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Carbon dioxide mitigation from public procurement with environmental conditions: The case of short-sea shipping in Norway

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ABSTRACT

We investigate the potential for greenhouse gas (GHG) emission cuts for the Norwegian short-sea (domestic) maritime segments of express boats, offshore support vessels, and aquaculture support vessels in comparison to ferries in Norway. Public procurement conditional on climate-friendly operation is catalyzing a transition to battery-electric operation, where most ferries will be battery-electric or fueled by hydrogen by 2030. The comparison to ferries is performed with the help of a methodology inspired by the multi-attribute utility method, which contains 11 features related to technology, operation, and acceptance. This score is used to adjust the 70% CO_2 emission reduction achieved by ferries. Based on this methodology, the CO_2 emission reduction potential for express boats, offshore support vessels, and aquaculture support vessels is estimated to be 46%. Consequently, these short-sea shipping segments could reduce CO_2 emissions by 0.8 million tonnes from 2017 to 2030, which is equivalent to 1.5% of Norwegian emissions in 2017. Norway's experience indicates that there is a sizable potential for reducing CO_2 emissions for public procurement conditional on climate-friendly solutions for short-sea shipping in other shipping nations.

Abbreviations

AIS	Automatic Identification System
ETS	Emissions Trading System
EU	European Union
GHG	Greenhouse Gases
IMO	International Maritime Organization
LNG	Liquified Natural Gas
MAUT	Multi-Attribute Utility Theory
NCA	Norwegian Costal Administration
NEEZ	Norwegian Exclusive Economic Zone
NIS	Norwegian International Ship Register

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NOR Norwegian Ordinary Ship Register
TIS Technological Innovation System

1. Introduction

The maritime industry has responded slowly to the climate and greenhouse gas (GHG) emissions challenge. Extensive and fast-growing measures are required to sufficiently reduce global emissions to meet the ambitious Paris Agreement target of limiting temperature increases to well below 2 °C compared to pre-industrial levels. The International Maritime Organization (IMO) targets a 50% cut in GHG emissions by 2050 (compared to 2008 levels) and is working toward phasing out GHG emissions from shipping entirely in the second half of this century. In the long run, new technological solutions may transform the shipping industry into a close-to-zero-emissions industry, but increased global seaborne trade may jeopardize the ability to meet this target. The IMO foresees a reduction in GHG intensity, that is, GHG emissions per unit of transport performance (in tonnes miles), of at least 40% by 2030, and aims at a 70% reduction by 2050 (IMO, 2018).[1]

Short-sea (domestic) shipping, which is under coastal states' control, faces similar tough GHG emission reduction targets. Under the Paris Agreement, Norway's nationally determined contribution is to reduce emissions by at least 40% in 2030, compared to the 1990 levels (Norwegian Government, 2019a). Norway's climate agreement with the European Union (EU) for GHG emissions that are not included in the EU's Emissions Trading System (EU ETS) aims to cut emissions by at least 40% by 2030 (compared to 1990 levels). Emissions from the transportation sector are exempt from the EU ETS, but the EU plans to include segments of the maritime and vehicle sectors. According to the Norwegian National Transportation Plan 2022–2033 (Norwegian Government, 2021), the government's goal is even more ambitious: reducing GHG emissions by 45% by 2030 (compared to 2005).

Many measures and policy instruments are available at the national level to reduce GHG emissions from short-sea shipping and facilitate a green transition through strengthening incentives for ship owners to modify the operation of ships, make modifications to ships, or invest in new ship designs. These measures can be divided into six categories: public procurement of transportation services and license conditions, taxing and emissions trading, government support schemes, research and development, favorable green finance, and regulatory measures. In this article, we focus on one policy instrument with merit in Norway, namely, public procurement and licensing processes entailing environmental conditions, mainly low CO_2 emissions. Thus far, such green procurement processes have been used successfully in the ferry sector, leading to around 70 battery-electric ferry connections by the end of 2022 (out of a total of 132 connections) and covering most of the remaining ferry connections over the next few years (Ministry of Climate and Environment, 2021). Hydrogen is being developed as a fuel alternative for express boats in anticipation of similar procurement conditions for this shipping segment. We examine the potential CO_2 emission reduction effect of green procurement and licensing processes across the most relevant short-sea shipping segments in Norway in addition to ferries, which are express boats, offshore support vessels, and aquaculture support vessels.[2] The comparison to ferries is performed with the help of a methodology inspired by the multi-attribute utility (MAUT) method, containing 11 features related to technology, operation, and acceptance, to assess the potential effects of applying green procurement and licensing processes for the three shipping segments (Jansen, 2011). Express boats, offshore support vessels, and aquaculture support vessels mostly involve short-distance transportation with frequent stops, where alternative low- or zero-emission technologies are available, the foremost being battery-electric operation. Express boat services are based on concessions awarded through public procurement processes. Petroleum companies operate under a regulatory framework with production licenses governed by the Ministry of Petroleum and Energy, whereas aquaculture companies require licenses managed by the Directorate of Fisheries. The licensing processes for petroleum and aquaculture companies provide an opening for the inclusion of low-emission conditions for the operation of supply vessels. Fishing vessels are not included in this study, as the institutional arrangements and government regulations are very different from those for other shipping segments (Isaksen et al., 2021). A few scientific studies on the CO_2 emission mitigation potential of procurement processes, fuel taxing, and low-carbon fuels for specific shipping segments exist but not many in terms of the broad application of green procurement and licensing processes for short-sea shipping (e.g., Bjerkan et al., 2019). The potential of green procurement processes as climate policy tools should also be of interest to other shipping nations.

The literature on sustainable short-sea shipping is reviewed in Section 2, before the status of this industry in Norway is discussed in Section 3. The experience with public procurement conditions for ferry services in Norway is examined in Section 4, followed by a description of the analytical framework in Section 5. The CO_2 emission reduction potential for green public procurement and licensing is examined in Section 6, followed by the conclusions in Section 7.

2. Short-sea shipping

The literature on sustainable solutions for short-sea shipping is still limited, but there are some recent contributions to the general transformation of the maritime industry and specific shipping segments. Bouman et al. (2017) review 150 studies on CO_2 emission reduction potential and measures for shipping globally, including technologies and operational practices. They divide emission mitigation measures into hull design, economy of scale, power and propulsion, speed, fuels and alternative energy sources, as well as weather routing and scheduling, finding that a CO_2 emission reduction of more than 75% is possible before 2050. Balcombe et al.

[1] Greenhouse gas (GHG) emissions from shipping are dominated by CO_2; therefore, we mostly refer to this gas (Olmer et al., 2017).

[2] Offshore support vessels assist oil- and gas-producing platforms in the North Sea. They are also referred to as offshore service vessels. Similarly, aquaculture support vessels are sometimes referred to as aquaculture service vessels.

(2019) present a broad review of fuel, technology, and policy options for reducing CO_2 emissions from shipping, mainly through slow steaming, changes in ship design, and the use of low-carbon fuels. Gilbert et al. (2018) present a comprehensive life-cycle analysis of alternative shipping fuels with regard to emissions to air, concluding that there are no readily available fuel alternatives to significantly reduce local pollutants and GHG emissions. Psaraftis et al. (2021) review market-based measures associated with the IMO's strategy for reducing GHG emissions, finding that a levy-based mechanism has several advantages compared to emissions trading. Christodoulou and Cullinane (2021) examine voluntary sustainability initiatives in the ferry line industry for the case of the short-sea shipping operator Stena Line. They find a significant GHG emission reduction potential from provision of onshore power supply, alternative fuels, electrification of vessels over short distances, increased vessel size, optimal timing of port calls in combination with slow steaming, and crew training. In terms of procurement policies in the marine sector, Rehmatulla et al. (2017) analyze EU ferry procurement policies, finding that different incentives for government, ferry operators, and ferry owners have stymied efforts to improve the energy efficiency of ferry services.

Bach et al. (2020) and (2021) and Bergek et al. (2021) apply a Technological Innovation System (TIS) approach to investigate battery-electric versus hydrogen and fossil versus biofuel technologies in a Norwegian coastal shipping context. The performance of the battery-electric TIS has matured rapidly over the last few years and is stronger than the TIS for hydrogen, ammonia, biodiesel, and liquefied biogas. Hessevik (2022) examines green shipping networks in offshore shipping companies in Norway, where the main drivers are key persons, participation in voluntary programs, regulations, and customer demand. There are no major shifts in companies' strategies after they join such networks; however, support for funding applications from the network may stimulate zero-emission technologies and fuels. Bergek et al. (2021) argue that coastal ferries are early adapters in Norway and coastal fishing late adapters of battery-electric technologies due to different 'windows of opportunity'. Handberg et al. (2019) discuss cost-effective measures and fuel alternatives to reduce GHG emissions from marine and land-based freight transport in Norway and find that the most interesting solutions for ships are hybrid electric solutions, biogas, and hydrogen. Sundvor et al. (2021), using Automatic Identification System (AIS) data, find that 51 out of 73 vessels in the express boat fleet in Norway can be operated by hydrogen fuel or batteries, and 12 of them on batteries.[3] The limiting factors for the transformation of the express boat fleet are travel route characteristics, distance, battery capacity, charging time, local power grid capacity, hydrogen fueling time, and hydrogen infrastructure. The procurement system is likely to be instrumental in speeding up the process toward low-emission technologies. Sæther and Moe (2021) find that the specific historical background and institutional conditions in the maritime industry in Norway have made electrification of ferries possible. The main success factors are an innovation system characterized by close collaboration between private and public stakeholders, an entrepreneurial state, and ambitious climate policy targets. This development was also catalyzed by the drop in oil prices in 2014, which reduced new contracts for offshore support vessels, and shipyards found new opportunities to build battery-electric ferries. Steen (2017) lists five categories of policy instruments: research on energy technologies and infrastructure for shipping, government support for pilot facilities, taxing of GHG emissions and pollutants (including the NO_x fund established by the Confederation of Norwegian Enterprises [NHO]), public procurement with environmental conditions, and regulation of minimum percentage mixing of biofuels in fossil fuels. Zero (2022) estimates that various measures in the maritime industry can reduce CO_2 emissions by 56% by 2030. Public procurement (tendering) with environmental conditions could be a suitable measure for reducing CO_2 emissions not only for ferries but also for other shipping segments. More emission regulations and green public procurement processes are estimated to reduce maritime emissions by 1.3 million tonnes (Mt) CO_2 by 2030 (Zero, 2022).

Most of these studies focused on the CO_2 emission mitigation potential of alternative fuels, some on changes in operational practices, and a few on efficient policy instruments for the green transition of shipping. Given the success story of the green transition for ferries in Norway, our contribution to the literature is a comprehensive analysis of the potential CO_2 emission reduction from green public procurement and licensing for other relevant short-sea shipping segments in Norway.

3. Greenhouse gas emissions from Norwegian short-sea transport

Two approaches to recording Norwegian short-sea transport emissions dominate: emission estimates based on fossil fuel sale statistics and emission estimates based on actual vessel movements from AIS data and technical data on individual vessels. In the context of Norway's commitment to the Paris Agreement, Norwegian short-sea shipping is defined as 'shipping between two Norwegian ports, including Svalbard and installations on the Norwegian continental shelf' (Norwegian Government, 2019a, p. 11). It does not include the Norwegian deep-sea fleet that mainly operates in international waters without calling at Norwegian ports, the Norwegian vessels doing short-sea transport in other countries, and vessels from other nations calling at ports in Norway. In this study, we apply the Paris Agreement's definition of short-sea shipping. In 2020, total emissions from domestic short-sea shipping were estimated at 3.6 Mt CO_2 equivalents (Statistics Norway, 2022a). The corresponding numbers for the benchmark years 1990 and 2005 were 2.6 and 3.2 Mt, respectively, which implies that the 2020 emissions were 38% higher than the 1990 benchmark and 13% higher than the 2005 benchmark.

Statistics Norway's emissions inventory is based on registered short-sea fuel sales in Norway. However, short-sea vessels that mainly sail between Norwegian ports may occasionally also refuel abroad. This suggests a potential underestimation of GHG emissions from coastal navigation. Fig. 1 shows GHG emissions from short-sea shipping from 1990 to 2020 based on Statistics Norway's emissions inventory. There have been only small variations in emissions over the last two decades. Despite the shortcomings of the

[3] AIS is an automatic tracking system that uses transceivers on ships and is used by vessel traffic services worldwide. When satellites are used, the term is Satellite-AIS (S-AIS).

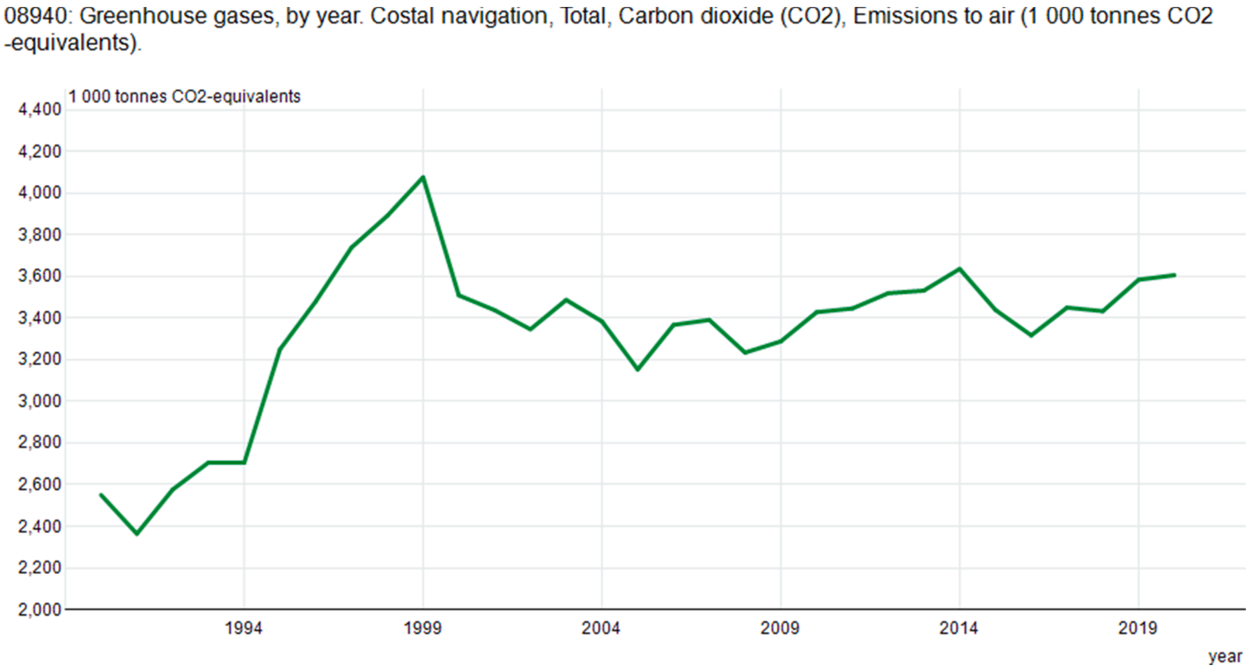

Fig. 1. Greenhouse gas emissions from domestic shipping in Norway 1990–2020, 1000 tonnes (ktonnes) CO_2 equivalents based on fuel sales data. Source: Statistics Norway, 2022a.

statistics, they are highly relevant as policy benchmarks given that the government's commitments are based on the Norwegian emission inventory. This means that these data and any revisions have direct policy implications.

The Norwegian Coastal Administration (NCA), in cooperation with DNV GL, estimates emissions from shipping and fisheries in Norwegian waters based on AIS observations and technical information at the individual ship level. Observations are activity based, which removes the challenges related to fuel sales statistics. However, the observations are limited to vessels that use the AIS. This means that emissions from small vessels are mostly excluded from the database. For some sub-categories, this has a significant impact on emission estimates, for example, for fisheries. In addition, the AIS data do not discriminate between Norwegian vessels and foreign-owned vessels as long as the transportation is between Norwegian ports and not for exports or imports to Norway. The NCA/DNV approach allows for the detailed specification of sub-categories. They define GHG emissions from short-sea shipping as emissions from vessels that sail between two destinations within the Norwegian Exclusive Economic Zone (NEEZ). For 2018, the DNV estimates the total CO_2 emissions from short-sea shipping as 4.3 Mt. This aggregate is based on estimated emissions from a total of 7114 vessels that operated within the NEEZ for shorter or longer periods of time in 2018. Additionally, 1.2 Mt CO_2 are related to activities in ports (DNV GL, 2019). Only 1518 out of the observed 7114 vessels were carrying the Norwegian flag (NOR [the Norwegian Ordinary Ship Register] or NIS [the Norwegian International Ship Register]). Most of these vessels spent only a short period of time in Norwegian waters. To establish sub-categories that better resemble the fleet that constitutes the basis for Statistics Norway's emission inventory numbers, NCA/DNV also reports emissions from vessels that spent 80% or more of their time in the NEEZ. This reduces the number of vessels to about 1300. In 2018, the CO_2 emissions from such vessels were estimated at 2.9 Mt. Combining these emissions with emissions from Norwegian ports adds up to 4.1 Mt CO_2 equivalent emissions from short-sea shipping.

4. Experience with green public procurement conditions for ferry services in Norway

The Norwegian government and the Norwegian Public Roads Administration supported the first LNG-fueled (liquified natural gas) ferry in 2000, the first battery-electric ferry (MF *Ampere*) in service in 2015, and the testing of the first hydrogen ferry MF *Hydra* in 2022 (Jakobsen and Helseth, 2021).[4] MF *Ampere* is regarded as the first battery-electric car ferry in the world. Today, battery technology is regarded as a proven technology for regular ferry services and short crossings. In 2021, shipping company Bastø Fosen

[4] The battery-electric catamaran ferry MF *Ampere* is operated by the shipping company Norled and entered into service at the crossing between Lavik and Oppedal, i.e., the 3 nautical mile crossing of the Sognefjord. MF *Hydra* is also equipped with batteries and a diesel-fueled generator as back-up.

introduced the battery-electric ferry *Bastø Electric* on the service crossing the Oslo Fjord, between the towns of Moss and Horten, which is the busiest car ferry service in Norway.[5] Of the 16 ferry connections in the main road network in Norway, around 80% were battery operated by the end of 2022. Two new hydrogen-fueled ferries will be in service in Nordland County (Torghatten Nord) by 2025, which will reduce CO_2 emissions annually by 26.5 ktonnes CO_2 (Norwegian Public Roads Administration, 2022a, 2022b). Vestland County will reduce CO_2 emissions from ferries by 47 ktonnes (70%) CO_2 annually from 2019 to 2022 through battery-electric operation, which makes this the region with the most electric ferries in the world (Vestland fylkeskommune, 2021). In 2017, emissions from 203 ferries totaled 605 ktonnes CO_2 (Ministry of Climate and Environment, 2019; based on AIS data). In 2016, the CO_2 equivalent emissions from ferry connections administered by counties totaled 332 ktonnes (Menon, 2018). DNV GL's reference emission scenario from ferries will total 180 ktonnes CO_2 by 2030, because all national road-related ferry connections (operated by the Norwegian Public Roads Administration) and some county ferry connections are assumed to become zero emissions before 2030 based on battery-electric solutions (in addition to a few hydrogen-operated ferries and the limited use of marine diesel; DNV GL, 2019). Sufficient power infrastructure for charging ferries has been a challenge, but the government has provided support to cover additional costs by introducing these low-emission technologies. The short distances and fixed patterns of most ferry routes create favorable conditions for introducing zero-emission technologies.

The reduction in CO_2 emissions is mainly achieved through public procurement processes with environmental conditions. The Norwegian Agency for Public and Financial Management (DFØ, 2022) states that the goal is zero-emission solutions regarding procurement of transport services from ferries and express boats unless there are significant operational obstacles. The agency outlines a procurement process to secure environmental conditions and estimates that the potential CO_2 emission reduction will be 135 ktonnes for ferries and 40 ktonnes for express boats until 2030. Bjerkan et al. (2019) examine the governance of green procurement of ferry services in Norway, which has been considered for more than 250 ferry and express boat connections. Relevant governance mechanisms are based on regulation, the market, and cognitive as well as normative framings. Green public procurement and tendering processes can be divided into procedural and service delivery issues and are closely related to private–public partnerships. Studies show that emissions, fuels, and energy are pronounced requirements in public tenders for transport services. Timelines, contract duration, standardization, requirements, and weighting of different aspects are important procedural issues, whereas technology lock-in, technology costs, energy capacity and costs, and infrastructure for charging and refueling are important service delivery issues. The state enterprise Enova (supporting energy efficiency and greenhouse gas emission mitigation investments) allocated €70 million to 17 projects in maritime passenger transport between 2015 and 2017.

The successful transformation of ferry services in Norway thus far suggests that close to 100% zero-carbon operation for conventional ferry services may be possible in the medium term. The political acceptance of investing in the transformation from marine diesel and LNG to battery-electric operations for conventional ferries is strong. Against this background, the technical potential for further reduction in CO_2 emissions for county-operated ferry connections is estimated to be 180 ktonnes of CO_2 (DNV GL, 2019). This is a 70% emission reduction compared to the 605 ktonnes of CO_2 in 2017 (Ministry of Climate and Environment, 2019).

5. Methodology

To compare express boats, offshore support vessels, and aquaculture support vessels to ferries, we introduce a methodology inspired by MAUT. This theory has been used to support complex decision making, for instance, for ranking irrigation systems for agriculture, mapping flood risks, managing the environment, and choosing among housing alternatives (Jansen, 2011). In this study, we apply a MAUT-inspired methodology to estimate the CO_2 emission mitigation potential of green public procurement and licensing for the three shipping segments mentioned above. Ferries are taken as the reference case, given their success story. The MAUT method consists of five steps (Jansen, 2011):

1 Define alternatives and attributes that are important for the value (utility) associated with the choice of an alternative.
2 Define a scoring system for each attribute and assign a score for each attribute across the alternatives.
3 Assign relative weights (i.e., importance) to the attributes.
4 Calculate an overall score per alternative using the score and weight of each attribute.
5 Test the robustness of the overall score by testing different scoring and weighting systems.

In our case, the 'alternatives' are the three shipping segments express boats, offshore support vessels, and aquaculture support vessels, with the ferries segment as the reference. We dedicate *index s* to the shipping segment, taking values of 0 (ferries), 1 (express boats), 2 (offshore support vessels), and 3 (aquaculture support vessels). 'Attributes' are features associated with each shipping segment that are relevant for the potential for CO_2 emission reduction. Based on the literature of different shipping segments and assessments of what features and conditions are important for potential CO_2 emission reductions, we chose 11 features and organized them into three categories: technology, operation, and acceptance related (see Table 1). These features are denoted by *index a,* numbered 1 to 11.

We define ferries as the reference shipping segment based on the success of the battery-electric transition for this segment, and

[5] Another innovative green shipping design, which was not incentivized by green public procurement, is *Future of the Fjords*, which is the first carbon-fiber electric boat designed for sightseeing tours. The boat has been in service since 2018, operated by The Fjords. Furthermore, the world's largest plug-in hybrid roll-on/roll-off passenger vessel, the MS *Color Hybrid*, entered service in 2019 and is operated by Color Line.

Table 1
Features to compare CO_2 emission reduction potential of express boats, offshore support vessels, and aquaculture support vessels to ferries.

Category	No.	Features	References
Technology	1	Alternative fuels	Bouman et al. (2017) Balcombe et al. (2019) Bergek et al. (2021) Handberg et al. (2019)
	2	Infrastructure	Bjerkan et al. (2019)
	3	Efficient and co-operative innovation system	Sæther and Moe (2021) Bach et al. (2020, 2021) Bergek et al. (2021)
Operation	4	Slow steaming	Balcombe et al. (2019) Christodoulou and Cullinane (2021)
	5	Improved scheduling and logistics	Bouman et al. (2017) Christodoulou and Cullinane (2021)
Acceptance	6	Consistency with current regulation regime	Roll et al. (2022)
	7	Industry acceptability	Roll et al. (2022) Bergek et al. (2021)
	8	Public expectations	Bergek et al. (2021)
	9	Potential for public–private partnerships	Sæther and Moe (2021) Bjerkan et al. (2019)
	10	Coordination of policies and incentives	Sæther and Moe (2021)
	11	Facilitation by external crisis	Sæther and Moe (2021)

therefore, we compare the opportunities for reducing CO_2 emissions through procurement and licensing processes for express boats, offshore support vessels, and aquaculture support vessels to ferries. With this scoring system, each feature (attribute) is given a score compared to ferries, where the latter is assigned a value of 1.0. If, for example, express boats are deemed to have the same opportunity for reducing CO_2 emissions through alternative fuels as ferries, the score would be 1.0, whereas the score would be 0.1 if the availability of alternative fuels for express boats is very low. Thus, scores between 0.2 and 0.9 are given in the case of intermediate opportunities for emission reductions. The scores are assessed and determined by the authors based on a systematic comparison of each of the features to ferries, and for each shipping segment. A detailed account of the comparison to ferries and the setting of scores is given in Section 6. The score is denoted by S_{sa} and the weight W_a. We begin with a simple system of equal weights on each of the 11 features (1/11) but test the robustness of the CO_2 emission reduction estimates with different weighting alternatives. The weighted score for shipping segment s and feature a is denoted as $S_{sa}\, W_a$, whereas the overall score for a shipping segment is the sum across all 11 features, as shown in the following equation:

$$M = \sum_{s=1}^{3} \left\{ E_s \cdot 0.7 \sum_{a=1}^{11} [S_{sa} W_a] \right\} \tag{1}$$

As CO_2 emissions from ferries are expected to be reduced by 70% from 2017 to 2030, this is given a reference value of 0.7. Consequently, the overall score across the features for a shipping segment receives a value between 0.07 (0.1 × 0.7) and 0.7 (1.0 × 0.7). The potential for CO_2 emission reduction from green procurement and licensing in Norway for shipping segment s is then calculated as the overall score $\Sigma_a\, S_{sa}\, W_a$, multiplied by the reference value 0.7 from ferries and CO_2 emissions (E_s) in the base year (2017). Finally, the total emission reduction potential for express boats, offshore support vessels, and aquaculture support vessels (M) is the sum of the emission reduction potentials over the three shipping segments, as shown in Eq. (1). All emissions are annual and measured in ktonnes CO_2.

In the next section, we assess how each feature S_{sa} for each shipping segment compares to ferries in terms of facilitation of CO_2 emission reduction, inserting a score between 0.1 (very different) and 1.0 (similar), according to how the conditions differ from the conditions for ferries. Furthermore, the estimated CO_2 emission reduction potential per shipping segment is calculated according to Eq. (1).

6. Emission reduction potential from green public procurement and licensing

The operational and government-instituted conditions for ferries, express boats, offshore support vessels, and aquaculture support vessels differ in many respects. This affects the opportunities for using green public procurement and licensing processes to reduce CO_2 emissions across these shipping segments. We assess the differences and suitability of using conditional public procurement and licensing processes for the three shipping segments compared to the ferries segment for each of the 11 features outlined in Table 1. Possible barriers, costs, and other factors affecting the potential compared to CO_2 emission reduction for ferries are examined. As some of the features depend on investments in supporting infrastructure, such as sufficient local grid capacity to support battery solutions, the possibility of aligning public procurement with government support schemes is important. In the ferry case, Enova and Innovation Norway have supported investments in local grids and charging infrastructure.

Initially, each of the 11 technology, operational, and acceptance features is assumed to have the same effect on potential CO_2 emission reduction for a shipping segment, for example, alternative fuels compared to slow steaming. Accordingly, all 11 features are given the same weight in the calculation of the score for each shipping segment (1/11), making the average score equal to the simple arithmetic mean of the features.

6.1. Express boats

According to the Ministry of Climate and Environment (KLD, 2019), express boats emitted 146 ktonnes CO_2 in 2017, and the Coastal Route from Bergen to Kirkenes 242 ktonnes.[6] The Coastal Route is subject to the procurement of services. Two competing operators won contracts to sail the route between 2021 and 2030.[7] The total annual CO_2 emissions from the 11 vessels operating on the Coastal Route (according to contract requirements; see the Norwegian Ministry of Transport and Communications [NMTC], 2017) should not exceed 173 ktonnes CO_2 annually, while the annual average over the period should not exceed 162 ktonnes CO_2. Despite these requirements, emissions from the Coastal Route contribute significantly to the total emissions of the short-sea passenger fleet. The newly signed contracts limit the possibility of using procurement requirements to transform the coastal fleet into low-carbon technologies before 2030. When the existing contracts expire, and in the case of stakeholder acceptance, the introduction of further low- or zero-carbon technologies for the Coastal Route is likely. Current operators have taken small steps in that direction.

Battery-electric operation of express boats is challenging due to battery capacity and charging limitations in ports. Alternative fuels, such as ammonia and hydrogen, may eventually be available, but many new boats need to be commissioned, and production capacity for fuels and infrastructure for distribution must be developed. Against this background, the alternative fuel and infrastructure features received a score of 0.4 (see Table 2; ferries have a score of 1.0 for all features). An innovation system exists, in part overlapping with ferries. New express boat designs have been developed; therefore, this feature gets a value of 0.8. Slow steaming is not an alternative for express boats, and receives a score of 0.1, whereas improved scheduling and logistics likely have some potential, and thus receives a score of 0.4. As express boats operate on public concessions and licenses, and with our focus on public procurement, the regime consistency feature receives an above-medium score of 0.7. The industry acceptability score is medium at 0.6, given that the industry is developing new, low-emission designs. Due to the general focus on climate measures in Norway and the willingness to provide public support, public expectation is set at 0.8. Given the integration of express boats into Norway's transportation infrastructure and related coordination with the government, the public–private partnership score is high at 0.8, and the coordination of policies and incentives scores 0.7. The facilitation by external crisis feature gets a score of 0.6 because this shipping segment is not much affected by the energy crisis in Europe and has started the green transformation. The average score across the 11 features is 0.57. Applying Eq. (1) thus results in a potential emission reduction through green public procurement and licensing of 155 ktonnes CO_2 by 2030, which is close to the annual average emission in the contract for 2021 to 2030 between the Coastal Route operators and the NMTC (162 ktonnes). Accordingly, CO_2 emissions are expected to decrease from 388 ktonnes in 2017 to 233 ktonnes by 2030 (see Table 2).

6.2. Offshore support vessels

According to the Ministry of Climate and Environment (2019), CO_2 emissions from offshore support vessels totaled 1096 kt CO_2 in 2017. In historical terms, activity in the Norwegian offshore petroleum sector is relatively high. This is partly due to tax incentives introduced to counteract the impact of the oil price downturn in 2014 and weaker investment prospects in the wake of the end of the construction phase of the major Johan Sverdrup oil field in 2019. The operations of the support fleet are characterized by fixed sailing patterns between coast bases and petroleum fields. The main activities are centered on a few bases on the Norwegian west coast and the main oil and gas fields off the west coast. The regular sailing pattern of offshore support vessels is favorable for a transformation from marine diesel to LNG or battery-electric hybrid operation. Lindstad et al. (2017) examine potential GHG emission reductions for the offshore support vessel fleet by introducing battery-electric hybrid technologies in existing and new vessels, finding that LNG-battery hybrid solutions may lead to 20% GHG emissions cuts in the North Sea area and even more in Arctic waters. The redistribution of goods between coastal bases can be part of a future electrified coastal transport system. Østensjø Rederi and Eidesvik started with battery-hybrid offshore support vessels in 2013 (Jakobsen and Helseth, 2021). Thirty offshore support vessels support Equinor's installations in addition to standby and anchor handling vessels (Equinor, 2020a, 2020b). All vessels on longer-time contracts for Equinor (approximately 20) have been equipped with batteries and a shore-based power system since 2021. One support vessel will be prepared for an ammonia fuel system to be tested in 2024. Ammonia will deliver 60–70% of the power requirement onboard this vessel, which will be supplemented with LNG and battery operation.

Offshore support vessels receive scores of 0.8 for alternative fuels, as there is a significant potential for battery-electric and hydrogen/ammonia operation; see Table 3 (where ferries have a score of 1.0 for all features) (Zero, 2022). Some infrastructure for alternative fuels could be developed over the next few years; thus, this feature receives a score of 0.6. The innovation system feature receives a score of 0.6, because this partially overlaps with the system for ferries, and because the potential for co-operative efforts is good; see the efforts already undertaken by Equinor. The slow steaming feature gets a score of 0.6, given the opportunities for offshore support vessels. The feature of consistency with current regulation is set at 0.6, given the opportunity for the government to include climate- and environment-related conditions when approving concessions for oil companies to operate petroleum fields. Industry acceptance is assumed to be quite high, at 0.8, based on the political climate–related pressure on the petroleum industry, also indicated by Equinor's early initiatives for low-emission support vessels. Given the green shift focus among the public and petroleum's large

[6] Menon (2018) estimates 149 ktonnes CO_2 equivalent emissions from short-sea express boats in 2016, which is close to the KLD's (2019) emission estimate for express boats.

[7] Havila Kystruten AS and Hurtigruten Cruise AS.

Table 2
Scores for CO_2 emission reduction potential of express boats from green public procurement and licensing compared to ferries. Annual emissions in 2017, estimated CO_2 emission reduction potential, and emissions by 2030.

Express boats - Feature		Score
Technology	Alternative fuels	0.4
	Infrastructure	0.4
	Efficient and co-operative innovation system	0.8
Operation	Slow steaming	0.1
	Improved scheduling and logistics	0.4
Acceptance	Consistency with current regulation regime	0.7
	Industry acceptability	0.6
	Public expectations	0.8
	Potential for public–private partnerships	0.8
	Coordination of policies and incentives	0.7
	Facilitation by external crisis	0.6
Average score		0.57
Annual CO_2 emissions (2017); ktonnes		388
CO_2 emission reduction potential; ktonnes	388 × 0.7 × 0.57	155
Estimated CO_2 emissions 2030; ktonnes	388 - 155	233

Table 3
Scores on CO_2 emission reduction potential of offshore support vessels from green public procurement and licensing compared to ferries. Annual emissions in 2017, estimated CO_2 emission reduction potential, and emissions by 2030.
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Offshore support vessels - Feature		Score
Technology	Alternative fuels	0.8
	Infrastructure	0.6
	Efficient and co-operative innovation system	0.6
Operation	Slow steaming	0.6
	Improved scheduling and logistics	0.6
Acceptance	Consistency with current regulation regime	0.6
	Industry acceptability	0.8
	Public expectations	0.8
	Potential for public–private partnerships	0.8
	Coordination of policies and incentives	0.5
	Facilitation by external crisis	0.9
Average score		0.69
Annual CO_2 emissions (2017); ktonnes		1096
CO_2 emission reduction potential; ktonnes	1096 × 0.7 × 0.69	529
Estimated CO_2 emissions 2030; ktonnes	1096 - 529	567

emissions share, we assume a high public expectation score of 0.8. The potential for public–private partnerships is sizable due to the governance system for the petroleum industry and its importance for meeting climate policy targets; thus, this feature receives a score of 0.8. Coordination of policies and incentives receives a medium score of 0.5; thus far, little attention has been given to this issue. Due to the very challenging energy situation in Europe (linked to insufficient renewable energy production, drought, less nuclear capacity, high gas prices, and the Ukrainian war), energy security and more gas production combined with the green transition have received higher priority; therefore, we choose a high score of 0.9 for the external crisis facilitation. The average score across the 11 features is 0.69. The methodology applied in this study thus results in a potential emission reduction from green public procurement and licensing of 529 ktonnes CO_2 by 2030, reducing emissions from 1096 ktonnes in 2017 to 567 ktonnes in 2030 (see Table 3).

6.3. Aquaculture support vessels

CO_2 emissions from aquaculture support vessels in 2017 are estimated at 205 ktonnes (Ministry of Climate and Environment, 2019). Aquaculture (fish farming) has created a specialized transportation industry, and emissions from aquaculture support vessels are now larger than for express boats (excluding Coastal Route emissions). In tandem with the growth of the Norwegian fish farming industry, the number of fish carriers and well vessels has increased. Ninety-three vessels were registered under the domestic NOR flag in 2020 (up from 63 vessels in 2007), and the size of the vessels has increased significantly (Statistics Norway, 2022b). These vessels typically operate in sheltered waters along the Norwegian coast. The profitability of the fish farming industry is high, as is acceptance for companies to present the industry as environmentally friendly. In the case of substantial investments in charging facilities along the coast, the aquaculture fleet could be at the forefront of a shift toward battery-electric operation. The aquaculture industry operates under a licensing regime. In 2024, if feasible, the government will gradually introduce requirements for zero- or low-emission technologies for aquaculture support vessels (Norwegian Government, 2021b). The Ministry of Trade, Industry and Fisheries can establish conditions for allowable equipment used in the aquaculture industry, as well as equipment used for supply chains on commodities and services, for example, regarding well vessels and vessels used for fish feeding (Norwegian Ministry of Fisheries and Coastal Affairs, 2005). These conditions can be motivated by the risk of fish escaping the facilities, sea use and the hindrance of traffic, and negative impacts on the environment.

Given the operational mode of aquaculture support vessels, there should be significant potential for replacing traditional fuels with battery-electric solutions for short-distance and ammonia or hydrogen for longer-distance operation; thus, this feature receives a score of 0.9 (see Table 4; ferries have a score of 1.0 for all features). Not many alternative fuel infrastructures are currently available; thus, this feature receives a score of 0.5. The relevant innovation system can learn from the ferry segment, but sizable investments are needed; therefore, this feature receives a score of 0.4. Slow steaming and improved scheduling and logistics should be realistic possibilities for many aquaculture support vessel operations; therefore, both features receive a score of 0.7. Consistency with the current regulation regime receives a medium score of 0.5, where the existing aquaculture concession system increases the score, but the slow progress in expanding Norway's green governance system to this shipping segment pulls down the score. Industry acceptability receives a medium score of 0.6, whereas public expectations are scored at 0.8 due to the attention to the green transition. Given the current governance system based on concessions, the opportunity for public–private partnerships receives a medium score of 0.6. Coordination of policies and incentives receives a medium score of 0.5, as climate considerations must be balanced with the economic importance of aquaculture, which is a big industry in Norway, especially in rural areas. The energy crisis in Europe will not significantly affect the importance and profitability of aquaculture; therefore, this feature receives a medium score of 0.6. The average score across the 11 features is 0.62. The methodology applied in this study thus results in a potential emission reduction from green public procurement and licensing of 89 ktonnes CO_2 by 2030, reducing emissions from 205 ktonnes in 2017 to 116 ktonnes in 2030 (see Table 4).

6.4. Total CO_2 emission reduction potential

The emission reduction potentials of express boats, offshore support vessels, and aquaculture support vessels, as well as the total potential, are summarized in Table 5. The CO_2 emission reduction potential is also shown as a percentage of 2017 emissions.

The robustness of the CO_2 emission reduction potential based on equal weights on all 11 features is tested with two alternative weighting alternatives. In the first, the three technology features are given a total weight of 0.5 (compared to 0.27 with equal weights). With this weighting alternative, the total CO_2 emission reduction is 764 ktonnes CO_2. In the second, the six acceptance features are given a total weight of 0.7 (compared to 0.55 with equal weights). With this weighting alternative, the total CO_2 emission reduction is 796 ktonnes CO_2. In summary, these sensitivity calculations lead to either a small decrease in the CO_2 emission reduction potential of 9 ktonnes or a small increase of 23 ktonnes. Given the small deviations with different weightings, we conclude that the results based on equal weighting (the simple arithmetic mean) are relatively robust.

7. Conclusions

Comparing the scores on the 11 features across the three shipping segments, the largest variation is found for alternative fuels, efficient and co-operative innovation systems, slow steaming opportunities, opportunities for improved scheduling and logistics, and facilitation by external crisis. Based on a comparison of the CO_2 emission reduction potential of public procurement and licensing conditional on low-emission solutions for express boats, offshore support vessels, and aquaculture support vessels to ferries, we estimate that the total reduction potential will be 0.8 Mt CO_2 annually for Norway by 2030. This estimate is associated with some uncertainty given the assessment of the 11 features related to technology, operation, and acceptance in comparison to the ferries case. Nevertheless, this is an indication of the transferability of green public procurement and licensing procedures to express boats, offshore support vessels, and aquaculture support vessels, and indicative impacts on Norwegian CO_2 emissions. This is equivalent to a 46%

Table 4
Scores on CO_2 emission reduction potential of aquaculture support vessels from green public procurement and licensing compared to ferries. Annual emissions in 2017, estimated CO_2 emission reduction potential, and emissions by 2030.

Aquaculture support vessels - Feature		Score
Technology	Alternative fuels	0.9
	Infrastructure	0.5
	Efficient and co-operative innovation system	0.4
Operation	Slow steaming	0.7
	Improved scheduling and logistics	0.7
Acceptance	Consistency with current regulation regime	0.5
	Industry acceptability	0.6
	Public expectations	0.8
	Potential for public–private partnerships	0.6
	Coordination of policies and incentives	0.5
	Facilitation by external crisis	0.6
Average score		0.62
Annual CO_2 emissions (2017); ktonnes		205
CO_2 emission reduction potential; ktonnes	$205 \times 0.7 \times 0.62$	89
Estimated CO_2 emissions 2030; ktonnes	205 - 89	116

Table 5
Potential CO_2 emission reduction potential from green public procurement and licensing across three shipping segments in Norway. Equal weights on all technology, operational, and acceptance features. ktonnes CO_2.

Shipping segment	Annual CO_2 emissions (2017); ktonnes	CO_2 emission reduction potential; ktonnes	Estimated CO_2 emissions 2030; ktonnes	CO_2 emission reduction potential; percentage of 2017 emissions
Ferries	605	425	180	70
Express boats (incl. Costal Route)	388	155	233	40
Offshore support vessels	1096	529	567	48
Aquaculture support vessels	205	89	116	43
Total CO_2 emissions/reduction excluding ferries	1689	773	916	46

reduction in emissions for these three shipping segments from 2017 to 2030. An emission reduction of this scale is within the scope of the overall national goal for GHG emission reduction for Norway, 45% from 2005 to 2030 (Norwegian Government, 2021). From a national perspective, the contribution of express boats, offshore support vessels, and aquaculture support vessels implies a reduction of 1.5% of Norway's overall GHG emissions from 2017 to 2030.

The transferability of experience from Norway's public procurement and licensing program on green shipping depends on the degree of similarity to conditions in other shipping countries, specifically regarding facilitative factors and barriers. In terms of the 11 features in Table 1, the availability of alternative fuels, slow steaming opportunities, improved scheduling and logistics, industry acceptability, public expectations, potential for public–private partnerships, and facilitation by external crises should largely be similar for Norway and other shipping nations. However, infrastructure, innovation systems, consistency with current regulation systems, and coordination of policies and incentives depend more on the specific conditions, institutions, and governance structures of other shipping countries compared to Norway. This implies that there is likely some transferability and learnings for other shipping countries regarding Norway's policy design to stimulate green shipping through incentive mechanisms, collaboration and coordination between government and industry, innovation system, and infrastructure development.

Further research could venture into more detailed analyses of facilitative factors and policy instruments for greening short-sea shipping, learning from success stories in Norway and other countries. There are also possible learnings relevant to the application of green procurement and licensing processes in other industries, such as land-based transportation. In addition to the three shipping segments included in this study, more studies on fishing vessels and general cargo transport are needed. One important question is whether some of the learnings from short-sea coastal shipping are relevant for deep-sea (international) shipping, which is more challenging due to the need for international agreement among nations with differing interests, as well as less developed climate-friendly fuel alternatives for large vessels and long-distance transport.

CRediT authorship contribution statement

Asbjørn Torvanger: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Jostein Tvedt:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft. **Inger Beate Hovi:** Conceptualization, Data curation, Resources, Supervision, Validation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

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