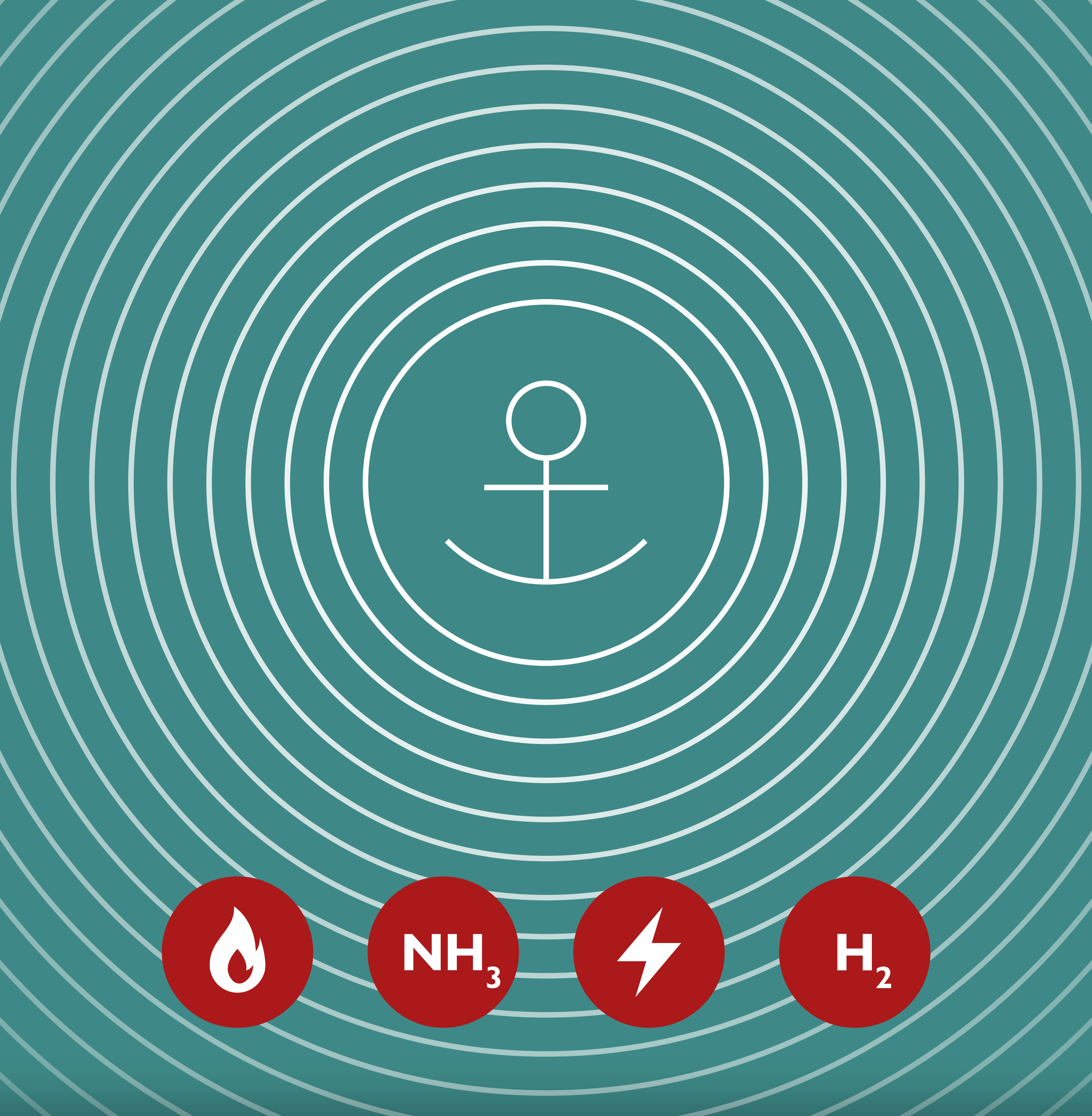

Alternative fuels' infrastructure for ships in the Baltic ports – current status and outlook

ABOUT BPO

The Baltic Ports Organization (BPO) is a regional ports organization inspiring and supporting its members while cooperating pro-actively with relevant partners. BPO was established on October 10, 1991, in Copenhagen, with an aim to facilitate cooperation among the ports and to monitor and improve the possibilities for shipping in the Baltic Sea Region.

Development over the past years has proceeded very quickly and at present BPO has entered a new and challenging phase. Currently, there are 45 major ports in the nine countries surrounding the Baltic Sea that are part of BPO, together with seven friendship members. BPO is well-recognized within the BSR, in EU bodies and other European regions.

The organization's mission is to contribute to sustainable development of maritime transport and the port industry in the Baltic Sea Region, thereby strengthening its global competitiveness.

ABOUT MOTUS FOUNDATION

'MOTUS Foundation: facilitating transfer of sustainable solutions for maritime, energy, transport logistics as well as environment and blue economy'

Motus Foundation scope of activities includes:

- Conducting research and reports as well as evaluation of studies and analysis.
- Promotion of the latest knowledge and advances in the areas of transport, logistics, energy, environment, infrastructure, economic development, utilization of marine resources and all related areas.
- Supporting the development of innovative, environmentally-friendly technologies and solutions for efficient use of natural resources in energy production.
- Advocating management systems to reduce the impact of economic activity on the environment, in particular in the areas of transport and energy, both in the private and public sectors.
- Initiating cooperation and running projects and lobbying activities with local authorities, governments, non-governmental organisations, public and private sectors as well as media, and social environments.

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The report "Alternative fuels' infrastructure for ships in the Baltic ports- current status and outlook" has been accomplished by collaboration among Baltic Ports Organisation and Motus Foundation.

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INTRODUCTION

The report **"Alternative fuels infrastructure in the Baltic Ports – current status and outlook"** highlights the latest regulations and policy framework for alternative fuels in the regional ports. In addition, it summarises the most popular technologies for new alternative fuels for shipping namely Liquefied Natural Gas (LNG), Hydrogen, fuel cells as well as Methanol and Ammonia and Onshore Power Supply (OPS).

Baltic Ports Organisation reacted very fast to the promotion of LNG as an alternative fuel for ships. BPO proposed a few LNG initiatives among the regional ports in the Baltic Sea. As a follow up, within the last decade a dozen of Baltic ports participated in projects co-financed by EU programmes and jointly developed facilities for LNG availability for ships. Consequently, Baltic Sea Region has developed a network of ports that can provide LNG as a bunkering fuel for approaching ships.

Moreover, during the last several years onshore power supply for ships (OPS) has become a common alternative energy solution for ships during their stay at the ports. The OPS technology is widely recommended as it reduces noise and air pollution, as well as greenhouse gas emission of vessels while at berth in ports. However, it has to be pointed out that the OPS infrastructure is developing at a slower pace among the Baltic Sea ports as they are some challenges associated with the development process.

Lately, the electric propulsion vessels are gaining more popularity as the most environmentally friendly solution to reach decarbonisation targets and minimize noise levels in the ports. Nowadays, there are a few electric power solutions that are available for a short distance sea transport, by linking islands with mainland and coastal zones as well as inland waterways in Europe.

However, this technological solution is still a challenge to apply in order to enable storage of electrical energy for propulsion in different types of vessels. There are more solutions of electric propulsion for ships today, but the technology needs further development and improvement. Additional research on the capacity and durability of battery systems is necessary to find and apply technologies that will meet customized needs of different types of vessels.

In addition, besides that introducing electric and battery shipping solutions there will be an increase in the use of alternative fuels such as LNG, biofuels, and developing future fuels such as methanol, hydrogen or ammonia. The shipping industry driven by international agreements and climate change will aim to decrease greenhouse gas and NO_X and SO_X emissions.

BPO follows the technology development in ship propulsion and supports its members in order to facilitate the deployment process of alternative fuels for ships in Baltic ports. The BPO's policy is to establish Baltic as a model region for green ports and maritime transport. Moreover, the mission of BPO is to contribute to the economic, social and environmentally sustainable development of maritime transport and the regional port industry, thereby strengthening the global competitiveness of the Baltic Sea Region. Therefore, BPO strives to be a leader in the development of 'green technology and solutions for green shipping and ports'.

With this report BPO, representing over 45 major regional ports, aims to highlight the importance of further development of infrastructure for alternative fuels and energy supply for shipping.

Considering BPO contribution towards the development of LNG regional ports' network, it is of crucial importance to continue the pace for deployment facilities for LNG, along with future fuels like Hydrogen fuel cells, Methanol and Ammonia in the region. Moreover, BPO aims to further stimulate the development of OPS facilities for ships as well as charging installations for electric ships in the Baltic Sea Region.

I. REGULATION AND POLICY FRAMEWORK FOR ALTERNATIVE FUELS IN THE PORTS

According to the information published by the European Commission, dated at June 2019, concerning carbon dioxide, emissions from the ships is exceeding 5 000 gross tonnage, operating within the European Economic Area, the emission levels reach the value over 130 million tonnes in 2018. Regarding the global scale emissions from international shipping, the Fourth Greenhouse Gas Study 2020, by International Maritime Organization (IMO), reported an increase of greenhouse gas emissions of shipping from 977 Mt in 2012 to 1.076 Mt in 2018 so an almost 10% rise. According to current estimations by 2050 those emissions are to increase by up to 50%.[1]

[1] **Fourth IMO GHG Study 2020**

Maritime pollution has been the focus of the International Maritime Organization since the 70s of the twentieth century, along with the tanker accidents and resulting oil spills. Annex VI toy MARPOL - the International Convention for the Prevention of Pollution from Ships, had been adopted along with the Protocol amending Convention in 1997 and finally entered into force on 19th May 2005. Revised version of Annex VI was adopted in 2008 and entered into force on 1st July 2010, tightening the SO_x emission limits. The revised MARPOL Annex VI reduced allowable Sulphur content in the maritime fuels from the level of 3.5 % to 0.5%. Regulation entered into force from 1st January 2020. Tighter limits concerning SO_x emissions had been in force at the Emission Control Areas since January 2015.

Regulations concerning NO_x emissions are the subject of the Tier II and Tier III. IMO's Tier II imposed limits for engines of ships constructed on or after 1st January 2011 at all water, while Tier III refers to engines of the shits built on or after 1st January 2016, at the North American Emission Control Area or the U.S. Caribbean Sea Emission Control Area. In the case IMO's Marine Environment Protection Committee decided on adoption of Tier III to other ECAs, the Tiger III limits would become eligible on or after the date of the decision. Tier II limits are applicable regardless of whether ECAs for NO_x have been established or not. Comparison between the limits imposed by Tier II and Tiger III indicates the necessity of 75% NO_x emissions' reduction.

Exclusions from the Tier III requirements apply to marine diesel engines on the ships constructed before January 2021, less than 500 gross tonnage and 24 m. or more in length, which have been designed and used only for recreational purposes.

Regulations concerning sulphur content in the maritime fuels have been reflected in the EU directives. First regulations had been included in the Directive 1999/32/EC that was later amended by the Directive 2005/33/EC. Further amendments were introduced by the *Directive 2016/802 of the European Parliament and of the Council of 11th May 2016 relating to a reduction in the sulphur content of certain liquid fuels.* In accordance with the directive the limit of Sulphur content was set at 3.5% by mass, except for the cases when the ship is equipped with scrubber. The above mentioned levels had become obligatory since 18th June 2014, while the level of 0.50% came into force since 1st January 2020.

The directive obliged Member States to take necessary measures that marine fuels used at their territorial seas, exclusive economic zones falling within SECA, should not exceed 1% of sulphur by mass until the end of December 2014 and 0.1% since 1st January 2015.

In the case of territorial seas and exclusive economic zones outside SECA, the passenger ships on regular services to or from any EU port, were allowed to use the fuel of the Sulphur content below 1.5% by mass until 1st January 2020.

The directive set the emission levels for the fuels used by ships docking at berths of the EU ports, which sulphur content should not exceed 0.1% by mass. Ship crew should be given sufficient time to complete necessary fuel-changeover operation as soon as possible after arrival at berth and before departure at latest. The regulation does apply to ships, which expected time at berth is less than two hours as well as for the ships, which switch off the engines and use the onshore power supply systems.

Further regulations concerning emissions from maritime transport were constituted by the Energy Efficiency Design Index (EEDI) included into the amendments to MARPOL Annex VI, by the resolution of the Maritime Environment Protection Committee (resolution MEPC.203(62)). Enforcement of the EEDI stimulates innovation leading to more efficient solutions in design or propulsion technology. Value of the index has been differentiated, depending on the ship type and size segment.

The obligation of applying measures determined by the EEDI was set on 1st January 2013 and followed by an initial two year phase zero, design of new ships was expected to meet the requirements developed for the specific type. Regulation assumed that CO_2 reduction level at 10% for the first phase and would be tightened every five years in order to follow technological development. Relevant measures improving energy efficiency in accordance with the reduction factors are applicable to large vessels, such as bulk carriers, gas carriers, tankers, container ships, general cargo ships, refrigerated cargo ships and combination carriers. These types of vessels are responsible for 85% of the CO_2 emissions from international shipping. Besides the initial zero phase, three phases were planned, which final time perspective was set at 2025 and onwards. Expected level of the CO_2 reductions was set at 30%, calculated, and based on interpolation between the values of ship's average efficiency for ships built between 2000 and 2010.

Application of the measures necessary to meet the EEDI requirements is obligatory for each new ship, which has undergone a major conversion and new or existing ship, which has undergone a major conversion at the extent that is regarded as a newly constructed ship.

Regulations supporting utilization of alternative fuels by the development of infrastructure facilitating access to electricity, Liquefied Natural Gas (LNG) and hydrogen in ports are the subject of the ***Directive 2014/94/EU of the European Parliament and of the Council of 22nd October 2014 on the deployment of alternative fuels infrastructure***. The Directive provided the Member States with the framework for the elaboration of national policies on alternative fuels, determining national targets and objectives concerning i.e. refueling points for LNG at maritime and inland ports as well as infrastructure for shore-side electricity supply in maritime and inland ports. The Directive determines the schedule for the implementation of the alternative fuels infrastructure that assumes deployment of the onshore power supply systems in the TEN-T Core Network ports as well as other ports, by 31st December 2025, unless there is no demand and the costs are disproportionate to the benefits, including environmental benefits. Regarding accessibility to natural gas as a fuel for transport, 31st December 2025 was indicated as the date for implementation of the LNG refueling points at maritime ports within TEN-T Core Network.

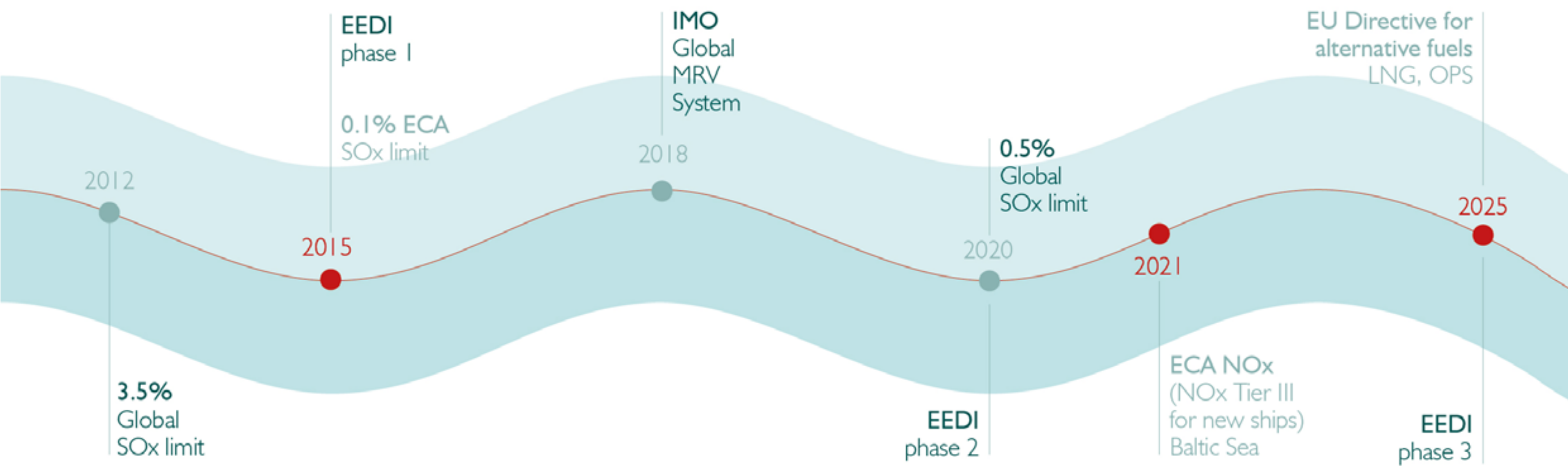
New regulations and support instruments are expected with reference to the European Green Deal. Action 2.1.5 ***Accelerating the shift to sustainable and smart mobility*** defines tasks to be undertaken by the European Commission with regard to the transport sector. The action plan emphasizes the role of multimodal transport, hence the European Commission aims to revise the Combined Transport Directive to support multimodal freight operations, which involve water-borne transport and rail.

With regard to maritime fuels, the Commission plans to revise the Energy Taxation Directive in terms of the tax exemptions concerning the maritime and aviation fuels and close any loopholes present in the current system.

The Commission also aims to propose extension of the European emissions trading system to the maritime sector. Relevant action will be taken in cooperation with the International Maritime Organization. Further activities aiming at the deployment of alternative transport fuels will include legislative options, which aim at boosting the production and use of sustainable alternative fuels and acceleration of zero- and low-emission vessels.

A timeframe of current and future regulations is presented in figure 1. New regulations concerning sustainable and smart mobility are expected to be developed by the end of 2020.

FIGURE 1
Existing and new regulations aiming at cleaner Baltic transport
Source: Report "The Baltic Sea as a model region for green ports and maritime transport, BPO



2. EXISTING CLEANER FUEL TECHNOLOGIES FOR THE SHIPPING SECTOR

International regulations on maritime transport, driven by air pollution and climate change, aim to stimulate the innovation in the field of marine fuels, hull design or smart solutions, which collectively result in enhancement of energy efficiency and reduced emissions.

Along with the legislative works conducted by the IMO, concerning reduction of SO_x, NO_x and other emissions, the research and development works have been conducted, focused on technology development in order to meet requirements imposed by the legislation.

Range of marine fuels and technologies powering propulsion systems, analysed at the beginning of the previous decade by the Royal Academy of Engineering (2013), besides LNG, batteries, fuels cells or hydrogen, included also nuclear power, anhydrous ammonia, compressed air and liquid hydrogen[2]. Throughout the decade the technologies, which achieved the most significant advancement are LNG and power storage. LNG is being currently incorporated into vessels' propulsion systems, regasification of the gas transmission and distribution systems, distributed energy generation or the large trucks' engines. Deployment of LNG infrastructure and battery charging stations as well as onshore power supply systems is required along the major TEN-T corridors and in core ports, in accordance with the EU Directive on the deployment of alternative fuels infrastructure[3].

[2] **Royal Academy of Engineering, 2013. Future ship powering options. Exploring alternative methods of ship propulsion. Royal Academy of Engineering, London.**

URL: *http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/*

Last visit: 11.05.2020.

[3] **Directive 2014/94/EU of the European parliament and of the council of 22 October 2014 on the deployment of alternative fuels infrastructure**

2.1 LIQUEFIED NATURAL GAS

Liquefied Natural Gas (LNG) is the fuel characterized by low carbon content, compared to other fuels. It is characterized by 18% higher energy density per mass than Heavy Fuel Oil (HFO) and its volumetric density is 43% of the HFO. Crucial component of LNG is methane (CH_4), capable of reducing CO_2 emissions by 25%. Carbon dioxide emission balance should also include the methane emissions. The methane release (slip) may take place as a result of thermodynamic cycle, when minor volumes of heat are being transferred to a well-insulated tank, capable of increasing the pressure inside. Security valves release the gas to maintain a secure pressure. The released methane should be recycled in the re-liquefaction plant on-board the vessel. Otherwise it can be either vented or burnt, significantly impacting the efficiency of carbon dioxide reduction. Due to a very low boiling point of LNG, equal to –163°C, the cold can be utilized in various ways, e.g. cooling the inlet air of prime mover, which contributes to the increase in turbine efficiency or using the cold for air conditioning purposes.

Also a low content of nitrogen in the combustion process results NO_X production by c.a. 85%. According to DNV GL (2019)[4], low pressure Otto-cycle engines (four-stroke as well as low-pressure two-stroke engines) comply with IMO Tier III NO_X limits and do not require exhaust gas treatment.

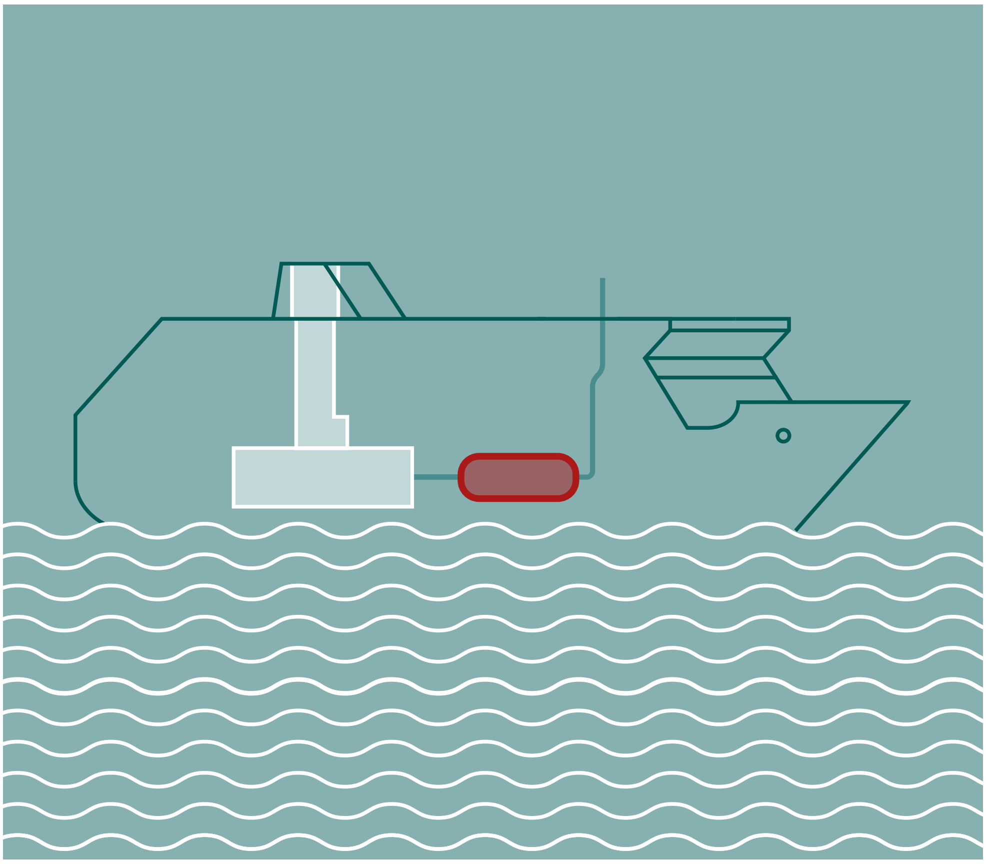
Important aspect of the application of LNG as a marine fuel refers to the vessel design as a result of a demand for an increased storage space. LNG requires approximately 4 times larger storage space than traditional marine fuels. As a consequence space on board such vessels is reduced; figure 2 represents an example of additional space needed for retrofitting a cruise ship.

[4] ***Assessment of selected alternative fuels and technologies.*** **Hamburg: DNV GL.**

Retrieved from *https://www.dnvgl.com/maritime/publications/alternative-fuel-assessment-download.html*

FIGURE 2
Cruise ship retrofit with LNG tank

Source: "Case Studies about New-building and Retrofitting LNG Fuelled Vessels", Dr Evangelos Boulougouris, University of Strathclyde.



Choice of the relevant LNG technology for the specific applications in shipping partly depends on the way of LNG extraction, as a result of thermodynamic changes. One type of the gas – ***natural boil-off gas*** is the evaporated gas, collected in the upper part of the tank, above the liquid surface. Evaporation results from minor amounts of heat permeating through the insulated tank. The gas is characterized by high content of methane and some nitrogen, which results in high knocking resistance[5].Another type of gas is a ***forced boil-off gas*** – LNG is being extracted from the lower part of the tank, still in a liquid state and evaporated in a separate chamber. Depending on the mixture of hydrocarbons in the liquid its properties may differ depending on the origin or sometimes it may also differ between the loads. The forced boil-off gas is characterized by lower methane content than the natural boil-off gas, however, its calorific value is higher than natural boil-off gas. The natural boil-off gas is being applied for fueling of LNG tanker propulsion plants, while the forced boil-off gas is popular in general shipping.

[5] **Knock resistance – chemical property of a fuel preventing self-ignition and uncontrolled combustion while compressing.**

In effect, factors necessary to start the ignition, besides the ignition spark also require compression of a fuel. (Source: Marquard & Bahls, 2020)

Technological development resulted in three main types of the LNG engines:

- the spark-ignited, running only on LNG, primarily dedicated for the power industry, characterized by simplicity, good overall performance and lowest emissions. Initially applied at short-distance ferries;
- the diesel-ignited engine for dual-fuel applications, primarily developed for power plants, where feasibility to operate on liquid and gaseous fuels was considered as an advantage. Currently it is a dominating type of engine in marine industry;
- the direct gas injection diesel gas engine, characterized by complete combustion, which is compromised by higher NOx emissions in comparison to other types of engines. Limited application in maritime industry, however with potential for further developments.

FIGURE 3
CMA CGM Tenere

Source:
https://www.rivieramm.com/news-content-hub/worldrsquos-first-lng-fuelled-vlcs-joins-cma-cgm-fleet-60937

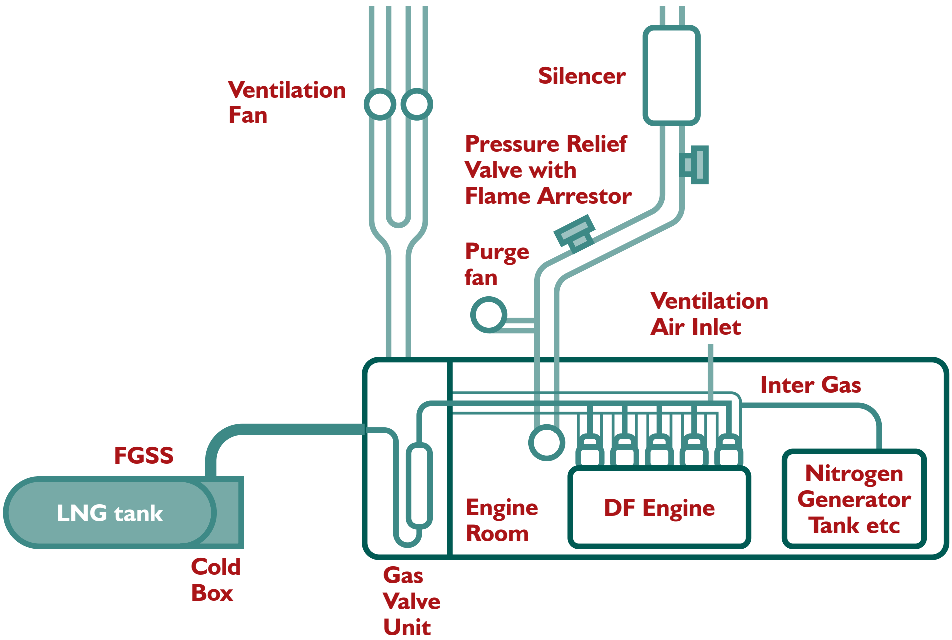
Although LNG significantly contributes to decrease in emissions and increase in energy efficiency when compared to other marine fuels, due to the need for fundamental reduction of CO_2 emissions, current developments tend towards abandonment of fossil fuels for maritime applications , figure 3 represents the world first ULCS fuelled by LNG.

In 2020, there have been 169 LNG fueled ships in operation and 222 on order (Alternative Fuels Insight, 2020). Spatial distribution of the operated ships includes Europe (111 ships), Norway (75), Americas (33).

Figure 4 represents a dual-fuel engine for diesel and LNG propelled vessels.

FIGURE 4
LNG-Diesel, Dual-Fuel engine

Source:
Daihatsu Diesel MFG. CO., LTD.



2.2 BATTERIES

Owing to a dynamic development of batteries as the energy storage solution for the automotive industry, the technology accounted for a dynamic advancement throughout the last decade, resulting in the improvement of performance as well as reducing the battery prices and costs of energy stored in batteries. In the case of the lithium-ion batteries, since 2016 the prices were reduced by more than 50%, however, according to DNV GL, depending on the application, technology, performance the prices may vary widely. The costs are being influenced by different factors, resulting from such factors as integration with the vessel, hardware and software for battery control, power electronics, etc.

The goal set by the automotive industry by 2020, assumes achievement of price levels 100 USD/kWh, for the lithium-ion batteries. In the case of the maritime systems, the price level might be achieved at 200 USD/kWh[6].

Major goal concerning technology development is the increase of energy density of batteries accompanied by further price reduction. The reports assume that lithium-ion batteries remain leading technology[7]. Other technologies, besides lithium-ion have the potential to reach market maturity and become potentially competitive in terms of costs. Future developments may be based on the following raw materials:

— **Graphite** – popular material, which c.a. 80% originates from China. Price increase expected as a result of stricter environmental regulations;

— **Cobalt** – originating, in over 50% of the global demand, mainly form Congo, a country of unstable political circumstances.

— **Lithium** – available sources in Chile, China and Australia, however only one-third can be utilized economically;

— **Nickel** – currently used in the stainless steel industry as an important component. Competition between branches of stainless steel and chemical may result in the increase of prices, which can be neutralized with larger supplies.

Technological developments refer to application of different chemical compositions of anodes and cathodes as well as research of the chemical processes in batteries, which contribute to optimization of the design. Technically, maritime application of batteries needs to meet much more stringent requirements in order to ensure safety.

FIGURE 5
Battery driven cruise ship MS Roald Amundsen, operated by Norwegian company Hurtigruten,

Source: Hurtigruten/Reuters

[6] *Assessment of selected alternative fuels and technologies.* Hamburg: DNV GL.
Retrieved from *https://www.dnvgl.com/maritime/publications/alternative-fuel-assessment-download.html*
Last visit: 02.06.2020

[7] IBID

2.3 HYDROGEN AND FUEL CELLS

Hydrogen (H2) is an effective energy carrier, which utilization for electricity production does not result in emission of greenhouse gases or other pollutants. Another advantage of hydrogen is its availability as a side product of chemical processes involving fossil fuels. Hydrogen can be also produced in a process of electrolysis using energy generated from renewables, which might be considered also as an effective measure for grid balancing and storage of the surplus electricity, generated by wind or solar farms. According to the DNV GL[8] only 5% of hydrogen is being produced from sources other than fossil fuels. Share of the hydrogen production of fossil fuels include natural gas (68%), oil (16%) and coal (11%). Origin of hydrogen influences the carbon footprint of its use.

[8] *Assessment of selected alternative fuels and technologies.* **Hamburg: DNV GL.**
Retrieved from *https://www.dnvgl.com/maritime/publications/alternative-fuel-assessment-download.html*
Last visit: 02.06.2020

Although at the moment demand for hydrogen for maritime applications is limited to some cases in the region of Baltic and North Sea, there are significant prospects for technology development as the important part of the European Green Deal, serving decarbonisation of the energy and transport sector.

Besides the application of fuel cells as a major technology for converting hydrogen into electricity, other applications and technologies are being developed, which include gas turbines and internal combustion engines. However, the latter technology has been concluded as less efficient than diesel engines. Better performance could be potentially achieved in the case of larger scale maritime applications, which combine waste heat recovery, hence making it suitable for high-temperature technologies, such as solid oxide fuel cells (SOFC). Combination with batteries might be helpful to protect SOFC technology against extreme power loads.

While full scale commission of hydrogen ship is still a future perspective, there are already planned pilot actions for such vessels. Plans for the world first hydrogen powered cruise ship have been already announced in 2017 by Viking Cruises[9].Currently, hydrogen is undergoing tests by early movers as Norled and Wärtsilä. Most research projects estimate the increase and viability of hydrogen technology around 2030–2050. Pilot projects aimed at introduction of hydrogen-powered vessels are currently performed. As an example in 2017 DNV GL joined a project in collaboration with the Norwegian national road authorities, with the goal to introduce a short-sea shipping hydrogen-powered ferry by 2021. The target of the pilot is the introduction of a zero-emission alternative for ferry routes where e-ferry operation is not viable. Another project is the HYBRIDShip initiated in 2016 by Fiskerstrand, with the goal of converting a diesel ferry into a hydrogen fueled vessel that would be operational in 2020. Both pilots aim to explore the feasibility of short range hydrogen fueled routes, once those would be mastered, further research is expected to be dedicated towards long range routes[10].

[9] *https://www.maritime-executive.com/article/worlds-first-hydrogen-powered-cruise-ship-scheduled*

[10] **DNV GL** *https://www.dnvgl.com/expert-story/maritime-impact/Power-ahead-with-hydrogen-ferries.html*

Another challenge concerning hydrogen technology is its storage. Transport of hydrogen can be conducted in a similar manner to LNG, in a liquefied form. The boiling point of hydrogen is at –253°C, hence the cost of storage tanks is higher than in the case of LNG, because of the need of better insulation to maintain lower temperatures. Cost of other elements of the system, including piping, ventilation, heat exchangers are considered to be similar as in the case of LNG. In 2020, there are 3 ships run on hydrogen fuel, both operating and on order[11].

[11] **DNV GL (2020, June 26). Retrieved from** *Alternative Fuels Insight: afi.dnvgl.com*
Last visit: 02.06.2020

2.4 METHANOL

Methanol (CH3OH) is characterized by the lowest content of carbon and highest content of hydrogen. Similarly to hydrogen, methanol is an easily available product, being applied in a number of products and can be derived from different resources, such as natural gas, coal and biomass, such as black liquor from pulp and paper mills, forest biomass and agricultural waste.

Emissions related to methanol production from coal are twice as high as in the case of natural gas. Methanol is also characterized by lower heating value than the oil. Also due to its density the size of storage tanks for methanol are 2.5 times larger than oil tanks, in order to achieve the same amount of energy.

As the maritime fuel, methanol can be used in a two-stroke diesel-cycle engine or four-stroke, lean-burn Otto-cycle engine. As methanol does not differ significantly from other liquid fuels, it can be stored in fuel tanks, which require modifications due to low-flashpoint.

Price of methanol is bound to the prices of natural gas however it is higher compared to other fuels of similar or higher energy content. At the beginning of the previous decade, prices of methanol fit into the range between the European prices of the heavy fuel oil (HFO) and the marine gasoil (MGO).

Currently, there are 24 ships using methanol as a fuel[12]. The number includes both operating ships and those on order, figure 6 represents an example of a methanol fuelled tanker.

[12] IBID

FIGURE 6
Methanol fueled tanker M/T Mari Couva

Source: **Methanex**/*gCaptain.com*

3. FINANCIAL INSTRUMENTS AND OTHER INCENTIVES TO SUPPORT INFRASTRUCTURE FOR ALTERNATIVE FUELS

There are several funds for co-financing of alternative fuels infrastructure developments. A few financial sources for development of sustainable green facilities in Baltic Sea ports can be indicated. Current EU programmes are:

— Connecting Europe Facility

— HORIZON 2020

— INTERREG European Territorial Cooperation (ETC).

Apart from the programmes and funding instruments, support from banks such as European Investment Bank (EIB), European Bank for Reconstruction and Development (EBRD) or Nordea Bank could be considered as well.

Another programme – still under development - is the European Green Deal (EGD)[13], which aims towards a climate-neutral economy by 2050. European Commission presented a five years plan and its strategic vision for a prosperous, modern, competitive and climate-neutral economy by 2050.

[13] **The European Green Deal, COM(2019) 640 final Brussels, 11.12.2019 2020**

3.1. CONNECTING EUROPE FACILITY (CEF)

The Connecting Europe Facility (CEF) is a key EU funding instrument to promote growth, jobs and competitiveness through targeted infrastructure investment at European level. It supports the development of high performing, sustainable and efficiently interconnected trans-European networks in the fields of transport, energy and digital services. CEF investments aim to fill the missing links within these three fields[14].

[14] *https://ec.europa.eu/inea/en/connecting-europe-facility*
CEF Implementation Brochure 2019 at
https://ec.europa.eu/inea/sites/inea/files/cefpub/cef_implementation_brochure_2019.pdf
eg. "..all alternative fuel actions have a clear energy dimension, and many of them involve telematic applications.."

The CEF for Transport, including Motorways of the Sea (MoS) priority, is the funding instrument to realize European transport infrastructure policy. It aims at supporting investments in building new transport infrastructure in Europe or rehabilitating and upgrading the existing one. CEF Transport also supports innovation in the transport system in order to improve the use of infrastructure and to reduce the environmental impact of the sector also to enhance energy efficiency and increase safety in ports and in maritime shipping.

The CEF, being the TEN-T funding instrument, makes inter alia infrastructure for alternative clean fuels eligible for grants. These kinds of facilities can be deployed mainly on the TEN-T Core Network (including Core Seaports). The infrastructure projects should concentrate on new technologies and innovation solutions. In addition, the deployment of infrastructure for alternative clean fuels is possible on the broader comprehensive network as well. The comprehensive ports are able to receive financial assistance from the CEF in the form of procurement and financial instruments, such as project bonds.

A horizontal priority of the Connecting Europe Facility (CEF) is the "Motorways of the Sea (MoS)". The programme aims to promote green, viable, attractive and efficient sea-based transport links integrated in the entire transport chain. Maritime link based projects and projects of wider benefit are given priority in the selection process.

Main conditions for the project to obtain co-financing are:

— Project should include at least two EU ports (two core ones or one core and one comprehensive) from two different Member States,

— At least one maritime operator and ideally hinterland transport operators.

The project proponents may apply for up to 30% co-financing. Facilities amongst the infrastructure that are subject to co- financing have to be open to all users. The total budget for CEF Transport in the period 2014-2020 was EUR 24.05 billion.

For the next EU financial perspective period 2021-2027 the final budget has been agreed by the European Council in July 2020[15] that proposed to have a total budget of EUR 28.39 billion of which EUR 21.38 billion for CEF Transport.

[15] https://www.consilium.europa.eu/media/45109/210720-euco-final-conclusions-en.pdf **European Council's Conclusions from special meeting 21.07.2020**

3.2. THE HORIZON 2020 FRAMEWORK PROGRAMME

The Horizon 2020 framework programme was established by Regulation (EU) No 1291/2013 of the European Parliament and of the Council. Its objective is to provide support for research and innovation with regards to alternative fuel vehicles and the related infrastructure, in particular through the societal challenge 'Smart, green and integrated transport'. That specific source of financing should also contribute to the development of alternative fuels infrastructure and should be fully considered as an additional opportunity to ensure a sustainable mobility.

Horizon 2020 projects funded by Innovation and Networks Executive Agency (INEA) develop and test new clean energy and transport technologies whilst CEF deploys innovative solutions on a large scale, which means there is a natural link between the programmes. The total budget of Horizon 2020 is EUR 80 billion throughout the Union.

Horizon Europe is the European Union's next seven-year perspective research and innovation programme, which will run from 2021 to 2027. The programme's general objective is to deliver scientific, technological, economic and societal impact from the Union's investments in Research and Innovation (R&I), to strengthen the scientific and technological bases of the Union and foster its competitiveness in all member states. The expected budget of Horizon Europe (2021–2027) is estimated at EUR 100 billion[16].

However under post COVID-19 circumstances the European Council has agreed on lower budget dedicated to Horizon Europe[17] – it is going to be EUR 5 billion under Next Generation EU and EUR 75.9 billion under Multiannual Financial Framework (MFF), so altogether EUR 80.9 billion.

The Horizon Europe framework foresees some areas for possible institutionalized European partnerships (as based on Article 185/7 TFEU). Hydrogen and sustainable energy storage is one of them.

EU Commission proposes for Horizon Europe synergies with other Union programmes such as Connecting Europe Facility (CEF), ERDF, Digital Europe and Innovation Fund. This idea is based on compatibility (e.g. harmonisation of funding rules, pooling resources at EU level) and coherence plus complementarity (alignment of strategic priorities in support of a common vision).

[16] https://ec.europa.eu/info/files/horizon-europe-investing-shape-our-future_en **European Council's Conclusions from special meeting 21.07.2020**

[17] **IBID quoted under 15**

3.3. INTERREG EUROPEAN TERRITORIAL COOPERATION (ETC)

INTERREG European Territorial Cooperation is one of the two goals of cohesion policy and provides a framework for the implementation of joint actions and policy exchanges between national, regional and local actors from different Member States. The main objective of European Territorial Cooperation (ETC) is to promote a harmonious economic, social and territorial development of the Union as a whole. Interreg is built around three strands of cooperation: cross-border, transnational and interregional. The fifth programming period of Interreg has had a budget of EUR 10.1 billion invested in over 100 cooperation programmes between regions and territorial, social and economic partners. This budget also includes the ERDF allocation for Member States to participate in EU external border cooperation programmes supported by other instruments. The expected budget of ETC for period 2021-2027 is EUR 7.95 billion.

Within Interreg territorial development cooperation there have been several different programmes dedicated to certain regions. As Baltic Sea Region and seaports in the area are concerned it is worth to name: Baltic Sea Region, Central Baltic, Interreg South Baltic and also Northern Periphery and Arctic, Interreg Nord and Interreg Europe.

[18] https://ec.europa.eu/regional_policy/en/2021_2027/

The "new" Interreg[18] is going to aim for removing cross border obstacles and supporting interregional innovation projects. Interregional and cross-border cooperation will be facilitated by the new possibility for a region to use parts of its own allocation to fund projects anywhere in Europe jointly with other regions.

The new generation of interregional and cross-border cooperation ('Interreg') programmes will help Member States overcome cross-border obstacles and develop joint services. The Commission proposes a new instrument for border regions and Member States eager to harmonise their legal frameworks, the European Cross-Border Mechanism.

3.3.1. INTERREG BALTIC SEA REGION PROGRAMME

The Programme is an agreement between EU member states Denmark, Estonia, Finland, Latvia, Lithuania, Poland, Sweden and the northern parts of Germany as well as partner countries Norway, Belarus and the northwest regions of Russia. The Programme is funded by the European Union and approved by the European Commission.

Total project budgets typically range between EUR 1.5 and EUR 4.5 million for seven or more partners working together for two to three years. Some of the projects within the priority are directly linked with the Action Plan of the EU Strategy for the Baltic Sea Region and are therefore marked as flagship projects of the Strategy:

Within the Interreg BSR funding from ERDF, more than EUR 136 million has been allocated to 60 flagship projects including 15 ones of transport priority.

The Interreg finances mostly soft projects or pilot initiatives. Therefore, they can elaborate for example a multidimensional strategy approach for sustainable future development in the port area to be carried out later on with the other financial support or grant (e.g. Green Cruise Port Action Plan 2030 project).

The European Commission has been still developing the legislative package of the future Interreg Programmes. As the adoption of the Multiannual Financial Framework is expected in 2021, so it is with a budget for the future Interreg Baltic Sea Region Programme as a consequence.

At the next meeting of the Joint Programming Committee Task Force, which is planned in late October 2020, there should be the future Programme's priorities agreed on[19].

[19] https://www.interreg-baltic.eu/news-detail/news/next-steps-taken-to-develop-the-future-programme.html

3.3.2. INTERREG SOUTH BALTIC PROGRAMME

The "Interreg South Baltic Programme" aim at unlocking South Baltic's potential for blue and green growth through cross-border cooperation between local and regional actors from Denmark, Germany, Lithuania, Poland and Sweden. Building on the maritime character of the Programme, "blue growth" addresses the economic potential of the Baltic Sea for growth and jobs across the shores of the South Baltic. At the same time, "green growth" underlines the need to pursue the path of economic growth in balance with the environment, in particular by utilizing South Baltic's rich natural and cultural heritage in a sustainable and preserving manner. The Programme provides co-financing from the European Regional Development Fund (ERDF) for cooperation activities between two or more organisations from at least two participating Member States. The funds available for cross-border efforts that unlock the potential for blue and green growth amount to EUR 78 million. The co-financing rate for Polish, Lithuanian and German beneficiaries is up to 85% of their eligible project costs, while Swedish and Danish beneficiaries can receive up to 75% of ERDF co-financing. The ERDF co-financing is paid on the basis of semi-annual reimbursements.and green growth amount to €78 mil. The co-financing rate for Polish, Lithuanian and German beneficiaries is up to 85% of their eligible project costs, while Swedish and Danish beneficiaries can receive up to 75% of ERDF co-financing. The ERDF co-financing is paid on the basis of semi-annual reimbursements.

3.4. BANKS PROVIDING FINANCIAL SUPPORT FOR SUSTAINABLE PROJECTS

3.4.1. EUROPEAN INVESTMENT BANK / EUROPEAN INVESTMENT BANK GROUP

The European Investment Bank is the lending arm of the European Union. This is the biggest multilateral financial institution in the world and one of the largest providers of climate finance. The EIB Group has two parts: the European Investment Bank and the European Investment Fund. The EIF specializes in finance for small businesses and mid-cap.

The European Investment Bank focuses on six areas: climate and environment, development, innovation and skills, small businesses, infrastructure and cohesion.

All the projects must be bankable, but they also must comply with high technical, environmental and social standards. Since the beginning of its operations in 1958, the EIB has provided long-term finance to support the development of infrastructure. Today, banks play a significant role in shaping a low-carbon future in Europe and beyond. It acts as the European Investment Advisory Hub[20] providing support to identify, prepare and develop investment projects across the European Union. In its effort to support a green and competitive economy, EIB supports projects involving for example: energy efficiency, water and wastewater management.

[20] https://www.eib.org/attachments/thematic/eiah_flyer_en.pdf
The European Investment Advisory Hub is a partnership between the EIB Group and the European Commission. Both institutions financially contribute to the initiative. The EIB Group is responsible for the management of the Hub.

3.4.2. NORDEA BANK AND SUSTAINABLE SELECTION GREEN FINANCING

Nordea is the largest financial services group in the Nordic region and one of the biggest banks in Europe. It is a full-service universal bank and the third largest corporation in the Nordic region and one of the top 10 financial services companies in Europe based on market capitalization.

Nordea is present in 17 countries, including its four Nordic home markets, which constitute the 10th largest economy in the world.

Sustainable Selection is a product family of Nordea Bank, which includes the most sustainable products, such as the Nordea Star funds and Climate & Environment fund. In order to be selected for the Sustainable Selection family, an investment product undergoes an in-depth ESG, (Environmental (E), Social (S), and Governance (G) - refer to the three main areas of analysis in modern responsible investment.), i.e. sustainability analysis. The Sustainable Selection family was launched in end-2018, and had EUR 9.95 billion in assets under management (AuM) by the end of 2019.

To support companies' transition to more sustainable business models, Nordea has started to offer green bonds. There are two different ways of green bonds issue. First, Nordea issues its own green bonds where proceeds are earmarked to finance such loans to customers, which have environmental benefits and mitigate climate change. The second way, Nordea serves as the intermediary between its customers as issuers and investors, by helping them to issue or invest in green bonds via the capital markets.

Green Bond Principles (GBP) was defined to include among others the "Clean Transportation" category. Within this category it means projects or activities and related equipment, technology and processes towards clean transportation infrastructure.

Green loans are used to finance specific investments with environmental benefits and give Nordea's corporate customers the opportunity to address climate change in their financing. The customer commits to using the financing for a sustainable investment, which requires them to report the positive impact from the investment in energy.

3.4.3. THE NORDIC COUNCIL OF MINISTERS AND THE NORDIC COUNCIL

The Nordic Council of Ministers (NCoM) and the Nordic Council (NC) are the main forums for official Nordic co-operation, which involves Denmark, Finland, Iceland, Norway, Sweden, the Faroe Islands, Greenland and Åland. Their vision is to make the Nordic region the most sustainable and integrated region in the world by 2030. The Nordic Council of Ministers is the official body for inter-governmental co-operation in the Nordic Region. It seeks Nordic solutions wherever and whenever the countries can achieve more together than by working on their own. The co-operation in the Nordic Council of Ministers aims to serve this purpose. To achieve 'The Vision 2030'[21], the Nicoma will prioritise:

[21] https://www.norden.org/en/declaration/our-vision-2030
'The Vision 2030' was adopted in August 2019.

— A green Nordic Region – together promotes a green transition of Nordic societies and work towards carbon neutrality and a sustainable circular and bio-based economy.

— A competitive Nordic Region – together promote green growth in the Nordic Region based on knowledge, innovation, mobility and digital integration.

— A socially sustainable Nordic Region – together promote an inclusive, equal and interconnected region with shared values and strengthened cultural exchange and welfare.

Within the NCoM the Nordic working group for Climate and Air (NKL) is working to limit and prevent serious climate change and negative effects of transboundary air pollution, including harm to human health. NKL wishes to focus on projects that describe the interactions between climate and air pollution issues and the synergies with other areas, enhanced by a holistic approach guided by the Sustainable Development Goals[22]. The group can fund various types of activities such as

[22] http://norden.diva-portal.org/smash/get/diva2:1092868/FULLTEXT01.pdf
The SDG was published in 2017.

studies, workshops and other outreach. NKL operates through targeted public procurements and open calls. The NKL's criteria for prioritizing projects and activities in 2021 are based on objectives from the Programme for Nordic Co-operation on the Environment and Climate 2019–2024. NKL wants to focus on projects that address climate and air pollution issues in the Nordic Region, the Arctic and globally.

3.5. EUROPEAN GREEN DEAL (EGD) AND INNOVATION FUND

In November 2018, the European Commission presented its strategic vision for a prosperous, modern, competitive and climate-neutral economy by 2050. Based on this, European Commission proposed in December 2019 an ambitious programme for the five years ahead. This new strategy for Europe is named the new ***European Green Deal (EGD)***. It includes a package of legislative proposals designed to reach the vision of a climate neutral Europe by 2050. In terms of transport, a vast field of actions within the Green Deal is open to reach this aim, and all transport modes are concerned. The EU Emission Trading System should be extended to maritime transport.

To finance EGD, European Commission has proposed the Innovation Fund[23], which aims for driving low-carbon technologies towards the market. It is one of the world's largest funding programmes for demonstration of innovative low-carbon technologies.

[23] *https://ec.europa.eu/clima/policies/innovation-fund_en#tab-0-0*

The Innovation Fund focuses on:

- Innovative low-carbon technologies and processes in energy intensive industries, including products substituting carbon intensive ones
- Carbon capture and utilization (CCU)
- Construction and operation of carbon capture and storage (CCS)
- Innovative renewable energy generation
- Energy storage.

The EU Emissions Trading System (EU ETS), the world's largest carbon pricing system, is providing the revenues for the Innovation Fund from the auctioning of EUR 450 million allowances from 2020 to 2030, as well as any unspent funds from the NER300 programme.[24] The Fund may amount to about EUR 10 billion, depending on the carbon price. In parallel to the Innovation Fund, the EU ETS provides the main long term incentive for these technologies to be deployed.

[24] **NER 300 is a funding programme pooling together about EUR 2 billion for innovative low-carbon technology, focusing on the demonstration of environmentally safe Carbon Capture and Storage (CCS) and innovative renewable energy technologies on a commercial scale within the EU.**

The Innovation Fund will focus on highly innovative technologies and big flagship projects with European value added that can bring on significant emission reductions. It is about sharing the risk with project promoters to help with the demonstration of first-of-a-kind highly innovative projects. The Fund will also support cross-cutting projects on innovative low-carbon solutions that lead to emission reductions in multiple sectors, for example through industrial symbiosis or business model innovation.

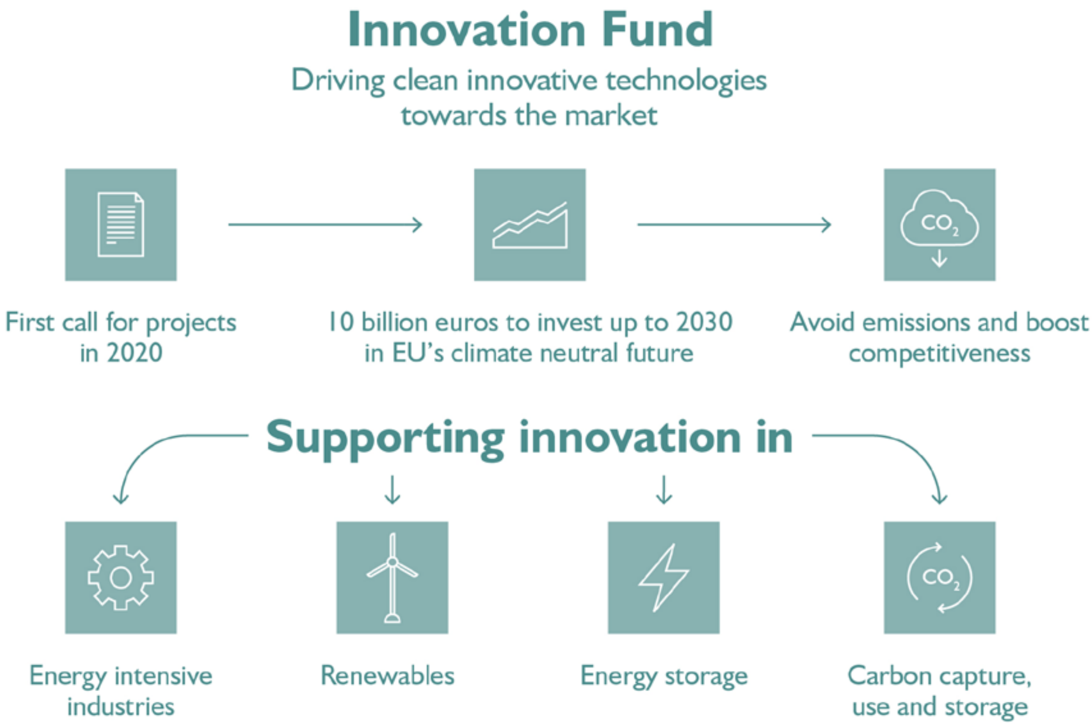
The Fund is also open to small-scale projects with total capital costs under EUR 7.5 million, which can benefit from simplified application and selection procedures.

The Innovation Fund grants can be combined with other sources of funding, for example: Horizon Europe, connecting Europe Facility, National Programmes or private capital.

The Commission aims to launch the first call for proposals still in 2020, followed by regular calls until 2030.

FIGURE 7
European Green Deal (EGD) and proposed Innovation Fund

Source:
https://ec.EUR opa.eu/clima/policies/innovation-fund



3.6. OTHER INCENTIVES TO SUPPORT INFRASTRUCTURE FOR ALTERNATIVE FUELS

3.6.1. POLICIES AND INCENTIVES AT THE EU LEVEL

Taxation of energy products and electricity in the Union is governed by Council Directive 2003/96/EC (referred to as the 'Energy Taxation Directive' ETD).

Pursuant to Article 19(1) of the ETD, in addition to some other provisions foreseen, the Council, acting on a proposal from the Commission[25], may authorise any Member State to introduce further exemptions or reductions in the level of taxation for specific policy considerations. There are three Member States with seaports located on the Baltic coastline that have been allowed to apply a reduced rate of electricity tax to electricity directly provided to vessels at berth in a port (referred as 'shore-side electricity' or 'onshore power supply' (OPS)). This kind of exemption is meant to give an economic incentive to the use of shore-side electricity by ships in order to reduce air pollution in port cities.

Sweden, Germany and Denmark have been provided under the Energy Taxation Directive with a permit to temporarily apply a reduced rate of taxation to shore-side electricity for ships.

In September 2018 the European Parliament's Transport Committee supported the removal of tax barriers for the uptake of onshore power supply in ports for ships at berth. As taxation has a major impact on the price competitiveness of alternative fuels and underlined that disparities in energy taxation for shore-side supply for ships should be addressed. Nowadays, electricity produced from the combustion of marine fuel on board ships is tax-exempt. However,

[25] https://ec.europa.eu/info/sites/info/files/swd_2019_0329_en.pdf **European Commission SWD(2019) 329 final Brussels, 11.9.2019**

when ships at berth are plugging into the shore-side electricity system, they have to pay taxes applied to electricity.

In October 2018 the European Parliament adopted a resolution, which concluded that it was time for real action to take place. Parliament called on the Commission to bring forward a revision of Directive 2014/94/EU on the deployment of alternative fuels infrastructure and to focus on its proper implementation, taking into account that only 8 of 25 Member States have so far fully implemented it.

The Commission's earlier evaluation (before 2018) of the National Framework Plans (NFPs) in member states has revealed differing levels of effort, ambition and available funding between countries and that the deployment of alternative fuels falls short of being comprehensive and evenly distributed.

3.6.2. INCENTIVES AT NATIONAL LEVEL INTRODUCED BY THE STATES' OWN POLICIES

EU member states should have their National Policy Frameworks (NPF) towards the broadest use of alternative fuels. It is part of an Action Plan for Alternative Fuels Infrastructure under Article 10(6) of AFI Directive 2014/94/EU.

In a few of the Baltic countries, national policy programmes were introduced aiming at activities to reduce Greenhouse gases (GHG) emissions and defining the state criteria that should be met by the local industry and transport sector.

More comprehensive information on National Policy Frameworks and financial incentives towards alternative fuels in the Baltic States can be found within Appendix 1 of this report.

3.6.3. INCENTIVES OF PORT AUTHORITIES

There is a group of EU ports, including several Baltic ports, with different charges based on environmental criteria. Some seaports in the EU states apply lower port fees based on environmental criteria such as:

The Environmental Ship Index (ESI) – is the main global index for the provision of port incentives to cleaner vessels. ESI identifies seagoing ships that perform better in reducing air emissions than required by the current emission standards of the International Maritime Organization.

The ESI formula evaluates the amount of nitrogen oxide (NO_x) and sulphur oxide (SO_x) that is emitted by a ship. The calculation also rewards vessels equipped to use available onshore power, which demonstrate fuel efficiency improvements over time, reducing carbon dioxide (CO_2) and particulate matter (PM) emissions. ESI scores range from zero that indicates ship's legal compliance to hundred that indicates close to zero exhaust emissions.

Green Award (GA) – The Green Award certification scheme is open to oil tankers, chemical tankers and dry bulk carriers from 20.000 DWT and upwards, LNG and container carriers and inland navigation vessels (Ports GA incentive providers e.g. Riga, Klaipeda and Hamburg).

Environmentally differentiated port charges or fairway dues may be options to further affect the air pollution cost of maritime transport. With respect to GHG emissions of maritime transport, the EU already works with global partners in the International Maritime Organisation (IMO) on further policy instruments.

Examples of the environmentally differentiated port charges in the Baltic Sea and North Sea are given in Table 1.

TABLE 1
Discounts incentives offered by several Baltic seaports

Discounts:	Examples of Ports providing discounts/ incentives:
Based on ESI	Helsinki, Tallinn, Rostock, Gothenburg, Ports of Stockholm (OPS), Aarhus, Kiel, Hamburg (OPS) and Oslo (Hamburg and Oslo are BPO members)
Based on GA	Riga, Klaipeda and Hamburg (BPO member)
LNG fueled ships	Tallinn, Vaasa, Pori, Gothenburg, Ports of Stockholm

4. REVIEW OF EU FUNDED PROJECTS IN THE BALTIC PORTS

During the last several years, projects dealing with deployment of sustainable infrastructure for alternative fuels in the Baltic Sea ports were co-financed from several different sources.

As listed in Chapter 3, the main EU programmes for financial support are – Connecting Europe Facility (CEF) Transport, CEF Energy, HORIZON 2020, INTERREG Baltic Sea Region, INTERREG South Baltic and INTERREG Europe.

4.1. INVOLVEMENT OF BALTIC PORTS IN EU CO-FINANCED PROJECTS

Over 600 transport projects were supported from all EU programmes since 2014, with a funding exceeding EUR 23 billion.From the main programmes, CEF Transport and Energy, about 80 projects were dedicated to maritime transport. Within CEF calls, with MoS priority about 20 projects were located in the Baltic Sea, and more than five were situated in the Baltic Sea and the North Sea.

In the CEF programme during 2014–2020 funding period a Cohesion Fund was introduced. Countries from the Baltic Sea Region included in this envelope are: Estonia, Latvia, Lithuania and Poland.

Within the CEF, Cohesion Envelope, by 2016 the entire available budget of EUR 11.3 billion has already been distributed for the financing of 244 projects of which 29 were located in Poland, 5 in Lithuania, 4 in Estonia and 3 in Latvia.

Table 2 gives a short description on selected infrastructure projects from CEF, Transport and Energy programmes during 2014–2019. Previous projects, granted financial support prior to this period, are not included.

TABLE 2
EU co-financed projects in the Baltic ports

Baltic Port	Country	Year	Project Name/Scope	Comments/ Programmes
Frederikshavn	Denmark	2014	Development of LNG bunkering facility	TEN-T, CEF Transport, EUR 14.5mln LNG Bunkering Facility
Helsingor Helsingborg	Denmark Sweden	2014	Converting two RoPax vessels to electric powered	TEN-T, CEF Transport, EUR 13.15mln HH Ferries Helsingor ApS
Helsinki Tallinn	Finland Estonia	2014	Twin Port 2 – Constructing a new generation LNG vessel – Megastar	TEN-T, CEF Transport, EUR 29.3mln
Turku Stockholm	Finland Sweden	2014	LNG bunker filling infrastructure Onshore Power Supply (OPS)	TEN-T, CEF Transport, EUR 6.6mln The Northern ScanMed Ports – Sustainable Maritime Links
Helsingborg Klaipeda	Sweden Lithuania	2014	HEKLA – LNG Infrastructure Facility Deployment	TEN-T, CEF Transport, EUR 11,9mln LNG station, Liquefaction station

Helsinki Lubeck	Finland Germany	2014	Upgrading Baltic MoS link Helsinki-Lubeck	TEN-T, CEF Transport, EUR 9,9mln Scrubbers and Infrastructure
Trelleborg Szczecin	Sweden Poland	2015	Blue Baltics – LNG infrastructure facility deployment	TEN-T, CEF Transport, EUR 16.6mln LNG station, Refuelling infrastructure LNG Terminal upgrade
Lulea, Oxelosund Raahe	Sweden Finland	2015	Bothnia Bulk – upgrade of year-round supply in the northern Baltic Sea	TEN-T, CEF Transport, EUR 9.4mln OPS, LNG carriers, upgrades
Turku Stockholm	Finland Sweden	2016	NextGen Link – maritime link, port interconnection, LNG vessels	TEN-T, CEF Transport, EUR 12.8mln LNG propulsion vessels
Helsinki Tallinn	Finland Estonia	2017	Twin Port 3 – Constructing a new generation LNG vessel - Megastar	TEN-T, CEF Transport, EUR21.4mln Port infrastructure upgrades
Ystad Swinoujscie	Sweden Poland	2017	Cargo capacity upgrade and LNG bunkering. Swinoujscie – Ystad maritime link	TEN-T, CEF Transport, EUR34.9mln LNG infrastructure, LNG bunker vessel, LNG ferry
Gdansk	Poland	2017	LNG small scale reloading terminal and bunkering study	TEN-T, CEF Transport&Energy, EUR1.7mln Small scale LNG reloading terminal
Kiel	Germany	2019	Blue Port Kiel – [...] sustainability upgrades in the seaport of Kiel	TEN-T, CEF Transport, EUR1.6mln OPS Facility
Karlshamn	Sweden	2019	The port of Karlshamn – [...] and provision of onshore power supply	TEN-T, CEF Transport, EUR 3.0mln OPS Facility

At the beginning of the period, more mixed projects (studies and works) were granted financial support. The mixed projects consist of studies (feasibility, location and design etc.) related to the planned infrastructure and the works projects include activities involving the deployment of sustainable infrastructure. At a later stage, only works' projects with a scope that concentrates on LNG infrastructure in ports and LNG dual propulsion systems on ships and OPS have received financial support. In addition, at the beginning of the period there were several projects with scrubbers installations on ships and these projects were interconnected with some of the Baltic ports.

However, within the last couple of years there are not too many works and infrastructure projects granted from CEF- general, blending and other calls among the ports in the Baltic Sea Region.

There is only one approved synergy project (between CEF- Transport and Energy programmes) and the scope is concentrated on studies only.

4.2. BALTIC PORTS WITH INFRASTRUCTURE PROJECTS FOR ALTERNATIVE ENERGY AND FUELS SUPPORTED FROM EU FUNDS

Infrastructure projects in the Baltic ports are mainly co-financed by CEF, Transport within MoS priority. In some projects a synergy is achieved between CEF Energy and CEF transport projects.

The general scope of sustainable energy projects are concentrated on: LNG bunkering facilities, onshore power supply (OPS), energy management and waste from ships in ports and initiatives providing alternative energy and other fuels supply. Besides, projects involving partnership among ports and ship-owners e.g. – retrofitting vessels with scrubbers, LNG and electrical propulsion and other alternative fuels initiatives have been granted financial support from EU programmes.

Other regional programmes- INTERREG Baltic Sea Region, INTERREG South Baltic and INTERREG Europe, generally provide financial support for implementation, studies, and research and pilot actions projects. There are a significant amount of environmentally sustainable projects granted from these programmes that include Baltic ports. Nevertheless, INTEREG programmes do not support large works projects with infrastructure deployment in the ports. However, some multinational projects involving most of the Baltic States and regional ports developed within the INTERREG programmes should be highlighted.

GoLNG[26]

The "Go LNG" project was a continuation of "MarTech LNG" project and part-financed by the INTERREG Baltic Sea Region programme. The project concluded in 2019 and it was focused on the development of demand and accessibility of LNG in the Baltic Sea Region. Activities aimed at the implementation of the EU Clean Fuel Strategy and the EU Directive on Deployment of Alternative Fuel Infrastructure in order to establish a strategic approach for the development of LNG infrastructure and promote its usage in the transport industry.

The project consortium consisted of 18 partners from 6 Baltic States and Norway and gathered all major regional LNG stakeholders that resulted in estimated business projects valued at EUR 46 mln.

The main project achievements were the establishment of Baltic Sea Region LNG business cluster and LNG competence centre. Moreover, the project helped transport and marine technology industries to be more competitive and establish the value chain for the BSR as a hub for clean shipping.

Connect 2 Small Ports[27]

The "Connect 2 Small Ports" is a project within the frame of the INTERREG South Baltic Programme 2014 – 2020. The project consists of 9 partners including a few regional ports and will conclude in the second half of 2021.

The challenges faced by the regional small ports are related to small freight volumes, missing smart specialisation, out-dated infrastructure, poor investments and a lack of new business models that could contribute to blue and green growth. The project aims to assist South Baltic small ports in reaching a satisfactory growth level by introducing tailor-made digitalization strategies to help them compete and provide for the sustainable development of the respective regions.

[26] **Go LNG project**
http://www.golng.eu/

[27] **Connect 2 Small Ports project**
https://connect2smallports.eu/

Main activities are based on five pillars: Mobilise & integrate supply and demand side; Learn & Exchange; Design & Confirm; Test & Future Transfer and Sustain & Internationalise.

Real Time Ferries[28]

The "Real Time Ferries" is a part-financed project and developed within the INTERREG Baltic Sea Region Programme 2014 – 2020. The project consortium involves 22 regional partners, including several Baltic ports and their stakeholders as well as 23 associated organisations.

The project assumes that 11 ferry real time demo lines will start operating from 2019. The lines cover the prevailing ferry line types of the Baltic Sea Region and involve major ferry operators. By the end of the project, the benefit is expected to be for all relevant transport actors to generate and to utilize ferry real time information for optimising intermodal transport chains for both goods and people across the entire region.

Project's main objective is sustainable transport and specifically the interoperability of transport modes. The aim of the RTF project is to increase interoperability in transporting goods and persons in north-south and east-west connections based on increased capacity of transport actors. Moreover, it aims at sharing real time departure and arrival times for ferries in the Baltic Sea Region to facilitate passenger and goods transport.

The majority of the listed projects, within Chapter 4, have a sustainable and environmental character. The main concept is focused on the development of infrastructure for alternative fuels and sustainable energy at the regional ports. Baltic Ports Organisation has been closely involved in several flagship regional projects as well as projects of common interest (PCI) and in the future will continue to support alternative energy initiatives on regional and EU level.

[28] **Real Time Ferries project** *https://www.seatrafficmanagement.info/projects/real-time-ferries/*

5. LNG BUNKERING IN THE BALTIC PORTS

LNG infrastructure facilities in the Baltic Sea Region have been constantly increasing since the beginning of the last decade. Baltic Ports Organization played a key role in the development of a network of regional ports with LNG facilities.

BPO initiated 'LNG in Baltic Sea Ports' projects as a response to the IMO's decision to establish new sulphur content limits in ECA from 1st January, 2015. The first project (co-financed by the EU, TEN-T, MoS priority), started in early 2012 and concluded at the end of 2014. The main aim of the project was to foster a harmonised approach towards LNG bunker filling infrastructure in the Baltic Sea area. Seven regional ports were involved in the project – Aarhus, Copenhagen-Malmö, Helsingborg, Helsinki, Stockholm, Tallinn and Turku. Each of the project partners was planning the development of port infrastructure to offer LNG bunker stations to ship-owners in the future. The works in the ports focused on pre-investment studies such as environmental impact assessments, feasibility analyses for LNG terminals or bunkering vessels, project designs, regional market studies, safety manuals, etc.

In 2013, BPO started a sequel project that involved three ports from Sweden - Helsingborg, Trelleborg, and Sundsvall also port of Rostock from Germany and port of Klaipeda from Lithuania. The second project concluded at the end of 2015 and concentrated on more advanced activities aiming at the deployment of small scale LNG bunkering infrastructure comprising planning, location and storage as well as bunkering vessel's design.

BPO initiatives 'LNG in Baltic Sea Ports', were jointly developed by 11 ports and resulted in the establishment of a network of ports with developed LNG bunkering infrastructure. This on its own is a significant achievement in meeting the future clean shipping strategy in the Baltic Sea Region and in the EU.

Consequently, the establishment of the network of ports with LNG infrastructure contributed towards the increased number of LNG powered ships- another achievement due to the joint efforts involving the regional Baltic ports.

There are a few bunkering methods currently performed on the approaching LNG fueled vessels. Most of the LNG storage tanks are based within the premises of the ports, however, in some cases the LNG is delivered by truck from distant terminals.

The Port to Ship (PTS) bunkering method is generally available in ports with medium to large size of LNG storage. This method allows bunkering directly from small LNG storage tank via pipe; small station or from an import or export terminal. It's characterized by higher refueling rates but in some cases may be difficult for the refueling vessel to get an easy access to the terminal.

Another type of LNG bunkering is performed by Truck to Ship (TTS) method and the truck can be loaded with LNG from larger storage terminals based away from the ports. An LNG truck is bunkering the connected ship via a flexible hose assisted by a mechanical arm or a crane. Majority of the LNG loadings in the Baltic ports are performed by TTS bunkering.

The Ship to Ship (STS) bunkering is more common in the last few years and it can be performed at ports and in some cases is possible to bunker at anchor. Usually the vessels are moored at the quay and LNG hose is handled by the bunker. STS is the most favorable bunkering option for ships with a short port turnaround time.

5.1. BALTIC PORTS WITH LNG BUNKERING ACTIVITIES

Small scale LNG bunkering activities in the Baltic ports started with a few ports performing TTS method to the approaching vessels. With the development of the technology higher bunkering rates and volumes were demanded by the shipping lines, therefore, some Baltic ports considered investing in more advanced refueling technologies. Some of the ports adopted a new technology and infrastructure allowing a direct PTS bunkering via pipeline. In addition, the first of its kind, bunkering vessel was developed in the Ports of Stockholm allowing for more flexible STS bunkering while the main ship was at berth. With time, the amount of Baltic ports providing bunkering possibilities gradually increased and matured, as a result faster and higher bunkering rates methods are now available.

Currently, within the Baltic Sea Region there are over 20 ports that have performed bunkering operations on LNG propelled vessels. Table 3 presents ports with small scale LNG activities, type of bunkering and country of origin.

TABLE 3
List of Baltic Sea ports performing LNG bunkering

LNG Port	Country	Start in Year	Type of Bunkering	Comments
Hirtshals	Denmark	2015	Port to Ship	TEN-T, CEF Transport, EUR 14.5mln LNG Bunkering Facility
Hou	Denmark	2015	Port to Ship	TEN-T, CEF Transport, EUR 13.15mln HH Ferries Helsingor ApS
Samso	Denmark	2015	Port to Ship	TEN-T, CEF Transport, EUR 29.3mln
Tallinn	Estonia	2016	Truck to Ship	TEN-T, CEF Transport, EUR 6.6mln The Northern ScanMed Ports – Sustainable Maritime Links
Helsinki	Finland	2014	Truck & Ship to Ship	TEN-T, CEF Transport, EUR 11,9mln LNG station, Liquefaction station
Hanko	Finland	2019	Truck to Ship	TEN-T, CEF Transport, EUR 9,9mln Scrubbers and Infrastructure
Oulu	Finland	2019	Truck to Ship	TEN-T, CEF Transport, EUR 16.6mln LNG station, Refuelling infrastructure LNG Terminal upgrade
Pori	Finland	2016	Truck to Ship	TEN-T, CEF Transport, EUR 9.4mln OPS, LNG carriers, upgrades
Tornio	Finland	2019	Port to Ship	TEN-T, CEF Transport, EUR 12.8mln LNG propulsion vessels
Turku	Finland	2016	Truck & Ship to Ship	TEN-T, CEF Transport, EUR21.4mln Port infrastructure upgrades
Rostock	Germany	2016	Port to Ship	TEN-T, CEF Transport, EUR34.9mln LNG infrastructure, LNG bunker vessel, LNG ferry
Klaipeda	Lithuania	2017	Port to Ship	TEN-T, CEF Transport&Energy, EUR1.7mln Small scale LNG reloading terminal

Gdansk	Poland	2019	Truck to Ship	TEN-T, CEF Transport, EUR1.6mln OPS Facility
Gdynia	Poland	2019	Truck to Ship	Bunkering of Ireland vessel
Gothenburg	Sweden	2017	Port, Truck, Ship to Ship (PTS & TTS, STS)	Bunker vessel Coralius M/T Ternsund
Lulea	Sweden	2017	Truck to Ship (TTS)	ships Haaga and Viikki; MS Greenland
Nynäshamn	Sweden	2013	Port to Ship (PTS & TTS)	Nynäshamn vessel Seagas
Stockholm	Sweden	2013	Ship to Ship (STS)	Bunker vessel Seagas Ferry MS Viking grace
Visby	Sweden	2019	Ship to Ship (STS)	Bunker vessel Kairos Ferry MS Visborg
Hamburg	Germany	2015	Port & Truck to ship (PTS & TTS)	Small scale terminal and bunkering station
Hamburg	Germany	2019	Ship to Ship (STS)	Kairos LNG bunkering vessel

Majority of LNG bunkering activities in the Baltic Sea Region are performed within the ports of Sweden and Finland.

FIGURE 8
Baltic Sea ports performing regular LNG bunkering activities as of October 2020

Source:
own elaboration

It is worth underlining some of the leading Baltic ports in LNG bunkering procedures. The Ports of Stockholm is the first port within the Baltic Sea Region to make LNG available as fuel for ships. M/S Viking Grace (figure 9), is the first large scale passenger ferry, bunkered and powered by LNG since 2013 that operates between the Ports of Stockholm in Sweden and Port Turku in Finland.

FIGURE 9
M/S Viking Grace,

Source:
Ports of Stockholm

The most preferred LNG bunkering method for vessels within the Baltic Sea Region is by truck. Several Baltic ports are currently performing the TTS method (figure 10). Ports are able to organise and perform TTS on a short notice and bunker various LNG propelled vessels.

FIGURE 10
TTS bunkering of Turva LNG propelled vessel

Source:
Ports of Helsinki

M/S Megastar (figure 11) is operating between the Baltic ports of Tallinn and Helsinki. The Tallink's ferry has been successfully performing the TTS bunkering method about 2500 times. The loading of the trucks with LNG has been sourced from different locations and regional countries.

FIGURE 11
TTS bunkering of M/S Megastar

Source:
Ports of Tallinn

However, currently the PTS and STS method is delivering a higher bunkering rate of LNG and is starting to be more common in the Baltic ports.

5.2. LNG BUNKERING VESSELS IN THE BSR

Within the Baltic Sea Region there are three LNG bunkering vessels operating that can perform LNG transfer services in proximity of the ports. Currently, all three LNG bunker vessels – Seagas, Coralius and Kairos are operated by Gasum[29].Gasum is a Finnish owned energy company that aims to develop an ecosystem based on renewable biogas, natural gas and LNG.

FIGURE 12
STS bunkering of M/S Viking Grace

Source:
Ports of Stockholm

Seagas (figure 12) is the world's first dedicated LNG bunker vessel. The converted old ferry to a small bunker vessel has a capacity of just 167 cbm. The Seagas receives LNG from the Nynäshamn LNG Terminal and has been performing bunkering operations for the Viking Grace LNG-fueled ferry in the Port of Stockholm since 2013. Since then, over 2000 successful STS bunkering operations have been performed on a regular basis.

Coralius (figure 13) is the first dual fuel LNG bunker and feeder vessel built in Europe. The 5800 cbm vessel has a dual fuel engine and was optimised for safe and reliable bunkering operations. The bunker vessel performs STS services in the region around Port of Gothenburg. In addition, the port's harbours provide PTS and TTS bunkering to LNG vessels as well.

FIGURE 13
STS bunkering of Ternsund by Coralius
Source: Port of Gothenburg

Kairos (figure 14) is the latest Gasum vessel, acquired from Nauticor, and is one of the largest dedicated LNG bunker supply vessels in the world. The 7500 cbm vessel is equipped with a dual-fuel engine using LNG as main fuel and was designed to supply LNG to various vessels in Northwest Europe. The bunker supply ship operates from Lithuania to Finland, Sweden and Estonia as well as Latvia and Russia.

FIGURE 14
First ship-to-ship SIMOPS LNG bunker operation in the Port of Helsinki. Wes Amelie – Kairos
Source: Port of Helsinki

6. ONSHORE POWER SUPPLY IN BALTIC PORTS – RECENT STATUS AND DEVELOPMENT

Onshore power supply (OPS) is known under many names such as: High Voltage Shore Connection, Alternative Maritime Power, Cold Ironing, Shore-to-Ship Power, Shore Connection Supply and Shore Side Electricity. The OPS technology is widely recommended as a means to reduce the noise nuisance, air pollution and greenhouse gas emission of vessels while at berth in ports.

Ships at berth remain consumers of energy, as the on-board environmental control, cargo handling, lighting and control systems must be maintained to keep the ship operational during unloading procedures or temporary stay. The electricity is generated by the auxiliary engines, this in turn means that docked ships with functioning engines remain a source of noise, air pollutants such as sulfur oxide SOx, nitrogen oxide NOx and particulates and greenhouse gas pollutants, such as carbon dioxide CO2. Consequently, all pollutants negatively affect the climate, local air quality and living conditions, this in turn affects the health of port and vessel employees as well as nearby residents. Therefore, reduction of the pollutants is an important task and especially in the case of internal ports rooted deeply in city centers.

An important stimulant supporting the development of OPS in ports is the Directive 2014/94/EU, which states that all ports (with a high pressure on those in the TEN-T Core Network) should be, equipped with OPS solutions by the end of 2025. It is also worth noting that the Directive 2014/94/EU is currently subject to revision under "Fit for 55" and could be referred to the provisions of the proposed revised directive under "Fit for 55". Ports, where the investment costs would be too high in relation to the potential environmental benefits, are exempt from the directive. Moreover, the OPS infrastructure is also encouraged by the European Green Deal as an important element of achieving the goal of zero emissions at berth. As a result, the increased focus on green technologies and reduction of greenhouse gasses and air pollution indicates a bright future for the development of OPS infrastructure.

6.1. ONSHORE POWER SUPPLY TECHNOLOGY

The OPS is an alternative technology that facilitates ships with the required stationary energy, and thus reduces the above listed toxins. The equipment is connected to the local electricity grid and as a result there is a complete reduction of pollutants from auxiliary engines. Figure 15 represents a general design of a high voltage OPS installation and Figure 16 shows an example of OPS connection.

FIGURE 15
General design of a high voltage installation

Source: EAFO

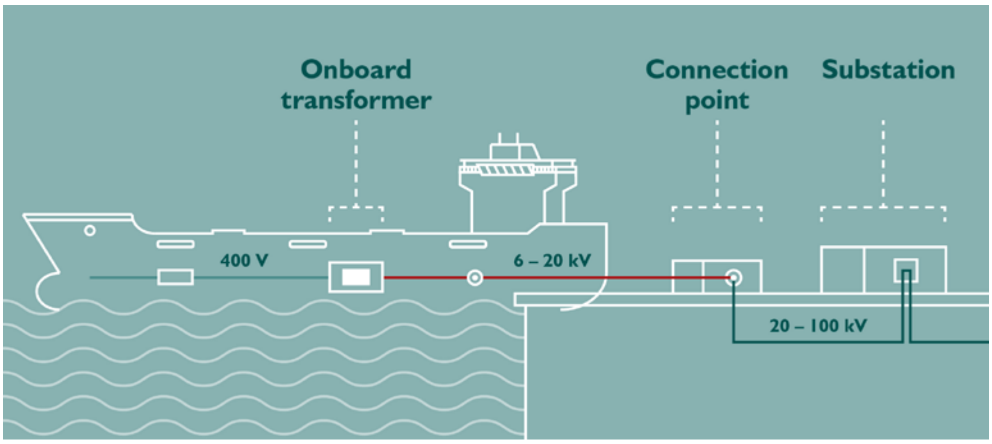
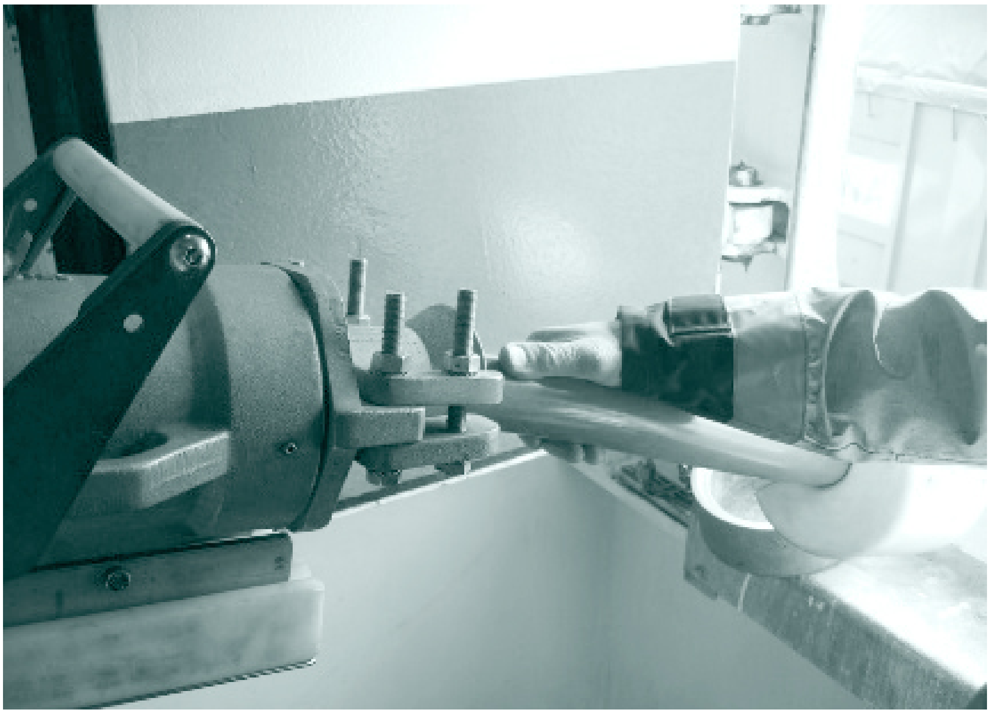


FIGURE 16
OPS connection on Stena Jutlandica
Source: Stena Line



Installation of OPS for smaller vessels with lower power demand, a 100kW, is used extensively as the equipment is able to use normal grid voltage and frequency and as such do not require high investments. When it comes to units that require energy above 100kW, both installations (on the shore side and on-board) may require additional investments as frequency converters, high power connectors and an increase of the grid capacity.

The OPS technology can be divided in two additional categories – a low voltage OPS, composed of a multi-cable system (figure 17) and high voltage (HV) OPS system.

FIGURE 17
Old low voltage OPS – Port of Majnabbe
Source: Stena Line

Currently, the HV technology is becoming more popular and available in the Baltic ports as it lowers the complexity of the connection process. In addition, it is better suited for ships with high energy demands such as ferries and cruise ships and it is composed of a single cable system (examples of such systems are presented in figures 18, 19, 20 and 21). Low voltage installations are mostly used for inland, domestic and port auxiliary vessels, whereas the strong development of high voltage OPS installations in the Baltic Sea Region can strongly be attributed to the high amount of operating ferries.

FIGURE 18
High voltage OPS – Port of Karlskrona
Source:
Stena Line

While the technologies used for construction of OPS infrastructure are diverse and handled by various cable cranes used in different ports the general system functionalities remain the same.

FIGURE 19
OPS – Port of Trelleborg

Source:
Port of Trelleborg

FIGURE 20
OPS – Port of Ystad

Source:
Port of Ystad

FIGURE 21
OPS – Port of Värtahamnen

Source:
Stockholm Ports

The most important aspect for the functionality of an OPS connection point is the connection time of vessels to the power grid. In the older, low-voltage systems case, the process often needed several cables to be connected to the vessels resulting in a significant amount of time being used on the connection procedure. Whereas the high voltage system is connected by a singular cable and takes about 15 minutes to connect. Although, high voltage systems require more safety measures that need to be considered.

Alternative new OPS solutions can also include mobile connection points, which allow berths and ports to be more versatile and serve different types of vessels at them. An example of a mobile OPS system is presented in figure 22.

FIGURE 22
OPS – Port of Hamburg

Source:
Christian O. Bruch / LAIF.

Taking into account the recent increase in port digitalization, alternative systems become more autonomous and can even provide wireless charging solutions that can be automated. Automated and wireless OPSs are currently utilised for smaller electrical ferry units. In addition, an auto mooring solution can be added to the system that can save more time and energy. An example of OPS systems with wireless charging solutions is presented in figure 23.

FIGURE 23
Wireless charging system

Source:
Wärtsilä

With the continuous evolution of OPS technologies new solutions such as mobile OPS containers are available. The potential mobility offered by them, contributes to minimize some of the problems related to the high need of cooperation between port authorities and ship owners (examples are presented in figures 24 and 25).

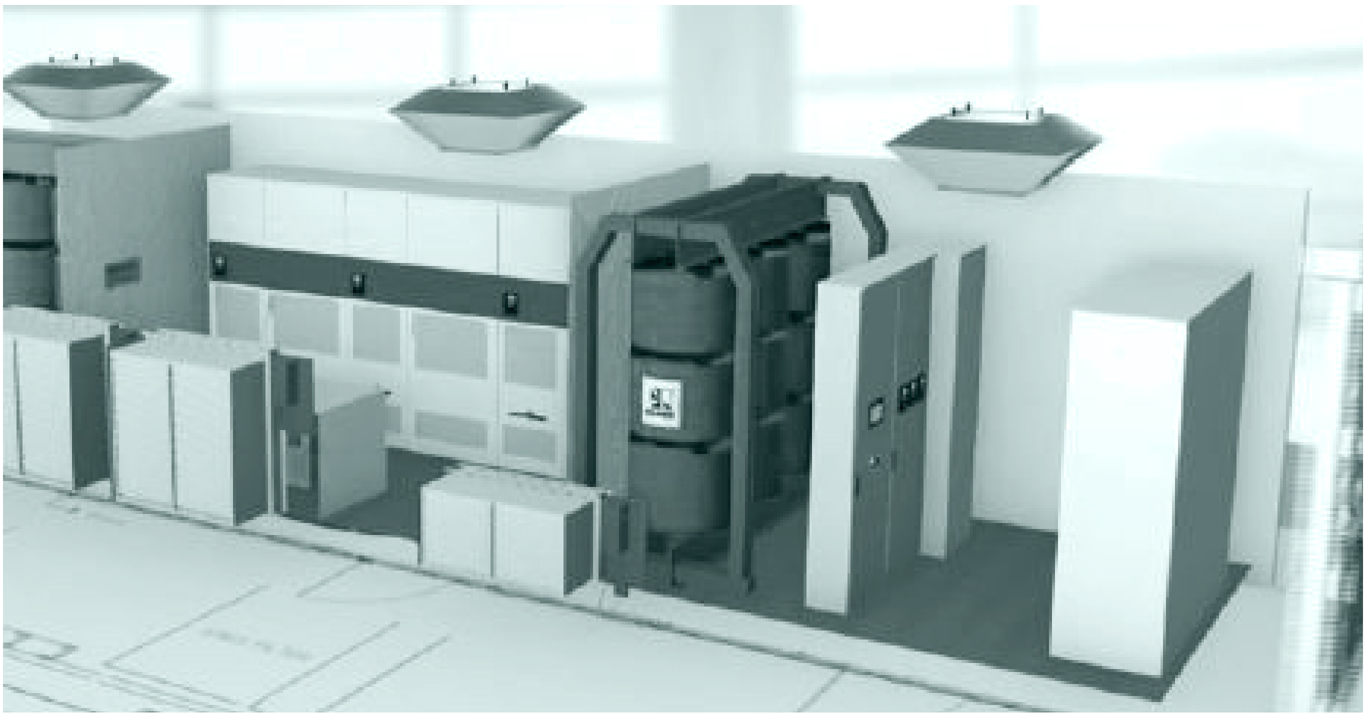
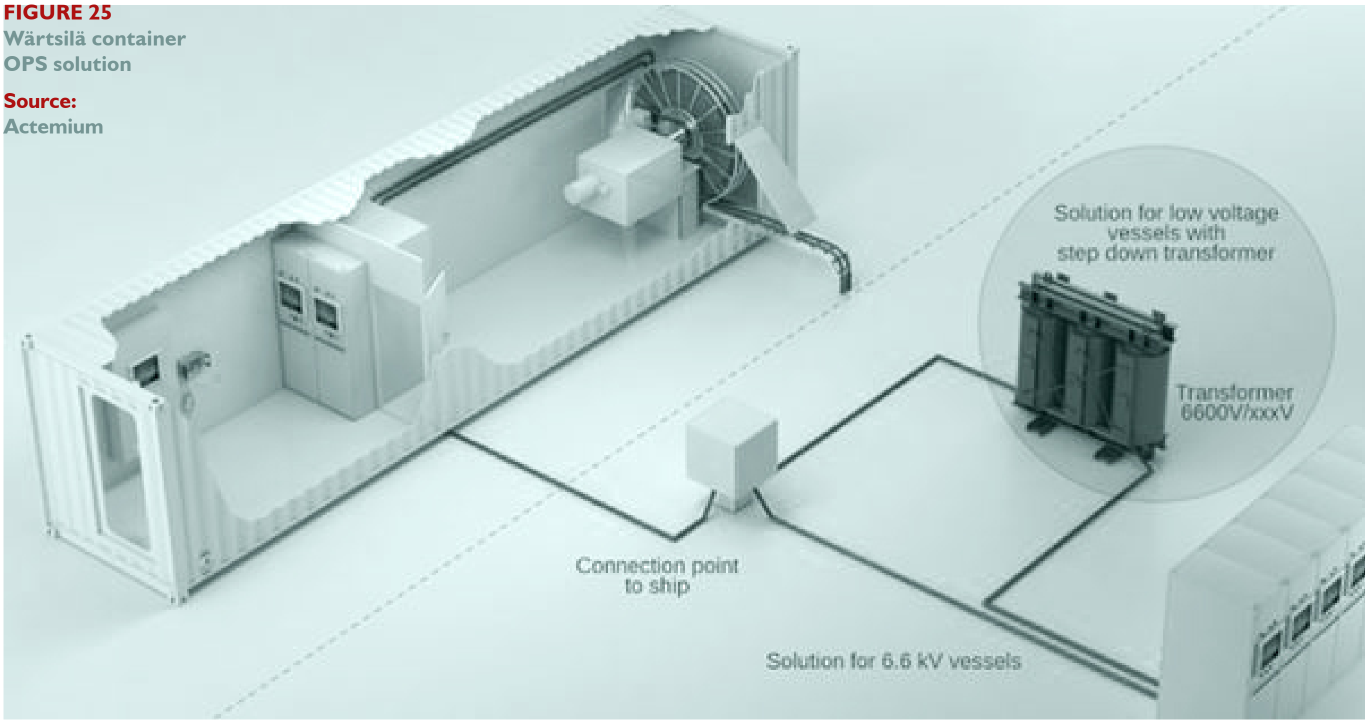


FIGURE 24
Actemium mobile OPS plant

Source:
Actemium

FIGURE 25
Wärtsilä container OPS solution

Source:
Actemium



6.2. EXISTING AND PLANNED ONSHORE POWER SUPPLY (OPS) INSTALLATIONS

[6] **Nordregio research results *"Shipping routes and OPS ports"***

Source
https://nordregio.org/maps/shipping-routes-and-ops-ports/

Table 4 presents some of the current OPS installations existing in Baltic and North Sea Region ports. In comparison to Nordregio's research from 2016, it is noticeable that the number of existing OPS in the ports within the Baltic Sea Region has increased more than twice since in 2016[30]. Starting from 11 and gradually expanding to 27 OPS ready ports in 2022. Hence, the total number of OPS ports in the Baltic Sea Region has tripled over the last few years.

Country	Port	Types of vessel	Connecting points	Voltage (kV)	Frequency	Max Power (MW)	Year
DENMARK	Helsingor	Ferry	1	11		4,5	2018
	Kaldunborg			0,4		0,065	
	Rønne	Ferry		0,4			
FINLANDIA	Kemi	RoPax	1	6,6	50		2006
FINLANDIA	Kotka	RoPax	1	6,6	50		2006
	Oulu	RoPax	1	6,6	50		2008
	Helsinki	Ferry	1	6,6 / 11	50/60	4	2012
	Turku	Bulk		0,4			
ESTONIA	Tallinn (Old City Harbour)	RoPax	5	11		14	2020

Country	Port	Types of vessel	Connecting points	Voltage (kV)	Frequency	Max Power (MW)	Year
GERMANY	Hamburg	Cruise ship Container ships (2020)	1	11		9,8	2016
	Kiel	Ferry, Cruise ship	1	10		4,5	2019
	Lubeck	Cruise ship, RoPax, RoRo	2	6,6; 11	50	0,5; 2; 3,5; 9,8	2010
NORWAY	Oslo	Ferry	2	11	50	3,75: 4,5	2017
SWEDEN	Gothenburg	RoRo, RoPax	6	11; 6,6	50/60	1,25-2,5	2000
	Trelleborg	Ferry	6	10,5	50	3,6	2017
	Helsingborg	Ferry	1	11; 0,4		4,5	2018
	Ystad	RoPax	4	11	50/60	6,25-10 5	2013
	Visby	Ferry	4	11	50/60	5	2019
	Karlskrona	RoPax	1	11		2; 2,5	2011
	Port of Frihamnen (Stockholm)	RoPax	2	0,69	50	4 (2*2)	1990
SWEDEN[31]	Port of Stadsgården (Stockholm)	RoPax	2	0,69	50	4 (2*2)	1980
	Port of Värtahamnen (Stockholm)	RoPax	2	11	50	6 (2*3)	2019
	Port of Nynäshamn (Stockholm)	RoPax	1	6,6	60	1,8	2017
	Piteå	RoRo	2	6	50		
LATVIA	Riga			0,4		0,25	
LITHUANIA	Klaipeda	Oil, Product tankers, Barges,		0,4		0,015; 0,4	
POLAND	Port of Gdynia	Ferry		11	50/60	3,5	2021

TABLE 4
Existing OPS installations in Baltic Sea Region and North Sea Region

Source:
Motus research, Actemium, EAFO research

[31] https://www.sspa.se/sites/www.sspa.se/files/field_page_files/kaj-el_final_report_0.pdf

Within Europe, Norway is the leader in OPS systems availability in ports. Most of the Norwegian major and smaller ports have existing OPS installations. In addition, some ports and ferry crossings support OPS infrastructure specifically constructed for fully electrical ferries.

Sweden and Finland are the leading Baltic countries with existing port OPS installations. The remaining Baltic States maintain mostly low voltage installations or are during the planning phase of more OPS systems. A clear relation between the number of calls and the viability of OPS can be seen in the example from the existing installations in the ports. In the Baltic Sea Region, most of the ports declare that types of vessels that use OPS installations are ferries, ro-ro and RoPax. Therefore, vessels operating regular lines, with a significant amount of time dedicated to loading and unloading passengers and goods are mainly using the OPS technology. Extensive activity of vessels will potentially mean a faster investment return for ports. Similarly, ship owners will benefit more from OPS installations at common destinations where their fleet spends a prolonged amount of time (e.g. cruise and ferry activities). Moreover, benefits can be noticed in the nature of pollution emission, where ports with high intensity of cruise calls will significantly lower those emissions, where vessels will use shore power instead of auxiliary engines.

In the research carried out by Motus Foundation, ports from the Baltic Sea Region and some ports in the North Sea have shared their plans and actions towards building OPS installations in the future. There are several ports within the Baltic Sea Region that plan to deploy new OPS installations as presented in table 5.

TABLE 5
Regional ports and terminals with ongoing development of OPS systems

Country	Port	Planned Investments
Poland	Port of Swinoujscie	Planned ferry terminal in the mid of 2023, the system will enable the power supply to ships at 5 ferry berths with a frequency of 50 Hz and 60 Hz with a rated power of up to 3 MW
	Port of Gdansk	Planned 40 kW, 0.4 V / 50 Hz OPS
Denmark	Port of Aarhus	Planned cruise OPS from spring 2023.
Finland	Port of Helsinki	Planned 2 connection points for ferries in west harbour
		Planned 3 cruise ship mobile connection points at Hernesaari, 11kV, 60Hz, 20MVA
		Planned 2 RoRo/RoPax connection in Vuosaari
		Planned Cruise ship connection in Katajanokka
	Port of Rauma	Planned five shore-side electricity connections points/power outlets for the vessels in 2022 for roro and storo traffic in four different quays. Currently there are no OPS available in the port.
Norway	Port of Oslo	Planned for cargo and container port,
		Plannned for containership (3 outlets) Total capacity of 1,6 MW
		Planned mobile unit, for vehicle carries 0.4/0.44/0.69kV, 50/60Hz 1000kVA

Country	Port	Planned Investments
Sweden		Planned: Stockholm Norvik 11 kV 50 Hz Ferries 2022 Kapellskär 11 kV 50 Hz Ferries 2022
Germany	Port of Kiel	Planned 2 OPS plants for cruise and ferries, 11 kv and 6.6 kV, and both 50 and 60 Hz, by the end of 2023

Figure 26 represents Current and planned OPS in the Baltic Sea Region.

FIGURE 26
Current and planned OPS in the Baltic Sea Region

Source:
Own elaboration

6.3. CHALLENGES AND BARRIERS FOR OPS INSTALLATIONS

Some of the main factors that cause slow OPS development are the high investment costs related to the installations. Those costs, among others, are caused by the lack of standardization. An important technological problem that still remains today is that vessels use either 50 Hz (EU standard) or 60 Hz electrical frequency. Therefore, the ability to utilize OPS is dependent on frequency converters (both shore and vessel sides) and standardization of the frequencies used is of high importance for any future OPS investments. As a result, the ports must consider installation of a frequency converter, which adds a significant sum to the total investment costs and any modernization and standardization plans of the currently operating vessels are associated with significant costs to the fleet operators.

Standardization of OPS technological solutions, both onshore and on-board, would be the main factor leading to its growing interest, while at the same time potentially reducing the investment costs and rate of investment return. Another potential growth factor for OPS would be reducing the differences in electrical energy costs at ports. However, such changes should take place on an international scale, as individual national changes to OPS energy costs will only be enough to address the issue on a national and regional scale.

In other cases, the higher electrical energy costs in comparison to the costs for auxiliary engine fuel as well as difficulties in communication between ports and ship owners. While the electrical energy costs can be beneficial to use OPS energy in one port, other port destination can be unfavourable and the higher energy costs could make the overall investment not feasible.

The vessel's calls in ports can increase or decrease in numbers and therefore, can affect the feasibility of the OPS systems at individual berths. Thus, OPSs are in general considered as long term investments, where preparing a proper OPS deployment strategy will minimize initial investment as well as time frame to both- port authorities and ship owners.

As a result, it is easier and less cost intensive to prepare such installations for newly constructed vessels or port berths. Retrofitting older vessels usually involves additional investment costs such as replacing the older electrical installation, cutting hatches for cable access, as well as preparing storage location for the plugin system and energy converters. In the case of installation of OPS in older ports, additional investment costs can be influenced by the preparation of shafts and tunnels for the cabling system between the powering point and the substation, as well as building a substation to connect the system with the energy grid. In those cases, of key importance is the cost efficiency of choosing appropriate installations, and the investment rate of return not only for ports but also for ship operators.

A substantial amount of OPS infrastructure focuses primarily on ferries, RoRo and RoPax vessels, while infrastructure for cruise ships is being actively introduced. However, OPS for cruise ships is limited by the viability of such investments as it is highly dependent on the number of port calls. Relationship between the number of ships and average time spent at harbour is an important factor for calculations of potential benefits brought by OPS.

The number of cruise vessel calls within Baltic Sea Region fell significantly in 2020 and 2021 over 2019 because of the coronavirus (COVID-19) pandemic. Profitability of investment in OPS is largely dependent on the number of ships calls. Therefore, the pandemic was an unfavourable time to plan OPS infrastructure for cruise vessels. The predictions for 2022 are rather positive for cruise traffic, however, the war in Ukraine could make the cruise ship market hard to forecast in a short and medium term plan.

Considering the above, further ecological benefits depend highly on the source of power generation and how carbon intensive, regional or national energy as well as how high is its share of renewable energy sources. Collaboration between ship owners/shipping lines and port authorities is crucial, as the OPS installations have to fit like a "glove" to the ships that intend to use them. This is of high importance as not all berths are accessible by the different types of vessels.

7. ELECTRIC PROPULSION VESSELS

[32] https://oceanvolt.com/#blogPage

"Today's electric motor technology has already moved from the open road to the open ocean"[32]

Chapter 7 encompasses maritime battery applications related to pilot projects, which have focused on research and safety activities and the majority of effort has been put on implementation of battery technology in the maritime sector. The results were needed to understand how batteries will react in the maritime environment – primarily from the perspective of power system integration and operation.

With the global goal set to cut greenhouse gas emissions and become carbon-neutral by 2050, the shipping industry and the ports are striving for more advanced battery systems and storage of green energy received from renewable sources.

7.1. ELECTRIC PROPULSION VESSELS TECHNOLOGY

Nowadays, decarbonisation is an essential strategy in the European Union policy and has become a higher priority for the transport sector and the maritime industry. On a worldwide scale, the cutting of Green House Gases (GHG) emissions, as maritime transport is concerned main goals to be achieved, are addressed mainly to the shipping industry. However seaports, especially those operating close to cities and town centers, need to cope with local emissions and noise generated by port operations. One of the ways to reach decarbonisation targets and minimalize noise levels in the ports is to apply electric battery or hydrogen fuel-cells technologies. These technologies are known as alternative fuels or so-called transition fuels. Today, there are a few electric power solutions that are available for a short distance sea transport, by linking islands with mainland and coastal zones as well as inland waterways in Europe.

There are a few main factors favouring lithium-ion batteries as more attractive to the shipping industry:

- significant drop in price,
- new regulations requiring low-emission or emission-free operation in some regions.

Nevertheless, this technological solution is still a challenge to apply in order to enable storage of electrical energy for propulsion in different types of vessels. Additional research on the capacity and durability of battery systems is necessary to find and apply technologies that will meet customized needs of different types of vessels.

At the present time, electric ships are an attractive option for short sea shipping and inland water transport used at short distances. However, the long distance ships are not an attractive segment at the moment due to the lack of advanced technology and higher implementation costs.

Within the Baltic Sea Region, there are some selected maritime battery applications in the regional ports and on ferry links. There are examples of hybrid and fully electric ferries already in operation.

[33] **SCANDLINES company's motto in Green Agenda**

https://www.scandlines.com/about-scandlines/greenagenda

"Conventional ferry operation is the past, hybrid is the present, and zero emission ferries are the future"[33]

FIGURE 27
Scandlines routes in the Baltic

Source:
https://www.scandlines.com/tickets-und-tarife/tickets-and-prices

7.2. VESSELS WITH HYBRID PROPULSION

The hybrid ship propulsion means that the vessel can be propelled in two ways: electrical (via battery power or diesel electric driven) or mechanical (directly diesel driven). Such a combination allows the advantages of diesel electric propulsion at low power, as well as the benefits of direct diesel driven propulsion at high power.

7.2.1. SUSTAINABLE TRAFFIC MACHINES I AND II – THE GREEN LINK BETWEEN SCANDINAVIA AND CONTINENTAL EUROPE

This pilot project was carried out by Scandlines - ferries operator in two phases in the period from 2012 to 2015. The innovative concept had been planned to be tested within the taken actions. The main objective was to reduce the vessels' total energy demand to be able to reach a goal of zero emission on Rødby (Denmark) -Puttgarden (Germany) link within a few years.

The first phase involved the installation of hybrid propulsion and exhaust gas cleaning systems on two RoPax vessels owned by Scandlines: M/V "Prinsesse Benedikte" and M/V "Schleswig Holstein". Both ferries operate on the route Rødby and Puttgarden. The process was completed in 2013. The second phase involved the state-of-the-art technology hybrid propulsion on the sister vessels of the above mentioned vessels: M/V "Prins Richard" and M/V "Deutschland" and was completed in 2014.

Energy savings were achieved by installing new sets of propellers and a hybrid drive, which at the time represented the world's largest ever marine hybrid solution (battery's capacity of 2,6 MWh).

The installed batteries reduced the fuel consumption and the system contributed to increased safety and reliability of the vessels and prevented blackouts.

[33] The project TEN-T Priority Project 21 (Motorways of the Sea) covers the necessary technical, supply and marketing measures in preparation of the upcoming environmental requirements, in particular meeting the SECA (Sulphur Emission Control Areas) regulations of IMO (International Maritime Organisation), as well as EU's stricter sulphur limits for marine fuels, used by ships operating in the Baltic Sea, as from January 2015.

The project was implemented and managed by Scandlines Deutschland GmbH and Scandlines Danmark A/S, acting as ferries and port/terminal operators. It was co-financed in 2012, by EU within TEN-T, Multi - Annual Programme as part of Priority Project no 21[34].

7.2.2. HYBRID FERRIES ON THE ROSTOCK – GEDSER ROUTE – MOTORWAY OF THE SEA LINK PROJECT PART 2

Another project by Scandlines was carried out from 2014 to 2017 as a continuation of the first one completed in 2010-2014. The aim of it was to upgrade and increase maritime capacity of the Rostock (Germany) – Gedser (Denmark) motorway of the sea. The project involved a conversion of the two RoPax vessels M/V "Berlin" and M/V "Copenhagen" into ships with hybrid propulsion to secure environmental and efficiency compliance. Both above vessels belong to the world's largest fleet of hybrid ferries and have been in operation since 2016.

FIGURE 28
M/V "Berlin" in Rostock port
Photo by Annemarie Zinck

Source:
Scandlines
https://www.scandlines.dk/om-scandlines/presse

The hybrid-propulsion on these two ferries uses marine fuel and provides energy from batteries, which guarantees optimal engine power loads. Each engines on-board the two RoPax ships are equipped with an adequately dimensioned hybrid wet exhaust gas cleaning device.

The shipowners ambitious environmental goal was achieved by combining traditional diesel power with battery power, so the company had managed to reduce CO_2 emissions on these two RoPax ships.

TABLE 6
Details of MoS Rostock – Gedser hybrid ferries

Project name:	Motorway of the Sea Rostock-Gedser
Location	Germany – Denmark
Ports	Rostock (D), Gedser (DK)
Vessel names:	"Berlin" and "Copenhagen"
Vessel type/ capacity:	Passenger and car ferry (RoPax); Pax 1300 cars 460

Owner:	Scandlines
Solutions and scope of supply:	1x4500 kWh energy storage system output 1x1500 kWh energy storage system capacity
Main benefits:	CO2 emission reduction up to 15%

Terminal improvements and berths adaptation for this MoS link encompassed an installation of sludge treatment facility in the Port of Gedser and an appropriate caustic-soda (NaOH) supply facility in the Port of Rostock. This facility was provided as required for the scrubbing process on-board of the two new buildings.

7.2.3. STENA LINE'S BATTERY POWER INITIATIVE ON "STENA JUTLANDICA" FERRY

Stena Line is introducing different projects on the company's way to search and find alternative and sustainable fuels for its ferries fleet. One concept being developed is a three-step innovation and it is an important part of Stena Line's sustainability strategy. This is a battery application on "Stena Jutlandica" RoPax, which operates between Gothenburg in Sweden and Frederikshavn in Denmark.

The works commenced in spring 2018 and later that year "Stena Jutlandica" was converted to a battery hybrid vessel. In the third final step of innovation the vessel will be able to operate for around 50 nautical miles – the distance on route Gothenburg – Frederikshavn, solely on electrical power. Callenberg Technology Group has been responsible for 1 MWh battery installation on-board ferry. The ship is assumed to charge green electricity in both ports and by her aux engines.

"Stena Jutlandica" was to be the first large plug-in hybrid RoPax in the world and the first step towards a fossil free ship Göteborg-Fredrikshavn 2030 by Stena Line.

FIGURE 29
"Stena Jutlandica" October 2018

Source:
"Stena Jutlandica" Photo by STENA LINE

7.3. ELECTRIC POWERED FERRIES

7.3.1. ZERO EMISSION FERRIES – GREEN LINK ACROSS THE ORESUND (DK/SE) REDUCING EMISSIONS FROM SHIPS

HH Ferries Group owns the ferry route between Helsingborg (in Sweden) and Helsingor (in Denmark), which operates under the trademark ForSea since 2018 (earlier: Scandlines Helsingborg-Helsingor).

The departures on this link are every fifteen minutes with a travel time of 20 minutes and this link enables transports up to 50,000 passengers and 9,000 cars as well as 1,600 buses and trucks across Øresund on a daily basis (7,1 M passengers, 1,3 M cars, 452K trucks 16,5 K buses annually).

The Zero Emission application involved a conversion of two existing RoPax vessels from marine gas oil to all-electric powered batteries. These were M/F "Tycho Brahe" and M/S "Aurora" ferries. The pilot initiative was carried out from 2014-2017 and the essential project was implemented from 2018. The action was co-financed by the EU Connecting Europe Facility CEF-Transport. Zero Emission Ferries green link across the Oresund (DK/SE)-reducing emissions from ships received EU support of EUR 13 million.

Within the Zero Emission concept ABB supplied the complete power and propulsion systems for two vessels, so they have become the world's largest emission-free electric ferries. The modernizations had utilized turnkey ABB solutions including batteries, an energy storage control system and On-board DC Grid technology.

The batteries are installed in four 32-foot containers mounted on top of the ship alongside two deck-houses containing transformers, converters and cooling systems for the batteries. The diesel engines were left and they function only as a backup to electric power.

FIGURE 30
Battery containers on "Tycho Brahe", Photo by Bengt Oberger

Source:
Scandlines
https://commons.wikimedia.org/wiki/File:Battericontainrar_Tycho_Brahe.jpg

In conjunction with the ship conversion, the required power provision and charging installations in the ports at ferry terminals were realized. Ferry terminals in Helsingborg and in Helsingor are located in densely populated areas, therefore the action has contributed to significant improvements of air quality. The project supported the development of clean Motorways of the Sea by testing and deploying new technological solutions in real operational conditions.

FIGURE 31
Port of Helsingborg, "Tycho Brahe" ferry

Source:
ForSea
https://www.skyfish.com/p/forsea/929497/25832663?predicate=created&direction=desc

In both seaports considered in this project, at berths being the ends of the ferry route Helsingor – Helsingborg there have been the first automated shore-side charging stations mounted using ABB industrial robots. Such a solution enables optimization of the connection time and therefore maximizes the charging time needed. The sub stations in each of two ports are medium voltage shore connection switchboards. Charging time lasts 5min 30s in Helsingor and 9 min in Helsingborg. The charging power is 11.2 MW and 10.35 MW respectively.

FIGURE 32
Automatic Shore Connections of ABB

Source:
https://new.abb.com/marine/generations/technical-insight/short-sea-solution

This industrial robot's arm is laser guided and it connects automatically the batteries to the grid. The robot orients itself using laser scanning and reaches out and grabs the electric cable from the ship. When the ferry is moored the charging of batteries starts. This technology is mounted in towers (as shown in figure 33)

FIGURE 33
Port of Helsingør, robot battery charge, Denmark

Source:
ForSea
https://www.skyfish.com/p/forsea/929497/27753430?predicate=created&direction=desc

TABLE 7
Details of Zero Emission Ferries

Project name:	Zero Emission Ferries
Location	Denmark – Sweden
Ports	Helsingor (DK) , Helsingborg (S)
Vessel names:	"Tycho Brahe" and "Aurora"
Vessel type/ capacity:	Passenger and car ferry (RoPax); Pax 1100/1250 cars 238/240
Owner:	HH-Ferries Helsingborg AB, ForSea Helsingor A/S
Supplier:	ABB
Solutions and scope of supply:	— 4160 kWh batteries storage capacity — Battery racks — Energy storage control system — On-board DC Grid™ — Automated shore-side charging stations with laser controlled robot arm — 6-9 minutes of charging for a 20-minute crossing
Main benefits:	Emission-free operation; batteries installed on two ferries have contributed to the air quality improvement in both ports and reduction of noise in these densely populated areas. Overall emissions reduction by 50% (due to Forsea-2018)

FIGURE 34
ForSea Battery Power – Robot

Source:
ForSea
https://www.skyfish.com/p/forsea/all-files/35330574?predicate=created&direction=des

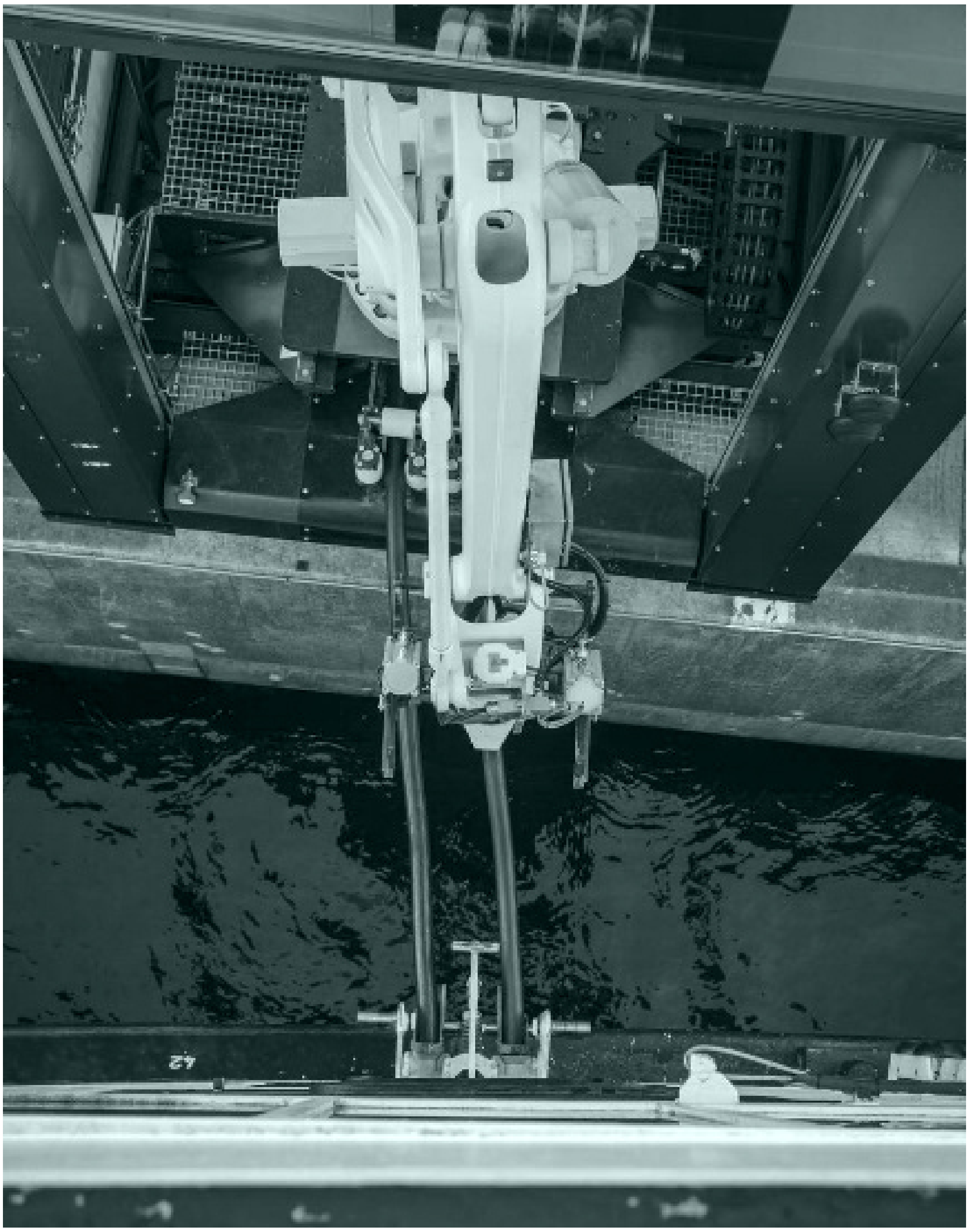
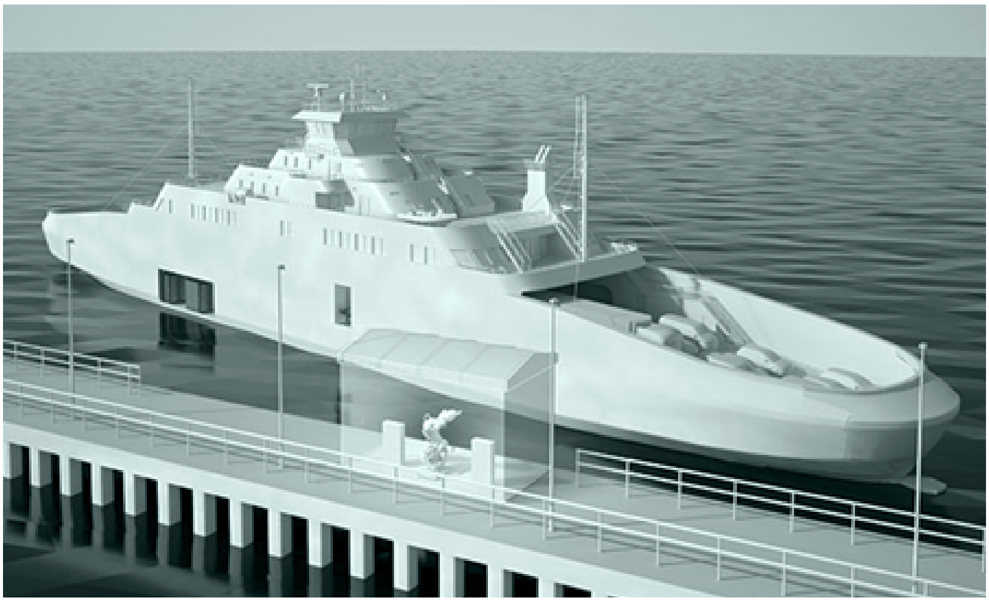


FIGURE 35
Automatic shore connection enabled by Robotic solution – visualization at berth in port

Source:
https://new.abb.com/provider-information



7.3.2. E-FERRY PROTOTYPE AND FULL-SCALE DEMONSTRATION OF NEXT GENERATION 100% ELECTRICALLY POWERED FERRY FOR PASSENGERS AND VEHICLES

The E-ferry Ellen is the first only and entirely 100% electric, medium sized and emission free ferry in the world. The ferry was approved without the presence of a diesel-backup generator, for producing power under special emergency circumstances. In addition, a new firefighting foam system specialized for large marine battery pack was introduced on board of this ship.

The E-ferry project was supported by the European initiative Horizon 2020 (EUR15 Mil.). It has involved the design, building and demonstration of a fully electric powered "green" ferry, which can sail without polluting and CO_2 emissions. The E-ferry aims to support and promote energy efficient, zero emissions waterborne transportation for island communities, coastal zones and inland waterways in Europe and beyond.

The project started in 2015 was supported by the Danish Maritime Authority and nine partners and it was coordinated by the Danish municipality /commune of Ærø[35].

[35] Spelling :
Ærø (DK) – Aeroe,
Søby (DK) – Soeby

In June 2019, ship E/F Ellen was launched and in August 2019 after receiving certification issued by DNV GL society entered into full-scale operation. She sails on a regular basis in the Danish part of the Baltic Sea connecting the island of Aeroe (Ærø) to the mainland. E-ferry is able to make up to seven round trips per day between Søby (Ærø island) – Fynshav (on mainland-Jylland) – Søby (Ærø), which means covering a distance of about 22 Nm (nautical miles) on one charge.

E-ferry, goes beyond current limitations of similar efforts targeting medium range connections and is likely to be the ferry with the largest battery pack ever installed in a vessel.

FIGURE 36
E-ferry Ellen
Photo by: Erik Christensen

Source:
https://commons.wikimedia.org/wiki/File:E-ferry_Ellen.3.JPG

In case of E-ferry the charging system/arm was developed by a subcontractor Mobimar[36]. It was developed just for Aero Municipality/Søby harbour through a tender. The one installed in Søby has been the first in what now seems to be becoming a series. It is rugged and durable (by spring 2020 more than a 1000 connections had been made). It is mounted on the ramp and this solution allows ferry connection to a charger in all circumstances - irrespective the tides are too low or too high.

[36] Mobimar is Finish company

info:
https://www.mobimar.com/electric-propulsion-and-charging/charging-system

It is expected that e-ferry's daily energy demand is charged during the night while ship is in Søby harbour and the rest of energy needed is charged while entering the port during a daily operation. Ellen is supplied with certified green (emission free energy), it is estimated that Ellen over a year will save the environment up to 4000 tons of CO_2, 70 tons of NO_x, 2 tons of SO_2, 3 tons of CO and 1.5 ton of particulate matter, compared to the other vessels in the fleet.

TABLE 8
Details of E-Ferry project

Project name:	E-Ferry Project
Location	Denmark
Ports/ Route	— Søby port , Ærø Commune – Fynshav port (DK) — Fynshav – Søby route
Vessel name:	E/F "Ellen"
Vessel type/ capacity:	RoPax ferry; 196 Passengers and 31 cars
Owner:	Ærø Ferries
Supplier:	Danfoss (DK), Mobimar (FIN)
Solutions and scope of supply:	— A fully new project, ferry designed from beginning. — Fully electric drivetrain supplied by Danfoss — Main engines: 2x700kW — Thruster engines: 2x 250 kW — 4.3 MWh nominal battery system capacity — Charging effect: 4MW — Automated shore-side charging connector Mobimar Nectors™
Main benefits:	— Emission-free operation — Lower spending on fuel (electricity) — Reduced time of crossing between ports by 10-15 minutes

FIGURE 37
E/F "Ellen" docking in Søby harbour Photo by Halfdan Abrahamsen
Source:
property of the Municipality of Ærø

FIGURE 38
Mobimar shore-side charging cable connector in Søby harbour Photo by Halfdan Abrahamse

Source:
property of the Municipality of Ærø

FIGURE 39
Mobimar shore-side charging connector in Søby harbour Photo by Halfdan Abrahamsen

Source:
property of the Municipality of Ærø

7.4. GOOD PRACTICES OF NORWEGIAN PORTS AND VESSELS

It is good to mention Norway as a case here. There are many examples of small and medium electric vessels already sailing on Norwegian Sea waters or on order.

The maritime industry is a priority area of the Government's industrial policy. The Government took steps to provide a stable framework for the industry. Green shipping was one of eight priorities in the Government's 2015 maritime strategy.

Port of Oslo in Norway, Baltic Ports Organisation friendship members, measures GHG emissions and takes steps to reduce them. In Oslo, to address local ferry emissions, the port awarded a contract to Norled, which is currently tasked with electrifying three of ten existing passenger ships. When these three heavily used ferries are outfitted with batteries, it is estimated the transit port emissions caused by them will decline by 70 percent. Norled has already delivered the first electric refit MS Kongen in September 2019.

In Port of Oslo there are a few onshore charging stations for vessels available. Norled AS is the owner of the e-ferry that uses the station to charge. The electric power is delivered by Hafslund Nett AS – Grid Company[37].

[37] https://lavutslipp.kystverket.no/en/facilities/ladestrom/18

FIGURE 40
Shore charging station in the city Port of Oslo – Ferry charge: Nesoddbåtene, Aker brygge

Source:
Photo Owner: Norled AS
Grid company: Hafslund Nett AS

Measures, such as an installation of shore-side electricity for use by ships at berth and introducing electric powered work boats in port's area contribute to air quality improvement in the city of Oslo. In addition, OPS utilization in the port also reduces noise nuisance.

8. OUTLOOK OF NEW ALTERNATIVE FUELS IN PORTS

The shipping industry driven by international agreements and climate change aims to increase reduction of greenhouse gas and particle emission such as NO_x and SO_x. In addition, besides that introducing electric and battery shipping solutions there will be an increase in the use of alternative fuels namely LNG, biofuels, and developing future fuels such as methanol, hydrogen or ammonia. According to the regulations set by IMO since 1st January 2020 the limit of a ship's fuel oil's sulphur content is 0.50% m/m.

8.1. METHANOL

Methanol as an alternative fuel solution is a readily available fuel solution, with existing global production infrastructure, and the potential to be produced as a fully renewable fuel of the future. Methanol as a fuel is free of SO_x emission and generates 60% less NO_x emission when compared to fuel oil, while generation of particle matter is 95% lower. Methanol also bears resemblance to other currently used marine fuels as it remains in a liquid form, meaning that retrofitting ships is potentially less expensive than in the case of other alternative fuels, since the ships systems, fuel tank, piping and engine, require minimal modernisation to adapt to this type of fuel. The case of port infrastructure investments faces a similar situation and thus is lower than in the case of other alternative fuels. Additionally, methanol has the potential to become an attractive fuel of the future as it is one of the top commodities shipped around the world. This in turn means that the existing infrastructure for fuel redistribution in combination with the global production capacities, methanol has the potential of widespread availability. Bunkering of methanol falls under the same bunkering and safety standards as conventional marine fuels, meaning that policy adjustments are not an issue, it also complies with IMO2020.

The properties of methanol imply that potential investments in methanol bunkering infrastructure are reasonably low, and retrofitting of currently functioning infrastructure is a possibility. The commercial use of methanol adds further familiarity to the procedures of loading and discharging methanol, even with the currently insignificant use as a bunkering product. As a consequence

FIGURE 41
Methanol bunkering at NorSea Vestbase
Source: NorSea

and based on the current knowledge, methanol bunkering operations could be easily adapted to be performed via ships, barges, terminals or trucks. Figure 41 represents a methanol storage tank directly adjacent to an LNG tank with both being available for bunkering from the same quay. Storage of methanol requires consideration of two main factors, designating it as a non-standard marine fuel. Firstly, its low flash point being 12 degrees on the Celsius scale, which suggests that potential ignition sources have to be handled with caution. Secondly, methanol toxicity and the possibility of causing poisoning while being inhaled or absorbed through skin. Due to those factors and differing rules set by ship classification societies in regards to ships running on methanol, port authorities might set special requirements in regards to methanol bunkering[38].

[38] Introduction to Methanol Bunkering – Technical Reference, Lloyd's Register, 2020

Stena Germanica, following a modernization in the Gda●k "Remontowa" shipyard in 2015, was the first RoPax ferry retrofitted to use methanol as fuel. The modernization of the Stena Line vessel was done in cooperation with Wärtsilä i Methanex, the fuel installation is based on a dual-fuel system, where marine gas oil is kept as backup fuel. The retrofitting costs amounted to EUR 13 million, while the whole project did cost EUR 22 million. The investment included construction of a bunkering station and adaptation of a bunkering barge in Gothenburg[39]. The vessel has successfully operated its course between Gothenburg and Kiel since its modernization.

[39] "Methanol as a marine fuel report", FCBI Energy, October 2015

FIGURE 42
Stena Germanica

Source:
Stena Line

In 2016 the first methanol fueled first dual fueled chemical tanker named Lindanger was launched at Hyundai Mipo in South Korea for the Norwegian company Westfal-Larsen. The ship is capable of faring through ocean routes using methanol as its primary fuel, and conventional marine fuel as backup, it was the first of seven new build methanol vessels. Currently four more ocean faring chemical tankers are planned to be constructed[40].

[40] Methanol Institute

MethaShip project concluded in 2018 and the project consortium reported findings that methanol offers a long term solution that could address the problem of emission reduction. The main benefits are its relatively low emissions and the ability to be water-soluble and biodegradable. Currently R&D projects focus on adapting the fuel for other vessels such as cruise ships, fishing boats and dredges.

8.2. HYDROGEN

Hydrogen is another alternative to the general fuels that is widely discussed today with more research being currently conducted to confirm its feasibility for maritime use. What is beneficial for hydrogen powered vehicles is that the range of the powered vehicles is greater than the range of vehicles powered by batteries. Moreover, its main advantage is that it does not emit harmful substances into the atmosphere, meaning that in the right conditions (if produced by energy gained from renewable resources) it is a fuel with the potential for extremely low amounts of greenhouse gas emissions.

Hydrogen also has a higher energy density than other fuels, however, it is also of low energy content by volume, meaning it takes up more space than other fuels. Additionally, the fuel faces some critical disadvantages and the main problem of utilization of this fuel is related to the storage possibilities. Hydrogen for the purpose of storage requires even lower temperatures then LNG, and requires high pressures to be stored efficiently. That in combination with the chemical processes needed to store it compactly means that potential vehicles will lose a significant amount of space for installation of a hydrogen fuel system, and the fuel efficiency of hydrogen is behind other fuels, further increasing the problem of storage.

When considering port infrastructure, hydrogen is a versatile fuel in terms of storage. However, its largest downsides are low volumetric energy density, meaning that potentially one ton of hydrogen in comparison to diesel will contain trice the amount of energy at the same time taking up to 6 times the space, and the need to be stored in special conditions at 700 bars. Liquefaction of hydrogen on one hand increases the volumetric energy density but in turn requires more specialised storage technologies and similarly as with LNG increases the potential risks associated with storing cryogenic fuel. As opposed to LNG the lower liquefying temperature –253 degrees Celsius, means that storage of hydrogen currently would be more cost intensive than LNG. As a high pressure flammable gas the bunkering process has to be controlled paying attention to the flow rate of hydrogen, unchecked bunkering could lead to risky situations caused by softening of pressure vessels[41].

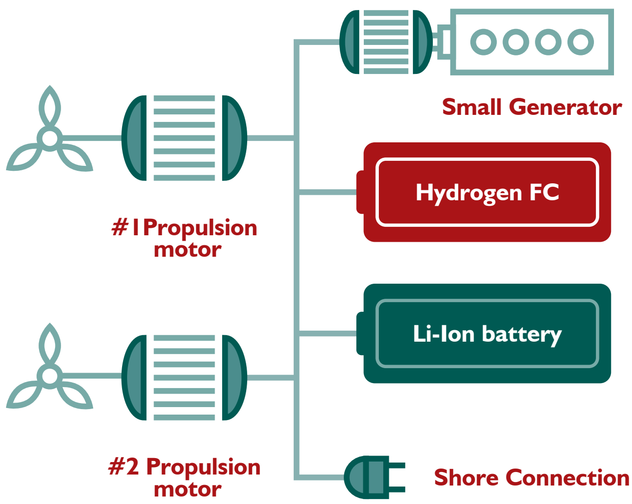
[41] Feasibility of Hydrogen Bunkering, ITM Power, 2019

During 2019, Tokyo Kisen along with 'e5 Lab' began developing a harbour tugboat, powered by hydrogen. The goal of the project is to deliver a fully electrified harbour tug where the main power source of the vessel is a large capacity battery system with a hydrogen fuel cell and generator serving as auxiliary power. As a result of the application of fuel cells the technology ensures reduction of CO_2 emission. Currently, the launch of the tug is planned in 2022 and should be in service in the ports of Yokohama and Kawasaki[42].

[42] Tokyo Kisen, e5 Lab, "e5 Tug" – electric tug powered by battery and hydrogen fuel cell, 29.10.2019

FIGURE 43
Li-ion Battery + Hydrogen FC pure electric powertrain for e5 Tug

Source:
Tokyo Kisen, e5 Lab, "e5 Tug" – electric tug powered by battery and hydrogen fuel cell



In 2008 a similar project was conducted within the frames of the SMART-H2 project. The goal was to test hydrogen fuel cells and land and sea vehicles, for this purpose the whale watching ship Elding was equipped with an auxiliary power unit fueled by a 10 kW hydrogen fuel cell, which provided electricity to the ships systems during its stops to observe whales[43].

[43] Icelandic New Energy: further steps to Hydrogen Society, SMART-H2 – sustainable marine and road transport, Icelandic New Energy Ltd.

8.3. AMMONIA

Ammonia currently remains an alternative fuel with a high amount of questions surrounding its potential use and feasibility for the maritime industry. In its liquid form ammonias energy density is lower in comparison to today's marine fuels such as LNG. However, in comparison with LNG ammonia has the benefit of being a non-cryogenic fuel as it remains a liquid fuel at -33.4 degrees in atmospheric pressure. Low flammability of ammonia causes that the risk of ignition is significantly lower, at the same time this generates a problem as its ignition has to be enhanced by the addition of a pilot fuel.

In current debates ammonia is considered as a potential future fuel, especially when considering its production from renewable resources. Other means of producing ammonia would require high energy input, meaning that they would steer far from the green concept of this fuel. Another benefit is that production of ammonia only requires the input of water and air. Water through electrolysis generates hydrogen and through the Haber-Bosh process binds the hydrogen and nitrogen present in air resulting in the production of ammonia. Similarly as methanol, ammonia is a commodity commonly shipped around the world as it is used in industrial processes, for example in the production of fertiliser. The clear advantage of ammonia is that it contains no carbon, with the downside that it is a gas with toxic properties, which in turn leads to higher security measures that normally would be needed on vessels potentially using this fuel. Current predictions estimate that ammonia would be commonly in use by 2050.

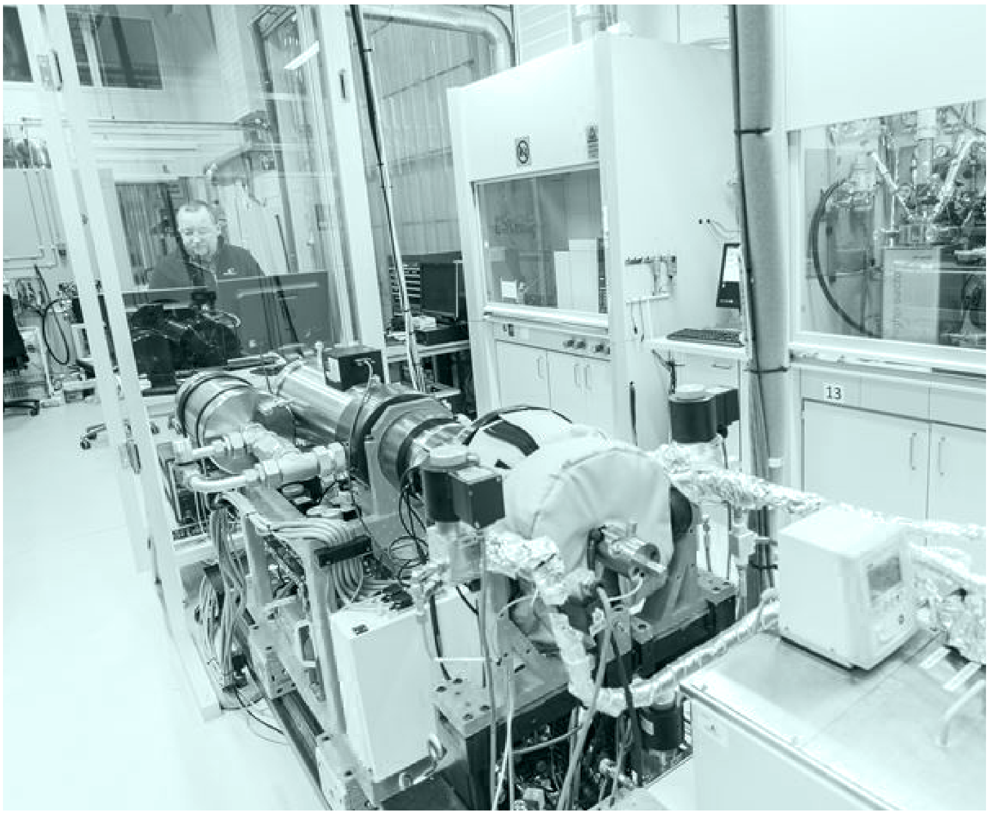


FIGURE 44
Ammonia fuel viability tests

Source:
Wärtsilä

In terms of potential ammonia port infrastructure development and bunkering operations, an important point to be taken into consideration is the toxic and corrosive nature of the fuel. As a result, special care and established technologies should be implemented to avoid potential risks of a toxic leakage. Port authorities interested in providing bunkering of this fuel should introduce additional safety procedures and regulation. Ammonia ignites and burns poorly, potentially causing higher emissions of nitrogen oxides that combined with ammonia's toxicity demands a special measures for fighting fire outbreaks. Ammonia can also be stored as a liquid providing it gets reduced to the temperature under –33.4 degrees Celsius, This cooling feature is an advantage in comparison to the storage of LNG and Hydrogen.

However, there is also another alternative to use ammonia as fuel, namely as fuel cells. Currently Wärtsilä among a consortium of other companies is working on the EU initiative ShipFC. The goal of the project is to retrofit Eidesvik's ***Viking Energy*** ship to use ammonia fuel cells. Success of this project would mean that through this conversion, ***Viking Energy*** would become the first zero emission vessel to use green ammonia as fuel. Ammonia for this project will be produced by Yara, the technology used to attain it will be hydropower[44]. Due to its cheap production costs, easy storage possibilities and usability in fuel cells, it potentially can be considered as a substitute to hydrogen.

Ammonia also plays a leading role in the Zero Emission Energy Distribution at Sea initiative also known under the acronym ZEEDS. Initiated in 2018 by Wärtsilä the project consortium explores the possibilities of strategically distributed energy hubs, mainly in proximity to main shipping lines. Such hubs would use the energy produced by offshore wind turbines, to generate hydrogen from water and later from hydrogen and nitrogen extracted from air ammonia. Green fuels would also be stored in seabed tanks allowing water pressure to maintain them in liquid form, it would be transported when needed to surface bunkering boys[45].

[44] **Wärtsilä**

Source:
https://www.wartsila.com/twentyfour7/innovation/successful-tests-pave-the-way-for-ammonia-as-a-future-marine-fuel

[45] **ZEEDS initiative**

Source:
https://zeedsinitiative.com/the-vision/

9. CONCLUSIONS

This report explores the current state of the alternative fuels development among the Baltic Sea ports. What is clearly noticeable is that the world is accelerating measures aimed at shifting the economy from fossil fuels to sustainable green alternatives. The driving factors are the policies aimed at reducing greenhouse gas and pollution emissions such as the Sulphur Emission Control Areas. Within Europe, the future road to sustainability and low emission will be supported by the European Green Deal. With the introduction of new regulations and support instruments, the balance will shift towards the alternative fuels and especially in the case of hydrogen, which not only is considered to be the fuel of the future but also a solution that would help mitigate the economic recession caused by Covid-19.

When analysing the technology development for cleaner fuels in shipping, a few solutions to find new alternative fuels that would serve as fossil fuels replacement are currently being explored. This race is strongly supported by the use of technological innovations as well as upgrading some previous solutions - for example batteries with greater efficiency. Hydrogen, being an important part of the European Green Deal, is explored both as direct liquid fuel and potentially as a fuel cell solution. Alternatively, methanol is explored due to its physical similarities to conventional maritime fuels currently used. Liquefied Natural Gas positions itself as a strong contender to be the current transition fuel, having gone through the rocky research and regulation creation phase, it currently is holding a strong position on the market with a decent distribution system already existing and numerous ships both in operation and in order along with multiple infrastructure investments still being explored around the world.

From the perspective of possible financing resources, alternative fuels are currently in a good position, with multiple opportunities for co-financing. Connecting Europe Facility (CEF) with Motorways of the Sea priority is currently the main programme supporting development of port infrastructure for alternative fuels. Innovative solutions can also be financially supported by the Horizon 2020 programme and in the upcoming financing period high focus will be placed on projects researching alternative fuels such as hydrogen. The potential for blue and green growth will be also explored within the Interreg programmes. Additionally, in the near future more financing possibilities are expected to be available within the frames of the European Green Deal, itt is expected to focus on exploring the viability and energy storage potential of hydrogen. Is also worth mentioning that financing can also be gained from national programmes and the regional and national development goals set by them, loans for green and blue development might also be gained from banks such as Nordea and European Investment Bank. However, what remains important, is that without the involvement and incentives taken up by ports, a green sustainable future is not possible even with multiple financing possibilities.

Within the financing period 2014–2020 high activity can be noted in the EU co-finance area. Within the CEF call about 20 projects alone were located in the Baltic Area, seventeen ports engaged in EU co-financed projects. High focus within those projects was dedicated towards testing the viability and development of LNG infrastructures. European projects also began focusing on digitalization or ports and maritime transportation, ensuring that the region's main ports remain up to speed with new technology solutions that help to save both time and fuel and at the same time further lowering emissions.

Supported by the BPO initiative with a focus on LNG, the mission resulted in preparing the Baltic Sea Region as an area ready to transition towards high LNG usage, with over 20 ports offering LNG bunkering possibilities, either directly through the ports infrastructure or through truck and ship bunkering options. As a result, Baltic is now a region with a sufficient amount of LNG port facilities and one of the highest numbers of LNG vessels. Consequently, the area is also better prepared to adhere to the emission limits established in the Sulphur Emission Control Area. While further investments in LNG infrastructure are slowing down, there are still plans to expand the existing network, and reap all the benefits provided by this low-emission fuel. With the expectation that LNG will remain a transition fuel for upcoming decades, the Baltic Sea area seems prepared to explore new alternative solutions while benefiting from the knowledge accumulated so far. An important role in this success can be attributed to the Baltic ports and their willingness to jointly cooperate and explore alternative fuels opportunities and in this case LNG infrastructure development is a clear example of such solidarity in action. The established collaboration model can serve as a benchmark when exploring the viability of other alternative fuels in the region.

Onshore power supply (OPS) represents an important solution to limit pollution and emissions caused by auxiliary engines of ships at berth. However, the implementation of OPS is a gamble of evaluating the foreseeable profit and loss. Caused by lack of standardization, investments in OPS infrastructure that operate on both 50Hz and 60Hz frequencies are still quite significant. In addition, the differences of OPS energy prices from port to port, compared to the relative stability of fuel prices used in auxiliary engines can be discouraging for ship owners. The ecological benefits brought by OPS introduction weight towards wider implementation, especially when applied in internal type of ports. The Baltic Sea Region is clearly an area where OPS infrastructure is continuously progressing, supported among others by the efforts of BPO. Such investments, kept in line with the considerations of EU Directives, are encouraged by the increase of green and blue energy production in the national energy mix and financially supported by the EU co-financing programmes. Overall, according to the increasing trend of OPS in Baltic ports, it can be expected that a bright future of shore powered ships is exactly what we can expect in the coming years. What remains to be seen is how vessels will use this infrastructure and close cooperation between ship-owners and ports is definitively needed to fully benefit from existing OPS installations.

New battery technologies, combined with more common OPS infrastructures and e-mobility financing opportunities, all contribute towards the growth and development of electric propulsion vessels. Hybrid and purely electric vessels in short distance ferry routes are becoming a new opportunity for investments, where the capacities of batteries can be used to their full extent. This in turn assists in cutting emissions and brings the shipping industry closer to carbon neutrality as the battery systems are fueled by green energy from sustainable energy sources. Involvement in projects and prototypes exploring waterborne e-mobility is also steadily growing, assisted by the research advancements in automation and digitalization technologies. As a result, electric vessels are becoming highly efficient, with first routes already operational in the Baltic Sea encouraged by multiple good practices and case studies shared by Norwegian stakeholders. It remains unclear if further technology advancements will allow the use of e-mobility on long distance routes, some expectations for such future solutions are found in hydrogen fuel cells.

Alternative fuels such as methanol, ammonia and especially hydrogen are currently explored by the maritime sector. Methanol fuel viability in the maritime sector was already confirmed by several pilot projects and the Baltic Sea Region served as a testing ground for the first methanol fueled ferry. With its availability as a commonly shipped commodity and with relatively low retrofitting costs of both port infrastructure and ship systems further increase in the number of methanol fueled vessels (currently 24 operating and on order) is highly probable. Ammonia is another fuel of the future and is currently on the brink of viability testing. While some downsides still remain such as the high toxicity of the fuel and low flammability, prospects for this fuel are looking rather promising. Similarly as methanol, ammonia is a shipped commodity that is cheaper to produce and more easily stored then hydrogen and could be considered as a potential substitute to it. Hydrogen on the other hand is the most anticipated zero emission fuel of the future, with a number of research and prototypes currently planned. However, there are still some barriers and other limitations that need to be addressed before its global implementation. Among others, the needs to develop a functional production base and distribution infrastructure as well as to further improve the storage technology of hydrogen remain some of the key obstacles at the moment.

Future development of alternative fuels would largely benefit from the creation of a stakeholder platform that would allow discussions on possible technological advancement paths, innovative solutions for storage facilities and harmonise bunkering methods of the new fuels. On this path to new future fuels the important role of a few funding sources is vital.

The leading co-financing programmes that should be considered are:

- CEF – assisting the development of port infrastructure;
- Horizon – filling an important role in innovative technology and solution development;
- Interreg – regional programs that bring different stakeholders together in an attempt to address regional issues and tighten cooperation.

BPO RECOMMENDATIONS

Baltic Sea is a model region for green ports and maritime transport as it has been proved, among others, by the regional approach and development of LNG bunkering facilities with more than 20 ports having LNG available now. Moreover, onshore power supply has been installed in many Baltic ports with clear plans in many others. In order to respond to ambitions and goals for CO_2 reduction, expressed in European Green Deal, a new technology for ships propulsion is being under rapid development. In order to make these new alternative fuels such as hydrogen, ammonia, energy charging available at berths, Baltic ports will work together to provide safe and sustainable infrastructure for future ships, by applying the regional approach.

Bogdan Ołdakowski / Secretary General, Baltic Ports Organization

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BPO is registered in Tallinn, Estonia

Figures

Tables

APPENDIX

Appendix No. 1 *National Policy Frameworks and financial incentives towards alternative fuels in the Baltic States.*

State	National Policy Framework	Financial Incentives/ Funds	Tax Incentives	Other comments
Denmark	No policy measures targeting shore sea power or LNG supply infrastructure in the national maritime ports.	During 2013–2015 the development of infrastructure for electricity, gas and hydrogen was supported by the infrastructure pool under the Ministry of Energy, Utilities and Climate (DKK 70 mil. of support– DKK 20 mil. for gas infrastructure, DKK, 10 mil. for hydrogen and DKK 40 mil. for electricity).	*Since 2015 reduced electricity tax on shore-side electricity supply,* (the only tax of DKK 0.004 per kWh is paid, corresponding to the EU min. tax), but it is difficult to assess whether the lowered tax is attractive.	Since 2019 a partnership of Blue Denmark[16] and the government. It developed 6 initiatives ready for investment and put forward 15 recommendations for government actions. *Regarding ports and short sea shipping, these are: green highways at sea, climate-differentiated toll at ports and new energy infrastructure for ports.* [16] Blue Denmark consists of shipowners and shipping companies www.dma.dk
Estonia	The NPF partially addresses the requirements of the Alternative Fuels Directive. Regarding: LNG- an LNG terminal and loading facilities for LNG tank vehicles at the Port of Tallinn. OPS supply- focusing on cross-border cooperation	No incentives or funds dedicated to alternative fuels infrastructure.	No tax incentives dedicated to alternative fuels.	As concerns hydrogen initiative - the first pilot project has been pointed out by the NPF.
Finland	The government accepted the National Alternative Fuels Plan in February 2017. According to the plan, a different fuels stations network should be built in Finland, for construction primarily commercial operators would be responsible.	A few seaports in Finland – four LNG projects (terminals in Pori, Tornio, Rauma and Hamina) – have received a conditional energy grant decision from the government.	No tax incentives dedicated to alternative fuels.	Some new measures are considered in order to open alternative fuel markets: the use of existing economic instruments (e.g. energy subsidies); a procurement subsidy for new technologies; developing information guidance.
Germany	The Federal Cabinet approved the Maritime Agenda 2025 in 2017 (NPF). The Federal Government is to provide targeted funding for green fuels and ship propulsion systems. Maritime measures aim to strengthen competitiveness in shipbuilding, marine technology, offshore wind energy, shipping and ports.	Infrastructure plans for port facilities are eligible for funding, mainly under the policy for the Improvement of Regional Economic Structures (GRW). Under the scheme, half of the costs are granted to approved projects. OPS projects in seaports are eligible for funding from this programme.	The German Renewable Energy Act (GREA) contribution is a major cost driver for shore power. *An exemption from the GREA contribution for power to be purchased during the period of demurrage in port* can contribute to enhancing the market penetration of OPS.	An additional federal programme for innovative port technology, *Förderprogramm für innovative Hafentechnologien* (IHATEC), has got potential to co-fund environmental projects in ports including infrastructure.

Latvia	The Latvian NPF addresses only part of the requirements of the Alternative Fuels Directive.	No incentives or funds dedicated to alternative fuels infrastructure.	No incentives and no any targets for LNG refueling points nor for shore-side electricity supply in sea or inland ports.	Latvia has no plans for the deployment of LNG refueling points in its ports. The NPF does not consider hydrogen for transport.
Lithuania	The NPF does not address the requirements of the Alternative Fuels Directive; No targets for increasing the availability of el. supply for OPS; LNG – no plans for new LNG refueling points besides the existing in the Port of Klaipeda.	No incentives or funds dedicated to alternative fuels infrastructure.	No tax incentives dedicated to alternative fuels.	As concerns hydrogen for transport the Lithuanian NPF has included a list of measures, but most of them are still under consideration and with little details.
Poland	The NPF addresses most of the requirements with comprehensive list of measures; however, most of them are under consideration or in an early stage of the adoption process. No targets are foreseen for increasing the availability of shore-side electricity in ports. LNG refuelling is planned for all maritime and inland ports in the TEN-T Core Network.	No government incentives to support infrastructure of alternative fuels in Polish seaports within the TEN-T Core network.	Excise duty exemption for electricity from renewable energy sources, however to be exempted the interested entity has to deal in renewable energy production and hold redeemed green certificates. From 2019, a zero excise duty exemption on natural gas intended for propulsion on vehicles on: LNG, CNG, biogas and hydrogen.	A new programme 'Hydrogen – Clean Fuel of the Future' has been announced by PGNiG. It consists of several projects - one of them aims at producing 'green' hydrogen to be used for storage, distribution and being used by the energy industrial sector.
Sweden	The national NPF does not reflect development of alternative fuels. There is a considerable interest in LNG by shipping and Swedish industry.	Vinnova Swedish innovation agency helps to build national innovation capacity and contributes to sustainable growth globally.	An incentive for vessel operators to use OPS. *The application of <u>a reduced tax rate was to strengthen the competitiveness of OPS</u> relative to the burning of bunker fuels on board, which is fully tax exempt*	
Norway	Norway has released an action plan for green shipping. Its maritime industry is to be a world leader in the development of low- and zero-emission solutions.	The government established a 'NO_x Fund' where entities can donate funds instead of paying NO_x tax. The fund is opened for applications by the fund members to invest in technology for further NO_x reductions. Enova agency supports: OPS investments and for electrification of maritime transport.	From 2017, a reduced electricity tax rate was introduced for commercial shipping. In 2019, the reduced tax rate is NOK 0.005 per kWh. The reduced tax provides an incentive for commercial shipping to use onshore power and electric means of propulsion.	In 2017 Norway has adopted a support system of the Ecobonuses. The initiative aims to catalyse a modal shift from roads to ship traffic. In 2019 national budget included an allocation of NOK 50 million to a temporary three-year grant scheme for investments in effective, environmentally friendly ports.