NTRANS
Norwegian Centre for Energy Transition Strategies

FME Forskningssenter for miljøvennlig energi
Norges forskningsråd

Implementing measures for environmental sustainability: barriers and drivers in Norwegian ports

Kristin Ystmark Bjerkan[1,2,*], Lillian Hansen[1], Hanne Seter[1] & Markus Steen[3]

[1]Department of Mobility and Economics, SINTEF Community
[2]Department of Interdisciplinary Studies of Culture, NTNU
[3]Department of Technology Management, SINTEF Digital
[*]Corresponding author: kristin.ystmark.bjerkan@sintef.no

Working paper 03/21

ISBN 978-82-93863-08-3

Highlights

- Survey targeting the experience of Norwegian ports with sustainability measures
- Low voltage shore power is the most implemented technology in Norwegian ports
- Knowledge, pressure from owner and economy especially important enablers of implementation
- Port sustainability efforts to date have mainly been incremental
- More stringent policies and requirements will be needed for radical change

Abstract: Despite extensive literature on port sustainability, research has so far neglected to explicitly investigate the empirical experiences with implementing measures that improve ports' environmental sustainability. This study abates this deficiency by investigating what measures Norwegian ports implement to improve their environmental sustainability and what drivers and barriers they associate with such implementation. We rely on a quantitative survey among 96 Norwegian ports, and find that 82 % of ports have implemented at least one measure to improve environmental sustainability. Most prominent is shore power, followed by increased energy efficiency. We find support from owners and surroundings to be prominent in sustainability efforts and that political governance and steering from port owners are important drivers. This study invites further research to present complementary empirical accounts and studies targeting sustainability efforts in different port contexts. This study calls for the port community to more strongly raise port sustainability on the political agenda.

Keywords*:* implementation, port, sustainability, technologies

1. Introduction

As stated by former Executive Secretary of the UNFCC, Christina Figueres, ‘ports are connecting nodes of global trade and world economy. There is no way that we can move this world towards sustainability without ports’ (World Ports Sustainability Program, 2018). Port authorities are experiencing increased pressure to address the negative environmental impacts of their own operations, as well as the operations of their customers and other stakeholders in and around ports (Lawer et al., 2019, Lozano et al., 2019). This has compelled ports to increasingly implement measures to improve environmental sustainability. This study addresses the implementation of solutions that enhance the environmental sustainability (hereafter: sustainability) of ports. In doing so, we fill a gap in the scholarly literature on port sustainability, which rarely reports empirical findings or experiences with implementing sustainability measures, especially beyond large frontrunner ports (Bjerkan and Seter, 2019). Research has also insufficiently investigated drivers and barriers associated with the implementation of sustainability measures in ports. This is recognised by the International Maritime Organization (IMO), which has called for more documented experiences of sustainability measures in different types of ports (see GloMEEP, 2018).

Thus, there is limited knowledge about the implementation of sustainability measures in ports in general, and in small and medium-sized ports in particular. This study therefore takes an exploratory approach to address these shortcomings. More specifically, we aim to provide new insights into actual sustainability efforts in ports, including how they have been fostered and encouraged, and to document barriers to such efforts. We therefore ask: *What characterises sustainability efforts in Norwegian ports and what drivers and barriers are associated with such efforts?*

We answer these questions by analysing data from a 2020 survey conducted among 96 Norwegian ports, comprised of a heterogeneous sample in terms of port size, ownership, and markets, representing approximately 26% of ports nationally. The analyses display what measures ports have implemented, what drivers and barriers are related to their sustainability efforts in general, and what drivers and barriers are associated with the implementation of specific measures.

When presenting and discussing the results from our study we will refer to the respondents as 'ports'. This refers not to the geographical confines of port activities, but rather to ports as actors and port management organisations. As the sample also includes private ports with no public authority, we consider it more precise to use 'ports' than referring to 'port authorities' and simpler than referring to 'port management organisations'.

The remainder of the paper is structured as follows. In Section 2 we present the case for studying the implementation of sustainability measures in ports and review scientific literature on sustainability efforts in ports. Our research setting, methods and data are described in Section 3. We present our results in Section 4, before they are discussed in Section 5. Section 6 presents our conclusions.

2. Implementation of environmental sustainability in ports

Pressure to improve the environmental footprint of transport and logistics operations is mounting worldwide. More pointedly, there is a growing sense of urgency to reduce greenhouse gas (GHG) emissions, as reflected in the 2015 Paris Agreement and in the United Nation's Sustainable Development Goals (SDGs). These developments are certainly impacting ports and key transport sectors, as seen in the IMO (2018) GHG reduction strategy and in different national policies. Norway is a case in point, as the current government aims to reduce GHG emissions from domestic shipping and fisheries by 50% in 2030 (Norwegian Ministry of Climate and Environment, 2019).

The transport system is therefore under strong pressure to reduce its emissions. In shipping, which along with aviation and heavy-duty transport (Sharmina et al., 2020) is considered a hard-to-abate sector (Energy Transitions Commission, 2020), environmental upgrading has mainly occurred through improved energy management and efficiency, as well as the introduction of end-of-pipe solutions such as marine scrubbers. However, to significantly reduce emissions it relies on the development and implementation of alternatives to conventional marine fossil fuels, and the greening of shipping is likely to require a mix of different low- and zero-carbon fuels and energy carriers (Steen et al., 2019). Onshore transport is also experiencing a shift from fossil fuels towards a mix of conventional and alternative low- and zero-carbon fuels and energy carriers (Dominković et al., 2018, Fridstrøm et al., 2018). Although electric mobility has gained foothold in some countries (e.g., IEA, 2020), the feasibility of decarbonisation options and strategies vary across regions and countries, leading the global share of alternative fuel vehicles to represent just 4.4% of the total number of vehicles in circulation in 2017 (Mohammed et al., 2020).

As nodes in transport systems, ports are required to assess these developments and their own role in shaping them. Ports are increasingly aware of the need to address environmental issues and environmental demands from customers, port users, policies and regulations (Loorbach and Geerlings, 2017, Bosman et al., 2018). This includes considering investments in infrastructures for various fuels, energy carriers and energy services, and rethinking the role of ports as integrated energy hubs for both sea and onshore transport that facilitate energy distribution (i.e., bunkering and charging) as well as production and conversion of fuels and energy carriers. Because they operate at the intersection between land and sea, and may host many industry actors, ports have an 'advantageous position' for becoming hubs for renewable energy generation (DNV GL, 2020). For ports to realise their potential as energy hubs, however, they depend on successful and effective implementation of a range of solutions that reduce climate and environmental impacts from port operations, as well as sea and land transport. Implementation thus remains at the core of environmental sustainability in ports.

2.2. Measures for port sustainability

Several studies have set out to map and describe the potential for improving the environmental sustainability of ports. Sislian et al. (2016) reviewed the literature on port sustainability to integrate indicators of port sustainability into the Ocean's Carrier Network Problem (OCNP), while Davarzani et al. (2016) conducted a bibliometric study to systematically define prominent research areas. More recently, Lim et al. (2019) conducted a literature review of quantitative assessments of port sustainability performance in which they focused on sustainable management of ports. Similarly, Di Vaio and Varriale (2018) focused on managerial instruments for sustainable port development in their systematic review of regulatory frameworks and research on environmental issues in ports.

In a broader review of the scholarly literature on sustainability efforts in ports, Bjerkan and Seter (2019) identified 26 measures that ports have at their disposal in their sustainability efforts. They comprised measures in port management and policies (e.g., energy management, concession agreements, port dues), power and fuels (e.g., energy production, fuel distribution), activities at sea (e.g., speed reduction) and activities on land (e.g., technology shifts in terminal operations and trucking, automation). However, this literature review (ibid.) concluded that research has not covered sustainability endeavours in the wide variety of ports globally, but rather efforts in a limited selection of large frontrunner ports. Further, Bjerkan and Seter (2019) pointed to a lack of empirical research on ports' experiences in implementing the different tools available to them, thereby reducing the ability of research to provide advice to the port sector on how to progress sustainability efforts.

The port literature is well equipped to aid ports in setting aims and ambitions related to their sustainability efforts. A large number of studies have been dedicated to the environmental performance of ports, developing and suggesting performance indicators that can guide sustainability efforts (e.g., Puig et al., 2014, Di Vaio et al., 2018). These suggest, among other, what issues ports should focus on to increase their environmental performance, such as resource consumption, carbon footprints, noise, air quality, and soil quality. However, this part of the port literature does not pay much attention to what measures or solutions should be implemented to succeed, nor what ports should or should not do to ensure successful implementation. To provide holistic knowledge about how ports could aim for and work with environmental sustainability, there is therefore a need to complement research on performance indicators with studies that emphasise implementation.

The last couple of years have seen a handful of studies starting to address the implementation of measures for environmental sustainability in ports. Sornn-Friese et al. (2021) investigated drivers behind adaptation of air emission abatement measures in 93 of the world's largest ports. They identified three key drivers: population density, a specialisation in servicing container shipping and the port landlord business model. Similarly, Ashrafi et al. (2020) reviewed existing literature to identify drivers behind corporate sustainability related to social, economic and market factors, as well as policy and governance. Further, Lozano et al. (2019) investigated sustainability drivers and barriers in the Port of Gävle (Sweden) through interviews with the port authority and external stakeholders, including port users. They highlighted the government, the business case and increasing societal awareness regarding environmental issues as the most important drivers for implementing sustainability measures. By contrast, they identified the most important barriers to be economic costs and the prioritisation of economy over environment. Ashrafi et al. (2019), whose online survey about corporate social responsibility (including sustainability efforts) in Canadian and US ports similarly found economic constraints to be among the most significant barriers. Hossain et al. (2019) also studied sustainability efforts in Canadian ports by surveying their implementation of administrative and managerial measures, albeit without considering the prerequisites for their implementation. Poulsen et al. (2018) did so, however, when studying sustainability efforts in five major frontrunner ports in North America and Europe. They found that a high degree of issue visibility (e.g., local air pollution) was an important driver for measure implementation, along with low implementation complexity (e.g., energy management for port operations). Issue visibility may also explain why shore power has been introduced in many ports (Krämer and Czermański, 2020).

Despite growing attention to implementation issues in ports, the above review suggests that there are still few empirical accounts upon which to build further research. Hence, research on drivers and barriers associated with the implementation of emission reduction measures in the shipping industry could provide useful inputs to our study. Serra and Fancello (2020) identified three main ‘pressure categories’: (1) regulatory and institutional pressures, (2) market factors and resource availability, and (3) social pressures and ecological awareness and responsiveness. Additionally, they identified several barriers to the implementation of sustainability measures in the shipping industry: economic barriers, technological barriers, time and planning barriers, barriers relating to unclear and unfair regulatory frameworks, negative side effects of the implemented measures, obstacles relating to contractual clauses and split incentives, barriers relating to incomplete and non-transparent information, conservative attitudes toward innovation, and political barriers. Other studies of the shipping industry (e.g. Bergek et al., 2018, Stalmokaitė and Hassler, 2020, Poulsen et al., 2016) have pointed out that the prospects and challenges facing shipowners regarding improving the environmental footprint of maritime transport vary considerably among shipping segments and actors. For ports, this means that user demand for alternative energy solutions to conventional fossil fuels will largely be contingent on what shipping segments dominate and whose demands and needs ports must serve.

3. Research setting, methods, and data

3.1 Research setting

Norway can be considered a frontrunner in the development and implementation of low- and zero-carbon energy alternatives to conventional fossil fuels for shipping (Steen et al., 2019). A key driver for this development is that reduction of GHG emissions from domestic shipping has been high on the national policy agenda in recent years (Regjeringen, 2019). Another driver is the ambition to develop solutions (e.g., battery-electric, LNG, hydrogen) that can be exported internationally, for instance by using innovative public procurement in the publicly governed passenger shipping segments (Bjerkan et al., 2019, Bach et al., 2020). Also, various public support instruments have been established that contribute to the innovation and implementation of low- and zero-carbon energy solutions for shipping and ports, such as investment support for onshore power supply from the state funding agency Enova.

Norway has a large number of ports of different sizes and types, due to the country's long and irregular coastline as well the importance of its shipping and maritime activities for many of its key economic sectors (offshore petroleum, shipping, fishing, aquaculture) and for the transport of goods and passengers. Norway has 32 'backbone ports', which are mainly located in cities and larger towns along the entire length of the coast. In addition, there are many specialised ports, such as those that function as supply bases for offshore petroleum activities, industry ports, cruise ports, and a large number of fishing ports. Whereas industry ports are privately owned, most other ports are locally owned by one or several municipalities, with the exception of the fishing ports (approximately 650), which are owned by regional county municipalities.

3.2 Port survey and sample

In this study, we explore Norwegian ports' implementation of measures that improve port sustainability, and what drivers and barriers are associated with such implementation. Given the lack of pre-existing research on sustainability efforts in ports we take an exploratory approach, based on an online questionnaire survey conducted among participants in 96 Norwegian ports. The questionnaire was distributed via an online tool, Survey Design, in the period March to June 2020 and was sent to individuals in public and private ports. Participants from public ports were recruited through the Norwegian Ports Association, which provided contact information for port personnel considered to have knowledge about each port's sustainability efforts. Participants from private ports were identified from a list of Norwegian port facilities certified through the International Ship and Port Facilities Security Code (ISPS), provided by the Norwegian Coastal Administration. Online searches on publicly accessible web pages were used to obtain contact information for the facilities, but we failed to obtain such information for all private facilities. Although private ports often had a general e-mail address listed as their contact information (e.g., shared mailbox), we tried to find as much detailed contact information as possible. The numbers of port facilities (public and private) included in the population, survey distribution and the final sample are listed in Table 1. As evident from the table, the response rates among public and private ports were 87% and 13% respectively, and the total response rate was 26%, which is relatively normal for online surveys of this kind (Sauermann and Roach, 2013). As the survey questionnaire was distributed as an open link, we could not identify which ports did or did not respond.

TABLE 1. PORTS TARGETED IN THE STUDY (N).

	Public ports	Private ports	Unspecified	Total
Population (N)	60	339		399
Survey distribution	60	304		364
Survey sample (n)	41	52	3	96

The survey covered five main topics: (1) information about port organisation and traffic, (2) the port's work concerning sustainability and emissions reduction, (3) the port's implementation or lack of implementation of specific tools and technologies, (4) port roles, and (5) expectations regarding the provision of alternative fuels and energy carriers.

The survey questions were developed on the basis of previous studies on port governance and sustainability (Bjerkan and Seter, 2019, Acciaro et al., 2014a). Another source of inspiration was various documents (e.g. reports, media) and online data resources, including those provided by Statistics Norway,[1] the ESPO Environmental Report 2019 (ESPO, 2019), the greenhouse gas protocol (Greenhouse Gas Protocol, 2014). In addition, we also developed the survey based on primary qualitative data:

- 39 in-depth semi-structured interviews with port authority representatives and various firms and non-firm stakeholders, where drivers and barriers were among the topics (see Damman et al., 2019 for details, Norwegian only)
- Several workshops with representatives of port authorities and other actors, where drivers and barriers have been one of the topics (see Damman et al., 2019 for details, Norwegian only).

The survey draft was reviewed by representatives from the Norwegian Ports Association. This quality check by a non-academic body, yet one with comprehensive experience and knowledge of the empirical domain (ports), helped to ensure internal validity of our survey data.

Table 2 describes the sample of ports in the study, based on self-reported characteristics from the survey regarding organisation and/or ownership, port size (number of employees), and traffic characteristics (port calls per year and types of traffic). In short, it shows predominant characteristics to include private ownership, small port size, bulk and general cargo transport. In addition we see that the sample includes a large variety of different types of ports, ensuring heterogeneity in our sample.

[1] https://www.ssb.no/a/kortnavn/havn/arkiv/tab-2008-08-29-05.html

Table 2. Main characteristics of the studied ports – port organisation and traffic.

	Categories	**Frequency**	**%**
Port organisation/ownership	Municipal enterprise	29	30.21
	Intermunicipal enterprise	11	11.46
	State-owned enterprise	1	1.04
	Private company	52	54.17
	Other*	3	3.13
Port size (No. of employees)	1–5	40	41.67
	6–19	25	26.04
	20 or more	31	32.29
Port calls (per year)	0–100	23	24.47
	101–350	24	25.53
	351–2000	24	25.53
	2001–10,000	17	18.09
	10,001 or more	6	6.38
Types of traffic	Bulk/container carrier (dry)	69	71.88
	Liquid bulk	51	53.13
	Container ship	30	31.25
	General cargo ship	58	60.42
	RoRo	34	35.42
	Barge	29	30.21
	Offshore/supply	42	43.75
	Fishing and aquaculture vessels	46	47.92
	Ro/Pax	30	31.25
	Cruise ship/Coastal routes	39	40.63
	Other passenger boats	29	30.21
	Other	20	20.83
Traffic complexity**	1	19	19.79
	2	10	10.42
	3	15	15.63
	4	9	9.38
	5	2	2.08
	6	7	7.29
	7	5	5.21
	8	11	11.46
	9	6	6.25
	10	6	6.25
	11	4	4.17
	12	2	2.08

*Not included in the analyses **Additive index based on types of traffic. The number categories show ports with between 1 and 12 types of traffic.

3.4 Operationalisation and statistical analyses

This study aims to answer *What characterises sustainability efforts in ports and what drivers and barriers are associated with such efforts?* To do so we set out to investigate (1) implementation of measures that can improve environmental sustainability in ports, (2) drivers and barriers associated with in the ports’ sustainability efforts in general, and (3) drivers and barriers associated with the implementation of a set of three specific measures.

To investigate the implementation of measures that can improve environmental sustainability (1), we relied on an adaptation of the 26 different measures identified by Bjerkan and Seter (2019). The 17 measures included in our study are listed in Figure 1 (see Appendix 2 for full questions).

To analyse what drivers and barriers ports experience in their sustainability efforts in general (2) we surveyed the ports' documented overview of emissions and energy. We use document overview to indicate whether or not ports had a sufficient basis for making implementation decisions, assuming that knowledge (or lack thereof) impacts implementation. We also relied on existing literature on port sustainability (see Section 2 and Section 3.2) to survey the ports' experience with different drivers and barriers. For all measures, the ports responded to whether they agreed with a set of statements on a five-point Likert scale as displayed in Table 3. However, it is worth noting that the scale of measures related to general barriers and drivers in sustainability efforts ranges from 1=Significant barrier to 5=Significant driver. Further, we investigated the association between these barriers and drivers against port characteristics: ownership, size, port calls and traffic complexity.

To gain detailed knowledge about implementation experiences, we investigated drivers and barriers associated with a set of specific measures (3). Shore power (low or high voltage) was selected as one of these because of its widespread implementation in Norwegian ports, driven by generous public funding schemes and vast hydropower supply. At current, more than 90 Norwegian ports have implemented shore power, echoing the strong focus on shore power in literature on port sustainability (Bjerkan and Seter 2019).

Alternative fuels was selected because it demonstrates the interdependence between the port sector and the shipping sector and because it represents a good example of how implementation can halt because the supply side (i.e., ports) and the demand side (i.e., shipping) are mutually inter-dependent in accelerating implementation (see e.g., Bach et al., 2021 on biofuels).

Finally, measures for reducing emissions from land transport were selected because they counterweigh the heavily maritime orientation of ports and because strengthening ports' efforts towards the hinterland domains is a prerequisite for capitalising on the hub position of ports in their sustainability efforts.

TABLE 3. OPERATIONALISATION OF MAIN VARIABLES.

Measure	Operationalisation	Scale in analyses
Measures of sustainability efforts	List of 17 measures	Yes, No
General drivers and barriers in sustainability efforts	*To what degree does the port have a documented overview of the following?:*	
	Energy use in the port area	1 No degree 2 Small degree 3 Neither/nor 4 Some degree 5 Large degree
	Emissions in the port area	
	In the port's sustainability work, to what degree do you experience the following?	
	Pressure from owner	
	Pressure from users	
	Pressure from surroundings	
	Support from owner	
	Support from surroundings	
	To what degree do you experience the following as barriers or drivers in your sustainability work?	
	Economy	1 Significant barrier 2 Small barrier 3 Of no consequence 4 Small driver 5 Significant driver
	Own competence	
	Time and personnel resources	
	Regulation	
	Technological maturity	
	Political governance and guidelines	
	Steering/governance from owner	
	Attitudes and ambitions among port users	
	Cooperation and coordination	
	Other factors	
Drivers and barriers in implementing specific measures	*To what degree has the following been important for the implementation or lack of implementation of the following?*	
	Demand (or low demand) from ports users	1 No degree 2 Small degree 3 Neither/nor 4 Some degree 5 Large degree
	Desire (or lack of it) to create demand	
	Sufficient (or insufficient) energy provision	
	Sufficient (or insufficient) knowledge about the tool/technology	
	Public economic support (or lack of it)	
	Cooperation (or lack of it)	
	Pressure from surroundings (or lack of it)	

Several methods were used to analyse the data. To investigate what tools and technologies for sustainability Norwegian ports have implemented (1), we conducted descriptive univariate analyses with calculation of percentages. To investigate what drivers and barriers ports experience in their sustainability efforts in general (2), we calculated the mean and standard deviation (SD) for all continuous variables. To investigate the association between port characteristics and drivers and barriers, several different measures were used, depending on the type of variables. To compare the distribution of barriers and drivers among public and private ports, Wilcoxon-Mann-Whitney rank sum test was applied. Wilcoxon-Mann-Whitney is a nonparametric test and appropriate when the dependent variable is not normally distributed. Thus, it is the equivalent of the t-test, but has the advantage of not being dependent on normal distribution. It tests for differences between two groups on a single, ordinal variable with no specific distribution (McKnight and Najab, 2010)[2]. However, we calculated the mean to show the direction more clearly. To measure associations with traffic volumes and complexity Spearman's rank correlation was used, both to measure the strength and significance of correlations (Akoglu, 2018). To investigate drivers and barriers ports experience when implementing specific technologies (3), we calculated and compared mean values for ports that had implemented technologies and mean values for ports that had neither planned to implement nor implemented technologies. For (3) we also conducted statistical testing of significance levels, comparing those ports that had implemented specific measures, with those ports who had not implemented. Here we used the Chi square test, which measures the difference between observed and expected outcome frequencies for a set of events or variables. It is used to test whether two variables are related or independent from one another. However, in certain cases, the Fisher test was applied, depending on the frequency in the cells of the tables (see Kim, 2017 for advantages with Chi square test and Fischer's exact). For ordinal variables, we applied the Wilcoxon-Mann-Whitney rank sum test. Details of the equations behind the different tests are listed in Appendix 1. The statistical analyses were run using STATA 16, while figures were made in Excel.

[2] See also ACCIARO, M., VANELSLANDER, T., SYS, C., FERRARI, C., ROUMBOUTSOS, A., GIULIANO, G., LAM, J. S. L. & KAPROS, S. 2014b. Environmental sustainability in seaports: a framework for successful innovation. *Maritime Policy & Management,* 41**,** 480-500. for the use of this test for comparison of specific objectives related to degree of success of innovation for environmental seaports; and KIM, S. & CHIANG BONG, G. 2017. The role of sustainability practices in international port operations: An analysis of moderation effect. *Journal of Korea Trade,* 21**,** 125-144. for application of the t-test for comparing level of implementation of sustainability practices in port operations.

4. Results

4.1. Implemented measures for port sustainability

Figure 1 shows how many ports have implemented the 17 different sustainability measures included in the survey[3]. The most prominent measure is low voltage shore power, implemented by 50% of the ports. This is an expected result as low voltage shore power is not demanding in terms of investments and infrastructure. High voltage shore power, which has been implemented in 21% of the ports, has been high on the political agenda in Norway in recent years, whereby investments in charging infrastructure have been supported by a generous public funding scheme (Bach et al., 2020). That many ports (29%) have implemented 'Increasing energy efficiency in buildings and infrastructure' is also an expected result, as the ports themselves usually can implement this measure without much interference from other stakeholders. Furthermore, increasing the port's knowledge also scores high (27%), which is expected since port decision makers with more information are more likely to act on sustainability issues (Ng et al., 2018).

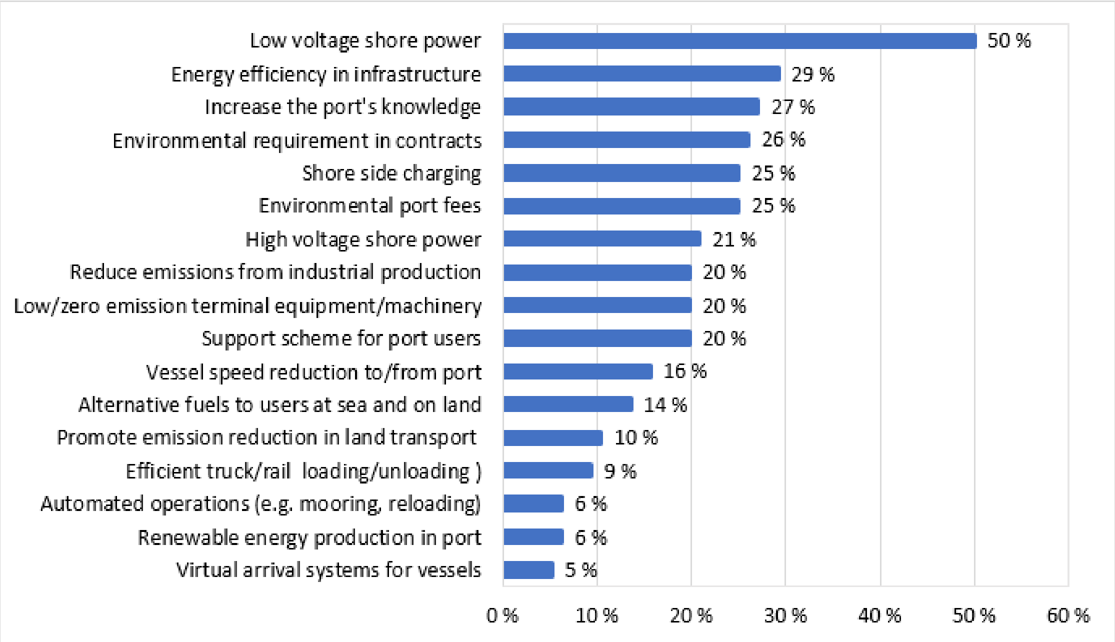

Figure 1. Percentage of ports that had implemented different measures for sustainability (N = 96).

Interestingly, only 14% of the ports have implemented alternative fuels, indicating that there might be considerable barriers for implementing alternative fuels in ports. Overall, however, the findings in Figure 1 support that ports are implementing many different measures to foster sustainability transitions. This is an interesting finding as it can be assumed that a host of measures will need to

[3] Frequencies for all measures are listed in Appendix 1.

be implemented to ensure that the ambitious emission goals of the maritime sector are achieved (Bjerkan and Seter, 2019). This finding also highlights the need to investigate sustainability efforts not just in frontrunner ports.

4.2. General drivers and barriers for implementing port sustainability measures

This section presents drivers and barriers associated with sustainability efforts in general. Table 4, first column, shows how pressure and support from different actors and the surroundings (politicians, neighbours, interest organisations, the public, media) impact the sustainability efforts of all ports on average. All values are above the mean, indicating that ports consider these variables to drive their sustainability efforts, and thereby supporting previous research suggesting that issue visibility (Poulsen et al., 2018) and societal awareness regarding environmental issues (Lozano et al, 2019) are important sustainability drivers in ports. Hence, as environmental issues gain attention among different actors in the port and its surroundings, the ports increasingly perceive this attention as pressure and/or support for them to progress sustainability efforts.

Conversely, Table 4, first column, shows that on average, ports consider economy, time and personnel resources to be barriers towards sustainability efforts, echoing previous research (Ashrafi et al. (2019) Lozano et al. (2019). The variables technical maturity and competence are also rated low, which supports previous research from the shipping sector that finds technology to be a barrier (Serra and Fancello, 2020). A range of other factors were not prominent neither as barriers nor drivers, such as regulation, attitudes and ambitions among port users, and cooperation and coordination with others. That regulation was not found to be a driver or barrier appears somewhat surprising. One reason could be that respondents may find it challenging to answer this question when not connected to a particular measure. Another explanation could be that current regulation simply is not very strong, where some (such as the Environmental Port Index) are also voluntary, and that effective policy needs both national and international coordination and alignment.

Table 4. General drivers and barriers – port experience regarding efforts with zero-emissions/sustainability. Means. Statistically significant findings p<0.1.

		All ports (N=96)	**Public ports (N=41)**	**Private ports N=52**
Documented overview in *	Total emissions	3.42	3.13	3.78
	Total energy use	3.73	-	-
Experience the following in sustainability efforts:*	Pressure from owner	3.52	4	3.13
	Pressure from users	3.10	-	-
	Pressure from surroundings	3.71	4.07	3.43

	Support from owner	4.27	-	-
	Support from surroundings	4.00	4.26	3.75
Experienced barriers or drivers**	Economy	2.41	-	-
	Competence	2.76	-	-
	Time and personnel resources	2.44	-	-
	Regulation	2.95	-	-
	Technological maturity	2.76	2.56	2.96
	Political governance and guidelines	3.45	3.78	3.21
	Steering/governance by owner	3.54	3.87	3.29
	Attitudes and ambitions among users of the port	3.17	3.44	2.92
	Cooperation and coordination with others	3.14	3.46	2.87
	Other factors	3.0	-	-

*Categories ranged from 1 (no degree), 2 (little degree), 3, (neither/nor), 4 (some degree), to 5 (large degree).

**Categories ranged from 1 (considerable barrier), 2 (small barrier), 3 (no barrier/driver/of no consequence), 4 (small driver), to 5 (considerable driver). -, indicates not significant.

Table 4 also shows how ports with different characteristics experience general drivers and barriers in their sustainability efforts. Sustainability efforts in public ports are driven by their relations with other actors such as owners, users, and surroundings. Further, political steering and governance, also from owners, are prominent in their sustainability efforts. In private ports, relations to other actors and governance are not as prominent drivers.

Our data further shows sustainability efforts relate to traffic volumes and complexity (see Appendix 9). More specifically, the prominence of collaboration and support from surroundings increases with increasing traffic volumes. Also, drivers related to political steering, governance and collaboration also increase with increasing traffic complexity. These findings could indicate that ports with high traffic volumes and complexity experience greater need and opportunity to align with their surroundings and the many users from many different segments. These findings all support the argument that the sustainability work in ports is highly dependent on port characteristics and operational context.

4.3 Drivers and barriers related to specific port sustainability measures

In this section we present our findings related to three specific measures for port sustainability: shore power, alternative fuels, and measures to reduce emissions in land transport to and from the port. Whereas 53 % of ports have implemented shore power (low or high voltage), 14 % and 10 % have implemented alternative fuels and emissions reduction measures for land transport, respectively. The results confirm that drivers and barriers vary between different sustainability measures (see Appendixes 3-5 for detailed results).

Table 5 gives an overview of statistically significant port characteristics among ports that have implemented the three measures. We see that significant differences between ports that had and had not implemented shore power are particularly prominent, which could stem from the relatively larger sample for shore power (n=49) compared to alternative fuels (n=13) and land transport (n=10). Furthermore, shore power may be characterised by stronger political guidelines, which could explain why the variables *pressure from owner, users*, and *surroundings* characterise ports who have implemented shore power. This assumption is further supported by significant result for the variables *political governance and guidelines*, as well as *steering/governance by owner*.

Interestingly, the variable *documented overview of total energy use* is significant across the three measures, indicating that this could be an important prerequisite for implementing different sustainability measures. We also see a pattern for alternative fuels, where the variables *pressure from owner* and *steering/governance by owner* are both significant. This could indicate that the role of the port owner is particularly important for implementation of alternative fuels.

Overall, these findings indicate that investigating different measures separately is important because they might be characterised by different drivers and barriers. In the next sections we will explore this even further.

TABLE 5. PORT CHARACTERISTICS OF THOSE WHO HAVE IMPLEMENTED MEASURES AS COMPARED TO THOSE WHO HAVE NOT IMPLEMENTED MEASURES. SEE APPENDIX 2-4 FOR FULL TABLES.

		Shore power	Alternative fuels	Land transport
Documented overview in the port area	Total emissions	-	*	-
	Total energy use	*	*	*
Experience the following in sustainability efforts:	Pressure from owner	*	*	-
	Pressure from users	*	-	*
	Pressure from surroundings	*	-	-
	Support from owner	-	-	*
	Support from surroundings	-	-	-
Experienced barriers or drivers	Economy	-	-	-
	Competence	-	-	-
	Time and personnel resources	-	-	-
	Regulation	-	-	-
	Technological maturity	-	-	-
	Political governance and guidelines	*	-	-
	Steering/governance by owner	*	*	-

Attitudes and ambitions among users of the port	-	-	-
Cooperation and coordination with others	-	-	-

*, indicates significant p<.10, -, indicates not significant.

4.3.1 Drivers for specific port sustainability measures

Figure 2 displays implementation drivers associated with shore power, alternatives fuels and measures related to land transport. More specifically, it shows to what degree factors have been important for ports' decisions to implement these measures (see appendixes 6-8 for full details). Overall, the desire to promote a measure by creating demand for it was the most prominent driver, for all three measures. The yellow line represents the mean value, "neither/nor", which implies that all values higher than 3 are considered by the ports as drivers for implementation.

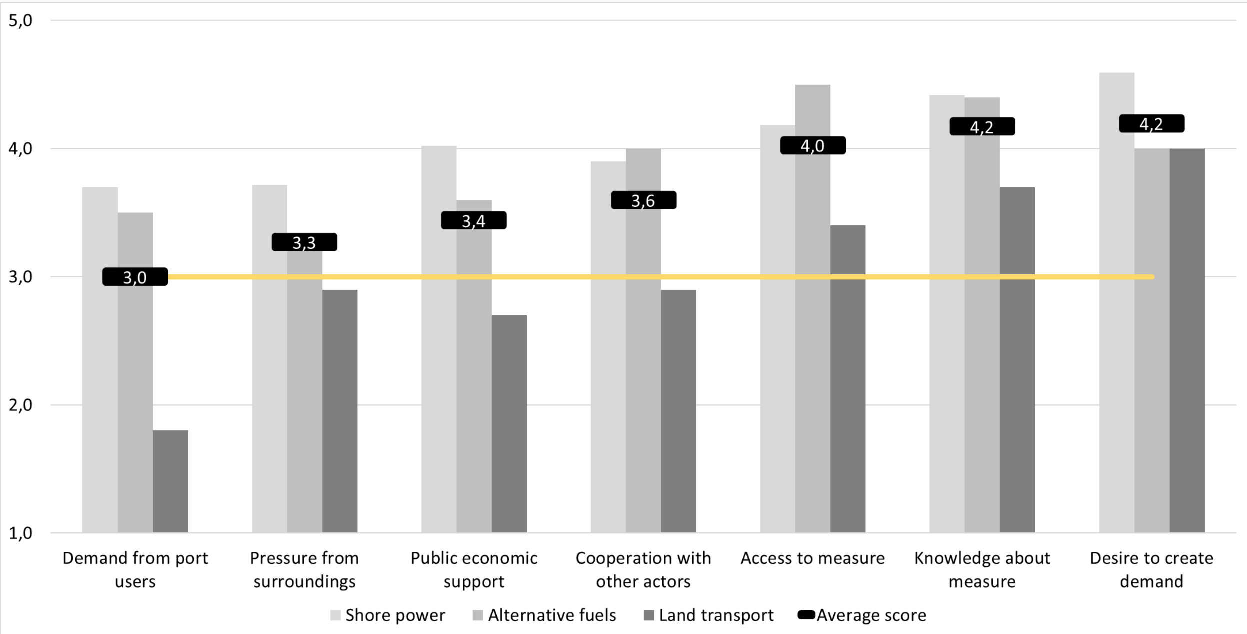

Figure 2. Implementation drivers. 'How important have the following factors been for your port's decision to implement shore power/alternative fuels/measures to reduce emissions in land transport? 1=no degree, 2=little degree, 3=neither/nor, 4=some degree, 5=large degree. Means. Yellow line indicates neutral responses.

There are differences between the measures as well. In implementing shore power, for instance, public economic support, pressure from surroundings and demand issues were particularly prominent. This is likely to reflect the importance of the public funding scheme provided by Enova. In implementing alternative fuels, such as LNG, biofuels, hydrogen, methanol, and ammonia, access to fuels was prominent. Based on these results, ports are less able to pinpoint drivers in implementing measures that reduce emissions in land transport, and four of seven factors were not considered important for the implementation of such measures. The most prominent implementation driver was the desire to create demand, which could reflect the heavy focus of the

Norwegian port sectors on shifting goods from road to sea, thereby reducing road transport volumes and associated emissions.

4.3.2 Barriers against specific port sustainability measures

Figure 3 displays implementation barriers, i.e., how important the above factors were for ports' decisions to *not* implement these measures. Values above the yellow line indicate that the variable is considered by the ports to be a barrier. In general, the many average values close to 3 indicates that ports find it difficult to identify why they have not implemented these measures. It could also indicate that other factors than those included here are more suited to explain non-implementation. This especially applies to shore power, where only public economic support leaned towards being an important barrier. The most prominent barriers related to alternative fuels were lack of public economic support, lack of demand, and insufficient access to fuels.

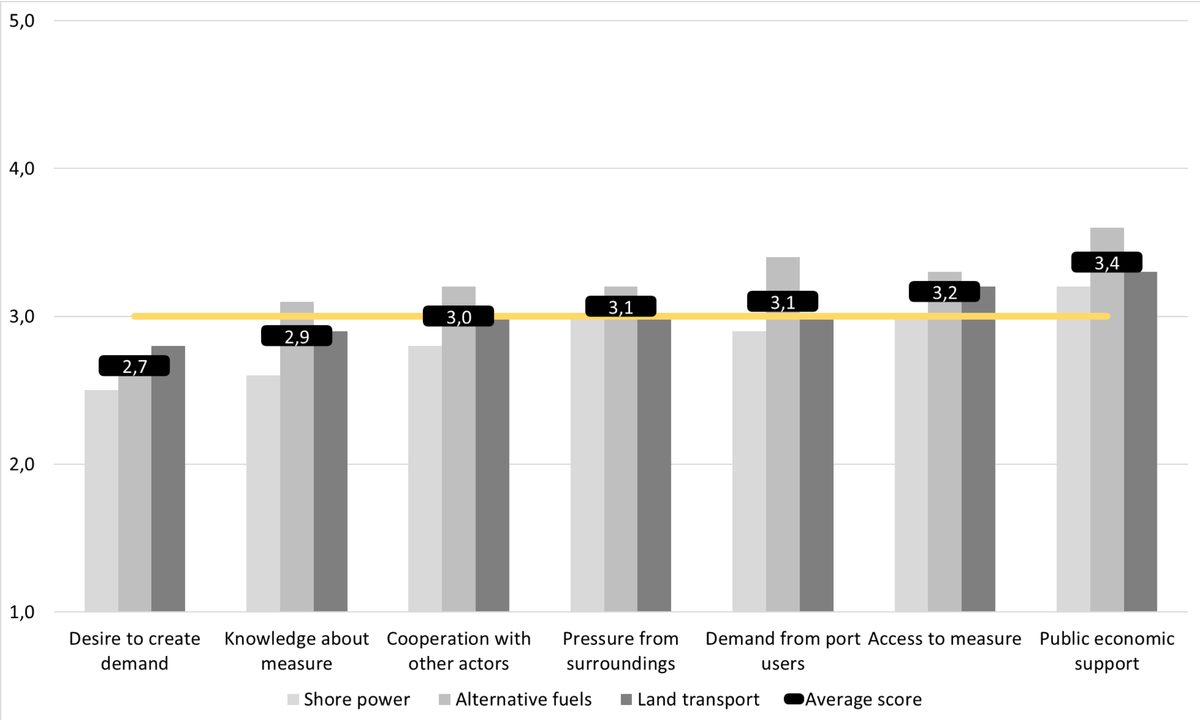

Figure 3. Implementation barriers. 'How important have the following factors been for your port's decision to not implement shore power/alternative fuels/measures to reduce emissions in land transport? 1=no degree, 2=little degree, 3=neither/nor, 4=some degree, 5=large degree. Means. Yellow line indicates neutral responses.

5. Discussion

The purpose of this study has been to explore sustainability efforts in Norwegian ports and what drivers and barriers that are associated with such efforts. An important motivation has been the lack of empirical research on ports' experiences with implementing sustainability measures (Bjerkan and Seter, 2019). Our results show that 82% of ports in the sample had implemented at least one measure for improving port sustainability, pointing towards a considerable effort among Norwegian ports to move towards a greening of the port sector. However, based on the analysis above, we argue that sustainability efforts seem to be highly dependent on the characteristics of the port, the context where the port operates, and characteristics about the sustainability measure itself. Summarising our analysis on drivers and barriers in ports' sustainability efforts, four groups of influences appear particularly important for measure implementation.

First, we found *steering and governance* to drive implementation. On the one hand, this relates to port governance, for example expressed through port owners' exertion of pressure. It is noteworthy that such pressure appears less prominent in private ports, indicating that active port governance is primarily a feature of public ports in this sample. This could reflect operational differences between private and public ports. Private ports are often specialised and adapted specifically to the needs of its users, specifically located to minimise logistics costs and reduce distribution with trucks (Prop. 86 L, 2018-2019). More limited, specialised operations could explain why private ports have a better overview of emissions and energy use in the port area. This could indicate also that the location of private ports (relatively more remote from dense residential areas than public ports, often in vicinity to industrial activities) would make them less likely to generate 'issue visibility' (Poulsen et al., 2018). In turn, private ports could be less likely to be pressured by their owners or their surroundings to implement sustainability measures. In contrast, public ports, and especially those located in urban areas, are more likely to be subject to restrictions that ensure amenity and recreational values associated with urban waterfronts.

However, differences between private and public ports could also demonstrate the role of political governance, which we have identified as a prominent driver in this study. Being a highly public and political concern, sustainability efforts in public ports – whose owners rely on political recognition – more likely bear political connotations. Our findings clearly demonstrate differences between public and private ports in terms of how prominent steering and governance from owners and politics are in driving sustainability efforts. Qualitative research on sustainability efforts in Norwegian ports suggests that municipal (i.e. public port owners) ambitions to reduce local climate gas and particle emissions is highly influential for ports environmental strategies (Damman and Steen, 2021, Bjerkan and Ryghaug, 2021). For instance in Bergen, exhaust emissions from docked ships (notably offshore supply and cruise) have caused detrimental local air qualities, and been a strong driver for the implementation of shore power. Also, the overweight of public ports among ports that provide shore power or alternative fuels could demonstrate that sustainability efforts in public ports go beyond their commercial interest. This corresponds with port functions described in the literature as "community management" (De Langen, 2007, Verhoeven, 2010). As community managers, ports attend to their societal functions and their social licence to operate, and it is reasonable to assume that public ports are more likely to take on such functions than private ones (Bjerkan et al., forthcoming).

Second, we found implementation to be affected by the relation between the port and its *surroundings*. Although our data do not identify what part of the surroundings are more important (e.g., politicians, port neighbours, interest organisations, media) they do show the importance of port users. This corresponds with previous studies (Lozano et al., 2019, Serra and Fancello, 2020) pointing to the importance of stakeholder support and pressure exerted to raise ecological awareness in ports' pursuit of sustainability. In our study, the implementation of shore power, alternative fuels and solutions for land transport all related to pressure from users and/or surroundings. Implementation was especially driven by the wish to create demand for specific technologies, while it was halted by the lack of user demand. This speaks to the importance of stakeholder management (Freeman, 1984), which is addressed by substantial research (see e.g. Becker and Caldwell, 2015, Notteboom et al., 2015, Aerts et al., 2015, Denktas-Sakar and Karatas-Cetin, 2012). Our findings support how crucial stakeholder management is to avoid challenges that arise from diverse and ambivalent political interests (Lam et al., 2013) and that port sustainability requires substantial and dedicated resources to stakeholder management (Dooms, 2019).

This brings us to the third influence; namely how important *economy* is for decisions to implement sustainability measures as well as decisions not to implement such measures. These findings correspond with other studies emphasising economic aspects in port sustainability (Lozano et al., 2019, Ashrafi et al., 2019, Serra and Fancello, 2020). In our study, economy was considered a small barrier in sustainability efforts in general, but a prominent driver in shore power implementation. This most likely captures the effect of a generous support scheme from a government enterprise responsible for promoting environmentally friendly production and consumption of energy (Enova). In 2020 alone, Enova granted economic support to more than 50 shore power projects, with a combined value of more than EUR 10 million.

Finally, we found *non-economic resources* to be prominent in the implementation of measures for environmental sustainability, above all relating to energy resources and knowledge. Previous research suggests that knowledge allows ports to make qualified decisions and increases the likelihood of implementing measures for sustainability (Ashrafi et al., 2019, Ng et al., 2018). In our study, implementation drivers related to the ports' knowledge about energy use and emissions in the port area, as well as knowledge about specific measures and technologies (e.g. shore power, alternative fuels, emission reduction in land transport). Another critical resource was the availability of energy. The importance of energy resources is particularly demonstrated by divisions between the implementation of shore power and the implementation of alternative fuels. Shore power is the most prominent sustainability measure in Norwegian ports, among other enabled by Norway's vast, renewable energy sources, which comprise 98% of electricity production (Ministry of Petroleum and Industry, 2016). In contrast, the marginal position of alternative fuels in the sustainability efforts of Norwegian ports likely related to inadequate resource availability and lack of demand among users (see e.g. Bach et al. 2021). In turn, the reluctance of ports to provide alternative fuels probably has a negative influence on demand. As such, indecisiveness and insecurity associated with various (novel) alternative fuels and energy carries represents a major barrier towards sustainability efforts in both sea and hinterland transport.

The above demonstrates the prominence of national contexts in the implementation of sustainability measures, relating to for instance energy resources and public funding schemes. This suggests a 'domestication' of global trends in port sustainability (for a similar argument with respect to adaptation to climate change, see Moser, 2014) that accentuates the need to explore not just frontrunner ports when investigating sustainability efforts in ports (Bjerkan and Seter, 2019). To assess how representative the sustainability efforts of Norwegian ports are to the greater port community, we have compared the prominence of sustainability measures in the scientific literature with their corresponding prominence in our study. This also serves to identify potential gaps between researchers and practitioners.

Table 6 shows the five most prominent measures for port sustainability found in the scientific literature and the percentage of studies addressing these, as presented by Bjerkan and Seter (2019). We compare this with our survey results. This comparison confirms a certain mismatch between scientific literature on port sustainability and sustainability efforts in ports. Although the port literatures' focus on shore power is reflected in the sustainability efforts of Norwegian ports, there are obvious gaps when it comes to for instance speed reduction and alternative fuels. These discrepancies could indicate that sustainability efforts in Norwegian ports overall differ from sustainability efforts in international frontrunner ports, which have so far been the main interest of the port literature. It could also, however, indicate that scholars have yet to catch up with the work of practitioners, which is essential should research be able to improve policies and practices (Seter et al., 2019).

TABLE 6. THE PROMINENCE RANK OF TOOLS AND TECHNOLOGIES IN LITERATURE AND IN SAMPLE. SOURCES: BJERKAN & SETER 2019, AND FIGURE 1 IN THIS PAPER.

	Rank in scientific literature	Percentage of studies addressing subject	Rank in survey	Implemented by percentage of Norwegian ports
Shore power[4]	1	36 %	1	53 %
Speed reduction	2	24 %	10	16 %
Modal shift[5]	3	17 %	Na	Na
Technological shift in shipyard vehicles/equipment[6]	4	17%	8	20 %
Alternative fuels	5	17%	11	14 %

This study clearly demonstrates the cruciality of policy and context in ports' sustainability efforts: the widespread implementation in Norway of shore power results from prominent policies enacted by Enova; political governance and guidelines drive implementation together with steering

[4] In this table, shore power includes both low voltage and high voltage, which was the most implemented solution. Thus, the rank listed in Table 11 disregards the rank of "High voltage shore power" in Figure 1.
[5] There was no direct equivalent to 'Modal shift' in our survey.
[6] Corresponds with "Low/zero emission terminal equipment/machinery" in Figure 1.

and pressure from (especially public) owners. This signals the importance of ambitious policy, and the will and financial muscle of policymakers to see ambitions fulfilled.

However, our study also shows that Norwegian ports are not united in considering policy and politics as enablers in sustainability efforts. This discrepancy is one expression of an overall fragmented and vague national port policy, which focuses mainly on administrative and financial structures. In total, 75% of the ports in our survey aimed for zero emissions, and for these ambitions to be realised there is need for more holistic policy approaches that incorporate not only the ports themselves but also the many sectors and actors that are part of transport and energy systems. Given how user demands and ports' desires to create demand drive sustainability efforts, policy should recognise more explicit stakeholder management and the ability of ports to influence sustainability efforts in several domains. Further, this study shows that many ports struggle with explaining why they do to implement specific measures, and that insufficient resources (economic and not) obstruct implementation. This could indicate lack of awareness or reflection around own sustainability efforts and challenges with setting sustainability on the agenda. For ports to make sustainability a priority, port policy should emphasise the role of ports as agents for societal change and extend their mandates beyond traditionally commercial business activity.

Furthermore, the fragmented prominence of policy in our study reflects the importance of *local* contexts and policy in port sustainability (Bjerkan et al., 2021, Damman et al., 2019). Ambitious local policy has proven vital to install ambition and motivation. As such, the development of national policies that not only spur but also align local efforts is required to transition the entire port sector in a sustainable direction. Finally, such transitions are tied to the inherently global character of ports, especially as represented by their close connection to shipping. Although the International Maritime Organization (IMO), international port organisations (European SeaPort Organisation, International Association of Ports and Harbours) and the EU have increasingly recognised the need and potential for the port sector to contribute to reducing greenhouse gas emissions, more efforts of a supra-governmental nature are still needed to align and raise international policy for port sustainability on the agenda.

This study identifies several avenues for future research on port sustainability. First, there is clearly a need to increase our understanding of how ports' sustainability efforts are influenced and conditioned by local or regional characteristics such as existing infrastructure and physical assets, institutions, capabilities, and market conditions. Second, there is a need to understand ports' sustainability efforts in different contexts worldwide, and therefore comparative studies (including studies of ports of different types and sizes) would be highly valuable. Third, we see a clear need for better understanding how ports use their different roles (e.g. Verhoeven, 2010) in their sustainability efforts. A final area of future research is enhancing our understanding of key port stakeholders, notably shipping and heavy-duty onshore transport, and how their sustainability endeavours align with those of ports. Although it is based on an almost unique dataset, there are some limitations to this study. We have not evaluated the degree or level of sustainability associated with the different measures, for example the degree to which LNG can be considered a sustainable technology. Furthermore, some sustainability measures have more radical implications than others, for instance their ability to reduce emissions or otherwise enhance sustainability. Such differences are not accounted for in this study.

On a conceptual note, future research on sustainability efforts in ports could also take a more theoretically guided approach. Given the lack of pre-existing research on the implementation of sustainability measures in ports, we chose an exploratory approach. Inspired by the insights from this study it would be useful to draw on one or several theoretical frameworks dedicated to understand factors that enable or disable the successful implementation of particular measures, such as the classic theories of policy implementation (Pressman and Wildavsky, 1973, Mazmanian and Sabatier, 1981, Mazmanian and Sabatier, 1983), the multiple streams approach (Kingdon, 1984), or the many approaches provided by literature on sustainability transitions to understand factors leading to the successful breakthrough of emerging sustainability solutions (see for instance Sovacool et al., 2020, Köhler et al., 2019). Such theoretically driven approaches to research port sustainability would benefit also from mixed-method and qualitative approaches and as such complement the scope set for our study.

6. Conclusions

In this study, we have asked what characterises sustainability efforts in ports and what drivers and barriers are associated with such efforts. We found that shore power was the most prominent measure, followed by energy efficiency in infrastructure, and increasing the port's knowledge. We further identified four sets of influences that were prominent in driving or obstructing sustainability efforts in ports: steering and governance, relations with surroundings, economy, and non-economic resources. Interestingly, we also found that the drivers and barriers were different for different measures, indicating that more knowledge is needed concerning particular sustainability measures. Our study also demonstrated differences between private and public ports: public ports experience more pressure from owners and surroundings to implement measures for environmental sustainability. An implication of this is that one-size-fits- all policy instruments to support sustainability efforts are likely less effective in some ports than in others.

The prominence of steering and government in this study suggests that both academics and practitioners should pay more attention to different roles in port governance, for instance the emergent community manager function (Verhoeven, 2010). Such a role not only (potentially) enables more active port governance in sustainability efforts, but also facilitates deliberate and targeted involvement of users and surroundings. Hence this study indicates that community management could be essential to succeed with measure implementation.

The broader implications emanating from our analysis is that although Norway can be considered a frontrunner in terms of ports' sustainability efforts and emission reductions from transport, the transition has not yet come far. This is evident from our empirical findings, showing that widely implemented measures, such as low voltage shore power and improving the energy efficiency in infrastructure, can be considered relatively easy to implement. While they may be important in terms of reducing emissions from ports and port users, they nonetheless signal mainly incremental improvements. However, the measures needed for considerable reductions in GHG emissions from ports and the transport sectors that they serve, such as high voltage shore power and alternative fuels, have so far only been implemented in a limited number of ports. This implies that continued policy support, and more stringent regulations and requirements for transport sectors, are likely to be needed if emission reduction targets are to be met. As such, this study points to the need for the port community to raise port sustainability on the political agenda and compel policy makers to recognise the crucial node position of ports also in transitioning the entire transport sector.

Acknowledgements

The authors wish to thankfully acknowledge the funding for this research from The Research Council of Norway, grant number 281002. We also thank the Norwegian Coastal Administration and the Norwegian Port Association for aiding with the distribution of the survey, and all respondents for providing their answers. We also extend our thanks to colleagues and reviewers for comments and feedback to previous versions of this article.

References

ACCIARO, M., CHIARA, H. & CUSANO, M. I. 2014a. Energy management in seaport: A new role for port authorities. *Energy Policy,* 71**,** 4-12.

ACCIARO, M., VANELSLANDER, T., SYS, C., FERRARI, C., ROUMBOUTSOS, A., GIULIANO, G., LAM, J. S. L. & KAPROS, S. 2014b. Environmental sustainability in seaports: a framework for successful innovation. *Maritime Policy & Management,* 41**,** 480-500.

AERTS, G., DOOMS, M. & HAEZENDONCK, E. 2015. Stakeholder management practices found in landlord seaport authorities in Flanders: an inside-out perspective. *International Journal of Shipping and Transport Logistics,* 7**,** 597-620.

AKOGLU, H. 2018. User's guide to correlation coefficients. *Tuskish Journal of emergency medicine,* 18**,** 91-93.

ASHRAFI, M., ACCIARO, M., WALKER, T. R., MAGNAN, G. M. & ADAMS, M. 2019. Corporate sustainability in Canadian and US maritime ports. *Journal of Cleaner Production,* 220**,** 386-397.

ASHRAFI, M., WALKER, T. R., MAGNAN, G. M., ADAMS, M. & ACCIARO, M. 2020. A review of corporate sustainability drivers in maritime ports: a multi-stakeholder perspective. *Maritime Policy & Management,* 47**,** 1027-1044.

BACH, H., BERGEK, A., BJØRGUM, Ø., HANSEN, T., KENZHEGALIYEVA, A. & STEEN, M. 2020. Implementing maritime battery-electric and hydrogen solutions: A technological innovation systems analysis. *Transportation Research Part D: Transport and Environment,* 87**,** 102492.

BACH, H., MÄKITIE, T., HANSEN, T. & STEEN, M. 2021. Blending new and old in sustainability transitions: technological alignment between fossil fuels and biofuels in Norwegian coastal shipping *Energy Research & Social Science*.

BECKER, A. & CALDWELL, M. R. 2015. Stakeholder Perceptions of Seaport Resilience Strategies: A Case Study of Gulfport (Mississippi) and Providence (Rhode Island). *Coastal Management,* 43**,** 1-34.

BERGEK, A., BJØRGUM, Ø., HANSEN, T., HANSON, J. & STEEN, M. 2018. Towards a sustainability transition in the maritime shipping sector: the role of market segment characteristics. *International Sustainability Transitions Conference.* Manchester, UK.

BJERKAN, K. Y., HANSEN, L. & STEEN, M. forthcoming. Accelerating transitions: the role of intermediation in transition work.

BJERKAN, K. Y., KARLSSON, H., SNEFUGLLI SONDELL, R., DAMMAN, S. & MELAND, S. 2019. Governance in Maritime Passenger Transport: Green Public Procurement of Ferry Services. *World Electric Vehicle Journal,* 10**,** 74.

BJERKAN, K. Y. & RYGHAUG, M. 2021. Diverging pathways to port sustainability: How social processes shape and direct transition work. *Technological Forecasting and Social Change,* 166**,** 120595.

BJERKAN, K. Y., RYGHAUG, M. & SKJØLSVOLD, T. M. 2021. Actors in energy transitions. Transformative potentials at the intersection between Norwegian port and transport systems. *Energy Research & Social Science,* 72**,** 101868.

BJERKAN, K. Y. & SETER, H. 2019. Reviewing tools and technologies for sustainable ports: does research enable decision making in ports? *Transportation Research Part D: Transport and Environment,* 17**,** 243-260.

BOSMAN, R., LOORBACH, D., ROTMANS, J. & VAN RAAK, R. 2018. Carbon Lock-Out: Leading the Fossil Port of Rotterdam into Transition. *Sustainability,* 10**,** 2558.

DAMMAN, S., KENZHEGALIYEVA, A., BJERKAN, K. Y. & STEEN, M. 2019. Mot nullutslippshavner i 2030? En studie av handlingsrom med fokus på havnene i Oslo, Narvik og Kristiansand. *SINTEF rapport.* Trondheim: SINTEF.
DAMMAN, S. & STEEN, M. 2021. A socio-technical perspective on the scope for ports to enable energy transition. *Transportation Research Part D: Transport and Environment,* 91**,** 102691.
DAVARZANI, H., FAHIMNIA, B., BELL, M. & SARKIS, J. 2016. Greening ports and maritime logistics: a review. *Transportation Research Part D,* 48**,** 473-487.
DE LANGEN, P. W. 2007. Stakeholders, conflicting interests and governance in port clusters. *In:* BROOKS, M. R. & CULLINANE, K. (eds.) *Devolution, Port Governance and Port Performance.* Amsterdam: Elsevier.
DENKTAS-SAKAR, G. & KARATAS-CETIN, C. 2012. Port Sustainability and Stakeholder Management in Supply Chains: A Framework on Resource Dependence Theory. *The Asian Journal of Shipping and Logistics,* 28**,** 301-319.
DI VAIO, A. & VARRIALE, L. 2018. Management Innovation for Environmental Sustainability in Seaports: Managerial Accounting Instruments and Training for Competitive Green Ports beyond the Regulations. *Sustainability,* 10**,** 783.
DI VAIO, A., VARRIALE, L. & ALVINO, F. 2018. Key performance indicators for developing environmentally sustainable and energy efficient ports: Evidence from Italy. *Energy Policy,* 122**,** 229-240.
DNV GL. 2020. *Port: Green Gateways to Europe. 10 Transitions to turn ports into decarbonization hubs* [Online]. Available: https://download.dnvgl.com/green-ports?portmain=1 [Accessed November 17th 2020].
DOMINKOVIĆ, D. F., BAČEKOVIĆ, I., PEDERSEN, A. S. & KRAJAČIĆ, G. 2018. The future of transportation in sustainable energy systems: Opportunities and barriers in a clean energy transition. *Renewable and Sustainable Energy Reviews,* 82**,** 1823-1838.
DOOMS, M. 2019. Stakeholder managment for port sustainability: moving from ad-hoc to structural approahces. *In:* BERGQVIST, R. & MONIOS, J. (eds.) *Green Ports. Inland and seaside sustainable transportation strategies.* Amsterdam: Elsevier.
ENERGY TRANSITIONS COMMISSION 2020. Mission Possible. Reaching net-zero carbon emissions from harder-to-abate sectors by mid-century.
ESPO 2019. ESPO Environmental Report 2019. Brussels: European Sea Ports Organisation.
FREEMAN, R. E. 1984. *Strategic management. A stakeholder appraoch,* Cambridge, Cambridge University Press.
FRIDSTRØM, L., TOMASGARD, A., ESKELAND, G., ESPEGREN, K. A., ROSENBERG, E., HELGESEN, P. I., LIND, A., RYGHAUG, M., BERG, H. B., WALNUM, H. J., ELLINGSEN, L. & GRAABAK, I. 2018. Decarbonization of transport. Trondheim: FME CenSES & FME MoZEES.
GLOMEEP 2018. Port Emissions Toolkit. Guide No.2: Development of port emission reduction strategies. International Maritime Organization, The International Association of Ports and Harbors.
GREENHOUSE GAS PROTOCOL. 2014. *Mitigation Goal Standard. Eexecutive summary.* [Online]. Available: https://ghgprotocol.org/sites/default/files/standards_supporting/Executive%20Summary%20%28English%29_0.pdf [Accessed December 9th 2020].
HOSSAIN, T., ADAMS, M. & WALKER, T. R. 2019. Sustainability initiatives in Canadian ports. *Marine Policy,* 106**,** 103519.
IEA 2020. Global EV Outlook 2020. Paris: International Energy Agency.
IMO 2018. Initial IMO Strategy on Reduction of GHG Emissions from Ships.
KIM, H.-Y. 2017. Statistical notes for clinical researchers: Chi-squared test and Fisher's exact test. *Restorative dentistry & endodontics,* 42**,** 152-155.
KIM, S. & CHIANG BONG, G. 2017. The role of sustainability practices in international port operations: An analysis of moderation effect. *Journal of Korea Trade,* 21**,** 125-144.

KINGDON, J. W. 1984. *Agendas, Alternatives, and Public Policies,* Boston, Little Brown & Co.
KRÄMER, I. & CZERMAŃSKI, E. 2020. Onshore power one option to reduce air emissions in ports. *Sustainability Management Forum | NachhaltigkeitsManagementForum,* 28**,** 13-20.
KÖHLER, J., GEELS, F. W., KERN, F., MARKARD, J., WIECZOREK, A., ALKEMADE, F., AVELINO, F., BERGEK, A., BOONS, F., FÜNFSCHILLING, L., HESS, D., HOLTZ, G., HYYSALO, S., JENKINS, K., KIVIMAA, P., MARTISKAINEN, M., MCMEEKIN, A., MÜHLEMEIER, M. S., NYKVIST, B., ELSIE ONSONGO, PEL, B., RAVEN, R., ROHRACHER, H., SANDÉN, B., JOHAN SCHOT, SOVACOOL, B., TURNHEIM, B., WELCH, D. & WELLS, P. 2019. A research agenda for sustainability transitions research: state of the art and future directions. Sustainability Transitions Research Network.
LAM, J. S. L., NG, A. K. Y. & FU, X. 2013. Stakeholder management for establishing sustainable regional port governance. *Research in Transportation Business & Management,* 8**,** 30-38.
LAWER, E. T., HERBECK, J. & FLITNER, M. 2019. Selective Adoption: How Port Authorities in Europe and West Africa Engage with the Globalizing 'Green Port' Idea. *Sustainability,* 11**,** 1-22.
LIM, S., PETTIT, S., ABOUARGHOUB, W. & BERESFORD, A. 2019. Port sustainability and performance: A systematic literature review. *Transportation Research Part D: Transport and Environment,* 72**,** 47-64.
LOORBACH, D. & GEERLINGS, H. 2017. Ports in transition. *In:* GEERLINGS, H., KUIPERS, B. & ZUIDWIJK, R. (eds.) *Ports and Networks: Strategies, Operations and Perspectives.* London: Routledge.
LOZANO, R., FOBBE, L., CARPENTER, A. & SAMMALISTO, K. 2019. Analysing sustainability changes in seaports: Experiences from the Gävle Port Authority. *Sustainable Development,* 27**,** 409-418.
MAZMANIAN, D. A. & SABATIER, P. A. 1981. *Effective policy implementation,* Lexington, MA, DC Health and Company.
MAZMANIAN, D. A. & SABATIER, P. A. 1983. *Implementation and public policy,* Glenview, IL, Scott, Foresman and Company.
MCKNIGHT, P. E. & NAJAB, J. 2010. Mann-Whitney U Test. *The Corsini encyclopedia of psychology,* 1.
MINISTRY OF PETROLEUM AND INDUSTRY. 2016. *Renewable Energy Production in Norway* [Online]. Available: https://www.regjeringen.no/en/topics/energy/renewable-energy/renewable-energy-production-in-norway/id2343462/ [Accessed November 26th 2020].
MOHAMMED, L., NIESTEN, E. & GAGLIARDI, D. 2020. Adoption of alternative fuel vehicle fleets – A theoretical framework of barriers and enablers. *Transportation Research Part D: Transport and Environment,* 88**,** 102558.
MOSER, S. C. 2014. Communicating adaptation to climate change: the art and science of public engagement when climate change comes home. *WIREs Climate Change,* 5**,** 337-358.
NG, A. K. Y., ZHANG, H., AFENYO, M., BECKER, A., CAHOON, S., CHEN, S.-L., ESTEBAN, M., FERRARI, C., LAU, Y.-Y., LEE, P. T.-W., MONIOS, J., TEI, A., YANG, Z. & ACCIARO, M. 2018. Port Decision Maker Perceptions on the Effectiveness of Climate Adaptation Actions. *Coastal Management,* 46**,** 148-175.
NORWEGIAN MINISTRY OF CLIMATE AND ENVIRONMENT 2019. The Government's action plan for green shipping. *In:* GOVERNMENT, N. (ed.). Oslo: Ministry of Climate and Environment.
NOTTEBOOM, T., PAROLA, F., SATTA, G. & PENCO, L. 2015. Disclosure as a tool in stakeholder relations management: a longitudinal study on the Port of Rotterdam. *International Journal of Logistics Research and Applications,* 18**,** 228-250.
POULSEN, R. T., PONTE, S. & LISTER, J. 2016. Buyer-driven greening? Cargo-owners and environmental upgrading in maritime shipping. *Geoforum,* 68**,** 57-68.
POULSEN, R. T., PONTE, S. & SORNN-FRIESE, H. 2018. Environmental upgrading in global value chains: The potential and limitations of ports in the greening of maritime transport. *Geoforum,* 89**,** 83-95.
PRESSMAN, J. L. & WILDAVSKY, A. 1973. *Implementation,* Los Angeles, University of California Press.
PROP. 86 L. 2018-2019. *Lov om havner og farvann (havne- og farvannsloven)* [Online]. Oslo: Samferdselsdepartementet. Available: https://www.regjeringen.no/no/dokumenter/prop.-86-l-20182019/id2640729/ [Accessed November 27th 2020].

PUIG, M., WOOLDRIDGE, C. & DARBRA, R. M. 2014. Identification and selection of Environmental Performance Indicators for sustainable port development. *Marine Pollution Bulletin,* 81**,** 124-130.
REGJERINGEN 2019. Regjeringens handlingsplan for grønn skipsfart [The Government's action plan for green shipping]. Oslo: Ministry of Climate and Environment.
SAUERMANN, H. & ROACH, M. 2013. Increasing web survey response rates in innovation research: An experimental study of static and dynamic contact design features. *Research Policy,* 42**,** 273-286.
SERRA, P. & FANCELLO, G. 2020. Towards the IMO's GHG Goals: A Critical Overview of the Perspectives and Challenges of the Main Options for Decarbonizing International Shipping. *Sustainability,* 12**,** 3220.
SHARMINA, M., EDELENBOSCH, O. Y., WILSON, C., FREEMAN, R., GERNAAT, D. E. H. J., GILBERT, P., LARKIN, A., LITTLETON, E. W., TRAUT, M., VAN VUUREN, D. P., VAUGHAN, N. E., WOOD, F. R. & LE QUERE, C. 2020. Decarbonising the critical sectors of aviation, shipping, road freight and industry to limit warming to 1.5-2 degrees C. *Climate Policy***,** 1-20.
SISLIAN, L., JAEGLER, A. & CARIOU, P. 2016. A literature review on port sustainability and ocean's carrier network problem. *Research in Transportation Business & Management,* 19**,** 19-26.
SORNN-FRIESE, H., POULSEN, R. T., NOWINSKA, A. U. & DE LANGEN, P. 2021. What drives ports around the world to adopt air emissions abatement measures? *Transportation Research Part D: Transport and Environment,* 90**,** 102644.
SOVACOOL, B. K., HESS, D. J., AMIR, S., GEELS, F. W., HIRSH, R., RODRIGUEZ MEDINA, L., MILLER, C., ALVIAL PALAVICINO, C., PHADKE, R., RYGHAUG, M., SCHOT, J., SILVAST, A., STEPHENS, J., STIRLING, A., TURNHEIM, B., VAN DER VLEUTEN, E., VAN LENTE, H. & YEARLEY, S. 2020. Sociotechnical agendas: Reviewing future directions for energy and climate research. *Energy Research & Social Science,* 70**,** 101617.
STALMOKAITĖ, I. & HASSLER, B. 2020. Dynamic capabilities and strategic reorientation towards decarbonisation in Baltic Sea shipping. *Environmental Innovation and Societal Transitions,* 37**,** 187-202.
STEEN, M., BACH, H., BJØRGUM, Ø., HANSEN, T. & KENZHEGALIYEVA, A. 2019. Greening the fleet: A technological innovation system (TIS) analysis of hydrogen, battery electric, liquefied biogas, and biodiesel in the maritime sector. *SINTEF rapport 2019:0093.* Trondheim: SINTEF.
VERHOEVEN, P. 2010. A review of port authority functions: towards a renaissance? *Maritime Policy & Management,* 37**,** 247-270.
WORLD PORTS SUSTAINABILITY PROGRAM. 2018. *Sustainable world ports* [Online]. Available: https://sustainableworldports.org/ [Accessed October 23rd 2020].

Appendixes

Appendix 1. Mathematical formulas for statistical analyses. Run by STATA 16.

Chi-Square:

The chi-squared test performs an independency test following the null hypothesis of independence, no association between groups, and the alternative hypotheses of non-independence with association between the groups.

$$\chi^2_c = \sum \frac{(O_i - E_i)^2}{E_i}$$

where:

$c =$ Degrees of freedom

$O =$ Observed value(s)

$E =$ Expected value(s)

Fisher's Exact test:

While the chi-squared test relies on an approximation, Fisher's exact test calculates directly:

$$p = \frac{\binom{a+b}{a}\binom{c+d}{c}}{\binom{n}{a+c}} = \frac{\binom{a+b}{b}\binom{c+d}{d}}{\binom{n}{b+d}} = \frac{(a+b)!\,(c+d)!\,(a+c)!\,(b+d)!}{a!\ b!\ c!\ d!\ n!}$$

Especially used when sample sizes are small, with cells having expected frequencies < 5.

The Wilcoxon Test

The Wilcoxon Rank Sum test can be used to test the null hypothesis that two populations have the same continuous distribution.

We used a normal approximation for Mann-Whitney u test Statistics, since N>20.

$$z = \frac{U - \frac{n_x n_y}{2}}{\sqrt{\frac{n_x n_y (N+1)}{12}}}$$

Spearman's Rank Correlation

The Spearman rank correlation coefficient, r_s, is the nonparametric version of the Pearson correlation coefficient. Measures the strength of a monotonic relationship.

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}$$

Appendix 2. Implemented sustainable tools and technologies – frequencies and percent

Implemented sustainable tools and technologies	**Frequency**	**Per cent**
Establish a support scheme for users in the port who want to reduce their own emissions	19	19.79
Include environmental and/or emission requirements in contracts with the port's users and tenants	25	26.04
Discounted or increased port fees based on the ship's environmental or emission characteristics (e.g. EPSI, ESI)	24	25.00
Increased energy efficiency in buildings and infrastructure	28	29.17
Targeted work to increase the port's knowledge of emissions and sustainability work	26	27.08
Establish own facilities for power from geothermal energy or solar, wind or wave power	6	6.25
Offer low voltage shore power	48	50.00
Offer high voltage shore power	20	20.83
Shoreside charging	24	25.00
Offer alternative fuels (e.g. LNG, biofuels, hydrogen, methanol, ammonia) to users at sea and on land	13	13.54
Measures to reduce the speed of ships to/from the port	15	15.63
Virtual arrival systems for ships	5	5.21
Use cranes, lifting equipment, port tractors, and other terminal equipment with zero/low emission technology	19	19.79
Automated operations (e.g. mooring, reloading)	6	6.25
Increase efficiency in loading/unloading of trucks/goods wagons (e.g. truck appointment system)	9	9.38
Measures to reduce emissions from industrial and production activities in the port	19	19.79
Measures to promote emission reduction in land transport to/from the port (e.g. freight transfer, promote the use of railways)	10	10.42

Appendix 3. Comparison of port characteristics and drivers/barriers in ports who have implemented and not implemented shore power.

	Not implemented	**Implemented**	**Test**	**P-value**
	Percent (Freq)	Percent (Freq)		
Ownership			Chi2	0.002***
Private	72.73 (32)	40.82 (20)		
Public	27.27 (12)	59.18 (29)		
Size			Fisher's exact	0.943
Small	42.22 (19)	41.18 (21)		
Medium	24.44 (11)	27.45 (14)		
Large	33.33 (15)	31.37 (16)		
	Mean	Mean	Wilcoxon-Mann-Whitney rank sum test	
Port calls	2.136364	2.94		0.0011***
Traffic Complexity	3.444444	6.313725		0.0000***
Documented overview of emissions	3.428571	3.411765		0.8110
Overview of energy use	3.428571	3.980392		0.0876
Pressure from owner	3.177778	3.823529		0.0139**
Pressure from users	2.866667	3.313725		0.0569*
Pressure from surroundings	3.318182	4.039216		0.0036***
Support from owner	4.159091	4.372549		0.4273
Support from surroundings	3.818182	4.156863		0.1995
Economy	2.311111	2.490196		0.7546
Competence	2.733333	2.784314		0.8239
Time and personnel resources	2.355556	2.509804		0.5627
Regulation	2.933333	2.960784		0.9043
Technological maturity	2.755556	2.764706		0.9957
Political steering and governance	3.133333	3.72549		0.0038***
Steering from owner	3.333333	3.72549		0.0215**
Attitudes and ambitions among users	3.088889	3.235294		0.3528
Collaboration/coordination from others	3.044444	3.215686		0.2952
Other factors	3.066667	2.941176		0.4758

*, **, *** indicates significance at the 90%, 95%, and 99% level, respectively.

Appendix 4. Comparison of port characteristics and drivers/barriers in ports who have implemented and not implemented alternative fuels.

	Not implemented	**Implemented**	**Test**	**P-value**
	Percent (Freq)	Percent (Freq)		
Ownership			Chi2	0.172
Private	58.75(47)	38.46(5)		
Public	41.25 (33)	61.54(8)		
Size			Fisher exact	0.333
Small	44.58 (37)	23.08 (3)		
Medium	25.30 (21)	30.77 (4)		
Large	30.12 (25)	46.15 (6)		
	Mean	Mean	Wilcoxon-Mann-Whitney rank sum test	
Port calls	2.493827	3		0.1406
Traffic complexity	4.686747	6.769231		0.0286**
Documented overview of emissions	3.3125	4.076923		0.0641*
Documented overview of energy use	3.625	4.384615		0.0440**
Pressure from owner	3.409639	4.230769		0.0188**
Pressure from users	3.060241	3.384615		0.3032
Pressure from surroundings	3.646341	4.076923		0.2205
Support from owner	4.256098	4.384615		0.8896
Support from surroundings	3.97561	4.153846		0.9580
Economy	2.457831	2.076923		0.2242
Competence	2.783133	2.615385		0.5733
Time and personnel resources	2.461538	2.461538		0.7503
Regulation	3.012048	2.538462		0.1467
Technological maturity	2.722892	3		0.4433
Political steering and governance	3.385542	3.846154		0.1180
Steering from owner	3.445783	4.153846		0.0118**
Attitudes and ambitions among users	3.096386	3.615385		0.0679*
Collaboration/coordination from others	3.108434	3.307692		0.3761
Other factors	3	3		0.8584

*, **, *** indicates significance at the 90%, 95%, and 99% level, respectively.

Appendix 5. Comparison of port characteristics and drivers/barriers in ports who have implemented and not implemented emission reduction in land transport to/from the port

	Not implemented	**Implemented**	**Test**	**P-value**
	Percent (Freq)	Percent (Freq)		
Ownership			Chi2	0.690
Private	56.63 (47)	50 (5)		
Public	43.37 (36)	50 (5)		
Size	2.571429	2.5		0.087*
Small	45.35 (39)	10.00 (1)		
Medium	24.42 (21)	40.00 (4)		
Large	30.23 (26)	50.00 (5)		
	Mean	Mean	Wilcoxon-Mann-Whitney rank sum test	
Port calls	2.571429	2.5		0.9586
Traffic complexity	4.976744	4.9		0.9421
Documented overview of emissions	3.361446	3.9		0.2565
Overview of energy use	3.626506	4.6		0.0353**
Pressure from owner	3.511628	3.6		0.9421
Pressure from users	3.162791	2.6		0.1011*
Pressure from surroundings	3.717647	3.6		0.6877
Support from owner	4.235294	4.6		0.0862*
Support from surroundings	4.011765	3.9		0.8847
Economy	2.383721	2.6		0.6446
Competence	2.732558	3		0.5640
Time and personnel resources	2.406977	2.7		0.5770
Regulation	2.918605	3.2		0.5724
Technological maturity	2.755814	2.8		0.9786
Political steering and governance	3.44186	3.5		0.9952
Steering from owner	3.511628	3.8		0.3591
Attitudes and ambitions among users	3.174419	3.1		0.7857
Collaboration/coordination from others	3.116279	3.3		0.5363
Other factors	3	3		0.7946

*, **, *** indicates significance at the 90%, 95%, and 99% level, respectively.

Appendix 6. Ports that had introduced/not introduced shore power – importance of factors for the ports.

Answers ranged from 1 (no degree), 2 (little degree), 3, (neither/or), 4 (some degree), to 5 (large degree)

Introduced shore power	**Mean (Yes)**	**SD.**	**Obs.**	**Mean (No.)**	**SD.**	**Obs.**
Importance of:						
Demand/low demand from port users	3.7	1.38873	50	2.913043	1.755848	23
Wanted to/did not want to create demand	4.591837	.9556492	49	2.454545	1.405	22
Good/insufficient access to power	4.183673	1.148794	49	2.952381	1.596126	21
Good/insufficient knowledge about shore power	4.416667	.8208282	48	2.636364	1.364358	22
Economic/lack of economic support from the public sector	4.020833	1.436449	48	3.2	1.576138	20
Cooperation/insufficient cooperation with other actors	3.897959	1.31093	49	2.809524	1.327368	21
Pressure/lack of pressure from the surroundings	3.714286	1.118034	49	2.954545	1.495303	22

Appendix 7. Ports that had introduced/not introduced alternative fuels – importance of factors for the ports.

Answers ranged from 1 (no degree), 2 (little degree), 3, (neither/or), 4 (some degree), to 5 (large degree)

Introduced alternative fuels for the port's users	**Mean (Yes)**	**SD.**	**Obs.**	**Mean (No)**	**SD.**	**Obs.**
Importance of:						
Demand/low demand from port users	3.538462	1.391365	13	3.431034	1.612583	58
Wanted to/did not want to create demand	4	1.290994	13	2.689655	1.187758	58
Good/insufficient access to alternative fuels	4.461538	.6602253	13	3.345455	1.363793	55
Good/insufficient knowledge about alternative fuels	4.384615	.9607689	13	3.068966	1.105998	58
Economic/lack of economic support from the public sector	3	1.414214	13	3.615385	1.105314	52
Cooperation/insufficient cooperation with other actors	4	.7071068	13	3.163636	1.134699	55
Pressure/lack of pressure from the surroundings	3.230769	1.235168	13	3.178571	1.063564	56

Appendix 8. Ports that had introduced/not introduced measures to promote emission reduction in land transport – importance of factors for the ports.

Answers ranged from 1 (no degree), 2 (little degree), 3, (neither/or), 4 (some degree), to 5 (large degree)

Introduced measures to promote emission reduction in land transport to/from the port	**Mean (Yes)**	**SD.**	**Obs.**	**Mean (No.)**	**SD.**	**Obs.**
Importance of:						
Demand/no demand from port users	1.8	.6324555	10	2.984375	1.303136	64
Prioritized/not prioritized to create demand	4	.942809	10	2.84375	1.042262	64
Good and available solutions/few solutions to reduce emissions in land transport to/from the port	3.4	1.349897	10	3.171875	1.1893	64
Good/insufficient knowledge of promoting emission reduction in land transport to/from the port	3.7	1.05935	10	2.875	1.147807	64
Economic/lack of economic support from the public sector	2.7	1.636392	10	3.296875	1.0937	64
Cooperation/insufficient cooperation with other actors	2.9	1.197219	10	3.03125	.9915316	64
Pressure/lack of pressure from the surroundings	2.9	.9944289	10	3.03125	.8903138	64

Appendix 9. Barriers and drivers ports experience in the sustainability efforts in general.

		Mean, all ports (N=96)	**Mean, public ports* (N=41)**	**Mean, private*** N=52**	**Correlation, port calls (N=96)*****	**Correlation, traffic complexity (N=96)*****
Documented overview in *	Total emissions	3.42	3.13	3.78		
	Total energy use	3.73				
Experience the following in sustainability efforts:*	Pressure from owner	3.52	4	3.13		
	Pressure from users	3.10				
	Pressure from surroundings	3.71	4.07	3.43		
	Support from owner	4.27				
	Support from surroundings	4.00	4.26	3.75	0.33	
Experienced [illegible]	Economy	2.41				
	Competence	2.76				

	Time and personnel resources	2.44				
	Regulation	2.95				
	Technological maturity	2.76	2.56	2.96		
	Political governance and guidelines	3.45	3.78	3.21		0.32
	Steering/governance by owner	3.54	3.87	3.29		0.38
	Attitudes and ambitions among users of the port	3.17	3.44	2.92		
	Cooperation and coordination with others	3.14	3.46	2.87	0.34	0.36
	Other factors	3.0				

*Categories ranged from 1 (no degree), 2 (little degree), 3, (neither/nor), 4 (some degree), to 5 (large degree).

**Categories ranged from 1 (considerable barrier), 2 (small barrier), 3 (no barrier/driver/of no consequence), 4 (small driver), to 5 (considerable driver).

***Only statistically significant findings p<0.1

www.ntnu.edu/ntrans

NTRANS

We study the role of the energy system in the transition to the zero-emission society.