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EFFORTS BY EUROPEAN PORTS TO IMPROVE THE SUSTAINABILITY OF THEIR OPERATIONS

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ABSTRACT

This paper examines how European seaports aim to improve the sustainability of their operations. This examination is approached with a literature search on the sustainability targets of ports, especially in Europe, and by reviewing the webpages of the ten largest European container ports. Based on this literature search and webpage review, limiting carbon dioxide (CO_2) and other greenhouse gas emissions seems to be a high priority in these ports. Limitation of CO_2 emissions is further investigated in the light of the Port of Helsinki's aim to become carbon neutral by 2035. Our analysis indicates that ports have a major role to play in the maritime transport sector's efforts to improve sustainability. However, this will require clear targets as the timeframe is long. Otherwise, efforts risk being focused on actions that merely push the problem around, like moving CO_2 emissions elsewhere or increasing other pollutants when CO_2 is cut. Besides concentrating on the organization and operations of ports, balancing subsidies for cleaner vessels with extra charges for more polluting ones could help motivate shipping companies to purchase new, cleaner vessels or acquire technological solutions to mitigate the harmful effects of existing ones.

Keywords: Port, Sustainable Supply Chain Management, EU Transport Policy, CO_2 Emissions

1. INTRODUCTION

Ports play a significant role in the economy of the European Union (EU), handling 75% of all international goods traffic. Within the EU, maritime transport carries 40% of all cargo. In 2011, the EU ports handled around 3.7 billion tons of goods, of which 70% were bulk, 18% container, 7% roll-on-roll-off (Ro-Ro) and 5% breakbulk traffic. (Veregge, 2013) Taking 2011 as the reference year, the volume of total goods is forecast to rise by 50% by 2030 (European Commission, 2013).

Growing environmental awareness among European citizens has forced both the public and private sectors to investigate the environmental effects of their decisions carefully. Carbon-footprint and ethical issues are important for a growing share of customers and increasingly hard for companies to overlook. In light of today's heavy emphasis on the ethical and environmental aspects of goods production, enterprises have adopted sustainable supply chain management (Dubey et al., 2017) practices, including improving the transparency of their supply chains and highlighting ethical and environmental issues like *Fairtrade*. The next logical step after ethical production is how goods are transported to consumers. For overseas products, sea cargo today is environmentally the best alternative for transporting goods to Europe, but how the goods reach the consumer from big European ports is then another multifaceted issue, and which ports are used is not irrelevant.

Port operations cause negative environmental impacts wherever they are, but ports are required to mitigate these impacts as best they can. How well they manage, and the size of their environmental footprint, gain importance as different enterprises seek to apply sustainable supply chain management principles and compare supply chain alternatives. As ports are important hubs in logistics chains, the choice of ports is a relevant factor for the entire chain. The first research question of this paper is therefore: How do European seaports aim to achieve the sustainability targets of the EU in their operations and maritime transport as a whole? In addition, we concentrate on the more specific research question: How is a port able to reduce the CO_2 emissions of maritime transport?

The paper is organized as follows: Following the introduction and an explanation of the methodology, we outline the background on port sustainability aims and targets by introducing the most relevant documents on the EU Commission's efforts and several studies relevant to the topic. This is followed by a summarized review of the webpages of the ten largest container ports. We then take a closer look at the Port of Helsinki's Action Plan to become carbon neutral by 2035, followed by an analysis of the ports' measures to improve their sustainability. The conclusions complete the paper.

2. METHODOLOGY

The methodology includes three phases: 1) a literature search of ports' sustainability targets, 2) a review of the webpages of the ten largest container ports in Europe, and 3) an evaluation of the Port of Helsinki's aim to become carbon neutral by 2035.

The purpose of the literature search was to identify European-level objectives for port sustainability improvements. The objectives were searched by examining the relevant directives related to waterborne transportation and ports. Next, the search covered different studies ordered by the European Commission or organizations related to ports or maritime transportation in Europe. The search also covered various types of articles on port sustainability issues. The results of the literature search are presented in section 3.

The webpage review aimed to ascertain how the ten largest container ports in Europe communicate their attempts at sustainability. The search covered English-language versions of public webpages of the selected ports and was conducted in April 2019. We looked for information relating to the port, any mentions of its sustainability targets, and how the port approaches environmental questions in general. The review material was collected mostly from the ports' annual and sustainability reports and from the environment, sustainability and news sections of their webpages. We also used search tools on the webpages to specify searches with more precise keywords such as environment, sustainability and various sustainability indicators. Throughout the search, we listed all the mentioned topics and examples of sustainability, what sustainability certificates the port has, and how the port monitors and measures its sustainability. The results of the webpage review are presented in section 4.

Based on the literature search and webpage review, limiting CO_2 and other greenhouse gas emissions seems to have high priority in ports. Many EU ports have set targets to decrease their CO_2 emissions in accordance with the general aims of the EU and its member states to become a carbon-neutral region by 2050 (European Commission, 2020). To find out what ports are doing to contribute to this target, we selected the Port of Helsinki for the single case study (Yin, 2013) of this paper. In this case study, a group of experienced scientists discussed with representatives of the Port of Helsinki their sustainability initiatives and evaluated the ambitious aims of the Port of Helsinki to become carbon neutral by 2035. The group of scientists consisted of four experts in maritime logistics management, ship technology, energy technology and economics, and climate change mitigation. The group evaluated the realism of the port's plans and the calculations of their Carbon Neutral Port Action Plan. This action plan and its analysis is presented in section 5.

Based on the literature search and review of webpages, it was possible to find out to what extent the European port industry is considering sustainability issues. The evaluation of the Port of Helsinki's Carbon Neutral Port Action Plan gave a deeper understanding of the port's opportunities and challenges related to improving the environmental sustainability of maritime transport. **Figure *1*** summarizes the used methodology and its relationship to the research questions.

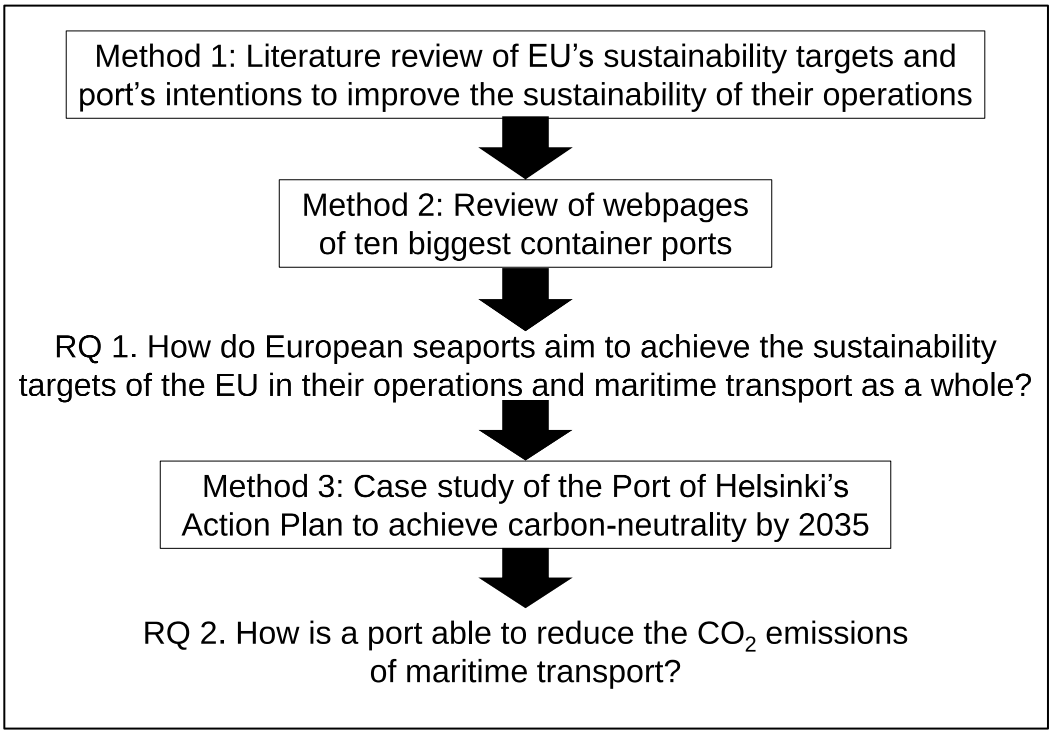

Figure 1. The methodology used and its relationship to the research questions

3. BACKGROUND OF EUROPEAN PORT SUSTAINABILITY AIMS AND TARGETS

The EU aims to increase the share of waterborne transportation, especially short sea shipping, as waterborne transport is considered to be the most environmentally friendly way to transport big volumes of cargo per cargo unit (European Commission, 2013). However, due to these large volumes, waterborne transport is responsible for 2.7% of total global CO_2 emissions (Mersin et al., 2019), which warrants consideration of the environmental impacts of this transportation mode. Moreover, without mitigation, it is estimated that the CO_2 emissions of shipping will reach 17% of total CO_2 emissions. Currently, shipping emissions are substantial even in ports, and in 2011 accounted for 18 million tonnes of CO_2 emissions, 0.4 million tonnes of NOx, 0.2 million tonnes of SOx, and 0.03 million tonnes of PM10 (Merk, 2014). Most of those emissions are estimated to grow fourfold by 2050 if current trends continue (Merk, 2014). Thus, to improve the sustainability of maritime transport, the European Commission has invited the member states and the European maritime industry to work together towards the long-term objective of 'zero waste, zero emissions' in maritime transport (European Commission, 2016). Adopting the principles of the circular economy concept helps approach this objective.

The circular economy concept refers to resource efficiency and sustainability, and it aims to keep products, equipment and infrastructure in use for longer (Invernizzi et al., 2020). According to the circular economy approach, waste can be turned into a resource by reusing, repairing, refurbishing and recycling existing materials and products (European Commission, 2014). The essence of circular economy in ports includes (Van Dooren and Braam, 2015):

- Minimizing the use of inputs and the elimination of waste and pollution;
- Maximizing the value created at each stage;
- Managing flows of bio-based resources and recovery of flows of non-renewable resources in a closed loop; and
- Establishing mutually beneficial relationships between companies within each circular chain.

The EU strives to minimize its dependence on oil and mitigate the environmental impacts of transport (European Commission, 2017). Besides, as energy trade continues to shift from oil and refined products towards gas, there is a growing need for gasification facilities in ports, including transport and storage of dry biomass and biogas (European Commission, 2013). According to Directive 2014/94/EU, member states should provide an appropriate number of liquified natural gas (LNG) refuelling points for maritime and inland waterway transport to enable ships to circulate throughout the TEN-T Core Network by 2025 (Directive 2014/94/EU, 2014). LNG must be stored cold (at around -160°C), which complicates its handling, maintenance and distribution and creates higher risk than traditional fuels. This requires new distribution and handling infrastructure and significant investments from both port authorities and ship owners. (European Commission, 2017). LNG could also be used in port machinery (Martínez-Moya et al., 2019).

For port machinery, there are also renewable energy sources that may replace the use of oil and gas. If electricity is used as an energy source and it is produced by using totally renewable energy like solar or wind power, it is possible to cut all CO_2 emissions. Hydrogen technology allows a 90% decrease of CO_2 emissions if hydrogen cells are used as an energy source, and biofuels enable a similar 90% reduction depending how these are produced. (Nylund et al., 2015)

According to ESPO/EcoPorts (ESPO, 2018), the ports' main environmental priorities include air quality, energy consumption and noise. These three priorities have topped the list, in the same order, in the last three surveys. The following priorities have also made the TOP 10 list every year for the last few years: relationship with the community, ship waste, water quality, port development (land), garbage/port waste, and dredging operations (not in 2016 report). The last two years have seen climate change added to the list, whereas dust has dropped off. Remarkably, although garbage/port waste is still on the most recent list, in tenth place, its significance has dropped in every report since 2004, when it was the top priority. (ESPO, 2018)

As a part of its 'Ports: an engine for growth' report, the European Commission suggested that ports become more active in improving the environmental image of waterborne transport by implementing an infrastructure-charging system that favours vessels fulfilling predefined environmental standards (European Commission, 2013). The European Commission has advanced this idea by contracting out a study on recommendations and guidelines on actions for port environmental charging (European Commission, 2017). Based on the ESPO/EcoPorts report, just over half of their survey respondent ports announced that they would offer different dues for greener vessels (ESPO, 2018).

In order to prevent vessels ditching their waste at sea, the European Directive 2000/59/EC stipulates that all ships stopping over at European ports must deliver their onboard waste to the port, unless they can prove the ability to store it until their next stopover port (European Directive 2000/59/EC, 2000). Based on the directive, the ports should set their waste tariffs according to vessel size and not the amount of waste, the tariff then being the same whether or not the vessels deliver their waste to the port (Pérez et al., 2017). However, based on a study funded by the European Maritime Safety Agency, different European ports have different systems, even within the same country. In some ports, charges increase with the amount of waste, while in others, financial sanctions are imposed for ships not delivering any waste (Ohlenschlager and Gordiani, 2012).

Summarizing the literature review from the port perspective, an important objective of EU transport policy has been to limit the negative environmental impact of ports (Pape, 2016). This impact has three sub-categories: i) problems caused by the port activity itself; ii) problems caused at sea by ships calling at the port; and iii) emissions from intermodal transport networks serving the port hinterland (Organisation for Economic Cooperation and Development (OECD), 2011). To address the first of these, the EU Commission has set emission standards for handling equipment and limits on permitted noise levels. Regarding the second category, a British study has demonstrated that emissions from shipping at berth are ten times greater than from a port's operations (Gibbs et al., 2014); the main question then is what the port can do about it. To address the third category, the EU Commission has set emission standards for vehicles used in hinterland transportation and is supporting investments in better road and rail infrastructure. (OECD, 2011; Pape, 2016). However, based on the paper by Acciaro et al. (2014), ports have been somewhat inactive in influencing the energy and emissions management of the shipping industry, but could take a more active role.

4. SUMMARY OF SEARCH RESULTS OF WEBPAGES BELONGING TO THE TEN LARGEST EUROPEAN CONTAINER PORTS

Our findings from searching the webpages of the ten largest container ports in Europe (see Table 1) were based on ESPO's (2018) environmental indicators and their prioritization in European ports. Therefore, we searched for information on the ten indicators considered the most important indicators in ESPO's survey. The environmental priorities listed in Table 1 are from the material available on their websites. For two ports, namely Algeciras and Gioia Tauro, we were unable to find on their webpages any material in English related to their sustainability.

Table 1: List of environmental priorities and the ports working on them.

	INDICATOR									
PORT	Air quality	Energy consumption	Noise	Relationship with the community	Ship waste	Port development	Climate change	Water quality	Dredging operations	Garbage / port waste
Rotterdam	x	x	x	x	x	x	x			x
Antwerp	x	x	x	x	x	x	x	x		x
Hamburg	x	x	x			x	x	x	x	
Bremerhaven	x	x	x	x	x	x	x	x	x	x
Valencia	x	x	x	x	x		x	x	x	x
Algeciras										
Felixstowe		x		x		x	x			x
Piraeus	x	x	x	x	x	x	x	x	x	x
Gioia Tauro										
Barcelona	x	x		x	x	x	x	x		x

Source: (Port of Algeciras, 2019; Port of Antwerp, 2019; Port of Barcelona, 2019; Port of Bremerhaven, 2019; Port of Felixstowe, 2019; Port of Gioia Tauro, 2019; Port of Hamburg, 2019; Port of Piraeus, 2019; Port of Rotterdam, 2019; Port of Valencia, 2019).

Based on ESPO (2018), European ports mention air quality as their number one environmental priority, and ports have numerous ways to approach this issue. Monitoring and smart monitoring networks, including weather stations, particle collectors and sensors for real-time data collection, were mentioned on most of the websites. Shoreside power supply, LNG networks and environmental discounts for clean vessels were also commonly mentioned. Use of green electricity and planning of hydrogen supply infrastructure were mentioned on some of the pages, and two ports (Antwerp and Rotterdam) reported using e-nose technology to detect odours from leaks or other environmental incidents. One of the ports (Hamburg) also mentioned a truck-tracking app for more efficient transport in-port, thus promoting air quality.

Energy consumption was mentioned as an important factor by most of the ports, with monitoring a key factor in developing more sustainable energy consumption. These ports also mentioned employee training, electrification of vehicles and patrol vessels, and improvements in lighting as practical examples. Many ports also reported a decrease in paper consumption, use of (electric) bikes in the port area and offering ECO calculators to clients as part of their energy consumption approach. A few ports mentioned promoting new technologies such as electrification of RTG cranes (e.g. Felixstowe), kinetic recovery container bridges (Hamburg), and piloting energy-neutral sea locks (Antwerp) as an important factor in cutting energy consumption in the port. One port (Hamburg) also mentioned that their electrically operated machines, vehicles and vessels are generally charged during green energy peaks.

The most common actions taken by ports to reduce noise-related harm included monitoring, static and predictive noise mapping and onshore power supply. Some of the ports also mentioned noise restrictions and port zoning as important factors. A couple of ports mentioned rail and road maintenance, and one port (Hamburg) reported using modern construction machines to mitigate noise-related impacts. One port (Hamburg) also reported imposing noise-dependent fees on railways.

Most of the ports considered relationships with the community to involve cooperation with local, national and international authorities and with other port and European bodies to standardize criteria and define environmental protection measures. Some of the ports mentioned working together in partner coalitions with NGOs and industrial, technological and regional stakeholders towards shared sustainability goals. Some ports also mentioned accessibility and openness to visitors and neighbours as part of the relationship with the community. One of the ports (Antwerp) mentioned special Greening Ambassadors as a way to enhance communication in the community.

The ports either offer vessels waste-handling services themselves or contract out external services in the port area. Four ports (Barcelona, Piraeus, Rotterdam and Valencia) mentioned that they regularly clean the waste from the port sea area. Depending on the port, this waste collection may concentrate on oil, plastics, or material raised from the seafloor by vessels' propellers.

Six ports mentioned rail transport connection improvements as their port connection development priorities, but other transport route development to and from ports was also mentioned. Six ports considered clean commuting to be important; thus, some of their transport route development efforts emphasized e.g. cycling routes and clean commutes by port workers and visitors rather than merely improving cargo transport connections. Emphasis was also placed on the energy efficiency of buildings, and in some cases enhancements of the port landscape were mentioned.

All eight ports that provide material concerning their sustainability intentions on their websites mentioned the objective of decreasing the carbon footprint of the port and its operations. Using renewable energy such as solar or wind power or non-fossil fuels such as biomass or biogas was most often mentioned as examples of how to achieve this. Some ports mentioned research and development efforts related to new, greener technologies or compensation of emissions and other environmental harm.

The most common efforts to improve water quality included monitoring and contingency plans to mitigate damage from possible leakages. Sea waste collection had already been mentioned as part of their ship waste handling approach. One port (Bremerhaven) mentioned the use of biocide-free underwater paint.

In order to decrease the negative environmental effects of dredging, especially on water quality, the ports mentioned e.g. using coordinated soil management concepts, recycling dredging material, and updates to their technologies and procedures.

Regarding port waste, most of the ports highlighted their recycling and reuse efforts and their attempts to separate hazardous waste, sort waste and use waste hierarchy principles. Sustainable procurement practices and land cleaning were also mentioned.

Based on the findings from the webpages, reducing energy consumption and lowering the carbon footprint was mentioned by all the ports that provide material on their sustainability efforts in English. The linkage of these two efforts is rather straightforward, as saving energy and favouring reusable energy will lower the carbon footprint. Even though in the ESPO (2018) report the ports had mentioned air quality as their number one environmental priority, most efforts related to air quality improvements would also have a positive effect on energy consumption and especially on the carbon footprint. For example, favouring vessels that are cleaner and able to use LNG as fuel has an instant positive effect on air quality, while at the same time lowering the carbon footprint. However, while improvements in air quality understandably benefit anyone in the vicinity of the port, changes in the CO_2 emissions of a single port will not be evident in everyday life in the short term.

Next, we take a closer look at the possibilities and efforts of ports to reduce their CO_2 emissions, using the Port of Helsinki as a single case study.

5. PORT OF HELSINKI'S MEASURES TO BECOME CARBON NEUTRAL BY 2035

The European Union has committed to reaching carbon neutrality by 2050 (UNFCCC, 2020). Many European ports, such as the Port of Rotterdam, have taken this aspect as a baseline to become carbon neutral by 2050 (Port of Rotterdam, 2019). Some ports have even more ambitious goals.

We examine the Port of Helsinki's aim to become carbon neutral by 2035 (Port of Helsinki, 2020a) as a case study for this paper, to find out what ports are able and willing to do to decrease their CO_2 emissions. The aim is described in the Action Plan that focuses on the Port of Helsinki's emissions. The Action Plan of the city of Helsinki (City of Helsinki, 2018) was published in November 2018, and that Action Plan worked as a baseline for creation of an Action Plan for the Port of Helsinki. The Port's Action Plan was finalized at the end of 2019 and evaluated during Spring 2020. The targets of the Port and the city of Helsinki are in line with Finland's national carbon neutrality target by 2035.

The Port of Helsinki is one of the biggest passenger ports in the world and the main port for foreign trade in Finland. In 2018, it was the second-largest passenger port in Europe, serving a total of 11.6 million passengers (Eurostat, 2020). Additionally, the port is a popular destination for international cruise ships, with around 600,000 passenger arrivals in 2019. In terms of combined liner and cruise passengers, the Port of Helsinki is the busiest passenger port in the world. It is also Finland's leading cargo port, with 14.4 million tonnes of goods transported through it in 2019 (Port of Helsinki, 2020b).

In 2018, CO_2 emissions at the Port of Helsinki were around 86,859 tonnes; 79% of the emissions are currently from vessel traffic, 7% from rubber wheel traffic, 9% from machinery, and 5% are the port's own emissions, including from acquired-on-shore power (Port of Helsinki, 2020a).

The Action Plan focuses on the Port of Helsinki's emissions. It also aims to affect other emission sources by cutting them by 30% by 2035. The year for comparison is 2015. Total emissions dropped by 3% from 2015 to 2018. According to the port's representatives, the purpose of the Action Plan is to ensure that emissions have really dropped, not just been transferred from the port to other actors.

For this reason, they do not intend to use emission compensations, as they believe it could demotivate the port from executing its development efforts and end up simply shifting the CO_2 emissions to other players. Nor do they wish to make decisions that remove emission problems by pushing them elsewhere. For example, imposing excessive surcharges for high-emission vessels could lead shipping companies to divert their vessels to other routes. Another risk is that vessels may, for instance, invest in battery technology and function on it while in port, then charge the batteries at sea using the vessel's engines that consume fossil fuels.

The greatest source of CO_2 emissions at the Port of Helsinki derives from its visiting vessels. The emissions are calculated from the point at which the vessel arrives in the port water area until the point at which it leaves the port's waters. Depending on the terminal, the port water area includes 1.5–4 km of fairways from the berths of the biggest vessels (Port of Helsinki 2020c). The Port of Helsinki aims to decrease CO_2 emissions from these vessels in the following ways:

1) The port is investing in shore power systems. The aim is for the majority of vessels at berth to use electricity provided by the port instead of from their engines. The Portensys calculation model estimates that a vessel is connected to shore power systems 80% of its time at berth, during which the vessel will not produce CO_2 emissions if the shore power is produced from renewable sources (Satamatieto, 2020).

2) The port is expanding its auto-mooring system, which recognizes an incoming vessel and enables faster mooring. This technology not only saves fuel, but especially allows scheduled passenger traffic to use the time saved to reduce their average cruising speed, which in turn has a positive effect on the vessel's fuel consumption at sea. A captain from the Tallink shipping line estimates that auto-mooring cuts an average of five minutes from each visit in port (Räsänen, 2020). Given that the scheduled length of travel between Helsinki and Tallinn is only two hours, every saved minute counts.

3) The port will offer biofuels for vessels. To motivate shipping companies to use biofuels, the port could possibly subsidize future biofuel use by paying part of the difference between the costs of fossil fuels and those of eco-friendlier biofuels. However, to what extent this is possible under EU competition laws is still under investigation.

4) The port is already offering LNG fuel. The downside, however, is that although LNG decreases CO_2 emissions, it releases methane, which traps 25 times more heat in the atmosphere than CO_2. Thus the overall impact of LNG could be even more harmful to the climate if the latest engine technology is not used.

5) The port is encouraging shipping companies to modernize their vessel fleet, as new vessels use less fuel and are better able to make use of the footprint-friendly solutions offered by the port.

Overall, the Port of Helsinki aims to reduce CO_2 emissions from vessels by 25% by 2035, compared to 2015 emission levels. Implementation of shore power systems will be the main method to achieve this, even though the Action Plan considers that the emission reduction estimated by the Portensys calculation model may be too optimistic.

To address CO_2 emissions from machinery, the Port of Helsinki has two approaches: 1) Encourage terminal operators to use biofuels by possibly paying part of the price difference between fossil fuel and biofuel, and 2) invest in charging infrastructure to enable terminal operators to adopt electric machinery. We also identified possibilities for using hydrogen cells. Based on our discussions with port representatives, we estimate that all three proposed energy sources will very likely be utilized, depending on the type of machinery and operator. Based on our evaluation and analysis, CO_2 emissions from machinery could be cut by 90% if biofuels or hydrogen fuel cells are used, and by 100% if electric machinery is used and the electricity is from a carbon-free source. With all three sources in use, along with the proposed actions, we estimate a possible reduction of CO_2 emissions from machinery of 95%.

Although the Port of Helsinki has limited possibilities to decrease CO_2 emissions from rubber wheel traffic, both Finland and the City of Helsinki have ambitious aims to cut these emissions by 60% by 2035. This should be achieved by increasing the share of rail transport, development of transport technologies, and stricter emission regulations of trucks (Andersson et al., 2020). The port believes that this development would also drop CO_2 emissions of rubber wheel traffic visiting the port by 60%. The port's development efforts include simplification of the gate system, which reduces idling of trucks by 30–90 seconds per visit, and implementation of the Truck Appointment System (TAS), which cuts truck waiting time. According to the literature, in the best possible scenario CO_2 emissions from trucks could drop by over 20% (Azab et al., 2017; Schulte et al., 2017) with TAS, but both the Port of Helsinki's and our estimation is a mere 1–5%.

The aim of reducing the Port of Helsinki's CO_2 emissions is first to decrease energy consumption as far as possible, then produce the remaining required energy from carbon-free sources. Based on our analysis of the Port of Helsinki, the biggest energy savings could be made by changing the lights to LED (seven actions), using heat pump technology for warming and cooling (four actions), and updating ventilation systems (four actions), because most of the energy consumption of the Port comes from these sources (Port of Helsinki, 2020d). Additionally, the port has plans (five actions) to install solar panels on the roofs of their buildings. Based on these investments, the port estimates that their CO_2 emissions will drop by 34%. According to our analysis of all 20 actions, we concluded that the reliability of this estimate is bolstered by the calculations having been based on products already on the market, and the literature also gives values for savings of these technologies (e.g. Koljonen et al., 2020). In many cases, the solution provider can even give some guarantee as to the savings obtained, as there are references to using these technologies. Of course, the exact saving percentage will depend on a number of factors including weather.

In total, the Port of Helsinki estimates that with the Action Plan, CO_2 emissions in the port area will be 32% lower by 2035 than in 2015. This is a weighted average of the following figures: Vessels 25%, machinery 95%, rubber wheel traffic 60%, and the Port's own emissions 100%.

6. ANALYSIS OF PORTS' INTENTIONS TO IMPROVE THEIR SUSTAINABILITY

Based on our webpage search, it seems that the majority of ports are aiming to decrease the harmful environmental impact of port operations in various ways and are putting in place related development efforts and plans. They are aware of their influence on the surrounding neighbourhood, of their part in the supply chain seeking to reduce emissions (e.g. by arranging smooth transition between sea and rail cargo), and as a workplace for thousands of people in the port area. However, based on our study, they seem to be focused largely on their operations and hinterland connections, with the vessel side receiving little attention. It also seems that some ports are reporting efforts that have a minimal effect on their total footprint, like reducing the use of printed paper. Focusing on unimportant details could indicate that the ports lack systematic sustainability plans.

The case of the Port of Helsinki highlighted the challenges of improving the sustainability of maritime transport. The port itself is making a serious effort through various developments, and if the will persists, it could well move towards carbon neutrality by 2035. However, looking at the wider picture, the environmental impacts of the port organization are rather small compared to all the impacts of vessel operations in particular. Landside transport and port operators may also have bigger environmental impacts than the port organization, as seen when comparing CO_2 emissions in the Port of Helsinki. The challenge then is how the port can influence other actors.

The shipowner side is the most challenging. Despite growing awareness of the negative environmental impacts of the shipping industry, influencing these issues has been difficult. For example, international shipping is not even mentioned in the Paris Agreement of the United Nations, which aims to reduce greenhouse gas emissions globally to a safe level (Traut et al., 2018). The International Maritime Organization (IMO) has started discussions with its member states on means to decrease CO_2 emissions (Joung et al., 2020). In order to achieve considerable savings in CO_2 emissions, new propulsion technologies need to be implemented in shipping on a large scale (Nguyen et al., 2020). However, the realization of these technological implementations can be slow and difficult, as they require considerable investments from shipping companies and the usage age of vessels is long (Walker, 2019; Joung et al., 2020). Besides, the shipping industry is poorly aware of methods to report its sustainability (Di Vaio et al., 2020).

The case study also showed why influencing other impacts is not an easy task. To help address the greatest environmental challenge—shipping vessels—the port should somehow be able to motivate shipping companies to invest in cleaner vessels and more eco-friendly technological solutions. Given the heavy competition in the logistics sector, shipping companies have limited willingness to make investments simply in order to operate in a more environmentally friendly way. In the case of the Port of Helsinki, such positive initiatives do exist thanks to the large share of passenger ferries on established routes and the environmental awareness of consumers.

Regarding freight vessels, however, consumer pressure is substantially less. The problem for a port in dealing with freight transport is that supply networks may opt for alternative ports if their operating costs rise due to additional charges for polluting vessels, or they may move the most polluting vessels to other routes. The port must achieve a balance between extra charges for the most polluting vessels and subsidies for cleaner vessels if they wish to motivate shipping companies to renew their vessel fleet. One important step that a port can take is to invest in new technological solutions, such as auto-mooring and shore power, to ensure that technically advanced vessels can benefit from these when visiting the port.

If a port has difficulties influencing emissions from vessels, the case study also showed that it will have limited possibilities to influence emissions by trucking companies. The Port of Helsinki is counting on general developments in the field, such as a growing share of rail transport, developing transport technologies, and stricter emission regulations for trucks. The results of the port's own development efforts—such as implementing systems that prevent queues and reduce waiting times—will remain modest unless there are ongoing concomitant efforts.

7. CONCLUSIONS

Ports play a major role in efforts by the maritime transport sector to improve sustainability. Based on their different ways of reporting sustainability issues, large European container ports vary in the way they consider environmental issues. However, air quality, energy savings and preventing climate change were mentioned as the key sustainability issues that ports concentrate on. Even if these issues belong to European Commission's long-term objective of 'zero waste, zero emissions' in maritime transport, based on the port's webpage reviews, the intensity of efforts to achieve the target varies considerably.

As the timeframe of development actions is long, especially what comes to achieving carbon neutrality, clear targets are required. Otherwise, development efforts risk being focused on actions that merely transfer the problem elsewhere. These pitfalls include e.g. cutting CO_2 emissions but pushing them elsewhere, or increasing other pollutants in place of CO_2. In addition to concentrating on the port's organization and operations within the port, there must be a balance between subsidies for cleaner vessels and extra charges for more polluting vessels. These could help motivate shipping companies to purchase new, cleaner vessels or to acquire the technological solutions that mitigate the harmful environmental effects of their existing fleet.

As there are differences in the way EU regulations and targets are met, there is a need to harmonize practices within the EU area. Otherwise, some ports may gain an (economic) competitive edge by slipping in their environmental commitments. Common environmental standards and approaches by European ports will also have more substantial influence on shipping lines' investments in new, more environmentally friendly technologies, as it will no longer be possible to select ports that allow less environmentally friendly vessels to operate.

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REFERENCES

Acciaro, M., Ghiara, H., & Cusano, M. I. (2014). Energy management in seaports: A new role for port authorities. Energy Policy, 71, 4-12.

Andersson, A., Jääskeläinen, S., Saarinen, N., Mänttäri, J., & Hokkanen, E. (2020). Road map for fossil-free transport – Working group final report. Publications of the Ministry of Transport and Communications. 2020:18. (In Finnish) https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/162516/LVM_2020_18.pdf?sequence=1&isAllowed=y. Accessed 29 November 2020.

Azab, A., Karam, A., & Eltawil, A. (2017). Impact of collaborative external truck scheduling on yard efficiency in container terminals. In International Conference on Operations Research and Enterprise Systems (pp. 105-128). Springer, Cham.

City of Helsinki. (2018). The Carbon-neutral Helsinki 2035 Action Plan. https://www.hel.fi/static/liitteet/kaupunkiymparisto/julkaisut/julkaisut/HNH-2035/Carbon_neutral_Helsinki_Action_Plan_1503019_EN.pdf. Accessed 29 November 2020.

Di Vaio, A., Varriale, L., Lekakou, M., & Stefanidaki, E. (2020). Cruise and container shipping companies: a comparative analysis of sustainable development goals through environmental sustainability disclosure. Maritime Policy & Management, 1-29.

Directive 2000/59/EC. (2000). Directive 2000/59/EC of the European Parliament and of the Council of 27 November 2000 on port reception facilities for ship-generated waste and cargo residues - Commission declaration. https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex:32000L0059. Accessed 10 April 2019.

Directive 2014/94/EU. (2014). Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0094&from=EN. Accessed 27 September 2018.

Dubay, R., Gunasekaran, A., Papadopoulos, T., Childe, S.J., Shibin, K.T. & Wamba, S.F. (2017). Sustainable Supply Chain Management: framework and further research directions. Journal of Cleaner Production, Vol. 142, pp. 1119-1130.

ESPO. (2018). https://www.espo.be/media/ESPO%20Environmental%20Report%202018.pdf

European Commission. (2013). 'Ports: an engine for growth'. COM/2013/0295, 23.05.2013, Brussels.

European Commission. (2014). The circular economy: Connecting, creating and conserving value. Publication Office, Brussels. http://www.eesc.europa.eu/resources/docs/the-circular-economy.pdf. Accessed 27 September 2018.

European Commission. (2016). COMMISSION STAFF WORKING DOCUMENT on the implementation of the EU Maritime Transport Strategy 2009-2018. https://ec.europa.eu/transport/sites/transport/files/swd2016_326.pdf. Accessed 3 April 2019.

European Commission. (2017). Study on differentiated port infrastructure charges to promote environmentally friendly maritime transport activities and sustainable transportation. CONTRACT MOVE/B3/2014-589/SI2.697889, FINAL REPORT. https://ec.europa.eu/transport/sites/transport/files/2017-06-differentiated-port-infrastructure-charges-report.pdf. Accessed 3 April 2019.

European Commission. (2020). Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing the framework for achieving climate neutrality and amending Regulation (EU) 2018/1999 (European Climate Law). https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1588581905912&uri=CELEX:52020PC0080 Accessed 4 August 2020.

Eurostat. (2020). Maritime ports freight and passenger statistics. https://ec.europa.eu/eurostat/statistics-explained/index.php/Maritime_ports_freight_and_passenger_statistics#Increase_in_seaborne_goods_and_passengers_in_EU_ports.

Gibbs, D., Rigot-Muller, P., Mangan, J. & Lalwani, C. (2014). The role of sea ports in end-to-end maritime transport chain emissions. Energy Policy 64, 337-348.

Invernizzi, D.C., Locatelli, G., Velenturf, A., Love, P.E., Purnell, P., & Brookes, N.J. (2020). Developing policies for the end-of-life of energy infrastructure: Coming to terms with the challenges of decommissioning. *Energy Policy*, 144, 111677.

Joung, T.-H., Kang, S.-G., Lee, J.-K. & Ahn, J. (2020). The IMO initial strategy for reducing Greenhouse Gas (GHG) emissions, and its follow-up actions towards 2050. Journal of International Maritime Safety, Environmental Affairs, and Shipping, 4 (1), 1-7.

Koljonen, T., Aakkula, J., Honkatukia, J., Soimakallio, S., Haakana, M., Hirvelä, H., Kilpeläinen, H., Kärkkäinen, L., Laitila, J., Lehtilä, A., Lehtonen, H., Maanavilja, L., Ollila, P., Siikavirta, H., & Tuomainen, T. (2020). Hiilineutraali Suomi 2035 - Skenaariot ja vaikutusarviot. VTT Technical Research Centre of Finland. VTT Technology No. 366. (In Finnish) https://doi.org/10.32040/2242-122X.2020.T366. Acessed 29 November 2020.

Martínez-Moya, J., Vazquez-Paja, B., & Maldonado, J. A. G. (2019). Energy efficiency and CO2 emissions of port container terminal equipment: Evidence from the Port of Valencia. Energy Policy, 131, 312-319.

Merk, O. (2014). Shipping Emissions in Ports. Discussion Paper No. 2014-20. International Transport Forum. https://www.itf-oecd.org/sites/default/files/docs/dp201420.pdf. Accessed 3 April 2019.

Mersin, K., Bayirhan, İ., & Gazioğlu, C. (2019). Review of CO2 emission and reducing methods in maritime transportation. Thermal Science 23 (6), 2073-2079.

Nguyen, H.P., Hoang, A.T., Nizetic, S., Nguyen, X.P., Le, A.T., Luong, C.N., Chu, V.D. & Pham, V.V. (2020). The electric propulsion system as a green solution for management strategy of CO2 emission in ocean shipping: A comprehensive review. International Transactions on Electrical Energy Systems, e12580.

Nylund, N.O., Tamminen, S., Sipilä, K., Laurikko, J., Sipilä, E., Mäkelä, K., Hannula, I. & Honkatukia, J. (2015). Appendix 9. How to Reach 40% Reduction in Carbon Dioxide Emissions from Road Transport by 2030: Propulsion Options and their Impacts on the Economy (VTT). https://www.doria.fi/bitstream/handle/10024/162111/Tieliikenteen%2040%20hiilidioksidip%c3%a4%c3%a4st%c3%b6jen%20v%c3%a4hent%c3%a4minen%20vuoteen%202030%20K%c3%a4ytt%c3%b6voimavaihtoehdot%20ja%20niiden%20kansantaloudelliset%20vaikutukset%20%28VTT%20Oy%29.pdf?sequence=1&isAllowed=y. Acessed 29 November 2020.

OECD. (2011). Environmental Impacts of International Shipping: The Role of Ports. OECD Publishing. http://dx.doi.org/10.1787/9789264097339-en. Accessed 4 April 2019.

Ohlenschlager, J.P. & Gordiani, G. (2012). Final Report of EMSA Study on the Delivery of Ship-generated Waste and Cargo Residues to Port Reception Facilities in EU Ports. EMSA/OP/06/2011.

Pape, M. (2016). EU port cities and port area regeneration. European Parliamentary Research Service. http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/593500/EPRS_BRI(2016)593500_EN.pdf. Accessed 10 April 2019. Accessed 5 August 2020.

Pérez, I., González, M.M. & Jiménez, J.L. (2017). Size matters? Evaluating the drivers of waste from ships at ports in Europe. Transportation Research Part D 57, 403-412.

Port of Algeciras. (2019). http://www.apba.es/en/. Accessed 18 April 2019.

Port of Antwerp. (2019). https://www.portofantwerp.com/en. Accessed 18 April 2019.

Port of Barcelona. (2019). http://www.portdebarcelona.cat/en/. Accessed 18 April 2019.

Port of Bremerhaven. (2019). https://bremenports.de/en/. Accessed 18 April 2019.

Port of Felixstowe. (2019). https://www.portoffelixstowe.co.uk/. Accessed 18 April 2019.

Port of Gioia Tauro. (2019). http://www.portodigioiatauro.it/porto-gioia-tauro/storia/?lang=en. Accessed 18 April 2019.

Port of Hamburg. (2019). https://www.hafen-hamburg.de/. Accessed 18 April 2019.

Port of Helsinki. (2020a).Carbon-neutral Port of Helsinki. https://www.portofhelsinki.fi/en/port-helsinki/sustainable-port-operations/carbon-neutral-port-helsinki Accessed 7 August 2020.

Port of Helsinki. (2020b). PORT OF HELSINKI PORT STATISTICS 2019 (9.1.2020). https://www.portofhelsinki.fi/sites/default/files/attachments/12%20Traffic%20in%20the%20Port%20of%20Helsinki%2C%20December%202019.pdf. Accessed 5 August 2020.

Port of Helsinki. (2020c). The map of all Port areas. https://www.portofhelsinki.fi/sites/default/files/attachments/Helsingin%20Satama%20Oyn%20KAIKKI%20ALUEET_ETRS_GK25.pdf. Accessed 29 November 2020.

Port of Helsinki. (2020d). Energy efficiency. (In Finnish). https://www.portofhelsinki.fi/energiatehokkuus. Accessed 29 November 2020.

Port of Piraeus. (2019). http://www.olp.gr/en/. Accessed 18 April 2019.

Port of Rotterdam. (2019). https://www.portofrotterdam.com/en. Accessed 18 April 2019.

Port of Valencia. (2019). https://www.valenciaport.com/en/. Accessed 18 April 2019.

Prokopowicz, A.K & Berg-Andreassen, J. (2016). An evaluation of current trends in container shipping industry, very large container ships (VLCSs), and port capacities to accommodate TTIP increased trade, 6th Transport Research Arena, Warsaw, April 18-21, 2016.

Räsänen, A. (2020). Helsingin Satama auttaa laivoja vähentämään päästöjä Itämerellä. (In Finnsh). https://www.portofhelsinki.fi/verkkolehti/helsingin-satama-auttaa-laivoja-vahentamaan-paastoja-itamerella. Web-magazine of Port of Helsnki. 23.4.2020. Acessed 29 November 2020.

Satamatieto, (2020). https://www.satamatieto.fi/?lang=en. Acessed 29 November 2020.

Schulte, F., Lalla-Ruiz, E., González-Ramírez, R.G. & Voß, S. (2017). Reducing port-related empty truck emissions: a mathematical approach for truck appointments with collaboration. Transportation Research Part E: Logistics and Transportation Review 105, 195-212.

Traut, M., Larkin, A., Anderson, K., McGlade, C., Sharmina, M. & Smith, T. (2018). CO2 abatement goals for international shipping, Climate Policy 18 (8), 1066-1075.

UNFCCC. (2020). Long-term low greenhouse gas emission development strategy of the EU and its Member States. https://unfccc.int/documents/210328 Accessed 6 August 2020.

Van Dooren, N. & Braam, G. (2015). What flows to focus on? Examples of resource mapping in Rotterdam Harbour area. The Netherlands as a Circular Hotspot: Transitioning chains. Powerpoint Presentation. Available at: http://www.green-alliance.org.uk/Opening_up_new_circular_economy_trade_opportunities.php. Accessed 27 August 2020.

Veregge, A. (2013). "EU-Hafenpaket: gemischtes Echo." ITJ International Transport Journal, 23/26, 19.

Walker, T.R. (2019) Why decarbonizing marine transportation might not be smooth sailing. Phys.org, May 17. Available at: https://phys.org/news/2019-05-decarbonizing-marine-smooth.html Accessed 24 August 2020.

Yin, R.K., 2013. Case Study Research: Design and Methods. Sage Publications, CA, USA.

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