, region, goods type, etc. The price increase is very limited, even if a few percent increase of fuel consumption is taken into account in addition.

Larger impacts result from the introduction of distance based charges. Many countries with international truck transport have introduced a toll for trucks. Austria, Switzerland, Germany and Belgium have introduced such charges over the last ten years. The tolls for large trucks are typically around 15 ct per km driven on motorways, depending on the Euro standard.

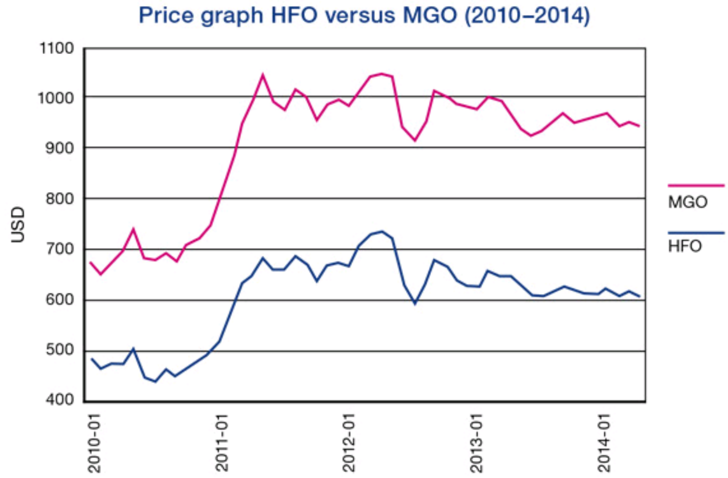
While both transport modes have been faced with increased costs due to internalisation of infrastructure and environmental costs, the impact for RoRo transport has been larger than for truck transport.

3.3 Fuel price developments

In advance of the introduction of the SECA fuel sulphur limits, various studies have been performed in order to estimate the potential modal shift. During the period of performing the studies, the price difference between MGO and HFO (3.5%S) was high. The price of MGO peaked at $ 1,200/tonne and the price difference with HFO close to $ 600 in early July 2008. Two months later, the fuel price difference reduced to $ 270.

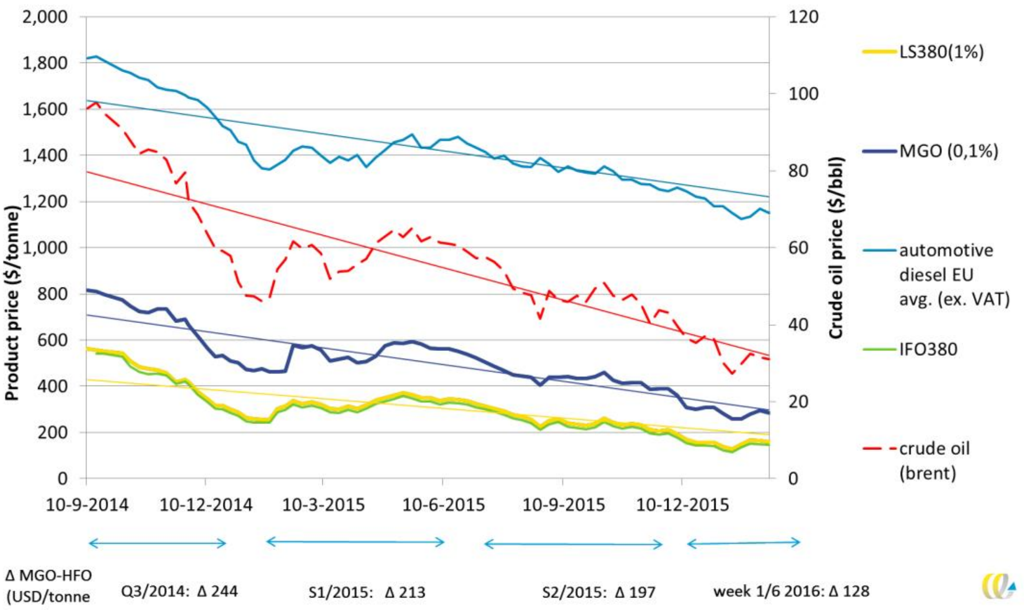
Figure 5 suggests a relatively constant price differential during from halfway 2011 until the beginning of 2014. Furthermore, the figure shows that the price differential is a function of the price level.

Figure 5 **HFO (3.5%S) versus MGO price (average value, 2010-2014)**



During the last quarter before the introduction of the 0.1%S regime in the Baltic and North Sea, the fuel price difference was $ 244$/tonne. During the first and second semester of 2015, this reduced to $ 213 and $ 197. In the first six weeks of 2016, the price differential even went down to $ 128.
The absolute reduction of fuel prices is obviously linked to the global reduction of the crude oil price from close to $ 100/barrel to $ 30/barrel. Figure 6 shows the trends of various product prices and the crude oil price.

Figure 6 Maritime fuel prices at Rotterdam and crude oil price



Note: The LS380 fuel price for 2015 is based on the price differential of IFO380 and LS380 in 2014, which was 15 $/tonne on average. The Crude oil price is depicted at the right hand axis.

Source: Shipandbunker.com; DG ENER oil Bulletin.

It is striking that MGO prices decrease more sharply than all the other product prices.

Both the automotive diesel price and the HFO price reduce relatively slow, compared to crude oil. This can be explained by the relatively high share of capital costs in the final product cost of the fuels. One would expect that MGO would follow the same trend. This is, however, not the case. The MGO price drops relatively fast in comparison to the HFO and automotive diesel price, while its characteristics are relatively similar to automotive diesel.

This notable price drop suggests the following:
- MGO fuel availability is uncritical (Woodall, 2016) and there may be even an oversupply of MGO. There is an ongoing shift towards increased MGO/distillate production and lower HFO production. E.g. increased supply of MGO from Russia, the Middle East and the United States. According to OPEC the world oil residuals production has been reduced by 10% over the 2010-2014 period, while the distillates production has been increased by 7% (OPEC, 2015).
- The correction may be the result of economy of scale advantages.

No firm evidence has been found to support the suggestions above but recent price developments do not hint at problems regarding fuel availability. Further research should be done on the question if the price differential between MGO and HFO would follow the same pathway as in 2015 if the crude oil price will increase again. This will answer the question if the changes mentioned above have resulted in a structural lower price difference.

Road fuel versus MGO
The relevant fuel price changes in the framework of modal shift is the price differential between on road diesel (excl. VAT) and 0.1%S MGO. The data presented in Table 5 illustrates the larger price difference in 2014, and the competitive advantage in 2015 for road transport. One would thus expect that the situation worsens for short sea shipping, and RoRo transport in particular, in comparison to truck transport.

Table 5 Relevant fuel prices for comparing maritime shipping and road transport ($/tonne)

Period	Shipping fuel price	EU weighted average automotive diesel price (incl. excise duty/ excl. VAT)	Delta fuel price
Q4/2014	448 (1%HFO)	1,690	1,242
1st semester 2015	528 (0.1% MGO)	1,414	886
2nd semester 2015	406 (0.1% MGO)	1,306	900

Therefore, modal shift developments (RoRo-road) are studied in depth in the Sections 0 and 3.5.

3.4 General trends in the RoRo market

The market for RoRo transport flourished in 2015. The large RoRo carriers are all expanding their routes in the aftermath of the economic crisis, and the general trend is positive. Although most companies did not report the financial figures about 2015, available published quarterly figures and news items suggest a profitability figures that will not be below the 2014 figures. DFDS reported the expectation that 2015 will be a record year and expects a doubling of profit before tax in comparison to 2014. In addition, the available nine month figures from Stena Line suggest a 2015 profit that is not deviating much from the 2014 profit. Also Finnlines, mainly active in the Baltic Sea, said it broke records quarter after quarter during the 2015 financial year.

The hypothesis that operators would have to close routes has not turned into reality. Many RoRo operators have expanded their network or increased the frequency of their services. The media shows expansion of the existing services at the North Sea, an area where fierce competition with Canal crossing (Dover-Calais) was expected due to the introduction of the 0,1%S sulphur cap:

- Cobelfret: Zeebrugge-Purfleet (two additional departures per week);
- Cobelfret: Zeebrugge-Dublin (one additional departure per week);
- Cobelfret: expansion of Rotterdam terminal;
- DFDS: Rotterdam-Felixstowe (one additional departure per week);
- DFDS: Rotterdam-Felixtowe (replacing one ship by a larger one: 300 extra trailers capacity);
- DFDS: Rotterdam–Immingham (three additional departures per week);
- Stena Line: Rotterdam-Killingholme (three additional departures per week).

It should be noted that some routes have been closed, but the link with the new sulphur limits is often of secondary importance. The pre-2015 profitability of the specific routes plays a more significant role.
An online survey[4] organised by ECSA (2015) in context of the ESFF platform supports the statement resulted in the following conclusions:

- the majority of the respondents (71%) to their survey reports zero modal shift implying that no customers are lost;
- 21% indicates that it is impossible to describe or quantify the impact of the sulphur directive in a changing environment;
- the vast majority of the respondents (94%) saw no impact on the level of service, i.e. no change in the frequency and number of vessels deployed;
- 57% of the respondents reported no increase of freight rates

Several respondents made an additional comment to the questionnaire illustrating the fall of the oil price, which has made the transition to MGO an exercise a lot less painful than anticipated. Should this factor change, respondents are confident that the situation on modal shift will be different. Interviews with two RoRo/RoPax operators support the above statements.

3.5 Modal split developments

In this section, we focus on the developments in the European RoRo sector on specific routes that were deemed to be most sensitive to modal shift in the ex-ante studies (see Table 7). Large and for modal shift relevant markets for RoRo transport are the North Sea/Dover Strait crossings, Germany-Southern Sweden and Western Europe-Scandinavia and to a lesser extent Western Europe-Baltic States, see Figure 7. Table 6 illustrates the RoRo cargo turnover for the largest ports in Northern Europe.

[4] 33 replies representing the entire short sea segment, representing both small (36% up to 10 vessels and large fleets (27% respondents more than 50 vessels).

Figure 7 Routes deemed most sensitive to modal shift or reduced cargo volumes

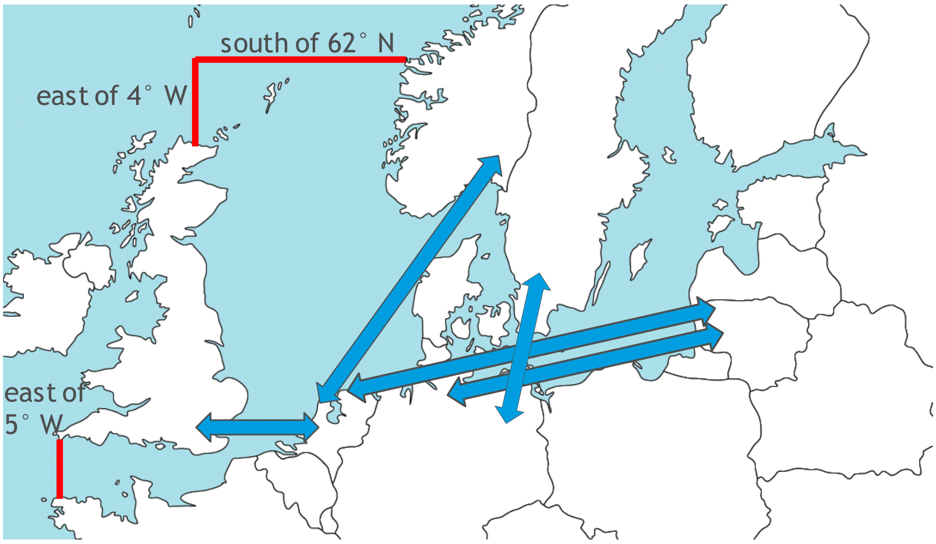


Table 6 RoRo cargo turnover in Atlantic (including cargo turnover outside the North Sea/English Channel) and Baltic ports by countries, and main ports (2013) in millions of tonnes cargo

Country		Port	RoRo cargo (mln tonne)	
United Kingdom			94.5	
	of which:	Dover		24.9
		Immingham		14.5
		London		7.6
		Liverpool		6.6
Sweden			43.0	
	of which:	Trelleborg		9.8
		Gothenburg		8.7
Germany			38.5	
	of which:	Lübeck/Travemünde		13.8
		Rostock		6.7
		Puttgarden		6.5
Belgium			22.3	
	of which:	Zeebrugge		12.6
Denmark			22.0	
	of which:	Rødby		6.5
France			21.7	
	of which:	Calais		15.2
Finland			17.2	
	of which:	Helsinki		6.1
Netherlands			16.8	
	of which:	Rotterdam		12.9
Ireland			11.6	
Norway			7.3	
Poland			6.4	
Estonia			3.7	
Latvia			3.1	
Lithuania			2.8	
Russia			2.4	
Spain			2.0	

Source: (Baltic Press Ltd, 2015b).

Of the individual Baltic Sea ports, ports in Northern Germany (Lübeck/ Travemünde, Rostock) and Southern Sweden (Trelleborg, Ystad and Malmö) are the largest, followed by ports in Denmark and the Baltic States. An extensive overview of Baltic Sea ports can be found in Annex A.

For the main routes, an analysis of the modal shift impacts is performed below. For each of the routes, the hypothesis from the ex-ante study is mentioned. All studies have been performed in a period when fuel price levels were much higher than today. As a consequence, many studies were performed using significant price differentials than those applicable today.
In fact none of the studies assumed actual fuel prices, all were well above and are therefore likely to overestimate possible negative impacts by far – at least at current fuel prices which are up to four times lower than assumed.
The studies included in Table 7 have been analysed.

Table 7 **Used studies setting hypotheses regarding the consequences of the stricter sulphur requirements for the North Sea and the Baltic Sea in 2015**

Title	Price MGO ($/tonne)	Reference
Impact study on the future requirements of MARPOL Annex VI	725	(SKEMA, 2010)
Analysis of the Consequences of Low-Sulphur Fuel Requirements	1,000	(ITTMA & TML, 2010)
Reducing the sulphur content of shipping fuels further to 0.1% in the North Sea and Baltic Sea in 2015: Consequences for shipping in this shipping area	1,300	(ISL, 2010)
Consequences of the IMO's new marine fuel sulphur regulations	662	(Swedish Maritime Administration, 2009)
The COMPetitiveness of EuropeAn Short-sea freight Shipping compared with road and rail transport	820	(TML, Nautical Enterprise, 2010)

In the following, five hypotheses are tested.

3.5.1 Western Europe hinterland - United Kingdom

Hypothesis
The cross channel rail business for truck/trailer combinations (Dover-Calais link) is likely to be benefit from the use of MGO. The use of MGO could well imply a major traffic loss of manned truck/trailer combinations per vessel across the southern part of the English Channel. Furthermore, the Rotterdam-Harwich and Rotterdam-Hull routes are expected to decline (SKEMA, 2010). The corresponding MGO price is $ 725/tonne.

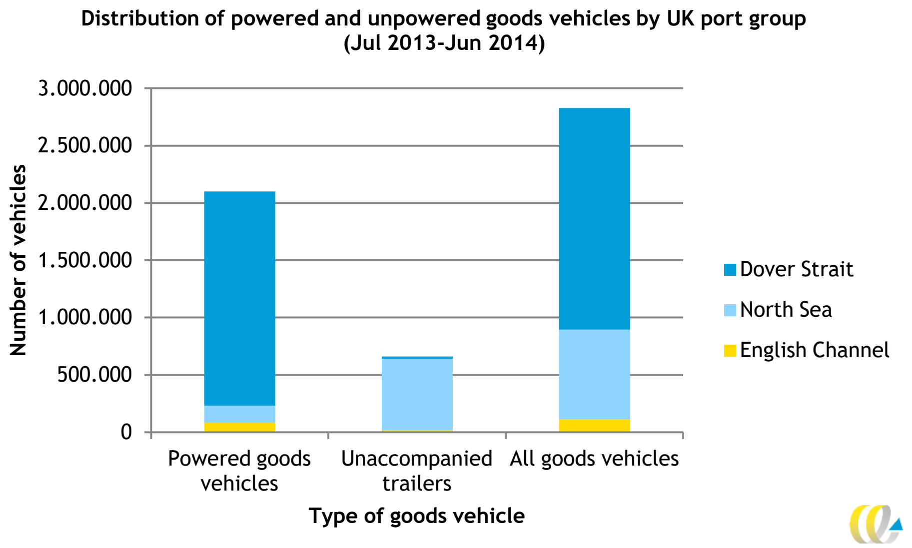
The 60% market share for the Rotterdam-Hull route will reduce to 50% at the benefit of the Dover-Calais route, for transport from the German Ruhr area.

Reasoning from the calculations made by SKEMA (2010), it is expected that the shorter Dover-Calais route will gain market share from the longer sea routes via Rotterdam and Zeebrugge.

North Sea crossing vs. Dover Strait
RoRo traffic between the United Kingdom and the mainland is generally performed with powered goods vehicles, as shown in Figure 8. The majority of

RoRo traffic with powered goods vehicles is transported across the Dover Strait. RoRo traffic with unaccompanied trailers is a smaller portion and is mostly performed across the North Sea. The English Channel represents a very small part of RoRo traffic from the United Kingdom to the mainland.

Figure 8 Distribution of powered and unpowered goods vehicles by UK port group

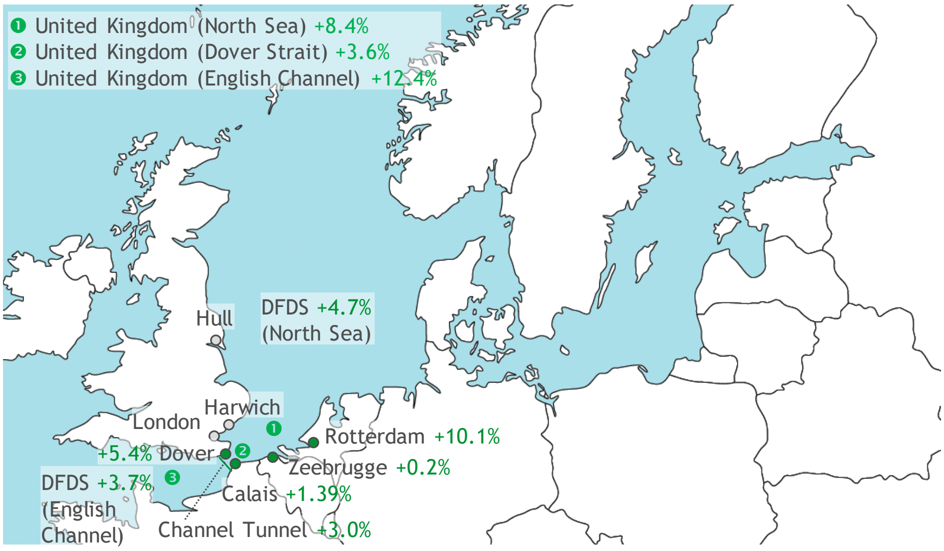


Source: (United Kingdom Department of Transport, 2014).

Statistics

Figure 9 provides an overview of statistics for crossings between Western Europe and the United Kingdom. This data supplemented with the exact quantity describing the RoRo volume, the change for 2014/2013, and the reference can be found in Table 10 in Annex A.

Figure 9 Statistics for crossings between Western Europe and the United Kingdom, change in RoRo volume 2015/2014



Analysis
The available data does not support a significant shift towards the Dover-Calais route. The Port of Rotterdam shows a significant increase in RoRo traffic, which is mainly UK-Netherlands trade. The Channel Tunnel does not show explicitly high growth figures over 2015, but lower growth figures than in 2013. The port of Calais shows a lower growth figure over the year 2015 compared to the year before.

Data from (United Kingdom Department for Transport, 2016) shows an increase in RoRo freight transport through the North Sea, the Strait of Dover, and the English Channel.

Conclusion
Available statistics do not support the hypothesis that the Dover-Calais route has gained market share from North Sea crossings.

3.5.2 Germany-Baltic States

Hypothesis
On the routes between Kiel and Klaipeda, 10% of the cargo volume transported by RoRo freighter is expected to be shifted to a truck/short sea combination (SKEMA, 2010). An MGO price of $ 725/ton is assumed. This prediction can be expanded to the statement that all routes between Germany and the Baltic States will see a shift from short sea shipping to truck-only or truck/short sea combinations.

At an MGO price of $ 1,300/ton, (ISL, 2010) predicts a shift of 46% of the trailers from RoRo to truck-only on the routes from the German Baltic Sea ports to Russia/Baltic States.

Statistics
Figure 10 provides an overview of statistics for crossings between Germany and the Baltic States. This data supplemented with the exact quantity describing the RoRo volume, the change for 2014/2013, and the reference can be found in Table 12 in Annex B.

Figure 10 Statistics for crossings between Germany and the Baltic States, change in RoRo volume 2015/2014

Analysis
The statistics do not show a clear picture of RoRo freight transport decreasing in the ports of Germany and the Baltic States. RoRo transport in the German port of Rostock shows a large increase over 2015. The Baltic harbours of Tallinn, Klaipeda, and Ventspils show both an increase and a decrease in their short sea shipping. The short sea shipping operator DFDS Group saw an increase in turnover of their Baltic Sea division.

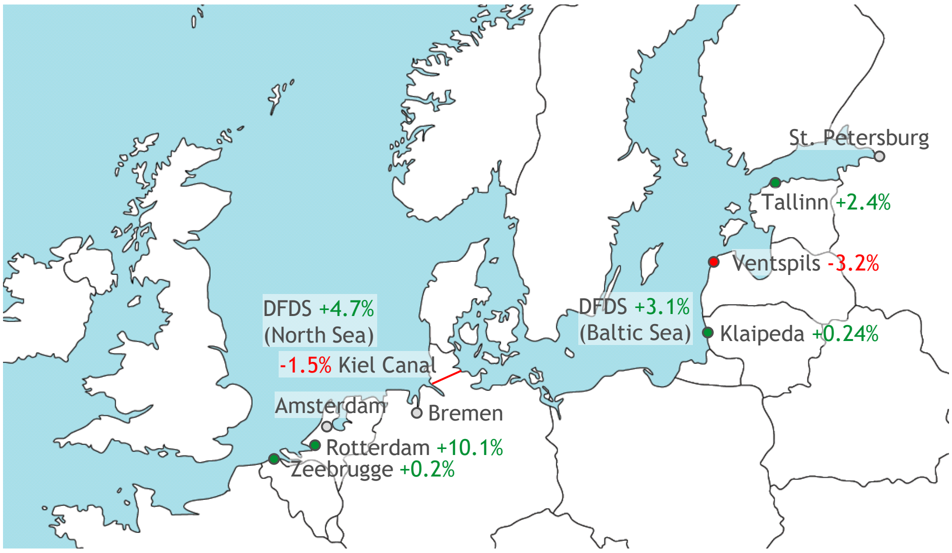
Conclusion
Available statistics do not support the hypothesis that the harbours on the Germany-Baltic States routes have seen a decrease in RoRo traffic in favour of truck-only options.

3.5.3 Western Europe-Baltic States/Russia

Hypothesis
The use of MGO (at $ 1,000/tonne) for the routes between Western Europe and the Baltic states will cause increased competition from trucking (ITTMA & TML, 2010). On some routes, the price difference between long-distance short sea shipping and truck/short sea combinations shrinks considerably, with the former still retaining the advantage. On other routes however, truck/short sea combinations are expected to become cheaper than long-distance short sea shipping.

Statistics
Figure 11 provides an overview of statistics for crossings between Western Europe and the Baltic States/Russia. This data supplemented with the exact quantity describing the RoRo volume, the change for 2014/2013, and the reference can be found in Table 11 in Annex B.

Figure 11 **Statistics for crossings between Western Europe and the Baltic States/Russia, change in RoRo volume 2015/2014**



Analysis

The statistics do not unequivocally show a decrease in short sea shipping in the Western European and Baltic harbours. The Western European harbours of Rotterdam and Zeebrugge show a large and a small increase respectively in the RoRo traffic from 2014 to 2015. The Kiel Canal shows a decrease in the total number of ships passing by. A fact that can also partly result from insufficient infrastructure and ongoing maintenance work especially during 2015. Drawing a conclusion on the RoRo traffic through the Kiel Canal is therefore, however, not possible. The Baltic harbours of Tallinn, Klaipeda, and Ventspils show an increase as well as a decrease in RoRo traffic, also not allowing to draw a conclusion.

Conclusion

Available statistics do not support the hypothesis that the harbours on the Western Europe-Baltic States/Baltic Scandinavia routes have seen a decrease in RoRo traffic in favour of truck-only options.

3.5.4 Germany/Denmark-Scandinavian Peninsula

Hypothesis

(ISL, 2010) expects that (at an MGO price of $ 1,300/ton) a percentage of the trailers from the German Baltic coast to Scandinavia will shift from RoRo to truck-only, specifically 14% in the routes to Western Sweden, 15% to Southern Sweden, and 27% to Finland.

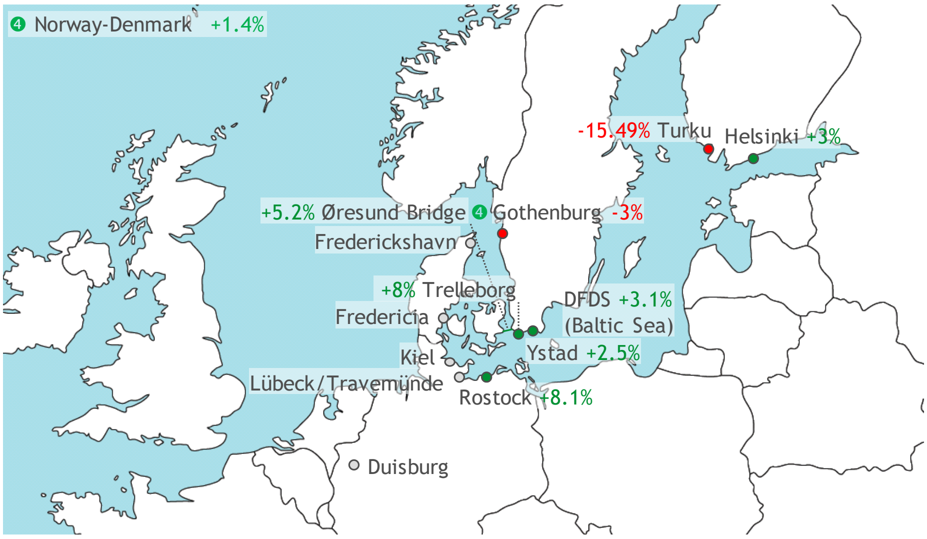
According to SKEMA, (2010) at an MGO price of $ 725/ton, the route from Gothenburg to Duisburg sees a shift in the part of the route by sea. This shift causes the shorter Gothenburg-Frederikshavn route to increase by 26% in cargo volume, while the longer Gothenburg-Travemünde route decreases by 15%.

At an MGO price of $ 662/ton, (Swedish Maritime Administration, 2009) predicts that routes by sea through the port of Gothenburg will switch to routes by road over the Øresund Bridge connecting Sweden and Denmark. Also, routes from ports in northern Sweden will shift to routes from ports in central or southern Sweden.

Statistics

Figure 12 provides an overview of statistics for crossings between Germany/ Denmark and the Scandinavian Peninsula. This data supplemented with the exact quantity describing the RoRo volume, the change for 2014/2013, and the reference can be found in Table 13 in Annex B.

Figure 12 Statistics for crossings between Germany/Denmark and the Scandinavian Peninsula, change in RoRo volume 2015/2014



Analysis

The German harbour of Rostock and the Swedish harbours of Trelleborg and Ystad show an increase in the transported RoRo freight. Because this is the shortest sea distance between Germany and Sweden, it is possible that this increase is due to the increase in costs for the fuel used. This statement is supported by data from the more northern Swedish port of Gothenburg showing a decrease, but contradicted by the increase in the RoRo volume between Norway and Denmark.

The Finnish harbours of Helsinki and Turku show mixed results with an increase for Helsinki and a decrease of RoRo freight for Turku. This could well be a change in the market.

RoRo transport between Norway and Denmark has seen a small increase, while one may expect a shift from RoRo transport to road transport across the Øresund Bridge for southern Denmark destinations.

Table 13 in Annex B shows that the RoRo cargo between Norway and Denmark or Germany did not decrease significantly. RoRo cargo to Sweden did not decrease significantly in total. The longer routes to the Baltic harbours of Sweden had an increase that was comparable to the decrease of the shorter routes to the North Sea ports.

Conclusion

Available statistics do not support the hypothesis that the harbours on the Germany/Denmark-Scandinavian Peninsula routes have seen a decrease in RoRo traffic in favour of truck-only options. Based on the decrease of RoRo volume in the Gothenburg port, there is weak evidence of a shift from more northern to the south-most Swedish ports.

3.5.5 Western Europe-Scandinavian Peninsula

Hypothesis

Between Western Europe (Belgium, The Netherlands, West-Germany) and the Scandinavian Peninsula (Norway, Sweden), short sea shipping faces limited competition from road haulage (ITTMA & TML, 2010). The main competing route uses the much shorter sea shipping connection between Travemünde and Trelleborg and therefore entails a much longer part of the route by road. Although the competition is limited, the use of MGO (at $ 1,000/ton) decreases the cost advantage of the direct sea link between Western Europe and the Scandinavian Peninsula and (ITTMA & TML, 2010) predicts more customers taking the competing road route.

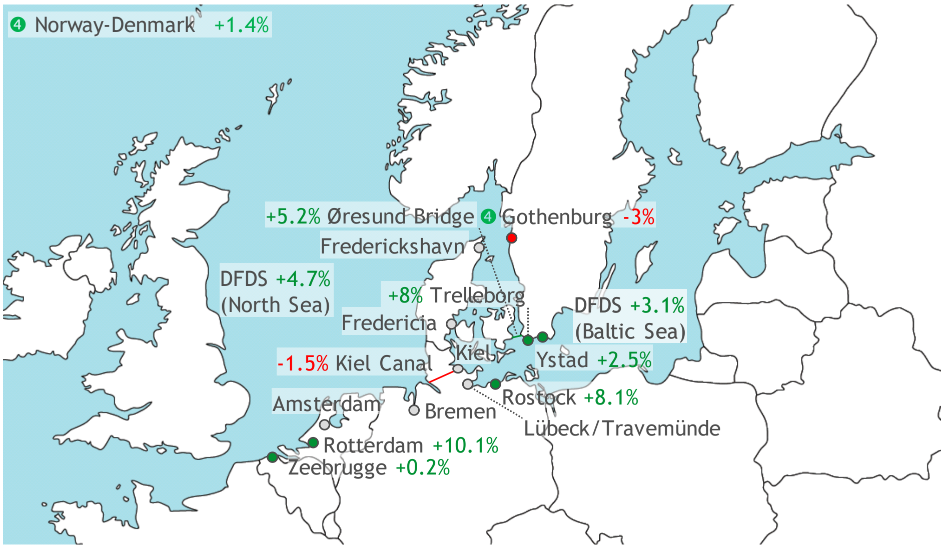
At an MGO price of $ 820, (TML, Nautical Enterprise, 2010) predicts the LoLo and RoRo routes between Belgium, UK, Germany on the one hand and Finland, Sweden, Norway on the other hand to decrease by 10-15% in volume.

(ISL, 2010) predicts a shift of 24% of the trailers from RoRo to truck-only on the routes between Belgium and Western Sweden (at an MGO price of $ 1,300/ton).

Statistics

Figure 13 provides an overview of statistics for crossings between Germany/Denmark and the Scandinavian Peninsula. This data supplemented with the exact quantity describing the RoRo volume, the change for 2014/2013, and the reference can be found in Table 14 in Annex B.

Figure 13 **Statistics for crossings between Western Europe and the Scandinavian Peninsula, change in RoRo volume 2015/2014**



Analysis
The Scandinavian harbour of Gothenburg shows a decrease, whereas the harbours on the shorter sea link between Sweden and Germany (i.e. Trelleborg, Ystad, Rostock), and the Øresund Bridge all show an increase. Although the decrease in Gothenburg is claimed to coincide with a general decline in Swedish container volumes (Port of Gothenburg, 2016), the hypothesis that the shift to MGO causes a shift to shorter sea links might explain the reducing volumes in Gothenburg.

On the other end of the Western Europe-Scandinavian Peninsula link, the harbours of Rotterdam and Zeebrugge show an increase in their RoRo volume. It is possible that a decline in their RoRo volume to the Scandinavian Peninsula is masked by an increase to the United Kingdom.

Conclusion
Available statistics do not contradict the hypothesis that the harbours on the Western Europe-Scandinavian Peninsula routes have seen a decrease in RoRo traffic in favour of truck-only options.

3.6 Conclusion

The 0.1% sulphur requirement has an impact on the operation of RoRo ships, since ships need to bunker the more expensive MGO instead of HFO. This has led to increased fuel costs in the beginning of 2015. However, since the fuel prices have decreased significantly as a result of low oil prices, MGO prices at the end of 2015 were at the level of HFO prices of beginning 2015.

The availability of fuel has not been restrictive, which can be illustrated by the absence of a price peak in the beginning of 2015, industry opinions and a lower price differential between MGO and HFO over the year 2015.

The competitive position of RoRo shipping in comparison with road transport became worse, since the difference in fuel price has become smaller. The fuel price difference decreased from $ 1,200 (HFO-diesel) to around $ 900 (MGO-diesel) per tonne of fuel[5]. Unless the worsening of the competitive position, the first available evidence shows that RoRo shipping has largely been able to cope with the fuel price increases. Some of the largest RoRo operators report outstanding financial figures over 2015.

It should be noted, however, that with increasing oil prices the situation might worsen as RoRo transport is relatively more sensitive to fuel price increases than truck transport. To what extent MGO prices may increase is unclear since increased supply and economy of scale advantages may extinguish the rise of MGO prices once the crude oil price will increase again. This needs to be further researched in order to draw firm conclusions.

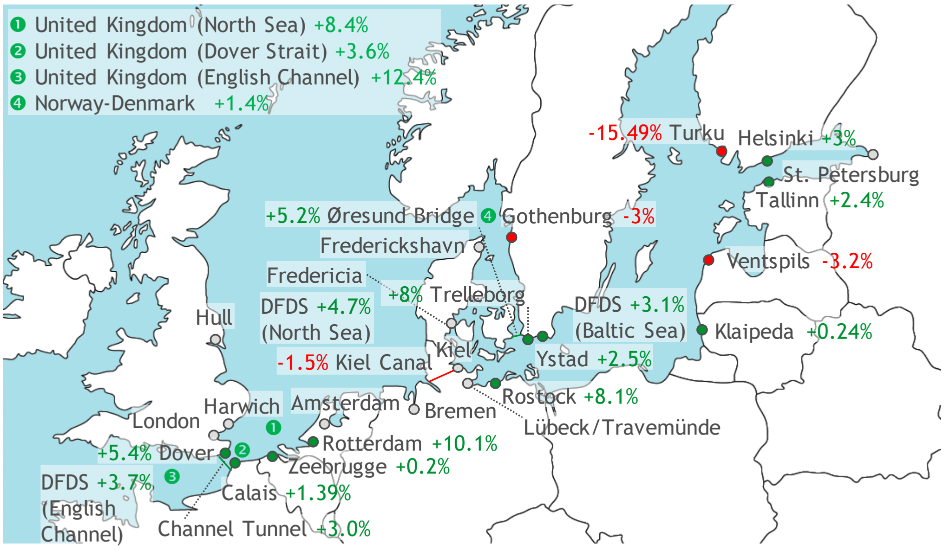
The hypotheses developed in advance of the introduction of the 0.1% sulphur requirement shows increased competition of road transport, and a stronger position for shorter sea routes at the costs of longer sea routes. On the basis of the analysed case studies, we can conclude the following:
- shorter sea routes did hardly gain market share from longer sea routes;
- on-land truck routes have not become more attractive.

[5] Not taking into account the higher energy content of MGO (5%).

The first conclusion can be supported by the relatively strong growth of the North Sea trade, in comparison to the Channel trade, while the available studies illustrate a decline in market share for North Sea trade.
However, refugees trying to reach the UK via Dover may also have played a role in the route choice.

The second conclusion can be drawn upon the operational and financial performance of the RoRo operators and ports. Hardly any significant drop in the number of trailers transhipped are reported. Most ports show an increase in the turnover, as illustrated in Figure 14. The largest RoRo companies report financial records following on outstanding operational performances.

Figure 14 Statistics for crossings in the North Sea and Baltic Sea area, change in RoRo volume 2015/2014



It should be noted that the actual fuel prices are lower than anticipated before by the studies. However, the drop in fuel price only mitigated part of the challenge for shipping companies. Although fuel prices went down, the competitive position of RoRo transported worsened anyway. Available data shows that the RoRo sector has been able to deal with the smaller getting cost advantage.

4 Compliance, enforcement and surveillance

4.1 Introduction

In addition to the assessment of health and economic impacts of the SECA fuel sulphur requirements, compliance, enforcement and surveillance are discussed in this chapter.

The following documents are normally checked on-board during ship inspection, in context of the fuel sulphur content: Oil Record Book, bunker delivery notes (BDN), logbooks and records related to the fuel switchover before entering SECA, and records of navigational activities. Fuel sampling is generally done if non-compliance is suspected.

4.2 European legislation on compliance and enforcement of SECA

European legislation regarding compliance and enforcement is described in Directive 2012/33/EU. Member States should take measures to check the sulphur content of fuels (EC, 2012). This is done by:

a Inspection of ships' log books and bunker delivery notes. **And**
b Sampling of marine fuel for on-board combustion while being delivered to ships. **Or**
c Sampling and analysis of the sulphur content of marine fuel for on-board combustion contained in tanks.

According to the Commission implementation Decision 2015/253 (EC, 2015), member states should carry out inspections of ships' log books and bunker delivery notes on board of at least 10% of the total number of individual ships calling in the relevant Member State per year. As from 1 January 2016, the sulphur content of the marine fuel being used on board will also be checked by member states, trough sampling and/or analysis of at least the following percentage of the inspected ships:

a 40% in member states fully bordering SECAs.
b 30% in member states partly bordering SECAs.
c 20% in member states not bordering SECAs.

Member states are encouraged to use a common data base and information system, developed and operated by the European Maritime Safety Agency (the THESIS-S system), available from 1 January 2015. This system serves as a platform to record and exchange information on the results of individual compliance verifications under Directive 1999/32/EC.

The 10% inspection requirement should be evaluated in the context of the overall number of calls. According to Sorgenfrei (Sorgenfrei, 2013) the overall number of ship calls in Europe was 800,000 in 2013. This implies that with about 80,000 individual ships calling a EU ports, the statistical average chance of a control is around 1% per call.

The number of inspections recorded by EMSA (EMSA, 2016) is slightly too low for the Baltic Sea (20%) and above the required number for the North Sea.

The fuel sampling rate was 13%, which is well below the required 30-40% for 2016. This implies that the sampling rate has to increase significantly in 2016. Penalties are not yet widely applied, only in 30% of the non-compliant cases a penalty was applied.

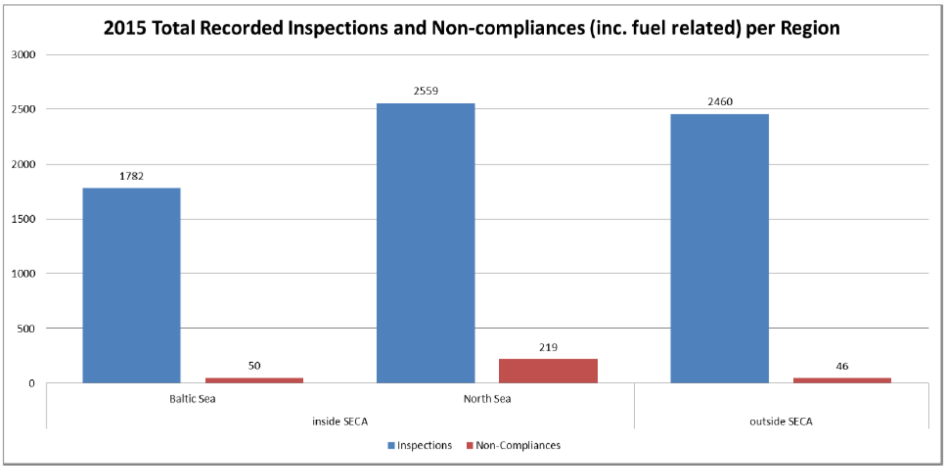
The accuracy and trustworthiness of bunker delivery notes have become more critical since the introduction of the 0.1%S sulphur requirements. Sampled fuel sulphur contents overrunning 0.1%S have been reported, while the bunker delivery note indicated a fuel sulphur content of below 0,1%S. Various stakeholders stressed the importance of intensification of control on the bunker fuels sold, e.g. through the issuing of licences that can be withdrawn. Such a system is used in the port of Singapore.

4.3 Compliance of SECA regulations

Figure 15 shows the number of inspections with and without non-compliance distributed over the regions for 2015 provided by EMSA (EMSA, 2016). It should be noted that these are not official figures and mainly applicable for the situation found in ports where experts expect the highest compliance rates, because of the inspections.

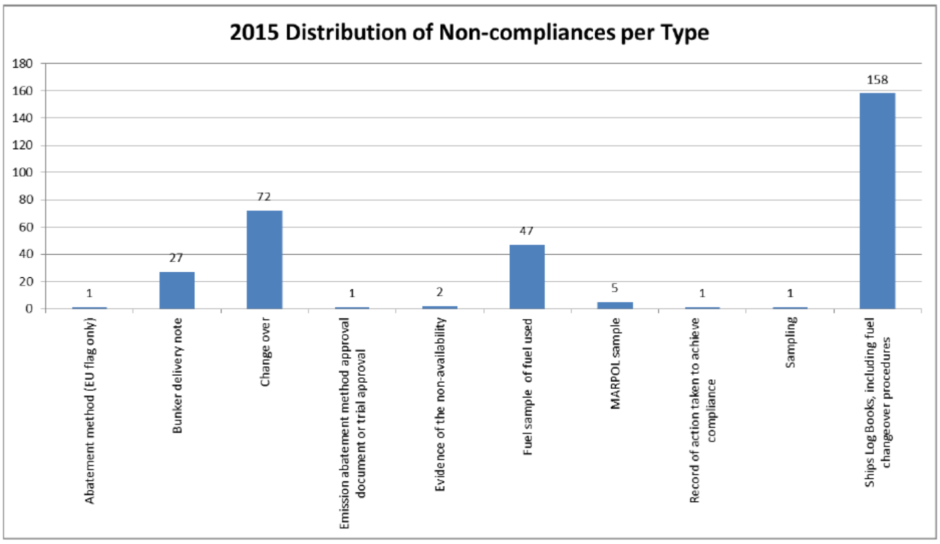
European Maritime Safety Agency data shows that 6,800 in-port inspections have been performed in 2015, of which 5% was non-compliant in European waters, and 6% in the SECAs. The figure shows that the non-compliance share is larger in the North Sea SECA (9%) compared to Baltic Sea SECA (3%) and waters outside SECA. Figure 15 shows the distribution of type of non-compliances. Most of the non-compliances were related to the fuel change over, the ship's logbook and the fuel sulphur content (Figure 16).

Figure 15 Distribution of non-compliances per region



Source: (EMSA, 2016).

Figure 16 Non-compliances per type in 2015



Note: The two largest contributors to non-compliance refer to no or late fuel change over, and to incorrect procedures and incorrect use of the ship log books.

Source: (EMSA, 2016).

The situation in the Baltic Sea can be illustrated by four countries reporting no detected volitions between 1st of January and 30th of June 2015. The number of non-compliances detected during the same period in three other countries was 20 (based on results of fuel sample analyses) and 39 detected by remote sensing. According to the information received, the highest sulphur content of fuel oil that has been detected was 0.6% (HELCOM, 2015).

In Germany, the University of Bremen and the German Federal Maritime and Hydrographic Agency have established a measurement station near the harbour of Hamburg called MESMART. In this project, more than 1,400 ship plumes have been analysed. Compliance, defined as not overrunning a 0.2%S threshold, was 100% in 2014, while this decreased to 95.4% in 2015 (Kattner, et al., 2015). The higher threshold was used because of measurement uncertainties within this this pilot project.

Thresholds above 0.1%S are wider applied, also by inspectorates for the application of legal sanctions. A sulphur concentration of 0.1-0.15% results in a warning, but no sanction. This may explain the relatively low level of penalties applied (30% of non-complinaces).

The Dutch inspectorate checked 160 vessels in 2015 of which 20 were non-compliant (> 0.15 %S), a non-compliance rate of 12.5 % (Trouw, 2016)

Remote measurements performed near Plymouth (UK) suggest a high level of compliance to the regulations (>95%) in 2015 (Yang, et al., 2016). It should, however, be noted that mainly local ship traffic is included in the figures and not North-South traffic passing through the English Channel.

The numbers show that the level of non-compliance differs among European countries and ports but ranges between 5 to 12.5%, depending on the definition of being compliant.

Compliance rate at open sea

Remote observations by plane in Danish waters show that ships have not continued to used high sulphur fuels in on the busy shipping lanes. Only a limited number (2%) of ships show a fuel sulphur content of above 0.3%S[6]. For 30% of the ships, a calculated fuel sulphur content of between 0.1 and 0.3% was found, but also a significant share of ships with calculated fuel sulphur contents close to zero.

Danish data based on the use of sniffer technology fitted on the Great Belt Bridge indicates that 98% of the ships meet the 0.1%S regulation, without mentioning the error margin used (The Ministry of Environment and Food of Denmark , 2015). This high compliance rate may be explained by the surveillance of Danish water by air planes equipped with remote sensing technology.

The uncertainty of measured values with sniffer and other remote sensing data should be reduced by verifying the measurements with the results of fuel analysis. This is the easiest for near ports measurement.

The actual compliance rate on the open sea is not yet widely assessed and can differ significantly because of variations in control and between regions. While the Danish data shows no continuation of the use of high sulphur fuels, evidence for other waters is lacking. Some experts indicate that non-compliance at open sea may be significant, especially close to the borders of the SECAs. It should be stressed that there is no evidence to underpin such a statement, Since only limited random checks on open sea are performed by member states.

Interviewed experts stress that more and well trained inspectors are needed in order to deal with potential misleading of the ship's professional staff. Current activities within the inspectorates focus on cooperative development of systems to better monitor and control the at sea compliance.

Experts indicated that being non-compliant is very cost efficient, compared to the chance of control. The penalties determined must be effective, proportionate and dissuasive and may include fines calculated in such a way as to ensure that the fines at least deprive those responsible of the economic benefits derived from their infringement. Fines should gradually increase for repeated infringements.

Sanctions and fines for SECA infringements

In several countries, legal procedures have been started against serious offenders. Since this is a new area in jurisdiction in most countries, national authorities have to gather relevant information and need to iteratively assess which information holds in lawsuits.

The sanctions and penalties for non-compliance with Directive 2012/33/EU are different for the EU member states. Some member states employ administrative fines for violation of sulphur requirements, while other countries use criminal sanctions. The latter implies that the size of the penalties is defined by the court on a case by case basis. For the Baltic Sea countries, the distribution is five against four in favour of administrative fines.

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6 Because a certain measurement error may in the data, Denmark uses an error margin. The data available certainly shows that this experiment is a weak basis for estimating compliance, since about half of the measurements were found to be under 0.005%S.

The minimum and maximum fines applied by the Baltic Sea countries range from € 350 to 57,000.

The limited information on the fines applied shows that the maximum fine non-compliant ships risk differs strongly among countries (Table 8).

Table 8 Maximum fines per country in for non-compliance

Country	Fine for non-compliance in SECA	Administrative/criminal sanction
Germany	€ 350-25,000	Criminal
Finland	max. € 800,000	Criminal
Latvia	€ 350-1,400	Administrative
Lithuania	max. 14,500	Administrative
Estonia	€ 32,000	Administrative
Norway	max. NOK 300,000	
Sweden	max. SEK 10 million	Criminal
Poland	max. € 57,000	Administrative
UK	£ 8,000-3 million	Criminal
Netherlands	max. € 800,000	Criminal
Belgium	max. € 6,000,000	Criminal
France	max. € 200,000	Criminal

Source: HELCOM, 2015; The Danish Ecological Council, 2015.

In case of criminal sanctions, prosecution is difficult, because of lack of proof. Various countries are considering the introduction of administrative sanctions if criminal sanctions prove to be inadequate. Sweden has sanctioned various offenders, but no infringements have been prosecuted so far.

In addition to the application of fines, member states can apply ship detention in case of non-compliance. In the Netherlands, 8 out of 20 non-compliant vessels got a detention in 2015. In case of a detention the ship can only leave the harbour after bunkering the compliant fuel or solving the irregularity. Detention could cost € 10,000 to 50,000 per day. No fines have been applied yet, but several legal cases are under preparation (Trouw, 2016). Ship detention is indicated as an effective mechanism, since ship detention may result in contract discharge and reduces the company performance[7] as part of the Paris Memorandum of Understanding on Port State Control.

Also stakeholders from industry are in favour of effective control, which may also be linked to the big economic advantage of non-compliance. Various industry stakeholders are engaged in the Trident Alliance group[8], lobbying for robust EU enforcement of the sulphur regulations.

4.4 Additional efforts to make control more effective

As revealed from the discussions with experts, it is necessary to better monitor the ship's operations for better control and understanding. The in-port inspections need to be expanded with a series of intelligent monitoring tools

7 Company performance takes account of the detention and deficiency history of all ships in a company's fleet.

8 http://www.tridentalliance.org/

that need to be intensively tested and used for monitoring purposes first. To this end, protocols should be developed and verified, potentially for legal use of intelligent control tools in a later stage:

– The use of a fuel calculator that allows to calculate the supposed amount of fuel used in the SECA in relation to the volume of bunker fuels in stock over time.
– The use of SO_2 sampling or remote sensing on open sea by use of air lanes/helicopters/drones. Such a method can control the behaviour on open sea. It should not only be used as an 'indicator' for control in ports, but should be further researched for development as a tool to prove incompliance at open sea.
– The use of portable equipment (XRF scanners) for in situ sulphur content measurement of the ship's fuel. This makes control more efficient.

Belgium, Finland, the Netherlands and Sweden co-operate in the project COMPMON in order to develop joint analysis tools and demonstrate the usefulness of these. The tools mentioned above are part of the project.

Intensified co-operation between the national inspectorates in Europe will be needed in order to develop and harmonize the use of the tools mentioned. This applies to:

– the coordination of surveillance activities and its results;
– back and forth reportings between national authorities in case of non-compliance;
– the use of common technical standards for e.g. remote sensing and fuel sampling;
– the alignment of legal actions and exchange of an effective approach for penal sanctions.

One could easily conclude that the use of one agreed sulphur limit for taking actions against non-compliance would be needed, but this might create a new 'de-facto' limit, which is not the intention.

The implementation of sealed continuous monitoring devices was mentioned frequently as an effective control tool, significantly reducing the enforcement efforts. This technology is currently already used on-board of ships fitted with a scrubber and therefore readily available.

4.5 Conclusion

The first year of 0.1% SECA regulation has shown that in ports, the largest majority of ships use a fuel that is compliant or within the accuracy margin used by European inspectorates. Between 3 and 9% of the ships were non-compliant in ports neighbouring the Baltic Sea and North Sea respectively. Figures on open sea are rather scarce. The available information from Denmark illustrates a significant lowering of the fuel sulphur content on busy Danish shipping routes, but at the same time reveals the current immaturity of remote sensing with air planes.

Additional monitoring and control techniques need to be developed in order to reduce the current inaccuracies and increase the intelligence of the monitoring system. These will incentivise industry to bunker and use the required fuels, and the error margins for fuel sulphur control by inspectors - up to 20% for reporting deficiencies and 50% for applying sanctions – could potentially be reduced on the basis of increased kowledge.

The coordination and development of surveillance activities (aerial and by ground based monitoring facilities) as well as processing and use of the collected data needs to be intensified. The back and forth reporting of non-compliant ships is an important precondition for increasing the effectiveness of the system.

The fines applied should be proportionate to the economic benefits of not complying with the regulations. The use of legal instruments (e.g. detention) should be coordinated, within the framework of varying national legal systems.

5 Conclusions

5.1 Introduction

This ex-post assessment documents the first experiences in Europe with the 0.1% fuel sulphur cap in the European SECAs. This chapter's results provide an overview of the current situation and lessons to be learned.

5.2 Air quality improvements and socio economic benefits

The available studies show a noticeable improvement of the air quality in port areas and along coast lines that has been measured during 2015. The specific reduction of the SO_2 concentration ranges between studies and sulphur concentration reductions of 50% and more have been reported. The actual reduction depends on the location, distance to source and the background concentration (e.g. near industry). In built areas close to busy port, the health impacts will be highest.

Using the reduction of the sulphur concentration from 1% to 0.1%, the health benefits from impact on air quality range between 4.4 and 8 billion euros. The additional costs of the use 0.1%S MGO in the North and Baltic Sea have been quantified at 2.3 billion euros, using the average price difference of $ 205 over 2015. The health benefits due to lower emissions of SO_2 and PM are between 1.9 and 3.5 times higher than the costs. This shows that the benefits of the introduction of the new regulations have outweighed the costs of that policy. This statement will remain valid with future rising fuel price differences (e.g. doubling).

5.3 Fuel availability and modal shift

MGO availability is uncritical. While it was estimated that a fuel shortage would result in an increase of MGO price, the opposite occurred mainly as the result of reduced oil prices. Notably, the MGO price decreased more sharply than the price of HFO and automotive diesel, illustrating sufficient supply and probably oversupply of MGO. No major shifts towards road transport have been found so far, and no company or even service shut-downs or decreasing cargo turnover in northern European ports, that can be clearly linked to the introduction of the 0.1%S sulphur cap.

5.4 Compliance, enforcement and surveillance

The first year of 0.1% SECA regulation has shown that in ports, the largest majority of ships use a fuel that is compliant or within the accuracy margin used by European inspectorates. Between 3 and 9% of the ships are non-compliant in the Baltic Sea and North Sea respectively, according to EMSA data. Most member states use a margin of at least above 20% the legal threshold during control in ports.

Figures on the compliance on open sea are rather scarce and available data remote sensing data needs to be verified in order to be able to draw firm conclusions. The available information from Denmark illustrates a significant lowering of the fuel sulphur content on busy Danish shipping routes in 2015, but at the same time reveals the current immaturity of remote sensing with air planes. Many of the measurements show results in a grey area (below 0,3%S) which needs clarification and verification.

The number of administrative inspections is only limitedly below the required numbers, but fuel sampling needs to be intensified in 2016, in order to meet the required 30-40 fuel samples per 100 inspections.

Additional monitoring and control techniques need to be developed in order to reduce the current inaccuracies and increase the intelligence of the monitoring system. This will deliver incentives for the industry to bunker and use the required fuels. The coordination and development of surveillance activities (aerial and by ground based monitoring facilities) as well as processing and use of the collected data needs to be intensified. More knowledge, better equipment will lead to better interpretation of the assessed logbooks and will increase the effectiveness of inspections.

The increase of knowledge may lead to a reduction in error margins – up to 20% for reporting deficiencies and 50% for applying sanctions and reduce the risk of having a defector higher sulphur cap in place. Also back and forth reporting of non-compliant ships is an important precondition for increasing the effectiveness of the system.

The sanctions applied should be proportionate to the economic benefits of not complying with the regulations. The use of legal instruments (e.g. detention) should be coordinated, within the framework of varying national legal systems.

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Annex A Turnover statistics for Baltic Sea ports

Table 9 Top 30 RoRo and ferry ports in the Baltic Sea (2014) by freight units

#	Port	Country	Freight units
1	Lübeck/Travemünde	Germany	744,860
2	Trelleborg	Sweden	670,776
3	Helsinki	Finland	503,354
4	Gothenburg	Sweden	497,609
5	Rostock	Germany	444,781
6	Puttgarden	Germany	412,151
7	Rødby	Denmark	412,151
8	Tallinn	Estonia	377,316
9	Helsingør	Denmark	375,450
10	Helsingborg	Sweden	369,908
11	Świnoujście	Poland	341,782
12	Malmö	Sweden	218,814
13	Ystad	Sweden	218,790
14	Kiel	Germany	191,000
15	Klaipeda	Lithuania	178,627
16	Stockholm	Sweden	176,677
17	Hanko	Finland	162,880
18	Kapellskär	Sweden	159,017
19	Frederikshavn	Denmark	154,454
20	Gdynia	Poland	141,670
21	Hirtshals	Denmark	137,868
22	Turku	Finland	123,141
23	Karlskrona	Sweden	116,828
24	Ust-Luga[9]	Russia	110,000
25	Naantali	Finland	99,454
26	Gedser	Denmark	96,348
27	Nynäshamn	Sweden	83,743
28	Esbjerg	Denmark	74,000
29	Ventspils	Latvia	72,758
30	St. Petersburg	Russia	72,000

Source: (Baltic Press Ltd, 2015).

[9] Estimated.

Annex B Statistical tables

Table 10 Statistics for crossings between Western Europe hinterland and the United Kingdom

Port/company	Quantity	%2015-2014	%2014-2013	Source
Calais	Number of freight units cross-Channel	+1.39%	+9.83	(Port Calais Boulogne, 2016)
Dover	Number of trucks	+5.4% (Q1-3)	+9.7%	(Port of Dover, 2016)
Channel Tunnel	Number of trucks	+3.0%	+5.7%	(Eurotunnel Group, 2016)
Rotterdam	RoRo gross weight	+10.1%	+8.1%	(Port of Rotterdam, 2016)
Harwich	N/a	N/a	N/a	N/a
Associated British Ports (21 ports in the East, South, and West of the UK)	Number of trucks	+8.9% (Q1-Q2)	-1.4% (Q1-Q2)	(Associated British Ports, 2015)
DFDS Group (North Sea)	Lane metres of freight	+4.7%	+1.4%	(DFDS Group, 2016)
DFDS Group (English Channel)	Lane metres of freight	+3.7%	+7.0%	(DFDS Group, 2016)
Zeebrugge	Number of trucks	+0.2%	+2.1%	(Port of Zeebrugge, 2016)
Hull	N/a	N/a	N/a	In associated British Ports
London	RoRo net weight	N/a	-0.2%	(Port of London, 2015)
United Kingdom (North Sea)	Number of trucks	+8.4% (Q1-Q3)	+6.7% (Q1-Q3)	(United Kingdom Department for Transport, 2016)
United Kingdom (Dover Strait)	Number of trucks	+3.6% (Q1-Q3)	+8.1% (Q1-Q3)	(United Kingdom Department for Transport, 2016)
United Kingdom (English Channel)	Number of trucks	+12.4% (Q1-Q3)	-5.2% (Q1-Q3)	(United Kingdom Department for Transport, 2016)

Table 11 Statistics for crossings between Western Europe and the Baltic States/Russia

Port/Company	Quantity	%2015-2014	%2014-2013	Source
Rotterdam	RoRo gross weight	+10.1%	+8.1%	(Port of Rotterdam, 2016)
Zeebrugge	Number of trucks	+0.2%	+2.1%	(Port of Zeebrugge, 2016)
Hamburg	N/a	N/a	N/a	
Bremen/ Bremerhaven	N/a	N/a	N/a	
Amsterdam	N/a	N/a	N/a	
Kiel Canal	Number of ships (including non-RoRo vessels)	-1.5%	+5.3%	(Kiel Canal, 2016)
Tallinn	Number of vehicles	+2.4%	+6.0%	(Port of Tallinn, 2016)
Klaipeda	Number of RoRo cargo units	+0.24%	-3.6%	(Port of Klaipeda, 2016)
Ventspils	Number of ferry line cargo units	-3.2%	+2.4%	(Port of Ventspils, 2016)
St. Petersburg	N/a	N/a	N/a	

Table 12 Statistics for crossings between Germany and the Baltic States

Port/Company	Quantity	%2015-2014	%2014-2013	Source
Rostock	RoRo net weight	+8.1%	+10.6%	(Port of Rostock, 2016)
Tallinn	Number of vehicles	+2.4%	+6.0%	(Port of Tallinn, 2016)
Klaipeda	Number of RoRo cargo units	+0.24%	-3.6%	(Port of Klaipeda, 2016)
Ventspils	Number of ferry line cargo units	-3.2%	+2.4%	(Port of Ventspils, 2016)
St. Petersburg	N/a	N/a	N/a	
DFDS Group (Baltic Sea)	Lane metres of freight	+3.1%	-1.2%	(DFDS Group, 2016)

Table 13 Statistics for crossings between Germany/Denmark and the Scandinavian Peninsula

Port/company	Quantity	%2015-2014	%2014-2013	Source
Rostock	RoRo net weight	+8.1%	+10.6%	(Port of Rostock, 2016)
Lübeck/Travemünde	N/a	N/a	N/a	
Kiel	Ferry net weight	N/a	-0.12%	(Port of Kiel, 2016)
Frederickshavn	N/a	N/a	N/a	
Fredericia	N/a	N/a	N/a	
Trelleborg	RoRo net weight	+8%	+4%	(Port of Trelleborg, 2016)
Gothenburg	Number of RoRo units	-3%	N/a	(Port of Gothenburg, 2016)
Ystad	Number of trucks and trailers	+2.5%	N/a	(Port of Ystad, 2016)
Stockholm	RoRo net weight	N/a	+0.4%	(Ports of Stockholm, 2014)
Helsinki	Number of trucks and trailers	+3%	+4%	(Port of Helsinki, 2016)
Turku	Number of trucks and trailers	-15.49%	-3.42%	(Port of Turku, 2016)
Øresund Bridge	Number of truck passings	+5.2%	+6.3%	(Øresundsbron, 2016)
Norway-Denmark	RoRo net weight	+1.4% (Q1-Q3)	+6.6% (Q1-Q3)	(Statistics Norway, 2016)

Table 14 Statistics for crossings between Western Europe and the Scandinavian Peninsula

Port/company	Quantity	%2015-2014	%2014-2013	Source
Rotterdam	RoRo gross weight	+10.1%	+8.1%	(Port of Rotterdam, 2016)
Zeebrugge	Number of trucks	+0.2%	+2.1%	(Port of Zeebrugge, 2016)
Hamburg	N/a	N/a	N/a	
Bremen/ Bremerhaven	N/a	N/a	N/a	
Amsterdam	N/a	N/a	N/a	
Kiel Canal	Number of ships (including non-RoRo vessels)	-1.5%	+5.3%	(Kiel Canal, 2016)
Trelleborg	RoRo net weight	+8%	+4%	(Port of Trelleborg, 2016)
Gothenburg	Number of RoRo units	-3%	N/a	(Port of Gothenburg, 2016)
Ystad	Number of trucks and trailers	+2.5%	N/a	(Port of Ystad, 2016)
Stockholm	RoRo net weight	N/a	+0.4%	(Ports of Stockholm, 2014)
Øresund Bridge	Number of truck passings	+5.2%	+6.3%	(Øresundsbron, 2016)
Rostock	RoRo net weight	+8.1%	+10.6%	(Port of Rostock, 2016)
Lübeck/Travemünde	N/a	N/a	N/a	
Kiel	Ferry net weight	N/a	-0.12%	(Port of Kiel, 2016)
Frederickshavn	N/a	N/a	N/a	
Fredericia	N/a	N/a	N/a	
Norway-Denmark	RoRo net weight	+1.4% (Q1-Q3)	+6.6% (Q1-Q3)	(Statistics Norway, 2016)