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Implementing zero emission vessels in ferry operations in Norway

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Abstract

Ferry crossing is considered a vital part of the Norwegian road network, both for passenger and freight transport. However, Norway ferry services contributes to 17% of greenhouse gas (GHG) emissions. Varied measures in the transport sector are put in place to achieve Norway's climate target as committed to in the Paris Agreement. The purpose of this study is to document how the authorities have reduced GHG emissions from the sector through the tendering process for the purchase of domestic ferry services. The study concludes that authorities have used a "push and pull" strategy to reduce the GHG emissions. We will investigate the economic and environmental effects of this new purchase strategy.

Introduction

The Paris Agreement (United Nations, 2015) has recently made Norway raise its climate target from 40% to 55% reduction in GHG emissions in 2030 with an ambitious target of 90-95% reduction by 2050 compared to 1990 levels (Ministry of Climate and Environment, 2021). A substantial emissions cut is seen in the vehicle segment of road transport in Norway, due to many incentive packages stimulating the use of electric battery vehicles (Steen et al., 2019). Norway being the largest ferry nation in Europe (Siemens Energy & Bellona, 2022), has extensive coastline, high mountains, and numerous fjords and islands. Therefore, ferry routes are very important for the public transport system (Odeck & Bråthen, 2009; Odeck & Høyem, 2021). In 2022, there are approximately 137 ferry connections operated by around 180 ferries. (Norwegian Public Road Administration, 2022a). The dominating shipping companies in domestic ferry operations are Fjord1, Torghatten, Norled, and Boreal. The responsibility for purchasing ferry services is split between the Norwegian Public Roads Administration (NPRA) and the County Councils. A regional reform in 2010, transferred the responsibility for many highways and highway ferry services from the state to the county councils. Today NPRA takes responsibility for 16 ferry crossings.

Norway ferries contribute 17% of emissions in Europe (Siemens Energy & Bellona, 2022). In 2017 total domestic shipping emissions accounted for 12.7% of Norway's total CO_2 emissions (Sæther & Moe, 2021). Moreover, 1.4% came from ferry operations. In 2015, Norwegian Public Roads Administration (NPRA) expected that by 2030 two thirds of the energy used to run the ferries would come from the electrical grid. Through public procurement, the government can set tender requirements for the operation of zero-emissions ferries, conditions for operators, and rules for shipyards and suppliers connected to the contract (Siemens Energy & Bellona, 2022). In the 2015 budget agreement, it was stated that all new competitive tenders for ferries should incorporate requirements for zero or low emission technologies as a priority (Bjerkan et al., 2019; Norwegian Ministry of Climate and Environment, 2015). There is an increasing number of electric propulsion ferries in Norway stimulated by environmental claims, as well as support from state agencies for technology development and building the charging infrastructure (Ministry of Climate and Environment, 2019). In 2022, around 72 ferries in Norway will have electric operation, and 14 more are expected to be put in operation in the years to come (Energy and Climate, 2022).

The aim of this paper is to study how authorities, have reduced GHG emissions from the sector through the tendering process for the purchase of domestic ferry services in Norway. Two main research questions to be addressed are:

1. How has the general environmental criteria in the tendering document been expressed for ferry operations in Norway?
2. What can we say about the economic and environmental implications of introducing environmental claims in tendering competitions?

The paper follows an overview of zero-emission ferries, tendering of ferry services, methods and material, results, concluding remarks, and implications for public procurement.

Zero-emission ferries in Norway

Until 2015, Norwegian ferries were dependent on fossil energy (Anwar et al., 2020; Opdal, 2010). In 2000 came M/F Glutra, the first modern liquefied natural gas (LNG) ferry. However, LNG is considered a fossil fuel, even if its use can reduce CO_2 emissions by 20% compared to diesel (Steen et al., 2019). The cut in NO_X is approximately 90% (Corbetta & Farrellb, 2002). This paper is mainly placed within the context of ”zero-emission” ferry operations. Currently, the catch phrase “zero-emission” is vigorously pursued by different stakeholders for emission and noise-free environment. Ultimately, the main goal for “zero-emission” is to cut CO_2 emissions so as to reach the target set in the Paris Agreement. Chiefly, among such technologies are ammonia, hydrogen, and battery electric. However, the two main leading technologies in Norway are the latter two.

Charging strategy and method for zero-emission ferries

Hensher et al. (2022) mentions two charging strategies and three charging methods for battery electric buses. For strategy, it is either depot or on route-charging. The methods involve using (1) direct charging cables and (2) plug-in using conductive charging with fast charging equipment like a pantograph and (3) using fast charging by means of induction or wireless charging with a magnetic field. For ferries, shore-based charging is used depending on energy source. In a situation where the coastline grid is not able to provide high energy requirements within the shortest possible time, there is the need for grid reinforcement or putting up dedicated grid stations for charging the ferries. Among the factors worth considering for the grid station design are energy type, the requirement of the ferry or vessel, crossing distance, and terminal time (Anwar et al., 2020).

The leading method for charging involves cable connection and induction/wireless with the use of magnetic field at the quay. About the former, the issues of wear and tear on cables and plugs and extra labour needed have cost implications. On the contrary, for the later, there is better utilisation of terminal time and limitation of maintenance.

Battery electric ferries

Battery electric vessels are available for short routes because of frequent recharging due to limited battery capacity, high energy requirements, and limited time operations (Anwar et al., 2020; Ministry of Climate and Environment, 2019). A review of the current state of affairs for battery electric vessels is highlighted by Anwar et al. (2020).

Hydrogen vessels

Hydrogen, with no CO_2 emissions, remains the most preferred energy source, especially when produced from renewable sources. Hydrogen's weight makes it an outstanding energy carrier as volumetric energy is low. One kilogram of hydrogen can produce 33 kWh of usable energy contrary to fossil fuel producing 12 kWh (Hensher et al., 2022). Compared with battery electric propulsion motors, hydrogen refuelling time is quicker and the range longer due to its high density and high load capacity (Deloitte-Ballard, 2020; Hensher et al., 2022). Production and transportation costs are crucial for contracts for hydrogen ferries (European Commision, 2021). In addition, because of low volumetric density, the distribution costs can be significantly higher than for the distribution of natural gas and other carriers (Clean Energy Finance Corporation, 2021). Hydrogen production involving steam methane reforming (SMR) and electrolysis are labelled as grey, blue, and green (e.g.,see, Clean Energy Finance Corporation, 2021; Steen et al., 2019).

The environmental status of ferry services

The environmental status of the 16 crossings under the NPRA responsibility is given in Table 1.

Table 1: Environmental status of national road ferry connections.

No	Connection	Details of development status
1	Moss-Horten	75% during 2022
2	Hjelmeland-Nesvik-Skipavik	MS Nesvik is 100% electric. MF Hydra on 50% hydrogen
3	Mortavika- Arsvågen	LNG- Liquefied natural gas
4	Haljem- Sandvikvåg	LNG- Liquefied natural gas
5	Lavik- Oppedal	Battery electric propulsion
6	Vangsnes – Hella- Dragsvik	80% electric during 2022
7	Mannheller - Fodnes	80% electric propulsion
8	Anda - Lote	90% electric propulsion
9	Volda - Folkestad	95% electric during 2022
10	Solavågen - Festøya	95% electric during 2022
11	Molde - Vestnes	Minimum of 95% electric for 2 vessels from 1 July 2022. 2 other vessel possible to receive electricity from land, but can also use LNG, Biodiesel, biogas or in combination of these sources
12	Halsa - Kanestraum	95% electric 2022
13	Bodø – Røst- Værøy-Moskenes	Minimum of 85% from hydrogen from October 1, 2025
14	Bognes - Lødingen	90% electric from 1 January, 2024
15	Bognes - Skarberget	90% electric from 1 December, 2024
16	Drag - Kjøpsvik	90% electric from 1 December, 2024

Source:(Norwegian Public Road Administration, 2021).

Further, Sæther and Moe (2021) reports of 55 county council ferry connections are not electrified. The plans for electrification of ferry connections is given in Figure 1.

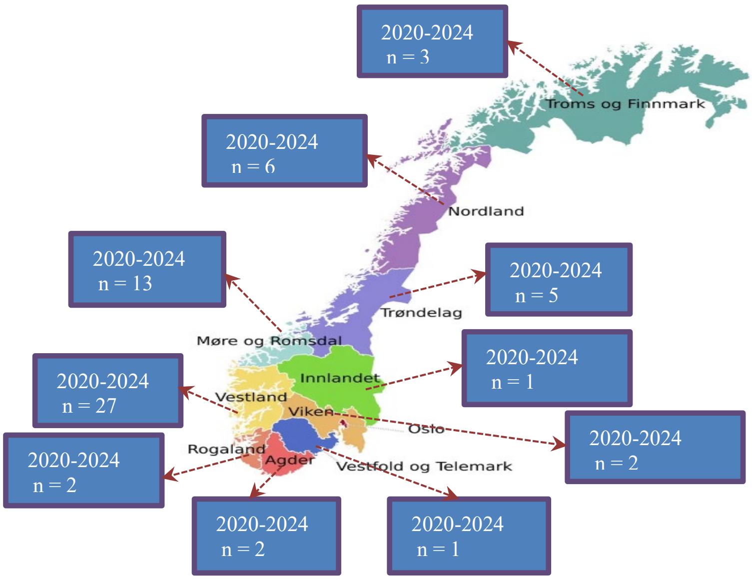

Figure 1: County level developments in ferry electrification in Norway from 2020-2024 (Energy and Climate, 2022; Sæther & Moe, 2021)

Tendering of transport services

The various procurement policies essentially furthers the ideal of competition, and therefore, tendering (Myers & Ashmore, 2007). The two key effects of the use of tendering are the selection effect and the incentive effect. The selection effect means that through the tender competition we can find the transport company that can produce the service at the lowest cost based on the specifications in the tender documents. The incentive effect means that the companies see that if they make their operations more efficient, they can submit a better offer which increases the chances of them winning the tender.

It is worth mentioning that tendering of transport services involves following certain procedures enshrined in public procurement. Among these procedures include open bidding, restricted and limited bidding, competition with negotiation, negotiating procedure without competition, competitive dialogue procedure, and innovative partnership. Literature on public procurement procedures on transport services is rich, (e.g.,see Hensher, 2021; Hensher & Wallis, 2005; Moe et al., 2017; Nash & Wolański, 2010; Official Journal of European Union, 2014; Uttam & Le Lann Roos, 2015).

Tendering of ferry operations in Norway

This section will describe how the tendering process have evolved, the type of tendering utilized in the transition process and how the environmental claims were implemented.

Historical Development of the tendering of ferry in Norway

Until 1990, the national road ferry operations had a grant system where the ferry companies were allowed to balance their accounts after a review by the authorities, popularly known in contracting literature as cost-plus system. This grant system did not give the shipping companies incentives for operating efficiently. From the 1st of January 1990, a fixed grant system was introduced. The size of the grant was now determined through negotiations between the ferry companies and the road administrations in each county. The ferry companies could either earn or lose money on the contract. Thus, the companies are paid based on the cost expected to be incurred and adding some markup to ensure continuity of operations. The markup was 10 percent of the operational costs and this cost-plus system existed for many years with negotiations every sixth year (Odeck & Høyem, 2021). Under both the balanced account system and the fixed grant system, the shipping companies who won the grant were given an exclusive right to operate the service for 10 years. Still, concerns were raised about efficiency improvement and the cutting of subsidies necessitating an avenue to embark upon.

With the happenings in Europe surrounding the local bus market against increasing costs and expectation of EU-regulation (1370/2009) made competitive tendering mandatory with few exemptions after 1990s (Aarhaug et al., 2018). Consequently, the Norwegian transport act got amended in 1991 in order to allow competitive tendering from 15 April 1994.

The NPRA took advantage of the opportunity and subjected six of these ferry crossings to competitive tendering on trial basis (Bråthen et al., 2004; Hervik & Sunde, 2001; Odeck & Høyem, 2021). On the 1st of December, 1995, the first 4 connections were announced with contract periods ranging from 5 to 8 years. After the trial period, the Norwegian parliament affirmed a full-scale implementation of tenders on the highway ferry crossings. From 2003, four ferry crossings saw full discharge of competitive tendering (Brathen et al., 2004). Thereafter, an appreciable number of ferry crossings were switched to competitive tendering, e.g., 7 in 2007, 8 in 2008 and 32 in 2010 (Odeck & Høyem, 2021). Today, all the ferry services are solicited through tendering (Mathisen, 2016).

There has also been a change in the division of responsibilities between the buyer of ferry services and the operators with a transition from net to gross grant contracts. Gross grant contracts imply that the state or the county municipalities have revenue responsibility, meaning that the shipping companies only have cost risk related to the operations. The net contract allows the operator to keep the revenue and when found to be insufficient to meet the operating expenses, the government intervenes with subsidy in order to allow recovery of the deficit (Aarhaug et al., 2018; Hervik & Sunde, 2001).

The tendering model applied for zero emission ferries in Norway

This section describes how the NPRA with other stakeholders have worked hand-in-hand in the cause of tendering process to implement and actualize the technological, innovative, and “green shift” in Norway.

Preparation of the tender

The tender regime in the 2000s was characterised by shipping companies interested in reducing their risk in their offers. The shipping companies adapted to the minimum quality criteria that NPRA required, and competed largely solely on price. NPRA realised that, tender contracts where the shipping companies only competed on price failed to achieve an implementation of new “green” technologies in the industry.

NPRA revises the requirements in the tender documents almost every year. Also, a number of county councils in 2009 began setting new requirements in their ferry tenders. At this time, NPRA and RLF, together with their members, discussed the possibilities of developing the ferry tenders towards an environmentally friendly ferry design that would provide significant energy and environmental benefits. The politicians gradually began thinking this was a good idea, and in the state budget for 2011 (Prop. 1 S (2010–2011), the following can be inferred about ferry operations: *The Ministry of Transport believes it is important that the state facilitates technical innovations on the material side. Therefore, it is planned that the connection Lavik–Oppedal in 2011 will be announced as a development contract, where the industry is invited to compete for the delivery of the most energy- and environmentally efficient ferry to the national highway ferry operation. An electrically powered ferry or a ferry with biofuel may be relevant in the competition for the operation contract.*

Following the above, the Ministry of Transport asked NPRA to announce a “development contract”. The transport companies and the shipbuilding industry were invited to compete for the tender on the ferry connection Lavik–Oppedal based on who had the most energy-efficient and environmentally friendly ferry for the service.

It’s worth noting that designing a successful tender against the complexity of achieving pollution footprint requires a considerable input. This means that, a technical specification pinpointing the precise solution should be established in the tender. In line with this, NPRA announced a tender in October 2010 with the aim of obtaining assistance in formulating the call for the development contract. This tender was won by Det Norske Veritas (DNV). As such, DNV helped NPRA choose which energy criteria to use in the announcement and to assess and analyse the energy figures provided by the suppliers. One unique observation is the need to engage experts in tender specification where the procuring authority competence is limited to a large extent. At the end, a tender was announced for competition utilizing competitive dialogue procedure.

Competitive Dialogue Procedure (CDP)

CDP was adopted for the procurement of the “development ferry”. The CDP is illustrated in Figure 2.

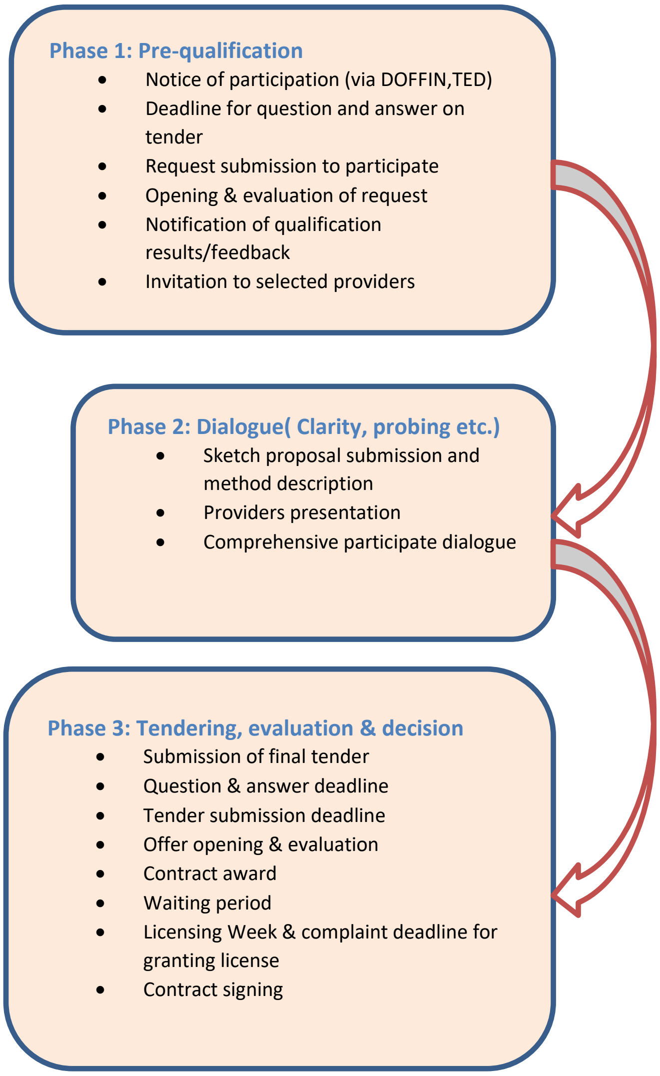

Figure 2: Competitive dialogue procedure for zero-emission ferry procurement- the Norwegian model.

Phase 1 sets the stage for all interested providers to submit a request to participate in the competition. There is an opportunity for bidders to seek answers about the tender before formally requesting to participate. Based on the number of applications received, request evaluation will be conducted upon which the client[1] sends feedback an invitation to selected providers.

[1] Client is used to refer to the procuring authority in this case NPRA/County municipalities.

Phase 2 commences a dialogue with the selected providers. The client normally invites four qualified providers to participate in the dialogue phase. The dialogue can be conducted on all aspects of the solution, including technical, temporal, and economic circumstances. Each participant can submit a maximum of three sketch proposals for the first dialogue meeting. The participant follows with a presentation. Feedback is given including e.g., clarification needs, assessment needs, improvement needs, etc. At the end of the dialogue phase, the client will invite remaining bidders to make final bids based on the solution from bids submitted and specified in the dialogue.

Phase 3 goes through the final tendering process with questions, answers, and tender deadlines being set. Specifically, the procurement is carried out in accordance with the Public Procurement Act of 17 July 2016 no. 73 (Procurement Act) and regulations on public procurement of 12 August 2016 no. 974 (procurement regulations) and any other relevant regulations that guide competition. The phase concludes with contract awarding and signing.

The first "environmental tender"

The tender was announced for Lavik–Oppedal connection in 2011 with its operational start in the 1st of January 2015. The tender process was in response to NPRA issuing a development contract in 2011 with a contract period of 10 years.). It was assumed that the ferry connection should be operated by 3 ferries, one of which should be the 'development ferry'. The development contract had the goal of "stimulating to zero or low emission technology in the developmental, yet commercial, tendering process" (Sjøtun, 2019,p.19). The client's goal was to achieve at least 15-20% energy and environmental improvement for the development ferry compared to "traditional" new ferries. Accordingly, Sjøtun (2019,p.21) stressed "Environmental friendliness" and "energy cost savings" remains two key factors in pushing the agenda of "future is electric." A specific exception existed for high chance consideration if an operator offers a significantly better service in relation to environmental factors; for example, it was less than 5% more expensive than the cheapest one (Odeck & Høyem, 2021).

To ensure that a battery-electric ferry could also be included as one of the solutions, it was mentioned in the tender documents that the ferry could sail at a speed of as low as 10 knots (18.5 km/h) and have a terminal time (charging time) of as long as 10 minutes. Charging towers were built on both sides of the fjord to provide electricity for propulsion. The suppliers who were pre-qualified for the tender competition and submitted tenders received NOK 3 million in compensation for the development work.

Criteria and weight put on these

The focus for the development aspect of the competition was on energy efficiency, with reduced energy consumption, and environmental efficiency, with reduced emissions as a result of the chosen energy carrier or technical solution. Energy efficiency was set to be the most important factor, as reduced energy consumption also leads to lower emissions. The criteria used to select a winner in the final tender competition, that is to be given the opportunity to operate the ferry service, was a weighted combination of the development ferry's energy and environmental efficiency and the lowest total price for the operation of the ferry connection, where the ferry's energy and environmental efficiency amounted for 40% and the total price amounted for 60%. The evaluation criteria used, and their associated weights, are presented in Table 3.

Table 3: Evaluation criteria with weights for the 'development ferry' for Lavik-Oppedal connection.

Category	Evaluation	Weight	Description
Energy efficiency	kWh/PCE km*	45%	Calculated based on documentation from the shipping company.
	Energy consumption	15%	Fuel consumption. It is energy density-megajoules (MJ)/year that is evaluated
Environmental efficiency	Tonne CO_2-eq./year (CO_2/kWh, CH4/kWh)	15%	Calculated based on the basis of annual total energy consumption for the ferry, a determined CO_2-factor for the energy sources (Marine gasoil, gas, biodiesel, battery operation, etc.) and documentation of methane emissions(CH4)
	kg NO_X/year	10%	Calculated based on weighted NO_X - factor and total fuel consumption for the ferry for one year.
Innovation		15%	Innovative solutions that are important for energy and environmental efficiency must be documented by the provider.

* Definition of PCE (passenger car equivalents): Length: 4,30 m, width: 1,85 m, weight: 1,3 tonne.
Source: The Norwegian Public Roads Administration.

Results of the CDP

Both Fjord1, Torghatten, Norled and Boreal participated in the competition to develop an environmentally friendly ferry. Most of them came up with 3-4 sketches for how the crossing could be operated. Technological solutions that were considered not to meet the requirement for 15-20% energy and environmental improvement were rejected. The same happened to the concepts NPRA believed were not possible to implement within the start-up time. Norled won the tender competition. Then, battery electric ferry "Ampere" was built at Fjellstrand shipyard in Hardanger. "Ampere" has a capacity of 120 passenger cars and 350 passengers, and schedules to carry out 34 daily departures on weekdays in 2022.

Tendering for hydrogen ferries

Subsequent to the outcome of the tendering of the world's first battery electric ferry "Ampere" provided sufficient insights and experiences into tenders for hydrogen-propulsion ferries. The 2015 state budget announced that a government development contract, similar to the one producing the world's first battery-powered ferry "Ampere", could be relevant in developing a hydrogen-powered ferry as well. Therefore, NPRA, in partnership with the environmental organization ZERO, held a dialogue conference about the use of hydrogen as an energy carrier in ferry operations in May 2016. The seminar aimed to uncover opportunities, barriers, areas needing more innovation, and possible associated risks in developing a hydrogen ferry. During a conference held in Stavanger on March 2017 by NPRA, the possibilities of tendering hydrogen technology in ferry operations on the Hjelmeland–Nesvik–Skipavik connection in Rogaland was discussed. Such technology is crucial for connections not suitable for fully electric operations.

The Hjelmeland-Nesvik-Skipavik connection was announced for tender on the 13th of July 2017. The goal of the procurement was to enable the development of a ferry with at least 50% of the required energy generated from hydrogen. Norled won the tender competition with the ferry "Hydra". In addition to two hydrogen-powered fuel cells, the ferry also has a large battery package on board. The batteries are continuously charged by the fuel cells, but can also be charged at the quays in Hjelmeland and Nesvik. At least 50% of the time, "Hydra" powered by liquid hydrogen.

A new supplier conference was organized in August 2019 focusing on the use of hydrogen as an energy carrier on the ferry connection Bodø-Røst-Værøy-Moskenes. The conference authored a recommendation to the government covering financial frameworks, environmental requirements, and procurement strategies. The contract duration was 15 years, from 2025 to 2040. There was a requirement for a minimum of 85% of the energy consumption produced from hydrogen with low greenhouse gas emissions for two vessels with a supplementary vessel using solutions such as biodiesel, biogas, electricity, hydrogen, or a combination (Norwegian Public Road Administration, 2022b).

Criteria and weight put on these

The tender on the Hjelmeland–Nesvik connection had the goal of facilitating the development contract of a ferry where at least 50% of the energy needs are covered by hydrogen. The weights were 70% on price and 30% on the environmental criteria. This consisted in 5% for energy consumption [GJ/year] and scalability weighting 25%. Other equally important environmental requirements from the operator includes the cost for NOx tax in its offer as well as used ferry equipment not having a NOx emission exceeding the Tier II requirement in MARPOL annex VI regardless of the year of construction (Norwegian Public Road Administration, 2019).

Result of the tender

The connection Bodø, Bodø-Røst-Værøy-Moskenes starting at the earliest from 2025 was won by Torghatten, which in collaboration with Norwegian Ship Design in Førde shall develop the hydrogen vessels with the contract value of about NOK 4.9 billion (approximately €488 million).

Method and Material

The research questions were addressed through utilizing qualitative basis for the analysis. In delineating the qualitative case study of the paper. it is important to mention that, we concentrated on zero emission involving battery electric and Hydrogen only for the analysis. In this way, the study relied mainly on interviews[2] and document analysis (i.e. content analysis). These documents and reports were secured through web searches. The study followed three steps of methodology for content analysis (see, Aldenius et al., 2021). The key interest of the content analysis focused on the call for tender, contract documents, inter alia, vessel requirements, energy source for propulsion, quay requirements, and infrastructure, environmental claims, technical specification (specific-type of renewable energy required vs. functional) and award criteria.

Results

The results presented in this section highlight how the environmental claims are expressed in the tendering for zero emission ferries. Such claims are examined with its economic and environmental consequences.

Expression of environmental claims for zero emission of ferry services

A cursory examination of the environmental claims (EC) in the tendering show a minimum of 30% weightings on EC and 70% on price. The reserve ferries are supposed to require low emissions technologies in combination. To monitor the environmental requirements, the client expects the operator to report monthly or annually on fuel consumption (weight and type), energy consumption, and NOx for all vessels that operate this connection.

Hydrogen-powered ferries are considered under the environment energy consumption (GJ/year) at 5% and a scalability of 25%. On the other hand, in the EC for the battery electric ferry “Ampere” CO_2 emissions counted 40% and total price for operating the crossing 60%. Largely, the client freely provides the ferry quays and land-based facilities to the operators and also takes charge of repairs. However, all associated fees, residual, and night currents are paid by the operators. At times, the operators are responsible for planning, marking, and financing modifications and must secure public permits and adhere to relevant plans connected with installations, conversions etc. (Bjerkan et al., 2019).

[2] The information so far is largely obtained from our contact at NPRA whom until 2022 was the director of ferry operations in NPRA. Other technical experts and key personnel engaged in development and procurement of zero-emission ferry operation reported interviews and comments have been relied upon.

Economic consequences

The economic consequences associated with EC in the tendering is observed through changes in investment, maintenance, and operational costs as well as changes in subsidy requirements. A review of nine contracts by DNV estimated approximately 5% net additional cost for a contract period for zero-emissions ferries compared to diesel ferries (Ministry of Climate and Environment, 2019). Essentially, Bjerkan et al. (2019) recognized three such related costs, namely technology costs, energy capacity costs, and infrastructure and charging or refuelling costs. Zero-emission ferries are approximated between NOK 50-100 million more expensive than ordinary ferries (E24, 2021b).

Although the battery price of electric propulsion systems is witnessing a significant price decline, this amplifies its profitability. A senior officer of Siemens, as reported by Madaling (2021) and dfly.no (2015) hinted "*'Ampere' has given us unique knowledge about profitability for battery ferries. If we compare this operating profile with other ferry routes in Norway, we see that electric operation crushes diesel ferries on profitability for seven out of ten ferries… Therefore, we should set ourselves high goals to quickly put in place the next battery ferries in Norway*." Nevertheless, hydrogen propulsion still have higher costs than fossil fuel ferries because of its high production cost as well as need for new refuelling infrastructure (Bjerkan et al., 2019).

Zero-emission solutions do have larger up-front investment costs despite the various established state funding schemes to cover infrastructure costs, training requirements, and financial support available to operators and county municipalities. A typical example is where the government provided a NOK 20 million grant in 2016 to county municipalities in order to enhance their expertise on the inclusion of environmental requirements in the procurement processes, as well as in 2018 with county municipalities receiving NOK 100 million in non-earmarked funding so as to strengthen the ferry and fast-craft operations (Ministry of Climate and Environment, 2019). State supports through Enova have been channelled through electrification of ferry connections involving many county municipalities. Of particular reference is the Hordaland county municipality, which received NOK 134 million towards building battery chargers on the quays (E24, 2021a) and the possibility of Møre and Romsdal counties being able to set stricter environmental requirements with NOK 30 million for ferries on Sunnmøre (E24, 2021c). Support schemes from Enova reduce the additional costs that county councils could incur when setting strict environmental requirements. This underscores the need for infrastructure investment in order to execute successful zero-emission solutions in the ferry sector. A review of the electricity grid and energy capacities identifies insufficient grid capacity, and that putting 52 ferry services on electrification requires about NOK 900 million in grid investments (DNV GL, 2015).

The inclusion of environmental requirements in the tendering process provides the suppliers of maritime components, shipyards, and ferry owners with opportunities for business growth, increases profitability, and creates job openings, which are critical for the sector's sustainability. In connection with hydrogen ferries between Bodo and Lofoten starting from 2025, an official of Torghatten stressed "*we are investing in hydrogen now, but there is no one to sell to. We will be the first major buyer of hydrogen in Norway, and we will also be providing significant opportunities for the shipyard and equipment industry to participate in the development of expertise in the use of hydrogen as an energy source. For tourism, the hydrogen ferries will be a unique opportunity to take the tourism investment and the international brand Lofoten a step further*".

Environmental consequences

The development contracts for the zero emission ferries have received substantial environmental consequences. This is corroborated by a product manager at Hordaland County Municipality maintaining that "*the environmental results of electrification have been better than expected when we decided to invest in low emissions transport…it was right for us to be visionary and not just think of costs*" (see, Taylor, 2017). With the increasing number of electric ferries in Norway, the transition could have environmental savings of 300,000 tons of CO_2 emissions annually, equivalent to about 9% of domestic shipping emissions in Norway, 100,000 tonnes of diesel as well as 8,000 tons of NOx (dfly.no, 2015; Madaling, 2021; Siemens Energy & Bellona, 2022). Hence, an NPRA representative stressed: *"In contrast with a diesel ferry, we are talking about* *a 50% reduction in the energy requirements. The zero emission will be reached"* (see, NRK, 2012). This was also indicated by the development manager at Fjellstrand shipyard: *"When we now get a fully electric ferry… as no one who has done before. The energy is completely clean, it is CO_2 neutral, climate friendly, and environmentally friendly"* (NRK, 2014).

Also, the connection Bodø-Røst-Værøy-Moskenes, which will become a hydrogen ferry connection, is expected to cut CO_2 emissions of 26,500 tonnes yearly compared to the current ferries using natural gas (LNG) (Norwegian Public Road Administration, 2022b). The emissions cut from the battery electric ferry "Ampere" are around 95% compared to fuel-powered counterparts (Lambet, 2018). Additionally, other non-economic consequences associated with ferry electrification is that it may reduce onboard passenger discomfort, exposure to noise for both onboard and nearby settlers, exposure to fossil fuel fumes and personnel working conditions being enhanced.

Concluding remarks

The purpose of this study is to document how authorities have reduced GHG emissions from the sector through the tendering process for the purchase of domestic ferry services in Norway. We observed that authorities have used a "push and pull'" strategy. Setting requirements in the tendering process to ensure the cutting of CO_2 emissions can be seen as a "push" strategy. When governmental funding schemes and instruments are geared towards actualizing sustainable maritime transport, including ferry operations, we see a "pull" strategy. These schemes include Enova, Pilot-E Klimasats, environmental technology schemes, NO_X fund, emission taxes on NO_X, CO_2, and sulphur, charts for green coastal traffic etc. (See, Bjerkan et al., 2019).

Tender evaluation in the public procurement process utilizes two main methods, the lowest price approach and the most economically advantageous tender (MEAT). The former subjects bids to be evaluated on a set of minimum requirements based on price only, whereas the later, conversely, considers different quality aspects in bid evaluation such as environmental impact (Bergman & Lundberg, 2013). Thus MEAT *is the weighted sum of different aspects of a product or service that provide value to the procurer in terms of economy, quality, environmental considerations, and social aspects* (Uttam & Le Lann Roos, 2015,p.404). This implies that the winning operators do not win exclusively based on the lowest price. Instead, the operator that has feasible technology in meeting the EC and at the same time offers the lowest contract price wins the bid. This makes the use of MEAT the preferred method in ferry services tendering evaluation rather than the lowest price approach so long as EC is a crucial factor. A study of Alhola (2012) among Finland, Sweden, and Denmark contents of MEAT and environmental award criteria put environmental criteria weight points between 5-20% with the dominant award criteria of 51% price weight and quality of 37%.On the contrary, the weightings in the Norwegian context were 70% for price and 30% for EC. This shows the immense commitment of the sector's contribution towards the overall net zero emission target.

There are both direct and indirect effects of green shift procurement. The direct effects occur with emission cutting as the client controls larger market share, whereas the indirect effects encapsulate induced innovation, niche market creation, cost reductions, and example setting (Marron, 2003). The study has clearly showcased that both effects are typified in the Norwegian context for zero-emission solutions.

Implication for public procurement

The "green shift" involves technological transition and therefore requires an appropriate procurement strategy. This can be seen in CDP where the technology is untested, but germane. It is important that, until the technology is fully matured in the market, competition through traditional tendering procedures should be carefully carried out. It should, rather, be subjected to competition with negotiation, especially the incumbent operator for a considerable period based on its vast experience with the technology. Similar recommendation was given with the transition to green bus fleet (Hensher, 2021).

Battery electric contributes to very high GHG emissions cuts and also cuts in other pollutants such as NOx and SOx. There are, also, significant investment needs and costs for such undertakings, although maintenance costs are low. It is crucial that, with the seemingly unpredictable geopolitical tensions that could destabilize global energy supply chain, governments will continue showing support for reducing the cost of electricity for commercial shipping. In Norway, the reduced tax rate for electricity for commercial shipping in 2019 was NOK 0.005 per kWh compared to the standard rate of NOK 0.1558 per kWh (Ministry of Climate and Environment, 2019). Such interventions will serve as an incentive for operators to use onshore power for battery electric propulsion at lower service costs, especially where energy sources are not generated from renewables.

This study is limited to the authorities' perspective on setting up EC in competitive tendering and its economic and environmental consequences. The operators' perspectives on such EC requirements are not explicitly focused on. Therefore, such insights are worth investigating in partaking in evolving the zero-emission solutions in the ferry sector. We also have not included public procurement of high-speed vessel services in our study – services that the county councils are responsible to offer. Those are, as with the ferry services, important transport services in the coastal areas of Norway that are in an early phase of their "green shift."

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