Low-Carbon Port Operations: Final Report of the Section by the University of Turku, Brahea Centre, Centre for Maritime Studies

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1 INTRODUCTION

1.1 Background

Ship emissions are regulated in ANNEX VI, in MARPOL 73/78 (International Convention for the Prevention of Pollution from Ships). The regulation includes two types of regulations: (1) global requirements, and (2) more stringent requirements applicable to ships in Emission Control Areas (ECA). The 1st of January 2020 has been set as entry-into-force date of the 0.5% global sulphur limit in maritime fuel, whereas ships trading in the North Sea and Baltic Sea SECA must use fuel oil on board with a sulphur content of no more than 0.10% since January 2015. In addition, according to the EU Marine Fuel Sulphur Directive (1999/32/EC, Art.4 and Amendment 2005/33/EC), the sulphur content in marine gasoil within the territorial waters of a Member States Member States of the EU (Baltic Sea, North Sea, English Channel) may not exceed 0.1% by weight, applicable to all vessels regardless of flags.

Besides sulphur oxides (SOx), shipping releases greenhouse gases (CO2, CO and methane), nitrogen oxides (NOx) and particles (PM) to the atmosphere. The IMO has set a target to reduce maritime GHG emissions by 50% by 2050 (with 2015 as a baseline). Maritime greenhouse gas emissions are presently regulated only indirectly. In order to monitor vessels CO2 emissions more effectively, the EU introduced MRV regulation (Monitoring, reporting and verification) which came in force July 1st, 2015 (European Commission 2017a). Since January 1st, 2018 vessels larger than 5,000 gross tonnage (GT) calling at any EU and EFTA (Norway and Iceland) port (regardless of their flag) must annually monitor, report and verify their CO2 emissions.). Regarding nitrogen emissions, s proposal for establishment of Nitrogen Emission Control Area (NECA) on the North Sea and Baltic Sea was made in 2016 (in MEPC 70). The aim is to get 80% reduction in NOx emissions. The decision is expected to be approved in the MEPC meeting in 2017. The regulation will be applicable to new ships built after 1 January 2021 when sailing in the Baltic Sea and the North Sea and other NECAs (Ministry of the Environment 2016).

Ports located inside the Baltic Sea and North Sea SECA (Sulphur Emission Control Areas) have started to provide the bunkering infrastructure for low sulphur fuels and LNG, and provide on-shore power supply for vessels to reduce local emissions while ships are in berth. In addition, many ports have reception facilities for scrubber sludge (ESN, 2013). Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure, requires that a core network of refueling points for LNG at maritime ports should be available at least by the end of 2025. According to the Directive, the TEN-T Core Network should be the basis for the deployment of LNG infrastructure. The ports that belong to the TEN-T Core network in Finland, including Port of Helsinki, Port of HaminaKotka, Port of Turku and Port of Naantali, have made investment plans for LNG and other alternative fuels.

In the recent years an increasing amount of administrative and environmental policy instruments have emerged to complement traditional legislation in controlling the environmental impacts of ports. In addition to these instruments, ports are also trying to reduce the environmental impact of their operations with voluntary methods, for example, by developing best practices. However, at the moment, the ports do not actively share their best practices with each other (Brunila et al. 2015).

This study is a part of Low-Carbon Port Operations project, the aim of which is to develop ports and port related companies to operate more eco-efficiently and in a more low-carbon way. The project is funded by the European Regional Development Fund, Regional Council of Kymenlaakso, City of Kotka, Port of HaminaKotka and Port of Loviisa. The project partners are: Kotka Maritime Reseach Association; Kymenlaakso University of Applied Sciences; Turku University of Applied Sciences and University of Turku, Brahea Centre, Centre for Maritime studies.

1.2 The aim and structure of the report

The aim of this study is to give an overview on alternative fuels in shipping. Special focus is given to LNG as a ship fuel, since many investments have already been made to the LNG terminal network and vessel bunkering infrastructure around the Baltic Sea invested in. Besides LNG, several other fuels and different renewable energy sources (wind, solar and wave energy) and technologies with zero emissions (hydrogen, fuel cells, batteries) are already in use in maritime transport. One of the aims of this study is also to establish such environmental best practices that are used in ports that are also applicable in other ports.

The research questions of this study are:

- How the forthcoming emission regulation affects the propulsion choices used in vessels?
- What alternative fuels and renewable energy sources are in use in shipping? What is the applicability of these different energy sources in shipping operations in the Baltic Sea?
- What experiences there are with methanol as a ship fuel in the Baltic Sea?
- What kind of LNG terminal infrastructure and network is being built in Finland?
- What kind of environmental best practices are used in ports and are they applicable in other ports also?

This study comprises of literature reviews, a questionnaire, a case story and interviews. The literature review on alternative fuels and energy sources in maritime transport gives an overview on emission regulation and available energy sources in shipping. An electronic questionnaire (Webropol) on the supply and demand of alternative fuels in the Baltic Sea region and the plans and views of the seaports on alternative fuels was sent via e-mail to several ports, port-based organizations, energy companies and shipping companies located within the Baltic Sea region. The feasibility of methanol as a ship fuel was assessed with a literature review, and a case story on Stena Germanica that operates between Gothenburg and Kiel. The methanol study was planned in cooperation with PP Maritime Ltd., which is a privately owned company that offers comprehensive and tailored logistics and shipping services, such as shipping, ships agency and forwarding, and methanol logistics.

During this study organizations that participate in Finnish LNG terminal projects in different parts of the country were interviewed. Representatives of different LNG projects planned in different locations were chosen to ensure if there is regional variation in the answers. In addition, the interviewees represent different parties in the projects: one port, one energy company, and an LNG supplier company, whose operations consists of the purchase of feed gas, LNG liquefaction, distribution of LNG by trucks and ships through receiving terminals, to customer facilities where LNG is re-gasified to natural gas or delivered as fuel to the end-user. Best practices in ports were collected from previous studies, web-pages from the ports and interviewing the main actors.

1.3 Study Structure

After the introduction Chapter 1, the following Chapter 2 provides an overview on maritime air emission regulation and the different energy sources for maritime transport. Special emphasis is on alternative fuels and non-fossil energy sources. Thereafter, the results of the questionnaire addressed to maritime actors operating in the Baltic Sea are presented. Chapter 3 presents methanol as a maritime fuel and the Stena Germanica case story. The results of interviews with representatives LNG terminal projects in different locations in Finland are discussed in Chapter 4 that is followed by the Chapter 5 that shows the best practice examples that are collected from Finnish ports. The report ends with a discussion and conclusion section (Chapter 6). The report is the result of the joint effort of Kotka Maritime Research Association (Piia Nygren) and University of Turku/CMS (all other authors). M.Sc. (Admin) Vappu Kunnaala-Hyrkki and M.Sc. (Tech) Olli-Pekka Brunila were responsible for conducting the research including questionnaire, and writing this study report, except following: Ph.D Johanna Yliskylä-Peuralahti wrote the chapter 2 and Chapter 5.2 is written by PhD Katariina Ala-Rämi. M.Sc. (Tech) Piia Nygren helped with the interviews and in the writing of the Chapter 3. The project was directed first by Prof. Esa Hämäläinen (2015) and then by Prof. Tommi Inkinen (2016–2017).

2 ALTERNATIVE FUELS AND RENEWABLE ENERGY SOURCES IN MARITIME TRANSPORT

2.1 Towards low-emission maritime operations

Greenhouse gas emission regulation

New regulation to reduce vessel air emissions have recently been enforced or are being proposed by the EU and the IMO. The IMO has set a target to reduce maritime GHG emissions by 50% by 2050 (with 2015 as a baseline). However, at the moment these emissions are not regulated. Measures already in place (EEDI and SEMP) primarily target the general energy efficiency of a vessel (EEDI and SEMP below) and they are insufficient to reduce the GHG emissions (Bows-Larkin 2015). Therefore the EU Parliament and Commission have already announced that in case the IMO does not take action soon enough, they will (see Alhosalo et al. forthcoming).

In order to monitor vessels CO2 emissions more effectively, the EU introduced MRV regulation (Monitoring, reporting and verification) which came in force July 1st, 2015 (European Commission 2017a). Since January 1st, 2018 vessels larger than 5,000 gross tonnage (GT) calling at any EU and EFTA (Norway and Iceland) port (regardless of their flag) must annually monitor, report and verify their CO2 emissions. Data collection takes place on a per voyage basis. Each vessel must report their fuel consumption, distance travelled, and the amount of cargo carried for the calculation of CO2 emissions. Software for shipping companies to do that is already available (see MarineLink 2017a.) The reported CO2 emissions, together with additional data, are to be verified by independent certified bodies and sent to a central database managed by the European Maritime Safety Agency (EMSA). The aggregated ship emission and efficiency data will be published by the EC by 30 June 2019 and then every consecutive year (DNV-GL 2017).

In addition, a global fuel consumption reporting system (DCS) will come in force Jan 1st, 2019 (Trafi 2017). The IMO guidelines regarding the implementation of the global system are expected to be approved at the Maritime Environmental Protection Committee meeting (MEPC 71) in May 2017. The EU Commission is expected to make its own scheme compatible with the global scheme (Ship & Bunker 2017).

The IMO has created a Roadmap for the years 2017-2023 to reduce the GHG emissions (see IMO MEPC 70, Annex 1). The GHG Roadmap consists of a preliminary GHG Strategy and Comprehensive IMO Strategy on Reduction of GHG Emissions from Ships to be adopted in 2023. The preliminary strategy includes three steps: data collection, analysis and decision on policy measures. The preliminary maritime GHG strategy is aim to be approved during spring 2018, enabling the IMO to report the actions it has taken to the 24th United Nations Framework Convention on Climate Change (UNFCCC). The preliminary strategy includes a plan for a Fourth IMO GHG Study (covering the years 2012) which will be initiated in 2019 and submitted to MEPC in the autumn of 2020, when phase 2 of the three-step approach (data analysis) is set to start. The Comprehensive IMO Strategy on Reduction of GHG Emissions from Ships) includes activities and measures (near, mid- and long-term measures, including alternative fuels) to reduce maritime greenhouse gas emissions (IMO MEPC 70, Annex 1). Regarding the measures the introduction of bunker fee, and Maritime Emissions Trading Scheme (METS) have been discussed (see Alhosalo et al., forthcoming).

Emission Control Areas (ECAs) and global SOx emission reduction:

Presently vessel air emissions are regulated by MARPOL Annex IV with two sets of emission and fuel quality requirements: (1) global requirements, and (2) more stringent requirements applicable to ships in Emission Control Areas (ECA). An Emission Control Area can be designated for SOx and PM, or NOx, or all three types of emissions from ships (IMO 2017). Existing Emission Control Areas include (Figure 1):

- Baltic Sea (SOx: adopted 1997 / entered into force 2005; NOx: 2016/2021)
- North Sea (SOx: 2005/2006; NOx: 2016/2021)
- North American ECA, including most of US and Canadian coast (NOx & SOx: 2010/2012).
- US Caribbean ECA, including Puerto Rico and the US Virgin Islands (NOx & SOx: 2011/2014)

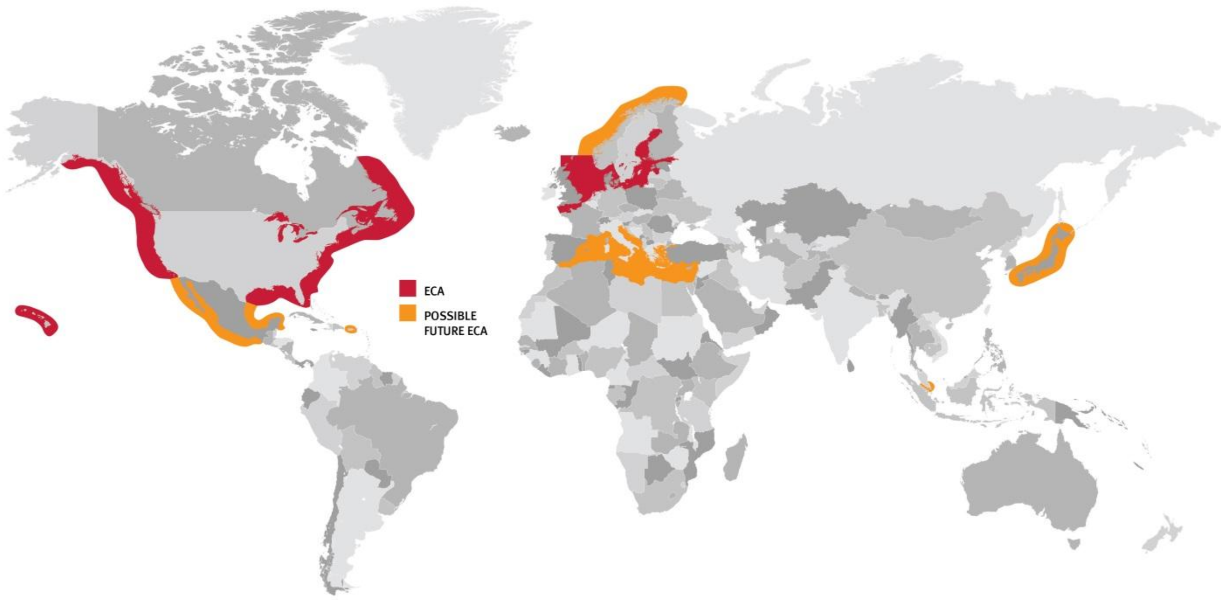

Figure 1. Present and future Emission Control Areas (Source: DuPont 2017)

The 1st of January 2020 has been set as entry-into-force date of the 0.5% global sulphur limit in maritime fuel. As already discussed in chapter 1 of this report, in the Baltic Sea and the North Sea the cap for sulphur content in fuels is 0.1%, as set out in the IMO regulation and EU Sulphur Directive that entered into force in 2015. On the basis of the EU Sulphur directive, the 0.1% SOx limit is also in place in the EU ports since January 1st, 2010. The sulphur emission limits can be met either by using low-sulphur fuels, or by an exhaust gas cleaning system (a “scrubber”). The different fuels and energy sources for maritime transport are presented below in chapter 2.2.

NOx emission reductions

A proposal for establishment of Nitrogen Emission Control Area (NECA) on the North Sea and Baltic Sea was made in 2016 (in MEPC 70). The aim is to get 80% reduction in NOx emissions. The decision is expected to be approved in the MEPC meeting in year 2017. The regulation will be applicable to new ships built after 1 January 2021 when sailing in the Baltic Sea and the North Sea and other NECAs (Ministry of the Environment 2016).

Nitrogen emissions can be reduced either by combustion modification, flue-gas treatment (either exhaust gas recirculation EGR or selective catalytic reduction SCR), exhaust gas cleaning (using a scrubber or filtering), or by using “cleaner” fuels that produce less PM and NOx emissions in the combustion process (EMSA 2017). The SCR is the most efficient method, capable of reducing up to 90-95% of NOx emissions (MarineInsight 2017).

PM and black carbon (BC) emission reductions

Black carbon emission restrictions have been discussed in the IMO, especially due to their impact on climate change globally and especially in the Polar regions. No timeline for regulation has been set. PM and BC emissions can be reduced by fuel switching, slow-steaming combined with engine de-rating, exhaust gas scrubbers, exhaust gas recirculation, slide valves, water in fuel emulsion, liquefied natural gas (LNG), and diesel particulate filters (DPFs). With scrubbers PM can be reduced up to 70-80% when HFO is used (Hansen et al. 2014).

2.2 Alternative and non-fossil energy sources in maritime transport

Besides LNG and methanol discussed in chapters 2 and 4 in this report, several “alternative fuels” are already in use on ships. “Alternative fuels” means fuels or power sources which serve, at least partly, as a substitute for fossil oil sources in the energy supply to transport and which have the potential to contribute to its decarbonisation and enhance the environmental performance of the transport sector (DG Move 2015). Different energy sources are listed in Table 1. Vessels equipped with dual fuel engines are capable of using LNG, methanol and biofuels.

In addition, several renewable energy sources (wind, solar and wave energy) and technologies with zero emissions (hydrogen, fuel cells, batteries) are already in use in maritime transport. The use of non-fossil, renewable energy sources improves air quality both locally and globally and contributes also to other aspects of sustainability (Winnes et al. 2015.) Renewable energy can be utilized either as an auxiliary and/or ancillary energy source in an existing vessel or as a primary energy source. Many forms of renewable energy can be installed by retrofitting an existing vessel. A small but increasing number of shipowners are targeting l00% renewable energy or zero-emissions technologies for primary propulsion (e.g. Greenheart, Orcelle). However, investments into renewable energy utilization in shipping are still seriously lagging behind other energy user sectors (IRENA 2015).

Table 1. Energy sources for maritime transport, their main benefits and disadvantages. Based on McGill et al. (2013); DNV-GL (2014); DG Move (2015); IRENA (2015); Lindstad et al. (2015); Lloyd’s Register (2016a, 2016b); Mander (2016); and Yliskylä-Peuralahti (2016).

Energy source	Benefits	Disadvantages
LNG (methane) and LPG (mixture of propane, butane,	Significantly lower SOx, NOx, and PM emissions compared	Methane slip in LNG production, storage and bunkering; does not

propylene)	to other fossil fuels, slightly lower CO_2-emissions Primary energy source suitable for all shipping segments Increasingly available in SECAs, bunkering infrastructure and vessel technology developing fast	offer a solution to greenhouse gas reduction LPG not suitable for deep-sea or offshore shipping Liquefaction and storage are energy consuming High investment costs – require new bunkering infrastructure
Methanol, DME (dimethyl ether) and ethanol (ethyl ether)	No SOx emissions, low levels of PM and NOx emissions Primary energy source, compatible with existing bunkering infrastructure Conversion of the vessel is easier than with LNG	Methanol is toxic; additional safety measures required On-board catalysis unit required for DME Adjustments and decarbonizing required with existing engines
Synthetic and "hybrid" (fossil) fuels (with 0.10% m/m sulphur content), and "distillates" (fossil fuels)	Lower emissions SOx, NOx, and PM compared to HFO Can be used in existing diesel engines and fuel infrastructure Fossil fuels; produce CO_2-emissions	Higher production costs and selling price compared to conventional fuels Viscosity and fuel needs to be controlled due to the risk of thermal shock Contain increased filter loading and other operational issues
Biofuels: biodiesel, bioethanol, biomethane (see above), straight vegetable oil (SVO), dimethyl ether (DME, see above), pyrolysis oil, hydrogenated vegetable oil	Biodegradable and sulphur-free. Low levels of NOx, CO_2 and PM emissions	The amount of emissions depend largely on which sources are used as the raw material

(HVO).	Primary energy source: Liquid biofuels be used solely or blended with fossil fuels in existing engines (adjustments to engine often required) Existing bunkering infrastructure is suitable for liquid biofuels and existing LNG network for the gaseous biofuels	Higher production costs compared to conventional fuels (HFO, MDO) Lower energy content compared to HFO and MGO and thus fuel consumption is 7-10 % higher. Chemical structure may change when stored Corrosion and bio-fouling of the fuel tanks Competition with other transport modes and with energy production
Hydrogen and fuel cells	Zero emissions if electricity for hydrogen production is coming from renewable sources Widely used technology in submarines Suitable for many types of vessels as an auxiliary or ancillary energy source	The amount of emissions depend largely on how hydrogen is produced Hydrogen is costly to produce, transport and store Safety issues regarding storing hydrogen on board of vessels
Electricity/battery electric propulsion	Zero emissions if electricity is produced from renewable sources Electricity can be produced from all primary energy sources	Suitable only for short distances (e.g. Ro-Ro ferries, tugboats, service vessels) or in combination with renewable energy sources Technical problems with availability of materials and durability

	Several devises available Suitable for auxiliary systems	
Wind energy: Flettner rotors, sails, kites, wind turbines	Zero emissions Available everywhere Sails and kites are suitable for many sized vessels	Wind conditions differ between regions; Cause difficulties in harnessing the full propulsion potential Sails and Flettner rotors require suitable deck space Kites and Flettner rotors are unsuitable for general cargo, container, reefer, chemicals, LNG and LPG vessels Stability and vibration problems with wind turbines
Solar energy/photovoltaics	Zero emissions Currently suitable mainly as an auxiliary or ancillary energy source	Solar panels require space on-board Most potential when used with other energy sources Application requires further technical development
Wave energy	Zero emissions	The technology is still in the experimental stage

The use of LNG can lower vessels' SOx emissions by 100%, NOx emissions by 85% and CO_2 emissions by 20% compared to traditional heavy fuel oil (HFO) (DNV-GL 2015). However, large amounts of methane are released during production of LNG, so with the present technology the use of LNG accelerates rather than diminishes climate change (Winnes et al. 2015).

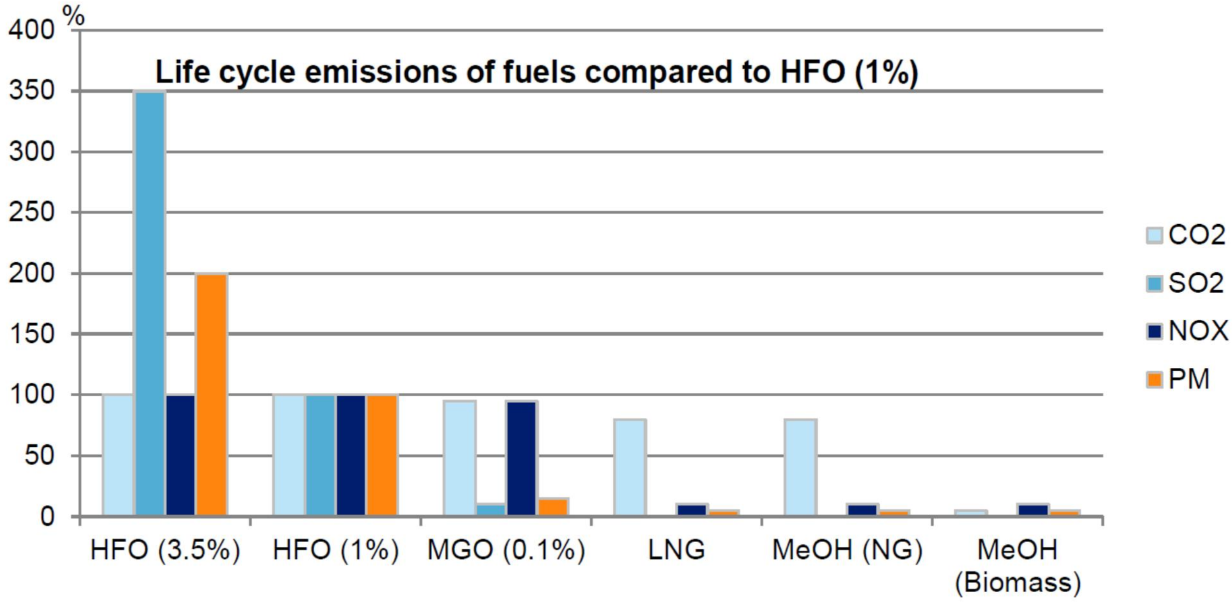

Figure 2. Life cycle emissions of selected maritime fuels. Source: Stena Teknik

Synthetic fuels, such as coal-to-liquid (CTL) and gas-to-liquid (GTL), can be produced from mixture of carbon monoxide and hydrogen (syngas). Synthetic diesel or other liquid hydrocarbons can be produced from syngas made from lignite, cokes, natural gas, methane or biomass by Fischer-Tropsch process. Synthetic fuels produced from biomass (biodiesel, bioethanol, biomethane, straight vegetable oil (SVO), dimethyl ether (DME), pyrolysis oil, and hydrogenated vegetable oil (HVO) are treated here as biofuels (see next page). Synthetic fuels are sulphur-free and have a lower content of other emissions compared to HFO (Taljegård 2012). Methanol as a maritime fuel is discussed in detail in chapter 3 in this report. The main features of methanol as a maritime fuel are summarised in the table above.

Major reductions of emissions of GHGs from marine engines can be achieved by replacing fossil fuels with biofuels (see Figure 2). Biofuels are biodegradable, so they are less harmful to the environment compared to fossil fuels in case of an accident or operational spill occurring in the sea or on-shore during production, storage or transport. They can be mixed with fossil fuels and biogas can be used instead of LNG. 2nd and 3rd generation biofuels are made from residues, waste, and other non-food biomass, including algae, sewage sludge and microorganisms, so they do not compete with food production. However, due to lower energy content compared to HFO and MGO, the use of biofuels typically increase fuel consumption of the (main) engine by 7-10 %. In addition, the production of biofuels is more costly compared to fossil fuels and large scale production of biofuels requires considerable amount of raw materials. Currently marine biofuels are not produced or used in large scale. Up scaling the production of biofuels depends largely on price of fossil fuels and demand in other uses. As biofuels are also increasingly used in other transport sectors and also in energy production, the extensive use of the biofuels is limited in shipping (McGill et al. 2013; DNV-GL 2014; IRENA 2015).

Hydrogen and fuel cells have potential in shipping and several shipping companies have already invested in them. Fuel cells are installed e.g. in Royal Caribbian Cruises new buildings to produce energy needed in hotel functions of the vessels. The vessels are planned be delivered in 2022 and 2024 (Meriteollisuus 2017.) Kongsberg and Yara have developed a battery powered, autonomous container vessel (Kongsberg 2017).

Hydrogen production technology is mature and cheap production pathways are already in place. Hydrogen can be produced either from coal, natural gas or biomass, or by using solar power in thermal splitting of water or electrolysis through photovoltaic electricity. Also wind can be used to generate the power needed to produce hydrogen. In vessels hydrogen is often used in combination with fuel cells (Taljegård 2012; DG Move 2015). Fuel cell's greatest potential lies in using them in combination with renewable energy solutions in hybrid energy modes and when used together with waste heat recovery systems (DNV-GL 2014; IRENA 2015). However, safe storing hydrogen safely on-board required plenty of space. Compressed hydrogen requires six to seven times more storage tank space compared to HFO. Liquid hydrogen requires cryogenic storage at very low temperatures (- 253 Celsius) and very well insulated storage tanks (DNV-GL 2014; IRENA 2015).

Energy storage devices such as batteries can be used to power ships' propulsion systems and also to store and optimize energy in vessels using hybrid energy systems. For large deep-sea vessels the technology is currently suitable for powering auxiliary systems and reducing local emissions during port operations and when the vessel is close to populated areas (DNV-GL, 2014). Presently, batteries are mainly used in Ro-Ro and offshore supply vessels. Batteries offer balancing energy to cover the peaks, resulting in a more stable load on the engines. When the battery is used as power redundancy and the engine runs at its most efficient load, the fuel saving potential is 30 percent (MarineLink 2017b).

Before the era of the steam and diesel engines, wind was the main energy source for vessels. Presently wind energy is used mainly as a complementary energy sources in combination with other forms of energy. There are different technologies for wind propulsion: Flettner rotors, sails, kites, and wind turbines. Sails are a mature technology that can be used both as primary or auxiliary propulsion in many types of vessels (IRENA 2015). Flettner rotors have an energy saving potential typically by 5% to 20% without lowering the operating speed of the vessel, while with sails or kites can offer 10-15% fuel savings in existing vessels. Sails and Flettner rotors require suitable deck space.

Solar energy is most suitable as an auxiliary or ancillary energy source, or when used in combination with other energy sources. Because solar panels require space on-board, they possess most potential when used in combination with other energy sources. Together with wind and wave energy solar energy can also be used as a hybrid energy source for hydrogen separation from seawater for hydrogen fuel cell technology (IRENA 2015).

Some tests (e.g. Orcelle) have been done to utilise wave energy in shipping but the technology is not yet mature enough for use (IRENA 2015). In addition, there are several new vessel concepts designed to harvest wind energy in combination with other "clean" energy sources. B9 cargo vessel concept uses a (rigid) sail propulsion system utilizing wind energy to produce 60% of the power for ship propulsion and the rest from ancillary engines powered by bio-gas. The vessel looks similar to a traditional sail vessel. Eco Marine Power's Energy Sail technology utilizes an array of rigid sails which can utilize both wind and solar energy. STX Eoseas, an innovative cruise ship concept, aims at reductions in power consumption by 50%, emissions of CO_2 by 50%, SO_2 by 100%, NO_x by 90%, and ash by 100% with LNG diesel electric generator sets and an innovative sail concept patented by STX France which helps in using wind energy for propulsion.

The world's first zero emission vessel concept, Wallenius Wilhelmsen's E/S Orcelle has sails, solar panels and wave energy converters to move the vessel and also to generate the energy which is then used to extract hydrogen from water with the aid of fuel cell technology to generate electricity. The produced electricity can be used immediately or stored for times of no wind, sun or waves (MarineInsight 2016).

2.3 Transition to cleaner fuels and renewable energy sources?

Traditionally, seaports have been rather passive and merely facilitators than active promoters of energy issues. The pronounced role of sustainability and need for reduction of emissions and energy efficiency urges port authorities to take a more active role in energy production and consumption processes within their jurisdiction. Many ports in the Baltic Sea are ideally located in terms of utilisation of renewable energy including wind, waves or tides, carbon capture and storage, and geothermal energy. Ports also possess plenty of flat open space, such as roofs of warehouses and other buildings that can be used for installing solar panels. In addition, ports are engaged in biofuels production, storage and distribution, and circular economy (Acciaro et al. 2014). Although port authorities can only indirectly influence the decision making of shipowners and maritime and terminal operators, seaports can facilitate the transition to cleaner fuels and renewable energy sources in many ways. Several ports in the Baltic Sea region have already invested in reception facilities for scrubber wash waters and sludge. In order to reduce especially vessel PM emissions, ports can offer on-shore power supply for vessels. The infrastructure built for LNG can also be used for supplying biofuels at a later stage.

In the Baltic Sea region the Ports of Stockholm, Gothenburg, Rostock and Riga offer discounts for vessels on port fees for environmental reasons (European Commission 2017b). In the Ports of Gothenburg the vessel performance is assessed on the basis of vessel scores on Environmental Ship Index and Clean Shipping Index. This has turned out to be an effective way to encourage shipowners to reduce emissions (Port of Gothenburg 2017).

Several ports are already offering vessels low-emission fuels (e.g. biofuels) and they are investing in wind and solar energy for their own energy use. The transition away from fossil fuels also means reduction of transports of coal and crude oil. The storage capacities freeing from fossil fuels can be put to other use (see e.g. Port of Amsterdam 2017). In addition, geothermal energy can be utilised e.g. for heating buildings in the port area. Wave energy can be utilised to produce electricity (Coastal & Marine 2013).

2.4 Questionnaire on alternative fuels in the Baltic Sea Region

A questionnaire-based study was conducted to assess the current situation regarding the supply and demand of alternative fuels in the Baltic Sea region and the different maritime actors' own plans and views. A Webropol questionnaire was sent in autumn 2015 via e-mail to 742 respondents from ports, port-based organizations and operators, energy companies and shipping companies located within the Baltic Sea region. Unfortunately, the questionnaire yielded only 12 answers. Majority of the respondents were from Finland (8), and two (2) responses were received from Germany and Sweden, respectively. Respondents are mainly from the shipping companies. One port, two port-related organizations and one energy company focused on sales and marketing of fuels answered the questionnaire. Due to low response rate the results presented below should be treated with caution and they cannot be generalized to reflect the overall situation in maritime transport, since majority of the responses are from one country only. It is likely that only those with positive attitude towards LNG and/or other alternative responded. They may not represent the opinion of the majority of the maritime actors. Nevertheless, the results can give an indication on the current situation regarding the use of alternative fuels within the Baltic Sea region.

In the questionnaire the respondents were asked what they thought would be the most common alternative fuels in shipping in the future. The respondents were given different alternatives, including LNG, methanol, biofuels, propane, vegetable oil and other. The most common answer was LNG. The justifications for the answer were that new LNG ships have been ordered, LNG fulfills the requirements regarding present vessel exhaust gas emission reductions and upcoming emission regulations,. LNG is technically functional fuel, already well available, infrastructure for LNG is developing and the fuel is easy to provide and supply, LNG is environmentally friendly and it is being used increasingly as a maritime fuel and using LNG is the current trend in the market. For eight respondents LNG was the only chosen option. One respondent chose three options: LNG, biofuels and propane, because they are already available or will become available. The responding port replied that the most common fuels in maritime industry in the future will be LNG, methanol and biofuel, but the most common fuels in the port's own region will be LNG and biofuels. The answers were based on the port's experiences so far. Most of the responding shipping companies chose only LNG as the most common alternative fuel in the future, but two shipping companies chose both LNG and methanol. The justification for their answers was the availability of both fuel types.

In the questionnaire, the respondents were asked whether they thought that a bunkering option for alternative fuels can affect ports' competitiveness. Over half of the respondents (7 respondents) did not see that bunkering alternative fuels affects the ports' competitiveness. They justified their answers by pointing out that ships mainly visit ports due to cargoes, not bunkering issues. There are other commercial reasons for the choice of port and bunkering will be done where the ships call. Five of the responding shipping companies told that a bunkering station for alternative fuels would not affect their decisions regarding ports. One of the predominant reasons was that the shipping companies operate in liner traffic. The respondents that thought that bunkering of alternative fuels can affect ports' competitiveness replied that an LNG bunkering station can attract new business and create new routes. Some shipping companies told that loading and crew change locations will be chosen so that bunkering can be done at the same port.

Of all the shipping companies that answered the questionnaire, only one shipping company was already using alternative fuels. Those fuels were LNG and ultra-low-sulfur diesel (ULSD). The responding shipping companies were also asked about their future plans regarding alternative fuels. Three of the responding shipping companies told that they will not be introducing alternative fuels into their ships. Five respondents told that they have considered using or introducing alternative fuels. Most common alternative fuel that the shipping companies were planning to introduce was LNG, but one shipping company told that they have considered using bio-diesel. Since most of the responding shipping companies did not use alternative fuels and some of them were not planning to use them in the future either, they were asked what kind of measures they do you apply in order to reduce emissions. The most common answer was the use of low sulphur fuels, but some shipping companies also use scrubbers, slow steaming, fuel efficient engines, different hull design and energy management onboard among other things.

On the basis of the questionnaire, all shipping companies plan to use different low emission techniques simultaneously in different ships, but also within single ships. The chosen techniques will depend on their customers and on trade. One shipping company already has catalysts in combination with ULSD fuel. One shipping company pointed out that, for them, energy saving measures is the most important issue and after that comes the fuel. Half of the responding shipping companies had performed research or surveys regarding the introduction of alternative fuels. These included technical studies, offers from yards manufacturers for dual fuel main engines and other feasibility studies.

Other parties related to alternative fuels in shipping have also performed research and surveys regarding the introduction of alternative fuels. The responding port had studied LNG bunkering possibilities and other studies related to the requirements of alternative fuels bunkering for ports. The responding energy company had performed market studies and investment studies.

According to the questionnaire the most discussed and requested alternative fuel has been LNG. The responding energy company had been asked, whether it could supply LNG and LBG for maritime industry use. The questions had come from shipping companies located in Norway, Sweden and Finland. Also the responding port had received requests for the bunkering of LNG, which they currently offer by trucks. According to the port, the markets will decide whether there will be only one or more alternative fuel options in the port in the future. Half of the responding shipping companies had discussed about their needs or interests for alternative fuels with other parties. Those parties include gas companies, local bunker suppliers and ports that they use. However, one shipping company reminded that LNG is an issue for the next ship generation.

During the questionnaire, the respondents were asked whether they thought that building alternative fuel bunkering stations and terminals in Finland is reasonable. According to the answers, building is reasonable, since the demand for alternative fuels will grow and there will be more need for them in maritime traffic. Yet, one respondent pointed out that currently it is not feasible in ports outside of LNG liner or passenger traffic. Two of the responding shipping companies told that they use or plan to do bunkering in the Baltic Sea in Tornio and in Vasari. Other shipping companies had no need for alternative fuel bunkering or found that the bunkering stations for alternative fuels in the Baltic Sea were not competitive or not an option for their existing ships. One shipping company replied that they have not employed container ships with dual fuel engines yet.

According to the questionnaire, it is not easy to tell how many alternative fuel terminals there should be in Finland. Since alternative fuels can be transported on trucks, it was generally considered that few terminals are sufficient enough. LNG can be bunkered practically in all ports in Finland from truck to ship. Nevertheless, for larger volumes, bunkering from ship or barge is more suitable. According to one respondent, bunkering should be possible at least in TEN-T core ports, but also in comprehensive ports if demanded. Shipping companies listed some locations, in which they would want a bunkering option to be found in the Baltic Sea. Those locations include: Ust Luga in Russia; Tallinn in Estonia; Ventspils in Latvia; Rostock, Kiel and Brunsbüttel in Germany; inside Skaw in Denmark; Naantali, Turku and Hanko in Finland. Other, more general answers were also given. These include: south of Finland, Gulf of Bothnia, Finnish coastline and Germany or Sweden. One shipping company replied that due to the nature of their business they prefer bunkering stations in the hub ports like Hamburg (Germany) and Rotterdam (Netherlands).

3 METHANOL AS A MARITIME FUEL

3.1 Methanol as an alternative fuel

Methanol has attractive features for use in transportation. It is a high octane fuel with combustion characteristics that allow engines specially designed for methanol fuel to match the best efficiencies of diesels. Methanol is low-emission fuel and as such, a promising alternative fuel for ships. Methanol is already used as fuel, but in limited areas, such as car racing, mainly because of its high octane rating. It can help the shipping industry meet the requirements of the increasingly strict emissions regulations. Methanol significantly reduces emissions of sulphur oxides (SOx), nitrogen oxides (NOx) and particulate matter. It is also a safe and a cost-effective alternative marine fuel (Ellis & Tanneberger, 2016; Andersson & Salazar, 2015; Methanex, 2015, ESN, 2013).

It should be noted that methanol can be manufactured from a wide variety of fossil and renewable feed-stocks, including second generation biomass, wastes, and even CO2, and thus it is an ideal path to a sustainable future, in which shipping companies can be operate by using renewable fuels with a lower carbon footprint (Methanex, 2015; Ellis & Tanneberger, 2016). In addition, the world methanol production is relatively large with an annual world supply of 55 million tons. Norway is the largest producer in Europe. (ESN, 2013)

Methanol is available worldwide through existing global infrastructure. Methanol is used widely especially in the chemical industry and thus, there is storage and distribution infrastructure for this in Europe, including large bulk storage terminals in both Rotterdam and Antwerp. In addition, methanol's properties are well-known, since it has been shipped globally, handled and used for a wide variety of ends for more than 100 years. (Andersson & Salazar, 2015; Methanex, 2015; Ellis & Tanneberger, 2016)

Methanol has lower energy content than conventional fuels. Because of the energy density it thus requires more storage volume. The space needed for storing methanol in tank is approximately twice that of traditional diesel fuels. Yet, when compared to LNG, methanol is liquid at normal on-board conditions but LNG has to be stored at -162°C to remain in a liquid state. This requires additional tank space requirements due the insulation necessary to maintain the low temperatures (Andersson & Salazar, 2015; Ellis & Tanneberger, 2016).

The availability of terminals for bunkering is important for encouraging the uptake of methanol as maritime fuel. Terminals for methanol fuel would be similar to those for liquid oil fuels, since methanol remains in a liquid state. This means that the existing storage, distribution and bunkering infrastructure could handle methanol and would require only minor modification to handle methanol, thus necessitating relatively modest infrastructure investment costs compared with the sizeable investments required for the construction of LNG terminals. This is an advantage compared to LNG, but an area that needs some development, since conventional fuels have terminals and bunkering systems already in existence (Andersson & Salazar, 2015; Methanex, 2015; Ellis & Tanneberger, 2016).

The cost to build new and convert existing vessels to run on methanol is significantly less than other alternative fuel conversions. It has been estimated that investment costs for methanol conversion and new build solutions are in the same range as costs for installing exhaust gas after treatment, such as scrubbers, for use with heavy fuel oil, and below the costs of investments for LNG solutions.

In order to minimize the risk of fuel price volatility, shipping companies can also choose to operate on flex-fuel methanol/diesel engines, which would allow ships to switch between fuels, depending on fuel availability (Methanex, 2015; Ellis & Tanneberger, 2016). When comparing to LNG, methanol has equally good environmental properties. CO2 emissions from methanol are at par with LNG, but the net greenhouse gas emission is better for methanol due to the methane slip from LNG. The reduction of SOx, NOx and particulates is similar to LNG. The advantage of methanol is substantially cheaper distribution compared to LNG, yet, the production of methanol is more expensive than LNG (ESN, 2013). Methanol is also a safe fuel, since its toxicity is comparable to or better than gasoline. The behavior of methanol fuel when spilled is also important from an environmental performance perspective. Methanol dissolves readily in water, is biodegraded rapidly, and does not accumulate. In practice, this means that the environmental effects of a large spill would be much less severe than from an equivalent oil spill (Ellis & Tanneberger, 2016; Andersson & Salazar 2015).

There is a general lack of awareness about the potential of methanol as a marine fuel. Methanol is a fuel that fulfills SECA sulphur emission criteria and it should be identified more widely as a compliant and cost-effective fuel that can enable a sustainable future, in which the shipping industry is powered by a fuel that is 100% renewable. Nevertheless, current policy does not consider methanol as a potential maritime fuel and research and funding on alternative fuels for shipping tend to be focused on LNG. In addition, regulations are not in place and not fully adapted to the properties of methanol (Andersson & Salazar, 2015).

3.2 Case Story: Stena Germanica

Stena Rederi in Sweden chose a more uncommon way of meeting the requirements for reduced sulphur emissions. Stena started to use methanol, when most shipping companies chose low Sulphur MGO, scrubbers or LNG. Stena's ships are mostly in regular service in the English Channel, the North Sea and the Baltic Sea and thus they had to find a feasible way to react to the new emission regulations (ESN, 2013).

The company started testing the performance of methanol on the existing passenger ferry Stena Germanica (Figure 3) as a part of a project ‘Methanol: the marine fuel of the future’. The project was granted 50% support under the 2012 Trans-European transport network (TEN-T) multi-annual program Priority Project 21 Motorways of the Sea. The project partners were Stena AB, Wärtsilä Finland OY, Stena Oil AB, SEEHAFEN KIEL GmbH & Co. KG and Göteborgs Hamn AB; and the member countries involved in the project were Sweden, Germany and Finland. The project begun in January 2013 and it ended in December 2015 (European Commission, 2014).

Figure 3. Stena Germanica (Ellis & Tanneberger, 2016)

Stena Germanica traffics the route between Gothenburg, Sweden, and Kiel, Germany. It is the world's second largest Ro-Pax ferry and after the conversion it was the world's first methanol powered ferry. The running of the Stena Germanica on methanol allowed the ship to comply with the SECA rules ahead of the 2015 deadline. The project provided a 'live test' to prove the feasibility of methanol as a future fuel for shipping and also delivered an engine conversion kit that can be further implemented on other ships. The project also included the creation of the port infrastructure for the supply of methanol for bunkering in both ports (European commission, 2014; Stenaline, 2015).

The chosen technology for the conversion is called dual fuel. During the conversion, the Stena Germanica's fuel system and one main engine were converted to methanol/MGO dual fuel operation, in methanol is the main fuel, but there is the option to use MGO as backup. The actual conversion was carried out in Gdansk, Poland, at the Remontova shipyard and the ship re-entered service on March 26, 2015 (Stenaline, 2015).

According to the representatives of Stena Line (Stenaline, 2015) the use of methanol to propel ships is a serious alternative to the present industry norm of burning high sulphur bunker fuel and the shipping industry continuously and urgently needs to explore new ways to increase energy efficient and lower emissions. They see the advantages of methanol being, for example, that it is easier to handle than LNG as methanol is a liquid and does not require to be held frozen nor be under a specific set of pressures. In terms of logistics, transportation and bunkering facilities are simpler and a conversion of existing tonnage is therefore lower in cost than LNG (Stenaline, 2015; Seatrade maritime news, 2016).

Stena Line aims to pursue change and development in the shipping sector they feel that, with the Stena Germanica, their environmental impact will be completely different to what the industry has seen before (Stenaline 2015). It should also be noted that since methanol can also be produced by renewable feed-stock, when such production reaches larger volumes the environmental footprint of methanol as a fuel is reduced even more (Seatrade maritime news, 2016).

In the views of Stena Line representatives (Seatrade maritime news, 2016), it should be noted that the shipping industry comprises of very different ships with various age profile and trading patterns and thus there is a need for a combination of different alternatives as no one fuel type fits all models. Also Stena Germanica uses MGO together with methanol. Other alternative fuel and energy sources can also emerge in the shipping industry, such as biofuels and electricity, as ports install shore side power facilities of cold-ironing for ships at berth (Seatrade maritime news, 2016).

4 LNG TERMINALS IN FINLAND

4.1 LNG in Ports

The EU Marine Fuel Sulphur Directive and the enforcement of Emission Control Areas (ECAs) work as a motivation towards the adoption of LNG as a maritime fuel. New ships that are fueled by LNG are being ordered and thus there will be a significant rise in the demand of LNG bunkering facilities (see Figure 4).

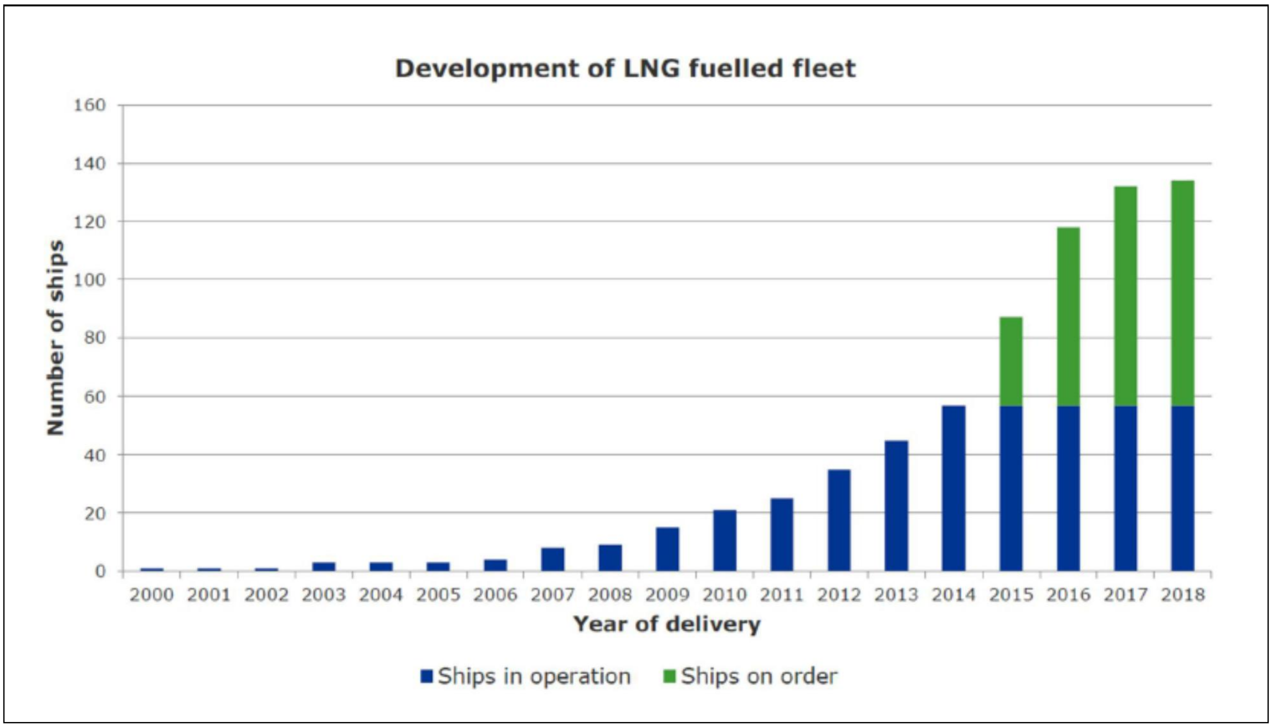

Figure 4. LNG fleet (Det Norske Veritas January 2015, source: Pöntynen & Lempiäinen, 2015)

According to a survey by European Shortsea Network (ESN, 2013) the main alternatives for shipping companies to comply with the sulphur emission limits are the use of low sulphur MGO, scrubbers and LNG both in old and new ships (Figure 5). Competition amongst ports is becoming increasingly fierce. Availability of LNG infrastructure can nowadays be an important driver for the ports after shipowners' demand and many ports believe that LNG bunkering operations will commence at their port in the near future (Lloyd's Register, 2014).

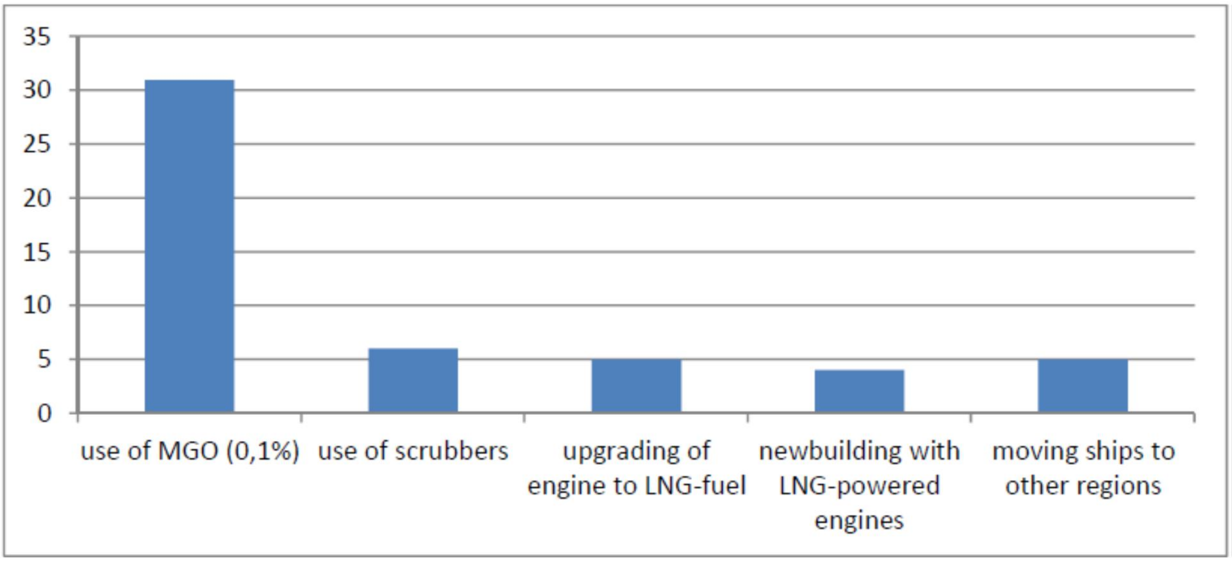

Figure 5. Estimation on the plans of the shipping companies to meet the sulphur limit of 2015 (ESN, 2013)

Investments on LNG are influenced by assumptions on its price development. The LNG market is also influenced by the price development and also the technology development of other competing alternative fuels. These include for example, low sulphur MGO and HFO. Nevertheless, LNG is probably one of the main fuels of the future. Thus, making it available for ships may affect the competitiveness of future ports. Depending on the method of bunkering, introducing a new fuel demands new infrastructure or logistics setup to be built in the port. In order to supply LNG as fuel, a port needs to have a good logistics connection to an LNG terminal by sea, rail, road or pipeline (Stopford, 2009). It should also be noted that, LNG in ports can be used by different applications. LNG can be the main bunkering fuel or it can be used only for auxiliary engines, in order to avoid exhaust emissions at berth. LNG can also be available as fuel for trucks and cranes operating in the port. The port infrastructure and logistics need to take all these factors into consideration.

4.2 LNG terminals in Finland – Interview study

4.2.1 Background of the interview study

There is currently one operational LNG terminal in Finland. The LNG terminal in Tahkoluoto, Pori started its operation in September 2016. There are also several on-going LNG terminal projects in Finland, some of which are already at the construction stage. For example, an LNG terminal in Tornio is already being built. The locations of current and planned LNG terminals in the Gulf of Finland and Gulf of Bothnia can be seen in the Figure 6. It should be noted that the LNG project in Rauma is currently on hold due to changes in oil prices, which have affected the economic viability of the project.

Figure 6. LNG Map 2016 from Gulf of Finland and Gulf of Bothnia (Gas Infrastructure Europe, 2016)

During this research, phone interviews were conducted with representatives of LNG projects located in different parts of Finland to ensure geographical representativeness. Among the interviewed organizations there was one port, one energy company and an LNG operator. The interviews were done so that one researcher performed the interviews on the phone and the other took notes.

The interviews were constructed around pre-defined interview guide but did not concentrate strictly on a defined list of questions. Instead, the interviews allowed discussion on issues that were significant to the interviewee. No all issues were discussed with every interviewee and the order of the themes discussed varied. The semi-structural manner of interviewing also allowed the interviewer to produce additional questions outside the original plan or list of questions. The pre-defined interview themes included, for example, the purpose of the planned LNG terminals, infrastructure needed for the terminals, the interviewees' views on LNG and alternative fuels in the future, the location of LNG terminals in Finland, the use of LNG as ship fuel, bureaucratic difficulties related to the use of LNG and bunkering of LNG. Even though the focus of the interviews was on LNG, the participants were also asked about their interest and views on other alternative fuels and their future potential.

4.2.2 Haminan Energia Ltd

Haminan Energia Ltd. is a municipal energy distribution company situated in Hamina in the southeast of Finland, serving the region with supply of electricity, heat and gas and other services. Haminan energia Ltd. established Hamina LNG Ltd. as a joint venture with Alexela Varahalduse AS, which is a company with extensive oil terminal experience in Estonia, Russia and Norway and is involved in the Paldiski LNG project. Hamina LNG was established with the intention to operate the LNG terminal in the Port of HaminaKotka, since the operator of the terminal is not allowed to trade with gas. The terminal's LNG storage capacity will be 30,000 m3 and it is estimated that the terminal will be operational in the year 2018. The estimated costs of the project are EUR 90 million. The terminal is currently waiting for an investment decision and the estimated time of introduction is in 2019. The interviewed person is the director of LNG sales.

During the interview, the following topics were discussed: the use of the new LNG terminal, motivations to take part in the LNG terminal project, views on LNG and other alternative fuels and their business potential in the future and views on authorities and bureaucracy related to LNG.

According to the interview, Haminan Energia Ltd. has been in natural gas business for over 40 years and the municipality of Hamina, in which they operate, has an existing gas network. Because of this, it was easy for them to decide to take part in the LNG terminal project. In addition to, LNG Haminan Energia Ltd. also deals with wind power and production of biogas. When it comes to maritime alternative fuels, LNG was considered to be the most potential winner in the long run, but not in the near future. The potential future gains related to LNG, including the use of LNG in as ship fuel, were one of the main reasons why Haminan Energia Ltd. took part in the terminal project. In addition, Haminan Energia has a filling station for gas operated cars and plans to expand that business also with the introduction of LNG.

Nevertheless, according to the interview, it is not feasible to build a LNG terminal for ship bunkering alone, since there is not enough LNG operated ships yet. That is why the primary use for the LNG will in the municipality of Hamina, including the local heavy industry and production of electricity and heat. Yet, the constructed terminal will include the option for bunkering. According to the interview, the terminal will have a berth with 12m depth and also road, railroad and gas pipeline connections, with the facilitation to receive, take out, store and deliver LNG.

According to the interview, the availability of LNG along the coast of Finland is good, if you take into account the current terminals, the ones that are being built and the ones that are in the works. LNG is not suitable for long transportation distances and that is why there current plans form a reasonable logistics area.

In the views of the interviewee, there have been some issues with authorities that have made the practical operation related to the project more complicated. The reason for this is probably the novelty of the situation, which requires a lot of learning and sorting out from all participants. For example, the amount of safety issues, permission proceedings and clarifications has been bigger than anticipated and a smaller organization would not necessarily have resources for such measures.

4.2.3 Port of HaminaKotka Ltd

Port of HaminaKotka was selected as the location for the LNG terminal that will be built in cooperation with Haminan Energia Ltd. and Alexela Varahalduse AS. During this research, a respondent from the Port of HaminaKotka was interviewed in order to establish the views of the port on the use of LNG and the building of the LNG terminal.

According to the interview, LNG bunkering for ships has not yet been done in the port of HaminaKotka from trucks or by any other means, but theoretically it would be as simple as traditional bunkering. Correspondingly, the main purpose of the new LNG terminal is not LNG bunkering for ships, but the purpose is to serve the local area and industry. According to the interview, in the future it could be possible to use LNG as a fuel for the port equipment also. Nowadays some port equipment operates on gas, but not on LNG. Yet, there is a growing interest in environmental issues amongst port related operators and thus, if using LNG proves to be cost-efficient, it could become a popular fuel for port equipment.

According to the interview, the LNG terminal will be built right into the heart of the port, to the best place in the liquid port. The construction will require a lot of land reclamation, building of new infrastructure and will cause dumper traffic, but will not significantly affect other operations within the port.

Before the Sulphur Directive, there were a lot of LNG related discussion between the port and shipping companies. Nevertheless, since the oil prices have been so low, the discussions have diminished. According to the interview, at some point people working in the maritime industry seemed to think that soon all ships will operate on LNG. The enthusiasm for swift changes has lessened with the reduction of oil prices.

According to the interview, building a LNG terminal with an option for ship bunkering will bring added value and competitive advantage to the port at some point. It was considered that the rather comprehensive network of LNG terminals amongst the coast of Finland does not make the competition more difficult, but helps the shipping companies in making their decisions regarding the use of LNG as ship fuel. The port will promote the LNG terminal in the future both as an environmental measure and as an additional service. The environmental aspects are always important, but the concrete benefit for the customer is even more significant.

4.2.4 Skangas Ltd

Skangas is a Nordic company. Gasum Ltd., which is a Finnish expert in natural energy gases, holds 51% of Skangas. Lyse Ltd., which is a Norwegian Group, operating within the fields of electricity generation, distribution and telecommunication, holds the other 49% of Skangas. Skangas has Finland's first LNG terminal in the Port of Pori at the oil and chemical harbor Tahkoluoto. The terminal's LNG storage capacity is 30,000 m3. Skangas is also a shareholder of the Manga LNG. Manga LNG is a project development company owned by Outokumpu, SSAB, energy company EPV Energy and Skangas. Manga LNG is responsible for the construction and operation of a new LNG terminal, which will open in Tornio in 2018. The storage capacity of the new terminal will be 50,000 m3 and the estimated cost of the project is approximately EUR 100 million. During the interview, both LNG terminal projects were discussed. The interviewed person is the director of sales and marketing.

According to the interview, the interest towards LNG has risen during the last decade. During that time period it was noticed that LNG can have a greater market potential in heavy industry. LNG could provide the solution in replacing oil as the primary fuel in the industry and also in reducing environmental impacts. Simultaneously the emissions of maritime traffic became an important discussion topic, which culminated with the introduction of the Sulphur Directive.

To Skangas, building LNG terminals in Western Finland and Norhern Finland means a logistical solution to industry customers located outside the gas pipe network. This is evident especially in the LNG terminal in the Port of Pori, which is entirely a project of Skangas Ltd. alone. Port of Pori is located near industry areas that are not connected to the gas pipe network. These customers secure the basic operation of the LNG terminal. LNG deliveries are made to industrial customers through a local pipeline that connects the terminal to the local industry park or by truck.

According to the interview, the LNG terminals also serve the maritime industry sector and gradually also truck traffic. The LNG terminal located in the Port of Pori is not optimally located, when it comes to maritime traffic, since there is more traffic in, for example, Port of Turku, Port of Helsinki and Port of HaminaKotka. Skangas had originally planned on building the LNG terminal in Port of Turku, but due to delays and several complaints regarding the related city plan, the project was moved to Pori, where it could be commenced earlier. Yet, Port of Pori has a good and deep harbor, which is easy to access. Ships can bunker LNG by bunker vessel at the terminal or by truck in different ports.

Skangas holds 25% of the LNG terminal that is being built in Röyttä, Tornio. The terminal is located in the North of Finland and it is aimed to serve customers both in Northern Sweden and Northern Finland. According to the interview, the basic use of the terminal is also secured by local industry. In this instance, the biggest shareholder of the LNG terminal, which is Outokumpu, has started to replace the traditional fuels they use in operations with LNG. According to plan, a reception, unloading and bunkering facilities, LNG vaporizing facility and a storage tank will be constructed in Tornio terminal. In addition, a pipeline will be built to the local industry site and a truck loading facility will be built for LNG trucks. It will be possible for ships to bunker LNG straight from the terminal.

According to the interview, the LNG terminal projects would not have been commenced, if the purpose had been to serve only the local industry sector. The fact that LNG is gaining popularity as the future fuel of maritime traffic was a big factor in the decision making process. The combination of industry use and future maritime use is important so that the same infrastructure and LNG can be used in both instances. In the long run, the biggest growth potential lies in the maritime industry. According to the interview it should be noted that oil will still be the primary fuel for quite some time. Currently the share of gas is marginal, even though the growth potential is big. It should also be noted that the shipping industry has a lot of alternatives when it comes to fuels and the selections keeps getting wider. When it comes to other alternative fuels, it was discussed during the interview that Skangas also handles liquefied biogas that is passed also to the Finnish gas network. What is good about biogas is that it can be fully mixed with LNG in any ratio and it is still usable.

According to the interview, LNG can be bunkered from trucks in practically every port that has done the necessary safety clarifications and practically in every berth as long as the necessary safety requirements are met. In the views of the interviewee, bunkering from a truck is the quickest and handiest way to operate and it can be possible to bunker from two trucks at the same time. This is especially valuable in the case of AS Tallink Grupp's new LNG fueled ferry Megastar, which only stays at the West Harbour in Helsinki for one hour at a time.

Skangas is not afraid of competition in the LNG sector. According to the interview, the sooner there are new actors in the market the faster the markets start to operate. It has been a pleasant surprise that new LNG fueled ferries and LNG ship orders have come true so soon.

5 BEST PRACTICES

5.1 Best Practices in Ports

Environmental effects of port activities can be controlled and decreased in several ways. In Finland, both EU and national legislation regulate the port operations, but the ports can go even further in controlling and decreasing their environmental effects than required by law. Environmental effects can be controlled with voluntary actions, such as certifications, corporate social responsibility and developing of best practices. (Brunila et al. 2015). The term best environmental practice means the application of the most appropriate environmental control measure or combination of measures that show results superior to those achieved with other means (e.g. GHD, 2013).

Furthermore, one key element in the competition between the Baltic Sea ports now and in the future will be their environmental status and their capability to response to the challenges of sustainable development. Also the society is expecting that the ports take responsibility of environmental protection and sustainable development (Brunila & Anttila, 2013; Van Breemen et al. 2008).

In addition to managing the port's own environmental impacts, port operators are also beginning to see the potential advantages of sharing ideas on best practice. Sharing knowledge allows the ports to enhance their operations and helps to choose the most cost-effective measures for decreasing their environmental impacts. Because of the recent economic recession, some ports have found that reducing environmental impacts voluntarily is too costly. Yet it should be noted that the environmental initiatives done by the ports can also become a strong competitive advantage. In addition, implementing state-of-the-art sustainable practices can reduce costs and enhance the port's operational efficiency (Brunila et al. 2015; Hiranandani, 2014).

Yet, every port and its surrounding area can be considered to be unique and the importance of different environmental aspects depends on the characteristics of each port. Thus not all best practices applied in one port are directly applicable in another. Nevertheless, sharing ideas openly is still recommended as different practices are applicable in different parts of port operation. In addition, some best practices can be altered to suit each port's unique needs, since ports share several common environmental issues and face common environmental challenges (Brunila et al. 2015; Hiranandani, 2014). In addition to ports themselves, also the organizations that operate within the ports can have an effect in reducing the ports' environmental impacts. The organizations can reduce environmental impacts by optimizing their logistics, introducing gas fueled or electrically powered machinery, minimizing unnecessary driving and by investing in heating, cooling and lightning systems with low energy consumption.

5.2 Best practices in port operations

In this part of the research, those existing best practices uses to support energy efficiency and lessen environmental effects in those ports that were involved in this study, ports of Loviisa, KotkaHamina and Turku, were collected by using previous research materials, ports' web-pages and interviewing central actors. Sharing knowledge about best practices allows enhancing their operations. However, it has to be noted that the ports are not the same, still share several common environmental issues and face common environmental challenges so they can learn from each other and develop those practices further.

Previous researches (i.e. Hippinen, & Federley, 2014) have noted that some environmental issues such as dredging operations, port land development and dust have been among the top 10 priorities in Europe over 20 year and are forming a basis for environmental collaboration in the port sector. However, as Hippinen & Federley (2014) argue in their study, energy consumption and efficiency have been raising topics for the port industry along new political priorities on energy efficiency and climate change. As PIANC (2014) points out about ports: “Increasingly, they are also centres of energy production (and consumption) and ports of departure for the offshore industry.”

Most important practices are based on different research and projects and includes voluntary operations and standardizations, but also memberships in different interest groups, life-cycle-modellings and analyses in building and developing port. PIANC, The World Association for Waterborne Transport Infrastructure and ESPO, European Sea Ports Organization, are focal organizations promoting safe, efficient and environmentally sustainable European port sector. Best practices are closely linked to “Green port”-concept that aims for long term vision, stakeholders participation, shift from sustainability as a legal obligation to sustainability as an economic drive (Hiranandani, 2014). Also, it should be noted that ports has meaningful influence on ship-owners by motivating use of cleaner fuels and renewable energy sources by investing waste management in ports or giving discounts to environmental-friendly solutions.

Found best practices were various and by generalizing can be listed in following sectors:

1. water (quality, sediment and storm water management plans)
2. waste (management and efficiency)
3. transport (intermodal)
4. electricity (connection shore to ship, onshore electric power supplies, bulbs)
5. recycling (disposing dredge materials – recycling and reuse programs)
6. fuel (alternative)
7. air pollution, noise
8. building, extension
9. environmental regulation and plans
10. snow and ice removing
11. co-operation with different stakeholders
12. safety and maintenance optimizing

To point out some more detailed case studies, port of Loviisa points out importance of environmental issues are especially important because of location in close proximity of housing and recreation activities. Important experiences have been implemented during this project such as optimizing electricity consumption in port house such as electricity saving bulbs and lighting and heating only needed rooms and port areas. Furthermore, ice removing system has been optimized and that has been notable decreasing energy consumption. Also, port of Loviisa explains its waste systems highly detailed in its web-pages.

Port of KotkaHamina has been highly active in projects supporting environmental solutions such as Ecologically Friendly Port, OXY. Its specific “Green paper”- procedure includes the safety of chemical transportation, reducing emission, optimizing lightning and energy use, and smoothens and safety of transportation. Port of KotkaHamina is presenting its certificated environment and quality system (ISO9001 – ISO14001) in the web-pages.

Port of Turku has had environmental based port fees since year 2006, since year 2015 the amount of reduction has been tied on NOx emissions, which aims guiding ship-owners to invest on emissions reduction techniques. It also publish yearly environmental report that summarize all activities and monitoring during a year. Environmental work is based on certificated environmental system.

6 DISCUSSION AND CONCLUSION

The aim of this report was to give an overview on alternative fuels and energy sources in shipping, the regulation underpinning the transfer towards cleaner fuels, and assess current trends in their use in the Baltic Sea region. Special focus was given to LNG as a vessel fuel, since the LNG infrastructure is expanding in the Baltic Sea region, and several shipping companies operating in the Baltic Sea and North Sea SECA area have invested in LNG fueled vessels. The EU Directive 2014/94 on the deployment of alternative fuels infrastructure, which requires that a core network of refueling points for LNG at maritime ports should be available at least by the end of 2025, has speeded up the process. Nevertheless, this study also debated the use of methanol as a ship fuel, since it is already being used by some shipping companies. One of the aims of this study was also to establish environmental best practices for ports that could be applicable in other ports.

The shipping sector releases greenhouse gases (CO2, CO and methane), sulphur oxides (SOx), nitrogen oxides (NOx) and particles (PM) to the atmosphere. In order to reduce especially greenhouse gas (GHG), particulate matter (PM), and black carbon (BC) emissions, presently used fossil fuels need to be replaced by renewable energy sources. Regulation to speed up this process has been introduced both globally, and in regionally in the form of Emission Control Areas, of which the Baltic Sea and North Sea is one.

Sulphur emission regulation for vessel exhaust gas emissions has been in place in the Emission Control areas since 2015, and a new global regulation is coming in force in 2020. The regulation regarding reduction of nitrogen emissions in the North Sea and Baltic Sea was made in 2016 and is expected to be approved soon by the IMO. The regulation will be applicable to new ships built after 1 January 2021 when sailing in the Baltic Sea and the North Sea and other NECAs. Greenhouse gases are currently regulated only indirectly and the IMO together with the EU Commission have started to take first action to monitor these emissions. Since January 1st, 2018 vessels larger than 5,000 gross tonnage (GT) calling at any EU and EFTA (Norway and Iceland) port must annually monitor, report and verify their CO2 emissions. A global fuel consumption reporting system (DCS) will come in force Jan 1st, 2019. In order to meet these regulations, shipowners and other maritime actors may need to update and reconsider their investment plans and fuel choices.

Especially the need to cut greenhouse gas emissions will have a major impact on shipping, since majority of vessels use fossil fuels as their main source of energy. In order to reduce greenhouse gas emissions, fossil fuels need to be replaced either by renewable energy sources (biofuels, solar, wind, or wave energy), or technologies producing zero emissions (e.g. fuel cells, hydrogen). Shipowners should be aware that measures primarily aiming for reduction of SOx emissions, such as use of LNG, low-sulphur MGO or installation of a scrubber do not sufficiently reduce greenhouse gas emissions. Large amounts of methane are released during production of LNG, so with the present technology the use of LNG accelerates rather than diminishes climate change. However, LNG is considered to be a helpful transitional fuel towards the use of zero emission technologies and renewable energy options. Although the biggest excitement with LNG has calmed down, many shipping companies operating in the Baltic Sea invested in it, primarily to meet the sulphur emission regulations.

Besides LNG, several other fuels and different renewable energy sources (wind, solar and wave energy) and technologies with zero emissions (hydrogen, fuel cells, batteries) are already in use to some extent in maritime transport. Many of the technologies can be installed by retrofitting an existing vessel. The renewable energy sources and zero emission technologies have much potential in shipping in the Baltic Sea, and shipowners have many alternatives to choose to be used solely, or in combination. The examples of zero emission vessel concepts and technologies available now indicate that in the future vessels will be using several energy sources. Ports must prepare for this by providing the needed infrastructure and services.

However, investments into renewable energy have been slow among maritime actors in the Baltic Sea. Investments in shipping are also lagging behind respective investments within land-based industries in the Baltic Sea region. Until now, the low price of fossil fuels, reluctance to make investments due to market and technological uncertainties and non-existing regulation regarding greenhouse gas emissions has hindered the willingness to invest into low-emission technologies and alternative energy sources in shipping (Yliskylä-Peuralahti 2016). To speed up the transfer away from fossil fuels, regulators should give clear incentives for shipowners to use cleaner technology e.g. providing support for investments and retrofitting.

In addition, the results of the survey conducted for this report indicate, that maritime actors do not know enough about alternative fuels and renewable energy sources. For the respondents LNG was the best known alternative fuel. A questionnaire-based study was made during years 2015-2016 in order to get an overview on the supply and demand of alternative fuels in the Baltic Sea region and the plans and views of maritime actors the results of the survey show that LNG is the most discussed alternative fuel. Shipping companies, ports, gas companies and local bunkering suppliers have discussed about it. Nevertheless, when the questionnaire was made LNG was so far used by only one of the responding shipping companies. Most of the respondents we confident that a bunkering station for alternative fuels does not affect the ports' competitiveness.

According to the views of the companies that answered the questionnaire, LNG is going to be the most common alternative fuel in the future. For example, new ship orders, availability of LNG and current and upcoming infrastructure were mentioned as justifications for the responses. In addition, it was mentioned that LNG is a good option, since it fulfills the current and upcoming environmental emission regulations and is technically a fully functional fuel. According to the questionnaire, shipping companies do not plan to introduce only one technique or measure in order to reduce emissions, but are planning to introduce different measures on different ships. Three of the responding shipping companies answered that they are not going to shift to alternative fuels, but are using, for example, 0,1% sulphur MGO and scrubbers.

LNG seems to be the most popular alternative fuel for the shipping companies operating in the Baltic Sea, but also biofuels, such as methanol could also a promising alternative. Major reductions of emissions of GHGs from marine engines can be achieved by replacing fossil fuels with biofuels, such as methanol. Yet, there seems to be a general lack of awareness about the potential of methanol as a marine fuel. Methanol has several advantages (see Ellis & Tanneberger, 2016; Andersson & Salazar, 2015; Methanex, 2015, ESN, 2013):

- Methanol significantly reduces emissions of sulphur oxides (SOx), nitrogen oxides (NOx) and particulate matter
- Methanol is available worldwide through existing global infrastructure
- Methanol can be manufactured from a variety of fossil and renewable feed-stocks
- The cost to build new and convert existing vessels to run on methanol is significantly less than other alternative fuel conversions
- The existing storage, distribution and bunkering infrastructure could handle methanol or would require only minor modifications
- Methanol is a safe fuel and the environmental effects of a large spill would be much less severe compared to fossil-fuel spills

Stena Rederi AB started to use methanol, when most shipping companies chose low Sulphur MGO, scrubbers or LNG. The company started testing the performance of methanol on the existing passenger ferry Stena Germanica and after the conversion it became the world's first methanol powered ferry. The vessel has dual fuel engines capable of using methanol is the main fuel and MGO as a back-up (European commission, 2014; Stenaline, 2015).

At the time of writing this report, there is one operational LNG terminal in Finland. The LNG terminal in Tahkoluoto, Pori started its operation in September 2016. There are also several on-going LNG terminal projects in Finland, some of which are already at the construction stage. During this research, an interview study was conducted, in which organizations that participate in different Finnish LNG terminal projects were interviewed. Among the interviewed organizations there was one port, one energy company and an LNG operator.

According to the interviews, it is not feasible to build a LNG terminal for ship bunkering alone, since there is not enough LNG operated ships yet. Nevertheless, according to Skangas, the current LNG terminal projects would probably not have been commenced, if the purpose had been to serve only the local industry sector. The fact that LNG is gaining popularity as the future fuel of maritime traffic has been a big factor in the decision making process. The combination of industry use and future maritime use is important and, in the long run, the biggest growth potential lies within the maritime industry.

Seaports can facilitate the transition to cleaner fuels and renewable energy sources in many ways in their own operations and in collaboration with shipowners. Several ports in the Baltic Sea region have already invested in reception facilities for scrubber wash waters and sludge. In order to reduce especially vessel PM emissions, ports can offer on-shore power supply for vessels. The infrastructure built for LNG can also be used for supplying bio fuels at a later stage.

In the Baltic Sea region the Ports of Stockholm, Gothenburg, Rostock and Riga offer discounts for vessels on port fees for environmental reasons, and other ports could consider similar measures. In the Ports of Gothenburg the vessel performance is assessed on the basis of vessel scores on Environmental Ship Index and Clean Shipping Index. This has turned out to be an effective way to encourage ship-owners to reduce emissions (Port of Gothenburg 2017).

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7 REFERENCES

Acciaro, M., Ghiara, H., and Cusano, M. I. (2014). Energy management in seaports: a new role for port authorities. *Energy Policy* 71, 4-12.

Alhosalo, M., Erkkilä-Välimäki, A., Haavisto, R., Haukioja, T., Jalkanen, J-P., Niemi, J., Ojala, L., Pohjola, T., Pöntynen, R., Repka, S. and Solakivi, T. (2017). MERSU-Merenkulun ympäristösääntely ja Suomen elinkeinoelämä. Unpublished report, forthcoming in Valtioneuvoston selvitys- ja tutkimustoiminnan julkaisusarja.

Andersson, K. & Salazar, C.M. (2015). *Methanol as a Marine Fuel report*. FCBI Energy/Methanol Institute, 2015.

Bows-Larkin, A. (2015). All adrift: aviation, shipping, and climate change policy. *Climate Policy* 15, 681-702.

Brunila, O.-P. & Anttila, A. (2013). Green co-operation in the eastern Gulf of Finland. *Baltic Rim Economies* 2017/3, 23.

Brunila, O.-P., Kunnaala-Hyrkki, V. and Hämäläinen, E. (2015). Trends in Environmental Policy Instruments and Best Practices in Port Operations. *TransNav 2015* approved and peer reviewed conference paper. Published in Conference Journal.

Coastal & Marine (2013). Coastal climate change. Ports and renewable energies: impacts, vulnerabilities and adaptation. Available at: *www.eucc.net/coastalandmarine/coastalandmarine13-1.pdf*. [Accessed 23 May 2017].

DG Move (2015). State of the art on alternative fuels transport systems in the European Union. Available at: *ec.europa.eu/transport/themes/urban/.../2015-07-alter-fuels-transport-syst-in-eu.pdf*. [Accessed 23 May 2017].

DNV-GL (2014). Alternative fuels for shipping. DNV-GL Strategic Research and Innovation Position Paper 1-2014. Available at: *http://www.billionmilessg.com/sites/billionmilessg.com/files/PositionPaper_AltFuels_280214_tcm4-592866_0.pdf* [Accessed 23 May 2017].

DNV-GL (2015). LNG as a ship fuel. Available at: *https://www.dnvgl.com/maritime/lng/index.html.* [Accessed May 29, 2017].

DNV-GL (2017). EU MRV regulation. Info on www-page. Available at: *https://www.dnvgl.com/maritime/eu-mrv-regulation/index.html.* [Accessed May 22, 2017].

DuPont (2017). Exhaust gas regulatory requirements for maritime industry. Available at: *http://www.dupont.com/products-and-services/clean-technologies/products/belco-clean-air/sub-products/belco-marine-systems/belco-marine-regulatory-issues.html*. [Accessed 24 May 2017].

Ellis, J. & Tanneberger, K. (2016). *Study on use of ethyl and methyl alcohol as alternative fuels in shipping*. Final Report Version 20151204.5. Report prepared for the European Maritime Safety Agency (EMSA). Available at: *www.emsa.europa.eu/news-a-press-centre/external-news/download/4142/2726/23.html* [Accessed 24 May 2017]

ESN (European Shortsea Network) (2013). Way Forward SECA Report. 26 November 2013.

European Commision (2017a). Available at: *https://ec.europa.eu/clima/policies/transport/shipping_en*. [Accessed May 22, 2017].

European Commision (2017b). Available at: Towards and implementation strategy for the sustainable blue growth agenda for the Baltic Sea region. Available at: *https://ec.europa.eu/maritimeaffairs/content/new-study-implementing-sustainable-blue-growth-agenda-baltic-sea-region_en.* [Accessed June 21, 2017].

European Commission (2014). *Methanol: The marine fuel of the future*. Project 2012-EU-21017-S, Part of Priority Project 21. Available at: *https://ec.europa.eu/inea/en/ten-t/ten-t-projects/projects-by-country/multi-country/2012-eu-21017-s* [Accessed 24 May 2017]

European Maritime Safety Agency (EMSA)(2017). Air emissions. Available at: *http://www.emsa.europa.eu/main/air-pollution.html*. [Accessed May 22, 2017].

Gas Infrastructure Europe (GIE) (2016). *LNG Map (version: December 2016).* Available at: *http://www.gie.eu/index.php/maps-data/lng-map* [Accessed 24 May 2017]

GHD (2013). Environmental Best Practice Port Development: An Analysis of International Approaches. Department of Sustainability, Environment, Water, Population and Communities. Canberra, Australia.

Hansen, J.P., Kaltoft, J., Bak, F., Gortz, J., Pedersen, M., and Underwood, C. (2014). Reduction of SOx, NOx and particulate matter from ships with diesel engines. Miljostyrelsen. Available at: *www2.mst.dk/udgiv/publications/2014/03/978-87-93026-57-5.pdf* [Accessed May 29, 2017].

Hippinen, I. & Federley, J. (2014). Fact-finding study on opportunities to enhance the energy efficiency and environmental impacts of ports in the Baltic Sea Region*. Motiva Services Ltd.*

Hiranandani, V. (2014). Sustainable development in seaports: a multi-case study. *WMU Journal of Maritime Affairs* 13, 127–172.

International Maritime Organization IMO (2017). Prevention of air pollution from ships. Available at: *http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Air-Pollution.aspx.* [Accessed 24 May 2017].

IRENA (2015). Reneable energy options for shipping. Available at: *www.irena.org/.../Publications/IRENA_Tech_Brief_RE_for%20Shipping_2015.pdf* [Accessed June 5, 2017].

Kongsberg (2017). Autnonous ship project, key facts about Yara Birkeland. Available at: *https://www.km.kongsberg.com/ks/web/nokbg0240.nsf/AllWeb/4B8113B707A50A4FC125811D00407045?OpenDocument.* [Accessed June 19, 2017].

Lindstad, H., Verbeek, R., Blok, M., van Zyl, S., Hübscher, A., Kramer, H., Purwanto, J., Ivanova, O. and Boonman, H. (2015). GHG emission reduction potential of EU-related maritime transport and on its impacts. Available at: *ec.europa.eu/clima/policies/.../shipping/docs/report_ghg_reduction_potential_en.pdf* [Accessed May 23, 2017].

Lloyd's Register (2012). Implementing a ship energy efficiency management plan (SEEMP). Available at: *http://www.navtronic-project.eu/userdata/file/Public%20deliverables/Lloyds%20SEEMP%20Guidance%20Notes%20for%20Clients%20v2_tcm155-240651.pdf*. [Accessed May 22, 2017].

Lloyd's Register (2014). *Report indicates LNG bunkering is likely to develop fast as global ports get ready for shipping's gas fuelled future.* Lloyd's Register, 7 April 2014. Available at: *http://www.lr.org/en/news/news/lng-bunker-report.aspx* [3.5.2017]

Lloyd's Register (2016a). Your options for emissions compliance. Guidance for shipowners and operators on the Annex VI SOx and NOx regulations. Available at: *http://www.lr.org/en/services/environment-and-sustainability/airemissions.aspx.* [Accessed May 29, 2017].

Lloyd's Register (2016b). Using hybrid fuels for ECA-SOx compliance. Operational guidance for shipowners and operators. Available at: *http://www.lr.org/en/services/environment-and-sustainability/airemissions.aspx.* [Accessed May 29, 2017].

Mander, S. (2016). Slow steaming and new dawn for wind propulsion: a multi-level analysis of two low carbon shipping transitions. *Marine Policy* 75, 210-216.

Marineinsight (2016). Top 7 green ship concepts using wind energy. Available at: *http://www.marineinsight.com/green-shipping/top-7-green-ship-concepts-using-wind-energy/*. [Accessed June 5, 2017].

Marineinsight (2017). 10 technologies/methods for controlling NOx & SOx emissions from ships. Available at: http://www.marineinsight.com/tech/10-technologiesmethods-for-controlling-nox-sox-emissions-from-ships/. [Accessed May 29, 2017].

MarineLink (2017a). ABB launches emissions monitoring module. Available at: *https://www.marinelink.com/news/monitoring-emissions425471#.WR28FeUXTsM.linkedin*. [Accessed May 29, 2017].

MarineLink (2017b). Wärtsilä to replace OSV's generator with batteries. Available at: *https://www.marinelink.com/news/generator-batteries425742#.WSkKIaUfy4k.linkedi*n. [Accessed June 5, 2017].

McGill, R., Remley, W., and Winther, K. (2013). Alternative fuels for marine applications. Available at: *www.iea-amf.org/app/webroot/files/file/Annex%20Reports/AMF_Annex_41.pdf.* [Accessed May 23, 2017].

MEPC 70. Annex 1. Draft roadmap for developing a comprehensive IMO strategy on reduction of GHG emissions from ships.

Meriteollisuus (2017). Meyer Turulle kaksi uutta suurta laivatilausta Royal Caribbian Cruisesilta. Available at: *http://meriteollisuus.teknologiateollisuus.fi/fi/uutiset/meyer-turulle-kaksi-uutta-suurta-laivatilausta-royal-caribbean-cruisesilta*. [Accessed June 5, 2017].

Methanex (2015). *Methanol Marine Fuel.* Available at: *https://www.methanex.com/about-methanol/methanol-marine-fuel* [Accessed March 4, 2017].

Ministry of the Environment (2016). Nitrogen emissions restricted in Baltic Sea and North Sea. News release published 2016-10-28 at 12:15. Available at: *http://www.ym.fi/en-US/Latest_news/News/Nitrogen_emissions_from_ships_restricted%2840755%29*. [Accessed May 22, 2017].

Pöntynen, R. & Lempiäinen, P. (2015). *Rikkisääntely ja uudet polttoaineet - Parhaat käytännöt, toimintamallit ja vaikutusten mittaaminen Pohjois-Pohjanmaan näkökulmasta.* Publications of the Centre for Maritime Studies, Brahea Centre at the University of Turku B202/2015. Turku 2015.

Port of Amsterdam (2017). Energy transition: towards an international port with renewable fuels and energy. Available at: *https://www.portofamsterdam.com/en/port-amsterdam/energy-transition-towards-international-port-renewable-fuels-and-energy* [Accessed May 23, 2017].

Port of Gothenburg (2017). Growing number of vessels receive environmental discount at the Port of Gothenburg. Available at: *https://www.portofgothenburg.com/news-room/press-releases/growing-number-of-vessels-receive-environmental-discount-at-the-port-of-gothenburg/*. [Accessed May 23, 2017].

Seatrade Maritime News (2016). *Methanol is promising alternative to bunker fuel: Stena.* Posted 17 August 2016. Available at: *http://www.seatrade-maritime.com/news/americas/methanol-is-promising-alternative-to-bunker-fuel-stena.html* [Accessed March 4, 2017].

Ship & Bunker (2017). IBIA outlines IMO "Roadmap" Strategy for GHG reduction, global sulphur cap implementation challenges. Available at: *https://shipandbunker.com/news/world/183831-ibia-outlines-imo-roadmap-strategy-for-ghg-reduction-global-sulfur-cap-implementation-challenges*. [Accessed May 22, 2017].

Stenaline (2015). *Stena Line launches the world's first methanol ferry*. Press release Mar 31, 2015. Available at: *http://news.stenaline.co.uk/pressreleases/stena-line-launches-the-world-s-first-methanol-ferry-1137516* [Accessed March 4, 2017].

Stojcevski, Toni (2015). *METHANOL – as engine fuel, status Stena Germanica and market overview.* Pilot Methanol project 01/01/2012 - 31/12/2015. Available at: *https://www.google.fi/search?q=METHANOL+%E2%80%93+as+engine+fuel%2C+status+Stena+Germanica+and+market+overview&ie=utf-8&oe=utf-8&client=firefox-b&gfe_rd=cr&ei=ATziWNbNLMiq8we1jI4Q* [Accessed March 4, 2017].

Stopford, M. (2009). *Maritime Economics*. 3rd edition. Routledge, London.

STT (2017*). Skangas bunkered LNG-powered Tallink's Megastar at Helsinki's West Harbour – Cleaner energy for the Baltic Sea.* Posted 26.1.2017. Available at: *https://www.sttinfo.fi/tiedote/skangas-bunkered-lng-powered-tallinks-megastar-at-helsinkis-west-harbour-cleaner-energy-for-the-baltic-sea?publisherId=15612462&releaseId=56281158* [Accessed March 4, 2017].

Tarjegård, M. (2012). Cost-effective choices of marine fuel under stringent carbon dioxide targets. Results from the Global Energy Transition (GET) model. University of Gothenburg, Master's thesis. Available at: *bioenv.gu.se/digitalAssets/1375/1375340_maria-taljeg--rd.pdf.* [Accessed June 5, 2017].

Trafi (2017). Merenkulun uutiskirje 4.1.2017. Globaali MRV ja tiekartta alusten kasvihuonekaasupäästöjen vähentämiseksi. Available at: *http://trafi.mailpv.net/archive/show/1559863*. [Accessed May 22, 2017].

Van Breemen, T., Popp, C., Witte, R., Wolkenfelt, F. & Wooldridge, C. (ed.) (2008). *Good Practice Guide on Port Area Noise Mapping and Management*. Developed by the partners of the NoMEPorts (Noise Management in European Ports) Project. Port of Amsterdam. Available at: *http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.showFile&rep=file&fil=NoMEports_GPG_PANMM1.pdf* [Accessed March 4, 2017].

Winnes, H., Styhre, L., and Fridell, E. (2015). Reducing GHG emissions from ships in port areas. *Research in Transportation Business & Management* 17, 73-82.

World Shipping Council (2017). NOx, SOx, PM. Available at: *http://www.worldshipping.org/industry-issues/environment/air-emissions/nox-sox-pm*. [Accessed May 23, 2017].

Yliskylä-Peuralahti, J. (2016). Sustainable energy transitions in maritime transport: the case of biofuels. *Journal of Sustainable Mobility* 3, 67-93.