



Alternative fuels for shipping

in the
Baltic Sea Region


Baltic Marine Environment
Protection Commission

Maritime activities



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Author:

Alexey Bakhtov

Contributors:

Minna Alhosalo¹, Paul Altena¹, Hermann Backer, Tadeusz Borkowski, Jan Boyesen², Susanne Heitmüller³, Jukka-Pekka Jalkanen⁴, Agni Kaldma⁵, Eija Kanto⁶, Maija Kokkonen⁷, Przemyslaw Kowalak⁸, Joanna Łyjak⁹, Annaleena Mäkilä¹⁰, Anita Mäkinen¹¹, Bogdan Oldakowski¹², Anna Petersson¹³, Sari Repka¹⁴, Deborah Shinoda, Charlotta Solerud¹⁵, Nariné Svensson, Johanna Yliskylä-Peuralahti

¹) CLIA Europe, ²) Maritime Development Center, ³) Federal Maritime and Hydrographic Agency (BSH) Germany, ⁴) Finnish Meteorological Institute, ⁵) Ministry of the Environment of Estonia, ⁶) WEGA, ⁷) Port of Helsinki, ⁸) Maritime University of Szczecin, ⁹) Ministry of Maritime Economy and Inland Navigation of Poland, ¹⁰) Finnish Port Association, ¹¹) Finnish Transport Safety Agency, ¹²) Baltic Ports Organization, ¹³) Swedish Transport Agency, ¹⁴) University of Turku, Centre for Maritime Studies, ¹⁵) Ports of Stockholm

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1. Summary



With new IMO regulations in place the ship owners have to implement new technology solutions to meet the requirements: install a scrubber system to “wash” the sulphur from the exhaust gas, shift to Marine gas oil (MGO), which has a low sulphur content or to switch to alternative compliant types of fuels.

The objective of this document is to provide an overview of the recent development in use of alternative fuels by the Baltic Sea countries, with the focus on liquefied natural gas (LNG) to highlight existing and ongoing programs and incentives on a country / port level and to indicate long term trends according to available data.

With due account of the fact that the data on fuel use in the Baltic Sea region is fragmented, this report has been prepared on the basis of available online resources and personal input of the contacts in ports, institutions, ship-owner companies and ports.

This Overview has been prepared as part of the EnviSuM project (Environmental Impact of Low Emission Shipping: Measurements and Modelling Strategies). The EnviSuM project addresses measurement and modelling strategies to assess present and future cost and the health and environmental effects of ship emissions in view of the IMO emission regulations that entered into force in January 2015. HELCOM’s role is to provide policy linkage to the project, to promote the project outcomes and facilitate involvement of the competent authorities from the Baltic Sea region.



Ship exhaust fumes. © Evelyn Weiser (CC BY-SA 2.0)





2. Introduction



Figure 1. Ships in the Baltic Sea (based on HELCOM AIS data from 2006 to 2016 including cargo, tanker, passenger and container ships which account for 80% of the traffic of the larger (IMO) ships).



The environmental impact of shipping has been and remains one of the key concerns shared by the Baltic Sea countries.

Emissions to air, mainly exhaust gases and particulate matter, illegal and accidental oil pollution, hazardous substances and other wastes, the unintentional introduction of invasive alien organisms via ships' ballast water or hulls and the increase of underwater noise levels are the main impacts. Shipping adds to the problem of eutrophication of the Baltic Sea with its nutrient inputs from nitrogen oxide (NO_x) emissions and sewage discharges.

The first gas fuelled ship was launched in 2000 (MF Glutra) and as of March 2017 the in-service and on-order fleet of LNG-powered seagoing ships has reached the 200 mark worldwide – over 100 are in operation while the remaining are on order.¹ Most of these are operating in Norwegian waters (>50%).

In the Baltic Sea region significant investments in LNG bunkering infrastructure are being made to strengthen the cost/benefits of using natural gas as marine fuel. The density of shipping lines in the Baltic Sea is high compared to other aquatic areas, with more than 2000 vessels navigating simultaneously at any given moment, out of which 35% are ships of lengths up to 100 m (Fig. 1). About 20% of the ships have a length of 200 m and more.

In the Baltic Sea the RoRo shipping lines density is higher compared to other world regions. Intensive shipping is one of the factors of environmental pressure on the sea. Emissions to the air from shipping in ports can make up a significant part of total emissions in port cities and running ships' engines cause atmospheric emissions, noise and vibrations at ports. Therefore to improve the environmental condition of the Baltic Sea, strict regulations of the International Maritime Organization (IMO) entered into force on 1 January, 2015.

The Baltic Sea, the Northern Sea and the English Channel were declared Sulphur Emission Control Area, SECA, meaning that all ships in these areas are forced to run on fuel with less than 0.1% sulphur by weight. Besides, from 1 January 2010 a 0.1% maximum sulphur requirement for fuels used by ships at berth in EU ports was introduced. The Baltic Sea Nitrogen Oxide Emission Control Area (NECA) agreed in October 2016 under the IMO MARPOL Convention applies only for new ships built after 2021. One full renewal cycle of the Baltic Sea fleet may take up to 30 years. The slow natural fleet renewal calls for voluntary measures including economic incentives to speed up reductions in emissions via alternative fuels.

¹ http://www.lngworldshipping.com/news/view,the-worlds-lngfuelled-fleet-in-service-in-2017_47076.htm



3. International, EU and HELCOM regulations



Environmental regulations in general are described in detail in numerous resources, therefore the focus of this section is on regulations applicable to alternative fuels in shipping. The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main global instrument on environment and shipping and is the central source of environmental shipping law also in the Baltic Sea. Together with the Annexes to the MARPOL Convention, several EU directives form the core regulatory framework in the field of alternative fuels.

Annex VI of the MARPOL Convention – Prevention of Air Pollution from Ships (entered into force 19 May 2005)¹

This Convention sets limits on sulphur oxide and nitrogen oxide emissions from ship exhausts and prohibits deliberate emissions of ozone depleting substances. Designated emission control areas set more stringent standards for SO_x, NO_x and particulate matter. A chapter adopted in 2011 covers mandatory technical and operational energy efficiency measures aimed at reducing greenhouse gas emissions from ships.

From January 2015, all ships navigating in the Baltic Sea are obliged to use fuel oil with a sulphur content not exceeding 0.10% m/m. In order to prove compliance a bunker delivery note accompanied by a representative sample of the delivered fuel shall be kept on board the ship for port state control inspection. Alternatively, the ship may use an exhaust gas cleaning system or other technical abatement methods reducing the total emission of sulphur oxides from ships ensuring the same level of emissions as with fuel containing 0.10% m/m of sulphur.

New ships with the keel laid from the first of January 2021 or later, and sailing in the Baltic and the North Sea NECA, have to meet the stricter Tier III standards of MARPOL Annex VI, in com-

¹ <http://www.imo.org/en/OurWork/environment/pollutionprevention/airpollution/pages/air-pollution.aspx>

parison to the Tier II standard applied globally to these ships outside NECA. This corresponds to approximately 80% reduction in NO_x emissions compared to current levels and can be achieved by technologies such as selective catalytic reduction (SCR), exhaust gas re-circulation (EGR) or using liquefied natural gas (LNG) as a fuel.

Resolution MEPC.304(72) (adopted on 13 April 2018) Initial IMO Strategy On Reduction Of Ghg Emissions From Ships²

The Resolution does not contain any binding regulations, although it sets the goal of at least 50 % GHG reductions until 2050 for maritime shipping.

Resolution MEPC.259(68), 2015 Guidelines for Exhaust Gas Cleaning Systems.³

IMO Resolution MEPC.259(68) sets out guidelines for exhaust gas cleaning systems which operate by having water washing the exhaust gas stream prior to discharge to the atmosphere.

Directive 2012/33/EU of the European Parliament and of the Council of 21 November 2012 amending Council directive 1999/32/EC as regards the sulphur content of marine fuels.⁴

Directive 2012/33/EU specifies the maximum sulphur content of marine fuel oils, and also specifies the methods to be used to measure the sulphur levels in both marine and motor fuels.

² <http://www.imo.org/en/OurWork/Documents/Resolution%20MEPC.304%2872%29on%20Initial%20IMO%20Strategy%20on%20reduction%20of%20GHG%20emissions%20from%20ships.pdf>

³ <http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/MEPC.259%2868%29.pdf>

⁴ <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:327:0001:0013:EN:PDF>



Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the Deployment of Alternative Fuels Infrastructure.⁵

Directive 2014/94/EU sets a common framework of measures for the deployment of alternative fuels infrastructure in the European Union in order to minimize dependence on oil and to mitigate the environmental impact of transport. Minimum requirements for the building-up of alternative fuels infrastructure include and refuelling points for natural gas (LNG and CNG) and hydrogen.

Article 4.

§5. Member States shall ensure that the need for shore-side electricity supply for inland waterway vessels and seagoing ships in maritime and inland ports is assessed in their national policy frameworks. Such shore-side electricity supply shall be installed as a priority in ports of the TEN-T Core Network, and in other ports, by 31 December 2025, unless there is no demand and the costs are disproportionate to the benefits, including environmental benefits.

§6. Member States shall ensure that shore-side electricity supply installations for maritime transport, deployed or renewed as from 18 November 2017, comply with the technical specifications set out in point 1.7 of Annex II.

Article 6.

§1. Member States shall ensure, by means of their national policy frameworks, that an appropriate number of refuelling points for LNG are put in place at maritime ports, to enable LNG inland waterway vessels or seagoing ships to circulate throughout the TEN-T Core Network by 31 December 2025. Member States shall cooperate with neighbouring Member States where necessary to ensure adequate coverage of the TEN-T Core Network.

§2. Member States shall ensure, by means of their national policy frameworks, that an appropriate number of refuelling points for LNG are put in place at inland ports, to enable LNG inland waterway vessels or seagoing ships to circulate throughout the TEN-T Core Network by 31 December 2030. Member States shall cooperate with neighbouring Member States where necessary to ensure adequate coverage of the TEN-T Core Network.

§3. Member States shall designate in their national policy frameworks the maritime and inland ports that are to provide access to the refuelling points

⁵ <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex-%3A32014L0094>

for LNG referred to in paragraphs 1 and 2, also taking into consideration actual market needs.

Directive (EU) 2016/802 of the European Parliament and of the Council of 11 May 2016 relating to a reduction in the sulphur content of certain liquid fuels⁶

Directive (EU) 2016/802 is a codification of Directive 1999/32/EC which has been substantially amended five times (in particular by Directives 2005/33/EC et 2012/33/EU). The aim of this codification is to clarify and rationalise the Directive. The new Directive brings together in one single act all the provisions of the six legislative acts (the original Directive and the five acts amending it).

Regulation (EU) 2015/757 Of The European Parliament And Of The Council of 29 April 2015 on the monitoring, reporting and verification of carbon dioxide emissions from maritime transport, and amending Directive 2009/16/EC⁷

Regulation (EU) 2015/757 lays down rules for the accurate monitoring, reporting and verification of carbon dioxide (CO₂) emissions and of other relevant information from ships arriving at, within or departing from ports under the jurisdiction of a Member State, in order to promote the reduction of CO₂ emissions from maritime transport in a cost effective manner.

Commission Recommendation of 8 May 2006 on the promotion of shore-side electricity for use by ships at berth in Community ports (Text with EEA relevance) (2006/339/EC)⁸

European Commission Recommendation 2006/339/EC recommends the Member States, inter alia, to “consider the installation of shore-side electricity for use by ships at berth in ports; particularly in ports where air quality limit values are exceeded or where public concern is expressed about high levels of noise nuisance, and especially in berths situated near residential areas”.

⁶ <https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX-:32016L0802>

⁷ <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex-%3A32015R0757>

⁸ <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=O-JL:2006:125:0038:0042:EN:PDF>



HELCOM Recommendation 28E/13 “Introducing economic incentives as a complement to existing regulations to reduce emissions from ships”.⁹

HELCOM Recommendation 28E/13 adopted in 2007 recommends “that the Contracting Parties investigate and, when appropriate, introduce feasible and effective economic instruments as a possible complement to existing regulations to further reduce air pollution from shipping” and includes specifications on NOx and SOx emission-related economic incentives.

HELCOM Ministerial Declaration from 2013¹⁰

The HELCOM Ministerial Declaration 2013 emphasized the need to work jointly in co-operation with other regional governmental and non-governmental organizations, the industry and research community, to further promote development and enhanced use of green technologies and alternative fuels, including LNG, methanol as well as other propulsion technologies, in order to reduce harmful exhaust gas emissions and greenhouse gases from ships.

⁹ <http://www.helcom.fi/Recommendations/Rec%2028E-13.pdf>

¹⁰ <http://www.helcom.fi/Documents/Ministerial2013/Ministerial%20declaration/2013%20Copenhagen%20Ministerial%20Declaration%20w%20cover.pdf>

In early 2014 the Roadmap for Green Technology and Alternative Fuels for Shipping was established as an outcome of the HELCOM HOD 47-2014. To take the roadmap further HELCOM MARITIME 14 established a new sub-group (later named GREEN TEAM) under the MARITIME Working Group to promote public and private co-operation at national and Baltic Sea levels to enhance development and uptake of green technology and alternative fuels in shipping.

The creation of a joint “Green Technology and Alternative Fuels Platform for Shipping” was agreed with a purpose to gather national administrations, industry, research community and NGOs involved in green technologies and alternative fuels. The platform was launched at a joint event on 16 January 2013 organised by HELCOM, the Finnish presidency of the Council of the Baltic Sea States (CBSS), Baltic Development Forum (BDF) and the Northern Dimension Partnership for Transport and Logistics (NDPTL). The platform is also related to the activities around the “St. Petersburg initiative”, an international public-private partnership platform to unite governmental, business and financing organizations for Baltic Sea cooperation established at the St. Petersburg Baltic Sea Forum in April 2013.



4. Alternative fuels and technologies



The main fuels used in the Baltic Sea are petroleum fuels divided into residual oils, or heavy fuel oils (HFO) and distillate oils (MGO, MDO). HFO usually has a higher sulphur content than 0.5 per cent, but can be used in ships that have installed exhaust gas cleaning system, or a scrubber to reduce the amount of sulphur oxides (SO_x). A category of fuels “in between” HFO and distillates with less than 0.1 per cent sulphur has also come into use. The category is often called “hybrid fuel” or “ECA fuel”. In general, the marine fuels have a flash point above 60°C for safety reasons. For fuels with lower flash point than 60°C special regulations for use apply¹. Low flashpoint fuels are usually more or less sulphur free and offer an opportunity to fulfil the SECA regulation. A change to low flashpoint fuels requires technical modifications to the engine but can be economically attractive. The most common low flash point fuel used in the area is LNG, but methanol is also tested.²

The sulphur content of a marine fuel depends on the crude oil origin and the refining process. When a fuel burns, sulphur is converted into sulphur oxides. These oxides reach the lubricating oil via the blow-by gas. These oxides are corrosive to engine piston liners and must be neutralized by the cylinder lubricant. Marine engine lubricants are developed to cope with this acidity (high Base Number). If the correct lubricant is used, the sulphur content of a marine fuel is technically not important for the engine itself, but may have other implications including environmental.³

1 [http://www.imo.org/en/KnowledgeCentre/IndexofIMOResolutions/Maritime-Safety-Committee-\(MSC\)/Documents/MS.C.391\(95\).pdf](http://www.imo.org/en/KnowledgeCentre/IndexofIMOResolutions/Maritime-Safety-Committee-(MSC)/Documents/MS.C.391(95).pdf)

2 https://www.trafa.se/globalassets/pm/2016/pm-2016_12-fuels-in-the-baltic-sea-after-seca.pdf

3 http://www.chevronmarineproducts.com/content/dam/chevron-marine/Brochures/Chevron_EverythingYouNeedToKnowAbout-Fuels_v3_1a_DESKTOP.pdf

Low-sulphur residual fuel oil

Low-sulphur residual fuel oil may be selected for moving in the SECA zone. Such fuel can be obtained either from low-sulphur oil or through a desulfurization process. The high cost of this process, as well as its complexity, directly affect the final fuel price. At the same time, some companies note that fuel oil with ultra-low sulphur content has a complex chemical composition, and this may cause additional risks when operating vessels.

Methanol, bio-methanol and ethanol

Methanol is the simplest form of alcohol by its chemical structure and is widely used in the chemical industry. It can be produced from many different feedstocks, both fossil and renewable, with the majority produced from natural gas. The main renewable sources used in methanol production include pulp mill and other forestry industry residues (Sweden, Finland, Canada), organic wastes and CO₂. Ethanol is also an alcohol and is mainly produced from biomass, with the majority on the world market produced from corn and sugar cane. Both methanol and ethanol have less than half of the energy density of conventional fossil fuels, which means that more fuel storage space (about 2.5 times more) will be required on board a vessel as compared to conventional fuels.⁴

Since methanol does not contain sulphur, it is environmental friendlier option than HFO. Besides, nitrogen oxides content of the exhaust gases are much lower than those of gasoline. However, carbon monoxide and carbon dioxide gases are released in the chemical process of methanol production and also by combustion in the vessel engine. At ambient temperature, methanol is a liquid and can be refuelled and transported just as gasoline and kerosene. But methanol vapours are more poisonous than gasoline vapours, inhaling them could lead to blindness and death. Tanks for embarking methanol on board ships, as well as the necessary equipment, occupy much less space than for LNG suitable for use in the SECA zone. Methanol production volumes are insignificant.

Bio-methanol is produced from biomass such as residues from forestry. Biomass materials are used to make black liquor in pulp and paper mills, where it is normally combusted to generate energy and recover chemicals. However, black liquor can also be gasified in an oxygen-rich atmosphere and methanol produced from the resulting syngas, without compromising the recovery of the

4 Study on the use of ethyl and methyl alcohol as alternative fuels in shipping. Final Report Version 20151204.5. J.Ellis (SSPA Sweden AB), K. Tanneberger (LR EMEA)



chemicals. CO₂ from combusted bio-methanol is considered climate neutral.

Ethanol as fuel is widely used as blends in gasoline in various ratios, mainly in land transport (cars, buses, trucks and work machines, e.g. tractors). No ship engines have so far been developed to run solely on ethanol as fuel. However, Scania has developed a heavy duty bus engine which operates on 95% ethanol + 5% ignition improver, indicating that in a future scenario ethanol may also be made available as maritime fuel assuming that competitive prices and production volumes can be achieved.

Marine Gas Oil (MGO) and Marine Diesel Oil (MDO)

MGO consists of a blend of various distillates and it can be supplied with sulphur content below 0.1%. It does not have to be heated during storage. Furthermore, it must be ensured that the engine technology or any installed exhaust filter systems on the ships are compatible with the relatively low sulphur content of heating oil. MGO is used in smaller medium- to high-speed auxiliary units or auxiliary motors and ship's engines⁵. The latter are typically found on fishing boats, small ferries or tugs. Compared to marine fuels with a more or less large proportion of heavy fuel oil, emissions from marine gasoil contain significantly less particulate matter and soot. The sulphur content of distillate fuel can rather easily be kept very low and refineries may optimize their production processes to produce less residual fuel and more distillate fractions. Switching to such fuel only requires minor modifications to the fuel system on board the ships, but if both residual fuel oil (RFO) and distillate fuels are used on board the same vessel, care must be taken to perform the switchover properly because of the large temperature difference between the fuels. However, MGO and MDO fuels are significantly more expensive than heavy fuel oil. The availability of low sulphur fuel is already limited and rising demand is expected to increase its price uncertainty.

Biofuels

Biofuels can be produced from a wide range of feedstock through technologies in constant evolution and used directly or blended with conventional fossil fuels. They include bioethanol, biomethanol (as mentioned here above) and higher bioalcohols, biodiesel (fatty-acid methyl ester, FAME), pure vegetable oils, hydrotreated vegetable oils, dimethyl ether (DME), and organic compounds.

⁵ <https://www.marquard-bahls.com/en/news-info/glossary/detail/term/marine-gasoil-mgo.html>

First generation biofuels are based on food crops and animal fats. They mainly include biodiesel and bioethanol.⁶ Second generation biofuels are based on non-edible biomass, second-generation technologies are mainly in a pilot or demonstration stage and are not yet operating commercially.

Biofuels face some significant obstacles as a maritime fuel replacement, their availability being the major one. There is not enough biofuel production to sustain its use in the marine sector. Heavy fuel oil is traditionally 20-30% less expensive than gasoline or diesel fuels⁷. The energy density of biofuels is often lower than current fuels.

Nuclear power

Nuclear power has obvious advantages in terms of its low emissions and extensive experience in naval fleets and in a few civilian icebreakers. However, the use of nuclear power in commercial vessels is considered to be too risky. Nuclear propulsion has proven technically and economically essential in the Russian Arctic where operating conditions are beyond the capability of conventional icebreakers. The power levels required for breaking ice up to 3 metres thick, coupled with refuelling difficulties for other types of vessels, are significant factors. The nuclear fleet, with six nuclear icebreakers and a nuclear freighter, has increased Arctic navigation from 2 to 10 months per year, and in the Western Arctic, to year-round.⁸

Wind, solar and hydrogen cell energy

Solar and wind energy use for ports and ships in the Baltic Sea Area could possibly reduce consumption of traditional power used for ships.⁹ Wind propulsion can be categorised under soft-sail, fixed-sail, rotor, kite and turbine technologies. The Baltic Sea is relatively small, with a very high ship density and in such situations the use of sky sails is complicated. Typical sail ships could be used as pleasure ships for tourists, and possibly for cargo transportation. Wind rotor systems could be used on many types of the cargo vessels, but today such systems request additional ship stability in comparison with conventional cargo ships, and

⁶ <http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex-52013PC0017>

⁷ <http://www.biofuelsdigest.com/bdigest/2016/11/22/ocean-going-vessels-going-green/>

⁸ <http://www.world-nuclear.org/information-library/non-pow-er-nuclear-applications/transport/nuclear-powered-ships.aspx>

⁹ CLEANSHIP (Clean Baltic Sea Shipping). Sustainable Shipping and Port Development V. PAULAUSKAS, V. LUKAUSKAS http://www.clean-baltic-sea-shiping.com/uploads/files/Sustainable_shipping_and_port_development_Task_3.6.pdf





such systems are today is relatively expensive. At the same time, wind rotor systems for the Baltic Sea have potential and it is necessary to concentrate on this direction to use wind energy (Fig. 2).

Wind power systems have several disadvantages: they rely on the wind strength to be effective; the use of some wind-based systems rely upon adequate control system technology being installed on board the ship; while a return to full sail propulsion is possible, this may have a number of adverse commercial and financial implications in some instances in terms of voyage times, number of ships required, etc.

Solar PV applications use electricity generated by photovoltaic (PV) cells. All advances in this fast

evolving technology are available for maritime transport use. The primary limitations are the lack of sufficient deployment area for the PV panels and the energy storage required. Recent advances in energy storage technology offer higher potential and better prospects for solar PV powered propulsion systems for ships in the short term, but full ship propulsion using solar PV requires further technical development¹⁰ (Fig. 3).

Disadvantages: solar power availability is global position dependent; solar energy is feasible as an augment to auxiliary power but photovoltaic processes are inherently of low effectiveness, even under the best of conditions, and require a significant deck or structural area upon which to place an array of cells.



Figure 2. E-Ship – a RoLo cargo ship owned by Germany's Enercon GmbH. Four large rotorsails that rise from its deck are rotated via a mechanical linkage to the ship's propellers. The sails, or Flettner rotors, aid the ship's propulsion by means of the Magnus effect – the perpendicular force that is exerted on a spinning body moving through a fluid stream. © Alan Jamieson (CC BY 2.0)



Figure 3. Auriga Leader is a car carrier owned by Nippon Yusen Kaisha used for shipping cars and mobile machines worldwide, for example cars from Japan to the United States. It is the first large ship to have auxiliary power partially supplied by photovoltaic panels. © Goodwillgames (CC BY-SA 4.0)

Ship electrification

Recent developments in ship electrification hold significant promise for more efficient use of energy. Enhancing the role of electricity on ships will contribute towards improved energy management and fuel efficiency on larger vessels. Additional benefits include power redundancy and noise and vibration reduction, which is particularly significant for passenger ferries. There are several energy storage technologies currently available. Battery powered propulsion systems are the most popular ones, and they are already being engineered for smaller ships.

Advantages of technology are: i) Battery-based propulsion of merchant ships is beneficial from the CO₂, NO_x, SO_x, volatile organic and particulate emissions points of view since during operation none occur. ii) Batteries, by virtue of the rapidly developing technology surrounding them, offer a potential solution for the propulsion of smaller ships in the medium to long term. iii) Batteries in conjunction with other modes of propulsion may offer a potential hybrid solution for the propulsion of small- to medium-sized ships.

Disadvantages: i) At present, the size of the necessary battery pack would preclude their use as the sole means of propulsion in all but the smallest of ships on short sea voyages. ii) Full battery propulsion must await further technical development and even then it is likely to be connected to the smaller ship end of the market. iii) The battery pack requires replacement when it reaches the end of its life as determined by the total number of charge/discharge cycles.¹¹ iv) Depletion of the global supply of rare earth metals.

¹⁰ http://www.irena.org/DocumentDownloads/Publications/IRENA_Tech_Brief_RE_for%20Shipping_2015.pdf

¹¹ <http://www.raeng.org.uk/publications/reports/future-ship-powering-options>



Fuel cells are the most commonly used devices to convert the chemical energy of hydrogen into electricity. When a fuel reformer is available, other fuels, such as natural gas or methanol can also be used to power a fuel cell. Although operational experience has shown that fuel cell technology can perform well in a maritime environment, further work is necessary before fuel cells can compete with existing technologies powering ships. Challenges include high investment costs, the volume and weight of fuel cell installations, and their expected lifetime.

Hydrogen cells – this alternative is quite attractive in terms of emission reduction. However, production, storage and supply issues of hydrogen need to be solved. Therefore, this alternative might be considered just as long term perspective. Special consideration has to be given to storage of hydrogen on board ships, to ensure safe operations.¹²

Liquefied natural gas

Liquefied natural gas (LNG) – is natural gas cooled to around -162 °C. At this temperature and one bar, gas condenses into liquid and takes 600 less volume, enabling to solve the problem of long-distance gas transportation. LNG usually consists of methane, nitrogen and a small proportion of ethane, propane and other heavy carbon chain

components. Natural Gas is the cleanest fossil fuel in the world, it's odourless, colourless, non-toxic and non-corrosive, but methane has also an important greenhouse gas effect when released. Two processes, liquefaction and re-gasification of the natural gas are carried out in accordance with modern proven technologies either in land-base or in maritime environment. Thus, based on a long track record, suitable rules/regulations and safe practice, LNG processes are well tested and reliable. LNG is, in vast majority of the cases, transported in tankers with double wall containment systems in order to maintain low temperature of LNG at atmospheric pressure.

The use of LNG as a fuel in shipping has earlier been limited to LNG carriers, which use the boil off gas as fuel traditionally in steam turbines but these days in Dual Fuel (DF) engines either in electric systems or mechanical propulsion. But from 2000, as many as 200 LNG-fuelled ships are in operation or on order (DNV GL, December 2017). The LNG-fuelled ships are either equipped with spark-ignited (SI) lean-burn gas engines or dual-fuel (DF) engines. DF engines can run on either LNG or/and HFO/MGO. When using LNG in Otto cycle, a small amount of diesel pilot fuel is injected for ignition.

Natural gas is the cleanest fossil fuel in terms of emissions (Table 1-2). This essentially comes from the much shorter carbon proportion in methane than in any other carbon chain constituting the other fossil fuels. However, methane slip, which depends on the combustion principle, needs to be considered in the final CO₂ equivalent reduction which is in the end estimate to around 20% by the diesel manufacturers (not considered in the here below table).

12 Maritime in focus – LNG as ship fuel. DNV 2015

Table 1-2. Environmental benefits of LNG as a fuel. Comparison of emissions from different fuels (DNV 2015)

Emission component	Emission reduction with LNG as a fuel
SOx	100 %
NOx, Low pressure engines	85 %
NOx, High pressure engines	40 %
CO ₂	25-30 %
Particulate matter	95-100 %

Fuel type	CO ₂ equivalent, g/MJ			%CO ₂ (HFO = 100%)	
	Well to tank CO ₂ emissions (WTT)	Tank to propeller CO ₂ emissions (TTP)	Total CO ₂ emissions	% total	% tank to propeller (TTP)
Oil fuel (HFO)	9.80	77.70	87.50	100.00	100.00
Oil fuel (MGO)	12.70	74.40	87.10	99.54	95.75
LNG (from Qatar used in Europe)	10.70	69.50	80.20	91.66	89.45



5. LNG for maritime transport



At present, LNG represents the first and most likely alternative fuel to be seen as a genuine replacement for HFO for ships. The adoption of LNG will be driven by fuel price developments, technology, regulation, increased availability of gas and the development of the appropriate infrastructure. Using LNG as fuel offers clear environmental benefits: elimination of SOx emissions, significant reduction of NOx and particulate matter, and a small reduction in greenhouse gas (GHG) emissions.

The conversion to LNG is currently associated with substantial additional costs for shipowners¹. These expenses would be also valorised with the incentive of stricter emissions standards and not only depend on the relative price between natural gas and traditional fuels. Thus, regulations and implementation of new standards in combination with stringent controls act as major drivers for the utilisation of LNG. Shipowners will make the decision between LNG, marine diesel oil and HFO in combination with scrubbing technology

based on the cost development of the available technologies. Another driver may be seen in laws, standards and regulations. LNG use will need a necessary development of bunkering procedures in ports to allow LNG refuelling to be a wide spread practice.

In maritime transport, two different engine concepts for the application of LNG are currently available: gas only engines exclusively powered by LNG, and dual-fuel engines that either run on blends of diesel and natural gas, or switch between operation with diesel and gas. Engine technology for dual-fuel operation is further sub-divided into low-pressure and high-pressure concepts.

The refuelling operation in port, either sea or inland, can be executed adopting the logistics solution for refuelling in the different approaches:

- TTS – Tank Truck to Ship
- TPS – Terminal to Ship via Pipeline
- BTS – Barge to Ship
- STS – Ship to Ship
- RCS – Removable Container to Ship

The facilities used for this operation can be:

- LNG terminals
- tanks
- mobile containers
- bunker vessels and barges

The starting point for supplying LNG as a marine fuel is construction of large-scale import terminals (Fig. 4). In general, these terminals are built to import gas to national gas networks and they must be expanded to include small scale reload facilities for reload of smaller LNG tankers or LNG bunkering vessels and/or LNG trucks. However, for

1 R. Wurster, W. Weindorf, W. Zittel, P. Schmidt (LBST), C. Heidt, U. Lambrecht (IFEU), A. Lischke, Dr. S. Müller (DLR) LNG as an alternative fuel for the operation of ships and heavy-duty vehicles

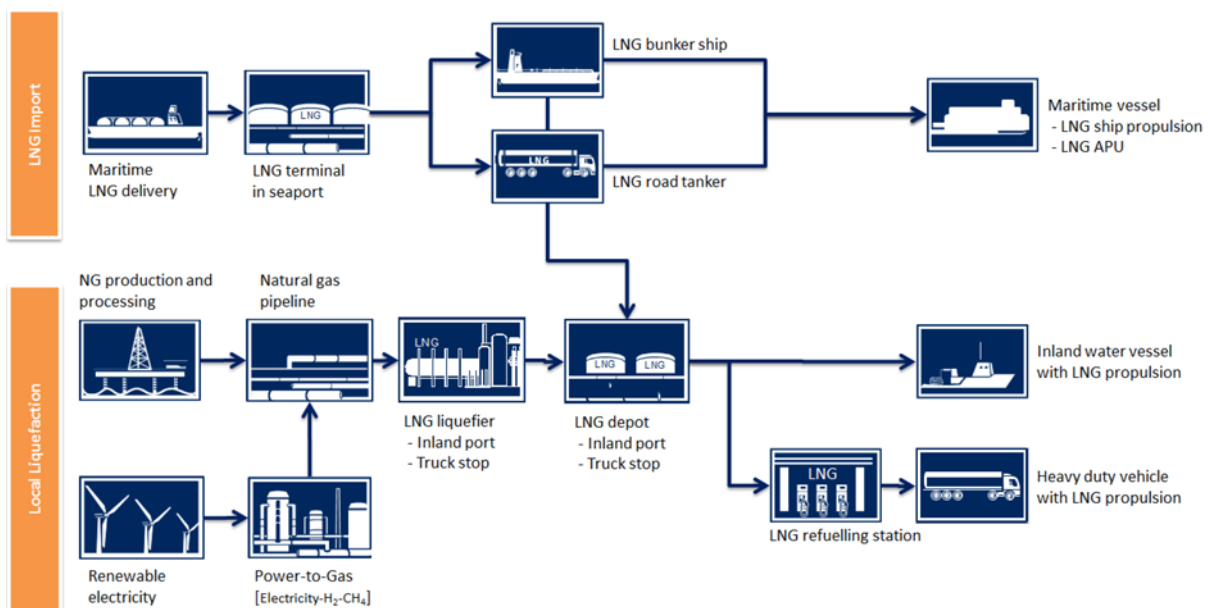


Figure 4. LNG supply chain (Source – R. Wurster et al., 2014)





a developed infrastructure, more LNG terminals or storage facilities will be needed. These small-scale and medium-scale intermediary terminals will be centered within ports; they can be onshore in the form of tanks or offshore e.g. as vessels. Furthermore, small-scale LNG liquefaction plants fed from national gas grids could be seen as part of these intermediary LNG terminals.

Currently the lack of infrastructure for alternative fuels is a major obstacle for development of alternative fuelled maritime transport. In order to overcome this need the European Commission, by means of Directive 2014/94/EU, has mandated the deployment of an appropriate alternative fuels infrastructure's coverage.² To this purpose, the

EU Member States should define national targets and objectives so as to encourage the circulation of AFVs, in particular for electric (Article 4), hydrogen (on a voluntary basis, Article 5) and natural gas (Article 6) powered vehicles.

Member States are requested to ensure “that an appropriate number of refuelling points for LNG are put in place at maritime ports, to enable LNG inland waterway vessels or seagoing ships to circulate throughout the TEN-T Core Network by 31 December 2025” (Article 6(1)). In both cases, the designation of maritime and inland ports which are going to provide access to refuelling points for LNG has to “take into consideration actual market needs” (Article 6(3)).

² <https://ec.europa.eu/transport/sites/transport/files/themes/urban/studies/doc/2016-01-alternative-fuels-implementation-good-practices.pdf>



6. International projects in the Baltic Sea region



In Europe there are several initiatives related to the installation of LNG facilities in ports, both sea and inland. The TEN-T programme has co-funded more than 20 initiatives both at study level and at design and implementation level. The support provided by the Union is continuing with the CEF Programme, which usually funds projects involving more than one Member State.

Blue Baltics

<https://www.blue-baltics.eu/>

The proposed Action Blue Baltics provides investment into LNG infrastructure & mobile equipment in Lithuania, Sweden and Estonia making available LNG as fuel for maritime and road transport. The aim of the Action is to establish a LNG infrastructure and offering bunkering activities across the Baltic Sea. Such a harmonized approach contributes to the sustainable development of the LNG market and helps to remove arisen bottlenecks.

The Action builds on successful previous LNG projects in Klaipeda/Lithuania (FSRU & LNG Re-loading Station) and in Nynäshamn/Sweden (LNG Terminal & bunker vessel Seagas).

Member States: Lithuania, Sweden, Estonia and Germany

Implementation: March 2016 - June 2019

LNG in Baltic Sea Ports II

<https://ec.europa.eu/inea/en/ten-t/ten-t-projects/projects-by-country/multi-country/2013-eu-21007-s>

The main objective of this project, part of TEN-T Priority Project 21 (Motorways of the Sea), is to minimise maritime transport pollution in the Baltic region by supporting the widespread use of LNG (liquefied natural gas) while maintaining the competitiveness of maritime transport.

Member States: Sweden, Germany, Lithuania

Implementation: January 2014 - December 2015

LNG in Baltic Sea Ports

<https://ec.europa.eu/inea/en/ten-t/ten-t-projects/projects-by-country/multi-country/2011-eu-21005-s>

The aim of the proposed action is to develop a harmonised approach towards LNG bunker filling infrastructure in the Baltic Sea region. By sharing knowledge between 7 Baltic partner ports (Aarhus, Helsingborg, Helsinki, Malmö-Copenhagen, Tallinn, Turku, Stockholm) from 4 countries and their stakeholders, a more standardised process for planning and constructing LNG infrastructure shall be achieved.

Member States: Denmark, Sweden, Finland, Estonia, Poland

Implementation: January 2012 - December 2014

LNG Bunkering Infrastructure Solution and Pilot actions for ships operating on the Motorway of the Baltic Sea

<https://ec.europa.eu/inea/en/ten-t/ten-t-projects/projects-by-country/multi-country/2012-eu-21009-m>

The aim of the Global Project is implementing three pilot actions for LNG, methanol and the use of scrubbers. These pilots look at meeting the sulphur legislation in 2015 in the Sulphur Emission Control Area and support the development of a competitive and environmentally sustainable shipping sector in the Baltic Sea.

Member States: Sweden, France, the Netherlands, United Kingdom

Implementation: January 2013 - December 2015

GoLNG

<http://www.golng.eu/en/about-the-project/>

The project is focused on the development of demand and accessibility of LNG in the Baltic Sea Region (BSR). The project activities are 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.

Member States: Lithuania, Germany, Sweden, Denmark, Norway, Estonia, Poland

Implementation: May 2016 - April 2019



LNG Rotterdam Gothenburg

<https://ec.europa.eu/inea/en/ten-t/ten-t-projects/projects-by-country/multi-country/2012-eu-21003-p>

The aim of the project is to create break bulk infrastructure for small-scale LNG supply in the Ports of Rotterdam and Gothenburg. These large ports combined have a critical mass to assist in the market transition to maritime LNG in northern Europe.

Member States: *The Netherlands, Sweden*

Implementation: *January 2012 - December 2015*

Shore Side Electricity In Ports

Shore Side Electricity (SSE) is a process that enables a ship to turn off its engines while berthed and to plug into an onshore power source. The ship's power load is transferred to the shore-side power supply without a disruption of on-board services. This process allows emergency equipment, refrigeration, cooling, heating, lighting, and other equipment to receive continuous electrical power while the ship loads or unloads its cargo. Shore Side Electricity has been adopted in some ports around the world as a measure belonging to the "Green Ports" concept. This

concept refers to a set of several measures aimed at achieving sustainability at ports, considering that a port not only meets all the environmental standards in its daily operations, but also has a long-term plan for continuously improving its environmental performance.

EU Recommendation 2006/339/EG invites Member States to promote shoreside electricity facilities. The EC recommendation also called for the development of harmonized international standards and provided guidance on costs and benefits of connecting ships to the electricity grid. Directive 2014/94/EU includes the aim to include shore-side electricity supply for inland waterway vessels and seagoing ships in maritime and inland ports.

The cost of electric energy represents a first barrier to the spread of shore side electricity in Europe. However, shore side electricity could represent a cheaper solution in certain cases if compared with vessels switching to marine distillate (MDO) while in port as required by many local regulations (MDO burns cleaner than bunker fuel, but it is about twice as expensive). Another barrier can be found in the shore side electricity infrastructure at marine terminals. They require extra electrical capacity, conduits, and the "plug" infrastructure that will accept power cables from a vessel.

Several ports around the world have already implemented shore-to-ship power. Table 3 illustrates the developments of SSE installations in European ports.

Table 3. SSE installations in European ports

Year of introduction	Port name	Country	Capacity (MW)	Frequency (Hz)	Voltage (kV)	Ship types making use of SSE
1985	Stockholm	Sweden	2.5	50	6.9	ROPAX
2000-2010	Gothenburg	Sweden	1.25-2.5	50 and 60	6.6 and 11	RoRo, ROPAX
2006	Kemi	Finland		50	6.6	ROPAX
2006	Kotka	Finland		50	6.6	ROPAX
2006	Oulu	Finland		50	6.6	ROPAX
2008	Lubeck	Germany	2.2	50	6	ROPAX
2010	Verko, Karlskrona	Sweden	2.5	50		cruise
2012	Ystad	Sweden	6.25-10	50 and 60	11	cruise
2013	Trelleborg	Sweden	0-3.2	50	10.5	
2017	Ports of Stockholm	Sweden	3		11	



In the Baltic Sea region, there are several LNG terminal projects of various capacities and at different stages. Existing medium-scale terminals are approximately 10,000 m³ of LNG, and large-scale capacity terminals are more than 100,000 m³ of LNG¹. The following table, prepared by the project LNG in Baltic Sea Ports II, provides an updated list of LNG terminals in the Baltic Sea region in operation, under construction during planning. There are on-going projects under construction and under discussion that will be able to serve the bunkering market if needed. Also, the larger terminals built or planned could easily supply smaller terminals in the area with LNG, either by feeder vessel or by truck.

1 LNG in Baltic Sea Ports II. LNG Handbook

Table 4. Existing and planned terminal projects in the Baltic Sea region

Terminal	Type ¹	Capacity (m ³)	Operator	Status	Comment
Nyansshamn *Stockholm, Sweden	Closed	20,000	AGA	In operation	Redistribution by track and pipeline
Lysekil/Brofjorden, Sweden	Closed	30,000	Skangas	In operation	Local gas delivery to refinery and redistribution by bunker barge. In operation since 2014
Świnoujście, Poland	Open	320,000	Polskie LNG	In operation	European gas grid and redistribution by truck. Maritime and rail based redistribution and bunkering is under discussion. In operation since 2016
Gdynia, Poland	TBD	25,000	TBD	Under discussion	LNG storage tank, a dedicated LNG bunkering facility for vessels, as well as LNG truck, rail wagons and containers loading facilities
Gdynia, Poland	TBD	up to 266,000	TBD	Under discussion	Floating Storage Regasification Unit (FSRU)
Klaipeda, Lithuania	TBD	170,000	Klaipeda's Nafta	In operation	Floating Storage Regasification Unit (FSRU) unit designed to connect to the local gas grid. In operational since December 2014
Regional terminal, Gulf of Finland	TBD	180,000	Gasum	Under discussion	Regional terminal for the Baltic energy market area located in either Finland (Inkoo) or Estonia (Paldski). Planned operation by 2021
Tallinn Muuga, Estonia	Open	180,000	Vopak/Elerig	Under discussion	Local gas hub in the first phase, regional open access hub in the second phase. Planned operation in 2019
Pori, Finland	TBD	30,000	Slangas	In operation	Regional terminal dedicated to Finnish gas market with planned truck distribution. In operation since 2016
Turku, Pansio Port, Finland	TBD	30,000	Gasum/Skangas	Under discussion	Terminal with pipeline distribution in the Turku area, truck loading facilities and loading/unloading via existing jetty
Tornio, Finland	Closed	50,000	ManGa LNG	Under production	Terminal mainly for industrial use. Uploading to trucks and vessels is under discussion, Planned operation in 2018
Gävle, Sweden	TBD	30,000	Skangas	Under discussion	Terminal with loading and unloading of LNG to vessels as well as to LNG trucks is discussed, for future – train unloading is discussed.
Gävle Norrsundet, Sweden	TBD	15,000	Swedegas	Under discussion	Terminal in Gävle, potentially with a connected gas pipeline infrastructure.
Sundvall, Sweden	TBD	5,000	TBD	Under discussion	Terminal dedicated to industrial purposes and transportation. Planned loading to trucks and rail distribution. Planned operation by 2020

1 Closed type terminal implies that only the operator can store LNG, while open type implies that independent LNG suppliers may reserve capacity in the terminal



Table 4 (continued). Existing and planned terminal projects in the Baltic Sea region

Terminal	Type ²	Capacity (m ³)	Operator	Status	Comment
Gothenburg, Sweden	Open	30000	Swedegas	Under discussion	Redistribution by truck and train and through the Swedish/Danish gas grid as well as bunkering. Planned operation in 2018.
Oxelösund, Sweden		30,000		Under discussion	LNG storage tank, a dedicated LNG bunkering facility for vessels, as well as LNG truck loading facilities
Port of Hou, Denmark	TBD	100	Kosan Crisplant	In operation	Two alternating LNG tanks on the quayside in Hou. Every three days, the empty tank is replaced with a full one from Rotterdam. LNG fuels the Samsø Ferry "Princess Isabella" on the route between Hou and Sælvig – since 2015
Malmö/Copenhagen, Sweden/Denmark	TBD	10000	TBD	Under discussion	redistribution by truck and train and through the Swedish/ Danish gas grid as well as bunkering is under discussion
Aarhus, Denmark	TBD	<10000	TBD	Under discussion	Terminal for marine purposes. Possible loading by trucks.
Helsingborg, Sweden	TBD	<15000	TBD	Under discussion	Redistribution by truck, train, maritime and through local gas grid as well as bunkering is under discussion
Trelleborg, Sweden	TBD	<5000	TBD	Under discussion	LNG supply for marine purposes, possible loading of trucks
Hirtshals, Denmark	TBD	500	HMN Naturgas	In operation	Small LNG tank for bunkering of ferries, in operation since 2015
Rauma, Finland	TBD	10000	AGA	Under discussion	Bunkering of ships from trucks and land.
HaminaKotka, Finland	TBD	30000	Hamnian Energia	Under discussion	Terminal with distribution to industries, shipping and trucks. Planned operation by 2020
Fjusö/Ingå Helsinki, Finland	TBD	TBD	Gasum	Under discussion	Floating storage facility is planned for maritime use. Planned operation by 2021
Rostock, Germany	TBD	25000	TBD	Planned	Potential for loading and unloading of (bunkering ships), trailers and containers.
Vaasa, Finland	TBD	TBD	TBD	Under discussion	Terminal for industrial and maritime use.
Vysotsk, Russia	Closed	1500000	Gazprom	Under discussion	Plant for LNG production, storage and bunkering. Expected start of operation: 2018
LNG Gorskaya	TBD	5500		Under construction	Delivery of LNG by vessels refuelling (bunkering), ship-to-ship. bunkering vessels. Expected start of operation: 2018

² Closed type terminal implies that only the operator can store LNG, while open type implies that independent LNG suppliers may reserve capacity in the terminal

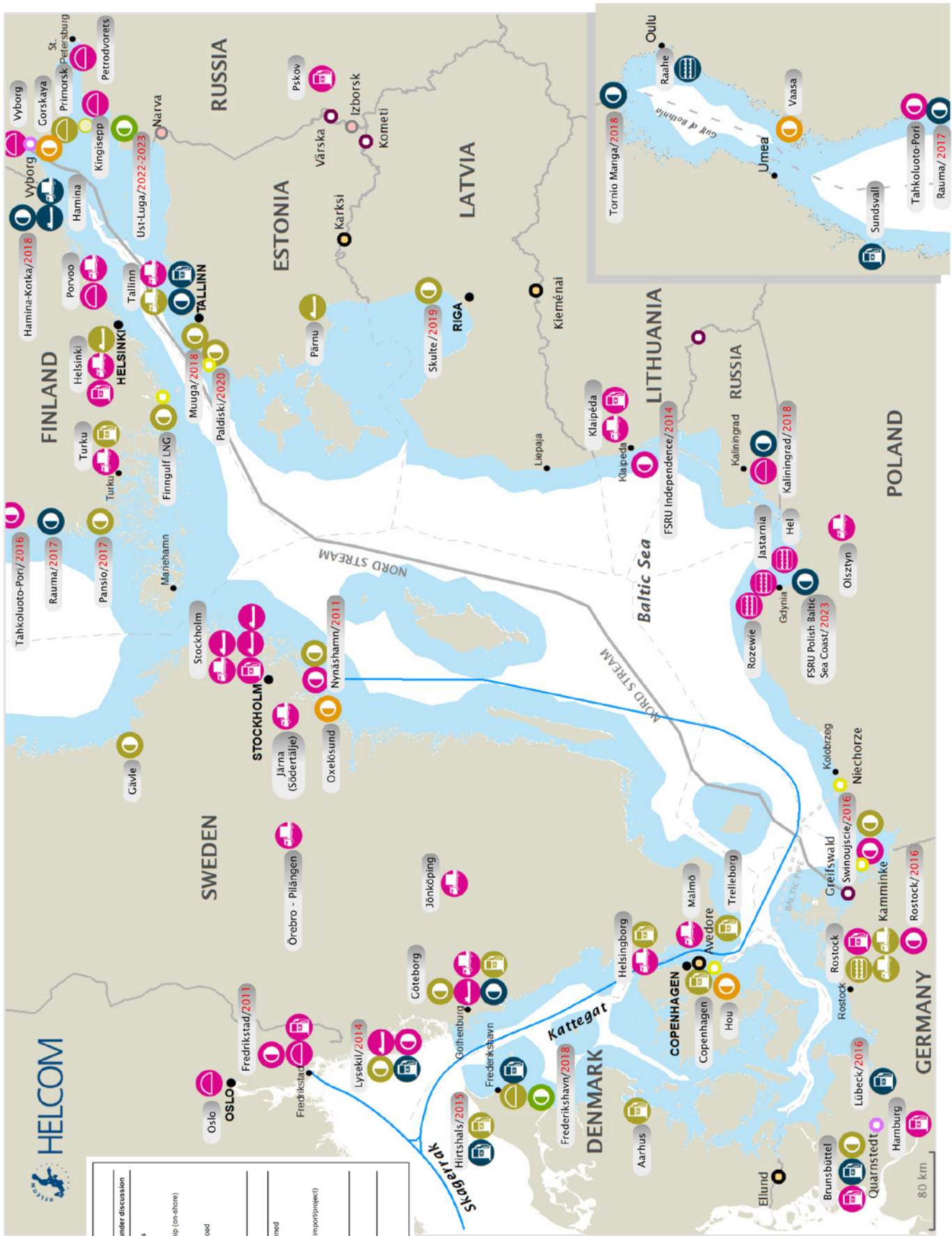


Figure 5. Small scale LNG Infrastructure in the Baltic Sea Region (Source – Gas Infrastructure Europe)



7. Overview of national policy framework



In November, 2017 European Commission released Detailed Assessment of the National Policy Frameworks (NPF) towards the broadest use of alternative fuels – an Action Plan for Alternative Fuels Infrastructure under Article 10(6) of Directive 2014/94/EU, including the assessment of national policy framework under Article 10(2) of Directive 2014/94/EU. It summarises the data on implementation of the NPFs in the member states and provides an up to date information on the state of deployment of alternative fuels in different types of transport, including the maritime. Information below contains data from the Baltic Sea counties which was submitted to the Commission and presented in the Assessment document.¹

Germany

Shore-side electricity supply for inland waterways vessels and seagoing ships in maritime and inland ports of the TEN-T Core Network and in other ports (2025)

Germany has 6 maritime ports and 21 inland ports within the TEN-T Core Network. The German NPF describes the installation of shore-side electricity supply for maritime ports as economically unfavourable and technically difficult, whereas perspectives were more promising with regard to inland ports, where energy requirements are lower and emissions and noise reduction requirements play a more important role. Several pilot projects have been launched. No targets are set. According to the NPF, responsibility for infrastructure development in inland and maritime ports lies with the federal states and support programmes should be addressed at that level.

LNG refuelling points in maritime ports along the TEN-T Core Network (2025)

There are six maritime ports in the TEN-T Core Network in Germany: Bremerhaven, Bremen, Hamburg, Lübeck, Rostock, and Wilhelmshaven.

¹ <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX-520175C0365>

For maritime vessels, the declared NPF objective is to establish an LNG service station network by 2025 that allows the operation along the routes of the TEN-T Core Network. The equipment of ports should follow market requirements.

In Germany, there is currently no stationary LNG infrastructure for waterways, and shore-to-ship concepts are seen as presently not economically viable. Truck to ship bunkering facilities are operational in the following maritime ports: Bremerhaven, Brunsbüttel, Hamburg and Rostock. In anticipation of more demand for LNG, the ports of Wilhelmshaven, Lübeck, Rostock, Hamburg and Brunsbüttel have announced interest for and declared intent of developing LNG bunkering facilities. According to the NPF, future demand can be covered by truck-to-ship and potentially ship-to-ship concepts. However, the fact that no quantified plans for maritime port LNG AFI build-up are announced raises some concern that lagging AFI construction might have negative impacts for the viability of LNG inland waterway vessels or seagoing ships.

The NPF does not establish target numbers for LNG refuelling points for ports, nor does it define an LNG distribution system as required by the Directive. According to the NPF, LNG infrastructure build-up will be pursued depending on market needs.

The German Ministry of Transport and Digital Infrastructure (BMVI) has implemented a funding program to promote the newbuilding and conversion of ships for the use of LNG as fuel. Further information are available under: <https://www.bmvi.de/SharedDocs/DE/Artikel/G/MKS/richtlinie-zuwendung-lng-seeschiffe.html>

Denmark

Shore-side electricity supply for inland waterways vessels and seagoing ships in maritime and inland ports of the TEN-T Core Network and in other ports (2025)

With regards to maritime ports, no targets are defined in the NPF. The decision to invest in shore-side electricity supply in Danish maritime ports is basically entrusted to the private sector.

LNG refuelling points in maritime ports along the TEN-T Core Network (2025)

The Danish NPF identifies the ports of Frederikshavn and Hirtshals as candidates for LNG refuelling to vessels. Whereas the LNG terminal in Hirtshals opened in 2015, the LNG facility in Frederikshavn is expected to be complete at the end of 2017. These two ports are part of the TEN-T Comprehensive Network. For ports of Copenhagen and Aarhus, the only ones that belong to the TEN-T Core Network, financial sustainability studies with EU funds have been prepared. The NPF endorses the continuation of EU funding for this purpose.

**Tables 5-9.** The national targets and objectives regarding alternative fuels infrastructure

Legend: AFV = Number of Alternative Fuels Vehicles, AFI = Number of Alternative Fuels Recharging/Refuelling Points

Denmark	Current (EAFO March 2017)		2020		2025		2030	
	AFV	AFI	AFV	AFI	AFV	AFI	AFV	AFI
LNG for maritime ports	1	2				d.o.*		

Estonia	Current (EAFO March 2017)		2020		2025		2030	
	AFV	AFI	AFV	AFI	AFV	AFI	AFV	AFI
SSE (shore-side electricity) for maritime ports		>1		>11		>11		
LNG for maritime ports	1			>=1				

Finland	Current (EAFO March 2017)		2020		2025		2030	
	AFV	AFI	AFV	AFI	AFV	AFI	AFV	AFI
SSE (shore-side electricity) for maritime ports	1	4						
LNG for maritime ports	12	2		4		6		6

Lithuania	Current (EAFO March 2017)		2020		2025		2030	
	AFV	AFI	AFV	AFI	AFV	AFI	AFV	AFI
LNG for maritime ports		1		1		1		

Poland	Current (EAFO March 2017)		2020		2025		2030	
	AFV	AFI	AFV	AFI	AFV	AFI	AFV	AFI
SSE (shore-side electricity) for maritime ports		l.p.**						
LNG for maritime ports		1				4		

*) d.o. = demand oriented

**) l.p. = low power

The Danish government highlights to role to be played by market forces in this sector and contemplates two feasible solutions: in the short-run, truck-to-ship LNG bunkering; in the long-run, ship-to-ship. The government of Denmark opens up the door to a reassessment of its position in the future, in view of the needs of the TEN-T Core Network.

There appears to be a lack of policy measures targeting LNG in the Danish maritime ports.

Estonia

LNG refuelling points in maritime ports along the TEN-T Core Network (2025)

The first LNG vessel in Estonia began sailing the Tallinn–Helsinki line in 2017. The NPF mentions that an LNG terminal including an LNG bunkering terminal is due to be completed in 2017 at the harbour of Muuga at the port of Tallinn. The Port of Tallinn is the only port in the TEN-T Core Network in Estonia. Alongside the terminal, a distribution system will also be developed. The future creation of LNG refuelling points beyond the TEN-T Core Network of maritime ports will depend on the demand that will appear after the completion of this terminal.

The Estonian NPF does not indicate future estimates for alternative fuels vehicles and vessels. Regarding LNG, the NPF mentions that an LNG terminal including an LNG bunkering terminal is due to be completed in 2017, at the Harbour of Muuga (part of the Port of Tallinn) where a distribution system will also be developed, including loading facilities for LNG tank vehicles.

Finland

Shore-side electricity supply for inland waterways vessels and seagoing ships in maritime and inland ports of the TEN-T Core Network and in other ports (2025)

Currently there are three Finnish ports offering shore-side electricity supply: the ports of Helsinki, Oulu and Kemi. A cooperation agreement was signed in 2016 between the port of Helsinki, Turku, Stockholm and Tallinn to further promote use of shore-side electricity in the port Turku and Helsinki, and the agreement is currently being finalized. It would ensure the SSE availability in the main maritime ports.

LNG refuelling points in maritime ports along the TEN-T Core Network (2025)

There are currently two maritime ports with LNG refuelling points. Target for 2025 is to build





four more LNG refuelling points, which will also serve heavy-duty trucks, totalling to six LNG refuelling points in maritime ports, which according to the NPF will be enough to fulfil the market needs in Finland.

The Finnish NPF states that a cooperation agreement was signed between Finland, Sweden and Estonia on promoting the usage of shore-side electricity on the Baltic Sea.

LNG with gradual increase of renewable share is foreseen as the main shipping and long-haul transport fuel. Six LNG refuelling points in maritime ports and one mobile inland waterway bunker are planned until 2030. Nine road LNG refuelling points on the TEN-T Core Network will ensure the minimum coverage criteria of one LNG refuelling point at least every 400 km for heavy-duty motor vehicles, already by 2020.

Lithuania

Shore-side electricity supply for inland waterways vessels and seagoing ships in maritime and inland ports of the TEN-T Core Network and in other ports (2025)

The Klaipėda maritime port and inland ports in the country are equipped with shore-side electricity supply facilities. The NPF does not see additional needs for further development of SSE in Lithuanian ports.

LNG refuelling points in maritime ports along the TEN-T Core Network (2025)

According to the Lithuanian NPF, there are no further plans for an extension of LNG refuelling points in ports, besides the already existing LNG refuelling point in Klaipėda, Lithuania's only maritime port in the TEN-T Core Network.

Latvia

Shore-side electricity supply for inland waterways vessels and seagoing ships in maritime and inland ports of the TEN-T Core Network and in other ports (2025)

Backed by two studies, one for the port of Riga and the other for Ventspils, the Latvian NPF concludes that for shore-side electricity supply for inland waterways vessels and seagoing ships the costs outweigh the benefits. No targets are communicated in the NPF. The Latvian NPF provides no targets for LNG refuelling points along the TEN-T Core Network by 2025. The Latvian NPF communicates that a study to assess the possibility of building an LNG terminal in Ventspils led to the conclusion that it is not economically justified. The Latvian NPF provides no targets for LNG refuelling points in maritime ports by 2025.

Poland

Shore-side electricity supply for inland waterways vessels and seagoing ships in maritime and inland ports of the TEN-T Core Network and in other ports (2025)

The NPF states that in the Polish maritime ports of the TEN-T Core Network there is already shore-side electricity (SSE) infrastructure of the older generation (400 V / 50 Hz / <100 kW) available, while modern, high power infrastructure is missing. The port in Gdynia already developed a concept of modernising the whole port area. Its realisation is however pending, except of the new ferry terminal where SSE is currently being built (expected to finish by end 2019). The port in Świnoujście - only for the ferry terminal a concept is already developed; the realisation date is not decided yet, pending also availability of European funds. The Polish NPF states that the best approach would be to create a pilot project in one of the four TEN-T Core Network ports to practically assess the benefits and costs. Placing such infrastructure in all ports of the TEN-T network, according to the Polish NPF, is not economically justified.

LNG refuelling points in maritime ports along the TEN-T Core Network (2025)

LNG refuelling is foreseen for all four Polish maritime ports of the TEN-T Core Network by 2025. Ship-to-Ship, Truck-to-Ship or Container bunkering is expected to be used instead of stationary on-land infrastructure. In Gdansk, LNG bunkering is already available today.

The number of permanent refuelling points is not defined, however already now it is possible to refuel the LNG ships in Gdansk harbour (four companies competing; using a cistern, directly from a pier, on ad-hoc agreements, the fixed procedure for a permanent service is in preparation). Other refuelling methods (from a dedicated ship or using a container) are also considered. Building permanent onshore infrastructure is depending on the market development. The organization and procedures for LNG fuel deliveries at the ferry terminal in Świnoujście are already prepared and developed but until now no LNG fuel delivery has been made due to the lack of such demand.

Sweden

The Swedish NPF indicates neither targets nor future estimates for alternative fuels and vessels. With regards to the environmental impact of ships, Sweden considers that an important step in the Baltic Sea Area would be to create 'similar' charging structures (fairway and port dues) in 'as many ports as possible'.





8. Country developments and incentives

Finland

The first LNG fuelled ship in Finland, Viking Grace (fig. 6), started operating on Baltic Sea passenger services in 2013 on the route between Stockholm and Turku. In 2018 it was modernized to become the only vessel with Norsepower rotor sail unit. Turva, the Border Guard's LNG-powered ship, has been deployed in various patrol and SAR missions in the Baltic Sea since 2014.¹ Around ten other LNG ships are either in service or on order in Finland: icebreaker Polaris, Tallink Megastar (passenger ferry operating on a route Helsinki – Tallinn), two ships for ESL-shipping, and six ships for Container-

¹ Alternative transport fuels infrastructure Finland's National Plan, 2017



Fig.6. The Viking Grace is the first LNG fuelled ship in Finland. It is also equipped with a rotor sail unit. © Viking Line

Table 10. EU financing of LNG initiatives in Finland

Project	Action n°	EU Contribution
Into the future – Baltic SO ₂ lution	2013-EU-21003-S	3,6 M€
DOOR2LNG	2015-EU-TM-0098-M	17 M€
Bothnia Bulk	2015-EU-TM-0178-M	6,8 M€
NextGen Link	2016-EU-TM-0092-W	11,9 M€

ship. A network of LNG terminals with a relatively wide coverage will emerge on the Finnish coast in the Bay of Bothnia and Gulf of Finland over the next few years. The first terminals are being built in Pori (completed in autumn 2016) and Tornio (<https://www.gasum.com/en/insights/gas-industry/2018/five-facts-about-the-tornio-lng-terminal/> due for completion in 2018), and the following ones probably in Hamina and potentially also in Rauma. While the new terminals will cater to different regional needs, by means of tank trucks, rail transport and bunkering vessels they may serve industries, energy plants and ships within a 300 – 500-kilometre radius. The technical solutions at the terminals in Pori and Tornio will also allow direct bunkering. The aforementioned four projects have received a conditional energy grant decision from the government. Grants have also been applied for by the builders of three other terminals, but these plans have not yet been finalised.

Finnish shipping companies and ports have used the European Union co financing instruments to support the investments. Table 10 provides the examples of such aid.

Reliable electric motors using lithium batteries and their power generation systems for new sailing boats and the replacement engines of old boats have been developed in Finland. The new electric propulsion systems can be used as power sources for boats, and they can also recharge the boat's batteries while it is sailing. This is a useful feature, especially when sailing long distances and facing a need to maintain the electrical equipment with the propulsion batteries for a lengthy period. Long-life and energy efficient lithium batteries can also be used outside the boating season. The first electric ferry is to be deployed in Finland in 2017. In the future, Finnish cable ferries could also be powered by electricity.

The first LNG-powered icebreaker in the world, Polaris, represents a new generation of icebreakers. It is the world's first icebreaker powered by liquefied natural gas (LNG). The use of both LNG and low sulphur diesel reduces the vessel's emissions significantly, making it also the most environmentally friendly dieselelectric icebreaker ever built. Polaris is built and delivered by Arctech. Building began on 4 March 2015, at the Helsinki Shipyard. Polaris represents a new generation of icebreakers. It is the world's first icebreaker powered by LNG. The concept design for the icebreaker was developed by Aker Arctic. Polaris is powered by Wärtsilä's dual-fuel engines operating on LNG and low sulphur diesel fuel. The built-in oil recovery system delivered by Lamor Corporation has a recovery capacity of 1015 m³ with a rate of 200 m³/h.²

² http://arctia.fi/wp-content/uploads/2016/10/Polaris_aluse-site_2016.pdf



With EU supported ScanMed project (01.2014-12.2016) the Port of Turku promoted the use of LNG and supply of on-shore electricity for vessels. The joint project promoted the use of LNG in maritime traffic on the Baltic Sea and supply of on-shore electricity for vessels. In Turku, the system of on-shore electricity for vessels was completed in the Linnanaukko berth area in the end of 2016. The project aim was to improve the energy efficiency of shipping and providing alternative fuels infrastructure. Several ports performed activities under the project. Ports of Stockholm: onshore power supply installations and planning of waste water reception facilities. Port of Naantali: implementation of waste water and development of scrubber sludge reception facilities; planning of port environmental and security investments. Port of Turku: building a LNG bunker filling infrastructure and a waste water reception facility; preparation of onshore power supply. Port of Hamina/Kotka: planning of port environmental and security investment. Viking Line: study of energy efficient ferry and installing reference unit. Its successful completion will advance the Global Project of creating a sound maritime access to EU's northern markets and will result in improved environmental impact of shipping.³

Port of Turku together with Ports of Stockholm, Port of Mariehamn and Viking Line has received EU support within the program Connecting Europe Facility (CEF) for the project NextGen Link. Project upgrades an existing maritime link to cross the Baltic Sea from Finland to Sweden in the Scandinavian-Mediterranean Corridor and develops green shipping and port interconnections. Upgrade of the maritime link includes the environmental upgrade with a new sustainable LNG powered ro-pax vessel and the infrastructure development in ports. The EU project, led by the Port of Turku, is expected to be completed by the end of June 2020.⁴

Finland's first LNG-import terminal began commercial operations in September 2016 at the oil and chemical harbor Tahkoluoto in the Port of Pori, marking the launch of an €80 million (US\$89 million) venture to diversify the country's energy market, supporting off-grid industrial, maritime and heavy-duty road transport firms. The terminal has an LNG storage capacity of approximately 30,000m³ (15,000t). It includes an LNG tank with a height of 35m and an outer diameter of 42m.

Viking Line ordered a Chinese company Xiamen Shipbuilding Industry Co., Ltd for a new passenger LNG-fuelled ro-pax cruise ship on the Turku (Finland)-Åland Islands-Stockholm (Swe-

den) route with planned delivery in 2020. The new vessel will be a collaborative project, and the plan is to engage a number of Finnish and other European suppliers.⁵

In the Port of Helsinki there is a possibility to bunker LNG by truck-to-ship bunkering. At the moment there are one passenger ferry in frequent traffic that uses LNG (Megastar of Tallink-Silja since 2017) and bunkers approximately 5 times a week, and also Finnish Border Guard's vessel (Turva) has used LNG since 2014. LNG is offered also to other vessels according to their needs in every harbour of the Port of Helsinki (South Harbour, West Harbour and Vuosaari Harbour).

In September, 2016, Port of Helsinki, Port of Turku, Ports of Stockholm and Port of Tallinn, signed a Memorandum of Understanding (MoU), where they set a common approach for the new on-shore power supply for vessels. The aim is to actively contribute to reducing negative effects on the environment.

The four ports see that one option for reducing or even eliminating all the negative effects (combination of noise, vibration and other ship emissions (CO₂, NO_x, PM)) is to connect ferries to the on-shore electricity grid while berthed. With the MoU the four ports wish to set a common approach for the new on-shore power supply in three aspects:

- The Ports will provide new built connections with a voltage of 11 kV and a frequency of 50 Hz.
- The Parties will jointly encourage other ports and shipping companies to follow the initiative and recommendations concerning on-shore power supply standards.
- The Parties will continue to work to minimize the negative effects on the environment of port operations and shipping in the Baltic Sea region.

The Port of Helsinki provides the opportunity to apply for vessel charge discounts on the basis of reduced environmental impacts.⁶ The discount is available to those who implement measures that reduce vessels' environmental impacts: lowered air emissions, noise reduction while in the harbour, or other investments that improve environmental efficiency. Good results are a decisive factor. Since the beginning of 2016 the Port of Helsinki introduced a price incentive to attract international cruise ships to discharge wastewater at the Port. The incentive proved effective: in 2016 waste water was discharged into the Port's systems at almost 90% of all cruise ship visits.

³ <https://ec.europa.eu/inea/sites/inea/files/2014-eu-tm-0066-m.pdf>

⁴ <https://www.portofturku.fi/en/news/2017/07/nextgen-link-project-received-financial-support-from-the-european-union/>

⁵ www.vikingline.com

⁶ <http://www.portofhelsinki.fi/en/port-helsinki/whats-new/news/port-helsinki-offers-price-incentive-reduce-vessel-emissions-and-noise>



Sweden

Although development of alternative fuels is not reflected in the National Policy framework, there is considerable interest in LNG, in shipping and Swedish industry.⁷

The Port of Gothenburg is working actively to promote the use of LNG, as a marine fuel. Swedegas and the Dutch company Vopak are planning a major investment in an LNG terminal at the largest port in the Nordic region. The Port of Gothenburg is supporting the project and investing in the port area. By offering open access to the terminal for any company seeking to import LNG into Sweden, the market will for the very first time be completely free to choose LNG supplier. LNG import terminal at the Port of Gothenburg will be operated by Swedegas, which owns the Swedish gas grid, and will be built at the Skarvik Harbour. The planned capacity is 20 000 cubic metres with potential for expansion in line with market growth. The terminal at the Port of Gothenburg will be run in accordance with the open access principle, which means that any operator that is interested in supplying LNG to the Swedish market can purchase capacity at the terminal.

Bunkering solutions for alternative fuels, such as LNG and methanol, are already in place, alongside a dedicated pipeline for low-sulphur fuel. A so-called “Sniffer” has been installed at the entrance of the port, which is capable of detecting sulphur content in exhaust fumes. The Swedish authorities also charter regularly a small plane to patrol the Skagerrak Kattegat equipped with a sniffer to trace ship exhaust entering the Baltic Sea and eventually fine them when they enter Swedish ports.

Gothenburg along with Luleå, Stockholm, Copenhagen/Malmö and Trelleborg are Sweden's core ports where LNG bunkering facilities are being developed following to the Directive 2014/94/EU.

Currently the Port offers a discount to vessels that report good environmental performance. An extra discount is being introduced for vessels that run on LNG, making a total discount of 30 per cent for each call. The LNG discount will be applied until December 2018.

The Ports of Stockholm offers a grant of SEK 1 million to every vessel in regular traffic during at least 3 years that carries out restructuring work to enable the vessel to connect to onshore power supply. This applies for the quays where Ports of Stockholm offers electricity connection capabilities. The port fee for LNG vessels is discounted by SEK 0.05 per unit of gross tonnage. For a vessel of the size of Viking Grace, calling at Stockholm daily,

this amounts to a rebate of around SEK 1 million annually. For a vessel calling at the port every second day the rebate is around SEK 500,000 per year. The discount for reduced emission of nitrogen oxides follows the seven-level scale applied by the Swedish Maritime Administration. For a normal-sized vessel operating daily calls this equates to a discount of between SEK 3 million to SEK 4 million annually, depending on the amount of nitrogen oxide emissions. A discount of SEK 5.69 per passenger is offered to international cruise ships offloading sorted waste in port.⁸

The Port of Nynäshamn, Ports of Stockholm's most southern port – is located approximately sixty kilometres south of Stockholm. In Nynäshamn is a Mid-scale LNG terminal, which is fully owned and operated by AGA AB, a subsidiary of Linde, selling and distributing LNG to various companies. The LNG terminal commenced operations in March 2011 and is the first of its kind in the Baltic Sea region. The Swedish company offers various shipowner bunker solutions, such as LNG truck, local storage facility, dedicated bunker barge directly from the LNG terminal. The LNG-terminal supplies LNG by truck to Stockholm, where the bunkering ship Seagas sources LNG to the passenger ferry Viking Grace.

Stockholm Norvik Port in Nynäshamn with motorway and railway connections, built using state-of-the-art technologies, is an efficient and sustainable transport solution. Construction is underway, although there is no information available yet on the development of LNG infrastructure in the port. The new port will open in 2020.

Sweden-based shipowner Furetank Rederi AB and its compatriot Rederi AB Älvtank have contracted two additional product/chemical tankers with LNG propulsion at China's Avic Dingheng Shipyard. The vessels will be delivered during 2018 and 2019. Featuring a dual fuel/LNG propulsion, the vessels will have close to 50% reduction of CO₂ emissions. As part of the Gothia Tanker Alliance, the companies, along with their partner Thun Tankers BV, already have four LNG-fuelled tankers under construction at the same yard. The previous vessels were ordered by the alliance in 2015. From the six tanker vessels on order, three will be owned by Furetank, two by Älvtank, while Thun Tankers is the owner of the remaining vessel.⁹

In 2017, ABB, leading supplier of products and systems for power transmission in Sweden, has been converting two of Sweden's HH Ferries Group's massive ferries from diesel engines to being completely battery-powered.¹⁰

⁸ http://www.portsofstockholm.com/siteassets/trycksaker/ports_of_stockholm_2016.pdf

⁹ <http://worldmaritimeneews.com/archives/205071/two-more-lng-powered-tankers-for-gothia-tanker-alliance/>

¹⁰ <https://electrek.co/2017/08/24/all-electric-ferries-abb/>

⁷ www.portofgothenburg.com



Now the ships are reportedly close to launching, which would likely make them the biggest all-electric ships in the world.

Ferries will often travel only short distances and stay for relatively long periods of time at the same ports, where they can be charged.

The HH Ferries Group's two ferries, the Tycho Brahe and the Aurora, operate a 4-km (2.5 miles) ferry route between Helsingborg (Sweden) and Helsingør (Denmark). Therefore, the route that they are converting to all-electric transport is not exactly impressive, but the actual ships themselves are something. They are 238 meters long (780 ft) and weight 8,414 tonnes. They carry 7.4 million passengers and 1.9 million vehicles annually.



Fig.7. Stena Line's first methanol powered ferry, the Stena Germanica ©HenSti (CC BY-SA 4.0)



Fig.8. MS Sjövägen in the inner waters of Stockholm ©Wikimedia (CC BY-SA 4.0)

Those are incredibly large machines to power with electricity, but it is economically viable and reduces local emissions. They are already similar ferry routes going electric, but nothing of this magnitude in term of size.

The Swedish company Stena Line has chosen for itself methanol the main type of fuel for circulation in the SECA zone. The company was considering the possibility of building a series of ships on methanol by 2018, and in the long term, another 25 ships were being transferred to this type of fuel. In the spring of 2015, Stena Line began operating a ferry Stena Germanica (fig. 7), which propulsion systems operate on methanol. The vessel runs between the German Kiel and the Swedish Gothenburg. The Stena Germanica's fuel system and engines have been adapted in the Remontova shipyard Gdansk, Poland, in a collaboration between Stena Line and Wärtsilä. The cost of the project was 22M Euros with 50% support from the EU Motorways of the Seas project. Dual fuel technology is used, with methanol as the main fuel, but with the option to use Marine Gas Oil (MGO) as backup.

Swedish ferry operator, Ballerina added its first electrically-powered ferry to its fleet to transport passengers between 10 stops on the waterways of Stockholm.¹¹ MS Sjövägen (fig. 8), designed by Faaborg Værft together with Principia North AS and Wilhelmsen Technical Solution and built in DIAB's Divinycell H, provides silent, clean and cost-effective operations. It features 'sandwich composite', used mainly for the hull, topsides and wheelhouse and is ice-reinforced. It is equipped with a double propeller system, two 160kW electrical engines for propulsion, 500 kW battery bank, electrohydraulic steering system, electrical bow thruster and communication and navigation equipment. It operates throughout the year, completing eight round-trips per day, with the batteries being fully charged during the ferry's overnight stay in the harbour, and two partial charging sessions during the day.

Destination Gotland AB, incorporated company fully owned by Rederi AB Gotland, operates on behalf of the Swedish government, the ferry service between Gotland and the Swedish mainland, with harbours in Visby, Nynäshamn and Oskarshamn. The company will have first LNG fuelled RoPax ferry M/S Visborg in traffic within a few years.¹² LNG supply deal was signed between Destination Gotland AB and the leading provider of liquefied natural gas (LNG) as marine fuel Nauticor GmbH & Co. KG (Germany).

¹¹ <http://www.greenport.com/news101/europe/new-electric-ferry-unveiled-in-sweden>

¹² <https://shipandbunker.com/news/emea/569065-nauticor-inks-lng-bunker-supply-deal-with-swedish-shipping-company>



Denmark

The first Danish ferry powered by LNG is the Samsø Ferry owned by Samsø Rederi¹³. From spring 2015, the vessel has been sailing the route between Hou and Sælvig (Fig. 9). On board is a dual fuel engine from Wärtsilä, which makes it possible to operate on both marine gas oil and gas. The ferry is the first Danish domestic ferry powered by LNG, but the aim is to fuel it with locally produced biogas from the island of Samsø within 5-6 years. Apart from the fact that this is the first Danish domestic ferry to operate on LNG, the project is also unique in terms of its bunkering and logistical solutions. The LNG is transported 800 kilometres in a custom-built tanker from the Gate terminal in Rotterdam to the quayside in Hou Harbour, using two alternating moveable tanks. One tank stands on the quayside in Hou and is used for the bunkering of the ferry, while the other tank is transported back and forth between Hou and Rotterdam.

It is expected that the Samsø ferry will be bunkering in Samsø and eventually will be fuelled by local biogas. A future system will convert local biogas from the island to Liquefied BioGas (LBG), which will subsequently power the ferry. Samsø has an excess of wind power, so it is possible to exploit the power to produce biogas and liquid biogas – LBG.

The world first shortsea container vessel with LNG is operated by Unifeeder, Danish logistics company, one of Northern Europe's leading feeder

13 <http://www.kosancrisplant.com/media/172624/Samsøe-Ferry-Fuelled-by-LNG-Maskinmesteren-Sept2015-.pdf>



Fig. 9. M/S "Bergensfjord" © Ehrenberg Kommunikation (CC BY 2.0)

operators transporting containers from the large European container hubs. The vessel is primarily used on one of Unifeeder's routings between Rotterdam, The Baltics and Poland. C/v "Wes Amelie" is the first vessel of its kind worldwide that has been converted to an LNG propulsion system.

Port of Hirtshals became the first Danish port to offer LNG bunkering services following the opening of Fjord Line's LNG terminal in 2015. Fjord Line shipping company invested in a 500 cubic meters LNG tank and terminal facilities at Hirtshals to optimize operation of its two LNG-powered cruise ferries – M/S Bergensfjord and M/S Stavangerfjord – that sail the routes between Bergen, Stavanger and Hirtshals, as well as between Langesund and Hirtshals.¹⁴

Germany

National Strategy for Sea and Inland Ports 2015 specifies the challenges and opportunities of development of the German ports, use of alternative fuels is listed as one of the components of environmental protection. In close cooperation with the federal states and the private sector, a national strategy framework is to be developed for market development in the field of alternative marine fuels and their infrastructure, especially with regard to LNG. Incentives for market development are to be developed at Federal Government, federal state and European level. Regarding the deployment of an LNG supply system in the shipping sector, the challenges are to develop and provide the supply and storage capacities for LNG both at the ports concerned and on board ships.

LNG is considered to be a promising alternative fuel in waterborne transport. The Federal Government's Mobility and Fuel Strategy focuses in particular on a further reduction in emissions by means of a market entry strategy for LNG in shipping (including inland waterway transport).

The development of LNG infrastructure at ports is gradually gaining momentum. Whereas initially stationary LNG terminals at ports were favoured, companies are now increasingly focusing on more flexible bunkering vessels with a capacity of 6,000 to 7,000 m³ of LNG. In doing so, they are creating flexible storage capacity, which also makes ship-to-ship bunkering possible, which is in line with the expectations of the shipping industry. Initially, LNG is to be sourced from the ZARA ports. Later, stationary storage facilities in Germany are planned. Alongside the "large" bunkering vessels, smaller, flexibly deployable bunker barges are to be used. Brunsbüttel Ports, N-Ports and Rostock

14 <https://www.fjordline.com/en/media/press-releases/fjord-line-helps-bring-first-lng-plant-to-denmark/>



Port are working with companies in the energy industry on supply solutions, and are also exploring the installation of an import terminal. At smaller locations, such as Bremen, stationary LNG bunkering stations are planned.

The investment for the creation of an LNG bunkering infrastructure will be made by the port operators and/or the operators of the infrastructure. Accompanying measures will comprise both the transfer of appropriate land and the provision of regional financial assistance, decisions on which will be taken at the local level, especially by the port authorities. The port authorities and other decision-makers at the ports also have an important role to play from the point of view of port logistics, in other words the issue of location, hinterland connections and accessibility. The option preferred by operators, namely approval of ship-to-ship bunkering during the unloading procedure, having due regard to all necessary safety measures, is an important step towards establishing LNG as a marine fuel on a permanent basis in Germany. The same applies to the introduction of internationally recognized clearances during a joint unloading and bunkering procedure, in order to ensure maximum safety. All in all, the standardization and acceleration of internationally recognized approval procedures at German sea and inland ports is of crucial importance.

By transposing the EU's Clean Power for Transport Directive, which entered into force on 7 November 2014, Germany has undertaken to establish a national policy framework for the deployment of alternative fuels infrastructure within two years and transmit it to the European Commission.

The ports sector (port operators) is responsible for deploying the LNG infrastructure. The provision of land is to be coordinated between the federal states, local authorities and port administrations on the one side and the operators of the LNG installations on the other side. The Federal Government is responsible for providing support to the deployment of the infrastructure, conducting the negotiations on the harmonization of internationally recognized approval procedures and standards and developing the national policy.¹⁵

Russia

Russian Federation has developed draft State Program "Expansion of the use of natural gas as a motor fuel for transport and special purpose equipment" for the period 2018-2022. Currently the State Program is being finalized and approved. Subprogram 3 "Maritime and river transport" is therefore a major strategic document guiding the

¹⁵ https://www.bmvi.de/SharedDocs/DE/Anlage/VerkehrUndMobilitaet/Wasser/national-strategy-2015.pdf?__blob=publicationFile

development of LNG as alternative fuel in maritime transport.

Leading responsible authority is the Ministry of Transport of the Russian Federation, and other participants are the Ministry of Transport, Ministry of Industry and Trade and Ministry of Energy of the Russian Federation.

The objective of Subprogramme is stimulating the use of LNG on maritime and river transport, improving energy efficiency and reduction of the negative environmental impact.

The goals of Subprogramme:

- Creation of condition for the use of LNG at maritime and river transport;
- Development of fuelling infrastructure for LNG storage and bunkering in the ports and inland water ways;
- Formation of incentive mechanisms for research, development and production of marine vessels using LNG;
- Synchronized development of the LNG fleet, LNG production capacities for maritime transport, gas transportation and service infrastructure;
- Phased transition of maritime transport to the use of LNG;
- Creation of a modern legal and regulatory framework for the use of LNG in maritime transport;
- Increasing the total number of marine vessels using LNG by 14 units; the total number of LNG vessels – 25% of those certified by the Russian Maritime Register of Shipping, the number of gas storage and bunkering facilities will be 3 units in the sea ports, 3 units in the river ports.

The state policy of the Russian Federation in the field of development of gas engine technology aims, inter alia, at improving the competitiveness of the country's economy by transferring all types of transport to cheaper and more environmentally friendly gas fuels.

Priorities of the state policy are defined in a number of policy documents of the Russian Federation including the Transport Strategy of the Russian Federation for the period till 2030, the Energy Strategy of the Russian Federation for the period until 2030, the Strategy for Innovative Development of the Russian Federation for the period until 2020.

Currently LNG is practically not used as marine fuel in maritime transport. The only exception is OJSC "Sovkomflot". In 2017 Russian company Rosneft signed an agreement for the design, construction, technical supervision, operation and training of crews for five Aframax type tankers for Sovkomflot. The vessels will be built on the Zvezda shipyard in the Russian Far East. Also in



2017 Rosneft's subsidiary Rosneftflot and Zvezda signed an agreement to build five similar tankers. Vessels are planned to be delivered in 2020. Thus, Zvezda will build a series of ten ships.

In February, Sovcomflot signed a contract for the construction of four Aframax tankers for LNG with Hyundai, the total value of the contract is \$ 240 million. The delivery period is July 2018 - February 2019. In April Sovcomflot signed an agreement on LNG bunkering of these vessels with Shell. The tankers themselves will be used to transport oil and oil products in the Baltic and Northern Europe.¹⁶

The use of LNG as a fuel for maritime transport in Russia is constrained by a number of limitations:

- the lack of a coastal infrastructure for the supply and storage of LNG;
- high cost of vessels' retrofit;
- lack of qualified personnel.

Key measures for the transition of maritime transport to use of LNG include:

- stimulating the development and production of transport and delivering fleet operating on LNG, development of service infrastructure;
- development of the bunkering infrastructure taking into account the forecasted needs of the marine basins of the Russian Federation;
- improvement of regulatory framework as related to use of LNG at maritime transport.

In the Baltic basin

By 2020, it is planned to build LNG fuelled car-passenger ferry for the Kaliningrad-St. Petersburg line. In the area of the port of Ust-Luga, by 2020 - a plant for liquefying natural gas.

In the Gorskaya settlement and in the vicinity of the port of Vyborg - bunkering bases. In Gorskaya, LNG bunkering facility will include a liquefied natural gas plant with a capacity of 1.2 million tons per year, a bunkering terminal in Gorskaya and a number of Baltic Sea ports, as well as floating bunkers with a capacity of 7,000 m³.

By 2020, it is planned to build an icebreaker on LNG with a capacity of 10 MW for the Baltic Sea, as well as bunkering vessels and tugboats operating on LNG for the seaports of the Gulf of Finland.

Poland

Recent years were a very intensive investment period for the Port of Szczecin-Świnoujście, inter alia by launching the LNG Terminal opened in 2015. In the first stage of operation, the LNG terminal will en-

able the re-gasification of 5 billion m³ of natural gas annually, which corresponds to about one third of the Polish natural gas demand. In the next stages, depending on the increase of demand for gas, it will be possible to increase the dispatch capacity up to 7.5 billion m³, without the need to increase the area on which the terminal was constructed.

Within the next few years an investment construction of the vessel post for LNG export in the external port in Świnoujście has been planned. The investment constitutes the answer to the plans of Polskie LNG S.A. to expand the operations of the LNG Terminal by introducing re-exporting functions (including ship bunkering with LNG fuel). The investment will allow for the distribution of the LNG within the Baltic Sea Region as well as bunkering ships with the ecologic fuel. It is planned to be realized in the years 2021-2022. The investment consist in the construction of:

The dolphin type quay no. 1 with the length allowing for handling vessels of small, medium and large LNG scale (Q-FLEX), with their cargo capacity from a few hundred up to about 220 000 m³, which corresponds to vessels with LOA=315m, BEAM=50m and draught T ≤ 12,5m.

- The dolphin type quay with its length allowing for handling small LNG vessels (barges, bunker vessels) with their cargo capacity from a few hundred up to about 7 500m³, which corresponds with vessels with lengths within the region of 45m ÷ 110m and draught T ≤ 6,0m
- The fendering and mooring systems allowing for safe berthing and loading/unloading of LNG carriers and bunker vessels for STS fuel deliveries.
- The transshipment platform
- The pile supported trestle bridge connecting the platform with the shore on which gas transmission pipeline and communication catwalk will be placed
- The retention tank for LNG spills

The given information refers to the investment's preparation stage as in April 2018. It may change to some extent by the time of completion of the project preparation phase. The Port of Gdynia is conducting a number of activities to implement LNG fuel such as initiation of cooperation with LNG fuel suppliers. The purpose of cooperation is to create safety bunkering instruction in the Port of Gdynia. Such instruction would be the first in Poland. The Port of Gdynia Authority noticed the potential in using LNG fuel for electricity production for the needs of ships moored in the Port of Gdynia. The Port of Gdynia also submitted a project in the Connecting Europe Facility - CEF program for the construction of a barge with an LNG-powered power plant.

¹⁶ <https://www.rosneft.ru/press/releases/item/187873/>



9. EnviSuM Project

Environmental Impact of Low Emission Shipping: Measurements and Modelling Strategies



EnviSuM project studies technical efficiency and socio-economic impacts of clean shipping solutions and is funded by the European Union (European Regional Development Fund). The EnviSuM project supports the general aims of the Convention on the Protection of the Marine Environment of the Baltic Sea (Helsinki Convention) to achieve Good Environmental Status of the sea, and specifically it contributes to the implementation of the HELCOM Baltic Sea Action Plan (2007) and the follow up Ministerial commitments (Declarations from Moscow 2010 and Copenhagen 2013) to achieve the Baltic Sea unaffected by eutrophication by offering scenarios and building knowledge on the most efficient and cost-effective solutions for further reduction of emissions and deposition of pollution to the Baltic Sea from ships.

Project goals

- To provide policy makers and authorities with tools and recommendations for the development of future regulations benefiting the environment and public health in the Baltic Sea Region
- To provide tested and analysed results on efficiency of the different clean shipping solutions
- To assess present and future compliance costs, health and environmental effects of ship emissions in view of the IMO regulations that entered into force in January 2015*
- to enhance sustainable development in the form of cost effective means for clean shipping

Project activities

Work package 1

Concerns the coordination tasks and responsibilities of the Lead partner. The aim is to ensure effective and smooth implementation of the project. The Lead Partner ensures that the tasks are implemented as they were planned and that the project achieves the planned aims. The coordination responsibilities also include financial administration and communication tasks.

Work package 2

The aim is to create detailed emission data on SO_x, NO_x and PM emissions in the SECA area since the introduction of vessel fuel sulphur content reductions in 1.1.2015. The emission data of fixed site measurements collected in three large urban areas located in different parts of the Baltic Sea region (Gothenburg in Sweden, the Tri-City region of Gdansk, Sopot and Gdynia in Poland, and Saint Petersburg in Russia) are used together with emission data gathered from two flight campaigns in the Baltic Sea. The data from these measurements are combined with AIS-based ship emission modelling and measurements carried out on ships utilising scrubbers and LNG.

This work package also includes demonstration actions on energy efficiency of LNG fuel, the efficiency of scrubbers regarding particle emission reductions, Clean Shipping Café (organised in connection to Danish Maritime Fair 2016) and a study trip for 30 maritime stakeholders to introduce them clean shipping technological solutions.

Work package 3

Focuses on assessing the effect of ship exhaust gas emissions on air quality and depositions before and after the introduction of SECA regulations in the Baltic Sea in the beginning of 2015. The emission measurements conducted in WP2 as well as modelling are used to estimate air quality at a



Fig. 10. EnviSuM project area and project partners



regional scale in Europe (with focus on the Baltic Sea region) and at urban scale in three port cities: Gothenburg in Sweden, the Tri-City region of Gdansk, Sopot and Gdynia in Poland, and Saint Petersburg in Russia. The model calculations of air pollution from ships at different geographical scales combined with measurements provide gridded results for concentrations and depositions. These results in turn form the basis for calculations based on future emission scenarios (for the years 2020 and 2030), and for the assessment of health and environmental impacts carried out in WP4.

Work package 4

The health impact assessment is carried on the basis of results on pollutants concentrations and depositions achieved in WP3. The effects of vessel originated air pollutants on land vegetation (forests and farm crops), soils and water systems are estimated on the basis of measured and calculated concentrations of air pollutants.

On the basis of health and ecosystem-level impacts a cost-benefit analysis of the SECA regulations is carried out followed by visualization of alternative futures based on different policy options regarding different clean shipping solutions, and influencing of decision-makers and maritime stakeholders on the benefits of emission regulation.

Work package 5

Analyses the costs and benefits of emission abatement costs, administrative burdens, transport modal shift, and other socio-economic impacts both on macro and micro levels on the basis of previous studies, a survey, case studies, focus group meetings, expert interviews, a study visit to the Isle of Samso, and the results of other WPs. The aim of the analysis is to produce “Economic guidelines for SECA” comprising policy and business recommendations, and an economic decision making tool.

Project partners

- University of Turku (Finland - lead partner)
- Finnish Meteorological Institute (Finland)
- Chalmers University of Technology (Sweden)
- Maritime Development Center of Europe (Denmark)
- Norwegian Meteorological Institute (Norway)
- Maritime University of Szczecin (Poland)
- Tallinn University of Technology (Estonia)
- City of Gothenburg (Sweden)
- University of Gothenburg (Sweden)
- Baltic Marine Consult GmbH (Germany)
- Nordkalk Corporation (Finland)
- HELCOM (Finland)

Associated Organizations:

- Committee for Nature Use, Environmental Protection and Ecological Safety of St. Petersburg (Russia)
- State Company Mineral (Russia)
- Ministry of Infrastructure and Development (Poland)
- Port of Gothenburg (Sweden)
- Finnish Port Association (Finland)
- Faergen (Denmark)
- DFDFA/S (Denmark)
- SPC Finland
- Man Diesel & Turbo (Denmark)
- Union of the Baltic Cities (Poland)
- Port of Tallinn (Estonia)
- Ministry of Energy, Infrastructure and State Development Mecklenburg-Vorpommern (Germany)
- Agency of Regional Air Quality Monitoring in Gdansk (Poland)
- Port of Gdynia Authority (Poland)
- Port of Gdansk Authority (Poland)
- Port of Szczecin and Swinoujscie Authority (Poland)
- Polish Shipowners’ Association (Poland)

Project information

Project duration: March 2016 - February 2019
Project website: <https://blogit.utu.fi/envisum/>
Twitter: @EnviSuMproject

Lead partner representative:

Ms Sari Repka
 University of Turku
 Brahea Centre, Centre for Maritime Studies
 Tel. +358-40-8019206
 sari.repka@utu.fi

WP 1 Project management and administration	WP 2 Emissions and abatement strategies	WP 3 Air quality and deposition	WP 4 Social and political impact	WP 5 Economic impacts
University of Turku	Chalmers University of Technology	Norwegian Meteorological Institute	University of Turku	University of Turku

Fig. 11. EnviSuM work package overview