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ORIGINAL PAPER

Sulphur emission control areas and transport strategies -the case of Sweden and the forest industry

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Abstract
Background and purpose The International Maritime Organisation's (IMO) decision to lower the allowable amount of sulphur content in marine fuels to 0.1 % in the so-called Emission Control Areas (ECAs) beginning in 2015 has outraged the Swedish forest industry. The seas around Sweden are included in the ECA and achieving the new sulphur directive requires shipowners to take actions that will increase the cost of transporting goods by ship from Sweden. Swedish forest industry exports are transported mostly by ship and there is a possibility that the forest industry will shift freight from sea to land transport because of the sulphur directive. How greatly the transport costs differ between different transportation options is affected by several uncertainties such as price trends for fuel. Other restrictions for shipping, such as nitrogen oxide emissions and ballast water treatment, are also expected to become stricter in the future. The purpose of this paper is to examine the impact of the sulphur directive and associated uncertainties on the Swedish forest industry, its transport system structure, and its logistics strategies.
Results and conclusions Previous studies in the field have forecast that the freight will be transferred to land because of the sulphur directive. Our results also show that companies will transfer the cargo to land transport. The transfer will be greater the further south in the country production facilities are located. Goods that previously were shipped from ports on the Swedish east coast will instead be shipped more frequently from ports on the west coast to reduce transport time within the ECA region. Furthermore, the results show that firms do not sign agreements with shipping lines that extend beyond the year 2015, but instead write long, flexible agreements with rail operators, enabling an increase in freight strategy to address the sulphur directive. In this way, they have created the capacity to transform the transport structure.

Keywords SECA · Intermodal transport · Modal shift · Paper and pulp industry · Transport strategy

1 Introduction

When measured by weight, maritime transport is generally seen as one of the most environmentally friendly transportation methods. This is because ships move large volumes of goods, which means that emissions are low when distributed per unit weight. Even so, emissions from shipping are significant. Concern is primarily about emissions in the form of sulphur oxides, SOx [48, 8, 3], nitrogen oxides, NOx [21], carbon dioxide, COx [12] and particulate matter, PM [11].

The shipping industry has historically been slow and perhaps unwilling to address the issue of emissions. This is partly due to the international nature of the industry—meaning that regulations are difficult to agree upon and to enforce [13]. In recent years, however, attention given to emissions and the environmental impact of the shipping industry is increasing and measures to reduce emissions and impact have been and will be implemented. This is because emissions of NOx, SOx, and PM are all harmful to humans [12, 11].

According to Corbett et al. [11], the emission of particles from shipping causes about 60,000 deaths globally each year. The coastal regions along major trade routes are the most

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affected. Mortality is highest in Europe and Asia, where large populations and particulate emissions coincide.

The International Maritime Organisation (IMO) has adopted new rules for shipping emissions of sulphur oxides, the so-called "sulphur directive". IMO is an organisation within the United Nations (UN) with the task of developing and maintaining rules for international shipping [24].

The directive aims to reduce sulphur emissions from shipping by limiting the sulphur content of marine fuel (cf. Buhaug et al. [7]). The rules have been implemented gradually from 2010 and the sulphur directive was adopted by the IMO at the 58th Environment Committee meeting on 9 October 2008. Permissible sulphur content in fuel is controlled by MARPOL (the International Convention for the Prevention of Pollution from Ships) in Annex VI and differs among different geographical areas. Emission Control Areas' (ECAs) have been defined that are considered particularly sensitive. Permissible sulphur for ECAs was reduced from 1.5 to 1.0 % on 1 July 2010, and will be further reduced to 0.1 % from 1 January 2015. Included in the ECAs [25] are areas along the North American east coast and west coast, Hawaii, and the U.S. Caribbean, as well as areas in Northern Europe, see Fig. 1.

The impacted European seas include the Baltic Sea, North Sea, and English Channel. This means that the entire coast of Sweden is included in the area [25]. Figure 2 is an enlargement of the North European area, which this study focuses on.

The allowable sulphur content in marine fuel in the other seas of the world was reduced from 4.5 to 3.5 % by weight on 1 January 2012, with the aim that it should be lowered to

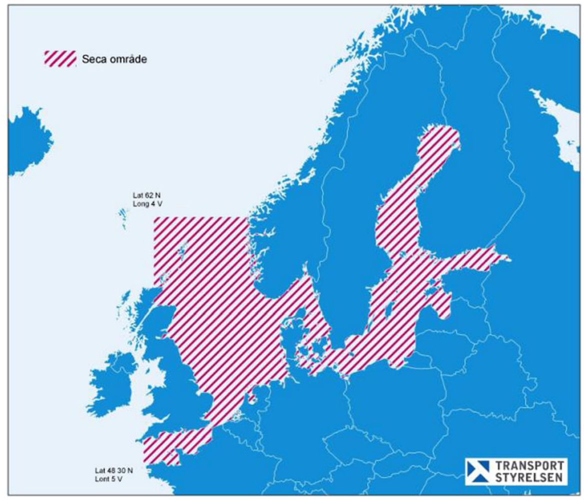

Fig. 2 North Europe ECA. Source: Transportstyrelsen [47]

0.5 % by the year 2020 or at the latest 2025. A feasibility analysis of the IMO is to be completed by 2018, which will evaluate whether it is possible to reduce the level in the year 2020 for the entire world's shipping. A decisive factor for this is a sufficient supply of low-sulphur fuel [25].

On 26 October 2012, however, the European Council decided that the allowable sulphur content for the rest of the EU seas should be lowered to 0.5 % effective 1 January 2020 even if enforcement for the rest of the world is delayed to 2025 (EU Directive 2012/33/EU [19]). Figure 3 clarifies the various limits that apply.

The EU has also already decided that vessels may use a maximum of 0.1 % sulphur content in fuel when they are at

Fig. 1 ECAs. Source: Lloyd's [31]

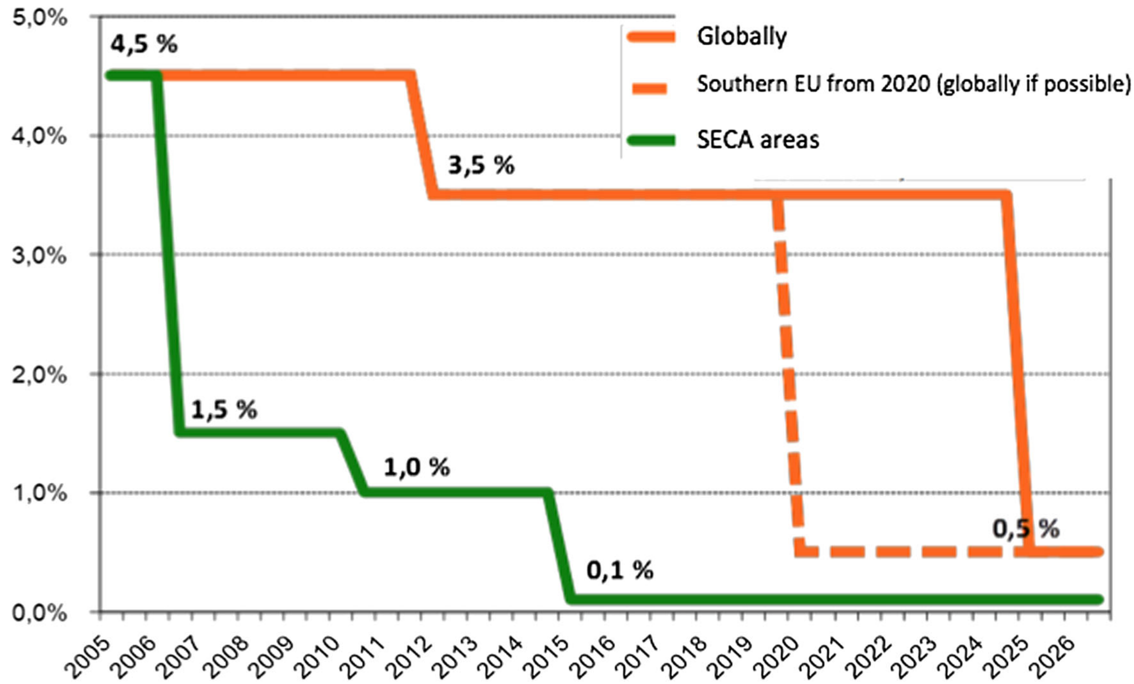

Fig. 3 Sulphur content in bunker fuel and SECA limits. Source: NECL II [34]

berth or at anchor in all EU ports, except for those that make a stop lasting less than two hours. Furthermore, regular passenger service operating to EU ports is to use fuels with maximum 1.5 % sulphur (or 1.0 % in the ECA). The rules were adopted on 1 January 2010 (EU Directive 2005/33/EC [18]).

The Northern European ECA region accounts for about 10 % of global maritime trade volume. In 2010 a total of 14, 000 vessels arrived in the ECA region, and thus it is these vessels that will be more or less affected by the sulphur directive. Especially affected are the 2,200 vessels that spend all their time, and the 2,600 vessels that spend 50 % of their time in the ECA region [34].

Today the vessels use a relatively cheap bunker fuel with a sulphur content of 1.0 % in the ECA region. To meet the new rules, the ships are forced either to switch to cleaner low-sulphur fuel, be equipped with flue gas/install−an exhaust gas cleaner, i.e., “scrubber” or be rebuilt to be powered by alternative fuels such as gas or methanol. Whatever choice shipping companies make will mean that the cost of transporting the vessels in the area will increase [15, 34].

How much costs will increase is very difficult to determine. One hypothesis is that the increase in cost will lead to a modal shift from sea to road and rail.

The uncertainty of exactly how much more expensive transporting by ship will become is therefore great. Consequently, it is interesting to study large shippers highly dependent on transportation in relation to total landed cost and their strategies for addressing these regulatory changes and dealing with the associated uncertainties. Hence, we decided to study how the Swedish forest industry is preparing for the legislative change, and what decisions have been taken or will be taken with regard to any changes in their transport structure.

The purpose of this paper is to examine the impact of the sulphur directive and associated uncertainties on the transport system structures and logistics strategies of the Swedish forest industry.

By uncertainty, we mean factors related to the sulphur directive where the value and/or consequences cannot be determined with certainty, but still need to be handled by companies in some way.

The Swedish forest industry consists of companies that operate in the global market with operations in several countries. When we study the Swedish forest industry, we focus only on the activities and facilities located in Sweden geographically.

We define transport structure as the choice of transport mode and transport routes and logistics strategies relaying how the company reflects on its choice of transportation structures.

The paper is structured as follows: *Literature review* examines alternatives for compliance with the SECA regulations, *Research design* explains the design and methodology of the research, *The Swedish Forrest Industry* provides an introduction and background to the case, *Case study analysis* analyses an individual company’s strategic decisions and processes, and finally *Conclusions* in which syntheses are constructed on the basis of literature review and case study analysis. The next section examines previous research and alternatives for compliance with the SECA regulations.

2 Literature review—alternatives for compliance with the SECA regulations

There are, in addition to moving or exiting the business, three different options for shipping companies and shipowners to customise vessels to the new, stricter sulphur restrictions within the ECA. One option is to switch to cleaner low-sulphur fuel. Another alternative is to continue with high-sulphur fuel and instead install an exhaust gas treatment system, a so-called scrubber. A third option is to switch to alternative types of fuel such as LNG and methanol.

All options have their advantages and disadvantages, but common to all the alternatives is that they involve increased costs, either in the form of higher fuel costs or investment costs [14]. One way for shipping companies to offset the increased fuel costs to some extent is to implement operational measures such as slow steaming. Shipping companies' tight margins will, however, probably force a transfer of the majority of increased costs to customer prices.

2.1 Switch to low-sulphur fuel

The easiest option, expected to become the most common solution for shipping lines, is to switch from bunker fuel with a sulphur content of 1.0 % to a cleaner and more expensive low-sulphur fuel in the form of MGO (marine gas oil) or MDO (marine diesel oil) with a sulphur content of 0.1 % (c.f. Entec [17], AMEC [2], NECL II [34]).

The extraction of crude oil produces waste products known as bunker fuel or HFO (heavy fuel oil) that is used as fuel for shipping [45]. The sulphur content in bunker fuel varies, but the limit used by ships globally is maximum 3.5 % according to IMO's global rules adopted in 2012 [25]. To achieve the desired level of sulphur, high-sulphur bunker fuel is mixed with low-sulphur distillate oils such as diesel with 0.001 % sulphur content in refineries [4].

The introduction of 0.1 % sulphur content in ECAs in 2015 will require a shift from bunker oil to pure distillate oils such as MGO or MDO. This is because such a large proportion of low-sulphur distillate in the high-sulphur bunker fuel would be required to reach the 0.1 % marker that it is not worthwhile to mix [4]. More purified distillate oils such as MGO or MDO are used initially, but can be mixed to a desired level of 0.1 % sulphur content.

However, it is also possible to desulphurise high-sulphur bunker fuel in special facilities at refineries. Such facilities don't yet exist and investing in additional capacity for desulphurisation is risky because the demand is uncertain [4]. Refurbishment of a refinery takes between 3 and 4 years [45].

The shift of fuel does not require any major investments in remodelling vessels, only a possible minor adjustment of tanks and engines. Vessels may choose a hybrid solution that allows them to switch between high- and low-sulphur fuel depending on whether they are within an ECA or not. This system is widely used now because all vessels have to use 0.1 % sulphur fuel when they are at berth or at anchor at all EU ports.

A clear effect of the transition to low-sulphur fuel in 2015 is increased fuel costs [46, 15, 2], especially for the ships that spend most of their time within the ECA region [34]. The fact that MGO and MDO are distillate oils, thus more expensive for refiners to produce, means they have a higher price than bunker oil [15]. Pricing of petroleum products depends on the demand and supply of crude oil (cf. Preem [35], Cullinane and Bergqvist [13]). The crude oil is then refined to various products such as MGO and MDO, which in turn are priced based on supply and demand. The price of oil is affected in the short term by expectations about the future, such as economic forecasts, unrest in different parts of the world, production estimates from the oil producing countries, stock levels, seasonality, weather, accidents, and more (cf. Swedish Maritime Administration [46]).

The difficulty to predict trends in fuel prices has been emphasised as the most critical in the majority of studies we have reviewed. The price of marine fuel fluctuates constantly due to market forces and the price of crude oil [15]. Over time, the price difference between high-sulphur bunker fuel oil (IFO 380) and MGO fluctuated between 30 and 250 % with a long-term average of 93 % [27]. Several studies have attempted to forecast what fuel prices will be in 2015 in order to analyse the sulphur directive effects. Table 1 summarises the studies' estimated price of MGO or expected price increase when switching to MGO in 2015.

All studies have forecast that fuel prices for shipping within ECAs will increase in 2015. However, they have come up with very different results for the price of MGO, ranging from 500 USD to 1650 USD per tonne. To compare the expected percentage increase between studies is problematic because it is relative. It is better to compare the price difference in monetary terms. The closer to 2015, the more confident the forecasts will be and recent studies (e.g., Sweco [45], AMEC [2]) estimate the price increase to switch from fuel with a sulphur content of 1.0 % to fuel with 0.1 % in 2015 will be around 300 USD/tonne All vessels are not affected equally by increased fuel prices. The vessel types with fuel costs as a large percentage of the total operational cost are more affected. A Finnish study by Karvonen et al. [29], has examined the operational costs of different ship types by studying the ships operating between Finland and other countries. In the calculations, a three-year average of fuel prices (2003–2005) is used where

Table 1 Summary of studies and forecasted price of MGO in 2015

Study	Forecasted price of MGO/MDO with 0.1 % sulphur content year 2015 per tonne	Forecasted price increase between HFO with 1.5 % sulphur content and MGO/MDO with 0.1 % sulphur content
VTI [49]	Scenario 1: 662 USD	–
	Scenario 2: 1158 USD	
	Scenario 3: 1650 USD	
Entec [16]	Scenario 1: 545 USD	Scenario 1: 92 USD/tonne, 42 %
	Scenario 2: 727 USD	Scenario 2: 119 USD/tonne, 59 %
COMPASS [9]	656 Euro, 883 USD	65 %
ITTMA [27]	Low-cost scenario: 500 USD	80 %
	Middle-cost scenario: 750 USD	
	High-cost scenario: 1000 USD	
ISL [26]	Low-cost scenario: 850 USD	70–86 %
	High-cost scenario: 1300 USD	57–75 %
Kalli et al. [28]	470–500 Euro, 633–673 USD	73–85 %
		51–61 %
Entec [17]	–	155-310 USD/tonne
Sweco [45]	–	350 USD/tonne (Price increase between 3.5 % and 0.1 %)
AMEC [2]	–	275-350 USD/tonne (Price increase between 1 and 0.1 %)

the price of high-sulphur bunker oil was 152 Euro per tonne and for MDO 281 Euro per tonne. The results showed that fuel costs were the single highest cost for most ship types and especially for container ships. The shares of fuel costs were 54 % for container vessels, 40 % for bulk carriers, 38 % for conventional cargo vessels, 36 % for RoRo vessels, 33 % for tankers, and 30 % for car and passenger vessels (see Fig. 4).

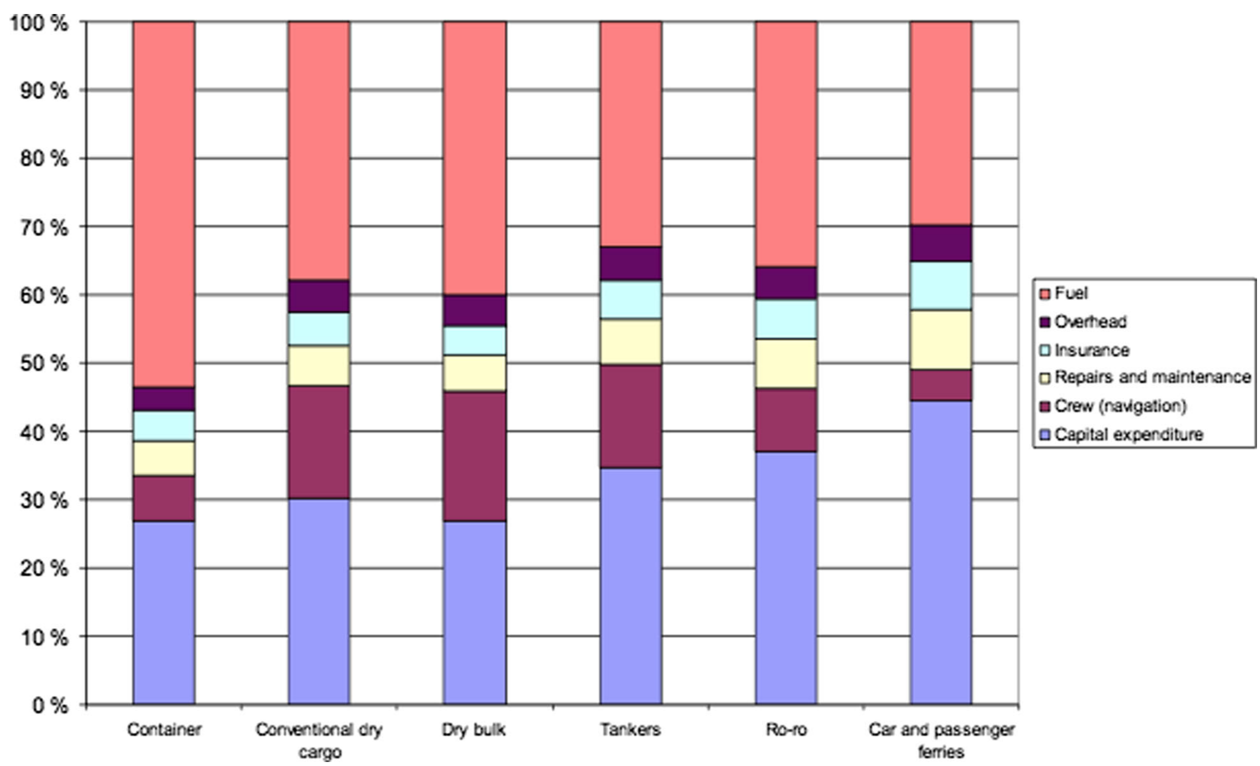

Fig. 4 Operational costs for different types of vessels. Source: Karvonen et al. [29]

A Finnish study by Kalli et al. [28], commissioned by the Finnish Ministry of Communications, made an impact analysis of how the sulphur directive will affect freight costs in Finland. Kalli et al. [28] used data on differences in total operating costs for various types of vessels from Karvonen et al. [29] to see how much a fuel price increase affects different shipping types per tonne transported.

Table 2 shows the study's prediction for transportation costs for different shipping types as a percentage per transported tonne or per TEU (twenty-foot container) due to switching from bunker oil (1.5 % sulphur) with a price of 271 Euro per tonne (370 USD) to low-sulphur fuel (0.1 % sulphur) with a price of 470 to 500 Euro per tonne (633–673 USD).

The results show that transport costs will increase between 28 and 51 % depending on the type of goods. The industries that import or export extensively and are far from their core markets, such as the steel and forestry industries are affected the most (cf. Kalli et al. [28], Swedish Maritime Administration [46].

There are other complications in addition to increased fuel costs associated with switching to LSFO. It will reduce sulphur emissions, but not the emissions of nitrogen oxides [14], which are expected to have stricter regulation in the future [15].

2.2 Scrubbers

An extension of the MARPOL Convention allows technical equipment that cleans emissions from sulphur to be used [25]. This purification method is called a "scrubber" and drastically reduces sulphur emissions (cf. EMSA [15]). The advantage of a scrubber compared to other methods for achieving the sulphur directive is that the ship can continue to be driven by cheaper high-sulphur fuel and still meet the stricter sulphur restrictions (cf. Lin [30], Cooper [10], Agrawala et al. [1], Fridell et al. [20]). Scrubbing is not new, as it has long been used on land, but it is only recently that the technology has been applied in shipping. Other advantages are that the shipping company does not need to rebuild or replace the ship's engine and there is sufficient availability of high-sulphur fuel [14]. There are two different types of scrubbers, wet scrubbers and dry scrubbers, on the market for marine use, and a scrubber can be installed on existing vessels or new vessels.

Wet scrubbers use water that is mixed with the exhaust gases to "wash" away the sulphur from the flue gases and are available in three different models: an open system, a closed system, and a hybrid of the two. In the open system, seawater is used for purification, and when sulphur oxides are washed out of the emissions the water is cooled down and then pumped back into the sea. The acidic water discharged requires a marine environment with high salinity and high alkalinity to neutralise. The scrubber itself occupies a lot of space on the ship. It is mounted near the chimney in the exhaust system, but it also requires space for water pumps and water treatment systems, which reduces the cargo capacity.

The closed system uses fresh water to clean emissions. The dirty fresh water that remains after a purification process is purified with chemicals (such as caustic soda) and then reused in the system. The residual waste generated is collected in special tanks and will then be filled in specially designed facilities at the port. A closed system requires more space on board the ship, as extra tanks for chemicals and residual waste have to be installed. A freshwater system is preferred for fragile, shallow, coastal waters such as the Baltic region since the outgoing wastewater from an open system is of low pH and is a negative from an environmental perspective, as it can contribute to an undesirable acidification effect [45].

There are also hybrid systems that use seawater when it is available and change over to fresh water in a closed system when it is suitable. These hybrid systems typically have only a capacity to wash exhaust in 2–3 days aboard [2].

Dry scrubbers use chemicals instead of water in the purification process. Usually, calcium hydroxide pellets are used. The pellets are kept on board the ship even after they have

Table 2 Transport cost increases for different goods types

Freight type	Total operational cost of vessel (Euro/Tonne or TEU) per travel day	Total operational cost of vessel (Euro/Tonne or TEU) per travel day after switch to LSFO	Effects of increased fuel costs on transport costs (increase in % from 2009 levels)
Container	23.24	33.56–35.12	44–51 %
Oil	0.86	1.10–1.13	28–32 %
Paper reel	1.29	1.74–1.80	35–40 %
Timber	1.29	1.74–1.80	35–40 %
Dry bulk (tonne)	0.53	0.74–0.77	39–44 %
Steel products	1.29	1.74–1.80	35–40 %
RoRo (tonne)	3.41	4.62–4.80	35–41 %

Source: Kalli et al. [28]

been used since they do not dissolve during the process. The process itself is very exothermic. Hence, it is important that the location of the scrubber is carefully chosen. The unit itself weighs approximately 250 to 300 tonnes (including 150 to 200 tonnes of pellets) and increases engine load by 0.15–0.2 % [2]. The pellets last about 10–14 days before they need to be replaced in port. Because of the great importance of the pellets, it is likely that a freighter will have to reduce valuable cargo space to house the unit.

The cost to install a scrubber on a vessel varies depending on technology and how difficult and complex the installation is. It is much more costly to install a system on an old vessel than a new one, and closed systems are more expensive than open systems [2].

To get an idea of the approximate costs of the different systems, EMSA [15] has made estimations of installation costs (see Table 3).

Costs vary widely depending on the configuration, ship construction, and price of scrubbers.

Installation of a scrubber incurs a substantial investment cost. It is estimated to take 2–5 years for the installation of scrubbers on an existing vessel to be profitable compared to the higher fuel cost in making the transition to low-sulphur fuel (MGO) (cf. NECL II [34]). The payback period varies depending on the size, type, and field of operation [15], and the price difference between HSFO and MGO.

Another cost is the loss of income during the installation of a scrubber. A common scrubber installation may take 4–8 weeks, which means that the owner loses revenue as he or she is forced to put the ship out of commission for the time required to complete the installation [1].

The Finnish government has decided to subsidise scrubber installations for Finnish ships up to 50 % if investments are made before the directive is effectuated [22]. However the Swedish government has not yet made such state-aid decisions.

Scrubbers are an emerging technology in shipping, but the general opinion among shipowners seems to be that scrubbers are so far not sufficiently reliable for use in maritime environments (cf. AMEC [1], NECL II [34]).

Table 3 Estimated installation cost for different types of scrubbers

Type of scrubber	Installation old vessel (cargo vessel, 20 MW)	Installation new built (cargo vessel, 20 MW)
Wet-scrubber open system	2.4 million Euro	2.1 million Euro
Wet-scrubber closed system	2.4 million Euro	1.9 million Euro
Hybrid system	3.0 million Euro	2.6 million Euro

Source: EMSA, [15]

2.3 LNG (liquefied natural gas)

LNG is liquefied natural gas, perhaps the most attractive alternative fuel to meet the sulphur directive. The gas reserves identified hitherto are already larger than the oil reserves available and new reserves are found continuously. Natural gas has long been widely used in industry on land as well as for heating and transport around the world. LNG is naturally low in sulphur and therefore meets the new restrictions without any problems during combustion [15]. When the gas is in liquid form, it contains more energy and is easier to process in a combustion engine. To keep the gas liquid, it must be cooled to below its boiling point of 163 °C, and then kept under pressure, which requires large tanks that can be mounted either above the deck or inside the ship [44]. These tanks take approximately 3–5 times more space than more conventional fuel tanks [15].

LNG is a more expensive option initially compared with the scrubbers, but the great advantage of LNG is that it is the cleanest fossil fuel [1]. This means that sulphur emissions are reduced by nearly 100 %. Emissions of nitric oxide greatly decrease by about 85–90 %, carbon dioxide emissions are reduced by about 20 %, and even particle emissions decrease slightly [23, 15]. The use of LNG as a fuel can be seen as an insurance against possible future tighter regulation of shipping emissions.

It is possible to convert existing vessels but it is likely that LNG will be used only in new vessels. This is because a conversion is very costly, between 12 to 16 million euro [1], and because LNG requires twice as much storage capacity as the usual marine fuel to provide the same amount of energy. Making such an adjustment will reduce the load capacity and be physically impossible or uneconomical for many existing vessels.

Another important aspect to take into consideration with LNG is the uncertainty and volatility in prices (see Fig. 5 for illustration). The low price compared to marine oils makes LNG attractive, but there are some concerns that when LNG becomes established in the market as a marine fuel, prices will be pushed to the same levels as the low sulphur fuel and thus rise sharply [1]. The total demand for LNG is forecasted to increase by 140 % until the year 2020 in the SECA area [14].

For the most part, the price of LNG for the years 2006–2010 has been below the price of bunker fuel (see Fig. 5), but the price of LNG does not follow the price of crude oil in the same way traditional bunker fuels do. More recently, however, LNG prices have increased and shown increased volatility.

According to a Danish study, DMA [14], that tested various scenarios of price differences between MGO and LNG, the payback period for choosing LNG is around 2 years for new construction and between 2 and 4 years for rebuilding of the existing vessels. As with the installation of scrubbers, the

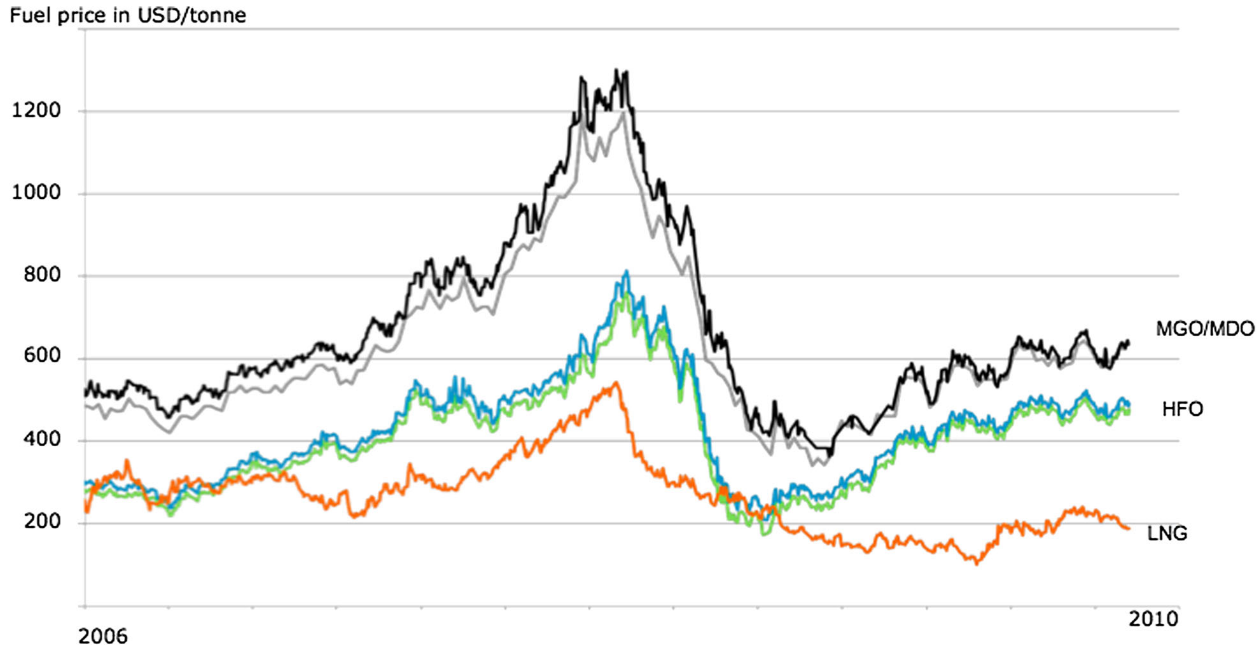

Fig. 5 Price of LNG 2006–2010 in USD/tonne. Source: EMSA [15]

vessel's size and type, and the field it operates in (cf. EMSA [15]) affect the payback period.

2.4 Methanol

A consortium, including Stena Line and ScandiNAOS, is conducting a demonstration project called Spireth to develop engines for methanol use. Methanol has so far been largely untested as fuel in shipping. The project converts the methanol to dimethyl ether (DME) on board the ship and then uses it as fuel in a modified diesel engine [43].

Both methanol and DME give very low emissions and can be extracted from fossil and renewable energy sources. It is expected to be much cheaper to convert to methanol operation than to convert to LNG [34]. However, technology is in the development stage so outcome, fuel prices, and availability are uncertain.

2.5 Actions to lower fuel consumption

Slow steaming is an operational measure to reduce fuel costs. By deliberately reducing vessel speed, fuel consumption is decreased and carbon dioxide emissions reduced. In itself this is not a way to meet the new sulphur directive because the sulphur content of the fuel is not affected if the ship is moving slower. The measure is often discussed in conjunction with operating larger vessels to reduce the increased cost fulfilment the sulphur directive entails. The increase in fuel costs with transition to cleaner fuels is offset by lower fuel consumption through slow-steaming and larger cargo volumes (cf. NECL II [34], Cullinane [12]).

There are other measures that shipping companies can take to reduce fuel consumption, such as better load planning for obtaining higher load factors and thus reducing fuel consumption per transported tonne [12].

As indicated in the previous sections and other studies, there are a number of uncertainties related to the alternatives for compliance with the sulphur directive. The next section elaborates on these.

2.6 Uncertainty related to the alternatives for compliance with the sulphur directive

Table 4 describes different external factors that play into companies' decisions and strategies related to sulphur directive compliance and the choice of alternative (cf. NECL II [34]).

Other external factors, such as future restrictions of nitrogen emissions and ballast water treatment, may affect the company's strategies for dealing with the sulphur directive. Rules regarding the use of scrubbers are another element of uncertainty.

There are also a number of crucial internal factors. Companies can be locked in transport contracts that bind them to continue with the existing logistics structure even though there might be cheaper alternatives. If the company owns its own vessels and built a logistics structure for maritime transport it will be harder to shift freight to land-based modes of transport. On the other hand, implementation of operational measures such as the use of larger vessels and slow steaming for companies that own their own vessels can help reduce

Table 4 External factors

Factor	Relevance	Determinants
Price of crude oil	Affects price of fuel and heavily affects cost for shipping and road transport	E.g. politics, regional conflicts, economic situation
Price increased to specific fuels	The price of LSFO is sensitive to supply shortages	Demand and refineries' production capacity
Currencies	Cost of fuel. Forest industry profitability and ability to absorb increased transport prices.	Economic situation and politics.
Supply and demand of alternative solutions (LNG, methanol, scrubbers)	Availability of alternatives and associated costs.	Motives, incentives, and subsidies for investments and innovation
Port infrastructure and other technology	Availability of alternatives and associated costs.	Motives, incentives, and subsidies for investments and innovation
Capacity of rail, road, and terminals.	Opportunity for modal shift and costs of alternative modes of transport.	Infrastructure investments, internalisation of external costs.

operational costs. The next section addresses the issue of research design with the purpose of analysing the above mentioned aspects in the context of the Swedish forest industry.

3 Research design

According to Yin [51], a case study approach is appropriate when "how" or "why" questions are being asked, when the investigator does not have control over events (as one might in an experimental methodology) and when the phenomenon being studied cannot be separated from its context. All of these criteria are present in the current research, and therefore a case study methodology has been adopted.

The sample group consisted of four companies: SCA, Stora Enso, Holmen, and BillerudKorsnäs (see Table 5). The main reason for the sample size was because the forest industry is characterised by a few large players.

The Swedish forest industry is geographically dispersed across the country, and companies often divide operations into business units by type of production, such as sawn timber, pulp and paper, and packaging. Interviewees were selected in such a way so that we could reach as many aspects of the forest industry as possible, resulting in as high validity as possible. Table 1 describes our respondents and their type of production area.

Much effort was put into identifying the appropriate respondent at each company since knowledge and insight into the strategic process was essential, therefore, all of the respondents hold senior management positions. The interviews were semi-structured telephone interviews in which questions were communicated beforehand to the respondents. Parallel to the interviews a desk research focusing on literature review related to alternatives for complying with the SECA-regulations was conducted. The analysis consisted of reviewing the interview material and documentary data. The data were organised according to a three-stage process of data reduction, display, and conclusion drawing and verification [32]. Gaps were identified and filled by follow-up emails as well as further data collection. An iterative process was followed, moving back and forth between data collection, analysis, interpretation and explanation, making use of triangulation where possible to strengthen interpretations.

Table 5 Respondents

Name, position and company	Production area	Geographical location
Magnus Svensson, CEO, SCA Transforest (part of SCA Group)	Logistics company within the SCA group, which mainly focus on forest products by means of shipping.	SCA Forest Products have production facilities in northern Sweden
Peter Olsson, Manager Mill Logistics, BillerudKorsnäs	Produces and transports packaging material and products	Production facilities mainly in middle and south of Sweden
Knut Hansen, Senior Vice President, Stora Enso Logistics (part of Stora Enso Group)	Produces and transports paper, pulp packaging material and wooden products	Stora Enso have production facilities in mid and south of Sweden
Christina Törnquist, Logistics manager, Iggesund Paperboard (part of Holmen Group)	Produces and transports packaging material and products	Production facilities in middle of Sweden
Johan Hedin, Marketing manager, Holmen Timber (part of Holmen Group)	Produces and transports sawn timber	Production facilities in middle and south of Sweden

4 The Swedish forest industry

The forest industry is one of the most important industries for the Swedish economy and creates jobs across the country. The forest industry consists of companies in the pulp and paper industry and the wood products industry (production of sawn timber). The largest amount of Swedish forest industry exports, over 70 % of pulp and paper, and over 60 % of sawn timber, are transported by sea and will therefore be affected by the new restrictions, as seen in Fig. 6 [37].

In 2012, the Swedish forest industry produced 15.9 million cubic meters of sawn timber, 12 million metric tonnes of wood pulp, and 11.4 million metric tonnes of paper and paperboard [42], and employed almost 60,000 people directly and up to 200,000 indirectly by subcontractors [41]. The industry is also important for Sweden's balance of trade because it is highly export-intensive. Almost 90 % of pulp and paper production and almost 75 % of sawn timber are exported [41]. The total value of Swedish exports of forestry and forest products was SEK 122 billion in 2012, representing 10 % of the total export value (all goods) [42].

A few large corporations characterise the Swedish forest industry, where SCA, Stora Enso, Holmen, and Billerud are largest in terms of turnover (see Table 6). In June 2012 a merger between Billerud and Korsnäs was completed [6], further contributing to a market largely consisting of four groups.

If we look at the Swedish forest industry development in recent years, neither the production of solid wood products or pulp and paper products recovered to the levels preceding the global economic crisis between the years 2008–2009 [40]. The share of transport by ship declined between the years 2007–2008 for the export of pulp and paper, while the proportion fell steadily for sawn timber (see Table 7).

While production capacity has increased, the number of plants in the forest industry in Sweden has decreased; Table 8 illustrates the capacity development.

The forest industry has experienced a dramatic change in market conditions over the last decades, and the regulatory framework related to the sulphur emission control area will add additional uncertainties to an industry that is already under great cost pressures and global competition. The proportionally high transport cost of the industry, its large goods volumes, and the global competitive landscapes makes it a compelling industry to research in connection to the stricter sulphur regulations of shipping.

5 Case study analysis

5.1 Alternatives for compliance with SECA regulations

From the interviews, it is evident that respondents expect shipping companies to switch to LSFO in order to comply with the sulphur directive.

The scrubber is primarily an option for older vessels according to many studies, but the respondents think that it is still best suited for newly constructed or medium-aged ships. Many of the vessels operating in the ECA region are older,

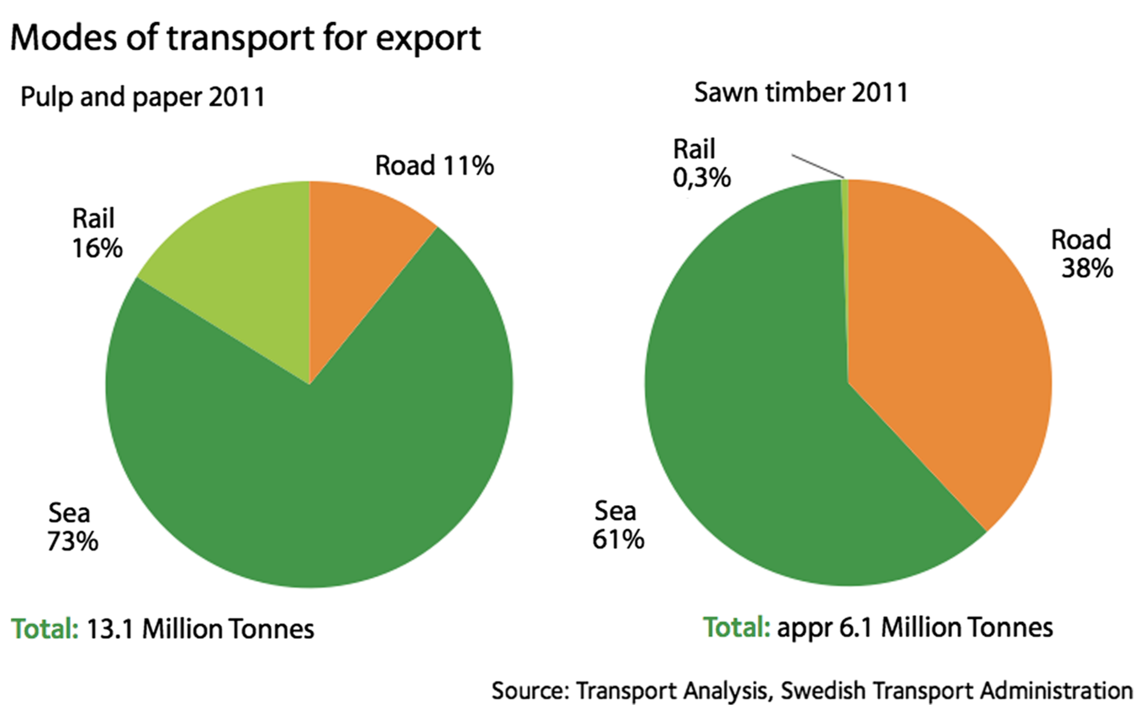

Fig. 6 Modes of transport for Swedish forest industry exports. Source: SFIF [37]

Table 6 The largest Swedish forest companies

Turnover and profits
for forestry industry companies quoted on the Stockholm stock exchange

	Turnover		Profits of the year[c]	
Company	2011	2010	2011	2010
SCA	105.75	106.97	5.92	6.28
Stora Enso[a]	99.01	98.23	3.09	7.34
Holmen	18.66	17.58	3.96[d]	0.70
Billerud	9.34	8.83	0.68	0.71
Rottneros	1.51	1.68	-0.14	0.13
Rörvik Timber	1.38	1.17	-0.16	0.23
Bergs Timber[b]	0.85	0.92	-0.04	0.02
SEK billions				

SEK billions

Source: Companies' year-end reports

Source: SFIF [40]

[a] Exchange rate SEK/EUR 9.54 in 2010 and 9.03 in 2011

[b] Financial years 2010–2011 and 2009–2010, respectively

[c] Profits after tax

[d] Including re-evaluation of forest assets

and a big investment is thus not relevant according to the respondents. Due to overcapacity of ships in the market, orders for new vessels are unlikely. The uncertainty in handling and rules on residual waste from scrubbers are also problems that Magnus at SCA Transforest and Knut at Stora Enso emphasise.

Knut Hansen from Stora Enso also points out that in the present situation there are over 2,000 vessels moving within the ECA and it is not realistic to believe that all of them could be converted in the near future.

LNG is also viewed as an uncertain alternative. Complications of LNG mentioned by the respondents are the limited availability of gas stations, the reduced cargo capacity, the uncertainty in prices, and opinions that the technology is best suited for newly built ships. Methanol is considered too undeveloped for marine use and will not yet have had an impact by 2015.

In summary, the respondents' perceptions are that scrubbers, LNG, and methanol will see increased prevalence in shipping in the future, but that the chance for a breakthrough by 2015 is very small.

Previous research (e.g., Cullinane and Bergqvist [13], Kalli et al. [28], AMEC [1]) asserts that the companies will pass on their increased costs to their customers in the form of higher transportation costs. ITTMA [27] points out that it is not certain that the companies will pass along the costs, as there is a risk that customers will move to land-based transport instead. The interviews show that all are convinced that the costs will be passed on to the customer, i.e., the forest industry. That they could in turn pass on the increased costs to their customers is in most cases not likely as they compete in a global market where other vendors must not elevate transportation costs.

5.2 The impact on companies' transport structures

The interviews show that sea transport will still be significant for companies, but they will modally shift to land-based transport because of the sulphur directive, something that several previous studies also indicate (e.g., Bergqvist and Cullinane [5], VTI [49], COMPASS [9], ITTMA [27], ISL [26], Sweco [45], AMEC [1], VTI [50]). These studies are based on cost minimisation models that make a series of assumptions about the costs of different transport options and do not take into account certain factors such as the maximum capacity of rail transport. Our results are based, unlike the previous studies, on more intangible evidence in the form of statements by respondents. When they say they will shift from sea to land, they have taken into account company-specific factors such as the company's facilities and markets, what they produce, and the opportunity they have to change their existing structure.

Companies' different geographic positions of production facilities determine the extent of modal shift. The farther south in the country, the greater are the transfer effects. None of the

Table 7 Swedish forest industry exports and modal share of shipping

	Share of shipping of total export volumes		Export volumes (millions of tonnes)	
Year	Paper and pulp	Sawn timber	Paper and pulp	Sawn timber
2006	71 %	72 %	13.9	6.6
2007	66 %	77 %	13.9	5.9
2008	59 %	70 %	13.5	6.3
2009	71 %	65 %	13.1	6.4
2010	72 %	64 %	13.3	6.0
2011	73 %	61 %	13.1	6.1

Source: SFIF [36–41]

Table 8 Number of production facilities and total capacity within the Swedish forest industry 1980–2012

	1980	1990	2000	2010	2012
Number of paper mills	62	51	48	40	38
Total capacity (million tonnes)	7.2	9.5	11.1	12.1	12.2
Number of pulp mills	72	48	45	41	41
Total capacity (million tonnes)	10.5	10.9	11.7	13.1	13.3
Number of sawmills (prod >10 000 m^3/y)	283	260	207	150	135
Total production (million m^3)	11.2	12.0	16.4	17.0	15.8
Number of wood board prod. facilities	32	18	12	7	5
Total production (in 1000 m^3)	1193	843	933	702	654

Source: SFIF [41]

respondents could answer how large an amount of goods might be transferred, but we got the impression during the interviews that BillerudKorsnäs, Iggesund Paperboard, Holmen Timber, and Stora Enso were more likely to change structure than SCA Transforest. One explanation for this may be that SCA Transforest is a transport company operating mainly in shipping with existing logistics structures and their own vessels. They have therefore invested heavily in this logistical structure and to reduce or change it would be costly. Another reason may be SCA Transforest's geographic base in northern Sweden. This location causes problems with return loads for trucking and capacity problems with the railroad.

The advantage of rail transport, compared to road transport, is its high-volume capacity that provides competitive rates, primarily for large flows of goods over long distances. It seems that an increase of the proportion of rail shipment is of most interest for Iggesund Paperboard, BillerudKorsnäs, and Stora Enso. These companies produce largely pulp and paper products, which are already transported by rail to a large extent in the current situation [41].

A shift to rail transport does not seem to be an option for sawn timber. The latest figures show that only 0.3 % of the Swedish forest industry exports sawn timber by rail [41]. The reason for this, according to Johan at Holmen Timber, is that transport costs account for a larger share of the value of goods for sawn timber than for pulp and paper. Railway transport implies huge costs associated with handling, making door-to-door transport by truck a more cost effective alternative. Long shipping distances are required to compensate for the extra handling costs. As for sawn timber, a modal shift to road transport is more likely than to rail when the sulphur limits of 2015 are implemented.

Furthermore, the results of the interviews show that goods that are currently shipped from ports on the Swedish east coast to some extent will be moved by land-based transport to ports on the west coast and shipped from there instead. This solution will reduce the transport by sea within the ECA. Land transport through southern Sweden and further down in Europe, will also be utilised more, thus completely avoiding transport by sea within the ECA,

It is uncertain whether the amount of cargo through the Port of Gothenburg, the main port on the Swedish west cost, will increase or decrease. Knut at Stora Enso is convinced that the Port of Gothenburg will have less cargo because enterprises will transport overland through south Sweden all the way into Europe instead. Peter, Christina, and Johan on the other hand believe that it is difficult to tell for sure because the port is also likely to gain goods previously shipped out from ports on the Swedish east coast in order to reduce the time vessels spend in the ECA.

Stora Enso currently transports large amounts of goods by rail to the Port of Gothenburg, but plans to reduce the amount and instead transport by rail all the way to Europe. This is interesting because it is easy to believe that Stora Enso is locked into the existing structure with the use of SECU containers specifically designed for flow through Gothenburg [33]. To transport these larger containers in other countries is impossible because of their load profile. This will force Stora Enso to transport in regular standardised units, which they still believe will be beneficial compared to the current system.

Of the logistical alternatives to transport by rail or road for shipment from Norwegian ports such as Narvik and Trondheim mentioned by the NECL II [34] study, none seem to be viable options for any of the respondents due to lack of infrastructure connections and lack of capacity.

5.3 Logistics strategies and the sulphur directive

Clear strategies for Stora Enso, Holmen Timber, and BillerudKorsnäs are to not sign vessel transport agreements with shipping lines that extend beyond the year 2015. In the case of Iggesund Paperboard, only one contract extends slightly longer. We see this as a strategy to not be locked in when the uncertainties related to the upcoming regulation decrease and the attractiveness of the different alternatives becomes clearer. Companies have the possibility to write new contracts with shipping companies in the case that ship transport is still the most beneficial, and also have the ability to change the transport solution if that will be more beneficial. This is in combination with the fact that these businesses sign contracts with flexible rail solutions beyond 2015 that have the option to adjust transport volumes for different modes of transport depending on the situation in 2015 and beyond.

For SCA Transforest, the situation is different because they are a transport company that owns and charters vessels. Their strategy is instead to implement operational measures to reduce fuel consumption, attract and consolidate volumes, and charter larger vessels, and thus offset the cost increases. Similarly, Stora Enso is pushing their shipping lines to implement these actions.

Another strategy we have noticed is that companies unite in common carriers and transport solutions such as ScandFibre Logistics, which is owned by different forest companies. In this way, they collect and consolidate larger volumes, achieve economies of scale, and increase utilisation of transport solutions.

Respondents also mentioned scenario planning as an important strategic tool in which factors such as available capacity of land transport, ports and nodes, and fuel prices can be assessed. Just like Peter of BillerudKorsnäs explains, it depends on the combined cost image and how it changes and is evaluated.

Respondents have different opinions regarding the time at which a transfer of goods to land-based transport will occur. BillerudKorsnäs and Holmen Timber seem to have a “wait and see” approach while Stora Enso and Iggesund Paperboard have already begun transferring goods. Those who already transferred have thus decided that a change will be favourable despite uncertainty about future outcomes. The advantage of a “wait and see” approach is that the company is allowed to be flexible and change the transport structure. It depends also on the conditions for a rapid change of the transport structure within the company. The size of the transport flow is another important factor. For a group like Stora Enso, with large production volumes, it takes a long time to change the structure, resulting in the fact that strategic decisions related to modal shift must be taken earlier.

Another advantage of a “wait and see” strategy may be that future policy decisions may change the context. Any decision on state aid for the installation of scrubbers, LNG or methanol operation in Sweden would not have a significant impact by 2015. However, in the longer term, such subsidies could affect transport costs for shipping and thus a “wait and see” approach may be advantageous.

Because some companies have already begun a modal shift of goods, it is interesting to consider when the modal shift effect can be noticed in the system and what, if any, effect is left to be noticed in 2014/2015. Due to a gradual modal shift, the traffic work between the various modes of transport directly before and directly after the introduction of the stricter sulphur rules in 2015 will not be so substantial.

6 Conclusions

Our results show that the respondents are convinced that the shipping companies will to a very large extent switch to low-sulphur fuel (MDO/MGO) to comply with the sulphur directive. The increased fuel costs for shipping companies will be transferred to the forest industry in the form of higher transportation costs. Scrubbers, LNG, and methanol functionality are uncertain and best suited for newer vessels or new builds. Due to overcapacity of vessels in the market the introduction of new vessels will be low in the foreseeable future.

The results of our study also show that the respondents will transfer cargo to land-based modes of transport because of the sulphur directive. How much is uncertain, but there are indications that significant shares can be transferred between modes. Companies’ different geographic locations of production facilities determine the opportunities of modal shift to a large extent. In northern Sweden, goods are transferred to land only to a certain extent because of capacity problems with rail infrastructure. Goods shipped from ports on the Swedish east coast will be moved by land through Sweden and shipped from the west coast to a greater extent. Goods that are already shipped from ports on the west coast will to a larger extent be transported by land through southern Sweden and farther down into Europe. Ports on the west coast of Sweden will most probably gain market shares.

To depart from Norwegian ports, such as Narvik and Trondheim, in order to evade the ECA entirely does not seem to be a viable option in the current situation because of the geographical inaccessibility of respondents’ facilities and market position and uncertainty in infrastructure capacity.

A clear strategy for respondents to address the sulphur directive and uncertainty factors is to not write sea transport agreements with shipping lines that extend beyond the year 2015. However, they write flexible agreements with rail operators so they have the ability to increase the volume of goods depending on the future cost structure change.

For companies who own and charter vessels and are locked into this structure, it is difficult to make major changes. Their strategy is instead to implement operational measures to reduce fuel consumption, consolidate volumes, and rent larger vessels to achieve economies of scale. They can thus offset the cost increases associated with the transition to cleaner fuels. Some transfer to land transport is nevertheless possible.

At what point a transfer to land-based transport occurs differs between companies. Some have already started while others have a “wait and see” approach. It depends on the flexibility that exists and what volumes are involved. In the case of large volumes, it takes longer to transfer the goods.

Other strategies used are collaborations with competitors in order to consolidate volumes, upscale transport solutions, and increase the fill rates. The stricter regulations and associated effects on transport costs have increased the incentives for collaboration, and companies seem to be able to collaborate on logistics although they are competitors in many cases.

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