The impact on short sea shipping and the risk of modal shift from the establishment of a NOx emission control area in the North Sea

Final report

North Sea Consultation Group
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

Table of contents

1 Summary & conclusions 3
2 Introduction 5
2.1 Background 5
3 Sea transport in the North Sea 8
3.1 The North Sea fleet 8
3.2 Ship types prone to modal shifts 10
3.3 Shipping routes prone to modal shifts 11
4 Selection of case routes 14
4.1 Modal shift case routes 14
4.2 Port shift case routes 17
5 Cost assessment 21
5.1 Land-based transport 21
5.2 Sea-based transport 24
6 Comparative analysis 33
6.1 Method 33
6.2 Modal shift 33
6.3 Port shift 39
6.4 Freight prices 41
6.5 Comparison to other studies 42
7 Modal and port shifts 45
7.1 Modal shift analysis 45
7.2 Port shift analysis 48
7.3 Modal and port shift rigidity 49
8 Socio-economic impact & environmental standards 52
8.1 Benefits 53
8.2 Costs 54
8.3 Benefits and costs compared 55
8.4 Environmental standards 56
9 References 57
1 Summary & conclusions

In the report, we assess the potential modal and port shifts following the establishment of a NOx emission control area (NECA) in the North Sea, taking into account expected future cost increases of shipping and other transport modes, including the establishment of a SECA in the North Sea. The report also includes a socio-economic impact assessment. Complying with the NECA requirements requires newly built ships to install new technology. Complying with SECA means installing new technology or changing to a more expensive fuel.

We identify ro/ro and container shipping, on a short sea route where a competitive land-based alternative exists, as being the only ship activities prone to modal shifts due to the cost of complying with the ECA standards. In general, we find that the introduction of an NECA in 2015 will increase the cost of sea-based transport by less than 1%. The total costs increase of sea-based travel are expected to be 8%-16%. The introduction of a SECA is the main cost increase. For the entire sea-based travel route (including road haulage), the cost increase is 5%-13%. Our findings on SECA are in accordance with recent studies.

We use the change in cost to assess potential modal and port shifts by analyzing case routes. The assessment is based on elasticities. The elasticities reflect the changes in demand as cost is changed. The size of the elasticities however reflect the general elasticity in the market due to logistic limitations, freight time, planning etc. The general factors affecting the choice of modal are implicit accounted for in the elasticities.

We find that a North Sea emission control area being SECA and/or NECA only will give rise to minor modal shifts.

Figure 1: Modal shift: Change in million ton-kilometre by sea

Note: 1. The relative changes of the total quantities of ro/ro and Container freight in the North Sea are shown in parenthesis. 2. The analysis is based on the expected cost in 2030. 3. The analysis applies NECA compliance to all ships, and not only ships built after 2015. This implies a minor overestimation of the effect of NECA.

Figure 1 shows that the total quantity of ro/ro freight is expected to fall by 0.6% measured in terms of ton-kilometres. It is evident that the modal shift originates primarily from the SECA. The effects of a NECA on modal shift are marginal.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

We did not find indication that the cost of complying with the ECA standards will result in port shifts. The shifts in costs were not high enough to indicate that another port cost would be efficient.

Furthermore, shifting port or modal is not a simple task, and rigidity limits the operators’ ability and incentive to respond to changes in costs. There is a lot of rigidity in the transport route selection. This affects the potential shift from sea to other modalities. The rigidity is caused by many factors:

- The geographical layout is the most important determinant for limiting a shift of modality and port shift rigidity. The cost advantage for the existing sea route often stems from a “geographical shortcut” in the distance travelled.
- The importance of the travel time and flexibility relative to the cost difference between land- and sea-based transport is difficult to measure. It is, however, included as a factor in the price elasticity and hence the estimated modal shift.
- The expectations for the future costs of both land- and sea-based transport will affect freight demand today. If the cost advantage for some routes tips towards land-based transport when SECA and NECA are introduced, the market might not change their preferred mode of transport if they expect the sea-based route to regain their cost advantage within a few years due to the cost of changing transport logistics.

We do a socio-economic assessment of establishing a North Sea NECA and SECA respectively, taking the expected modal shift into account. We find a benefit-cost relationship of around 2.5 for a SECA and 4.2 for an NECA, which implies that the benefits clearly outweigh the costs.

We have examined the robustness of our results on modal and port shifts in a range of sensitivity tests. The tests show that the overall conclusions of the analysis are robust. Also if a Baltic NECA is not established.
2 Introduction

In the report, we examine the economic consequences of introducing a nitrogen oxide Emission Control Area (NECA) combined with a sulphur oxide Emission Control Area (SECA) in the North Sea, effective 1 January 2015. The SECA requirement will affect all ships sailing in the North Sea, whereas the NECA requirement would apply only to ships built from 1 January 2016 and sailing in the North Sea.

In the report we evaluate and estimate:

- the types of ships and routes most prone to shifts,
- the current and projected costs of complying with the new NECA and SECA, through 2040, and
- the indirect economic impacts, including the potential modal and port shifts and the socio-economic effects.

This study assumes that the Tier III standards become effective on or after 1 January 2016. It does not take into account a possible MEPC66 decision to move this date at least five years to 1 January 2021. The designation of the North Sea as a NECA would result in a cost increase for shipping, although the magnitude is estimated to be significantly smaller than the cost increase due to the new sulphur standards in SECA’s in 2015. The North Sea Consultation Group conducted and funded the study: Economic Impact Assessment of a NOx Emission Control coordinated by the Danish Ministry of the Environment. The study concluded:

- The costs imposed on the ship operators are unlikely to facilitate modal shifts.
- The increase in freight rates is estimated to be 1%-2% for short-sea shipping.
- The increase in freight rates is estimated to be 0.2%-0.6% for long distance shipping.
- A rerouting of the shipping patterns is very unlikely.

However, the North Sea countries are of the opinion that the scope of this analysis is limited because only the increase of NECA related costs were taken into account. There is a general wish for an economic impact assessment including a comparison of future sea transport costs versus land transport costs, taking into account not only NECA related costs but also other factors such as SECA compliance costs and relevant cost developments for land transport. The assessment of the expected cumulative future cost increases may be valuable to policymakers for a better understanding of the relative role of a North Sea NECA.

2.1 Background

In 2008, the International Maritime Organization (IMO) adopted their revised MARPOL Annex VI, which outlines stricter regulations of air pollutant emissions from ships. Amongst others, the requirement applies to emissions of sulphur and nitrogen oxides.

In 2010, the North Sea countries decided to initiate a process that entails studies of environmental and economic implications of a nitrogen oxide emission control area (NECA) to comply with the TIER III standards.

In 2012, Incentive and LITEHAUZ conducted an economic impact assessment of a North Sea NECA and an environmental impact assessment was carried out by PBL, the Netherlands’ Environmental Protection Agency.
The SECA requirements are set in MARPOL Annex VI regulation 14, which lowers the permitted level of sulphur in fuels from 1% in 2010 to 0.1% in 2015 within the SECA.

**Figure 2: North Sea SECA and global sulphur requirements**

Source: (Green Ship, 2012).

*Note: Whether the global limit is lowered in 2020 or 2025 depends on the outcome of a review of fuel oil availability to be completed in 2018. However, 2020 is the reference date (Lloyd's Register, 2012).*

### 2.2 Method and report overview

What we do:

1. We map the North Sea fleet in order to identify the ship types and routes most prone to modal shifts.

2. Based on the mapping, we select a set of routes. The case routes consist of a sea route and the possible land-based transport alternative.

3. We map the costs of the sea- and land-based transport alternatives with and without the NECA and SECA costs and project the costs using the best available sources.

4. Based on the change in cost difference between the sea- and land-based transport alternatives, we use elasticities to estimate the expected modal shift. We also consider the possibility of port shifts motivated by avoiding or limiting the costs of complying with the NECA and SECA standards.

In chapter 3, we present the North Sea fleet and identify ship types and routes prone to modal shifts. We select the case routes in chapter 4. In chapter 5 we map the cost components for sea and land-based transport. In chapter 6 we do a comparative cost analysis by applying the unit costs found in
chapter 5 to the case routes defined in chapter 4. We estimate the potential modal and port shifts in chapter 7. In chapter 8 we evaluate the role of environmental standards and the socio-economic impact of a North Sea NECA and SECA.
3 Sea transport in the North Sea

We map the North Sea fleet in order to identify the ship types and routes most prone to modal and port shifts.

The mapping of the North Sea fleet is based on (Incentive, 2012a) which was based on 2009 data provided by the Finnish Meteorological Institute (FMI, u.d.). For a more comprehensive description of the North Sea fleet, see (Incentive, 2012a).

The geographical area referred to as the North Sea in the report is formally defined as the area marked “North Sea” in figure 3.

Figure 3: The North Sea

Source: (Incentive, 2012a)

3.1 The North Sea fleet

During 2009, a total of 20,400 ships were registered as having operated in the North Sea. Some of these ships sailed only a few kilometres in the North Sea. A logical consequence of an NECA would be some degree of specialisation of the fleet. Ships already operating in other NECAs would not require the installation of additional NECA-compatible technologies. This is especially relevant for ships already operating in the Baltic Sea as this area is expected to be designated as an NECA. In other words, ships equipped with the required technology would be expected to take over operations from other ships already sailing relatively few kilometres in the North Sea and from ships moving to operate in non-NECAs elsewhere to avoid installing the required technology. The same goes for ships least exposed to SECA - for example by having SECA-compatible technology (i.e. scrubbers) installed.

Consequently, the project scenario of the analysis is based on the assumption that operations handled by ships sailing less than 3,000 kilometres per year in the North Sea and not entering another NECA are overtaken by other ships. The figure of 3,000 kilometres is merely a qualified guess; the same approach was used in (Incentive, 2012a).
This requirement reduces the number of relevant ships by 15%, from 20,400 to 17,372. The 17,372 ships travelled a total of 184 million kilometres in 2009. Note that the number of travelled kilometres following the reduction in the number of ships does not change, because other ships take on new operations.

Figure 4 shows the distributions of ships and kilometres travelled, by ship type, for the 17,372 ships.

**Figure 4: Distribution of ships and distribution of kilometres travelled in the North Sea, by ship type**

The ship type ‘Other’ covers the largest number of ships, but these ships account for less than 10% of total kilometres travelled in the North Sea. The category ‘Other’ comprises a variety of minor ship types that most likely will not be affected by an NECA or an SECA.

General dry cargo is the most common ship type in the North Sea, both in terms of number of ships (16% of all ships) and kilometres travelled (23% of all kilometres travelled).

Passenger ships cover a relatively large share of the kilometres travelled in the North Sea, given the number of these ships. This is mostly because many of these passenger ships operate strictly within the North Sea area.

Ships of the same type differ greatly in size. Figure 5 presents the relative size distribution for each ship type.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

### Figure 5: The North Sea fleet, by ship type and size (gross tonnage)

Source: (Incentive, 2012a)

Note: The size groups are based on gross tonnage: Small <2,500, Medium 2,500-25,000, Large >25,000.

As figure 5 shows, almost 60% of all ships are in the small size category. Some types of ships consist of mostly small ships, including other, miscellaneous, general dry cargo and fishing. In contrast, some types of ships consist of mostly large ships, including ro/ro, container, and chemical and gas tanker. More than 60% of passenger ships are considered to be small.

### 3.2 Ship types prone to modal shifts

Not all ship types are prone to modal shifts. We identify the types of ships potentially prone to modal or port shifts:

- Ro/ro cargo
- Ro/ro passenger (RoPax)
- Container

The core criteria for a ship type to be prone to modal shift is quite simple: a plausible land-based transport alternative must exist. This is not the case for a large share of the North Sea shipping. The short list is the result of an elimination process and the report by (UK Chamber of Shipping, 2013).

We excluded certain ship types from being prone to modal shifts based on a range of criteria and circumstances:

- Modal shifts are generally not expected for long-distance transport and transport of goods with a low value. For example, bulk products such as grain are not affected by SECA and NECA. On the other hand, highly valued fragile goods might also be less sensitive to an SECA and an NECA, as they are sensitive to unloading, and transport by only one mode (truck) might already be preferred prior to an SECA and an NECA (Rich, Kveiborg, & Overgård, 2011).
- Some ships are designed to transport specific products, making substitution very difficult, for example, oil and gas tankers.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

- Some types of ships and/or products can be handled only in certain ports, making port shifts less likely for specific ship types.
- Most trucks operating in European countries operate with a total weight limit of 40 tonnes (54/60 tonnes in Denmark and up to 60 tonnes in Sweden and Finland), making weight restrictions an important restraining factor.
- For trucks operating within some segments (e.g. bulk products) a further problem is the lack of loads to return to the port.
- Some types of ships already use fuel not affected by SECA.

3.2.1 Freight quantities prone to modal shifts

Data on the transported number of ton-kilometres in the North Sea are not directly available from FMI. By assuming a load capacity of 65% of the gross tonnage, we are capable of calculating the number of ton-kilometres depicted in table 1.

Table 1: Ton-kilometres transported in the North Sea in 2009 by ship type

<table>
<thead>
<tr>
<th></th>
<th>Ro/ro</th>
<th>Container</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside the North Sea</td>
<td>122,000</td>
<td>7,000</td>
<td>161,000</td>
</tr>
<tr>
<td>28% 2%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inside and outside</td>
<td>308,000</td>
<td>425,000</td>
<td>1,488,000</td>
</tr>
<tr>
<td>the North Sea</td>
<td>72%</td>
<td>98%</td>
<td>90%</td>
</tr>
</tbody>
</table>

Source: (FMI, u.d.) and own calculations

We have distinguished between whether the ship has operated inside the North Sea only or also outside the North Sea. The reason is that freight transported inside the North Sea only is more prone to modal shifts since the relative increase in cost due to SECA and NECA will be higher.

3.3 Shipping routes prone to modal shifts

Having identified the ship types prone to modal shifts, we turn our attention to the shipping routes prone to modal shifts.

The maps in figure 6 and figure 7 display the operating patterns for the three relevant types of ships:

- Ro/ro cargo
- Passenger (because data on RoPax cannot be obtained)
- Container

The mapping of operating patterns has been made by (FMI, u.d.) and is based on Automatic Information System (AIS) data.

Figure 6 depicts the operating pattern for ro/ro ships in 2009. The operating pattern is similar for both medium and large vessels, and the operating pattern for small ships is quite different, with heavier traffic between Norway and Germany.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

**Figure 6: Operating patterns for ro/ro, segmented by GT**

<table>
<thead>
<tr>
<th>Small &lt;2,500 GT</th>
<th>Medium 2,500-25,000 GT</th>
<th>Large &gt;25,000 GT</th>
</tr>
</thead>
</table>

Source: (FMI, u.d.).

Figure 7 depicts the operating patterns for passenger ships in 2009. The operating patterns are quite different for all sizes, although both medium and large ships have heavy operating routes in the English Channel.

**Figure 7: Operating patterns for passenger ships, segmented by GT**

<table>
<thead>
<tr>
<th>Small &lt;2,500 GT</th>
<th>Medium 2,500-25,000 GT</th>
<th>Large &gt;25,000 GT</th>
</tr>
</thead>
</table>

Source: (FMI, u.d.).
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

Figure 8 depicts the operating pattern for container ships in 2009. The operating pattern is similar for all three ship sizes, although there are relatively more operating routes for small ships between the Baltic Sea and Norway. For all container ship sizes, there is heavy traffic in the English Channel and on the west coast of Denmark.

Figure 8: Operating patterns for container ships, segmented by GT

| Small <2,500 GT | Medium 2,500-25,000 GT | Large >25,000 GT |

Source: (FMI, u.d.).
4 Selection of case routes

In chapter 3 we identified the ship types prone to modal shifts and we mapped the operating patterns of the ship types. The next step is to define the case routes. Different routes are prone to port and modal shifts, therefore we define two different sets of case routes.

4.1 Modal shift case routes

We have defined the case routes on a set of criteria:

- The current sea route is an existing route.
- The sea route is either a major transport route or a competitive land-based alternative exists.
- The route includes pre/post-haulage to ensure all costs associated with the different transport solutions are included.
- The land-based alternative route is the best cost minimizing route possible by road. For most of the case routes, we have identified more than one land-based alternative.

4.1.1 Ro/ro case routes

The case routes for ro/ro shipping are shown in table 2.

<table>
<thead>
<tr>
<th>Case route</th>
<th>Current route at sea</th>
<th>Alternative routes</th>
<th>Total distance (Distance at sea)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Rotterdam-Leeds</td>
<td>1a. Rotterdam-Hull</td>
<td>1b. Truck, ferry at Calais-Dover</td>
<td>588 km (482 km)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1c. Truck, Eurotunnel (rail)</td>
<td>805 km (0 km)</td>
</tr>
<tr>
<td>2. Rotterdam-Ipswich</td>
<td>2a. Rotterdam-Felixstowe</td>
<td>2b. Truck, ferry at Calais-Dover</td>
<td>309 km (280 km)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>592 km (52 km)</td>
</tr>
<tr>
<td>3. Taulov-Brussels</td>
<td>3a. Esbjerg-Zeebrugge</td>
<td>3b. Truck</td>
<td>819 km (620 km)</td>
</tr>
<tr>
<td>4. Ghent-Stockholm</td>
<td>4a. Ghent-Gothenburg</td>
<td>4b. Truck, ferry at Travemünde-Trelleborg</td>
<td>1,610 km (1,102 km)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1,545 km (220 km)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>925 km (161 km)</td>
</tr>
<tr>
<td>6. Taulov-Ipswich</td>
<td>6a. Esbjerg-Harwich</td>
<td>6b. Truck, ferry at Calais-Dover</td>
<td>841 km (706 km)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1,283 km (52 km)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6c. Truck, ferry at Rotterdam-Harwich</td>
<td>1,076 km (280 km)</td>
</tr>
</tbody>
</table>

Sources: (Vesseldistance, 2013) (distances at sea), and (Google Maps, 2013) (distances on land).

Note: Land-based distances were calculated on a route without route-dependent tolls. The difference between the distances with and without road tolls is, at most, 6%.

The geographical layout of the routes is presented in figure 9.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

4.1.2 Container case routes

The case routes for container shipping are presented in table 3.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

Table 3: Specified selection of short sea routes for container ships

<table>
<thead>
<tr>
<th>Case route</th>
<th>Current route at sea</th>
<th>Alternative routes</th>
<th>Total distance (Distance at sea)</th>
<th>Total distance (Distance at sea)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Hamburg-Antwerp</td>
<td>7a. Hamburg-Antwerp</td>
<td>7b. Truck</td>
<td>720 km (700 km)</td>
<td>561 km (0 km)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Hamburg-Gothenburg</td>
<td>8a. Hamburg-Gothenburg</td>
<td>8b. Truck, ferry at Elsinore-Helsingborg</td>
<td>636 km (596 km)</td>
<td>731 km (5 km)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>8c. Truck, ferry at Frederikshavn-Gothenburg</td>
<td>612 km (91 km)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>8d. Truck, ferry at Puttgarden-Rodby and Elsinore-Helsingborg</td>
<td>597 km (25 km)</td>
<td></td>
</tr>
<tr>
<td>9. Brugge-Newbridge</td>
<td>9a. Zeebrugge-Waterford</td>
<td>9b. Truck, ferry at Calais-Dover and Holyhead-Dublin</td>
<td>1,145 km (998 km)</td>
<td>955 km (160 km)</td>
</tr>
<tr>
<td>10. Paris-Riga</td>
<td>10a. Le Havre-Riga via Rotterdam</td>
<td>10b. Truck</td>
<td>2,241 km (2,022 km)</td>
<td>2,340 km (0 km)</td>
</tr>
</tbody>
</table>

Sources: (Vesseldistance, 2013) (distances at sea), and (Google Maps, 2013) (distances on land).

Notes: 1. Land-based distances were calculated on a route without route-dependent tolls. The difference between the distances with and without road tolls is, at most, 6%. 2. The road distance at Hamburg-Antwerp is 0 because the route acts mainly as two ‘on the way’ stops on a longer container route. 3. Approximately 300 of the sea-based kilometres in Route 9a are outside the North Sea SECA and NECA and any other SECA or NECA. 4. Some of the sea-based kilometres in Route 10a are in the Baltic NECA, not the North Sea SECA and NECA.

The geographical layout of the routes is presented in figure 10.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

4.2 Port shift case routes

We identified existing sea routes where the ship operators can possibly eschew or minimize the cost of entering and operating inside the North Sea ECA by selecting an alternative port.

The new ports do not necessarily define an existing sea route. However, we do take into account that the port infrastructure is adequate to handle the goods and the types of ships necessary.

4.2.1 Ro/ro routes

The case routes are presented in table 4.
Table 4: Specified selection of sea routes and alternative sea routes for ro/ro

<table>
<thead>
<tr>
<th>Case route</th>
<th>Current route at sea</th>
<th>Alternative route at sea</th>
<th>Total distance (Distance at sea)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea-based routes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Rotterdam-Leeds</td>
<td>1a. Rotterdam-Hull, rest by truck</td>
<td>1d_sea. Rotterdam-Felix- stowe</td>
<td>588 km (482 km)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Rotterdam-Ipswich</td>
<td>2a. Rotterdam-Felixstowe</td>
<td>2d_sea. Rotterdam-Tilbury</td>
<td>309 km (280 km)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Taulov-Brussels</td>
<td>3a. Esbjerg-Zeebrugge</td>
<td>3c_sea. Esbjerg-Rotterdam</td>
<td>819 km (620 km)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Taulov-Ipswich</td>
<td>6a. Esbjerg-Harwich</td>
<td>6d_sea. Esbjerg-Tilbury</td>
<td>841 km (706 km)</td>
</tr>
</tbody>
</table>

Sources: (Vesseldistance, 2013) (distances at sea), and (Google Maps, 2013) (distances on land).

The geographical layout of the routes is shown in figure 11.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

**Figure 11: Geographical layout of Ro/ro sea routes and alternative sea routes**

Notes: 1. The sea-based routes are marked by the solid lines, whereas the alternative routes are marked by the dotted lines. 2. Rotterdam-Leeds is black. 3. Rotterdam-Ipswich is brown. 4. Taulov-Brussels is red. 5. Ghent-Stockholm is grey. 6. Bremen-Oslo is bronze. 7. Taulov-Ipswich is orange.

### 4.2.2 Container routes

The alternative sea-based routes are presented in table 5.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

Table 5: Specified selection of sea routes and alternative sea routes for container ships

<table>
<thead>
<tr>
<th>Case route</th>
<th>Current route at sea</th>
<th>Alternative routes at sea</th>
<th>Total distance (Distance at sea)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sea-based routes</td>
<td>Total distance</td>
<td>Alternative sea-based routes</td>
</tr>
<tr>
<td>7. Hamburg-Antwerp</td>
<td>7a. Hamburg-Antwerp</td>
<td>700 km (700 km)</td>
<td>7c_sea. Hamburg-Rotterdam</td>
</tr>
<tr>
<td>8. Hamburg-Gothenburg</td>
<td>8a. Hamburg-Gothenburg</td>
<td>636 km (596 km)</td>
<td>8e_sea. Aarhus-Gothenburg</td>
</tr>
<tr>
<td>9. Brugge-Newbridge</td>
<td>9a. Zeebrugge-Waterford</td>
<td>1,145 km (998 km)</td>
<td>9c_sea. Le Havre-Waterford</td>
</tr>
<tr>
<td>10. Paris-Riga</td>
<td>10a. Le Havre-Riga via Rotterdam</td>
<td>2,241 km (2,022 km)</td>
<td>10c_sea. Lübeck-Riga</td>
</tr>
</tbody>
</table>

Sources: (Vesseldistance, 2013) (distances at sea), and (Google Maps, 2013) (distances on land).
Notes: 1. Approximately 300 of the sea-based kilometres in Route 9a and 9c_sea are outside the North Sea SECA and NECA and any other SECA or NECA. 2. Some or all of the sea-based kilometres in Route 10a and Route 10c_sea are in the Baltic NECA, not the North Sea SECA and NECA.

The geographical layout of the routes is provided below in Figure 12.

![Figure 12: Geographical layout of container sea routes and sea routes](image)

Notes: 1. The sea-based routes are marked by the solid lines, whereas the alternative routes are marked by the dotted lines. 2. Hamburg-Antwerp is black. 3. Hamburg-Gothenburg is bronze. 4. Brugge-Newbridge is red. 5. Paris-Riga is grey.
5 Cost assessment

In chapter 4 we defined the case routes. In this chapter we have assessed the cost associated with the sea- and land-based transport solutions respectively.

5.1 Land-based transport

We have assessed the unit costs of land-based transport of one truck/trailer combination. We divide the costs into five components, as shown in figure 13. The figure illustrates the development of each cost component over the project period.

*Figure 13: Costs of land-based transport (for illustration purpose only)*

The figure is for illustration purposes only and is not based on the actual costs. The figure, however, summarizes our key findings:

- Congestion, salary and especially fuel become more and more dominating cost components over time.
- Capital costs, tolls and ferry cost will be smaller cost components in the future, relatively.

Section 5.1.1 reviews the current costs, and Section 5.1.2 presents the projected costs of each component, including the potential costs of increased congestion following modal shifts.
5.1.1 Current costs of land-based transport

The cost assessment is based on input from (ECSA, 2010), (OECD, 2013), (International Energy Agency, 2013) as well as several other sources for price information such as (Eurotunnel.com, 2013).

Table 6 summarises our method of cost assessment and projection.

Table 6: Land-based real cost variables: method of assessment and projection

<table>
<thead>
<tr>
<th>Cost variables</th>
<th>Assessment method</th>
<th>Projection method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital cost per hour and per kilometre</td>
<td>Adjusted transport calculation model. See (DTU, 2013).</td>
<td>Constant.</td>
</tr>
<tr>
<td>Tolls per kilometre</td>
<td>The cost of the Eurovignette is assessed per kilometre, using the same method as in (Incentive, 2012b). Other tolls and distance-based charges are assessed by (OECD, 2013).</td>
<td>Constant.</td>
</tr>
<tr>
<td>Salary per hour (domestic and foreign drivers)</td>
<td>The hourly salary is assessed by updating a transport calculation model (DTU, 2013) with East European wages. This is the wage for foreign drivers. We assessed wages for domestic drivers using the unadjusted transport calculation model and (ECSA, 2010).</td>
<td>Domestic wages are projected by the average real GDP for North Sea countries for 2000-2014. Foreign wages are projected by the average real GDP for a number of East European countries for 2000-2014.</td>
</tr>
<tr>
<td>Fuel cost per kilometre (low and high speed limits)</td>
<td>We assessed the price of fuel as the average diesel price in a number of North Sea countries. VAT and a standard discount of 0.15€ are subtracted from the market prices. The fuel cost per kilometre is calculated from an average fuel consumption of 3 km per litre.</td>
<td>The fuel cost is projected by an international price forecast for crude oil (US Energy Information Administration, 2013).</td>
</tr>
<tr>
<td>Congestion per hour (highways and non-highways, low and high speed limits, respectively)</td>
<td>The current levels of congestion on highways and non-highways, respectively, are assessed from the average daily level of congestion measured in 25 cities and areas within the North Sea (see (TomTom, 2013)). Congestion measured as the average level in these cities would be an overestimation due to selection bias. Therefore, we use the 25th percentile of the distribution of the 25 cities as an expression of the delay in travel time, compared to ‘free flow’ traffic. The hourly value of congestion is found as the percentage increase in the total hourly value of capital costs and wages.</td>
<td>It is assumed that congestion on both highways and non-highways will be twice as high in 2040 as in 2013. This is a conservative estimate based on the growth in congestion the past 15 years.</td>
</tr>
<tr>
<td>Extra infrastructural costs (ferry etc.)</td>
<td>Assessed using the relevant web pages for ferries, tunnels and bridges such as (aferry.co.uk, 2013), (Direct Ferries, 2013) and (Eurotunnel.com, 2013). We withdraw a discount from the official list prices (30% for all ferries and 15% for all bridges and tunnels). The total cost of each transport trip by ferry also involves a time cost, including the time-dependent capital costs and the wage of the driver. This part of the cost is estimated and projected as described in this table. The time-dependent cost depends on the number of trucks accompanied by a driver on the entire ferry route.</td>
<td>The share of the prices of ferry, bridge and tunnel costs not related to capital costs is projected by the average historical and projected GDP for North Sea countries for 2000-2014. From 2015, the ferry transport cost is added to the projected cost of SECA and NECA, depending on the length of the ferry route, assuming that all prices are fully transferred to the freight rates.</td>
</tr>
</tbody>
</table>

¹ The source is only available in Danish.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

The unit toll costs consist of all infrastructural costs of land-based transport except for bridges, etc. The tolls are country-dependent. As the land-based routes are specified in chapter 4 to avoid any variable toll costs\(^2\), it is not necessary to include, for example, highway road tolls which fluctuate.

The wages we assessed for foreign drivers (driving the land-based routes) are much lower than what is usually indicated about driver wages from other studies, such as the (ECSA, 2010). Our research indicates that the lower wages gives a better approximation of the wages for long-distance international drivers. We also estimated wages for domestic drivers, assuming they drive the shorter distances, and these wages are consistent with previously performed determinations. The cost of domestic drivers is assumed to be the relevant cost estimate for road haulage on sea-based routes.

We use the average diesel price for all North Sea countries as a single average for the cost of land-based fuel. On a few long-distance routes, the trucks might be able to take advantage of the lower fuel prices east of the EU or in the South European countries. This factor is handled in the sensitivity analysis, as a wide range is assigned to the cost of fuel.

In determining the total costs of road transport, we differentiate between two average speeds. This affects the driving time and fuel consumption. The two average driving speeds are the legal speed limits in urban areas and on highways, including mandatory breaks and without congestion. Any delay in this travel time is included in the cost of congestion. The cost of congestion is included for 2013, although a cost of increased congestion (due to SECA and NECA) is not included before 2015.

Even for mainly land-based routes, some type of sea transport is typically involved because it often is the most cost-efficient option. The current costs of a ferry on the relevant routes as well as the costs of tunnels and bridges are assessed as described in Table 6. The sensitivity analysis handles the uncertainty in the price discounts of ferry, tunnel and bridge transport.

### 5.1.2 Projected costs of land-based transport

The projection method is described in Table 6, but is elaborated for some variables below.

Capital costs are assumed to be constant throughout the period because we do not expect the costs of maintenance and financing, measured in real prices, to change. The same approach is used in (DTU, 2013).

In the main analysis, the cost of tolls is assumed to be constant for each country. However, considering the political focus on road tolls, in the sensitivity analysis we allow for a large change in the price of tolls.

Fuel prices are projected by an international price forecast for crude oil prices performed by (US Energy Information Administration, 2013). Crude oil prices usually fluctuate much more than do diesel prices for road transport, because a large share of land transport fuel prices are made up of non-value-added taxes. Therefore, we use this long-term projection of oil prices as the price development of diesel land fuel.

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\(^2\) For trucks, the driving speed on dual carriageways is not very different from the speed on highways. Therefore, these road tolls are avoided when the road distances travelled are not too different (which is the case for our selected routes).
transport prices. In their transport model, (DTU, 2013) assume a lower yearly fuel price increase than we do. This is handled in the sensitivity analysis.

Projecting the level of congestion is difficult. Historically, there has been a large increase in the amount of traffic and, as a result, the level of congestion. We assume a doubling of the current level of congestion through 2040, which is also tested in the sensitivity analysis.

5.1.3 Unit costs

The unit costs for land-based transport are shown in table 7.

Table 7: Cost of land-based transport per truck/trailer combination, 2014-2040

<table>
<thead>
<tr>
<th>Cost variable</th>
<th>Differentiation</th>
<th>2014</th>
<th>2020</th>
<th>2030</th>
<th>2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance dependent, euro/km</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel, highway (high speed)</td>
<td>Highways (high speed)</td>
<td>0.42</td>
<td>0.46</td>
<td>0.58</td>
<td>0.74</td>
</tr>
<tr>
<td></td>
<td>Urban areas (low speed)</td>
<td>0.63</td>
<td>0.70</td>
<td>0.88</td>
<td>1.11</td>
</tr>
<tr>
<td>Tolls</td>
<td></td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Capital costs</td>
<td></td>
<td>0.11</td>
<td>0.11</td>
<td>0.11</td>
<td>0.11</td>
</tr>
<tr>
<td>Time dependent, euro/hour</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salary</td>
<td>Foreign driver</td>
<td>8.04</td>
<td>10.14</td>
<td>14.94</td>
<td>22.02</td>
</tr>
<tr>
<td></td>
<td>Domestic driver</td>
<td>15.36</td>
<td>16.92</td>
<td>19.87</td>
<td>23.34</td>
</tr>
<tr>
<td>Capital costs</td>
<td></td>
<td>18.64</td>
<td>18.64</td>
<td>18.64</td>
<td>18.64</td>
</tr>
</tbody>
</table>

5.2 Sea-based transport

We assess the cost of sea-based transport for a truck/trailer unit in a ro/ro vessel. From this, we determine the cost of an equivalent for a container ship (assessed to be a 40-foot container).

In general, ship costs include vessel operating costs, capital costs, bunker costs and port costs. Figure 14 highlights the cost components most important to our analysis.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

The figure is for illustration purposes only and is not based on the actual costs. The figure, however, summarizes our key findings:

- Fuel becomes a more dominating cost component over time.
- The costs due to NECA are of lesser importance, whereas the costs due to SECA are significant.

The current costs of sea-based transport, including pre-/post-haulage, are described in Section 5.2.1. The projected costs are described in Section 5.2.2.

**SECA**

We consider the technologies immediately available to comply with SECA. In terms of fuel, this means that we use the cost of marine gas oil (MGO) as a cost benchmark. To estimate the direct cost of SECA, we use the cost difference between 0.1% S MGO and 1% S LS380, the latter of which is the fuel fulfilling the current SECA requirements. An equivalent approach is used by (Green Ship, 2012) and (ECSA, 2010).

Three alternative technologies exist that comply with the requirements of SECA:
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

- Use of low-sulphur fuel (LSF) with 0.1% sulphur content, such as MGO or low-sulphur MGO (LSMGO)
- Installation of scrubber systems and use of heavy fuel oil (HFO)
- Conversion to liquefied natural gas (LNG)

Note that conversion to LNG also makes ships able to comply with the NECA requirements without further investments. However, most still consider switching to MGO as the best short-term solution, and installing a scrubber as the most viable solution on a little longer term. See, for example, (Green Ship, 2012).

Using MGO requires a relatively small investment but implies larger operational costs. The two other alternatives require large investments but imply a smaller increase in operational costs. Also, the choice of technology depends on the type and size of the vessel. For example, scrubbers are suited only for larger ships.

Of course, not all vessels will choose MGO as their cost-minimising strategy. Some will choose a different technology if it is more cost-efficient for them. For example, (SWECO, 2012) expects that 10% of all vessels operating in SECAs will install scrubbers by January 2015. Assuming that all vessels use MGO as an alternative fuel will provide us with an upper-bar estimation of the costs of SECA.

A survey of ship owners performed by (Lloyd’s Register, 2012) considers low-sulphur fuel oil such as MGO as the short-term solution to comply with SECA and LNG-fuelled engines as a cost-efficient and long-term solution for a number of ship types.

We evaluate the cost of the other strategies relative to the cost of MGO to consider how large the annual cost of compliance by MGO has to be before ships find it profitable to invest in scrubbers or convert to LNG.

It is also worth noting that LNG — and scrubbers especially — are much cheaper to introduce to ships being built than afterwards (retrofit), when the technology must be applied to existing ship platforms (UK Chamber of Shipping, 2013). Therefore, we expect that ships will be more expensive to build and will have slightly higher operating costs after SECA is first effectuated. We also expect that most existing ships will have higher operational costs by using MGO and that fewer of these ships will make the necessary technology investment up front and thus have slightly higher operational costs. Existing ships operating in other SECAs already have the required technology and will have slightly higher operational costs within the North Sea SECA.

Based on data from (Jiang, Kronbak, & Christensen, External costs of maritime shipping: A voyage-based methodology, 2012) on container ships, we estimate that a retrofit scrubber solution will reduce fuel expenses by 4% as compared to using MGO in 2015. This fuel cost difference will increase to 16% in 2040. Installing scrubbers on new ships will provide a 14% fuel cost advantage relative to MGO based on the fuel price difference in 2015 and a 23% fuel cost advantage based on the fuel price difference in 2040.

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3 The LSF term is normally used for 1% sulphur fuel, whereas MGO normally characterises the 0.1% sulphur fuel which is required as part of SECA from 2015.

4 LNG bunkering infrastructure is already available in most of the larger North Sea ports (Lloyd’s Register, 2012).
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

(Johansson, Jalkanen, Kalli, & Kukkonen, 2013) refer to results which find that ships with an annual fuel consumption of more than 4,000 tonnes would benefit from installing a scrubber, provided that 0.1% S fuel is at least 50% more expensive than 1% S fuel. They estimate that 630 IMO-registered current ships will benefit from a retrofitted scrubber. These ships were responsible for 21% of the total fuel consumption in the North Sea and the Baltic Sea in 2011 (with more than 4 out of 5 ships being ro/ro or container ships).

Green Ship (2012) has estimated the payback time for a tanker vessel implementing either a scrubber or LNG technology compared to the MGO option. The payback time depends on both the price difference between MGO and 1% S fuel and the number of kilometres travelled within SECA. If the payback period for either a scrubber or LNG technology is less than 10 years, they assume that it is preferable to MGO, because the scrubber or LNG investment is amortised over approximately 12-15 years.

In general, scrubbers provide shorter payback times. Assuming the global sulphur cap is introduced in 2020, and using our estimated price difference between MGO and IFO380, scrubber technology is preferable to MGO in 2015 provided that more than 50% of a vessel’s operations are within the North Sea or other SECA (Green Ship, 2012). Given the size of the projected cost of SECA (the fuel cost difference between 0.1% S fuel and 1% S fuel) estimated in year 2040 and the payoff profiles provided by Green Ship (2012), all vessels operating within any SECA will choose to install scrubbers as the profitable solution by 2040.

Similar calculations are performed for LNG technology versus MGO, assuming that the global sulphur cap is introduced in 2020. Assuming a price difference between MGO and IFO380 as in 2014, the LNG solution is preferable to MGO if more than 75% of a vessel’s operations are within the North Sea. If the price difference is as we project in 2040, more than 40% of a ship’s operations would need to be within the North Sea in order for LNG technology to be preferable.

The comparison performed by (Green Ship, 2012) is performed for a tanker vessel. The (Danish Maritime Authority, 2012) performed a fleet projection of the fleet composition operating in the North Sea and the Baltic Sea in 2020 and concluded that only 6% of all small tankers and no large tankers operating in 2020 will be fuelled by LNG. The (Danish Maritime Authority, 2012) estimated the use of LNG will be most widespread among smaller vessels, such as small ro/ro/RoPax (60% of all ro/ro/RoPax vessels), small general cargo vessels (45% of all small cargo vessels) and utility vessels (31% of all utility vessels).

As such, these types of cost savings from alternative technologies to cope with SECA are relevant in our analysis. Scrubbers seem to be a better choice for container ships, and the LNG alternative seems to be more appropriate for ro/ro and RoPax vessels. The choice of these alternative technologies depends on the fuel price difference between the base and project scenario. This information is handled in the sensitivity analysis.

**NECA**

The cost assessment of complying with the requirements of NECA is based on (Incentive, 2012a).

For each ship type and ship size the most cost efficient technology is identified and the cost assessed. In (Incentive, 2012a) two technologies are considered:

- Exhaust gas recirculation (EGR)
- Selective catalytic reduction (SCR)
5.2.1 Current costs of sea-based transport

The methods of our cost assessment and projection are summarised in table 8.

Table 8: Sea-based travel-related real cost variables: methods of assessment and projection

<table>
<thead>
<tr>
<th>Cost variables</th>
<th>Assessment method</th>
<th>Projection method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital cost</td>
<td>Capital cost is assessed as a share of the total costs of operating a ro/ro/RoPax vessel (Stopford, 2000); (ECSA, 2010)</td>
<td>Constant.</td>
</tr>
<tr>
<td>Fuel</td>
<td>Fuel cost is assessed as a share of the total costs of operating a ro/ro/RoPax vessel (Stopford, 2000); (ECSA, 2010). The cost share has been corrected because the price of fuel has increased dramatically since the cost assessment was made in 2008.</td>
<td>Projected by an international price forecast for crude oil (US Energy Information Administration, 2013).</td>
</tr>
<tr>
<td>Other</td>
<td>These costs are assessed as a residual share of the total costs relative to fuel and capital costs of operating a ro/ro/RoPax vessel (Stopford, 2000); (ECSA, 2010).</td>
<td>Projected by the average historical and projected GDP for North Sea countries for 2000-2014 as at least some of the costs are related to wages.</td>
</tr>
<tr>
<td>NECA</td>
<td>The cost of NECA is assessed as described in (Incentive, 2012a), although the assumed loading factor per ship is assumed to be 65% for ro/ro and container ships instead of 75% as assumed in the previous study.</td>
<td>Constant.</td>
</tr>
<tr>
<td>SECA</td>
<td>The cost of SECA is assessed as the additional fuel cost between using 0.1% S fuel and the base scenario.</td>
<td>The cost of SECA is projected by an international price forecast for crude oil (US Energy Information Administration, 2013).</td>
</tr>
<tr>
<td>Pre-/post-haulage</td>
<td>The cost of pre-/post-haulage is assessed as described in chapter 5. It is assumed that the drivers performing the pre-/post-haulage are domestic and thus receive higher wages than do the long-distance East European drivers as assumed in chapter 5.</td>
<td>Costs are projected as described in chapter 5.</td>
</tr>
<tr>
<td>Loading cost (only container ships)</td>
<td>The loading cost consists of a lifting fee and a time-dependent cost. The lifting has previously been used in (Incentive, 2012b). The time cost is assessed as the time dependent capital costs and wage in chapter 5.</td>
<td>The lifting fee is projected as wages, described in chapter 5. The time costs are projected as described in chapter 5.</td>
</tr>
</tbody>
</table>

The total cost of actual sea transport is estimated from (ECSA, 2010) and is differentiated according to the length of the travel (measured in kilometres). Among other things, the total cost is adjusted according to a higher fuel cost currently than when the costs were estimated by (ECSA, 2010). The current price of fuel is considered the price of 1% S fuel (LS380) via (bunkerindex.com, 2013). We use the bunker prices of Rotterdam because it is the biggest port within the North Sea.

We differentiate between three segments in the total cost of sea transport in 2013 (before SECA and NECA): capital costs, other and fuel. The relative share of segments in total costs are estimated from (Stopford, 2000). Considering the age of this source, we only use the composition of vessel costs to estimate the relative share of capital costs, other and fuel respectively. As the composition of costs has changed since the estimation by Stopford, 2000 (fuel costs has increased relatively than other cost segments), we make corrections as described below.

The share of capital costs is estimated from (Stopford, 2000) and includes fixed costs such as port fees. As with the estimation of capital costs of land-based transport, the capital costs are not projected but remain a fixed part of the total cost, depending on the length of the travel.
The fuel expenses relative to total costs are estimated from a small selection of 15 ro/ro/RoPax vessels using 1.5% S fuel in 2008 (ECSA, 2010) and corrected for the change in fuel prices since the original assessment was made\(^5\).

The share of ‘other’ relative to total costs is estimated as the residual. This category includes wages, port and loading fees, and other variable costs for ro/ro vessels.

For container ships, we assess a separate loading cost, as the cost of loading is much larger than the loading fee included in the total costs assessed for ro/ro vessels. The loading fee is already included in the cost component ‘Other’ for ro/ro ships.

The cost components for transport of a 40-foot container with a container ship in general are assessed from the costs assessed for ro/ro vessels transporting a truck/trailer unit. To assess these costs, we have compared the relative vessel costs for container and ro/ro ships respectively, using both (Kristensen, 1999)\(^6\) and (Stopford, 2000). As for ro/ro vessels, we assume less than full capacity utilization; see (Incentive, 2012a). This estimation provides us with a lower cost per unit than for ro/ro vessels, due to the fact that container ships are able to carry more goods per deadweight capacity than ro/ro vessels. Container ships are able to carry about 4-5 times as many units as ro/ro ships. With this in mind, we assess the cost of container ships to be 35% of the cost for ro/ro vessels but add a loading cost for each container route.

### 5.2.2 Projected cost of sea-based transport

The projection method for all variables is described in table 8, but is elaborated for some variables in this section, with special focus on the cost of SECA and NECA.

The cost of the base scenario fuel is projected as the price of fuel which fulfils the global requirements or current SECA requirements of sulphur emissions. This implies that the relevant base scenario fuel will be LS380 with 1% sulphur content until 2020, when the global cap of 0.5% S emission will be introduced. Afterwards, the cost of fuel is implied by the price of 0.5% S fuel to fulfil the global requirements. A fuel with this exact specification currently does not exist, so the price is estimated to be 10% below the average of the projected price of MGO and LS380\(^7\). This emphasises that the relation between the content of sulphur and the price of fuel is not linear.

We project the prices of MGO and LS380, and hence the cost of fuel, by the projected price of Brent crude oil, as assessed by (US Energy Information Administration, 2013). The (Danish Maritime Authority, 2012) finds a very high correlation (>0.9) between the price of oil and the price of maritime fuels indicating this as a good method of projection. Furthermore, (Danish Maritime Authority, 2012) uses the same approach to forecast maritime fuel prices.

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\(^5\) Amongst others, the correction involves that the base scenario fuel is 1% S fuel in 2013 instead of 1.5% S fuel in 2008.

\(^6\) The source is only available in Danish.

\(^7\) According to (Green Ship, 2012) the price difference between 0.1% S fuel and 0.5% S fuel will be negligible. Following this, the additional cost of a 0.1% SECA will be very little once the global sulphur limit is introduced.
Few other studies have projected the prices for LS380 and MGO for as long a period as we have. Table 9 summarizes the fuel prices found in our and other studies. It seems our price predictions are within the interval already reported in other studies, although the price difference between 1% S fuel and 0.1% S fuel in our study is in the low end of the literature findings. However, the current price of base scenario fuel (LS380) is higher than the historic price level used in some previous studies, e.g. (ECSA, 2010). These conditions are handled in the sensitivity analysis.

Table 9: Fuel price projections, euro per tonne

<table>
<thead>
<tr>
<th>Fuel</th>
<th>2014</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>1% S</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1% S</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1% S</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1% S</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1% S</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1% S</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1% S</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1% S</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Our study</td>
<td>520</td>
<td>735</td>
<td>514</td>
<td>726</td>
</tr>
<tr>
<td>(Green Ship, 2012)</td>
<td>500</td>
<td>575-1,100</td>
<td>500</td>
<td>575-1,100</td>
</tr>
<tr>
<td>(Lloyd's Register, 2012)*</td>
<td>515</td>
<td>745</td>
<td>515</td>
<td>745</td>
</tr>
<tr>
<td>(Johansson, Jalkanen, Kalli, &amp; Kukkonen, 2013)</td>
<td>-</td>
<td>-</td>
<td>Price premium between HFO (380/180)*** and 0.1% S MGO of 50%, 75% or 100%.</td>
<td>-</td>
</tr>
<tr>
<td>(SWECO, 2012)</td>
<td>-</td>
<td>-</td>
<td>An additional 270 euro to 1% S fuel.</td>
<td>-</td>
</tr>
<tr>
<td>(UK Chamber of Shipping, 2013) 1**</td>
<td>-</td>
<td>-</td>
<td>An additional 246 euro to 1% S fuel.</td>
<td>-</td>
</tr>
<tr>
<td>(UK Chamber of Shipping, 2013) 2**</td>
<td>-</td>
<td>-</td>
<td>An additional 211 euro to 1% S fuel.</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: 1) * are approximations as they are read from a figure. 2) ** The prices referred to as (UK Chamber of Shipping, 2013) actually come from other studies, but are summarized in this study. 3) *** The price of HFO (380/180) was 611 USD pr. tonne in 2012 (approximately 470 euro) and the price of 1% S fuel was 668 USD pr. tonne (approximately 513 euro).

Projected cost of SECA

The projected cost of SECA is the projected price difference between the base scenario fuel and MGO. This implies that the cost of SECA is the cost difference between MGO and LS380 until 2020. After 2020, the cost of SECA depends on the price difference between MGO and 0.5% S fuel. If the introduction of the global cap is postponed until 2025, the cost of SECA will be lowered in the subsequent years. This is handled in the sensitivity analysis.

Projecting fuel prices with any certainty is very difficult. We do a range a sensitivity analyses on fuel prices.

Another factor we take into account is that an increasing demand for MGO may increase the price relative to other maritime fuels. However, as the price differential between 1% sulphur fuel and 0.1% sulphur fuel becomes large enough, and as scrubbing becomes more technically and economically viable,
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

an increasing number of ships will install scrubbers and prices will drop (UK Chamber of Shipping, 2013). The same effect will be obtained as new ships with cheaper scrubber systems replace older ships.

However, using MGO might imply a smaller increase in total costs than the full price difference between LS380 and MGO. MGO has a higher terminal value and is a cleaner fuel, implying slightly lower maintenance costs (ECSA, 2010).

As part of the cost of a SECA, (ECSA, 2010) emphasises the cost of switching fuels at sea, because it expects most ships to continue their journey using HFO outside the SECA. As the cost of switching increases, and as the difference in sulphur content is larger, we expect this cost to be of diminishing importance as stricter global sulphur requirements are imposed from 2020 or 2025.

Another important aspect of projecting the price of maritime fuel is whether the global refining industry will be willing and able to produce and sell the required amount of LSF such as MGO (ECSA, 2010).

Taking all factors into account, we assess that our cost estimation of SECA is an upper-bar estimation as we assume switching to MGO is the preferred SECA-compatible technology for all ships, although we leave room for an even larger cost of SECA in the sensitivity analysis before ship owners will shift towards another SECA-compatible technology.

Projected cost assessment of NECA

We estimate the cost of NECA compliance as described in (Incentive, 2012a). Because the cost of NECA is technology-dependent, we assume the costs will be constant over time. This might be an overestimation, because technology likely will become cheaper as it is further developed and it is still in its very beginning of its development.

5.2.3 Unit costs

The unit costs for land-based transport are shown in table 10 and table 11.

Table 10: Total cost in euros of sea-based transport per truck/trailer combination with a ro/ro vessel sailing 500 km

<table>
<thead>
<tr>
<th>Cost variable</th>
<th>2014</th>
<th>2020</th>
<th>2030</th>
<th>2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project scenario</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel</td>
<td>163</td>
<td>199</td>
<td>241</td>
<td>293</td>
</tr>
<tr>
<td>Capital cost and other fixed costs</td>
<td>137</td>
<td>137</td>
<td>137</td>
<td>137</td>
</tr>
<tr>
<td>Other costs</td>
<td>164</td>
<td>180</td>
<td>241</td>
<td>249</td>
</tr>
<tr>
<td>Total cost excluding SECA and NECA</td>
<td>464</td>
<td>516</td>
<td>590</td>
<td>678</td>
</tr>
<tr>
<td>Alternative scenario</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SECA</td>
<td>0</td>
<td>60</td>
<td>73</td>
<td>88</td>
</tr>
<tr>
<td>NECA</td>
<td>0</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Cost of SECA &amp; NECA</td>
<td>0</td>
<td>66</td>
<td>79</td>
<td>95</td>
</tr>
<tr>
<td>Total cost including SECA and NECA</td>
<td>464</td>
<td>583</td>
<td>669</td>
<td>773</td>
</tr>
</tbody>
</table>

Note: We have assessed the costs based on the assumption that the global sulphur cap will be introduced in 2020. Note that due to rounding of figures some of the totals might differ.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

Table 11: Total cost in euros of sea-based transport of one trailer with a ro/ro vessel sailing 1,000 km

<table>
<thead>
<tr>
<th>Cost variable</th>
<th>2014</th>
<th>2020</th>
<th>2030</th>
<th>2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project scenario</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel</td>
<td>402</td>
<td>490</td>
<td>594</td>
<td>720</td>
</tr>
<tr>
<td>Capital cost and other fixed costs</td>
<td>167</td>
<td>167</td>
<td>167</td>
<td>167</td>
</tr>
<tr>
<td>Other costs</td>
<td>369</td>
<td>407</td>
<td>478</td>
<td>561</td>
</tr>
<tr>
<td>Total cost excluding SECA and NECA</td>
<td>938</td>
<td>1,064</td>
<td>1,237</td>
<td>1,448</td>
</tr>
<tr>
<td>Alternative scenario</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SECA</td>
<td>0</td>
<td>148</td>
<td>179</td>
<td>217</td>
</tr>
<tr>
<td>NECA</td>
<td>0</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Cost of SECA &amp; NECA</td>
<td>0</td>
<td>160</td>
<td>191</td>
<td>229</td>
</tr>
<tr>
<td>Total cost including SECA and NECA</td>
<td>938</td>
<td>1,224</td>
<td>1,430</td>
<td>1,677</td>
</tr>
</tbody>
</table>

Note: We have assessed the costs based on the assumption that the global sulphur cap will be introduced in 2020. Note that due to rounding of figures some of the totals might differ.

The projected fuel prices are shown in table 12.

Table 12: Projected fuel prices for sea-based transport, euros per tonne

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Sulphur specification</th>
<th>2014</th>
<th>2020</th>
<th>2030</th>
<th>2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>LS380</td>
<td>1% S</td>
<td>520</td>
<td>566</td>
<td>700</td>
<td>872</td>
</tr>
<tr>
<td>*</td>
<td>0.5% S</td>
<td>565</td>
<td>615</td>
<td>760</td>
<td>947</td>
</tr>
<tr>
<td>MGO</td>
<td>0.1% S</td>
<td>735</td>
<td>800</td>
<td>988</td>
<td>1,232</td>
</tr>
<tr>
<td>Additional SECA cost</td>
<td>215</td>
<td>185</td>
<td>229</td>
<td>285</td>
<td></td>
</tr>
</tbody>
</table>

Note: The fuel type marked * containing 0.5% S does not currently exist and is therefore estimated as the average price of LS380 and MGO minus 10%, emphasising a non-linear relationship between fuel prices.
6 Comparative analysis

In this chapter, we apply the cost assessments of sea-based and alternative transport to the selected routes. The analysis assesses the change in the cost of transport due to the SECA and NECA in isolation. The cost comparison appears for ro/ro routes in Section 6.2.1 and for container routes in Section 6.2.2.

We estimate that the overall route cost increase in 2030 due to SECA and NECA will be about 5%-13% and that the cost increase on land-based routes will be less than 3%. Our findings are in accordance with existing analyses, such as from the (UK Chamber of Shipping, 2013) and (SWECO, 2012) – see section 6.5.

6.1 Method

In order to compare the costs of a sea- and land-based solution, we have made a range of assumptions.

We have deliberately chosen to overestimate rather than underestimate the costs of NECA and SECA. This is reflected in the assumptions we have made.

We have made the following simplifications/assumptions:

- We have not accounted for the fact that there are vessels already operating in other NECAs and therefore comply with the technical NECA requirements and would have only a relatively small increase in operating costs.
- We have applied the NECA compliance cost to all ships even though the NECA requirements only apply to ships built after 2015.
- We have not accounted for the fact that some ships will choose to comply with SECA by using a cheaper technology than the one we assume.

All of the assumptions point to an overestimation of the cost increase and thereby of the modal shifts away from shipping transport.

6.2 Modal shift

6.2.1 Ro/ro routes

Figure 15 shows the total cost in 2030 of every primary ro/ro route and the alternative routes.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

Figure 15: Cost comparison for ro/ro routes, 2030

The data labels show the relative cost increase due to SECA and NECA. For the route Rotterdam - Leeds, SECA gives rise to a 9.3% cost increase and NECA to 0.8% relative to the total cost excluding the ECA costs. The total increase in cost is 10.1%. In parenthesis, the total distances of the routes are shown.

For route 1, Rotterdam-Leeds, route 1a is the primary sea route and routes 1b and 1c are the alternative land-based routes. The total cost is segmented into the cost related to SECA and NECA and the rest of the total cost.

For the Taulov-Brussels route the land-based transport might become the slightly cheaper alternative, although the difference in cost advantages would be very small.

The total cost increase related to SECA and NECA is 10%-13% for the sea-based routes and no more than 2% for the land-based routes. Generally, the larger the part of transport by sea compared to total kilometres travelled, the larger the relative cost of SECA and NECA. This is why the cost increase is bigger for route 5, Bremen-Oslo, than for route 4, Ghent-Stockholm, despite more total kilometres being travelled by sea in route 4.

Generally, the cost increase related to NECA is about 1 percentage point for sea-based routes and quite negligible for all land-based routes.

Figure 16 shows the percentage increase in sea-related costs for ro/ro routes.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

Figure 16: Percentage cost increase in sea costs due to SECA and NECA in 2030 for ro/ro routes

The data labels show the relative cost increase due to SECA and NECA. For the route Rotterdam-Leeds, SECA gives rise to a 12.3% cost increase and NECA to 1.1% relative to the total sea-based costs excluding the ECA costs.

The sea-related cost increase due to SECA and NECA is between 13%-16% for sea-based routes and no more than 6% for land-based routes.

Figure 17 shows the cost difference between the sea-based route and the best alternative over the years. Taulov-Brussels seems to be the only route where the land-based solution has a temporary cost advantage. For all other routes, the cost advantage for sea transport is about 200 euros per truck/trailer combination.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

Figure 17: Cost advantage per truck/trailer combination: ro/ro sea routes over the best alternative route

Note: The cost advantage is calculated by subtracting the costs of sea-based transport from the costs of the best alternative land-based route.

The figure shows the enforcement of SECA and NECA in 2015, when the cost advantage for sea-based transport decreases. However, following the kink in 2015, the cost advantage for sea-based transport is regained as the projected costs of land-based transport increase more rapidly than the projected costs of sea-based transport. The cost advantage of calling a different port on the Taulov-Brussels route vanishes around year 2034.

It is possible that the cost advantage for sea transport might increase even more rapidly as SECA compliance technology is developed and cost-effectiveness of these technologies improves relative to using 0.1% MGO fuel. As already mentioned, a few vessels will begin using scrubbers and LNG-fuelled engines from the beginning of SECA, and even more vessels likely will follow suit.

6.2.2 Container routes

Figure 18 shows the total cost in 2030 for every primary container route and the alternative routes.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

Figure 18: Cost comparison for container routes, 2030

<table>
<thead>
<tr>
<th>Route</th>
<th>Total cost, excluding SECA &amp; NECA</th>
<th>SECA cost</th>
<th>NECA cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>7a (720 km)</td>
<td>9.7% + 0.8% = 10.4%</td>
<td>0.8%</td>
<td>0.0%</td>
</tr>
<tr>
<td>7b (561 km)</td>
<td>0.0% + 0.0% = 0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>8a (636 km)</td>
<td>7.0% + 0.6% = 7.6%</td>
<td>0.2%</td>
<td>0.2%</td>
</tr>
<tr>
<td>8b (731 km)</td>
<td>1.0% + 0.1% = 1.1%</td>
<td>0.1%</td>
<td>0.0%</td>
</tr>
<tr>
<td>8c (612 km)</td>
<td>0.9% + 0.1% = 1.0%</td>
<td>0.1%</td>
<td>0.0%</td>
</tr>
<tr>
<td>8d (597 km)</td>
<td>7.0% + 0.6% = 7.6%</td>
<td>0.2%</td>
<td>0.2%</td>
</tr>
<tr>
<td>9a (1,145 km)</td>
<td>4.9% + 0.4% = 5.3%</td>
<td>0.4%</td>
<td>0.0%</td>
</tr>
<tr>
<td>9b (955 km)</td>
<td>1.1% + 0.1% = 1.2%</td>
<td>0.1%</td>
<td>0.0%</td>
</tr>
<tr>
<td>10a (2241 km)</td>
<td>4.7% + 0.3% = 5.0%</td>
<td>0.3%</td>
<td>0.0%</td>
</tr>
<tr>
<td>10b (2,340 km)</td>
<td>0.0% + 0.0% = 0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

The data labels show the relative cost increase due to SECA and NECA. For the route Hamburg-Antwerp, SECA gives rise to a 9.7% cost increase and NECA to 0.8% relative to the total cost excluding the ECA costs.

Figure 18 shows that there are only minor changes in the relative cost advantage of sea- vs. land-based transport solutions. The total cost increase related to SECA and NECA is 5%-11% for the sea-based route and no more than 1% for the land-based routes in 2030.

Figure 19 shows the percentage increase in sea-based costs related to SECA and NECA for container routes.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

Figure 19: Percentage cost increase in sea costs due to SECA and NECA in 2030 for container routes

The data labels show the relative cost increase due to SECA and NECA. For the route Hamburg-Antwerp, SECA gives rise to a 13.1% cost increase and NECA to 1.1% relative to the total sea-based cost excluding the ECA costs.

Sea-based costs increase between 8%-14% for sea-based routes and less than 3% for land-based routes.

Generally, the cost increase related to NECA is less than 1 percentage point for sea-based routes and quite negligible for all land-based routes.

Figure 20 below shows the cost difference between the sea-based route and the best alternative route. The sea-based solutions continue to have a cost advantage compared to the land-based solutions.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

**Figure 20: Cost advantage per 40-foot container: Container sea routes over the best alternative route**

<table>
<thead>
<tr>
<th>Year</th>
<th>Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>7. Hamburg-Antwerp</td>
</tr>
<tr>
<td>2014</td>
<td>8. Hamburg-Gothenburg</td>
</tr>
<tr>
<td>2015</td>
<td>9. Brugge-Newbridge</td>
</tr>
<tr>
<td>2016</td>
<td>10. Paris-Riga</td>
</tr>
</tbody>
</table>

*Note: The cost advantage is calculated by subtracting the costs of sea-based transport from the costs of the best alternative land-based route. Following this calculation, the best alternative did not change over the years.*

The low unit costs for container ships relative to ro/ro ships makes the container routes in figure 20 relatively less sensitive to the cost of SECA and NECA.

### 6.3 Port shift

#### 6.3.1 RoRO

The cost comparison between the current sea route and the alternative sea route is shown in figure 21.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

**Figure 21: Cost comparison for ro/ro sea routes and alternative sea routes, 2030**

There is no change in the preferred route following the cost of SECA and NECA, although the cost difference decreases.

In the case of Taulov - Brussels the alternative sea-based Route 3b seems to become marginally cheaper with the cost of SECA and NECA, but even in this case a port shift is not likely to take place as further elaborated in section 7.2.

Approximately 5% of the total cost increase is due to the cost of NECA.

### 6.3.2 Container

The cost comparison between the current and the alternative sea route is shown in figure 22.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

**Figure 22: Cost comparison for Container sea routes and alternative sea routes, 2030**

There is no change in the preferred route following the cost of SECA and NECA, although the cost difference decreases. This indicates a minimal chance of port shifts. Even for the alternative sea route for Route 10, which involves a saving in travel distance of more than 10%, the alternative route is much more expensive as container ships seem to continue to have a large cost advantage over truck.

With the basis of this cost comparison, it does not seem attractive to increase the amount of land-based transport at the expense of sea-based transport by container ships, and hence change ports. Therefore, we do not expect port shifts following SECA and NECA.

### 6.4 Freight prices

So far, we have assumed that the cost increases in shipping will be fully passed on to the freight prices. However, this is most likely not the case. The shipping industry may absorb a share of the cost increase themselves. We expect this share to be case-specific as it will depend on the competitive situation between sea- and land-based transport solutions.

The more competitive land-based transport is relative to sea-based transport, the smaller profit margins for both industries implying a smaller chance for shipping to absorb the additional cost increase. Following this, a full increase in the cost of shipping to freight rates might be a reasonable assumption for the most competitive routes. However, some shipping routes continue to have a large cost advantage over land-based transport as an SECA and NECA is introduced, indicating that an adequate share of the cost increase is absorbed by the shipping industry to avoid modal shifts.

Especially specialized services on minor legs with a clear competitive edge towards road transport will surely be challenged by the cost increase within the sea-based transports. And as there are no or small
margins left for covering these costs within the system itself, the operators will do their utmost to transfer these to the costumers, i.e. the transport buyers.

A number of studies have addressed the issue of how and to what extent increased costs for ship owners due to new regulation are channelled on to transport buyers via freight rates.

(Ministry of Transport and Communications Finland, 2009) estimates that increased (fuel) costs will most probably be channelled to the sea freight charges.

The (Swedish Maritime Administration, 2009) suggests that it would be difficult to channel cost increases to freight rates, as industries within SECAs are competing with industries in regions that are not SECAs and do not have corresponding fuel requirements.

(ECSA, 2010) is mainly in line with the latter. The argument is that due to the competition with road transport, the shipping sector will find it difficult to charge their customers for the fuel cost increase. On average, the results of the ECSA study indicate that approximately 60%-65% of the increased costs are passed on to the customers. The majority of the 30 origin/destination routes examined in the study all face potential competition from road haulage.

6.5 Comparison to other studies

Not many other studies have estimated the cost increases due to SECA and NECA on relevant routes in the North Sea. In this chapter, we compare our results with the few existing results, taking into account that results are not fully comparable.

Figure 23 and Figure 24 illustrate the cost impact of SECA and NECA respectively on sea-based costs only for our 10 case routes in year 2015.

Figure 23 shows the percentage cost increase for ro/ro routes in 2015 related to the sea route only. Cost increases for the sea-based routes are between 15% and 20% for the distance on sea.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea.

Figure 23: Percentage cost increase in sea-based costs due to SECA and NECA in 2015 for ro/ro routes

Figure 24 shows the relative cost increase in sea-based costs for container routes in 2015. Cost increases for the sea-based routes are between 11% and 19% for the distance on sea.

Figure 24: Percentage cost increase in sea-based costs due to SECA and NECA in 2015 for container routes
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

(UK Chamber of Shipping, 2013) have estimated the effect on freight (ticket) prices due to SECA in 2015. Their estimation only involves the sea-based costs. The cost of SECA is estimated as the price difference between 1% S fuel and 0.1% S fuel. They estimate that ticket prices for lorries and unaccompanied trailers will increase between 12% and 16% for Western Channel routes. Ticket prices for passengers are expected to increase 9%-12%. For North Sea routes, they estimate ticket prices for lorries and unaccompanied trailers to increase 9%-14%. Ticket prices for passengers are expected to increase 10%-13%. They estimate prices for containers to increase 7%-10% on North Sea routes.

(ECSA, 2010) have estimated the impact on the shipping lines’ cost base in 2015 from shifting from 1.5% S fuel to 0.1% S MGO, implying that they consider the costs at sea only. They consider ro/ro ships sailing 18.5 knots as we do. In their main scenario, they find a 25.5% increase in the ship cost. This is translated into increases in freight rates of 10%-34% for short-sea vessels (with an average of 16%). For a low and high scenario respectively, they find the average cost increases to be around 19%-30% which translates into average freight rate increases of 11%-20%.

For fast short sea vessels (sailing 25-30 knots on average), (ECSA, 2010) finds the average ship cost increase to be 29%-40%.

As part of estimating the consequences of a North European SECA on emissions, (Johansson, Jalkanen, Kalli, & Kukkonen, 2013) also estimate the impact on ship costs from introducing a SECA. They estimate three different cost scenarios: the price of MGO being 50%, 75% or 100% higher than the price of HFO. In the base scenario, they find the direct fuel prices to increase 19% annually by switching to 0.1% S fuel. In the high cost case, the fuel prices are expected to increase by 64%. This is lower than the impact we estimate on fuel costs (as we find the direct fuel cost to increase 41% in the base case in 2015).

Assuming the ships eligible to be retrofitted scrubbers switch, (Johansson, Jalkanen, Kalli, & Kukkonen, 2013) find that the estimated fuel cost would increase in 2015 either by 10% or 46%.

Our ship cost increase findings are in line or even a bit higher than the findings in (UK Chamber of Shipping, 2013). The fact that our findings are somewhat higher might be due to the fact that the cost of NECA is included in our study as opposed to the study by the UK Chamber of Shipping. Another explanation is that we assume that the increases in cost are not absorbed by ship operators but instead result in higher freight prices.

On the other hand, our cost increase findings are somewhat lower than the findings in (ECSA, 2010). The difference between our findings and ECSA is largely due to the assumption on the shipping fuel used in the basis scenario. ECSA assumes 1.5% S fuel in the scenario without SECA, as it was the prevailing standard when the study was conducted. As 1.5% S fuel is cheaper than the 1% S fuel assumed in our basis scenario, the price difference between the basis fuel and the 0.1% S fuel in SECA is larger in the study of ECSA. As this price difference is used to estimate the cost of SECA, ECSA naturally finds a larger impact of SECA than we do. Correcting for this, their findings are within the same level as our findings.

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8 Note that, for the high cost scenario, they find the freight rate increase to be 13%-40% (low/high respectively) with the average being 20%.

9 A Northern European Emission Control area includes the North Sea, the Baltic Sea and the English Channel.
7 Modal and port shifts

Based on the comparative cost analysis in chapter 6, we perform the modal and port shift analysis in this chapter.

In section 7.1 we estimate the potential modal shift and in 7.2 the potential port shifts. In section 7.3 we discuss other factors facilitating modal and port shift rigidity.

7.1 Modal shift analysis

The modal shift analysis is performed for the prices in year 2030 and consists of three building blocks:

- The price increase for sea-based routes; see section 6.2.1 and 6.2.2.
- The quantities affected by the price increase; see section 3.2.1.
- Elasticities for sea- and land-based transport combined; see section 7.1.1 below.

7.1.1 Elasticities

We use the demand elasticities assessed for combi-ships (routes involving sea transport as well as truck) in a Scandinavian freight demand model by (Rich, Kveiborg, & Overgård, 2011). We use a demand elasticity of -0.13. This is an average elasticity covering transport of manufactured goods, machines and general cargo.

The elasticities reflect the changes in demand as cost is changed. The size of the elasticities however reflects the general elasticity in the market due to logistic limitations, freight time, planning etc. The general factors affecting the choice of modal are implicit accounted for in the elasticities.

In their estimation of elasticities, (Rich, Kveiborg, & Overgård, 2011) differentiate between situations where a competing mode exists and a situation covering all modes of transport. Naturally, where a competing mode does exist, the elasticity is more elastic. As the quantities we use are an aggregation of amounts where identification of the routes involving competing modes is difficult, we use the elasticity covering all modes.

The elasticities estimated by (Rich, Kveiborg, & Overgård, 2011) are in general more inelastic than what is found in other studies. For example, (Catalani, 2003) has assessed the cost/price elasticities of freight transport to be -0.77.

The elasticities which are estimated cover the structural elasticity and are estimated on the basis of Scandinavian countries and neighbouring regions, thereby covering a large part of the North Sea countries. We have contacted the main author of this paper, confirming that the geographical area covered in the freight demand model makes the elasticity estimates suitable to apply to all North Sea countries.

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Even within Denmark and Sweden, there are large differences in the elasticities which are estimated (-0.38-0). As these two countries cover a large part of the numerical range, it seems to be a reasonable approximation for all North Sea countries.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

Structural inelasticity results from the lack of physical networks in the freight transport market, reflecting the natural rigidity in the transport market. Many routes are only serviced by one mode of transport (truck). This causes the mode substitution elasticity to be zero for these routes. The longer the route, the more alternative modes of transport are available. The structural elasticity is also affected by the fact that trucks are nearly always used in the beginning and the end of each transport.

7.1.2 Results of the modal shift analysis

The results of the modal shift analysis are presented in figure 25.

**Figure 25: Modal shift: Change in million ton-kilometre by sea**

<table>
<thead>
<tr>
<th></th>
<th>SECA</th>
<th>NECA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>RoRo</td>
<td>-2,390 (-0.6%)</td>
<td>-2,547 (-0.6%)</td>
<td>-5,937 (-1.2%)</td>
</tr>
<tr>
<td>Container</td>
<td>-819  (-0.2%)</td>
<td>-870  (-0.2%)</td>
<td>-1,689 (-0.3%)</td>
</tr>
</tbody>
</table>

**Note:** 1. The relative changes of the total quantities of ro/ro and Container freight in the North Sea are shown in parenthesis. 2. The analysis is based on the expected prices in 2030.

Figure 25 shows that the total quantity of ro/ro freight is expected to fall by 0.6% measured in terms of ton-kilometres. It is evident that the modal shift originates primarily from the SECA. The effects of a NECA on modal shift are marginal.

**Figure 26: Modal shift: Change in million ton-kilometre by land**

<table>
<thead>
<tr>
<th></th>
<th>SECA</th>
<th>NECA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>RoRo</td>
<td>2,255</td>
<td>2,403</td>
<td>4,658</td>
</tr>
<tr>
<td>Container</td>
<td>148</td>
<td>905</td>
<td>1,053</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>SECA</th>
<th>NECA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>RoRo</td>
<td>57</td>
<td>962</td>
<td>1,019</td>
</tr>
<tr>
<td>Container</td>
<td>117</td>
<td>57</td>
<td>174</td>
</tr>
</tbody>
</table>
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

We estimate that total land-based transport will increase by almost 3.300 million ton-kilometres if a North Sea ECA is established. In comparison, the total land-based transport by trucks in the eight North Sea countries was 800,000 million ton-kilometres in 2009; see (Eurostat, 2013a).

(UK Chamber of Shipping, 2013) has completed a modal shift analysis and found a much larger share of modal shift: 6-16%.

Fundamental differences in data and method underlie the differences in results.

The (UK Chamber of Shipping, 2013) only considers a selection of routes between the UK and the Continent. Their data can be understood as a sample of the North Sea market and makes up approximately 10% of the traffic on the Harwich, Hull, Immingham-Netherlands and Tilbury routes.

This is in contrast to our analysis which covers all shipping traffic in the North Sea in year 2009. For many routes between the UK and Continent haulage is a feasible alternative. This is not the case for many shipping routes in the North Sea thereby making UK-Continent routes only unsuitable as a sample of the entire North Sea shipping.

The (UK Chamber of Shipping, 2013) rule out 70% of the total tonnage in their data sample as being prone to modal shifts as there is no financial incentive for the haulers. The remaining 30% is the source to their estimation of 6% (low scenario) and 16% (high scenario) shifts. Of the total tonnage prone to modal shifts they find that more than half will shift in their high scenario.

The analysis differs greatly in the use of elasticities compared to our analysis. For one of the routes they expect 3% shift in the low scenario and 92% in the high scenario. For another the figures are 27% and 40%. These very broad ranges indicate elasticities far greater than the ones upon which we have based our analysis.

In their high scenario, the (UK Chamber of Shipping, 2013) assumes a haulage price of €0.50 per kilometre. This is about half of the cost estimate we have used and significantly lower than the cost estimates we have ever come across.

We have replicated their assumptions on fuel prices in our sensitivity analysis. This does not alter the direction of our results.

7.1.3 Sensitivity of the modal shift analysis

The robustness of the results is elucidated and the decisive parameters are identified by a series of sensitivity tests. We have made more than 40 sensitivity analyses.

The sensitivity analyses are based on the classical principle of “all things being equal”. In each test, only a single parameter is changed, all things being equal.

In 2015, when SECA is introduced, most expect a demand shock in the prices of MGO fuel. We consider this shock in the sensitivity analysis on the cost of SECA. As the additional price of 0.1% S fuel relative to 1% S fuel becomes larger, more vessels will choose to install a scrubber. Therefore, we have used, the amortized cost of a scrubber, as estimated by (Green Ship, 2012), as the upper level of the cost of SECA following the demand shock. Using this fuel cost as the upper level of SECA in the sensitivity analysis is also well within the fuel cost difference used in the analysis by the (UK Chamber of Shipping, 2013).
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

Figure 27 shows the results of the sensitivity analyses. The black column represents the highest estimated change in ton-kilometre by sea we find and the gold bar represents the lowest estimate we find.

**Figure 27: Modal shift sensitivity: Change in million ton-kilometre by sea**

![Graph showing sensitivity analysis results for RoRo and Container ships under different emission control areas.

The sensitivity analysis defines an upper and lower estimate. For ro/ro ships, we find that if a SECA is established, between 1.673 and 3.585 ton-kilometres is expected to shift from sea- to land-based transport.

We have made sensitivity analyses on all central parameters. The most central ones are:

- Fuel prices
- Elasticities
- Congestion

### 7.2 Port shift analysis

We find in section 6.3 that the cost advantage of selecting another port is not changed if an ECA is established in the North Sea. In none of the selected case routes for either ro/ro or container do we find that port shifts are likely.

The only case that stands out is Route 3 from Taulov to Brussels. We find that calling Rotterdam rather than Zeebrugge is actually cheaper. The reasons Rotterdam is not preferred can be many. Calling Rotterdam would reduce the transport distance at sea. Such a shift is not likely to take place, as it would imply a shift not only to another operator, but also to another port located in another country. On top of this, this shift would result in a major detour for the goods before arriving in Rotterdam, due to another sailing route and schedule on the Rotterdam-based route.

This is but one example of the rigidity that keeps ship operators from port shifts. In section 7.3 below, we analyse the factors facilitating port shift rigidity.
We find no indication that the expected future development in the sea- and land-based transport mar-
kets will facilitate port shift.

7.2.1 Sensitivity of the port shift analysis

As we did in the modal shifts analysis, we undertake a long list of sensitivity tests to identify the robust-
ness of our results.

We find that the results are very robust in the sense the existing routes keep their cost advantage. Only
if we assume a fuel price 200% higher than our base will port shifts begin to be economically preferable
by the ship operators.

This scenario represents an extreme situation and based on the long list of sensitivity analyses we have
made, we deem the prediction that port shifts are unlikely is robust.

7.3 Modal and port shift rigidity

As indicated in section 7.1.1, there is a lot of rigidity in the transport route selection. This affects the
potential shift from sea to other modalities. The rigidity is a function of:

- The geographical layout
- Future cost expectations in both sea- and land-based transport
- Cost of transport relative to the value of the cargo
- Behavioural aspects
- Port facilities
- The volume of the cargo

The impact of the geographical layout is described in detail in section 7.3.1 whereas the other factors
listed above are described in section 7.3.2. Section 7.3.3 lists some likely future adjustments made by
the shipping industry to reduce the impact of SECA and NECA, if the competitive impact is large enough.

7.3.1 Geographical layout

The geographical layout is the most important determinant for limiting a shift of modality and port shift
rigidity. The cost advantage for the existing sea route often stems from a “geographical shortcut” in the
distance travelled.

Furthermore, it seems that the distance of the route as part of the geographical layout is an important
determinant of the transport mode. (Rich, Kveiborg, & Overgård, 2011) shows that currently, an average
of 78% of all transports covering less than 500 km is carried out using only one mode of transport. For
trips between 500 and 1,000 km, the corresponding share decreases to only 5%. For trips over 1,000 km,
the share is below 1% on average.

The total travel time for sea-based versus land-based routes also affects modal rigidity. For most routes,
the sea-based route has a higher travel time and has less flexibility due to less frequent departures than
the corresponding land-based route by truck. If the sea-based route is still preferred, it means that the
time and flexibility disadvantage for sea-based transport is more than outweighed by the cost difference
and other of the factors described in the section below, for instance the size, type and scope of the
goods being transported.
The importance of the travel time and flexibility relative to the cost difference between land- and sea-based transport is difficult to measure. It is, however, included as a factor in the price elasticity and hence the estimated modal shift in section 7.1. We shortly discuss the quantification of the two effects below.

The flexibility aspect in sea-based transport also affects most land-based routes due to geographical layout of the North Sea area. Hence, most of the land-based routes also involve some degree of transport by ship. However, these departures are more frequent than pure sea-based routes. Therefore, land-based transport seems to have an advantage over sea-based transport in flexibility. On the other hand, road transport is affected by congestion, which in turn affects the variation in travel time. This might make the duration of land-based transport slightly more unpredictable than sea-based transport, which is less affected by congestion and similar circumstances.

As land-based travel speed is affected by congestion, which increases during the examined period, we find that the time advantage for the land-based route decreases over the years. This indicates that we can expect a small share of the cost increase in sea costs due to SECA and NECA might be compensated by relatively shorter travel times. However, an option for ship operators is to decrease their fuel consumption and thereby the cost of SECA by lowering the travel speed at sea (slow steaming). If this happens, the development in the relative difference in travel speeds might not project as estimated in the table below.

### 7.3.2 Freight type

From an overall perspective, volume/size of shipments can constitute a hindrance for changing modality from sea to land. This is most common within bulk transports where ship-based transports often are very voluminous, constituting a real problem when being shifted from sea to land. Also large volumes of unitized goods going to the same customer are sometimes more easily handled by ship in combination with a pre- and post-haulage. One example of this is the handling of oversize units and special cargos in the range form large containers to windmills and similar components.

Facilities in ports related to the initial handling of the goods in combination with the possibility of including extra services is another reason for sticking to the sea-based solutions. Rather often these positive effects will also be connected with the geographical dimension. The same goes for geographic areas where the accessibility by road is low, even though it may only be for limited periods of time. Examples of the kind of goods that benefit from port facilities are wood and ore products as well as the automobile industry; see (Rich, Kveiborg, & Overgård, 2011). For many other products, the infrastructure of ports has a weaker connection to the location of industries.

Some types of dangerous goods are handled more easily by ships than by truck - especially if they have to drive through tunnels.

The cost of freight relative to the total value of the cargo usually turns out to be a small fraction of the final price for many goods, for example consumer goods transported by ro/ro ships. This makes increases in the cost of freight less important and the demand of freight services less sensitive to price changes.
7.3.3 Expected future costs

The expectations about the future costs of both land- and sea-based transport will affect freight demand today. If the cost advantage for some routes tips towards land-based transport when SECA and NECA are introduced, the market might not change their preferred mode of transport if they expect the sea-based route to regain their cost advantage within a few years due to the cost of changing transport logistics.

7.3.4 Ship operators

The shipping industry is expected to act to reduce the consequences of an SECA and an NECA:

- Reduce sailing speed and thereby fuel consumption (slow steaming). This concept is known from the Maersk Line. Other companies have introduced it on their feeder services as well. One major challenge is related to the fact that slow steaming on the overseas leg leaves less time for the feeder to reach the final customers on time. (Johansson, Jaikanen, Kalli, & Kukkonen, 2013) have estimated the impact of slow steaming on the fuel costs for different ship types. They find that a 30% reduction in sailing speeds decreased fuel cost 31% for ro/ro ships and 13% for container ships in 2011. Likewise, they estimate a 10% reduction in sailing speeds will decrease fuel cost with 13% for ro/ro ships and 6% for container ships.
- Develop ship technology, i.e. retrofitting energy-saving equipment. Depending on the type of ship, age, ownership, etc., such a solution might prove very efficient with respect to cutting fuel costs and thereby emissions. Installing scrubbers might prove to be a possibility especially on fairly new ro/ro ships with a long lifetime remaining.
- Replace existing vessels with larger units with more capacity, thereby reducing the fuel consumption per unit transported. This is an especially good possibility for companies operating within a “lean asset concept”, i.e. a concept where the ships have been chartered on a short-term basis with the possibility of opting out with short notice. Such possibilities are especially useful on the lo/lo feeder market.
- Raise the capacity utilization on the vessels whenever possible (as part of efficiency improvements). This can take its form as a reduction in frequencies, outperforming less efficient operators, etc. In the short-term perspective, cuts in service might lead to a modality swing back from sea to land. In a longer-term perspective it might cut off some of the sea-based legs in the outskirts leading to more transport by land.

All of the actions will limit the cost disadvantage facing ship operators due to an ECA and thereby limit modal shifts.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

8 Socio-economic impact & environmental standards

The socio economic impact of introducing an SECA and an NECA, including the effect on the environment, is estimated as a cost-benefit analysis in year 2030. The elements included in the analysis are illustrated in figure 28.

*Figure 28: Illustration of costs and benefits by introducing SECA and NECA*

The cost and benefit variables are estimated as described in table 13. Each side of the cost-benefit analysis is elaborated in section 8.1 and 8.2.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

Table 13: Method and source for estimating the cost-benefit variables in year 2030

<table>
<thead>
<tr>
<th>Variable</th>
<th>Method of estimation</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefits:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduction in NOx emissions</td>
<td>Monetary benefit estimated as the increase in the improvement of health.</td>
<td>(Incentive, 2012a) and (The Netherlands Environmental Assessment Agency, 2012).</td>
</tr>
<tr>
<td>Reduction in SOx emissions</td>
<td>The annualized monetary benefit estimated from the study of the emissions from a container ship doing round trips in the North Sea.</td>
<td>(Jiang, Kronbak, &amp; Christensen, Cost and benefits of sulphur reduction measures: Sea water scrubber versus marine gas oil, 2013).</td>
</tr>
<tr>
<td>Costs:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased external costs by trucks</td>
<td>Calculated from the additional truck kilometres found in the modal shift analysis in chapter 7 and unit costs per kilometre for air emissions, noise, accidents and infrastructural wear.</td>
<td>(DTU, 2013) and calculations in chapter 7.</td>
</tr>
<tr>
<td>Congestion by trucks</td>
<td>Calculated from kilometre- and time-dependent costs and the additional truck kilometres found in the modal shift analysis in chapter 7.</td>
<td>(DTU, 2013) and calculations in chapter 7.</td>
</tr>
<tr>
<td>NECA</td>
<td>Assessed as an additional technology cost as described in chapter 5.2. The estimated cost in 2030 is dependent on a projection of the North Sea fleet composition.</td>
<td>(Incentive, 2012a).</td>
</tr>
<tr>
<td>SECA</td>
<td>Yearly fuel consumption in the North Sea added an additional price of SECA compliance fuel.</td>
<td>AIS data from (FMI, u.d.) on the fuel consumption of ships when sailing the North Sea in 2009. Fuel prices from (bunkerindex.com, 2013) projected as described in chapter 5.2.</td>
</tr>
</tbody>
</table>

8.1 Benefits

The monetary benefits of NECA and SECA primarily involve the health effect by reducing emissions of NOx and SOx\textsuperscript{11} as described in section 8.1.1 and 8.1.2.

8.1.1 Benefit of reducing NOx emissions

The health care benefits of reducing NOx emissions are monetised based on:

- Cost of medication and medical care
- Lost productivity using business data
- Cost of pain, suffering and premature death assessed from willingness-to-pay studies

The estimated annualized benefits from a North Sea NECA are assessed in (Incentive, 2012a). The benefits in 2030 are found to be between 443 million euros and 1,928 million euros, depending on the method of estimation. There are a number of benefits not included in the monetary assessment. One,

\textsuperscript{11} Note that reducing NOx and SOx at sea has a relatively smaller health effect than reducing emissions by an equivalent on land.
for example, is the impact on the terrestrial and marine ecosystems. The impact on air quality and deposition is only included indirectly as part of the health effect.

8.1.2 Benefit of reducing SOx emissions

Very little work has been done with regard to this matter.

We base our assessment of benefits on the work by (Jiang, Kronbak, & Christensen, Cost and benefits of sulphur reduction measures: Sea water scrubber versus marine gas oil, 2013). Based on their work, we calculate a benefit-cost relationship of 2.1 - 3.4.

We must emphasize that this method is a simplification.

8.2 Costs

Each of the costs components listed in figure 28 are described in the following sections.

8.2.1 Increased external costs

More truck kilometres will result in increased external costs from trucks.

We use the marginal external costs per kilometre for air emissions, noise, accidents and infrastructural wear as estimated in (DTU, 2013). These costs are projected by the GDP increase for North Sea countries.

From the marginal cost per kilometre and the increase in truck kilometres we find the external costs in 2030 to be 131 million euros. Of these costs, infrastructural wear and an increased number of road accidents are the dominating components.

8.2.2 Cost of congestion

As for the estimation of increased external costs, we base the estimation of increased congestion on the number of additional kilometres driven due to modal shift and the marginal congestion costs estimated per kilometre in (DTU, 2013). These costs are projected by the GDP increase for North Sea countries, which we consider a conservative rate of projection.

The total annualized costs in 2030 are 22 million euros.

8.2.3 Cost of NECA

Following (Incentive, 2012a), the cost of an NECA in 2030 is estimated to be 282 million euros. This covers the increase in capital and operational costs following the requirement to comply with the NECA standards.

8.2.4 Cost of SECA

The cost of SECA is estimated using two variables: the fuel consumption in the North Sea and the additional price for purchasing SECA compliance.
The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea

The fuel consumption in the North Sea is assessed in 2009 using the data provided by (FMI, u.d.). We identify the fuel consumption of the ships required to comply with the SECA standards to 8.2 million tonnes of fuel per year in the North Sea. Disregarding efficiency effects from improved ship engines and higher terminal value of burning MGO, we assume the fuel consumption to be constant in all years.

The difference in fuel prices between SECA compliance fuel (0.1% MGO) and the basis fuel (1% S fuel until 2020, hereafter 0.5% S fuel due to global requirements) is estimated yearly as described in chapter 5.2.

From the fuel consumption and the fuel price difference, we estimate the annualized cost of SECA in 2030 to be 1,870 million euros.

8.3 Benefits and costs compared

The estimated benefits and costs are presented in figure 29. We see that the total benefits outweigh the costs by around 4,000 million euros which is the expected net benefit from introducing SECA and NECA.

![Figure 29: Costs and benefits in 2030 of introducing an SECA and NECA in 2015](image)

*Note: The two benefit scenarios represent the highest and lowest benefit of introducing NECA, as presented in section 8.1.1.*

We find a benefit-cost relationship of around 2.7 of establishing a SECA and NECA when accounted for modal shifts. The effect of an NECA only was analysed in (Incentive, 2012a) - a benefit-cost ratio of 1.6 - 6.8 was found. The result of the cost benefit analysis is not dependent on a designation of a Baltic NECA. The benefits still outweigh the cost if a Baltic NECA is not designated.
8.4 Environmental standards

Over the last decade and in particular during recent years a great number of environmental and climate performance assessment standards (ECPAS) have emerged for ships. Some are ubiquitous and quite comprehensive, while others are limited to a select group of vessels or focus on specific performance parameters.

The majority of the standards are voluntary and operated by companies or organizations. A few are in the hands of government authorities and some of those are mandatory such as the Norwegian NOx tax, or voluntary such as Singapore’s Green Port Programme on SOx emissions.

Some environmental requirements go beyond the existing conventions. Going beyond the regulatory requirements and voluntarily invoking more stringent standards is done typically for one or both of the following reasons:

1. The shipping company has a “first mover” policy on additional stricter regulations in preparation of future demands.

2. The shipping company and its ships with a “green” certificate can gain access to transport buyers (shippers) that require the carrier to take environmental issues into account.

Within road transport some transport companies have recently used a “green profile” in the marketing. Different environmental performance indices such as Clean Shipping Index (CSI), Environmental Ship Index (ESI) and Clean Cargo Working Group (CCWG) have developed environmental performance systems where it is possible for ships to obtain a “green” ranking. This makes it easy for transport buyers to compare vessels and figure out which vessel has the highest environmental performance.

If the focus on environmental standards is increased in the future, the expected modal shift will be smaller than what we have found in our analysis. The increased focus will represent an additional incentive for ship operators to comply rather than shift freight to land.
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The impact on short sea shipping and the risk of modal shift from the establishment of an NOx emission control area in the North Sea


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