CHALMERS

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The influence on electrifying ferries within short sea shipping in the Scandinavian countries

Bachelor thesis for Shipping and Logistics Program

JONATHAN GULLBRING
ANJA PANDIC

DEPARTMENT OF MECHANICS AND MARITIME SCIENCES

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Department of Mechanics and Maritime Sciences
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone: + 46 (0)31-772 1000

Cover:
The E-Ferry project Ellen by Ærø Energy Lab (Ærø kommun, n.d.). Used with permission.

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PREFACE

This bachelor thesis was conducted by Jonathan Gullbring and Anja Pandic in the spring of 2021. The study was done for Chalmers University of Technology in the maritime section, as the end for the three-year program in Shipping and Logistics. We would like to thank the companies and persons who participated and agreed on being interviewed, and who contributed to make this study possible. Thank you Erik Froste from Färjerederiet, Erik Lewenhaupt from Stena Line, Benjamin Fhager from Sirius Shipping AB, Anna Prytz from ForSea, and Fredrik Larsson from Swedish Shipowners Association. We would also like to thank our supervisor Daniel Eriksson for great guidance and support throughout the process. All of the mentioned participants have been asked for consent to be mentioned by name, title, and company as well as approved the content before it was published.

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SAMMANDRAG (in Swedish)

Under många år har den maritima sektorn använt sig av fossila bränslen för att driva fartyg framåt, vilket i sin tur har resulterat i bland annat stora koldioxidutsläpp. Detta examenarbete har valt att fokusera på ett av framtidens icke-fossila bränslen, elektricitet. Något som arbetet också kommer att undersöka är vilka lagar och regler som påverkar utvecklingen av elektriska färjor. Arbetet har avgränsats till närsjöfart i de skandinaviska länderna och ser på hur dessa länder skulle kunna skilja på sig när det kommer till denna typ av utveckling. Arbetet har genomförts som en jämförande systematisk litteraturstudie och även inkluderat en halvstrukturerad intervjumetod.

Forskningsfrågorna omfattar bredden av befintlig elektrifierad sjöfart, olika incitament till att bedriva utvecklingen av eldriven närsjöfart samt det nationella och internationella inflytandet som finns och motiverar för denna utveckling. Baserat på de intervjuer som hölls tillsammans med företag från svenska sjöfartsbranschen har en djupare undersökning kunnat utföras. De stora utmaningarna att köra på eldrift är bland annat avståndet mellan olika hamnar, möjligheten till laddning samt att finna ett elnät med tillräcklig kapacitet. De nationella reglerna kring utvecklingen av elektriskt drivna färjor bygger till stor del på konventioner från International Maritime Organization som är en del av FN som specifikt riktar sig mot sjöfarten, samt Europeiska unionen. En slutsats som kan dras av detta arbete är att utvecklingen av elektrisk framdrivning inom inlandssjöfart är en viktig och nödvändig utveckling. Utvecklingen har ett flertal goda incitament, men kräver också väldigt mycket. En övervägning varje företag och land måste göra.

En upptäckt som gjordes under arbetets gång var att trots att Skandinavien anses vara i framkant med utveckling och elektrifiering finns det än idag relativt få projekt i drift. De som arbetat med liknande projekt i Norge och Danmark hade dessvärre inte möjlighet att delta i några intervjuer och arbetet har därför begränsats till intervjuer med endast svenska företag.

Nyckelord: Eldrivna färjor, eldriven sjöfart, utsläpp, hållbarhet, hållbarhetsmål, minska utsläpp, närsjöfart, Sverige, Norge, Danmark,

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ABSTRACT

For many years in history, the maritime sector has propelled ferries using fossil fuels which have led to great carbon emissions, among others. This bachelor thesis is focused on the fossil-free fuel of the future, electricity. In addition, the thesis will investigate the international and national conventions which affects the development of electric ferries. The thesis has been limited to short sea shipping in the Scandinavian countries and investigates at how these countries could differ when it comes to the development of electric ferries. The work has been carried out as a comparative systematic literature study including a semi-structured interview method.

The research questions cover the extent of electric ferries, different incitements to manage the development of electrifying ferries as well as the national and international conventions. Based on the interviews that were held with companies from the Swedish shipping industry, a depper research could be conducted. There are several challenges when it comes to converting to electric propulsion such as the distance between the operating ports, the possibility of charging the batteries and finding an electricity network with enough capacity. Conventions from the International Maritime Organization and the European Union have been considered as the most important influence, which also has a big influence to create national laws and regulations. The International Maritime Organization is a part of the United Nations that is focusing One conclusion that can be taken from the research is that the development of electric propulsion in short sea shipping are an important and necessary development. The development includes multiple beneficial incitements but requires a lot as well. A consideration every company and country must make.

During our research, we discovered that although Scandinavia is seen to be at the forefront when it comes to the development of electric solutions for ferries the number of projects is relatively small. Companies in Norway and Denmark who are currently working on developing electric solutions for ferries did unfortunately not have time or the possibility to participate in any interviews and therefore the report was limited to interview Swedish companies.

Keywords: Electric ferries, electrified shipping, emissions, sustainability, sustainability goals, reducing emissions, short sea shipping, Sweden, Norway, Denmark

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ACRONYMS AND TERMINOLOGY

AI	Artificial Intelligence
BIMCO	Baltic and International Marine Council
EU	European Union
INEA	Innovation and Networks Executive Agency
IMO	International Maritime Organization
MARPOL	The International Convention for the Prevention of Pollution from Ships
NOx	Nitrogen oxides is a mixture of oxygen and nitrogen
RORO-ferries	Roll on Roll off ferries – Ferries loading rolling vehicles such as cars and trucks.
ROPAX	Ships that combine roll-on/roll-off features for the carriage of private cars and commercial vehicles
SECA	Sulfur Control Area
SDGs	Sustainable Development Goals – Goals developed by the United Nations to achieve a more sustainable future.
SOLAS	Safety of Life at Sea
UN	United Nations
Peak shaving	Lowering the highest observed peak in energy demand to reduce the energy-related cost

1. INTRODUCTION

Looking at the history of shipping, the way to propel a ship forward started with oars and sails. Arriving at distant shores, the first travelers found rare goods and precious items that could not be obtained in their native lands. As they brought their valuable cargo home, they knew that they had a taste for luxury. Increased global transportation forced the industries to develop solutions on how to meet the new demand. The ships had to go faster, more frequently and take as much cargo as possible. This later lead to the invention of the steam engine. In the following decades after inventing the steam engine, we could again see a change in the global demand. Again, asking for more, faster, and bigger ships. This time, the increased demand led to inventing new ships and engines powered by fossil fuels (Woods, 2018).

We are now in the moment of change, again. But this time it is not the human trade behavior that is causing change, it is our environment that requires it. Using fossil fuels to power global transportation is no longer sustainable. Pollution from all the ships creates environmental and human suffering, and there are already extensive environmental changes all over the world (Hester & Harrison, 2011). Therefore, the industry is now working towards a fossil-free future. One inventory that has been made towards this goal is electrification within the transport segment. Electrifying the marine sector is beneficial in many ways. It reduces pollution and the noise levels in the oceans extensively. Studies have also shown positive impacts on both workers and the working environment (Borgh et al., 2018a).

Jacobsson is writing in Dagens Industri on november 23, 2020, that Scandinavian countries highly believes in electric operations for shipping and especially within the ferry traffic. In Sweden today, there are two routes operated by ForSea and Stena that are partly electrified. The ferries were old and already existing ferries which were later converted from diesel to electric operation.

In this report, research will be done on the decision-making of electrifying ferries within short sea shipping in Scandinavia. It will also investigate how different authorities and organizations are influencing and to what extent short sea shipping is electrified, as well as what the incitements are.

1.1 Aim of the study

The aim of this report is to investigate the extent of electrified ferries within short sea shipping in the Scandinavian countries, what the incentives are, and what motivates the companies to choose electric operation.

1.2 Research questions

In this report, the research questions below will be handled.

1. To what extent are ferries within short sea shipping in Scandinavia powered by electricity?
2. What are, and have historically been incentives to choose electrification for ferries?
3. Which laws and regulations motivates the development of electrifying ferries in the Scandinavian countries?

1.3 Delimitations

The report is limited to short sea shipping and smaller ferries in Scandinavia, in addition to the influence of international and national authorities and organizations. The national politics and the EU-politics are in overall comparison relatively similar. The Scandinavian countries are well developed, meaning they have good opportunities to go electric if decided. In addition to the national authorities and organizations, the report will also investigate how international organizations such as IMO relates to electrifying ferries. The report focuses on what the incentives are for electrifying ferries that are in operation in short sea shipping and how environmental policies that influence from different directions matter for different companies' decision-making.

The limitation to Scandinavia is based on Norway being a well-known country to be in the forefront when it comes to electric power in general, but also ferries, and especially cars. Sweden and Denmark are two well-developed countries as well with modern technology and great possibilities to invest in the electric development. Since Norway is not a member of the EU, they have their own politics including laws and regulations such as reduced taxes on electric vehicles. This is something that can be seen as a motivation for companies and the population, in general, to push the development of electric vehicles further. Sweden and Denmark are members of the EU and are therefore primarily following the laws and regulations that have been set by the organization. In addition to the international regulations and laws each country has their own politics that governs.

2 THEORY

The following chapter is presenting theory about short sea shipping, incentives for electrification and the influence of different laws and regulations, both in general and how it is implemented in the Scandinavian countries. The aim is to provide the reader with the necessary information for a deeper understanding when later reading the result and discussion of this report.

2.1 Short sea shipping

Short sea shipping are important waterways when it comes to global sea transportation since it is often the final maritime route in the delivery chain. Many different types of ferries travel through the inland waterways such as tourist attractions and ferries to connect a city divided by big rivers or a sea such as Copenhagen, Gothenburg, and Stockholm. For the next generation of the European supply chain, the short sea shipping will play a big role (Tan et al., 2018).

2.1.1 Definition

Transport operating on inland waterways has been a big part of how we transport different types of cargo for many years (Wiegmans & Konings, 2016a). The short sea shipping developed during the 19th century since the roads of this time were not as developed as they are today, consisting of gravel or mud. With developments in the maritime sector, the proportion of vessels changed to steam engines. Ferries who are operating on inland waterways are today propelled by fossil fuels and mainly used to transport dry bulk but also to transport cargo such as containers, crude oil and LNG fuels (Wiegmans & Konings, 2016b). The development has therefore gone from operating with sails, to steam enginges, and fossil fuels, to now look at new solutions again.

The short sea shipping has important implications for global freight transport and is a competitive transport alternative for transports who otherwise operates on the road or rail. It can also be seen as an environmentally friendly transportation mode when being compared to rail and road, and is a relief for the trafficked roads (Tan et al., 2018).

Some of the transports on short sea shipping are made from the major ports to some of the land's hubs and smaller ports. The biggest port of the Nordic countries is the port of Gothenburg where cargo is being distributed to other ports within inland waterways where the transports continue into the country. In Sweden, it is possible to either operate short sea shipping our to go via Helsingør up to the ports on the east side.

2.1.2 Background

In Sweden 2016, close to 90% of all goods traveled through seaways according to (Björn Garberg, 2016). There has always been great competition between different types of transports, and during the 20th-century shipping was the dominating transport option. Flexibility, transport time and frequency are proved to be important factors for the buyers. Short sea shipping is developed to relieve the traffic on roads and reduce congestion. Looking at ports in Europe, this creates great potential in short sea shipping that is based on loops by connecting the different ports. However, the development of rail and trucks have made shipping increase and made it more difficult for shipping to compete with.

2.1.3 Different zones of inland waterways in Sweden

There is a certain type of ships and ferries that are built and equipped for a specific water area within short sea shipping and inland waterways. The area has been defined as inland waterways which is also divided into four different zones. The zones are defined by the significant wave height in the specific area where zone 1 has the biggest waves of 2,0 meters high and in zone 4 wind waves do not occur. The definition of significant wave height is the average height that is measured from wave valley to crest. Measuring 10% of the biggest waves among the total amount of waves that have been observed during a limited period (Transportstyrelsen, 2014).

Member states within EU have their own territorial waters where it is up to each member state to decide and classify which water should be inland waterways and to which zone different areas should belong to (Transportstyrelsen, 2014).

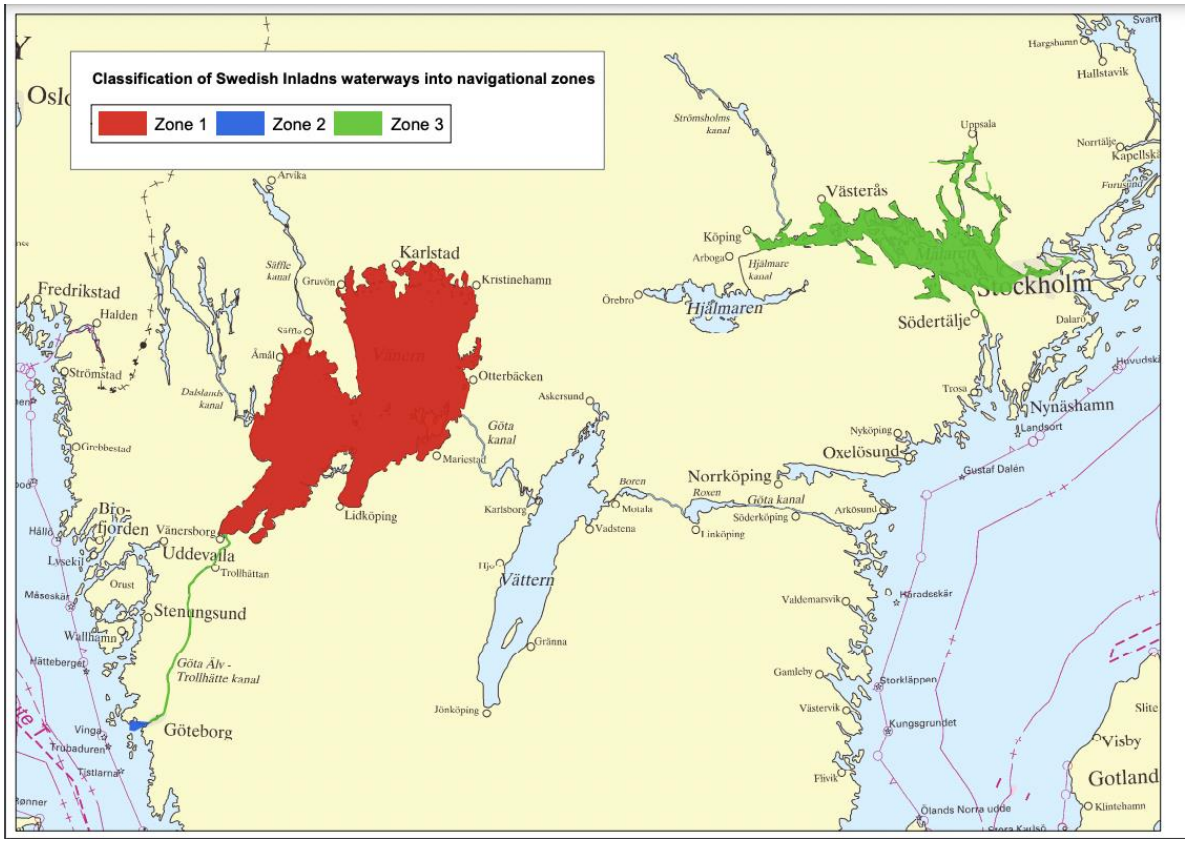

Figure 1: Example on how waterways can be divided into zones (Transportstyrelsen, 2014). Used with permission.

2.2 Environmental impact and incitements to electrify

The maritime sector and the shipping industry require great amounts of energy. This energy is mainly derived from fossil fuels which are resulting in pollution and a negative impact on the environment (Jivén et al., 2017, p.6). Global warming is a long-term change caused by human activities and is referring to "… the long-term heating of Earth's climate system observed since the pre-industrial period (between 1850 and 1900) …" according to (NASA, n.d.). Climate change is a long-term change caused by human activities as well and is referring to increased global land and ocean temperatures causing natural disasters. The shipping industry is a significant contributor to both global warming and climate change through its large number of emissions (NASA, n.d.).

Multiple countries and international organizations are today working on sustainable goals towards a fossil-free future. By increasing the use of electric power in all transport sectors it is possible to extensively reduce emissions from transports. The impact of using electricity can differ depending on whether it is renewable or not and if the vehicle is fully electric, diesel-electric or battery hybrid. In Norway, electrification is increasing, especially within the passenger vessel segment operating on defined routes over short distances (Borgh et al., 2018b, p.3). Looking at electrifying the maritime transport sector there are several actors involved according to (Borgh et al., 2018a). These actors are "…users (ports, shipping companies), suppliers (energy storage, vessel design, shipyards, shore power, system and components), regulatory authorities, class societies, and research organizations (institutes and universities)."

One of the big incentives to go electric in Europe is the goal for the EU to be carbon neutral by 2050 (European Union, n.d.), as well as Agenda 2030. This is both a motivation as well as it forces the industry to start looking at solutions for sustainable fuels. This has created increased development and interest in electric ferries. According to Cecile Larsen (2020) in her case presentation for E-Ferry and World Maritime University, an electric operation provides many benefits. These benefits include reduced emissions of pollution and greenhouse gases, high energy efficiency, reduced costs and a life-cycle economy, and reduced vibration and noise levels. According to Larsen, the number of reduced emissions annually is 2000 tons of CO2, 41 tons of NOx and 2,5 tons of particulates by operating with electricity. Larger up-front investments and lower operating costs, leading to economic benefits including less maintenance and lower fuel price, as well as a smaller crew operating the ferry. The crew, passengers and citizens located close to the operating route will benefit from the reduced noise and vibration levels. It is also more energy-efficient since the energy loss of the full chain is only around 20% – 30% and includes weight reduction of the ferry (Larsen, 2020).

2.3 How to electrify

The question of how to electrify a ship has developed over the years as the industry is working towards a sustainable future. The standard way to operate electrified ships is to use charging stations at each port for the route. Issues that may appear are that some of the charging stations are not created for a fully electrified ships. In some harbors instead, they are tailored for classical propulsion of ships that uses the charging in port to run the lights and electricity onboard. It is also a problem if the harbors only offer a low current (220v) instead of the power current that has 10Kv. One more issue for charging the ships is that ships can have different portions of the plugin for charging onboard (Borgh et al., 2018a). When it comes to the problem with having enough electricity to handle big ferries and ships, the main problem is that the normal power grid does not have the capacity to charge a larger ferry. So, for this issue to be solved the shipping company or the port needs to dig towards the transformation station and the main cables to be able to handle the amount of electric power needed for charging the electric vessel (Infrasverige, 2018).

One option when it comes to charging is to have a solution like the one that was developed by ForSea, which has an automated shore-side charging station by using an industrial robot to optimize the charging connection. This project is done in collaboration with ABB which supplied an automatic shore-side charging station the charging is done by wireless communication between shore and ship (Asea Brown Boveri, 2018).

"This is a landmark project, and we are convinced it will come to be seen as a critical step in shipping's environmental revolution, as well as a milestone in rolling out ABB's 'Electric,

Digital, Connected' strategy for shipping," according to Marcus Högblom in a press release for ABB Marine & Ports (Asea Brown Boveri, 2018).

When it comes to electrifying ferries there are not that many options today. One of the options is to do as the Swedish company ForSea, using batteries and an electric engine with charging stations in the ports (ForSea, n.d.). Another option is applied to RORO-ferries with routes that operate shorter distances. The technique is currently being used by Färjerederiet and works in the way that an electric cable is connected to shore while operating and the cable is being collected on a big wheel. After arriving at the destination on the other side of the route, the cable is being unrolled again (Trafikverket, 2020a).

When it comes to electrification, one important factor is the choice of batteries. The lithium battery is one of the most common battery that is used for transport electrification. Ferries of ForSea were converted to use new energy instead of diesel. It is possible to charge their ferries with 10,000 kW with the average charging time around seven minutes. The total capacity of these batteries is 4,160k Wh and was developed by the ABB (Moore, 2020).

2.4 United Nations

Today the UN has 17 global goals towards a better future, also called Agenda 2030. The goal of this agenda is for different sectors to work for sustainable development and human rights. The goals target not only on the already developed countries but also the developing countries that are still struggling with their everyday life. The goals were agreed on at the Sustainable Development Summit where the 193 members of the UN agreed on the terms of the goal (United Nations, 2015). For the developing countries this can help with further development, and to go from a poor country that has problems with poverty and hunger to a developing country. Agenda 2030 has been called a roadmap to ending global poverty. For the more developed countries, some of the goals that will be in their planning are the global goals in the environment sector.

2.4.1 International Maritime Organization and Sustainable Development Goals

The International Maritime Organization, IMO, was formed in 1958 and is a specialized shipping agency that supports the United Nations Sustainable Development Goals, SDGs. IMO is the global standard-setting authority with responsibility for the safety and security along with preventing marine and atmospheric pollution caused by ships. The main purpose of the organization is to create a fair field for involved actors to avoid any compromises when it comes to safety and environmental impact (IMO, 2019).

IMO consists of various bodies which all of them participates in the implementation of a new convention. When a new convention is implemented, it must be accepted by most of the member states within IMO and adapted globally to enter into force internationally (IMO, n.d.). The approval does not automatically make the convention binding. A binding convention requires that a certain percentage of the member states needs to ratify the convention for it to enter into force as a law. The percentages vary depending on the specific convention. Many times, the conventions are produced as a result of accidents, such as MARPOL. MARPOL is a convention that is built on a different Annex that regulates different parts of environmental impact at sea. Annex VI in MARPOL is the part that regulates emissions from ships which are partly relevant for this study.

Based on this information IMO has an important role in the work of increasing safety and reducing the environmental impact from the shipping industry. The organization works through the development of new conventions, in line with FN, Agenda 2030, and the global sustainability goals.

Electric ferries are today still very new and innovative. New specific regulations, requirements, and guidelines for these types of ferries have therefore not been developed yet by the IMO. Although, the safety onboard is still very important and high priority when operating electric ferries as well (E-ferry, n.d.-b, p.10).

Based on the research that has been done for this report, some of the SDGs are more pertinent when looking at incentives for electrifying and how companies are working towards a sustainable industry. Those SDGs are presented below according to how they are implemented and presented by the IMO.

Goal 3 - Good health and well-being

Goal 3 has a focus on making the lives of those who live in coastal areas healthier and promoting well-being. This by lowering the emissions and levels of Sulphur that is emitted from ships and ferries. Since January 1st in 2020, this has been a set goal (IMO, 2015).

Goal 9- Industry, innovation, and infrastructure

In goal 9 some of the important factors are in developing technology, including ports and how the ferries and ships are built. Regulations focusing on new technology will be important when it comes to mitigating environmental change something that can be seen already today on how ships are being built (IMO, 2015).

Goal 10 - Reduced inequalities

Objectives in this goal are to make sure to help developing countries with the ability to work with international rules and standards regarding maritime safety and control the pollution from the maritime industry. This will be achieved by providing the technical assistant to solve these problems with their integrated technical cooperation program (IMO, 2015).

Goal 11 - Sustainable cities and communities

Developments for this goal is to secure maritime safety and security for ports and the citizens of port cities. IMO helps the member states to focus on security and the civil maritime industry by setting norms on ports and coastal state authorities (IMO, 2015).

Goal 12 – Responsible consumption and production

Something IMO is working with when it comes to goal 12 is the technical capacities in wastewater management onboard ships and ports. Some of the conventions they are working with are the London convention and protocol to how they work with operational waste through MARPOL (IMO, 2015).

Goal 13 - Climate action

Through the Annex VI in MARPOL convention, the IMO is working towards lowering air pollution, energy efficiency and greenhouse gas emissions. This is a strategy from IMO to reduce greenhouse gases in the member states and hopes that the states will adopt as quickly as possible (IMO, 2015).

Goal 14 - Life below water

For shipping, this is an important goal. The IMO is currently covering goal 14 through implementing regulations in the member states where the main focus is marine pollution from sea-based sources but also the land-based sources. IMO is also protecting the coastal ecosystem by having special areas with special rules to protect this and have been doing this for many years. Some of the harmful consequences shipping has on the underwater environment are underwater noises and waste dumping. Something the IMO has been working with since 1972 with the London convention (IMO, 2015).

2.5 European Union

The EU is often involved in supporting projects that relate to their goals by financing them. It can be within fields such as maritime policies, urban development, innovation, and agriculture for example. There are five big funds which are managed in partnership by over 76% of the EU budget. Some funds are managed directly by the EU and not in partnership, which is provided in the form of grants or contracts (European Union, 2021). Below a few Scandinavian projects that were funded by the EU will be presented, more about them will be addressed further through the report.

E-ferry Ellen

E-Ferry Ellen is the name of a project in cooperation between the Danish Ærø Municipality and the European Commission's Horizon 2020 framework. The project received funds from the EU's Horizon 2020 research and innovation program. E-ferry started as a five-year innovation project with the goal to promote maritime transport on island routes in and outside of Europe that is CO2-neutral, energy-efficient and free from pollutions. The Danish E-ferry Ellen, is an electric ferry that was developed by this project backed by the EU (E-ferry, n.d.-a). The project costed EUR 21.3 million and although it was expensive, the ferry has a 75% lower operating cost compared to conventional vessels (E-ferry, n.d.-b, p.3-15).

FLAGSHIP

An EU research fund that supports the development of two electric ferries that will travel in Lyon, France and Stavanger, Norway. The subsidy was EUR 5 million, and the Norwegian ferry is estimated to travel in traffic during 2021 and has a capacity of around 300 passengers and 80 cars. The ferry will be refueled with hydrogen which is producing electricity through fuel cells (Färjerederiet Trafikverket, 2019).

Innovation and Networks Executive Agency

An agency that was officially launched in 2014 and established by the European Commission who supports transport, energy, and telecommunication projects (European Commission, 2021). INEA supported ForSea with 30% of the total costs of their project on building full-electric ferries, according to Anna Prytz (personal communication April 15, 2021).

2.6 The extent of electric ferries in Scandinavia

The Scandinavian countries and the extent of electric ferries will be presented in this section. How many and which routes that are electrified and incitements to why these are chosen will be elaborated. Different companies and organizations currently working with electric ferries will also be mentioned.

2.6.1 Norway

According to Bioenergy International, Norway has set a goal to lower greenhouse gasses by 40% compared to the European countries (International, 2021). Other countries within the same study are reaching for a goal of 30%. Based on this information, it is possible to assume that Norway is willing to lead a development in electrification. Something that has been had done on the roadside for some time, where they offer a tax reduction of fully electric cars.

Statens Vegvesen

Statens Vegvesen, the Norwegian Public Roads Administration in Norway is the government organization that takes care of road and sea networks. They also contribute to some electrifying projects such as the route between Oppedal and Lavik (vegvesen, 2014). Today they are currently working towards being greener and more sustainable. Terje Moe Gustavsen is the general director of Statens Vegvesen, and he believes that hydrogen is the solution for when batteries are not enough. The hydrogen can instead of batteries produce electricity through fuel cells. Norway's largest ferry operator Norled has been commissioned to build a ferry that is powered with at least 50% hydrogen (Färjerederiet Trafikverket, 2019).

Bastø

Bastø was founded in 1995 and are today part of the national road network and has five car ferries operating in the Oslo fjords. One of the projects that are currently running successfully in the Norwegian fjords is between Moss and Horten two towns separated by the Oslo fjord. This company has the most heavily trafficked ferry route in Norway currently and the latest ferry in the fleet is the Bastø electric. It is the first of the three battery ferries that are operating in the fjords (Chris Randall, 2021)one of the world's largest electrified ferries and went into service in the fall of 2020. Bastø has also received support from Envoa to convert their ships Bastø IV and Bastø VI to fully electric ferries. Bastø will also receive funding to build a brand-new charging station in Moss at the cost of 136 million NOK. This is planned to be in full operation from the summer of 2022 (Bastø, n.d.). Moss at the cost of NOK 136 million. This is planned to be in full operation from the summer of 2022 (Bastø, n.d.).

Rødne

Rødne is a family-owned ferry company, currently with 14 boats in their fleet. The company was founded in 1956 in the beginning of their operations, they provided school transportation for people living on islands around Sjernarøy (Rødne, n.d.-b). Today Rødne company does not only provide transportation of cars and passengers between islands, but they also have two ambulance boats and from 2020 they have bought a fully electric sightseeing ship (Rødne, n.d.-a). It will do around 50 nautical miles in one charge when the speed is around 18 knots. When the project was announced they received government funding of around 19,5 million NOK that is called Enova- support of the total building cost that is 120 million (Skipsrevyen, n.d.).

Hurtigruten

One of the larger companies when it comes to trips in the Norwegian fjords is Hurtigruten. The company has a history of transporting people from southern parts to some of the most northerly parts of Norway. It started with transportation between Trondheim to Hammerfest. After this, the route Hammerfest to Svalbard was introduced and this later marked the beginning of Hurtigruten as we know it today (Hurtigruten, n.d.-a).

Some of their new projects are to build new hybrid ferries. By building these ferries the company believes that they can cut fuel consumption by 20%. Hurtigruten has divided the project into two phases. In phase one they plan to put in battery-powered auxiliary engines that

will help in peak shaving and this installation has already started (Hurtigruten, n.d.-b). Hurtigruten can already see that from phase one they are saving around 3000 tons of CO2 per year even though they are only using around 15-30 minutes of electric propulsion this is about an 20% lowering. In phase two, the goal is to build a fully operating 100% electric ship for sailing longer distances. This can only happen if the technology is there, which it currently is not. As a result of this, Hurtigruten will not build these ferries in the near future (Hurtigruten, n.d.-b).

Ampere

Ampere is the first of its kind and was from the beginning a result of a competition that was launched by Statens Vegesen, where the goal was to build an environmental-friendly ferry. Ampere won the competition and therefore became the winning solution (Nordregio, n.d.).

Since the year 2015, the first fully electric passenger and car ferry has been operational in Sognefjord and goes between Lavik and Oppedal. Siemens is the electric company that is helping Ampere with the solution for electrifying Ampere. When it comes to electrifying and propulsion Ampere is using a total battery capacity of 1,000 kWh this is enough to make more than one round trip on the 5,7 km long route. At the end of each dock, there is a 260 kWh that will recharge the ferry without compromising the electric grid to the small villages that are nearby (Nordregio, n.d.).

2.6.2 Denmark

In Danmark, they are in their starting phase in electrifying ferries where they have started in the year of 2019 with one of the biggest electric ferries, the E-Ferry Ellen. As a result of the Ellen project, new projects took off such as the implementation of electric ferries operating in central Copenhagen.

E-Ferry Ellen

John Edgren (2019) is writing for the newspaper Ny Teknik, that the Danish ferry Ellen is one of the world's largest fully electric ferries that were in operation by the time. Ellen is 100% electric with the capacity to sail long distances and made her first trip in 2019. The possible distance between each charge is 22 nautical miles, which is up to seven times longer than earlier car ferries that have been fully powered by electricity. The ferry is sailing between Søby and Fynshav in Denmark, with a speed up to 14 knots and the capacity of 200 people (E-ferry, n.d.-b, p.3-15).

Damen Shipyards Group

The local transportation network in Copenhagen includes ferries that operate between Nyhavn to the Opera of Copenhagen (Manthey, 2018) A project on behalf of the Danish public transport agency Movia, is currently in progress and will include electric ferries from the company Damen Shipyards Group. According to the news article (Damen, 2020), Damen Shipyards Group had delivered five fully electric, zero-emission ferries called Damen Ferries 2306 E3 to Arriva Denmark in Copenhagen in July 2020. Damen E3 is a concept of the Damen Shipyards Group with the philosophy to be "… environmentally friendly, efficient in operation and economically viable." (Damen, 2020). Significant changes in the levels of emission have been made in the public transport sector in the city of Copenhagen since the Damen Ferries 2306 E3 were implemented. Reducing emissions such as NOX, CO2, and particulate emissions. Already at the beginning of the development of public transport through the inland waterways of Copenhagen, the aim was to be sustainable. Therefore, Movia has worked together with other parties who strive towards the same goal, such as Arriva and Damen. One specific goal that has

been set by Movia, is that the electricity that is used for operation is 60% derived from sustainable sources.

The Damen Ferries 2306 E3 are equipped with new, modern technology that gives extended efficiency. Allowing remote monitoring which controls the lifecycle of the batteries and sailing patterns, for example (Damen, 2020). They are also equipped with specific computational fluid dynamics used to develop an optimal usage of the battery packs by measuring different key points in the propulsion (Damen, n.d.-a). The charging is fully automated and repowers the ferry in seven minutes. The systems connect with the vessel as soon as it arrives at the jetty and is designed to endure motions due to waves (Damen, n.d.-b, p.13).

2.6.3 Sweden

In the year of 2018, Sweden invested SEK 1 billion in electromobility and new projects to electrify ferries. Different projects of electrifying are both made and in progress, and what can be seen in Gothenburg among others is a test project of fully electrified busses to be a part of the project "Electric City" (International, 2018). After some years more projects have started to be fully functional today. But there is also some that are going in a new direction and with new technologies. That can be the future for transport as we know it.

ForSea

One of the ferry lines that are operating between Helsingør, Denmark and Helsingborg, Sweden is the ferry company called ForSea. They are focusing on both transport for freight and travel between the two countries. Where the ferry is not only for a passage, but in addition offers food, cafées and a retail (Forsea, n.d.).

The Senior Chief Engineer at ForSea, Christian Andersson, was interviewed by Robert Llewellyn on the YouTube channel Fully Charged Show (2019). According to Andersson, the project took about three years to finish and included converting two of their old ferries to 100% electric power. Big investments were made in the infrastructure and charging systems in the ports of Helsingborg and Helsingør, which is the set route for their operating ferries. By making this project reality and when the two ferries are complete, it is estimated to save 24 000 tons of CO2 per year. New technology was implemented with a direct-driven battery system. This system increased the efficiency by 30-40% compared to the old diesel-electric system. In 2019, these ferries were the biggest ferries in the world that had been converted to fully electric. The investment was planned to be repaid in eight years counting on the present fuel prices of 2019. The batteries are lithium batteries which have a capacity of 800 volts and a lifetime of around five years. One ferry is equipped with 640 batteries which are stored in four containers. For safety, the containers have been placed on top of the ferry in case of accidents such as collision or fire, for example. The ferries could be operated in three different modes: hybrid, diesel, or electric. Although, the diesel mode is only considered as an emergency mode and shall not be used daily (Fully Charged Show, 2019).

Färjerederiet

Färjerederiet is a company owned by the Swedish state and an integral part of Swedish transport administration, Trafikverket, who controls the Swedish traffic network. Ferry routes are a necessary connection for public services and freight transports and some electric initiatives in Sweden has been done by Färjerederiet (Färjerederiet Trafikverket, 2020b).

Färjerederiet have fully electric cable ferries that are in full operation. Today, 21 of their total 41 ferries are driven by cable. Of these 21 ferries, 7 of them are propelled by fully electric power. Theise electric ferries operate in Hamburgsundsleden, Malöleden, Kornhallsleden, Lyrleden, Ängöleden, Kastelletleden, and Stegeborgsleden (Trafikverket, 2020b).

Trafikverket is also planning to build four new ferries that will be fully electric the delivery date for this is planned in the year shift of 2022 and 2023. These ferries will also be automatic and will depart from the dock drive the route and then arrive at the dock all by itself. During the trip over the autopilot system will look for traffic and other objects that may be in the way of the ferry. Charging is planned to take around 4 minutes (Färjerederiet Trafikverket, 2020a).

Candela

Candela is a company whose focus is on creating a ferry that will have a longer and better performance in the electric field. To do this, they have hired some of the world's leading experts within this area (Candela, n.d.-b).

Something they have already launched is an electric ferry called Candela P-30, which will be implemented in the archipelago of Stockholm, Sweden in 2022. The ferry should be both cheaper and faster than previous fast ferries and will be "… significantly more sustainable, faster and more efficient than today's diesel-powered ships." according to Anna Grietje Franssen (2021). The ferry is operated by electric hydrofoil and will reach up to 30 knots, and travel up to 60 nautical miles without recharging. The ferry will be charged at the end destination and during breaks throughout the day. It is seen as "The most effective way to reduce emissions at sea is to replace ferries, especially since many of those ships run on diesel." said Mikael Mahlberg from Candela in Grietje Franssen's article (2021). Using the hydrofoil technology results in benefits such as no or minimal wave action since the ferry is floating over the water with minimal friction, resulting in saved energy. According to Mahlberg, hydrofoil technology is both more environmentally friendly and cost-efficient according to previous technologies.

The project of De Candela P-30 is a cooperation between the shipping company Candela and Trafikverket, the Swedish Transport Authority. Funding's for this project is provided by Trafikverket and will cover 50% of the SEK 20 million costs that are estimated for building and testing the new vessel. To get the funding from Trafikverket, Candela will have to reach some goals throughout the process. Candela needs to aim for improving the transportation system by demonstrating a small-scale project (Trafikverket, 2021). Something Candela has demonstrated is their earlier project C-7, which shows that they can build a small scale of what they are promising in the range of its electric capacity (Candela, n.d.-a).

Stena Line

One of the other big ferry companies in Sweden is Stena Line. They have for some years now been driving a project towards an electric ferry. The first step in this project is a hybrid ferry called M/S Stena Jutlandica. This project is a step-by-step project where the first step concerns how to operate in the harbor and electrifying the bow thrusters (Stena Line, 2018). In the second step the goal is to bring in bigger battery packs, and by this get a 10 nautical mile-long reach. This is enough for Jutlandica to go from the Masthuggsterminal in Gothenburg's city to Vinga lighthouse. For the final and third step, the goal is to get the total 50 nautical miles between Gothenburg and Frederikshavn (Stena Line, 2018). In this final step, Stena is currently building a new vessel to be able for just this final step and is planned for 2030. This will operate between

Gothenburg and Frederikshavn and will be the first of its kind when being delivered (Christopher, 2021).

3 METHODS

The work has been carried out as a qualitative study and to answer the issues of this report both a systematic literature study and a semi-structured interview method has been done. Marine transport companies who operate in short sea shipping will be interviewed. The interviews are arranged for further opportunities and deeper analysis of the driving forces behind the decisions that are made about electrifying boats. All interviews shall be recorded and later transcribed to use in the report for further analysis. The literature study is implemented to investigate the internal and external political influence and driving forces on electrification.

3.1 Literature method

The literature that has been used was retrieved mainly from websites but also from printed literature that was collected from Chalmers Library. The CRAAP-test have been used to a certain extend when finding literature that provides the report with necessary and underlying facts (Fielding, 2019).

- Currency: When was the source published and is the information relevant?
- Relevance: Is the found information relevant for the report?
- Authority: Is the author a reliable person?
- Accuracy: Is the content reliable?
- Purpose: Why was the article and information produced?

Collecting information about political influence on the relevance of going electric the Scandinavian countries own websites have been a great source along with IMO and EU. Furthermore, internet-based websites and articles have been used to find more information and find different directives. Mendeley (*Mendeley*, n.d.) is a reference management software that was used to manage all the references in the report. The main sites to search for information were Chalmers lib, Google Scholar and Ulrichsweb to control the publications.

3.2 Interview method

Semi-structured interviews were made to help to answer the stated issues of this report. The semi-structured technique was used to easily be adjusted and adapt depending on who was interviewed. The technique is based on questions that are prepared beforehand and that are done in a way that supplementary questions can be asked (Denscombe, 2016a). Some basic questions were prepared and asked to those who agreed on participating. All interviews were voice and video recorded, and later transcribed. The transcriptions were analyzed and compared to other findings within the report. It was also rewritten to fit the formal language of the report. All interaction took place digitally according to the temporary restrictions in line with the ongoing pandemic.

3.3 Selection method

Companies that were currently within the process, or were planning to start electrifying their vessels were of interest when looking for candidates to interview. Nevertheless, one of the interviewed companies were not planning to electrify, since they are currently operating on the spot market. This company was chosen to expand the perspective of how different companies are thinking when it comes to electrifying their vessels. Selections of the candidates that were

interviewed were employees of the companies of interest and provided great knowledge within the topic. The companies and persons who were interviewed for this study will be presented below.

- Färjerederiet
  Erik Froste
  CEO/Shipping Manager

- Stena Line
  Erik Lewenhaupt
  Head of Sustainability

- Sirius Shipping AB
  Benjamin Fhager
  Technical Coordinator

- ForSea
  Anna Prytz
  Head of Sustainability

- Svensk Sjöfart
  Fredrik Larsson
  Environmental department

The research was limited to primary focus on Sweden since it was not manageable to get in touch with companies from the other Scandinavian countries. Although, we did try to contact a few Norwegian and Danish companies to participate in interviews without success. Information about Norway and Denmark was therefore collected in other ways such as company websites and research projects that are or will be in progress. The chosen Swedish companies that were interviewed for this report were chosen since they are either in the process of electrifying or are thinking about to. Being aware that there is a greater extend of ferries that are powered by electricity a choice was made to focus on some specific companies and projects since these were considered as a good match for this report. Meaning that the chosen companies and projects that were chosen to use in this report are either connected to the EU or IMO in any way or is also well-known on the market and industry. The report is focused on short sea shipping but made one exception to add one company that is operating on a different market, the spot market, using LNG, Chemical and Oil tankers. This was done to collect information and knowledge on how other shipping markets are looking at the issue of electrifying and compare any great differences that can be recognized.

3.4 Ethics

Throughout the study, the rights of each participant have been considered regarding information, confidentiality, consent and use of requirements (Denscombe, 2016b). All the interviewed participants were asked for consent and if they, or the company, wish to be anonymous or not. Participants were also given the opportunity to read the study before it was published and make corrections or withdraw their participation. All mentioned participants have approved to be recorded during the interviews and to later be mentioned by name, title and company in this report.

3.5 Validity and reability

It is important to consider the valkidity and reability of the research that has been conducted. Also, to question how reliable the data collection is and the relevance it has for the specific study. Based on the choice of a qualitative method for the study it is relevant to question the reability of the interviews for example, where the answers of five other companies, could have led to different answers and results. Also, if Norweigan and Danish companies had been interviewed as well and not only Swedish ones. Making time and space for the person who is being interviewed to answer the questions properly, and by asking follow-up questions it is possible to achieve extended validity (Bryman, 2011).

4 RESULTS

In this chapter, results will be presented based on interviews that have been done. The interviews were based on questions that were predetermined before each interview to fit each specific company.

4.1 Färjerederiet

From Färjerederiet we interviewed Erik Froste who is the shipping manager of the company (personal communication March 26, 2021). According to Froste, the company is currently working towards being carbon neutral by the year 2045. This will be reached both by building new ferries and by converting already existing ferries into greener fuels, such as electricity. Färjerederiet have for a long time been at the forefront of working with environmental issues within the maritime sector. When the company started working on greener transport there were no actual support or laws from the government. Therefore, the groundwork that was done early by Färjerederiet was later applied to other Swedish government-based companies within the maritime sector as well as they were fast to act on new climate laws in Sweden.

When being asked about how they are going to go from fossil fuels to a more electric field Erik said that they are currently working on two types of techniques when it comes to electrifying their ferries. One is to use a ferry that is connected all the time to a cable to shore and during the time the ferry goes over the cable will be rolled up. The other way to electrify the ferries is to lift out the engines to be replaced. This is planned to be done at the same time as the ferries are going in to be serviced and they think that they can convert around 1-2 ferries a year. Currently, four new ferries are planned to go to Stockholm and start operating there.

In the year 2019 Färjerederiet started their green work without any legalization or laws helping them on the right track. Intending to be carbon neutral by the year 2045 Färjerederiet released their own goal called vison 45. Vison 45 was then later used by the rest of the government-based shipping companies for their investigations when it comes to environmental development.

Froste said that even though they are a shipping company owned by the Swedish government, they are not only influenced by this. Specific directives that come from the Swedish authorities must be followed, such as where to wash of the ferries so it does not get into the ocean. In addition to this they are influenced by the IMO, then EU and Swedish regulations. But since they are a Swedish shipping company, they had to follow the Swedish climate legislation which they have already passed.

According to Froste, Färjerederiet sees their position as a government-based company to be a leader in this new technology and a leader for the smaller shipping companies. Here Froste sees that their work may help other companies to not making the same mistake as they have done and what technology to invest in.

4.2 Stena Line

Erik Lewenhaupt was interviewed (personal communication March 26, 2021) who is currently head of sustainability at Stena Line, which is a part of the Stena AB concern. The focus of Stena Line has been to lower emissions, minimize their carbon footprint, and develop and work towards equality within the shipping industry. Their work is connected to the SDGs – gender equality and lean energy and are besides this also certified by ISO 14001. Something Lewenhaupt mentions is that the standard language on their ferries is Swedish, and if this would be changed to English a wider range of people could apply for employment.

Stena Line is operating within Europe which includes multiple regulations that needs to be handled and considered. Some of these regulations could be the national ones from Sweden, UK, Ireland, or the Netherlands and so on. In addition to the national regulations, they need to consider the ones coming from the EU and the IMO. An issue according to Lewenhaupt has been to understand how different types of fuels shall be determined in the sense of carbon footprint since there is no common standard for all countries. This creates uncertainty and has led to slower development.

Speaking of political influence, the EU is influencing Stena Line. Presently they are pushing the development harder and faster than others, in his opinion. Another reason for this is that EU is covering most of their operating route. Close to half of their operating ferries are travelling to the UK which is a big uncertainty in the present since they do not know when the new policies will be released. UK are important for Stena Line since all their operating ferries are travelling on international water, except the ones travelling from Belfast to Scotland, Wales and, England which are domestic routes in the UK. Depending on how Brexit formulates its domestic transport policy things could change a lot regarding these routes. An equivalent in Sweden is that Stena Line does not have to follow the regulations of lowering their emissions by 70% by 2030. This does not apply to them since they are operating as international traffic. The regulation is however applied to Gotlandsbolaget who are operating ferries of the same size but counted as short sea shipping. A goal that the company has implemented by their own and for themselves, is to lower their emissions by 30% by 2030 beginning in 2019. This goal is based on previous work that has been done within the organization. Another goal they have developed for themselves is to be carbon neutral by 2050 in alignment with EU.

Stena Line does not operate any fully electric ferries but installed one hybrid ferry in 2018 named Stena Jutlandica which is operating between Gothenburg and Fredrikshavn. They have 14 ferries that are connected to shore power when in laytime and, two fully electric ferries are planned to operate before 2030. Some of the sustainable changes that have been implemented in the ferries are new technology and installations with the aim to lower emissions and make the ferries more energy efficient. A new system has been developed and installed using AI-technology providing guidance to the captain on how to operate the route in the most efficient way.

Another initiative was done in 2015 when Stena Line converted one of their ferries to methanol and diesel, a so-called Dual Fuel conversion. Methanol is a fossil fuel however new technology is developing towards renewable methanol, called e-methanol. Lewenhaupt believes that the

new ferries soon shall be built as hybrids. Especially within the ROPAX-segment since this includes smaller ferries travelling shorter distances, short sea shipping, with the possibility to charge when in port. Believing that 100% electric ferries will be unusual for many years forward if something drastically does not happen in form of technical development. Fully electric ferries require a high capacity of energy and large investment costs. A hybrid, on the other hand, has the possibility to charge in port and whilst operating and can implement peak-shaving with help engines that are powered by batteries. Another issue, and risk, with the implementation of fully electric ferries, are the safety risk and the big investments that needs to be done in land when speaking of power grids. The prices of electricity are different depending on where the ferries are operating. In Sweden, the prices are among the lowest in Europe. Travelling to UK for example, the prices rise, and the grids are not well-developed. If asking for green electricity this will increase the price even more.

4.3 Sirius Shipping AB

Benjamin Fhager is the Technical Coordinator on Sirius Shipping AB (personal communication April 6, 2021), a company that is different from the other ones that we interviewed. Unlike the others, Sirius is a shipping company that is operating on the spot market with LNG, Chemical and Oil tankers.

The company is working towards a sustainable industry. By certifying their tankers with different environmental index, both to stay in line with the competing companies as well as the ongoing sustainable development. Work that has been done is smarter investments when buying new, energy-efficient tankers. In addition to that, they follow both global goals from EU and IMO, such as Agenda 2030 and Agenda 2050, and general goals that have been set by Swedish authorities. They are members of Svensk Sjöfart and have together developed and implemented some current goals. The company follows the goals from Svensk Sjöfart strictly and have not implemented any specific goals for Sirius Shipping AB in addition. According to Fhager, a new goal from the EU will come forward and will be implemented in 2022 regarding taxonomy. The goal shall regulate emissions and include sub-goals where if succeeded, a green contribution shall be received to build new vessels.

An issue they have experienced while working towards sustainable development is that it is very capital intensive. Some of their existing vessels are built in 2006 and the counted lifetime is 20 years. This means that these tankers only have five years left, counting from 2021. It is not possible to economically defend sustainable investments on the old vessels, resulting in the tankers not being seen as good enough for their customers. Ignoring the economic perspective and only focusing on a sustainable future, one of the biggest questions for them is how much fuel to operate with, how to achieve the goal of 50% and becoming climate neutral by 2050. The operating tankers are counted to have a laytime of around 180 days per year. Here they can see solutions using electricity in the form of backup batteries which can be charged during laytime. However, they do not believe in operating fully electric tankers soon, as it would not be energy efficient when operating a long distance of 5-7 days. Instead, they are focusing on finding other sustainable fuels considering which fuel will also be seen as sustainable in the lap of 20 years. Investing in fully electric tankers are not profitable in the present since they are operating on the spot market and therefore do not operate on any set routes. The new investments shall include ships that are flexible to operate on fuels such as LNG, methanol, and hydrogen.

Sirius recently began to invest in Ballast water treatment systems. According to Fhager, the system was forced to achieve a regulatory framework for the environment. Although, since the tankers who had the system installed operates between Brofjorden, Gothenburg, and

Norrköping, which are local routes, the ships increased their emissions of CO2. The system is despite this a necessity when operating across the Atlantic. Operating in different areas and countries includes special laws and regulations. One example is the SECA area where the rules are very strict on the number of emissions that the ship can release. When operating outside SECA, it is permitted to emit 0,5 sulfur however, Sirius has decided to continue operating with 0,1 as they usually do.

4.4 ForSea

When interviewing Anna Prytz, who has the role as Sustainability Manager at ForSea, she told us that the environmental issue is a high priority for the company, and it has been for a long time (personal communication April 15, 2021). ForSea was one of the first Scandinavian companies to electrify ferries within the shipping industry. Before this, they were also one of the first companies to choose a low-sulfur fuel when it comes to the issue of sulfur emissions. They are working together with multiple companies, organizations, and universities such as: ABB, Svensk Sjöfart, currently working on a big project together with the Øresund Aquarium in Helsingør, which is managed by the University of Copenhagen, the Environmental Administration of Helsingborg, a voluntary organization called Havsresan and, the platform called a sustainable tomorrow.

Working towards sustainability comes with a lot of work and change within the organization, including more than only lowering the fuel emissions from the ferries. Since 2019, ForSea is primary following seven of the SDGs which they then base their own long-term and annual goals looking at waste, chemicals, and energy savings, among others. This includes developing technology to get more efficient use of fuel and eco-driving to reach the goals that have been set. ForSea is not only a shipping company but a shipping company with millions of passengers every year. The passengers are not only using the ferry for travelling, but for freight, food and beverage, and retail as well. So, there is also a great focus on climate-smart restaurants and cafés trying to lower the food waste and only serving food with low climate emissions.

Today the company have five ferries in a total of which two are powered by electricity: Tycho Brahe and Aurora. When they began their work in 2015 towards electrifying their ferries, the development and progress of using other green fuels such as ammoniac or methanol were not as developed as it is today. Also, the bunker prices were at an all-time high. Another incitement is that back in time, ForSea were owned by Scandlines. When they later became their own company, this was one great inspiration to the work that has been done. She mentioned how they believe that electric power could be an important part of the future, but that they believe in other fuels as well. Electricity can be seen especially important for short sea shipping that is including the short routes which they are operating. The current ferries that are operating are close to 30 years old. Prytz is proud that they succeeded to convert 25-year-old ferries to be powered by electricity, and that they therefore hopefully will live for 20 more years.

ForSea is strongly regulated by both international and national laws and conventions such as the IMO and the EU, as well as Swedish and Danish authorities. There are also certain expectations from society when it comes to sustainable development. The company is in general at the forefront with their sustainable development and therefore they are already in phase with many of the new regulations that are coming. The social pressure is relatively similar in Sweden and Denmark although the Danes are slightly sharper, and the Swedes are more personal when it comes to environmental issues. Although, it has been important to always see things from a bigger perspective as well.

ForSea is operating ferries between Helsingborg in Sweden, and Helsingør in Denmark. In addition to the national and international regulations, the company is affected by local agreements such as implementation of new routes that could limit their operating space.
According to Prytz, some of the extensive political challenges is that the national progress of developing regulations and laws for electrification is moving slow. When ForSea started their work towards electrification there were no actual laws, regulations, or previous work on such a big scale that had been done before within this field. They received a grant from the Innovation and Networks Executive Agency (INEA) which is an EU-fund program that covered around 30% of the total costs.

Looking at the use of batteries in 2015 when the project started, there was no legislation on which ones to use, how to use them, or even how to build an electric ferry. Using batteries and converting to electric power comes with a lot of safety risks. There were either no laws when it comes to charging the ships and building charge stations in the harbors. SOLAS contained a design chapter with important information on how to design the ship in a safe way which they followed. This chapter was although only adapted for regular ferries and not electric ferries, so they combined their own research and knowledge with the chapter and built the ferries based on that. Something the company took for granted while running this development, based on current laws, was that they in the end would get reduced taxes since they now would have electric ferries. This was not as obvious as they expected, but they got it after questioning it. “It is expensive to be in the lead,” Prytz said.

Another issue that they later faced was the charging process and how to implement charging stations in the harbors. According to Prytz, they also struggled with finding power grids that could provide the large capacity that they needed to charge the ferries. They had to dig new powerlines from the port to the switchgear since the usual electrical grid was not able to handle the requested capacity. The powerlines are 5km on one side and 7km on the other. Sweden and Denmark were both neutral to this decision when it first started. The risk of running out of electricity was not a concern at this time. Although today, more and more industries are converting to electricity meaning that the production of electricity has increased significantly. However, this is not a current issue for the company, but it could be in the future.

Being first does not always mean being the best or finding the right solution right away. This takes time and practice. And although there have been many ups and downs for the company during the process, Prytz said that they are extremely proud of what they have developed and achieved.

4.5 Svensk Sjöfart

From the Swedish Shipowners Association, Svensk Sjöfart, we interviewed Fredrik Larsson, who is working in the environmental department (personal communication April 16, 2021). Svensk Sjöfart is an association for Swedish shipowners. Since they are an association, it is mainly their members who together develop position and views on regulations. The members discuss common issues within politics, economics, sustainability, and more.

Working towards a sustainable industry has for some time been a great focus for all the members. Trying to find solutions on how to move forward and develop a greener industry. The greatest challenge from a political perspective has been to gain the politician's interest to help and support the association and its members. According to Larsson, the political engagement within the shipping industry is generally low.

Speaking about electric ferries, the association and its members have been positive towards this development. Many of their members have electric ferries already or are working towards it. Some general challenges have been that the batteries are not efficient enough for operating in bigger ferries. Although, for members operating short distances and smaller ferries this electrifying has been possible and implemented. The big incentive to electrification has been the benefit of lowering the emissions. Also, economic incentive including reduced taxes and lower operation costs. General challenges for converting to electric operation are the high investment costs, the supply and production of batteries, including the lifecycle of the battery – what to do when they cannot be used anymore and, finding space on the vessels to install the battery packages.

Svensk Sjöfart is mainly politically influenced by the IMO. Thereafter the EU and lastly Swedish authorities. Depending on where the members are operating, other laws and regulations can matter, although the IMO and the EU cover most of them. There are a few political challenges such as how to define a ferry and, tax regulations. It is important to always fulfil the national standards when operating across national borders.

5 DISCUSSION

When we started this thesis, one of the key points for us was to investigate if it is possible for the shipping industry to do what the car industry has done and standardize electric propulsion. After months of research, we can say that it is possible. But the journey towards a fully electric fleet has just begun, and it has a long way to go to be an option for all shipping companies. One of the main incitements to convert to electric power is to become carbon neutral. Some of the interviewed companies in this thesis have already begun their journey, some not, and one company that has already seen results and operated electric ferries for a few years already while others are still in the developing process.

To answer our first research question that was to investigate the extent of electric ferries within short sea shipping in Scandinavia. We looked into companies that had done projects of electrifying ferries or were currently in the progress of doing so. Limitiations were made, however we believed there would be a greater extend of electric ferries in Scandinavia. A thought that crossed our minds when conducting our research was that if the extend of electrified ferries is this small in Scandinavia that is including three well-developed countries, how does it look like in the rest of the world? And is electricity really the fossil-free fuel of the future? We do not know the answer to this but are eager to follow the development further. As expected, Norway had a greater extend compared to Denmark and Sweden. Norway is definitely one of the leaders when it comes to development in electric ferries. Which could be seen when counducting the research and investigating where most of the projects are in operation, and has the most planned projects for the future. A reason that Norway is in the forefront could be a result of their general motivation for a increased electric field of transport and the implementation of reduced taxes when operating electric. Something we did not expect was that Denmark had so few electric ferries, when considering the size of the country and its' many islands. The extent in Sweden was more or less as expected although we expected that there would be a greater extend of fully-electric ferries and according to our research the existing electric ferries hybrids are more common than fully electric. However, the research confirmed that the development of a fully electric fleet has just begun, and it is currently just a small part of the maritime sector that can benefit from building a fully electrical ferry. This mainly because the technology is not developed for long distance transportations on fully electric power.

We tried to contact Danish and Norwegian companies without succees. Interviews with these companies would provide the research with necessary and detailed information. Conducting interviews with companies from all Scandinavian countries and not only Sweden would strengthen the reliability of the thesis and affect our results and conclusion.

In response of our second question to investigate what the incentitives are to choose electric operation a common goal is clearly to lower the emissions. It takes a lot to convert to electric operation and big investments shall be made. However it is worth it according to the companies who has done it. There are multiple benefits that are not only environmental but economic and ecologic as well. Such as reduced emissions of pollution and greenhouse gases, higher energy effiency, life-cycle economy with larger up-front investments and lower operating costs, and reduced vibration- and noice levels. Choosing to go electric benefits the passangers, citizens who are located close to the operating route, and the crew by the reduced vibration- and noice levels. Electricity can also be a helping hand when it comes to peak shaving and electric engines were it can be used as an auxiliary engine. Which Stena Line are already using in their hybrid ferries, also Sirius sees this as an option in the future for their tankers and how to reach further laws and more strict emissions goals. We believe that a form of electric option can help both ferry companies and shipping companies in different ways since limitations when it comes to distance, how charging will work, and how far the development and new technology has come.

To answer our third question on which laws and regulations that motivates the development of electrifying ferries in the Scandinavian countries we concluded our interviews. During the interviews, one clear thing was that all the shipping companies were following the IMO and EU. This since these two organs will determine what shall be done to still be permitted to operate in specific areas. The laws and regulations from the IMO and the EU are decomposed to national level in line with what has been decided. When we spoke with the Swedish Shipowners Association. they said that something the company wished for from the Swedish government is to have a bigger interest in Swedish shipping, and understand that shipping is a big international market and from based on this create rules that can be more in line with the IMO. This was a common opinion when interviewing other companies as well, resulting in that the companies has to look up what is required for each authority and organization instead of them all being in line. It was expected that the IMO and the EU would be two important organs motivating the development of electrifying ferries in the Scandinavian countries. Although, we believed the Swedish authorities would be more in line with these regulations as well. As mentioned before, we would wish to interview Danish and Norweigan companies to inform us about the situation in their countries when it comes to this question.

We made the choice to interview Sirius Shipping AB despite the knowledge that they are operating tankers on the spot market. This since we wanted to compare their answers to the other companies who have set routes and smaller ferries in operation and see what differences there are. According to Sirius they do not see fully electric ships within their segment at all in the near future, compared to the others who absolutely could see this soon. There are too many complications which in our beliefes makes sense. the spot market is more complex than the short and set routes where we can see that electric operations are implemented. It is not possible to install batteries with the energy that a ship demands to operate 5-7 days without charging.

5.1 Interviews

Below, completed interviews are discussed based on the issues of the study.

To conclude the interviews that were made, the companies are either trying to go electric or are focusing on renewable fuels, sherd electric power for the harbors and a supplement for some auxiliary engines. Multiple factors need to be considered before deciding to convert a ferry into 100% electric propulsion. What has seemed to give the option to go fully electric is firstly to have a set route. The second factor is to have the economic capacity to invest in an electrification project since it demands many new implications both for the vessel but also for the infrastructure. Considering the infrastructure companies needs to find solutions on how to charge the ship and from where to get the energy. ForSea has solved this problem by digging cables directly to the transformation station since the regular grid was not strong enough to provide the energy with their vessels required.

A point that was common for the interviewed companies was that the national and international politics are moving too slow in comparison to what society is asking for and requiring, in the sense of climate change and global warming. They all mentioned that they are mostly influenced by the EU and the IMO and agree on that IMO shall work faster towards developing regulations and laws regarding electric ferries. There are some regulations and laws today from the different authorities and regulations, although they all need to become clearer and easier to follow. Both ForSea and Stena Line mentioned political confusion during their process throughout their electric projects.

When it comes to the initiative to run an electric operation the main benefit is to get a carbon-neutral ship and by this, it can get tax reduction from the government. When it is official and able for companies to see how and where other projects are done and that it is possible to get findings from the government and the EU, this may increase the interest of more companies starting projects towards electrification. This has been shown by the project by Candela P-30. One more incitement to go electric is that it can be used in marketing to get more customers and a better social picture of the company.

To conclude the interviews there are some ferries that are electric, most of them are operating in Norway. In the rest of Scandinavian, there is not as many in Sweden and Denmark but with new technology, it is coming more every year.

5.2 Method discussion

We were using the systematic literature study and a semi-structured interview method. A benefit of using a semi-structured interview is that the interview should feel more like a discussion and give a wide spread of answers. In our case, we had decided and prepared our questions before the interviews, and let the interviewed person then speak from their knowledge and experiences (Rosalind, 2015). Meaning the person who was being interviewed did not find out the exact questions before the interview, only what the interview shall be about. An alternative method could have been to expose the questions for the person who was interviewed befor the set meeting, for him or her to prepare their answers. Although, we decided not to do this since it would not give us a good discussion and the answers we were looking for.

Our view is that this method gave us good information. Based on this we could both do research and then get the knowledge from the people that work with these problems everyday and have more and deeper knowledge from the daily perspective. When it comes to the method reliability, during the study we have found it to be a reliable way to conduct research. A risk by

conducting interviews is that a person can always tell a lie or misinform. However, we chose to interview big and well-known shipping companies who would only lose and harm their brand by lying. Together with the literature study we get some base information before the interviews and based on previous information we should be available to understand what we can use from an interview. It would be possible to provide the research using other methods such as exposing the exact questions that shall be used for the interviews. This may have changed or affected the answers in both a positive and a negative sense. All the performed interviews were recorded with permission and later transcribed and used in the result. To conclude the interviews that were made, the companies are either trying to go electric or are focusing on renewable fuels, sherd electric power for the harbors and a supplement for some auxiliary engines. Multiple factors need to be considered before deciding to convert a ferry into 100% electric propulsion. What has seemed to give the option to go fully electric is firstly to have a set route. The second factor is to have the economic capacity to invest in an electrification project since it demands many new implications both for the vessel but also for the infrastructure. Considering the infrastructure companies needs to find solutions on how to charge the ship and from where to get the energy. ForSea has solved this problem by digging cables directly to the transformation station since the regular grid was not strong enough to provide the energy that their ferries required.

6 CONCLUSION

Concluding the thesis, all research questions have been answered and the aim of the report has been fulfilled. Our first research question is investigating the extent of electrified ferries within short sea shipping in the Scandinavian countries. The thesis can conclude that there is a relatively great extent of electric ferries in all the Scandinavian countries. Where Norway is the leading country when it comes to electric development and Sweden and Denmark are similar to each other. Why specific routes have been chosen to electrify are mostly related to the distance of the route, size of the ferry and possibilities for charging.

The answer our second question asking for incentives to choose electric operation have been similar for different companies and relies on economical, ecological, and social goals and situations. As well as there are many beneficial incitements to electrify there are also many challenges. Most often it is too expensive to invest in electric ferries since it does not only include installing battery-packs on a ferry but so much more. Looking at the infrastructure and finding solutions to access enough energy that is required to charge the ferry. One of the factors that were seen early was that for the technology to work in the near future. Is that not only the ships need to be developed and adjusted. But some of the infrastructure when it comes to the electric grid is going to be updated to handle more electric usage in the future not only in shipping but in general. As told by some of the interviewed for now to get a fully electrified ship on a route the route needs to be short and haw a sett destination to set up the charging stations to be able to get enough electric power.

Concluding our research on the third question on national and international influence that motivates the development of electrifying ferries in the Scandinavian countries, the motivation is mainly coming from the European Union and the International Maritime Organization. The national laws and regulations are later based on these. A conclusion that can be made based on interviews with Swedish shipping companies is that the politicians shall work faster to be more in line with the society and sustainable movements that are pushing for change. Even though

the development is moving faster today, the use of electric ferries are still very new and innovative and therefore new specific regulations, requirements or guidelines have yet not been implemented by the IMO. Agenda 2030 and 2025 has been brought up multiple times in addition to the SDGs. These are goals that the European countries, despite Norway, shall follow which are implementing social pressure on the companies to never stop developing towards a sustainable industry.

6.1 Recommendations for further research

- Research on future hybrid ferries that use fuel cells.

- Compare the ecological and economical outcomes of operating fully electric ferries to hybrid ferries.

- Research for students within marine engineering, to look more into how the engine room is changing through the development of electric operations.

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