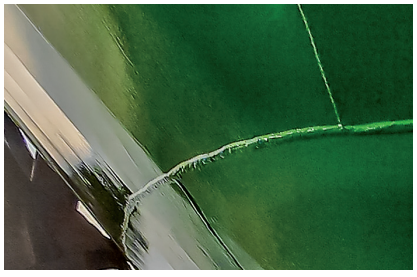
International Transport Forum

Decarbonising Maritime Transport

The Case of Sweden



Case-Specific Policy Analysis

OECD

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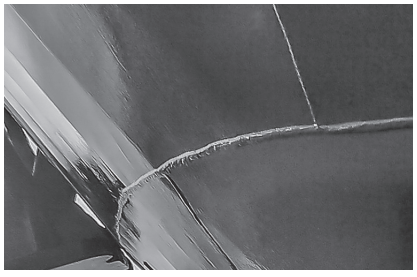

Case-Specific Policy Analysis

The International Transport Forum

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Case-Specific Policy Analysis Reports

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Executive summary

What we did

This report examines the factors that have put Sweden at the forefront of decarbonisation of maritime transport, and reviews how other countries could learn from this success story. It details Sweden's efforts to decarbonise its shipping industry as well as shedding light on remaining challenges and potential measures to achieve zero-carbon shipping. The analysis has particular relevance in the light of proposals to develop National Action Plans for the decarbonisation of maritime transport in the context of the International Maritime Organization's (IMO) Initial Greenhouse Gas (GHG) Strategy. As such, the analysis presented will be of use not only to policy-makers in Sweden but also to decision-makers in other countries seeking to reduce maritime GHG emissions. The analysis benefits from interviews with stakeholders, listed in the annex, conducted during study visits to Gothenburg and Stockholm.

What we found

The Swedish shipping industry has been very active in decarbonising shipping. Its industry association has formulated a target of zero-carbon shipping by 2050 and various Swedish shipping companies are pioneers in low-carbon shipping. The country now counts a number of innovative green vessels projects. Stena Line runs a ferry on methanol; Sirius Shipping has developed a ship-to-ship LNG bunkering vessel; numerous Swedish shipping companies - such as Terntank, Erik Thun and Rederi Gotland – have pioneered services with LNG-propelled vessels; and both HH Ferries and Green City Ferries have introduced electric ships.

This pro-active approach in Sweden is driven by an effective partnership of responsible shipping companies and shippers. Most Swedish shipping companies are family owned, and most shipping families are traditionally located in Donsö, a de facto maritime cluster that stimulates trust to cooperate in developing green and innovative ships. The interest of Swedish ship-owners in sustainability and innovation has been encouraged by large Swedish shippers, such as the energy company Preem, that are dedicated to green supply chains. This has resulted in partnerships between shippers and shipping companies that overcome barriers that have traditionally hampered progress in greening shipping. In particular the willingness of certain shippers to commit to long-term charter contracts with the new low-carbon ships seems to have been a main determining factor.

Sweden's progress can also be explained by stakeholder cooperation, some financial support and regulation. An exemplary case of stakeholder cooperation has been the "Zero Vision Tool", a platform for cooperation between shipping industry, government and the research community, to solve bottlenecks to greening maritime transport via specific pilot projects. This tool has made it possible to test possible solutions and share results with all relevant stakeholders, not only in Sweden but also in the Baltic Sea region. Some financial instruments, including EU assistance and the Norwegian NOx Fund, also helped ship-owners to invest in expensive but lower-carbon ships. Stricter regulations on sulphur emissions, such as the requirements in emission control areas (ECA), have further stimulated the demand for LNG-propelled ships that reduce sulphur emissions and – to a certain extent – carbon emissions.

Despite much progress, even in Sweden the decarbonisation of maritime transport is still at an early stage. More is needed if the sector wants to achieve its goal of zero-carbon shipping by 2050. The

major challenge is how to upscale current initiatives and obtain more finance and policy support, both nationally and globally.

The business case for low-carbon ships is not always very clear. Ship owners (and their financiers) wonder whether they will be able to recover the additional costs that they have to incur. Current financial frameworks do not value the external benefits of decarbonisation and sometimes apply a risk premium to unknown or untested technologies. Although the financial sector might eventually consider ships that run on heavy fuel oil as potential stranded assets (and add a risk premium for these ships), this is not yet the case. For a smoother transition towards a decarbonisation pathway, additional financial tools and incentives might need to be offered from both private and public finance.

The national government in Sweden has formulated ambitious decarbonisation targets. This ambition has not translated yet into a coherent and comprehensive decarbonisation strategy of the government for the shipping sector. In some cases, such as a recent reform of the fairway dues, government policy seems to be frustrating the development of low-carbon shipping.

Even if policies can move all Swedish shipping towards the level of the pioneers, the effect on global shipping emissions would still be marginal. Good practices thus need to be up-scaled globally for overall shipping GHG emissions to decline. Other countries can learn from Sweden that it is possible to move towards decarbonisation of maritime transport even when the global level of ambition is still undefined. Instruments such as the Zero Vision Tool could also be fruitfully applied in other countries to solve bottlenecks related to the decarbonisation of maritime transport.

What we recommend

Make available more financial tools and incentives to support the decarbonisation of shipping

The Swedish government could upscale financial tools and incentives to decarbonise maritime transport. Notably, it could facilitate a green ship financing instrument. It could also include decarbonisation in the mission of the state-owned shipping bank Skeppshypothek. A CO2 Fund for shipping could also be developed, analogous to Norway's NOx Fund. The government could also make the taxation system more favourable to decarbonising shipping, including in relation to electricity taxation.

Increase public policy support for decarbonisation of the maritime industry

The Swedish government could bring its shipping-related policies in line with its ambitious climate targets. For instance, it could introduce decarbonisation as a criterion in government procurement of shipping services, for example to remote islands and for urban public transport. It could also reconsider the recent fairway dues reform in order to increase incentives for green shipping and support platforms such as Zero Vision Tool to encourage stakeholder co-operation. Finally, it could stimulate an optimisation of supply chains, e.g. by better demand/supply matching via freight data from the Swedish Transport Administration.

Upscale best practices in maritime decarbonisation internationally

The Swedish government could make sure that the country's pioneering practices in decarbonisation of maritime transport are disseminated and used on a global level. For instance, Sweden could help improve supply chain efficiency by pushing for more vessel sharing through the use of HELCOM data. Sweden could also showcase national best practices internationally and submit proposals to the IMO that would help Swedish ship owners to decarbonise. It could also focus on stimulating outcome-driven regulation at the IMO level, similar to the approach that has delivered some of the achievements in Sweden. Finally, Sweden could push for a simplification of European Investment Bank (EIB) procedures for EU loans for low-carbon shipping.

Sweden: Pioneers in decarbonisation of shipping

Decarbonisation is a major challenge to the global shipping industry. Greenhouse gas emissions from shipping presented around 800 tonnes, 2.6% of total global emissions, which is the equivalent of emissions of a large country like South Korea. With maritime transport flows expected to grow, GHG emissions from shipping are projected to increase by 50-250% by 2050 (Smith et al., 2014). According to some studies the result could be that the share of global shipping emissions increases to 17%. Whereas the Paris Climate Agreement stipulates the ambition to reach temperature rise "below 2°C", shipping is not included in the scope of that agreement. Global shipping emissions are regulated by the International Maritime Organisation (IMO), but no emission target has yet been agreed within the framework of the IMO. An IMO Initial GHG Strategy for shipping is expected by April 2018 which will likely include targets and measures.

Sweden is one of the pioneers in decarbonisation of shipping. It is a country with a fairly small shipping sector: the Swedish Shipowners' Association currently counts 56 members that together own approximately 400 vessels, of which approximately 100 are flying the Swedish flag. This report will illustrate the pro-active role of Swedish shipping, assess main drivers of this decarbonisation process, analyse existing challenges and suggest policies that might help to sustain efforts for zero-carbon shipping. These policy recommendations are specifically aimed at Swedish policy-makers that want to increase the effectiveness of their policy interventions. The report could also be relevant for policy makers in other shipping nations, as the instruments that have contributed to Sweden's success might be rolled to other places. Current discussions at the IMO about the possibility of national action plans for decarbonisation of shipping that countries could submit to the IMO only increases the relevance of insights in possible interventions at the national level.

The pioneering spirit of Swedish shipping is evident from its commitment to decarbonisation, the green vessel projects that prove that the industry is serious about decarbonisation, green logistics initiatives and green policy innovations that have helped to move towards a decarbonisation pathway. This chapter describes these accomplishments.

Commitment of the shipping industry

The Swedish shipping industry has long expressed a strong commitment to decarbonisation. The "Climate Roadmap" of the Swedish Shipowners' Association (SSA), released in 2015, unambiguously states the ambition of zero CO_2 emissions and other harmful substances by 2050. This ambition builds upon adoption by the SSA in 2009 of the EU Maritime Transport Strategy 2009-18 that lays down the long-term objectives of zero-waste, zero-emission maritime transport. SSA's Climate Roadmap was also aligned to the climate strategy of the Swedish government. SSA's climate targets form part of a larger strategy, called Zero Vision, which includes objectives on growth, safety, innovation and sustainability.

The Swedish shipping industry stresses that decarbonisation of shipping is dependent on solutions in the whole logistics chain. Its "Climate Roadmap" formulates an intermediate goal, a 30% emission reduction by 2030 (compared to 2010 level), that can be realised with known technologies, mostly based on using better vessel technology, alternative fuels and other ship-based measures. However, it assumes that further reductions until 2050 would require new technologies and new logistics solutions. In this respect, it remarks that vessels need to be seen as parts of a larger maritime transport system, which in

turn is part of a larger logistics system (SSA, 2015). This means that not only vessel-related measures would be needed for the long-term emission reductions, but also a restructuring of the transport system, a different balance between delivery time and energy costs and increased collaboration between different stakeholders in the transport system. One of the platforms created to test new technologies for greener shipping is the Zero Vision Tool, which will be elaborated on later in this report.

The Swedish Shipowners' Association was one of the first shipping associations to commit to absolute emission reduction targets and it needs to be applauded for this. At this moment, there are only a few other ship-owners' associations in the world that have committed to similar targets. The global associations for ship-owners' have not committed to such absolute targets, e.g. the International Chamber of Shipping has proposed shipping emission reduction targets, but these are all relative targets: GHG emissions per tonne-kilometre.

Green vessel projects in Sweden

The strong decarbonisation commitment of Swedish ship-owners has translated into a range of innovative green vessel projects. Sweden is among the first countries with substantial uptake of LNG powered ships, ship-to-ship LNG bunkering ships, electric ships and methanol-powered ships.

A substantial share of the recent ship orders from Swedish ship-owners is in LNG powered ships. Swedish ship-owners have been at the forefront in introducing LNG-powered vessels in various shipping sectors. Terntank ordered four LNG-powered tankers, the first of which was delivered in 2015. Furetank converted a conventional tanker into a LNG/HFO dual fuel powered tankers. Erik Thun AB ordered and operates a LNG-powered ocean-going dry cargo vessel. Viking Lines operates the world's largest LNG-powered passenger ferry between Stockholm and Turku (Finland), which also happens to be the first LNG-powered vessel in the Baltic Sea. Main emission impacts of these LNG-powered vessels relate to local air pollutions, with emission reductions recorded of 83-96% for SO_2, 79-91% for NO_x and 80-84% for PM. Observed emission reductions in CO_2 equivalents are in the order of 23-24% (Zero Vision Tool, Pilot LNG Activity 7 Report). A LNG bunkering facility has been established in the port of Brofjorden, in which a pipeline and jetty were constructed to ensure the LNG terminal in the port could be used as a bunker facility for LNG-powered ships. The port of Gothenburg is also able to provide LNG bunkering. The Swedish ship-owner Sirius has been pioneering with LNG bunkering vessels - that can provide ship-to-ship bunkering.

Sweden is one of the first countries with electric ships. One of these is the ferry connection between Stockholm and Movitz, operated by Green City Ferries. The other recent example includes the ferry connection of HH Ferries Group between Helsingborg (Sweden) and Helsingor (Denmark), with two ships, the Tycho Braahe and the Aurora (Box 1). This project not only consisted in converting vessels into fully electric vessels, but also providing the charging infrastructure in the two ports. These ships have come into operation only very recently, so it is too early to assess their effectiveness. Other Swedish ship-owners, such as Stena, are also working on electric vessels, in particular for ferries over relatively small distances.

Stena Line is the first shipping company to have used methanol as ship fuel. They converted the Stena Germanica, a large passenger and car ferry vessel operating between Gothenburg and Kiel (Germany), into a methanol-powered vessel. The methanol used by the ship was supplied by Methanex, the largest methanol producer in the world, produced from natural gas. Stena operated the vessel with methanol for over a year. This pilot showed the technical viability of methanol as ship fuel (Box 2). The commercial viability depends on availability of methanol and the price gap between methanol and conventional ship fuel.

Box 1. Electric ferry between Sweden and Denmark

The project consists of both converting two diesel-electric HH Ferries (Tycho Brahe and Aurora) into the world's largest fully electric ferries to date and equipping the ports of Helsingør (Denmark) and Helsingborg (Sweden) with the first automated shore-side charging arms. The ferries operate on a 4-kilometre long route and can accommodate 1 100 and 1 250 passengers and 240 cars respectively, sailing around the clock, with an average journey time of 20 minutes. The investment amounts to SEK 300 million and the EU's INEA (Executive Agency for Innovation and Network) has provided a grant of SEK 120 million to the project, the rest being funded by HH Ferries. The Swedish-Swiss conglomerate ABB was in charge of supplying the complete power and propulsion systems. At both ends of the route ABB also supplied the automated shore-side charging stations using an ABB industrial robot, to optimise the connection time and therefore maximise the charging period. PBES designed the energy storage system to be integrated within ABB's solutions.

The project was successfully developed with the Tycho Brahe tested to start operations in mid-2017 and the Aurora to follow later in 2017. The two ships are the largest 100% electricly-powered Ro-Pax ships in the world. Both are hybrid: diesel-electric with the diesel engine from Wärtsilä as a backup for the electric engine. It is supplied by 640 lithium batteries placed in four 32-foot containers on top of the vessel between the two chimneys. The combined battery power of 8 320 kWh (4 610 kWh each) for the two ferries is the equivalent of 10 700 car batteries. The batteries must be charged with approximately 1 200 kWh every time the ferries are at port. This requires both automated charging and a unique cooling system for the lithium batteries. In Helsingør they have 5.5 minutes and in Helsingborg nine minutes to charge which is why the charging process has been fully automated in order to save time. The energy storage system embedded with a liquid cooling system is meant to provide a higher level of safety for customers and the ships have also been modernised to include energy storage control systems and on-board DC grid technology. The thermal management system constantly maintains optimal internal temperatures to maximise the lifespan of the battery.

Box 2. Methanol as ship fuel

Methanol could be one of the future marine fuels. Today, most of the methanol is produced from natural gas and has a CO_2 emissions reduction potential of around 25%, just like LNG. Compared with HFO, methanol has an emission reduction potential of 99% for SO_x, 60% for NO_x and 95% for PM. However, methanol can also be produced from renewable energy resources, such as CO_2 capture, industrial waste, municipal waste or biomass which reduces significantly its greenhouse impact. Methanol is available in large quantities and can be made out of a wide number of resources and there is a long history of transporting it, so experience in handling and operation already exists. Methanol is also convenient because it requires less important modifications to retrofit ships and bunkering infrastructure since it is similar to current fuels in several respects. It can be used in combustion engines that most ships are already equipped with. Regulation is less constraining because it is generally safer than conventional fuels and LNG. So far, methanol has been employed as a transportation fuel on a significant basis only for cars in China, where it is inexpensive and readily available and produced cheaply from coal thus having a negative GHG impact (IMO, 2016; Andersson and Marquez Salazar, 2015).

Sweden has been at the forefront of the development of methanol-powered ships. A pilot project was launched, with support from the EU Motorways of the Seas programme, to convert a Ro-Pax vessel into a methanol-powered vessel as well as the necessary facilities in ports and for bunkering. This project has led to the development of the Stena Germanica, a large passenger and car ferry operating between Gothenburg and Kiel. It is the first ship ever operating on methanol. Methanol used by the ship is supplied to Stena by Methanex, the largest methanol supplier in the world and is produced from natural gas so it does not achieve the full potential of CO_2 emissions it could achieve. The company partnered with Wärtsilä for engine retrofitting and installed new tanks on the bottom of the ship where void spaces at the bottom which was not possible for fuel, but is not risky for methanol. The company needs a pilot fuel to ignite the methanol (5% diesel and 95% methanol), which can be done for any large vessel. The conversion costed EUR 22 million, but Stena believes ship conversion will be much cheaper once it is applied to several ships at the same time, possibly around a third of that price. Stena believes methanol is the better alternative for medium- to longer-range routes and it is looking at ways in which to develop production based on biomass so that it fully achieves its greenhouse gases emissions reduction potential. The company has identified several potential sources for bio-methanol production in Sweden already. Through the project, the company has also developed a tool kit for ship conversion to methanol for others to be able to replicate their undertaking.

Green logistics

Swedish industries have innovated in providing green logistics solutions. One example is the triangular routes of many freight trains, to avoid the traditional empty backhaul problem. Another example comes from the wood industry; e.g. Södra engages in a system in which wood volumes are exchanged with other producers that are closer to end customers (Södra, 2016). In this way unnecessary transport movements are avoided. A similar approach is underlying the cooperation of tankers via the Gothia Tanker Alliance that allows for unloading or loading of the ship that happens to be closest to the location with demand for maritime transport services.

Green public policy innovations

Sweden is the first – and as far as we know – only country with environmentally differentiated fairway dues. This means that cleaner ships pay relatively lower fairway dues, whereas less clean ships pay relatively higher fairway dues. This system of environmentally differentiated fees has been operational since 1998. Although evaluations of its environmental impacts show mixed results, the system is unique in that all ships are covered by the polluter pays-principle. This is contrast to almost all "green" port fees that in essence consist of a rebate of regular port fees applied to just a fraction of the ships calling the port that happen to be green.

Sweden has been at the forefront of greening its ports sector. Swedish ports such as Gothenburg and Stockholm were among the first in the world to introduce shore power facilities that allow ships to use electricity from the grid and turn off their engines when at berth. This policy has been supported at the national government level by an exemption of the electricity tax for onshore power supply (Box 3). Swedish ports, such as Gothenburg, are now also at the forefront in stimulating LNG-propulsed ships, e.g. by LNG bunkering facilities and incentive schemes for LNG-propulsed ships.

Box 3. Exemptions of electricity tax for onshore power supply

Onshore power supply (OPS) in Sweden is exempted from the electricity tax that is applied for electricity uses that are not for business use, as it considers that ships using shore power does not constitute business use. These tax rates that should normally be paid are SEK 293 (EUR 33.94) per MWh or SEK 185 (EUR 21.43) per MWh in Northern Sweden. Instead, Swedish authorities apply SEK 50 (EUR 5.79) per MWh of electricity tax to shore-side electricity. So the reduction from the tax is about 98%. At the request of Sweden to provide an incentive for shipping companies to adapt ships and ports to develop shore power facilities, the European Union agreed to allow these exemptions on the grounds that it does not distort competition.

The Swedish authorities apply SEK 50 (EUR 5.79) per MWh of electricity tax to shore-side electricity. This tax rate is above the minimum rate of taxation for electricity as laid down in European Directive 2003/96/EC. Sweden will apply the reduced rate of electricity taxation to all supplies of shore-side electricity of at least 380 V to vessels used for commercial shipping of at least 400 gross tonnage. The limit is considered appropriate by the Swedish authorities so as to ensure that the absolute majority of vessels used in international traffic and larger vessels used in national traffic will be covered by the proposed reduction.

One of the policy innovations for better regulation is function-based regulation that has been applied to the shipping sector in Sweden. The idea is that the sector was over-regulated with very detailed rules and regulations that hampered flexibility and innovation of the sector. Function-based regulation consists of a few functional requirements, in addition to general advice and complementary information to give guidance when needed. This approach is applied in the Swedish Transport Agency's Regulations and General Advice on Ships in National Maritime Traffic (Transportstyrelsen, 2017)

Main drivers for decarbonisation

Sweden's pro-active role in the decarbonisation of maritime transport is driven by a powerful combination of innovative ship-owners and responsible shippers. Their constructive interplay is made possible by a wide range of platforms for stakeholder collaboration, the availability of financial support and regulation. This chapter assesses these drivers.

A tradition of shipping innovation

The Swedish shipping benefits from "cluster" effects that enhance its environmental innovation. A large part of the shipping industry is family-based; most of the shipping families live on the island of Donsö, close to Stockholm. This leads to knowledge spillovers usually associated with clusters: many of the ship-owners informally exchange with each other on technical innovations in ship design. Their links to the local economy and the marine environment have resulted in a high environmental consciousness that translates into willingness to pioneer environmental innovations in shipping.

This informal cluster effect is in some cases also transformed into more formal collaboration. An example of this is the Gothia Tanker Alliance, in which six different Swedish tanker companies work together, pooling their 32 vessels. In addition to functioning as a platform for vessel sharing and joint negotiation on port services, this alliance also acts as a pool for the design of new vessels. The main design characteristics of a new sustainable generation of tankers were developed together, leaving some room for individual ship-owners to add or delete features. Whereas development costs of new innovative vessels might be too high for small companies to cover, pooling resources to jointly develop spreads these costs.

Many of the innovations by Swedish ship-owners have also benefited from local knowledge and research. An example is the "catamiser" installed on the main and auxiliary engines of Terntank's tanker Tarnvag. This is a combined unit for waste heat recovery and NO_x reduction of exhaust gases, invented by the heat systems producer GESAB, based in Gothenburg. A remarkable amount of the shipping innovations applied by Swedish shipping companies have been developed in cooperation with local firms.

Responsible shippers

Swedish shippers have a highly developed sense of corporate responsibility. Many of Swedish leading companies, such as Volvo, IKEA, H&M and Tetra have formulated targets to reduce their carbon footprint, as well as companies from other Nordic countries such as Statoil and Skangas that regularly charter ships from Swedish ship-owners. This ambition also covers the decarbonisation of their supply chains and the transport movements that are related to these. Various large shippers monitor the CO_2 emissions related to the transport activities for which they are responsible. In many cases the focus is on road and rail transport; the monitoring of sea transport emissions is often rather approximate. However, many shippers indicated that this is on their radar screen of future priorities. Some large Swedish shippers have been driving the development of the Clean Shipping Index that aims at assessing the environmental performance of ships (Box 4).

Box 4. Clean Shipping Index

The Clean Shipping Index (CSI) was introduced in 2007 by the shipping industry and shippers in Gothenburg and western Sweden. The CSI is an online tool that provides a rating to each registered ship based on a range of environmental criteria to compare vessels' environmental performance. The scheme enables shipping companies and shippers to gain recognition for their environmental performance but also to secure economic opportunities on that basis. It is operated by the Clean Shipping Network which is composed of companies from a variety of sectors that make sure it develops and is applied properly. Members of the network are charged EUR 2 700 and meet several times per year to discuss strategic orientations and a full-time secretariat handles the daily operation and administration of the index.

The CSI is mainly directed at shippers and carriers, not as much to ports. As of 2017, 31 cargo owners (among which companies such as H&M, Philips, Volvo, Tetra Laval) are registered as well as 56 shipping companies with over 2 200 ships having a CSI rating. Companies from around the world use it though most remain based in Europe. Banks and investors can also use the rating to assess environmental performance when approving loans for the building of new ships. Though the scheme was not designed specifically as a tool for ports to develop incentive schemes, some do provide discounts on its base: the Port of Gothenburg in Sweden, the ports of Vancouver and Prince Rupert in Canada. The Swedish Maritime Administration will also use it to environmentally differentiate the national fairway dues from 2018 onwards.

Ship-owners have to answer a set of 25 questions about their operational environmental impacts that relate to five environmental impact categories: NO_x, SO_x and PM, CO_2, chemicals, water and waste. Information is recorded on a ship-by-ship basis and aggregated to a total carrier fleet score to determine average ratings per ship owner as well (also weighted in function of the number of registered ships). Third-party verification by accredited Classification Societies (such as DNV-GL, Bureau Veritas, Lloyd's Register) is required that for at least two vessels per carrier. Ship-owners bear theses costs themselves, as well as the ones related to providing data.

In 2017 a new scoring system was introduced. The CSI now gives each registered ship a rating ranging between 1 (CSI 1) and 5 (CSI 5) stars based on a number of points achieved. A total 150 points can be obtained with a maximum of 30 points for each of the environmental impact categories. The scheme is designed in such a way that ships only obtain points by going beyond existing IMO requirements.

- NO_x scores calculated based on how NO_x emissions from main and auxiliary engines relate to the standards (Tier I to Tier III) as set in the revised IMO MARPOL Annex VI, with the exception that between Tier II and III, two extra levels (respectively NOx performance 30% or 40% below Tier II levels) are included to reward different NO_x reduction techniques. Both pre- and post-combustion reduction techniques are rewarded and in case OPS is installed and used at all equipped ports a maximum score for auxiliary engines is granted.

- For SO_x and PM, the basis for scoring is the average SO_x content in fuels for main and auxiliary engines used during a running year (or the measured PM emissions for PM only). Scores can be obtained if the SO_x content in fuel, or in the treated exhaust gases, is lower than the global (IMO) standards for both main and auxiliary engines. Extra points are awarded to ships for using low-sulfur fuel in main engines, auxiliary engines, and/or boilers when navigating in port areas outside ECAs.

- For CO_2 emissions, scores are calculated by how well a vessel performs compared to a reference ship; the better it does, the higher the CSI score granted. Information required is the cargo carried, the distance travelled and the fuel consumption over 12 months. Operational factors are accounted for through estimates of engine load and payload factors. Depending on ship types there are several options for submitting CO_2 data: in grammes/ton-nm, in grammes/passenger-nm for cruise and passenger ships and in grammes per year/(transport work for freight + 0.7 × transport work for passengers) for Ro-Pax ships according to IMO's EEOI Guidelines; in grammes/TEU-km for container vessels according to the calculation formula of the Clean Cargo Working Group.

The role of shippers in greening maritime transport is crucial. This is particularly the case for shippers that also play a role as charterer of vessels. This is common in the energy sector, where companies charter ships from owners as they have enough cargo to transport on their own. In these situations, a common barrier that is mentioned in the literature is the existence of split incentives between owners and charterers. Owners will not invest in more energy efficient ships if they know that the benefits will accrue fully to the charterers. Unless charters are willing to share these benefits, owners will under-invest in greener ships.

One of the drivers of decarbonisation of Swedish shipping has been the support of shippers via favourable and long-term charter contracts. It is this long-term commitment that allowed ship-owners to order the ships, knowing that their risks would be covered. The Coralius from Sirius Shipping was facilitated by Skangas (Finnish) who agreed to a 15-year charter agreement. Preem and ST1 were willing to engage in long-term charters making it possible for Terntankers to order LNG-powered vessels. Shippers have also been supportive as regards the conditions of charters. Preem agreed to pay higher charter rates to compensate for higher costs related to greener vessels.

Stakeholder cooperation

The main platform for stakeholder cooperation on decarbonisation of shipping is a network that goes by the name of "Zero Vision Tool". Initiated in 2011 by the Swedish Shipowners' Association, this is a platform in which industry, governments and academia work together, supported by a small secretariat. The aim of the organisation is to achieve safer and more sustainable maritime transport (the Zero Vision) by formulating specific joint projects to solve bottlenecks. Three types of projects were defined: joint industry projects, joint university projects and joint authority projects. Around 160 companies have been involved in the platform, not only in Sweden, but in the whole Baltic Sea region via organisations like the Baltic Marine Environment Protection Commission (HELCOM).

The main accomplishment of Zero Vision Tool has been to channel energy and resources into pilot projects ranging from LNG bunkering, LNG-powered vessels to methanol-powered vessels. Financing has in many cases come from the EU Connecting Europe Facility (CEF). Main factors for the success of the Zero Vision Tool include its problem-driven, collaborative and bottom-up approach. Many of the successful projects in decarbonisation of maritime transport in Sweden have been facilitated by the Zero Vision Tool, and some of these projects might not have seen the light without it.

There is also a range of other business initiatives, in which the Swedish shipping industry is involved. One of these is the Haga Initiative, a network of companies that want to reduce carbon emissions. This initiative and similar initiatives serve the purpose of exchange between like-minded companies in different sectors that are dealing with similar issues, such as finance, technological and regulatory uncertainty.

Other initiatives, like Fossil-Free Sweden, aim to improve the interface between industry and government with regards to decarbonisation, by creating some sort of a one-stop shop that makes it easier for industry to canalise its visions on obstacles and challenges. Fossil-Free organises roundtables around common challenges and also sees a role for itself in story-telling. It has drawn up ten different roadmaps for different sectors, including one in which shipping is incorporated.

Financial support

Swedish ship-owners are dependent on banks and other financial institutions for financing new ships. As green ships are in many cases more expensive than existing conventional ships, they need to be

able to convince their financiers that they will be able to recover these additional costs. In the cases that were successful, determining elements were long-term commitments by charterers and additional financial support from the NO_x Fund and European Union, which we will treat below. In cases where upfront guarantees were absent or partially absent, banks were sometimes willing to take on some additional risk based on long-term relations of trust built up between the ship-owners and the bank.

Various Swedish ship-owners have been able to finance their green ships thanks to the Norwegian NO_x fund. The principle of the fund is that all ships operating in Norwegian waters pay a NO_x tax related to the NO_x emissions of the ship; part of these tax revenues are spent on innovative projects aimed at reducing NO_x emissions from ships (Box 5). Ship-owners and operators can apply for this financial support, also foreign owners that operate their ships in Norwegian waters. Various Swedish ship-owners indicated that approximately 80% of the additional costs of LNG ships related to equipment were covered by the NO_x Fund. These ship-owners were generally very happy with the speed and light administrative touch of procedures. Various innovative green ship-projects in Sweden were also funded by EU funds, in particular the Connecting Europe Facility, related to the Trans-European Networks for Transport (TEN-T).

Swedish ship-owners could not draw on financial support from the public sector in Sweden. There are no instruments similar to the Norwegian NO_x Fund. At the European level, ship-owners could use loan facilities from the European Investment Bank, but they hardly ever use these, as the procedures and requirements are considered too bothersome and outweigh the benefits.

Regulation of sulphur emissions

The 2015 sulphur regulation has made LNG-powered vessels a viable option for the Swedish ship-owners that operate mostly in emission control areas (ECAs). Since 2015, the maximum sulphur content allowed from ship exhausts is 0.1% in the four ECAs, including in the Baltic Sea. There are schematically three ways in which ship-owners and operators can comply with these new regulations: using low-sulphur fuels, scrubbers or LNG. Whereas LNG was not an attractive option in the past due to the generally higher costs, that picture has changed since the 2015 regulations. LNG can be an attractive compliance option compared to low-sulphur fuels or scrubbers, provided that these ships operate most of their time inside an ECA. Many of the LNG powered vessels referred to in earlier chapters were designed specifically to trade in the ECA.

Box 5. Norway's NO_x Fund

In 2007, the Norwegian Tax Administration introduced a NO_x tax applicable to domestic shipping emissions. It is levied on energy production from propulsion machinery (total installed capacity over 750 kWh), motors, boilers and turbines (total installed capacity over 10 MW), flares on offshore installations and land facilities as well as from waste incineration (since October 2010). The NO_x fund was created in parallel in 2008 so that companies can choose to pay a NO_x fee to the Fund instead of paying the NO_x tax (EUR 2.32 per kilo of NO_x emitted in 2017). Shipping and industry businesses affiliated to the fund pay EUR 0.5 and oil and gas producers pay EUR 1.5 per NO_x tonne they produce. Companies are exempt from the tax for a period of up to three years, but in return they commit to investigating investments required to reduce their NO_x emissions and to report back to the board of the fund every quarter (which is proof-checked by DNV-GL).

Funds collected this way are put into the NO_x fund which is administered by 15 business organisations that have signed the Environmental Agreement with the Ministry of the Environment for the period from 2018 to 2025 (as an extension of the two former agreements for 2008-10 and 2011-17). These member business organisations are exempt from the NO_x tax in return for their obligation to facilitate concrete NO_x reductions. Between 2011 and 2017, yearly emissions had to be reduced by 16 000 tonnes, with specific target reductions per year. In the new agreement, caps on

total NO_x emissions (from sources covered by the agreement) per year in Norway have been introduced for every two-year period. The cap for 2025 is 162 000 tonnes. The fund's support scheme is being reviewed with expected adjustments to come in the by 2018. Companies affiliated to the fund can apply for funding of up to 80% of the investment costs for emission reduction projects they want to implement. The Fund selects the most cost-effective projects and can also decide to support some operational measures. Its yearly budget is around EUR 80 million available to support NO_x reducing measures. Its total revenues from 2008 to 2016 have amounted to EUR 620 million. The Norwegian Pollution Control Authority oversees compliance to obligations set out each year. The agreement can be terminated if reductions achieved are more than 25% lower than the obligations set, which automatically leads to a termination of tax emptions effective from the following 1 January. If there is a deviation of more than 10% from the emission obligations for a given year, a collective sanction applies with companies in question requested to pay the NO_x tax for the percentage of the obligations to which the non-compliance applies.

The number of companies taking part in the fund has been steadily increasing since its creation in 2016, with 938 companies supporting it. It has enabled the reduction of NO_x emissions in Norway by 34 000 tonnes at the end of 2016. Shipping is by far the main source of emissions reductions. It is projected that in 2017, 60.3% of NO_x emissions reductions will be attributed to it, while 32.6% will be to the oil and gas industry. The NO_x fund remains focused on NO_x and provides little data on other emissions reductions. However, DNV-GL estimates that efforts of the NO_x Fund will have contributed to reducing annual CO_2 emissions by 670 000 tonnes at the end of the contract period in 2017 (Annual Report 2016, 2017).

The fund helped push the Norwegian fleet towards more sustainable forms of energy, contributed to advance technologies and to show others it is possible to run vessels cost-effectively without HFO on a significant scale. For instance, when the fund started in 2008, there were only three ships in Norway other than ferries using LNG to propel themselves but by 2015, the fund had granted support for 49 newbuilds and retrofits and there were 75 LNG-powered ships in Norway. Inevitably, greater adoption of green ship technologies will contribute to further emission reduction from all sources. The use of LNG-propulsed ships already leads to a reduction of 10-20% in CO_2 emissions (Lloyd's Register, 2012). The range of alternatives investigated through the NO_x Fund funded projects is growing with developments in battery technology, biodiesel that have a much larger impact on CO_2 emissions reduction than LNG does. Yet, NO_x emissions reductions related to these options remain very small for now (Annual Report 2016, 2017). The Norwegian government is also discussing the creation of a CO_2 fund modelled after the NO_x fund to focus specifically on reducing greenhouse gas emissions.

Norway benefits from strong business involvement and cooperation and from an already progressive environment, with early movers in the business sector driven by high consumer sensitivity and political support. Norway's economy also relies heavily on shipping and energy and would be strongly affected in case of regulatory changes, which can explain part of the reason its businesses are anticipating by getting involved to find solutions before others are. Therefore transitioning to LNG powered ships comes at a lower cost that in many countries and sustains the national energy market.

Challenges to shipping's decarbonisation

The main challenge to decarbonisation of shipping is the upscaling of current promising initiatives. How could the projects of today's frontrunners become tomorrow's new normal? How to upscale promising initiatives? This section identifies three avenues: finance, public policies and international policy development.

Finance for zero-carbon shipping

The successful examples in this report on low-carbon ships in Sweden were enabled by ship-owners who were willing to take risks or invest energy in mitigation of these risks. In order to upscale these examples, there would also need to be finance available for the ship-owners that do not have the same time or determination. In other words, the business case for green ships would need to be self-evident to a point that ship-owners would have a disincentive to invest in ships that are not green.

There is a growing awareness on fossil fuel-related stranded assets, that is: assets that have lost their value more quickly than foreseen due to the declining attractiveness of fossil fuels within the light of climate change agreements. Some ship finance institutions have warned that fossil fuel powered ships could quickly become stranded assets. Such a risk would translate into more difficulties to finance ships powered by fossil fuels, as banks and financial institutes will ask a risk premium to cover the risk that their loans for these ships become worthless.

In the longer term, the conditions for loans for zero-carbon ships will be more favourable than for ships powered on fossil fuels, considering their risk to become stranded assets. In the meantime, there might be a need to facilitate that transition, via favourable financial instruments. An example of such a favourable instrument is the bond programme developed by ABN AMRO Bank and the European Investment Bank (EIB). Similar programmes might also be developed by the shipping banks active in Sweden. Another possibility would be to publicly finance the gap between costs for a zero-carbon and conventional fossil fuel powered ship, e.g. via subsidies, national development banks or funds similar to the NO_x Fund in Norway.

A recurrent challenge for decarbonisation of shipping is the misalignment of fiscal policies with climate policies. Heavy fuel oil for ships is not taxed but generates huge negative externalities, whereas some of the alternative energy sources (e.g. electricity) with much less of these externalities are actually taxed. This complicates a massive transition from HFO to alternative fuels/energy.

Public policy alignment

Sweden has ambitious climate change targets. In June 2017, its government presented a climate law with a target of zero net greenhouse gas emissions by 2045, which was supported by seven of the eight political parties in Parliament. This law sets an emission pathway with intermediate targets and organises the follow-up of climate policy via the release of periodic reports to Parliament. It also establishes a climate policy council tasked with assessing whether government policies are compatible with the national climate objectives. In addition, the government has set up a special expert group to develop visions to achieve the government's targets called the Green Transition.

The Climate Law includes a sector-specific emission reduction target for domestic transport: 70% less CO_2 emissions in 2030 compared to 2010. This target does not specify which transport sectors should contribute to which share of the transport emission reductions. Yet, more than 90% of the domestic transport emissions in Sweden are from road traffic. The emission pathways underlying the targets suppose that emission reductions are reached via more energy efficiency, electrification, more bio-fuels and 25% lower transport demand. Domestic shipping is included in this target and a mode shift to coastal shipping could potentially play a role in decarbonising the domestic transport sector.

The current challenge is to translate this political ambition into a coherent strategy for the decarbonisation of shipping. As set out below, there are various areas of public policy that do not seem to be aligned with the political climate ambitions. Although only domestic shipping is covered by the national emission reduction targets – and this only represents a small share of the total national emissions – it can be assumed that the climate change mitigation ambition also extends to global shipping. There are various ways in which this ambition could be better reflected in government policies, including via public procurement, fairway dues, optimisation of supply chains and support for innovative shipping platforms.

Public procurement of shipping services does not systematically take decarbonisation into account. These are shipping services that are considered a public service, for example urban water transport in the Stockholm archipelago or to reach certain islands. There are good examples in this domain. The public procurement procedure for the maritime connection between Stockholm and Gotland incorporated GHG emissions; this – in combination with the 10-year duration of the contract – facilitated the order of LNG-propulsed vessels by Rederi Gotland AB that won that procurement that will decrease CO_2 emissions with around 20%. Yet, there are also public procurement procedures that do not take decarbonisation into account. The city of Stockholm is in charge of several intra-urban ferry services for which GHG emissions do not seem to be considered a priority.

Recent reform of the fairway dues reduces the extent of environmental differentiation. The reform, to be implemented 1 January 2018, consists of various changes. First, it introduces a broader set of environmental indicators: whereas the differentiation used to be based on NO_x emissions, the new fairway dues follow the scores of the Clean Shipping Index that takes not only NO_x emissions into account, but also SO_x, PM and CO_2 emissions, the management of chemicals on board, and waste management. A second change is the introduction of new elements in the charging, namely a passenger fee and a "preparedness fee". The result of these two changes is a more limited impact of environmental incentives, in particular the ones related to air pollution and decarbonisation. At the same time, the reform also increases the extent to which costs for the fairway system are covered by fairway dues. The consequence is a fairway due that is on average higher than the previous fee, e.g. Viking Line reported a likely increase for their vessels of 77% (Sjöfartstidningen, 2017). The perverse effect of the reform is that even the greenest vessels are confronted with an increase in fairway dues. According to an analysis of Trafikanalysis (2017) it cannot be excluded that the reform of the fairway dues will result in a mode shift from coastal shipping to trucking.

The public sector could help shippers and the maritime transport sector to achieve optimisation of supply chains. Shippers are already involved in ways to reduce inefficiencies in their supply chains, e.g. by the wood exchange described in an earlier section, that is: using a wood pile of a competitor that is closer to a client instead of using the firm's own wood pile that would incur more transport but would give a client basically the same product. Shipping companies also apply such systems, e.g. the Gothia Tanker Alliance. There is a lot of potential of reducing GHG emissions from smarter supply chains that reduce unnecessary transport movements. The public sector could help facilitate this; e.g. the Transport

Agency disposes of many data on transport good flows on a granular level that could help to reduce inefficiencies in transport supply chains.

The public sector could help sustain platforms that have been helpful in decarbonisation of shipping, such as the Zero Vision Tool. It is kind of ironic that this platform, which helped channel resources and energy towards decarbonisation projects in shipping, is disappearing at the same time that the Swedish government is stepping up its climate change ambitions. The Zero Vision Tool could play a useful role in the necessary roll-out of shipping innovations to a larger set of shipping companies.

International developments

The potential at the national level to reduce the GHG emissions of shipping has its limits. The reason is that the link between countries and the ships calling their ports is usually thin. Many ship-owners have registered their ships in open registries, so are not even subject to the rules of their national shipping registry. Even if Swedish ship-owners have registered a substantial share of their ships in Sweden, their behaviour is determined by national and international conditionalities. The role of national authorities should not be underestimated: there is a considerable amount of instruments at their disposal and this study pays tribute to these. The possible role of interventions at the national level is increasingly acknowledged, e.g. via the recent proposal for national action plans on decarbonisation of shipping that IMO member states could submit to the IMO and that could be part of their commitment to decarbonise shipping. Yet, there is only so much that states could do in isolation. An upscaling of good practices from the national to global level is necessary for a substantial reduction of GHG emissions to take place. So the challenge is to disseminate and upscale some of the good practices from Sweden internationally.

Policy recommendations: Upscaling what works

Upscaling Sweden's good practices would be required to achieve substantial GHG emission reductions from shipping. How could this upscaling be achieved? What are the policy recommendations for public policy-makers in Sweden that could help to achieve decarbonisation of maritime transport?

Financial tools and incentives

The Swedish government could upscale financial tools and incentives to decarbonise maritime transport. This could take the following forms:

- Help facilitate a green ship finance instrument. The government could for example create favourable conditions for financial instruments such as "Blue Bonds" that aim to channel private finance towards green shipping.
- Include decarbonisation into the mission of the state-owned shipping bank Skeppshypothek. Some proposals have been floated on how Sweden could initiate a national development bank that could stimulate green shipping. The same goal might be reached by revising the mandate of the state-owned Skeppshypothek and make it focus on financing initiatives aimed at zero-carbon shipping.
- Develop a CO_2 Fund for shipping, comparable to Norway's NO_x Fund. Such a proposal, as suggested by Statens energimyndihet (2017a), could help to upscale innovative solutions to decarbonise maritime transport.
- Guarantee that the taxation system is favourable to decarbonising maritime transport, e.g. the exemption of the electricity tax already in place for onshore power supply could be extended to the charging stations of electric vessels.

Support of public policy

The Swedish government could bring its shipping-related policies in line with its ambitious climate targets. This could take the following forms:

- Systematically introduce decarbonisation in government procurement of shipping services (e.g. to remote islands, urban public transport), including for decentralised levels of government. Long-term contracts for such services provide possibilities for the service provider to recover its investment in low-carbon shipping.
- Reconsider the reform of the fairway dues in order to increase incentives for green shipping.
- Support platforms such as the Zero Vision Tool.
- Stimulate optimisation of supply chains, e.g. by better demand/supply matching via freight data from the Swedish Transport Administration.

Disseminating best practices internationally

The Swedish government could make sure that Sweden's good practices in decarbonisation of maritime transport are disseminated globally and used as tools to achieve decarbonisation of maritime transport on a global level. This could take several of the following forms:

- Improve supply chain efficiency in the Baltic Sea area, e.g. by pushing for more vessel-sharing arrangements via HELCOM data, which would make it possible to avoid unnecessary transport movements, or avoid empty backhaul movements.
- Showcase Swedish best practices and submit proposals to IMO that would help Swedish ship-owners to decarbonise. Some of these best practices have been listed in this report and deserve further dissemination. As part of this upscaling of Swedish practices, the government could push for more outcome-driven regulation at the IMO level, similar to achievements in Sweden.
- In addition, the government might want to argue for simplification of procedures EIB for EU loans for low-carbon shipping, in order to increase the uptake by the shipping sector of these loans.

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Annex: Interviewed stakeholders

Angsell, Marina	Swedish Transport Agency
Ärlund, Joakim	Ports of Sweden
Axelsson, Svante	Fossil-Free Sweden
Back, Stefan	Swedish Confederation of Transport Enterprises
Backman, Fredrik	Preem
Berglund, Claes	Stena
Berglund, Pia	Swedish Shipowners' Association
Boholm, Karolina	Forest Industries Federation
Brödin, Henrik	Södra
Carlsson, Carl	Zero Vision Tool
Hermansson, Anders	Swedish Transport Agency
Höglund, Dick	Terntank
Johansson, Håkan	Rederi AB Gotland
Johansson, Lars	Skeppshypotek
Klingström, Anders	Ports of Sweden
Larsson, Jens	Port of Gothenburg
Larsson, Fredrik	Swedish Shipowners' Association
Lund, Fredrik	Thun Tankers
Sandersson, Mikael	Swedbank
Swahn, Magnus	Network for Transport Measures
Tormalm, Karina	Forest Industries Federation

International Transport Forum

Decarbonising Maritime Transport

The Case of Sweden

This report examines the factors that have put Sweden at the forefront of decarbonisation of maritime transport, and how other countries could learn from this success story. It details Sweden's efforts to decarbonise its shipping industry and sheds light on remaining challenges and potential solutions to achieve zero-carbon shipping.

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