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Differentiating on port fees to accelerate the green maritime transition

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ABSTRACT

This study investigates conditions under which differentiating port fees based on vessels' environmental performance could be an additional driver for cruise-ship owners to invest in green technologies. Our case study on liquefied natural gas (LNG) as fuel for a cruise ship shows that port-based incentives could help reduce emissions to air and drive uptake of green technologies.

Assuming an average rebate of EUR 1500 per port visit, the accumulated rebates globally for our case study ship exceed EUR 400,000 per year. Applying a rebate of nearly EUR 4800 per visit as currently offered in Norwegian ports, and assuming 50% of ports globally adopt the scheme, gives a cost benefit of EUR 700,000 per year, reducing the LNG technology payback time up to one year.

Our case study also shows that significantly reducing ship emissions in ports will bring social benefits through reduced risks of loss of life, health and wellbeing.

1. Introduction

Shipping accounts for 2%–3% of global GHGs (greenhouse gas) emissions. It also contributes substantially to emissions of nitrogen oxides (NOx), sulphur oxides (SOx) and particulate matter (PM) close to shore or to coastal communities, impacting on the environment and human health (e.g. Endresen et al., 2003; Corbett et al., 2008; OECD, 2011; Winebrake et al., 2009; Sofive et al., 2018). Local air pollution is a main cause of premature deaths. The World Health Organization estimates that approximately 4.2 million (m) premature deaths are related to ambient air pollution (WHO, 2018). As shipping contributes substantially to global SOx emissions, recent estimates indicate that ship-related health impacts represent around 400,000 premature deaths globally per year (Sofive et al., 2018). The European Environment Agency (EEA) assumes that poor air quality in the European Union (EU) causes nearly half a million premature deaths annually. It is estimated that close to 1500 people die prematurely in Norway each year for the same reason.

Several studies (e.g. Magnussen et al., 2010; McArthur et al., 2013; OECD, 2014; Ricardo-AEA, 2014) debate the loss of life, health and wellbeing because of local air pollution such as emissions of NOx, SOx and PM10.[1] Ship activity benefits ports economically, but ship emissions of GHGs and local air pollutants come at a cost related to societal damage. Even if port emissions account for a relatively small share of total ship emissions, they often occur close to human settlement, potentially exposing people to high levels of harmful air emission components.

A limited number of global studies estimate ship emissions in ports. They indicate that 2%–5% of shipping's carbon dioxide (CO_2) emissions occur in ports (e.g. Dalsøren et al., 2007; OECD, 2014). Taking advantage of detailed global tracking data based on Automatic Identification System (AIS) ship movement data, updated estimates indicate that around 15% of shipping's CO_2 emissions are when cargo vessels are in stationary mode, e.g. in port or at anchor (ICCT, 2017a, 2017b; DNV GL, 2018a). This is supported by the fact that large percentages of the world fleet's time are spent in port or at anchor.

Reducing ship emissions is becoming increasingly important following the IMO's adoption in April 2018 of an ambitious strategy to reduce GHG emissions from international shipping. Taking 2008 as a base year, this aims to at least halve total GHG emissions from shipping by 2050, and to reduce the average carbon intensity (CO_2 per tonne-mile) by at least 40% by 2030 while aiming for a 70% reduction by mid-

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[1] PM_{10}: Particulate matter 10 µm or less in diameter.

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century. Mitigation measures for ships include quite achievable operational measures such as slow steaming, efficient port operations, and reducing waiting times. They also encompass more capital-intensive technical solutions like shore-side electricity, LNG as fuel, and other alternative fuels (e.g. Eide et al., 2011; Winnes et al., 2015; Bouman et al., 2017; OECD, 2018a, 2018b; DNV GL, 2018b).

While emissions in port account for a modest fraction of total shipping emissions, those from ships outside ports (in transit) can still be severely impacted by the services and incentives provided by ports. Consequently, ports could play a key role in the green maritime transition by serving as energy hubs providing both shore-side electricity and infrastructure for storing and fuelling ships with alternative fuels. They could also play a significant role through investing in digitalization and improving coordination and synchronization between ship and port to reduce emissions and stationary time. Ports can also incentivize investment in green technologies on ships. Port-based incentives promoting environmentally friendly maritime transport are considered among the possible market-based measures that could help reduce GHGs and other emissions (COGEA, 2017; OECD, 2018a, 2018b, 2018c). Already, 28 of the world's 100 largest ports in terms of cargo and containers handled have port-based incentives of this kind (OECD, 2018a, 2018b, 2018c). However, very little is known about their actual impact on reducing GHGs and other emissions (COGEA, 2017; OECD, 2018a, 2018b, 2018c). Another key challenge is that only five ports use indexing systems where GHG emissions provide a substantial part of the evaluation (OECD, 2018a, 2018b, 2018c).

In addition, existing initiatives such as the Environmental Ship Index[2] (ESI), Clean Shipping Index[3] (CSI), and the Green Award[4] have less focus on ship emissions in ports. The Environmental Port Index (EPI) is an exception that aims to reward low-emission cruise ships in port.

While ports will play a vital role in maritime's green transition, there is a need for better understanding of how this role can be fulfilled. This paper demonstrates that basing port fees on vessels' environmental performance can positively impact on a shipowner's investment decision for environmentally friendly technology provided that:

- the size of the fee rebate is sufficiently large
- the fee rebate is targeting relevant parameters
- the scheme for differentiated fees is sufficiently scaled to cover enough ports.

2. Method and data

This study investigates under which conditions differentiating on port fees could be an additional driver for shipowners to invest in green technologies. The study's scope is limited to cruise ships but is relevant for all ship types.

Emission reductions and accumulated annual rebates are calculated by: globally tracking the port calls for a large cruise ship in 2016; assuming the ship is using LNG as fuel; and, by assigning potential port rebates in a 'what-if' scenario. The potential accumulated environmental rebates per year will depend on the number of ports visited, and the assumed rebate sizes. The accumulated rebate will reveal the financial incentive for the shipowner to invest in green technologies.

This approach calculates the following for the selected large cruise ship using LNG as an emissions abatement measure (the 'case ship'):

- The reduction in air emissions in ports.
- The accumulated annual rebate obtained in ports, assuming constant rebate sizes.
- The social benefit of emission reductions in Port of Bergen, Norway.

The modelling of accumulated rebate size and air emissions in ports for the selected LNG case ship has been conducted with DNV GL's software, MASTER (Mapping of Ship Tracks, Emissions and Reduction potentials). The model uses global ship-tracking data from the AIS, enriched with ship-specific data from other sources. The AIS data is merged with technical databases for detailed information on the LNG case ship, such as installed power on main and auxiliary engines, machinery configurations, emission characteristics, ship design speed, tonnage, etc. (e.g. Mjelde et al., 2014; DNV GL, 2014, 2016, 2018a, 2018b, 2018c). In this study, the model has been enhanced with assumed average rebate data for all ports worldwide, and more detailed data for those in Norway.

In the case modelled, it is assumed that all ports globally offer an environmental rebate of EUR 1500 per port stay. This represents a what-if scenario to illustrate what may happen if all ports adopt a common environmental charging scheme of a certain size.

AIS-based modelling offers great potential for performing in-depth studies and aggregation of results in 'at sea' mode and in ports, e.g. in time periods and for geographical areas. The results of the case study are aggregated for all ports globally, within the EU, and in Norway. Separate modelling has also been conducted for the Port of Bergen.

For the LNG case ship using four-stroke gas/dual-fuel engines, the emission reduction of CO_2e (carbon dioxide equivalents), NOx, SOx and PM_{10} are respectively assumed to be 7%, 90%, 100%, and close to 100%, compared with a similar ship using marine distillate fuels or heavy fuel oils.[5] The CO_2e emission factor for the four-stroke gas/dual fuel engines includes methane slip and builds on recent tank-to-propeller estimates (e.g. Stenersen and Thonstad, 2017; Lindstad et al., 2018).

2.1. Data collected for Norwegian cruise ports

A more in-depth analysis has been carried out for the Norwegian cruise ports to assess how representative the assumed rebate of EUR 1500 per port stay is. Open and available data on existing differentiated pricing schemes has been collected from six selected Norwegian cruise ports assumed to give representative coverage of Norwegian ports.

Cruise ships arriving at Norwegian ports are subject to compulsory pilotage nationwide. This results in a pilotage fee, which is linked to the actual use of a pilot, and a pilotage readiness fee. Moreover, designated areas along the coast are covered by the Vessel Traffic Service[6] (VTS). In some of these areas, cruise ships are subject to a security fee set by the national government. Cruise ships are also subject to fees and dues imposed by the local port authorities. These include a harbour fee, a quay due, an International Ship and Port Facility Security Code (ISPS) fee, and a passenger due. The harbour fee and the quay due are calculated from the ship's gross tonnage, while the ISPS fee and the passenger due are calculated from the number of passengers on board. The rates for fees and dues differ between ports. For example, one port does not have a quay (it uses anchorage area) and hence no quay due (Port 4 in Table 1 below). Some ports do not charge passenger dues (Ports 2 and 5) or harbour fees (Port 1).

This study has calculated the basic costs incurred for small, medium and large cruise ships arriving at six Norwegian cruise ports in 2016. Moreover, calculation has been made of the costs of LNG-powered cruise ships to exemplify the rebates offered to environmentally friendly ships according to the price lists that year. It should be noted, however, that since 2018 more ports have adopted environmental rebates for harbour fees and/or quay dues. Table 1 shows the cost of

[2] www.environmentalshipindex.org/Public/Home.
[3] https://www.cleanshippingindex.com.
[4] https://www.greenaward.org.
[5] The CO_2e reduction include methane slip.
[6] https://www.kystverket.no/en/EN_Maritime-Services/Vessel-Traffic-Service.

Table 1
The cost of arriving at six different Norwegian cruise ports, for a small, medium and large cruise ship in 2016[a].

Port	Cruise ship annual rebates (EUR) and port shares of the cost (%)					
	Small	Small LNG	Medium	Medium LNG	Large	Large LNG
Port 1	13,300 (35%)	8900 (40%)	19,100 (38%)	12,400 (46%)	35,200 (40%)	21,400 (51%)
Port 2	9300 (58%)	8000 (62%)	13,300 (62%)	11,300 (66%)	24,400 (65%)	20,400 (72%)
Port 3	9900 (66%)	8300 (66%)	14,800 (73%)	12,200 (78%)	28,200 (80%)	22,200 (87%)
Port 4	9200 (35%)	8700 (37%)	11,900 (44%)	11,000 (47%)	17,300 (54%)	15,600 (60%)
Port 5	6300 (53%)	5800 (56%)	8600 (61%)	7900 (65%)	14,500 (71%)	13,000 (78%)
Port 6	11,900 (74%)	11,300 (77%)	16,300 (78%)	15,500 (82%)	27,500 (83%)	25,700 (89%)

[a] The fees and dues included in Table 1 are: Pilotage fee, pilotage readiness fee, security fee, harbour fee, quay due, ISPS fee and passenger due.

arriving at six different Norwegian cruise ports. The share of costs going to the port authority is shown in parentheses. Among the ports, there are significant differences in costs between the LNG ship and the non-LNG ship. The average difference between the small standard ship and the small LNG ship is calculated at EUR 1480. For the medium and large ships, the corresponding numbers are EUR 2280 and EUR 4800. This reflects a greater rebate potential for the larger ships.

The share of costs attributed to the local port authorities varies from 35% to 89%, excluding rebates. The single largest rebate is 100% on the national government's pilotage readiness fee, which amounts to EUR 10,000 for large cruise ships.[7] We are not familiar with similar studies analysing cruise ships' costs for arriving in Norwegian ports. However, a few studies have been conducted on the costs for cargo ships visiting ports (DNV GL and Menon, 2018). Interestingly, the Norwegian Coastal Administration (2016) shows that for a container feeder ship, direct port costs (cargo handling, port fees and dues) and indirect costs from time in port (capital costs, salaries, insurance, etc.) amount to about 50% of the ship's round-trip costs. Similar analysis of cruise ships' round-trip costs should be conducted but falls outside the scope of this paper.

2.2. Applied damage cost for CO_2, NOx, SOx and PM_{10} emissions

The emissions (CO_2, NOx, SOx and PM_{10}) from ships in port impact on climate, the environment, and local air quality. These emissions therefore have a damage cost (negative externality) that has been estimated as the cost of continued emissions. Conversely, reducing their local emission to air will reduce the damage cost, with a corresponding increase in social benefit. The damage cost can be referred to as the unit price of an additional unit of the pollutant.

Valuation techniques can transform amounts of different pollutants into a common unit cost price. These unit prices are widely used in cost-benefit analysis and in Norwegian policymaking. In Table 2, the 2018-unit prices for Norway show the social cost of the pollutants included in this study (Norwegian Public Roads Administration, 2018; Norwegian Pollution Control Authority, 2005). It is noted that the German Environment Agency (UBA 2018) has updated its recommendations for the estimation of such damage, and has readjusted the costs of impacts in the newly published Methodological Convention 3.0. The cost

[7] Pilotage readiness fee is for a round-trip in Norway. The cost is spread across the number of port arrivals. Cruise ships to Port 1 tend to visit only it; so, all the pilotage readiness fee is attributed to it. Those using Port 5 tend to visit seven other Norwegian ports on a round-trip; so, an eighth of the pilotage readiness fee is attributed to this port.

Table 2
Damage costs as unit price per emission component.
Sources: The Norwegian Public Roads Administration (Norwegian: Statens Vegvesen), 2018; The Norwegian Pollution Control Authority (Norwegian: Statens forurensningstilsyn - SFT), 2005.

Area breakdown	2018-unit price per emission component (EUR)			
	CO_2 (2020) (EUR/tonne)	NOx (EUR/kg)	SOx (EUR/kg)	PM_{10} (EUR/kg)
Larger city area (Oslo)	38.0	25.4	11.4	461
Larger city area (Bergen, Trondheim)		25.4	(average)	343
Other large cities		12.7		194
Areas > 15,000 inhabitants		12.7		52
Other areas		6.4		52

readjustments imply that one tonne of CO_2 emissions, for example, incurs costs of about EUR 180 (German Environment Agency, 2018).

Introducing green technologies is likely to reduce the emissions from ships in port, and thereby lessen vessels' negative externality during stays, hence lowering the damage cost.

3. Results

The accumulated value of the rebate for the LNG-fuelled ship (case ship) depends on the number of ports visited and the assumed rebate size (case study). Using the method outlined above, the accumulated annual rebate is calculated and illustrated in Fig. 1 below for the local, national, regional and global levels. It is seen that the estimated accumulated annual rebate for the large LNG case ship is more than EUR 400,000 globally. The corresponding values for EU and Norwegian waters are EUR 270,000 and EUR 60,000 respectively. This is a what-if scenario reflecting one possible future where a rebate is available in every port and an assumed average rebate of EUR 1500 per visit.

Taking actual rebate values from six different cruise ports in Norway into consideration, accumulated annual rebates for the LNG case ship are estimated for a range of cruise ship sizes. These rebates are: small ship, EUR 1480; medium ship, EUR 2280; large ship, EUR 4800. This reflects a size-dependent rebate potential. Applying EUR 4800 for the large case ship's 39 port visits in Norway, the accumulated annual rebate more than triples from EUR 60,000 to EUR 190,000 per year. The results illustrate the importance of having access to more detailed fee and taxation data when carrying out such analyses.

Our case study results show that using LNG as a measure to reduce air emissions provides small rebates in the different cruise ports. When added together, they result in a sizeable annual financial incentive for the case ship. The results also show that if port-based incentives are available in only EU and Norwegian ports, the LNG ship could still receive substantial financial incentives. However, recent experience suggests that the cost of building a new LNG-fuelled ship is approximately 10%–30% higher than standard ships. This needs to be compensated for in operations and will depend on oil and gas prices as well as other operational savings (e.g. port fees, channels fees).

Currently, the additional cost for our case ship is EUR 10 m to EUR 14 m, based on recent DNV GL cost estimates for large cruise ships. Consequently, the value of the rebate needs to be significantly increased if port-based incentives are to become additional drivers for shipowners to consider investing in costly green technologies such as LNG-fuelled ships. For exhaust-gas treatment technologies with lower investment costs (compared with LNG ships), the rebate size used in this study could be an important additional driver.

Today, port-based environmental incentives are initiated in around 25% of the large ports. Adopting Norwegian rebate sizes globally, and assuming 50% coverage worldwide, this could give an environmental

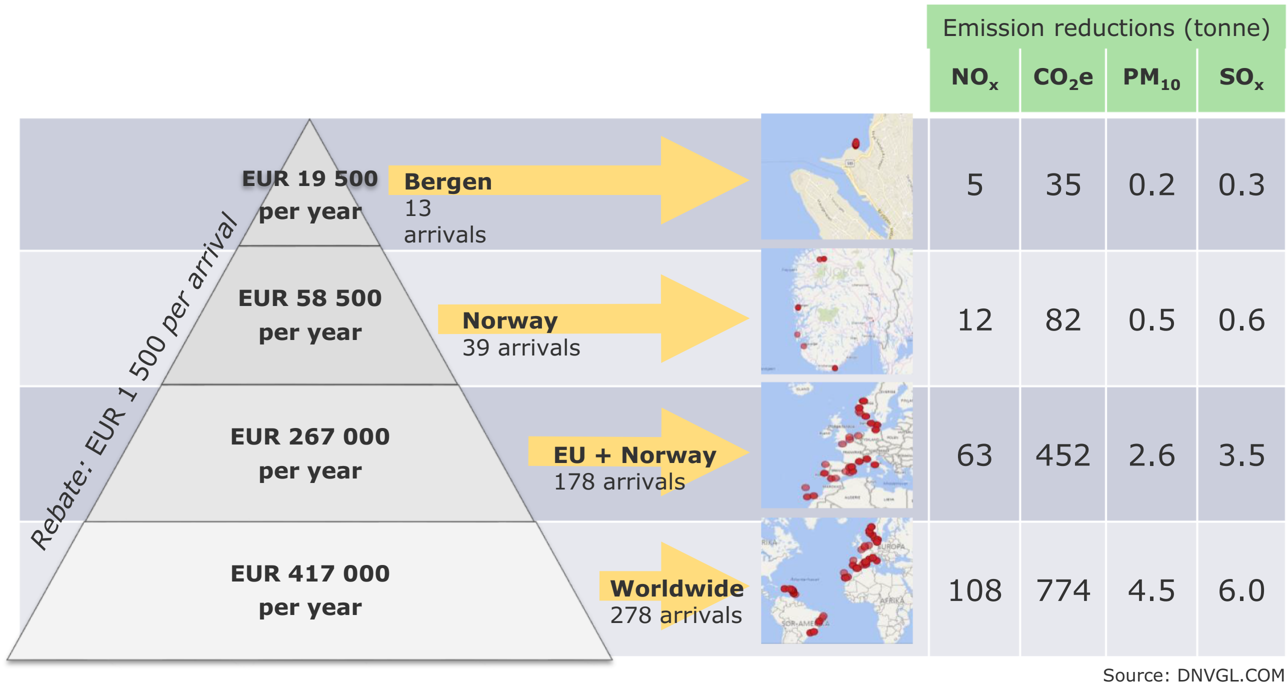

Fig. 1. Case modelling results for 2016 with geographical breakdown on emissions and accumulated rebate size for the LNG case ship compared with a ship using marine gas oil (MGO) and 0.1% sulphur.

cost benefit of more than EUR 700,000 per year for an LNG cruise ship. Over a five-year period, this could result in some EUR 3.5 m of cost savings and make an LNG business case attractive, as currently the additional cost for LNG as fuel represents an extra investment of EUR 10 m–14 m. It is recognized that this is optimistic but not unlikely, the what-if scenario will reduce the payback time from around six years to five years for the LNG case ship.

Overall, this shows that a port incentive scheme is backing the uptake and use of environmentally friendly technologies and can be profitable for shipowners.

The achieved emission reductions should also be seen in a socio-economic perspective. The social benefit of the reduced emissions in Port of Bergen is estimated to be approximately EUR 200,000 for the 13 port calls made by the LNG case ship in 2016 (Table 3). This value shows the social benefit of reducing damage cost from impacts on climate, the environment, and local air quality. The calculations for individual emission components are shown in the table below, where NOx is dominating.

4. Discussion

Ports do have a key role to play in the green maritime transition. The use of economic instruments as an environmental differentiator embraces uptake of green solutions, and disadvantages those not acting accordingly. This section presents key aspects of our study.

Table 3
The social benefit of emission reductions in Port of Bergen for the LNG case ship in 2016.

	CO_2	NOx	SOx	PM_{10}	Total
Emission reductions using LNG instead of MGO (tonne)	35	5	0.3	0.2	–
Corresponding social benefit of emission reduction (EUR)[a]	1300	127,000	3400	68,600	~200,000

[a] 2018 damage costs from Table 2 have been used. It is expected that the unit cost difference between 2016 and 2018 is negligible.

4.1. Reducing ship emissions based on port incentives

Many ports have introduced differentiated port fees to promote environmentally friendly maritime transport. Our results show that an attractive rebate on port fees and/or dues could reduce the payback time for LNG ships and other green technologies. By helping to drive uptake of green technologies, such financial incentives could significantly reduce ship emissions in ports and on voyages. This is supported by a recent study claiming that incentives from environmental charging can help to make investing in greener technologies more profitable and, under certain circumstances, shorten payback time on investments by one or more years (COGEA, 2017). However, due to the high investment-cost of LNG ships, the rebate size of EUR 1500 used in this study is not likely to be enough to be the decisive driver for LNG uptake. For less expensive technologies than LNG, we find that the estimated accumulated rebate is an important driver for uptake of green technologies for all ship types.

This 'picture' may change for green technologies, and when adding in other upcoming drivers. Some Norwegian cruise ports will give booking priority and attractive docking areas for green ships. This is expected to drive uptake of environmentally friendly technologies. Other national/local initiatives aim to reduce cruise ship emissions in Norwegian heritage fjords, and in Alaska through the US state's emissions standards. Norway's capital city, Oslo, has ambitious goals for reducing GHGs and local environmental emissions. The city council's November 2018 action plan called for a 95% reduction in CO_2 emissions from Oslo by 2030, and 85% from its port. (City of Oslo, 2018). This also applies to manoeuvring and sailing in and out of the Oslo sea area. The Cruise Lines International Association (CLIA, 2018) recently committed to reduce CO_2 emissions across the industry fleet by 40% by 2030.

The increased focus on reducing GHG emissions, and the growing number of ports worldwide applying differentiating port fees, could strengthen rebate schemes for environmental technologies and make the business case for green LNG more attractive. There are several other mitigation measures available for ships in port (e.g. Winnes et al., 2015); some influence specific exhaust gas components, while others impact on several or (in the case of electric power from shore) all emission components. Shore-based power is the most effective way of nearly eliminating emissions in port. Access to shore-based infrastructure for recharging onboard battery banks for ship propulsion is still limited, though progress is being made in certain regions[8,9] (e.g. Ecofys, 2015).

A range of available technologies can reduce emissions from ships in port and on voyage. Main categories include:

1. alternative fuels and energy carriers (e.g. LNG, biofuels, methanol, hybridization with batteries and hydrogen, etc.)
2. technical and operational measures (e.g. hull efficiency, propulsion/machinery efficiency (including hybridization), voyage execution, logistics, etc.)
3. after-treatment of exhaust gas (e.g. selective catalytic reduction (SCR), scrubbers, particle filters, etc.).

It is noted that the third of these categories will affect fuel consumption and GHG emissions. For example, uptake of scrubbers removes one problem (SOx) but increases fuel consumption and CO_2 emission.

4.2. Cleaner ship fuels provide health and environmental benefits

The impacts of shipping emissions are most noticeable in ports and coastal regions. UN Environment (2018) reports that roughly three quarters of the world's largest cities are on coasts, and half the global population lives within 60 km of an ocean. A large percentage of the maritime emissions happen close to shore or to coastal communities, with potential serious impacts on human health and the environment. DNV GL (2018a) reports that approximately 25% of the total maritime fuel is consumed by ships being stationary in port or operating closer than 10 nautical miles (nm) from shore (Fig. 2). More than half the total fuel consumed is by vessels closer than 40 nm from shore. Reducing ship emissions to air by introducing cleaner fuels in shipping will improve air quality for people living close to ports or coastal regions. Introducing low-sulphur fuels could provide large health benefits, particularly when used in a near-coast environment (Winebrake et al., 2009; Sofive et al., 2018). Sofive et al. (2018) reports that implementation of the IMO's global 0.5% S fuel standard in 2020 will reduce by more than a third (34%) the global population's premature mortality due to shipping emissions (403,000 versus 266,000 premature deaths). A shift to low-emission fuels such as LNG, addressed by this study, is expected to further reduce premature mortality. Cleaner fuels such as LNG will have an impact on climate change and reduce acidification, eutrophication and other environmental effects.

4.3. The role of ports in the green maritime transition

Ports could play a key role in the green maritime transition in at least three significant ways. First, they can make environmentally harmful activities more expensive (the ‘polluter pays’ principle), and environmentally friendly activities less costly. This is done by applying fees to tax unwanted behavior, or by incentivizing desired behavior. The most common incentive used is the environmentally differentiated port fee. According to OECD (2018a, 2018b, 2018c), this is applied in approximately 28 of the 100 largest ports in terms of cargo and containers handled. However, very little is known about their actual impact on reducing GHG emissions (NRDC, 2017; OECD, 2018a, 2018b, 2018c). A literature survey carried out in the Cleanship project (CLEANSHIP, 2014) found 50 different existing initiatives for environmental classification of ships. Of these, 18 mainly address ports. To recap, examples of initiatives used by ports are the Clean Shipping Index (CSI), Environmental Ship Index (ESI), Green Award, and the Environmental Port Index (EPI). It is noted that several ports based their evaluations on more than one initiative.

Second, ports as ‘energy hubs’ will provide shore-side electricity and necessary infrastructure for alternative fuels. Shore power is emerging in some ports. This allows for the ship's onboard generators to be shut down, reducing its corresponding emissions while in port. Shore power can also recharge ship batteries for later use during manoeuvring and sailing at low speeds. In the future, decentralized production of renewable marine fuels, with the process electricity coming from renewable energy like wind and sun, may emerge at seaports (Månsson, 2017). Such developments could challenge current bunkering infrastructure and practices.

Third, ports will have a key role in reducing stationary time and emissions through more automated and effective cargo-handling operations, as well as improved coordination and synchronization between ship and port. Fig. 3 shows the variation in the share of time spent in each operating mode by major cargo ship types and size categories. Time spent in port or at anchor (stationary) ranges significantly, reflecting variations in trading patterns, services, turnaround time, and operational efficiency. Bulk and container ships spend the lowest share of time being stationary and in manoeuvring mode, and oil tankers have the highest share of time in these modes. The figure shows that the largest ships spend 70%–75% of the time in cruising mode (at > 5 knots). The share of time spent in this mode is as low as 20%–30% for the smallest size categories, except for container vessels (DNV GL, 2018a). The small ships spend larger proportions of their operating time on short voyages with frequent port calls, which naturally reduces the time spent in cruising mode. Improved coordination and synchronization between port and ship will avoid waiting in port, with the time being taken instead to slow steam (e.g. Longva, 2011; Andersson, 2017; OECD, 2018b). Allowing the fleet to reduce sailing speed will lower overall fuel consumption and emissions. Digitalization will be a key enabler for exploiting this potential.

4.4. Development needed for ports

It is evident that port fees represent an opportunity for establishing incentives for emissions reductions. Since this is a pure commercial adjustment where all ships compete in an equitable way, it is relatively easy to adopt this type of system within each port.

The EU Commission's Greening Transport Package adopted in July Corbett et al., 2008 (EU, 2008) paved the way for introducing port dues based on environmental charging. Several such schemes are now in use, the Environmental Shipping Index (ESI) being the dominant one. COGEA's (2017) study on differentiated port-infrastructure charges is a good overview of the challenges involved in implementation. In our perspective, the key factors for successfully implementing environmentally charged fees are as follows:

- Make it mandatory for all ports to implement environmental differentiated fees/dues for ships.
- Establish specific and joint criteria for each parameter included in the scheme.
- Establish a structured process for data entry, calculations and reporting that serves each of the involved parties (ship, shipowner, port, verifier, etc.).
- Establish a close link to the environmental reporting and accounting system for ports.
- Establish national and international coordination and exchange of best practices.

[8] ‘First for Shore Power in India’, SM Arun, The Maritime Executive, 12 January 2017 [online], viewed a: http://www.maritime-executive.com.

[9] Shore power, Norway: http://www.tu.no/artikler/havner-vil-fa-hurtigruten-over-pa-landstrom/193818. http://www.mynewsdesk.com/no/enova-sf/pressreleases/140-millioner-til-landstroem-1689508.

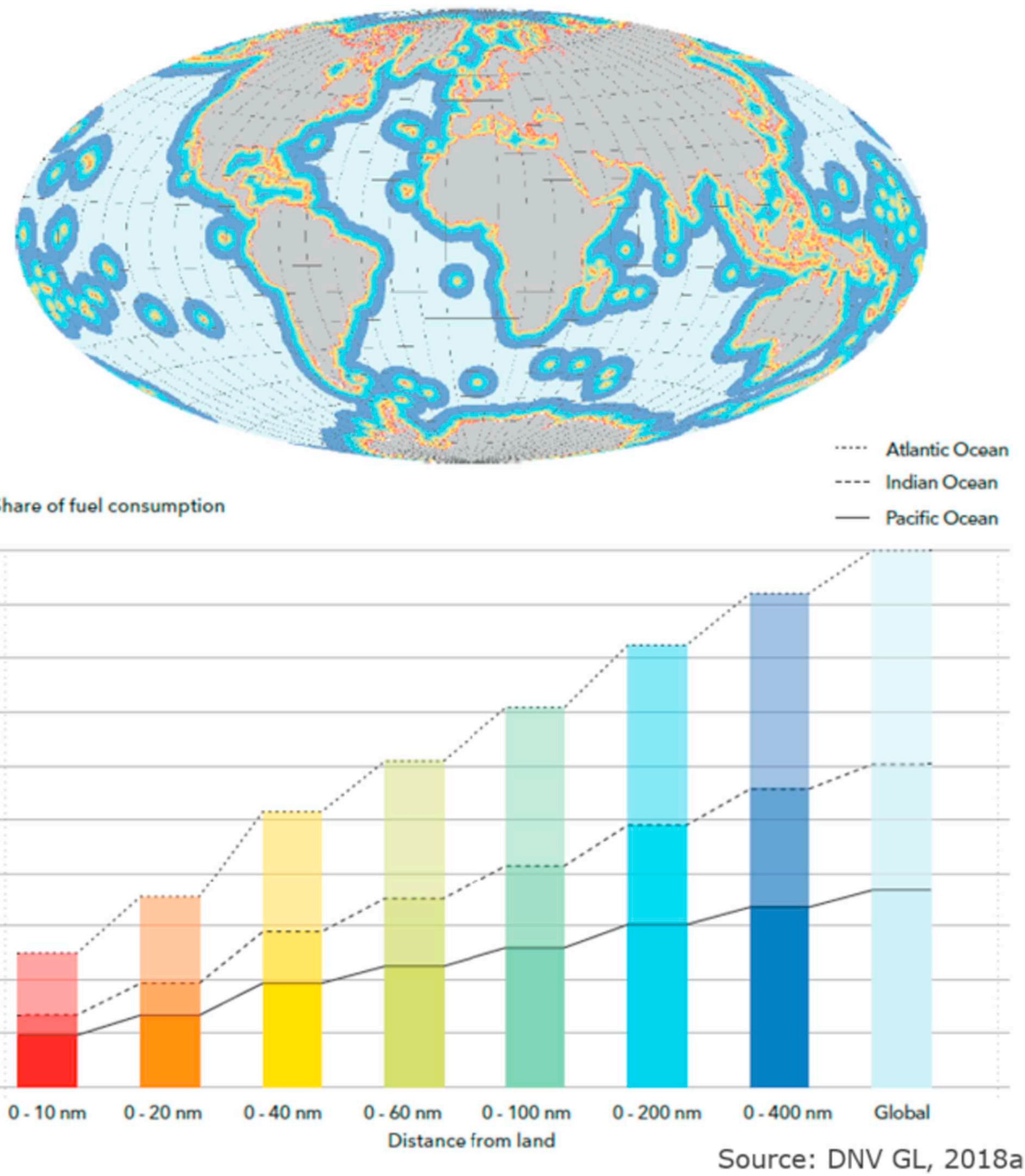

Fig. 2. Share of maritime fuel consumption in 2017 by distance from land. Upper figure illustrates different pre-defined zones by distance from land (coloured segments). Lower figure shows accumulated share of maritime fuel consumption within each zone. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Norwegian cruise ports have since 2017 joined forces with DNV GL to develop an environmental port index (EPI). The EPI emphasizes a ship's actual impact while in port, including operational factors, thus distinguishing it from the ESI, CSI and other systems. A pilot study for the EPI scheme in 2018 shows a large variation in how cruise ships operate while in port. The energy consumption of an individual ship may vary by nearly a third (30%) from one visit to another. The EPI will be in operation in several ports including Port of Bergen, Port of Trondheim, and Port of Stavanger during 2019, and by most Norwegian cruise ports by 2020.

Ports face a major challenge in being able to enhance the environmental charging of fees while maintaining competitiveness and revenue with other ports and transport modes. Finding ways to share this potential burden among ports is a key challenge that needs addressing at the national and regional political levels.

Successful implementation of differentiated port dues within a region may lead to a situation where shipowners move not-so-green ships to less-regulated regions. It is important to be aware of this and to advocate the adoption of similar schemes within all regions. A similar approach for all cruise ports in Europe would be advantageous, for example.

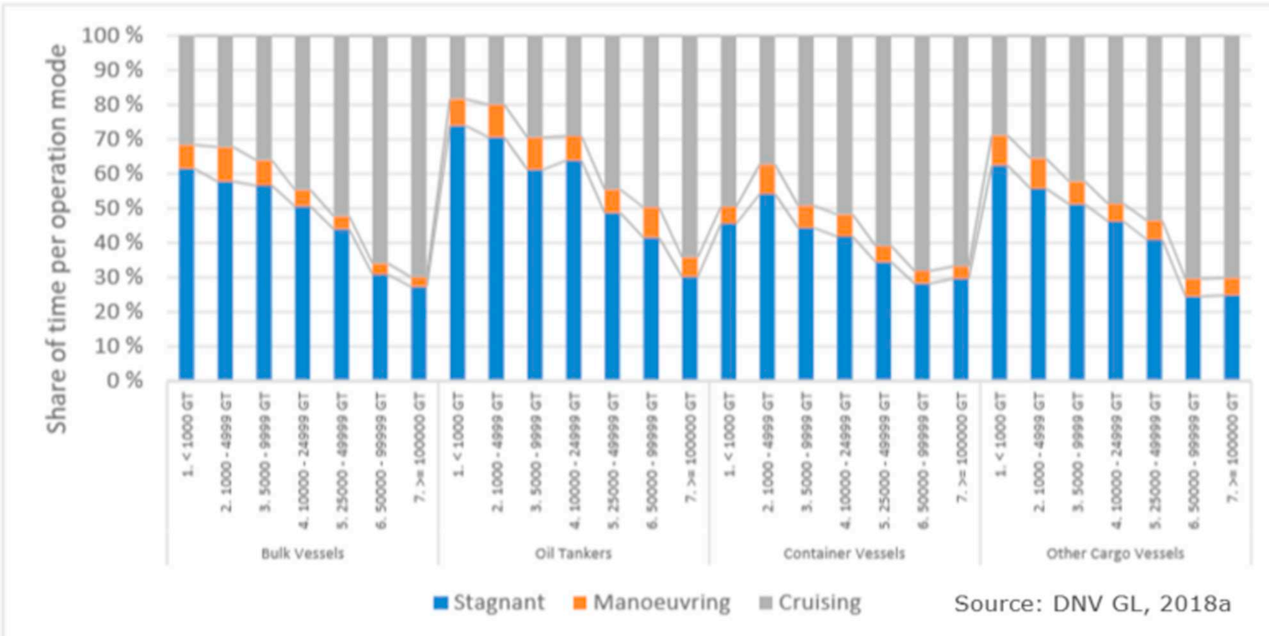

Fig. 3. Share of time per operation mode for cargo vessels by ship type and size.

5. Summary

Ports should play a key role in the green maritime transition. Environmental impacts from the entire shipping industry can be reduced by a wide range of ports using targeted economic instruments.

This study shows that port-based incentives promoting environmentally friendly maritime transport could be an important market-based measure that could help reduce GHGs and other harmful emissions. Our case studies demonstrate that port-based green incentives could be an additional driver for uptake of green technologies, lowering ship emissions both in port and on voyages. Our results show that, to be an important additional driver of emissions reduction, rebates need to be sufficiently large and offered by enough ports worldwide.

The accumulated annual rebate for the ship in our case study globally is more than EUR 400,000. The corresponding numbers for EU and Norwegian waters are EUR 270,000 and EUR 60,000 respectively. We acknowledge that this is a what-if scenario reflecting one possible future where a rebate is available in every port and the average rebate is EUR 1500 per visit.

We have conducted a more in-depth analysis for Norwegian cruise ports to assess how representative that assumed EUR 1500 rebate is. Inputting the actual current costs from six such ports in Norway, the accumulated annual rebate more than trebles from EUR 60,000 to EUR 190,000. The results illustrate the importance of having more detailed fee and taxation data when carrying out such analyses. It also shows that ship size matters, as the difference in rebate for small and large cruise ships on LNG is substantial.

For an optimistic future scenario in which Norwegian rebate sizes are adopted globally, and assuming 50% coverage among large ports worldwide, a cost benefit of more than EUR 700,000 per LNG cruise ship per year is achieved. A reduction of up to one year in payback time on the capital investment in the LNG ship is indicated. More accurate payback times can be estimated if data on actual rebate sizes in ports globally are collected.

Currently the additional capital investment cost for enabling our case ship to run on LNG is in the range of EUR 10 m to EUR 14 m. Consequently, the rebate's value needs to be significantly larger if port-based incentives are to become additional drivers for shipowners to consider investing in costly green technologies such as LNG-fuelled ships. That said, adding in other additional drivers could make investing in green technologies more attractive. These drivers might include local initiatives, and giving booking priority and assigning attractive docking areas for greener ships.

The value of the social benefit of reduced emissions in Port of Bergen is estimated at more than EUR 200,000 for the 13 port calls made by the LNG case ship in 2016. This value shows the social benefit of reduced damage cost from impacts on climate, environment and local air quality.

There are several indexing and rating systems for environmental classification of ships at sea (cruising), but few evaluate the environmental performance under individual stays in port. Taking advantage of available onboard sensor data and reporting capabilities, it should be possible to evaluate the environmental performance of ships under individual port stays. The EPI is an example of a system that does this. It is being piloted with an initial focus on cruise ships, but may eventually include other vessel classes.

The EPI is operating in several ports including Port of Bergen, Port of Trondheim and Port of Stavanger during 2019, and is scheduled to be in most Norwegian cruise ports by 2020.

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[10] The Green Shipping Programme at https://www.dnvgl.com/maritime/green-shipping-programme/index.html.

[11] https://www.innovasjonnorge.no/en/start-page.

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