REPORT

Drivers of a Ban on HFO in the Arctic – the Norwegian Case

SALT report nr. 1030

Report title Drivers of a Ban on HFO in the Arctic – The Norwegian Case	
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Client Seas at Risk	**Clients reference** -
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PREFACE

This report will highlight the drivers behind Norway supporting the decision to phase out heavy fuel oil (HFO) in the Arctic and analyze the drivers from an economic, political and environmental perspective.

These drivers will be studied through analyzing Norway's sustainable development trends in regard to the maritime sector in general, rather than focusing explicitly on the phasing out of HFO. This in order to create a holistic picture of Norway's role as a maritime nation, and its sustainable development strategies. The goal of this report is to identify drivers that can be relevant in a Russian context, and therefore contribute to Russia adapting a global leader role in phasing out HFO in the Arctic.

SALT would like to thank Seas at Risk and the Clean Arctic Alliance for the assignment.

Oslo, 11.04.2019

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Summary

Shipping is one of the most important methods of transport today, and its importance is expected to increase, especially in the northernmost parts of the world where the decline of sea ice is opening for new shipping routes. Increased traffic in the Arctic waters means more efficient global trade but can also put great environmental pressures on the Arctic ecosystems and the climate if not done in a sustainable and responsible way. In order to reduce pressure on the environment, a broad agreement exists among International Maritime Organization's (IMO) members for supporting a ban on the use of one of the most potent fuels, heavy fuel oil (HFO), in the Arctic. However, two countries, Russia and Canada, have yet to commit to the ban. Russia is the largest user of HFO in the Arctic, counting for 56% of the use of this type of fuel in the region (Comer et al 2017). In contrast, Norway has been one of the countries that have been most positive towards a ban of the fuel in the Arctic waters. This report will highlight the drivers behind Norway's decision to phase out HFO and analyze these drivers from an economic, social, political and environmental perspective. These drivers will be studied through analyzing Norway's sustainable development trends in regard to the maritime sector in general, rather than focusing explicitly on the phasing out of HFO. This in order to create a holistic picture of Norway's role as a maritime nation, and its sustainable development strategies. The goal of this report is to identify drivers that can be relevant in a Russian context, and therefore contribute to Russia adapting a global leader role in phasing out HFO in the Arctic.

1. DEFINITIONS

- Geographic Arctic: above 58.95 degrees north.
- Heavy fuel oil (HFO): HFO covers a broad range of different marine residual fuels, or blends of residual and distillate fuels (DNV 2011b, as cited in DNV GL 2019).
- Maritime industry: All actors that own, operate, design, build, deliver goods or specialised services to all types of ships and other floating units (The Norwegian Government, 2017).
- Economies of scale: The cost advantages that companies obtain due to their scale of operation, with cost per unit of output decreasing with increasing scale.
- Economies of scope: A proportionate saving gained by producing two or more distinct goods, when the cost of doing so is less than that of producing each separately.
- Economies of experience: Increased efficiency in operations or production due to gained experience.

2. BACKGROUND

Shipping stands for 80 - 90% of the world's trade today, a great part of which is transportation of food and raw materials (Shi, 2016; Harrould-Kalieb, 2008 as cited in Deniz and Zincir, 2016). With the expected population growth, that will increase the demand for food by 70% by 2050, the development of a sustainable global maritime industry will become increasingly important (Maritim21, 2010). The global maritime industry contributes to both air pollution and carbon dioxide (CO_2) emissions and stands for 2-3% of all global CO_2 emissions today. According to the Third International Maritime Organisation (IMO) GHG study 2014, the shipping industry stands for approximately 15% of the world's nitrogen oxides (NOx) emissions and 13% of the world's sulfur oxides (SOx) emissions (Deniz & Zincir, 2016). There are however, several initiatives taken by regional and global governing bodies, as well as the industry itself, to reduce emissions from shipping and other maritime industries. IMO has tightened the restrictions regarding NOx emissions and sulfur content in fuels and introduced the Energy Efficiency Index (EEDI) for new ships and the Ship Energy Efficiency Management Plan (SEEMP) for existing ships (Miola et al, 2011 as cited in Brynolf et al, 2014). In addition, the European Commission has a goal of reducing CO_2 from shipping by 40% by 2050, compared to 2005 levels (EC 2011 as cited in Brynolf et al, 2014). These restrictions put pressure on maritime nations, such as Norway, to develop their fleet in an increasingly sustainable way.

The maritime industry stands for approximately 10% of Norway's economy and in 2013 it was the second largest export industry, totaling 38% of Norway's total exports (excluding oil and gas) (Ministry of Trade, Industry and Fisheries, 2015). In addition, the knowledge and technological development within the maritime industry contribute to the development of other important industry sectors, such as fishing and fish farming, oil and gas, and renewable offshore energy (Maritim21, 2010). The Norwegian maritime sector is dependent on investments in sustainable and innovative technologies and systems in order to secure Norway's position as a leading international maritime nation in the long-term. Reduction of greenhouse gasses (GHG) from shipping is also one of Norway's focus areas in the fight against climate change (Ministry of Trade, Industry and Fisheries, 2015). The transformation from potent fossil fuels to lighter fossil fuels and renewable energy sources is a reaction to the current and awaited maritime regulations as well as marked trends (Maritim21, 2010). Investing in so-called green technology is seen as a necessity to remain an attractive employer to the younger workforce and as an exporter of maritime technology globally. The Norwegian maritime sector is also considering global energy trends that indicate that fossil fuels will become relatively expensive compared to renewable energy sources in the future. The inability to diversify and develop the fleet makes the whole sector extremely vulnerable towards increases in fossil fuel prices (Maritim21, 2010). Efficiency improvements in the maritime sector are also seen as not only investments in a more environmentally friendly maritime sector, but also as an economically smart investment that reduces the operational costs especially in the long run. These drivers are described in more detail in sections 3,4 and 5 below.

There are seven main drivers that affect the development of the maritime industry globally (Mellbye et al, 2016). These drivers are listed and described below:

- Internet and Communication Technology (ICT)
- Technological development within digitalisation, automatisation and robotification
- Societal and behavioural trends
- Trends in the global economy
- Fluctuations in oil and gas prices
- Structural requirements regarding climate and the environment
- Enhanced specialization and global knowledge flows

As it is beyond the scope of this study to examine all of these drivers from the Norwegian point-of-view, only the drivers considered to have the greatest impacts on the development of the Norwegian maritime industry are included. For example, trends in the global economy and fluctuation of the oil and gas prices are studied in more detail. For the Norwegian maritime industry, which is heavily dependent on the oil and gas industry, future fluctuations in oil price play an important role, as seen during the drop in oil prices in 2014. This drop helped to bring the need for diversification and transformation in the Norwegian maritime industry farther up on the political agenda (Asheim et al., 2016). In addition, the current and future environmental regulations affect the direction that the industry will take. Mellbye et al (2016) argue that the need to reduce emissions represents a great opportunity for the maritime industry to push technological advancements and the knowledge within the industry.

The transformation of the maritime sector is however far from straight-forward, as several factors need to be considered. Brynolf et al (2014) give an example of the factors to be considered in such a transformation process, see figure 1 below:

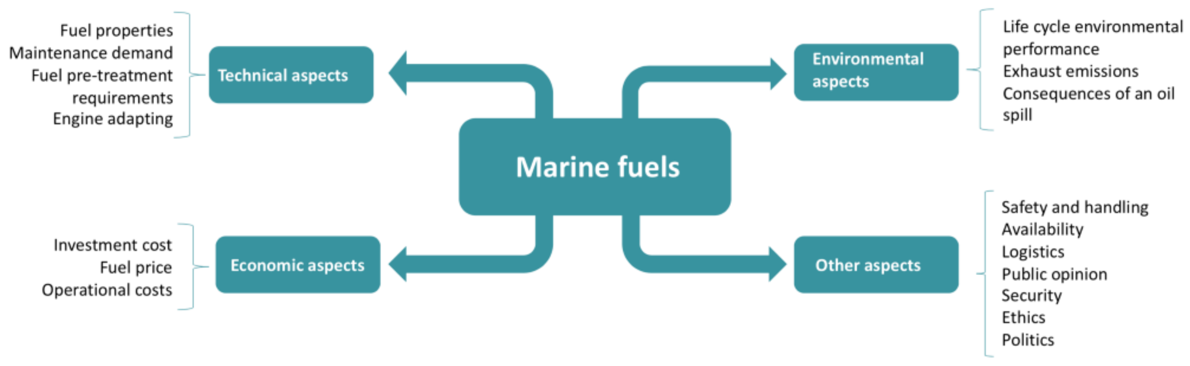

Figure 1: Factors to be considered when evaluating future marine fuels. Source: Adopted from Brynolf et al, 2014.

Some of these factors will be discussed in the sections below, when identifying and analyzing the drivers of a ban of HFO use and carriage in the Arctic, from a Norwegian point-of-view. This study also acknowledges that some of the characteristics of the Arctic region, such as remoteness, harsh weather conditions and lack of infrastructure create additional challenges for new fuel and propulsion technologies (DNV GL, 2019).

3. ENVIRONMENTAL DRIVERS

The Norwegian maritime sector is working actively to become more environmentally responsible, i.e. to reduce GHG, NOx, SOx, short-lived climate pollutants and particulate matter (PM), in order to meet the international goal set by IMO's environmental committee in 2018, of reducing emissions from shipping by 50% by 2050 (compared to 2008 levels)[1]. The maritime sector is also one of Norway's focus areas in the work of reducing national GHG emissions according to the Paris Agreement (Ministry of Trade, Industry and Fisheries, 2015). All countries that signed the Paris Agreement have committed to reduce GHG through national strategies, also called Intended Nationally Determined Contributions (INDCs). Only a few countries included shipping in their INDCs, including for example Marshall Islands and Norway.

In addition to the international drivers, Norway has some internal drivers that push the bar on environmental requirements set on the maritime sector. The negative impacts caused by air pollution and potential oil spills, especially in the Norwegian Arctic, have been highly discussed in Norway during the last few years. Norway is known for its pristine coasts that attract tourists, provide livelihood for the fishing and fish farming industries, and are an important part of Norway's national identity. The Norwegian waters are also used by shipping and oil and gas industries and therefore, developing the maritime sector in a sustainable and environmentally responsible manner helps secure that these industries can co-exist in the long-term.

Whilst some of the environmental drivers behind reducing the negative impacts caused by air pollution and oil spills may not be directly linked to the support of the ban of HFO in the Arctic, they give a holistic picture of the direction and role Norway is adapting in its environmental work in regard to the maritime sector.

3.1 Air emissions

HFO contributes to relatively high levels of emissions of SOx, PM and black carbon (BC), compared to distillates and other available fuels. The BC emissions are particularly concerning in the Arctic as BC interferes with the albedo effect, accelerating the melting of the sea ice (Flanner et al, 2007; Hansen and Nazarenko, 2004 as cited in DNV GL, 2019). As BC emissions stay in the atmosphere for only a few days or weeks, limiting these emissions would immediately reduce the negative effects that the arctic shipping has on the climate (DNV GL, 2019). In addition, NOx and SOx emissions are associated with negative effects on human health. The greatest health concern regarding exposure to the burning of HFO is associated with respiratory problems and damage in the lung tissue (WHO, 2018). NOx and SOx also contribute to acid rain and ocean acidification (Fritt-Rasmussen et al, 2018; Norwegian Maritime Authority, 2011).

1 https://www.dnvgl.com/news/the-imo-adopts-greenhouse-gas-reduction-strategy-116713

Norway is working actively to remove the above-mentioned health and environmental hazards associated with NOx, SOx and BC. Especially the emissions from cruise ships have been in the public eye for several years, due to high levels of air pollution observed in Norwegian fjords and cities. Air pollution is experienced as problematic both due to the ruined natural experience by tourists, the bad air quality onboard the cruise boats, and the health and environmental concerns of the locals[2]. Therefore, addressing the environmental issues caused by the cruise traffic has been put on the political agenda as well. In February 2019, mayors of Norwegian municipalities most affected by cruise traffic presented a list of environmental requirements to the cruise industry. The cruise industry's emissions (1 million tons CO_2 per year) count for 7-13% of the Norwegian maritime emissions annually[3]. Therefore, placing stricter requirements on emitting CO_2, NOx, SOx and PM is an environmental act, as well as a way to improve local air quality in the harboring cities. The list of requirements include a restriction of NOx and SOx emissions, according to the Norwegian Maritime Authority's definitions[4], requirement of use of land-sourced power from 2025, and the requirement of emission-free cruise ship operations as soon as technically possible (date for requirement for emission-free operations are likely to be set in the next evaluation process, in 2021).

Image 1: Mayors of the Norwegian cruise destinations gathered in Oslo 13th of February 2019, to present 14 stringent environmental requirements to the cruise industry. Photo: Nina Sandemose / Skipsrevyen.

2 See for example: https://www.aftenposten.no/norge/i/eVgWg/Turist-kom-for-ren-luft-og-fikk-en-sjokkerende-opplevelse-Se-hvordan-cruiseskipene-forurenser-Geiranger, https://e24.no/naeringsliv/cruiseskip-svir-av-7-000-tonn-drivstoff-i-bergen-havn/23928600, https://www.adressa.no/pluss/meninger/2018/07/14/Cruiseb%C3%A5ter-forurenser-like-mye-som-%C3%A9n-million-dieselbiler-i-Tr%C3%B8ndelag-17118396.ece, https://forskning.no/forurensning-ntb/cruiseskip-i-norge-slipper-ut-dobbelt-sa-mye-som-hurtigruten/1214130.

3 https://www.skipsrevyen.no/article/fjorder-og-byer-fronter-felles-krav-til-cruiseskip-om-lavere-utslipp/

4 SOx: 0.1 % sulfur contect, NOx: Level 1-requirements, MARPOL rule VI/13 from 1. January 2020.
See https://lovdata.no/dokument/LTI/forskrift/2019-03-01-170 for more details.

The tourism company, Hurtigruten, that has transported people on its cruise ships along the Norwegian coast for 125 years, has adopted an active role in pushing the environmental standards from within the industry. According to the CEO of Hurtigruten, Daniel Skjeldam, the motivation behind investing several hundreds of millions of Norwegian kroner on the upgrading of the ships lies in the responsibility Hurtigruten has towards the regions they visit, as well as in insuring the long-term competitiveness of the company[5].

The tourism sector is indeed dependent on the pristine nature within marine and coastal environments in order to attract travelers. However, the cruise industry is not the only industry taking air pollution seriously. The Norwegian maritime sector is motivated to reduce their NOx emissions by the establishment of the NOx fund incentive, described in more detail in section 5.1. Air emissions from shipping are not the only environmental concerns driving the green innovation in the maritime industry, oil spills and risk for oil spills have also been prioritized in Norway, due to previous accidents and the realization of high economic and environmental costs associated especially with HFO spills.

3.2 Bunker spills

«No one wants to see a polar bear covered in oil.»
- Tor Christian Sletner, The Norwegian Shipowners' Association, TU.no 29.06.2017.

An HFO spill could be devastating to the Arctic marine environment due to the way HFO reacts to sea water, slow rate of degradation, very limited evaporation, challenges caused by sea ice, and lack of adequate infrastructure and personnel in the region. Cold water temperatures prevent HFO from dispersing or degrading naturally, making HFO spills extremely persistent in the Arctic. In addition, HFO has negative buoyancy and therefore sinks to the bottom. It can then resurface once waters get warmer, prolonging the negative environmental effects of an oil spill (Biswajoy and Comer, 2017). In addition, changing ice conditions, floating ice masses and lack of daylight may hinder or prevent oil spill response teams from entering the area of the spill, which, combined with restricted access to infrastructure and response teams, adds to the riskiness, and potentially economic costs, of using HFO in the Arctic.

In the last two decades, four significant HFO spills have occurred in the Norwegian waters. The experience from these events has been that harsh weather, cold temperatures and ice complicate the recovery processes. A total of 164 kilometers of Norway's coastline have been affected by these oil spills (Fritt-Rasmussen et al, 2018). The HFO oil spills were damaging for the local environment and expensive to clean up. As an example, in the summer of 2009, a ship called Full City, which was carrying HFO, ran aground outside Langesund in Norway, close to nature reserve areas[6]. The clean-up costs after the accident were over 26 million euros, more than 2000 marine birds died as a direct consequence of the spill, and approximately 191 tons of oil remained in nature after the clean-up actions[7].

5 https://www.skipsrevyen.no/article/hurtigruten-med-gigantisk-miljoesatsing/

6 https://www.kystverket.no/Beredskap/aksjoner/Arkiv-over-aksjoner/Full-City/

7 https://www.kystverket.no/Beredskap/aksjoner/Arkiv-over-aksjoner/Full-City/

During the summer of 2017, the Norwegian Shipowners' Association announced that they were in support of a ban of HFO in the Arctic. The Association gave their support to the ban even though several of their own members would experience an increase in operational costs as a result. The Shipowners' Association were "not that concerned about the negative effects on climate (caused by the use of HFO)", but rather the damages an oil spill can have on the Arctic environment[8]. The concern about effects of oil spills was also one of the main motivators behind the ban of HFO in the waters around Svalbard; the HFO oil spill accident outside Langesund was mentioned as one of the drivers of the extension of the ban to the westside of Svalbard in 2010, in addition to the eastern side[9], where a ban on HFO was announced in 2007.

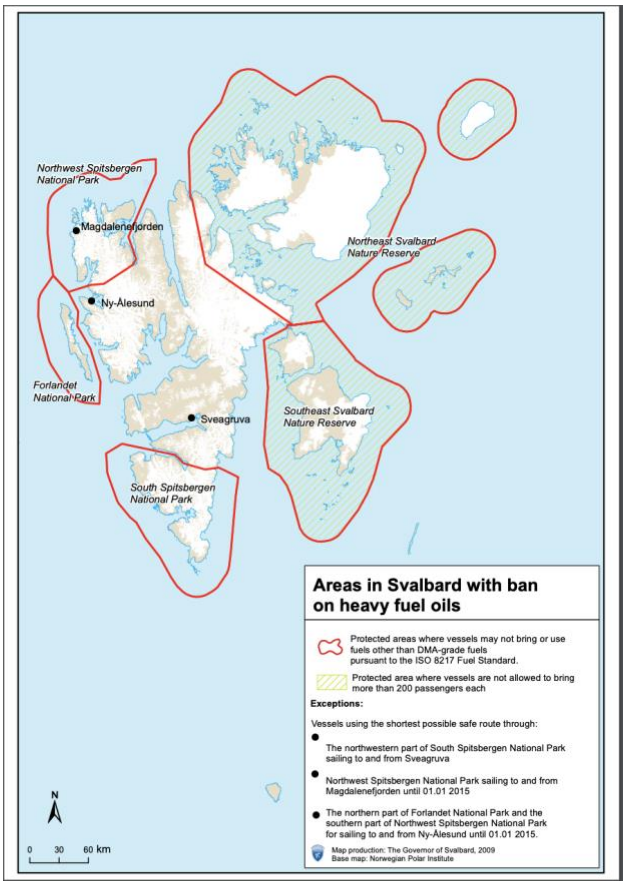

Figure 2. Areas in Svalbard with ban on HFO. Source: https://www.sysselmannen.no/contentassets/8a2bd87e520f46bf835affd9e343281e/heavy-oil-ban---svalbard.pdf

All of the four oil spill incidents happened in southern Norwegian waters, which are more accessible year-round and closer to infrastructure and response crews, than Arctic waters. The complexity of the Arctic conditions is relatively poorly understood, especially when it comes to the challenges related to oil spill response. Even though the Norwegian maritime industry has been a trailblazer within the tightening of environmental standards in the Arctic, the national offshore oil and gas industry is being widely criticized due to their aggressive approach to extending oil and gas

8 https://www.tu.no/artikler/forbud-kan-ramme-6000-fartoy/396773

9 https://fisk.no/fiskeri/662-nytt-forbud-mot-tungolje-ved-svalbard

exploration and extraction in the high north. The main concern of the critics is that the lack of oil spill preparedness could have huge consequences for the marine environment in the Norwegian Arctic and could potentially destroy valuable fishing grounds. While the risk of an oil spill has been one of the main reasons that both public and private sectors support a ban of HFO in the Arctic, there are still some controversies surrounding the economic and political strategies in Norway. The economic and political drivers of sustainable development of the maritime sector in Norway are described in more detail in the following section.

4. ECONOMIC AND POLITICAL DRIVERS

Norway has one of the longest coastlines in the world, which is why the Norwegian economy is built on industries such as coastal tourism, fishing and fish farming, shipping, shipbuilding, offshore oil and gas, and renewable energy sources offshore. The development of these industries, sustainably, is therefore a main focus area within Norwegian politics today. In this section the political and economic drivers behind a ban on HFO, as well as other potent pollutants, are highlighted.

4.1 Political drivers

The Norwegian maritime industry thrives to be innovative, technologically advanced, and environmentally friendly. In a report by The Norwegian Ministry of Trade and Industry (2013), it is stated that:

> *"The government's goal is that the Norwegian maritime industry is going to be the world's most environmentally friendly maritime industry and pioneer the development of new technological solutions."*

(Ministry of Trade and Industry, 2013:28).

The Norwegian government's main goal is to strengthen Norway's profile as a world-leading maritime nation through research and development, and through export of green solutions (Ministry of Trade, Industry and Fisheries and Ministry of Petroleum and Energy, 2017). Development of sustainable technological solutions in the Norwegian maritime industry represents an opportunity for international export of low-emission technology as the international demand for mitigative technology is expected to increase due to increasingly stringent requirements for emission reductions (Steen, 2018). The goal of the government is that the Norwegian maritime sector remains attractive for foreign investors as the industry changes and is therefore focusing on facilitating for knowledge-sharing between marine branches (e.g. oil and gas, renewable offshore energy, fisheries, shipping) and on creating international networking platforms through for example Innovation Norway (Ministry of Trade, Industry and Fisheries and Ministry of Petroleum and Energy, 2017). Furthermore, the government supports EU's initiatives aimed at reducing emissions from the maritime sector and is actively working to implement these initiatives in the Norwegian maritime sector.

Some of the measures taken by Norway are the establishment of the NOx fund (see section 5.1 for more details) and the implementation of stricter environmental requirements for public procurement of maritime services. Through public investments in innovative green technologies, these technologies are made more available to the private sector, helping to facilitate industrial competitive advantages based on economies of scale and scope and economies of experience (Benito et al., 2013), therefore removing some of the inertia associated with first-mover costs. The increased environmental standards for public procurements were crucial in the process of realization of the world's first LNG-ferry in 2000 and the world's first electric ferry in 2014 (Steen, 2018).

4.2 Economic drivers

As mentioned above, the Norwegian maritime industry is dependent on being competitive on the global market, which is why economic considerations have played a great role in the restructuring of the fleet. The Arctic fleet's fuel costs would increase by 3-18% in 2021, were HFO banned. However, the clean-up costs related to the clean-up of HFO would be between 5.3 and 70 million USD more for one bunker fuel spill, in comparison with the clean-up costs of other ban-compliant fuels (Delft 2018, as cited in DNV GL, 2019). Also, the socio-economic and environmental costs would be lower, given there were a ban on HFO in the Arctic. The Norwegian government has actively pushed the maritime industry towards more sustainable operations, but simultaneously acknowledged that the expected changes have to be realistic and implementable within the economic limits of the maritime industry, in order to create positive changes in the long-term, i.e. without running the industry to the ground (The Norwegian Ministry of Trade, Industry and Fisheries, 2015).

The Norwegian maritime industry is working on solutions to reduce GHG, NOx and other harmful emissions in expectation of more stringent international environmental regulations, to be set by the IMO. The likelihood of more stringent regulations in the next few decades is high, and therefore the need to restructure the fleet, as well as the supporting infrastructure, is urgent. Otherwise the industry will risk investing in technology that needs to be replaced within the next decades, and thus end up in a technology lock-in where rebuilding the fleet will be costlier in the future.

In addition to the long-term economic benefits of investing in sustainable solutions within shipping, there are some robust socio-economic benefits to be gained in the short-term. According to a study conducted by DNV GL (2018), reducing GHG emissions from domestic shipping according to goals set by the Norwegian government, would be socio-economically beneficial. DNV GL used realistic scenarios to measure the socio-economic effects. Such scenarios included making technical changes to the fleet for more effective operations and moving from traditional fuels (HFO/MGO) to LNG, Biofuels and electricity. The socio-economic benefits gained only from the reduction of NOx, SOx and BC emissions were estimated at 153 million euros per year. In addition, the estimated socio-economic benefits gained from reducing CO_2 emissions from the domestic shipping were positive. The study also shows that the socio-economic cost-effectiveness of each of the technology measures (electrification, LNG, biofuels, technical and operational measures) is profitable when measured separately. If all socio-economically profitable measures are implemented, approximately 80% of the CO_2 reductions are achieved. If biofuel is also included, which has a socio-economic cost efficiency very close to zero, 90% of the CO_2 reductions are achieved. This would correspond to average socio-economic cost-efficiency of -100 euros per tonne of CO2 (DNV GL 2018).

In conclusion, investing in alternative fuels will have immediate socio-economic benefits, as well as expected positive long-term returns on investments for the maritime industry. The industry will gain from avoiding technology lock-in and not being one of the later adopters of alternative fuels (DNV GL, 2019). The more countries that have adopted alternative, more sustainable methods, technologies and fuels by the time stricter environmental regulations are introduced, the faster these regulations will be enforced[10]. Therefore, delaying the technological development can be extremely costly to the countries forced to switch from HFO to alternative fuels once the regulations are introduced.

10 https://onsagers.no/aktuelt/gronn-skipsfart-gir-nye-muligheter/

5. CASE STUDIES

5.1 The NOx-fund

To stimulate emission reduction, the Norwegian government introduced a NOx-fee to emission-intense industries in 2007 (The Norwegian Ministry of Trade and Industry, 2013). The fee was a challenge for many Norwegian businesses, due to the high fee level. Therefore, it was recommended by the oil and gas industry that a fund be established through which the emission-intense industries can receive financial support for sustainable projects (NOx fund, 2019). As a response to these recommendations, the NOx fund was established by the Norwegian government. Adherence to the fund exempted businesses from the NOx fee but required paying a lower fee to the fund. All income to the fund goes directly back to the industry for emission reduction measures (NOx fund, 2019). Companies that want to implement such measures can apply for funding through the NOx fund. Since 2008 (NOx fund, 2019), the fund has:

- Supported approximately 1000 projects,
- Spent more than 416 million euros for emission reduction measures
- Reduced more than 35000 tons of NOx
- Contributed to international agreements on reducing NOx-emissions
- Contributed to significant development and commercialization of environmentally friendly technology

5.1.1 Experiences from the NOx-fund

Ibenholt et al (2014) did a qualitative study to investigate the effects of the NOx fund and its contributions to the Norwegian maritime industry. They found that the fund has accelerated emission reduction measures within the Norwegian maritime sector, as well as contributed to the use and development of LNG-based vessels in Norway.

In 2012, NSK Shipping built the first LNG-based feeding vessel for fish farming. The NOx fund supported the project with 2,3 million euros. This support from the NOx fund was very important for choosing LNG as propulsion system. In addition, the fund indirectly contributed to the company's experience within alternative technologies (Ibenholdt et al, 2014).

The offshore shipping company Eidesvik Offshore operates a total of 26 ships within the segments of supply, subsea and seismic. Five of their ships are dual fuel supply ships based on LNG, development of which was significantly supported by the NOx fund. According to Eidesvik Offshore, the vessels would not have been developed without the support from the fund (Ibenholdt et al, 2014).

5.2 Use of LNG as fuel

Since the early 2000's, there has been a significant increase in the demand for and number of vessels that run on LNG. In 2017, there were 56 vessels in Norway running on LNG and 11 LNG vessels ordered[11], see figure 3. Use of LNG reduces or eliminates SOx, PM, NOx and BC emissions from

11 https://www.tu.no/artikler/gassdrift-er-en-effektiv-mate-a-fa-ned-utslipp-fra-skipsfart-likevel-lar-den-store-veksten-vente-pa-seg/378406

shipping (DNV GL, 2019; Ibenholt et al, 2014), and reduces the risk of devastating oil spills (DNV GL, 2019). Further, switching from HFO to LNG contributes to a small reduction in GHG emissions (0-18%). However, these reductions are not great enough to meet the goal of reducing CO_2 emissions by 40% by 2030, compared to 2015 levels (DNV GL 2019; Steen, 2018).

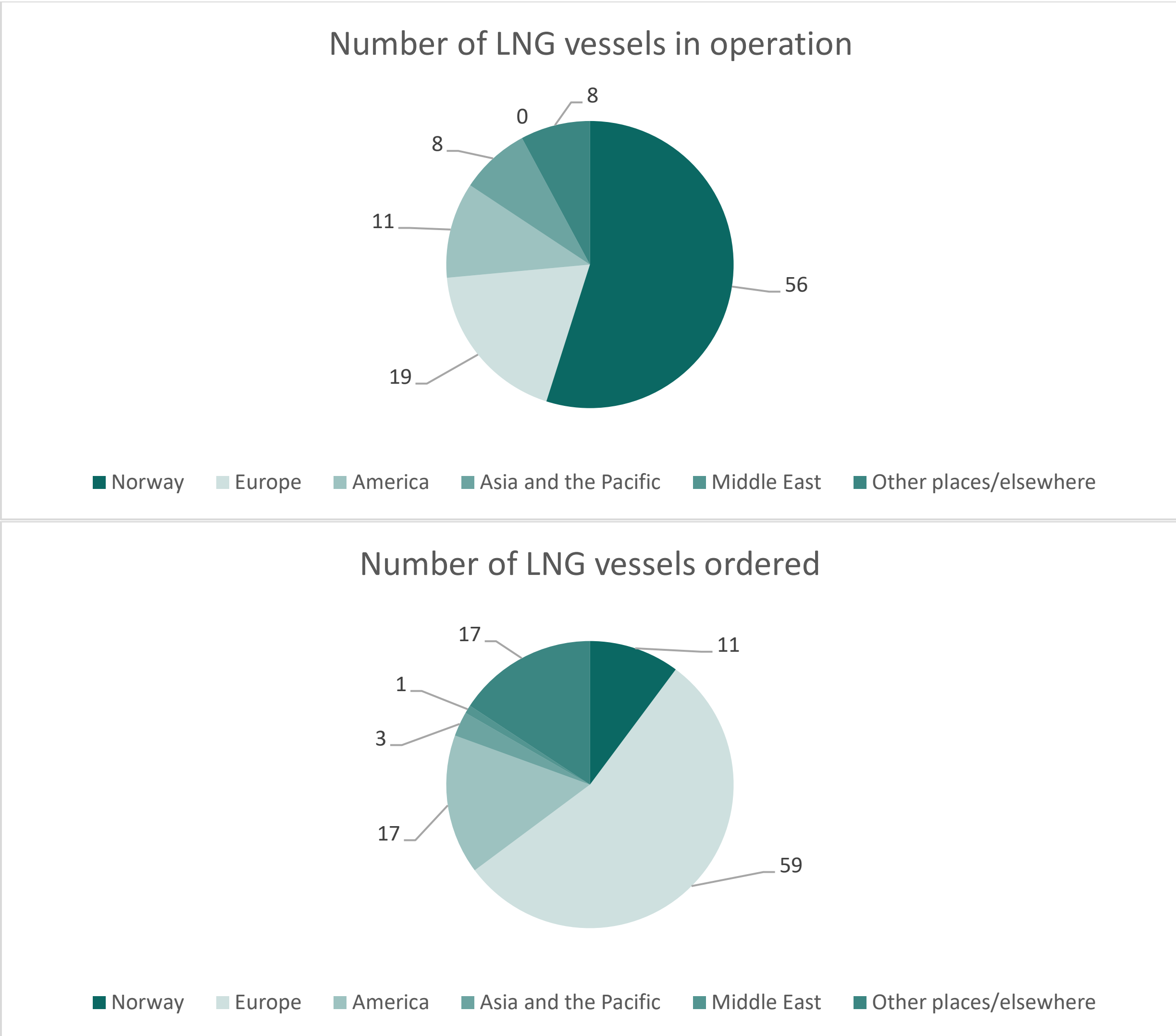

Figure 3. % of LNG vessels operating and ordered in 2017. Figures adopted from https://www.tu.no/artikler/gassdrift-er-en-effektiv-mate-a-fa-ned-utslipp-fra-skipsfart-likevel-lar-den-store-veksten-vente-pa-seg/378406

It is expected that future regulations on NOx and SOx emissions will contribute to a wider use of LNG in the maritime sector (DNV GL, 2019). In a study by DNV GL (2019), the benefits from switching from HFO to several alternative fuels (such as LNG, hybrid fuels, methanol and hydrogen) are calculated and ranked in regard to economic and environmental factors, as well as scalability of the fuels. Both for use in the short-sea (geographically limited; regional) and deep-sea vessels (geographically unlimited; national, global), the LNG battery-hybrid solutions were ranked highest, although the absence of sufficient infrastructure was not taken into consideration. In addition, dual LNG fuel engines are compatible with several alternative fuels, making the potential future transformation towards hybrid solutions easier (DNV GL, 2019).

Even though switching from HFO to LNG would reduce several environmental pressures, there are some economic and logistical barriers to be considered in the transformation process. The cost of building new ships with LNG solutions is about 10-30% higher than the costs of building ships with diesel solutions, making access to capital an important factor in the process. In addition, the lack of infrastructure internationally is a concern from the investors' perspective (Steen 2018; DNV GL 2019). In order to make the use of LNG more feasible, coordinated efforts from both the industry and governmental bodies are required. Phasing in LNG also leads to an urgent need for skilled personnel that can install, maintain and operate new solutions (DNV GL, 2019).

In conclusion, switching to LNG will not contribute sufficiently to the reduction of GHG emissions from shipping, but it is the only feasible alternative fuel for deep-sea vessels today and in the short-term (DNV GL, 2019). In the long-term, the LNG dual fuel engines have the advantage of being compatible with hybrid solutions that are currently under development. In addition, the LNG is relatively accessible in the Russian Arctic. There are several established and planned LNG production plants along the northern coast of Russia. These plants are located along the whole coastline, making the fuel available for the maritime fleet operating in the northern waters between Europe and Asia, as shown in figure 4.

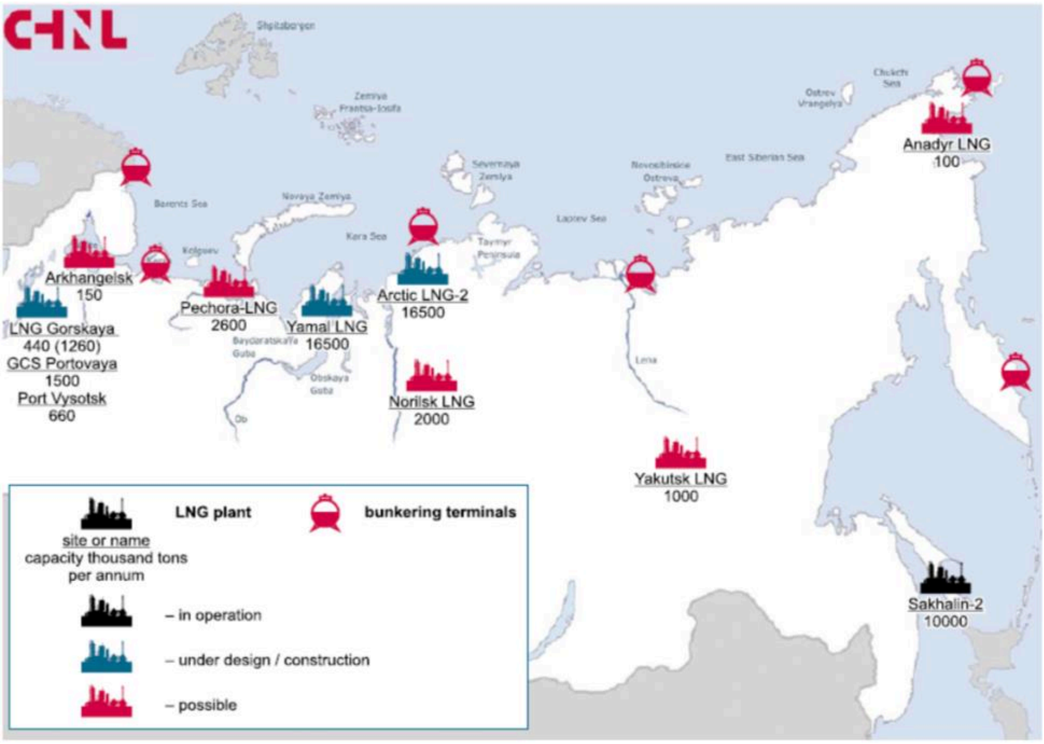

Figure 4. Geographical spread of Russian LNG-plants (In operation, under design/construction, possible). Source: DNV GL, 2019[12].

5.3 Electricity and hybrids in the maritime industry

The first coastal fishing boat with a hybrid solution and electric engine was tested in 2015. The testers reported that the electric engines led to less noise, exhaust gasses and vibrations, giving the

12 The Yamal LNG plant has been in operation since December 2017 (original source WWF 2017).

workers better working conditions[13]. The first electric ferry was also delivered and tested in 2015[14]. Since then there has been an increase[15] in the number of electric ferries and fishing boats both in operation and under construction in Norway.

In 2016, Norwegian Public Roads Administration announced that the first liquid hydrogen powered ferry is to be put in operation in 2021. The motivation behind the development of both electric and hydrogen powered ferries is to increase the demand of the Norwegian technology suppliers, and to give the industry a head start on development and testing of the technology that has potential for taking an increasing share of the maritime fleet in the future[16].

The coastal fleet is an ideal testing ground for new technologies and alternative fuels, and the speed at which the coastal fleet is taking into use new, more sustainable solutions, signals of a high potential of transferring these technologies to the deep-sea fleet in the nearby future. It is outside the scope of this study to analyze the development of electric and hybrid solutions in the coastal waters of Norway in more detail. However, it can be assumed that both the Norwegian and international maritime industries will increase the use of alternative fuels in the years to come, taking all the above-mentioned drivers into consideration.

6. CONCLUSION

There are several international factors that have affected and will affect the development of the Norwegian maritime industry in the future. For example, maritime nations are forced to develop their fleet bearing the potential for more stringent, international environmental regulations in mind. This in order to avoid technology lock-in and high costs of transformation in the future. Norway is also one of the few countries that have included reductions in the maritime sector in its INDCs in the work to reduce GHG emissions according to the Paris Agreement, and has a goal of reducing CO_2 emissions from shipping by 40% by 2030, compared to 2015 levels.

In addition, Norway is actively working on reducing or completely removing NOx, SOx and BC emissions, and reducing the risk of oil spills from the sector. The clean-up costs related to the clean-up of HFO spills would be between 5.3 and 70 million USD more for one bunker fuel spill, compared to the clean-up costs of ban-compliant fuels. Also, the socio-economic and environmental costs would be lower, given there were a ban on HFO in the Arctic. The socio-economic benefits gained only from the reduction of NOx, SOx and BC emissions in Norway were estimated at 1 472 million NOK per year, according to a model study by DNV GL (2019).

It can also be assumed that price of oil and gas will affect the development of the global maritime industry in the decades to come. Diversifying the fleet will make the Norwegian maritime sector less vulnerable to the volatile oil and gas prices and will thus secure its competitiveness in the global market in the long-term. LNG seems like the natural first step towards a more sustainable maritime industry in the Arctic, but in the long-term, the hybrid and electric solutions are expected to become more competitive also for the deep-sea fleet.

13 https://www.enova.no/2050-veien-mot-lavutslippssamfunnet/batterirevolusjonen-til-sjos/

14 https://www.tu.no/artikler/i-2015-ble-norge-forst-ut-med-elferge-na-skal-ny-milepael-nas/358972

15 https://bellona.no/nyheter/samferdsel/miljovennlig-transport/2017-11-strom-til-sjos

16 https://www.tu.no/artikler/norled-bygger-verdens-forste-hydrogen-ferge/452526

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