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Suplphur Regulation – technology solutions and economic consequences for the Baltic Sea Region shipping market

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Introduction

In recent decades global economic and social development has prompted the establishment of many different regulations and restrictions concerning further growth and development, the majority of them concerning the limitation and/or reduction of its negative impact on the world and the environment. An evaluation of such regulations would likely vary according not only to the evaluator, but also the aim and scope of the evalutation. However, in general it can be agreed that all implemented regulations are based on legitimate assumptions and positive results.

Undoubtedly this was also the reason for the issuing of Annex VI to the MARPOL 73/78 Convention a few years ago. Through the evaluation of Annex VI, most often called the "Sulphur Regulation", arises the veritable doubt as to whether the issuer – International Maritime Organization (IMO) was aware of all of the most important impacts and consequences, both technological and economical, when it was decided that the final limit of the sulphur content in a ships exhausts will be limited by 35 times (from 3.5% to 0.1%) as of 2015. Doubts also arise when analyzing the area of this limitation, reaching out to the SECA zones (Sulphur Emission Control Area) established for Europe within the area of the entire Baltic Sea and the majority of the North Sea. The aim, however, remains quite clear - the reduction of sulphur pollution as caused by sea transport.

However, based on 5 years of observation and analysis, it is safe to state that the maritime business has more doubts and problems than previously predicted or expected. Many different processes and phenomena have been noted, which leads us to the general conclusion that the Sulphur Regulation brought about more problems than benefits[1].

With this in mind, the monograph is an attempt at a market description and a summary of the current situation immediately prior to the new regulations taking effect. An attempt was made to collect all the most important aspects of the Regulation and possible solutions to the issues, including existing technologies, as well as those newly designed or under development. All of these solutions were finally subjected to synthetic, economic analysis. Additionally, we have endeavored to complete the survey on risk analysis and cost calculation with sensitivity analysis according to specific assumptions.

The aim of this publication is to give an accurate overview of the shipping market, especially in the Baltic Sea Region, which we judge to be most seriously affected by the

1 See: M. Matczak, *Redefining the Baltic Sea Maritime Transport Geography as a Result of a New Environmental Regulation for the Sulphur Emission Control Area.*[in:] *Marine navigation and safety of sea transportation.* Edit. A. Weintrit, T. Neuman. CRC Press Taylor & Francis Group, London UK 2013, pp. 2.

Regulation. The overview consists of a technical part in which the most popular and most probable solutions that shipping owners will undertake and invest in are presented. The second part concerns the economic consequences of specific, chosen technologies with special attention given to the cost analysis of them and the potential impact on the transportation market, which will affect freight rates and tariffs directly in the shipping industry and indirectly in the rail and road transport sector.

The reader will find in this book a few aspects, which vary in the way in which they are defined and/or named. This comes from the diversity of the regional and national nomenclature and business language. In choosing not to consolidate these terms, it was our intention to illustrate the complexity of the problem and to present some specific differences. Moreover, each contributor, being as they are experts in specific areas, draws from the knowledge of their expertise and hence the associated terminology.

Furthermore we wish to make the Reader aware about the need for further research, which we intend to carry out post January 2015 in the form of an *ex post* analysis in order to show the real impact of the Sulphur Regulation in the Baltic Sea Region shipping market. This will gain in importance especially following further evaluation of the Sulphur Regulation in 2018, during which a decision will be made with regards to the extension of the SECA zones on a global level as of 2020 or 2025.

Finally, we wish to thank all who have supported us in our research and to highlight the co-operation that has taken place between the Maritime Academy in Szczecin, the Maritime Academy in Gdynia and the University of Gdansk's Institute of Maritime Transport and Seaborne Trade.

Chapter 1.
Sulphur Emissions Limits in the Maritime Transport

1. Legal background

One of the most important legal acts concerning environmental aspects of maritime shipping (mainly to minimize pollution of the seas) is the MARPOL 73/78 – International Convention for the Prevent of Pollution From Ships. It was drafted in 1973, but thanks to its modification by the Protocol of 1978 was ratified by more than 150 countries, representing over 99% of total world's merchant fleet.[1] During this time a number of annexes were introduced concerning the following: oil pollution (I), Noxious Liquid Substances (II), Seawage (IV), garbage (V) and prevention of air pollution by ships (VI). The Annex VI standards entered into force in May 2005. This act established Emission Control Areas (ECA - an area where special mandatory measures are required to control NOx, or SOx and particulate matter (PM), or all three types of emissions from ships) with a global cap of 4.5% on the sulphur content of fuel, with a 1.5% limit in SECA (Sulphur Emission Control Area) zones. These standards were incorporated into EU law by Directive 1999/32/EC as amended by Directive 2005/33/EC. The Directive also set two additional sulphur emission limits in the EU: 1.5% for passenger vessels operating regular services from 2006, and 0.1% for ships at berth from 2010. In general the ECA established are within the Baltic Sea area – as defined in Annex I of MARPOL (SOx only), the North Sea area – as defined in Annex V of MARPOL (SOx only), the North American area (entered into effect 1 August 2012) – as defined in Appendix VII of Annex VI of MARPOL (SOx, NOx and PM) and United States Caribbean Sea area (since 1 January 2014) – as defined in Appendix VII of Annex VI of MARPOL (SOx, NOx and PM).

Due to European conditions, Annex VI has defined the SECA zone including the whole Baltic Sea and the majority of the North Sea (see fig. 1.1) with the following borders:

- The Skagerrak, the southern limit of which is determined east of the Skaw by latitude 57° 44.8' N,
- The English Channel and its approaches eastwards of longitude 5° W and northwards of latitude 48°30' N,
- The North Sea southwards of the latitude 62° N and eastwards of longitude 4° W.

1 www.imo.org/OurWork/Environment/PollutionPrevention/Pages/Dafault.aspx

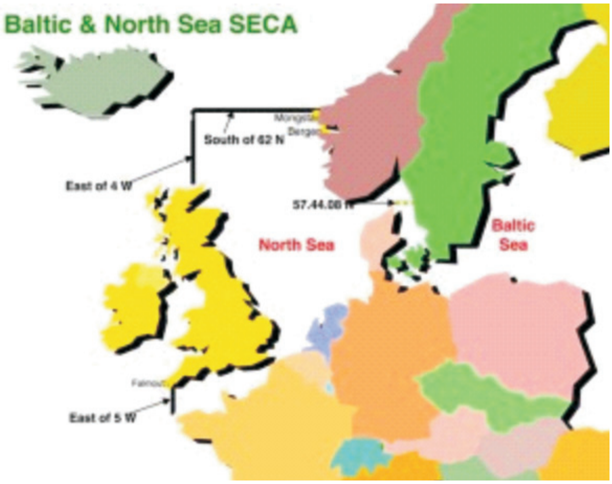

Figure 1.1. Baltic and North Sea SECA zone established by Annex VI MARPOL 73/78
Source: eceurope.net/wp-content/uploads/2007/08/seca1, 14/03/2014.

In accordance with the main aim of the paper, focus will be on the sulphur content aspect. In terms of this, as of 19 May 2006 on the Baltic Sea (ECA) all vessels bunker fuel must ingrid a maximum of 1.50% of sulphur, and as of 22 November 2007 on the North Sea. The next step was to decrease the allowable sulphur content to 1.00% m/m as of 1 July 2010 on the Baltic Sea (ECA) & North Sea (ECA). In the near future the limitation should be decreased to 0.10% of sulphur content in all vessel bunker fuel burned at sea and in sea ports, as of 1 January 2015.

The MARPOL Annex VI also introduced sulphur pollution restrictions also for other regions – 1% allowable in the North American zone as of 1 August 2012 and for the rest of world's seas and oceans – 4.5% also as of 1 August 2012. Moreover, Annex VI foresees a sulphur content limit of 0.5% on European Seas outside of the SECA Zone as of 2020 (due to EC Reg. from 11.09.2012.) and a 0.5 % limit for global maritime transport (beyond Europeans seas) since 2020 or 2025. But this will be regulated after revision of the on-going execution of current limits in the SECA zones and global maritime transport, and public consultations and should be confirmed by a separate Appendix. The timeline of different limits and regions are shown in figure 1.2 and summarized limits are presented in table 1.1.

Table 1.1. Sulphur content limits for vessels bunker fuel by MARPOT 73/78 Annex VI

Outside an ECA established to limit SOx and particulate matter emissions	Inside an ECA established to limit SOx and particulate matter emissions
4.50% m/m prior to 1 January 2012	1.50% m/m prior to 1 July 2010
3.50% m/m on and after 1 January 2012	1.00% m/m on and after 1 July 2010
0.50% m/m on and after 1 January 2020*	0.10% m/m on and after 1 January 2015

* depending on the outcome of a review, to be concluded in 2018, as to the availability of the required fuel oil, this date could be deferred to 1 January 2025
Source: IMO Publication, www.imo.org.

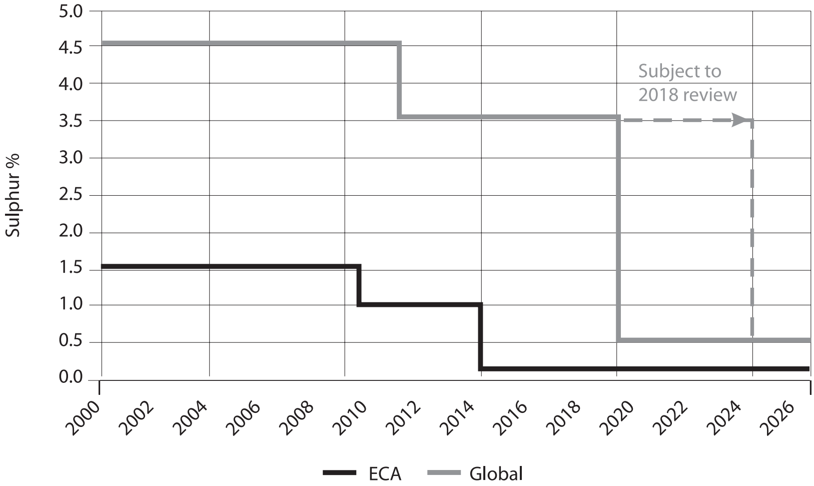

Figure 1.2. Timeline of the sulphur limits introduction by MARPOL 73/78 Annex VI
Source: http://www.kittiwake.com/emission_control_areas.

A more detailed, organizational analysis of the consequences of introducing Annex VI shows there is a great deal of problems to be solved onboard, at shipping company level and at the national and international level of procedures.

Firstly, all ships which operate both outside and inside these ECA zones should therefore operate on the appropriate fuel oil in order to comply with the respective limits. Therefore, before entering the ECA zone a complete oil changed-over is required with all non-compliant oil being replaced with ECA compliant fuel oil. Moreover, all ships are requested to be equipped onboard with written procedures for fuel changing and the possibility to generate adequate reports that are to be submitted to the appropriate authorities. This rule does not apply when travelling in the opposite direction – that is when exiting the ECA. At each change-over it is required that the quantities of the ECA compliant fuel oils onboard are recorded, together with the date, time and position of the ship when either completing the change-over prior to entry (usually it takes from a half hour up to 6 hours onboard, depending on the fuel mixing method and mixing tanks used) or commencing change-over after exiting such areas. These records are to be made in a logbook as prescribed by the ship's flag State, in the absence of any specific requirement in this regard the record could be made, for example, in the ship's Annex I Oil Record Book.[2]

For those who fail to comply with the new limitations, the European Commission has put a penalty system in place, which is adapted to national law systems. If the procedures are delayed (as it looks certain to be the case in some countries) or they are introduced disproportionately (i.e. the penalties are too low), it will most likely lead to a trend of intentional law-breaking.

It should, however, be pointed out that not all European sea regions are included in Annex VI. The Irish Sea, the Atlantic (European coastline) and the Mediterranean Sea together, as well as the Marmara and the Black Sea are all excluded Despite this, sufficient

2 www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Sulphur-oxides-%28SOx%29-%E2%80%93-Regulation-14.aspx.

justification for this is yet to be given – the only reasoning can be found in some statements concerning the inability to co-operate with North African and Arabian countries.

Annex VI to the MARPOL 73/78 Convention referred to the limits of the sulphur content in marine fuels. These restrictions were gradually tightened during the last thirty years. In 2012 the European Union adopted a directive, introducing strict standards in this field, to be enforced on seas and ports of Member States. The introduction of these rules should bring the expected positive effects for the natural environment. At the same time their use will trigger significant negative consequences, resulting mainly from the fact that the introduction of the required technological changes will be costly.

The introduction of strict Sulphur Regulation standards for the sulphur content of marine fuels shall have significant negative economic consequences. This became obvious immediately after the first Sulphur Directive (1999)[3] entered into force. The primary threat would be the general weakening in the competitiveness of European maritime transport. The other expected and yet undesirable problem is a modal shift of cargo flows from marine transport to inland transport routes. However, the crucial need for a further increase of stringent restrictions on the content of harmful substances in ship exhaust fumes in the future is recognized and appears to be logically and naturally understood.

Therefore, the political activity of EU bodies was already begun during the preparation of the IMO amendment of Annex VI of the MARPOL Convention. Political and legislative initiatives to support marine transport during the transition period were already at the stage of implementation when the European Commission's work on a new Sulphur Directive began. These political initiatives were in theory based on, and focused on the assumption that it is possible to create a legislative support system, designed and created to facilitate the smooth implementation of strict regulations by the maritime industry.

The fundamental document of the European Union in this respect was published in 2011. The European Commission prepared a report concerning the conditions of implementation, justified effects and expected impact of the Sulphur Directive (1999) and an amending document (2005). This document was entitled "Pollutant emission reduction from maritime transport and Sustainable Waterborne Transport Toolbox"[4].

2. An overview of accessible solutions

Ship owners and ports are forced to search for technological and organizational solutions that would allow them to fulfill the requirements for the reduction of shipping emissions in ECA. The problem may be considered in terms of two dimensions: long term and short term solutions. Long-term solutions require the implementation of a new development strategy within almost the entirety of the shipping industry. Short-term solutions must result meeting the new ECA requirements in the shortest possible time following their implementation on 1st January 2015.

3 Directive 1999/32/EC as regards the sulphur content of marine fuels; 26/04/1999; Brusseles.

4 SEC (2011) 1052 final; *Pollutant emission reduction from maritime transport and Sustainable Waterborne Transport Toolbox; 16/09/2011*; Brussels.

Strategic thinking must prompt action to be taken in order to change the standard fuel oil, which is used in shipping for alternative energy sources. The possible alternative sources of ship fuel are[5]:

- liquefied natural gas (LNG),
- biogas,
- biodiesel,
- ethanol,
- methanol,
- coal,
- nuclear power,
- wind,
- solar panels,
- hydrogen cells.

Liquefied natural gas (LNG) is predicted by many to be the first-choice fuel for the future within the shipping industry. The key drivers for this expected development is low nitrogen oxides (NOx), SOx and particulate matter (PM) emissions from LNG fuelled ships and the attractive price of LNG compared to distillate fuels. The most important technical challenge is finding the necessary space for storage of the fuel onboard the ship. LNG has lower energy density than fuel oil. The fuel oil volume has to be multiplied by approximately a factor of two to achieve equivalent energy content for LNG. For practical reasons LNG as marine fuel is most convenient for vessels trading between fixed ports where LNG fuel is available. In order not to scarify cargo capacity, large vessels engaged in deep sea shipping are therefore normally not candidates for LNG fuel; however several larger liner vessels, such as container and car carriers, are under consideration.

Biogas has the same chemical formula as natural gas – therefore its application as fuel and its environmental effects are similar to natural gas. However, because biogas is a renewable bio fuel, i.e. produced by biologic matter above ground, its CO_2 footprint is much lower compared to LNG. Cleaned biogas (bio methane) might be liquefied to so called bio-LNG (liquefied bio gas). Technically, usage and handling of LNG and bio-LNG are similar. Due to this reason biogas and bio-LNG are attractive alternatives for marine engines, however, commercial production and supply of biogas or bio-LNG needs to be established.

Biodiesel may be suitable for existing ship engines, but so far there is limited experience in using this fuel. Using biodiesel or biodiesel blends in ship engines are expected to have similar effects as on heavy duty highway engines with respect to emissions, i.e. a small increase in NOx and reduction of THC, CO and PM. The CO_2 benefits commonly attributed to biodiesel are the result of the renewability of the biodiesel itself, not the comparative exhaust of CO_2 emissions.

Ethanol as fuel is today used as blends in gasoline in various ratios. No ship engines have so far been developed to run on ethanol as fuel. However, using ethanol with ship engines is subject to the condition that competitive prices and production volumes can be achieved.

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5 Based on: vytautas Paulauskas V., Lukauskas V.: *Sustainable Shipping and Port Development*, CLEANSHIP Project Task 3.6, http://www.clean-baltic-sea-shipping.com.

Methanol is an alternative fuel for internal combustion and other engines, mainly in combination with gasoline. In general, ethanol is less toxic and has higher energy density, although methanol is less expensive to produce sustainably and is a less expensive way to reduce the carbon footprint. However, for optimizing engine performance, fuel availability, toxicity, a blend of ethanol, methanol and petroleum is likely to be preferable to using any of these individual substances alone. Methanol may be made from fossil or renewable resources, in particular natural gas and biomass respectively. Trials using methanol based auxiliary power systems for commercial vessels trials already began in 2010.

Coal can be still treated as a future source of energy in case of fuelling efficient gas turbines. Integrated Gasification Combined Cycle (IGCC) plants use a gasifier to convert coal (or other carbon-based materials) to syngas, which drives a combined cycle turbine. However cost, reliability and availability are all challenges facing IGCC development and application at the moment.

Nuclear power has obvious advantages in terms of its low emissions and extensive experience in naval fleets and in a few civilian icebreakers. Unfortunately, the disadvantages appear to be equally obvious with the risks of proliferation and terrorism, which at sea may be less manageable than onshore. Moreover, the majority of ports are closed for vessels with nuclear power plants.

Wind energy can be produced using special sails to reduce the fuel consumption and emissions of cargo ships. However, the Baltic Sea is relatively small with a very high ship density and given such conditions the use of sky sails is complicated. Alternatively, wind rotor systems could be used on many types of cargo vessels, but today such systems require additional ship stability equal to that of conventional cargo ships, and are currently relatively expensive.

Figure 1.3. Ship equipped with wind rotors system
Source: http://www.marinetraffic.com

Solar panels can be used as an additional ship's energy source, however due to the specific conditions of the Baltic Sea this alternative will not be feasible in the nearest future.

Hydrogen cells are attractive in terms of ecology and operation of the ship. However, the issues associated with the production, storage and supply of hydrogen are yet to be solved. Therefore, this alternative may be considered only as long term perspective.

In the short term internal combustion diesel engines will remain a dominant source of power for ships. There are many technical and operational methods available to reduce emissions from the ships operated today[6]:

- Low sulphur fuels,
- Scrubbing,
- Fuel water emulsion,
- Humid air motor,
- Direct water injection,
- Exhaust gas recirculation,
- Selective catalytic reduction (SCR),
- NOx traps,
- Selective non-catalytic reduction.

The big limitation is the fact that none of the above methods enable the simultaneous reduction of both SOx and PM in shipping emissions. Only low sulphur fuels and scrubbers reduce SOx in emissions, the remaining technical solutions reduce only NOx. Currently, the most developed and implemented technologies are scrubbers and SCR, which are characterized below.

There are few different marine **scrubber installations**:

- wet scrubbers: seawater open loop, fresh water closed loop and hybrid,
- dry scrubbers.

Taking into account economic and technical considerations, many ship owners decide to apply open loop or closed loop scrubbers. In open loop installations, exhaust gas enters the scrubber and is sprayed with seawater. The sulphur oxide in the exhaust reacts with water and forms sulphuric acid. In the closed loop installations, fresh water with added caustic soda (NaOH) is used. A small bleed-off is extracted from the loop to remove accumulated impurities from the scrubbing water. In both installation methods wash water from the scrubber is treated and monitored at the inlet and outlet to ensure that it conforms to the MEPC 184(59) discharge criteria[7], to ensure no risk of harm to the environment.

It should be mentioned that due to the space limitations it has been estimated that the scrubbing system can be retrofitted in up to 40% of the current fleet. Ships older than 20 years have been estimated to be beyond reasonable pay-back times and revenue generating potential to warrant scrubber installations.

Selective catalytic reduction (SCR) technology is based on the reduction of nitrogen oxides by means of a reductant on the surface of a catalyst. The exhaust gas is mixed

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6 Based on: Paulauskas V., Lukauskas V.: *Sustainable Shipping and Port Development*, CLEANSHIP Project Task 3.6, http://www.clean-baltic-sea-shipping.com.

7 *Guidelines for exhaust Gas cleaning systems*, resolution of IMO Marine Environment Protection Committee (MEPC) Adopted on 17 July 2009.

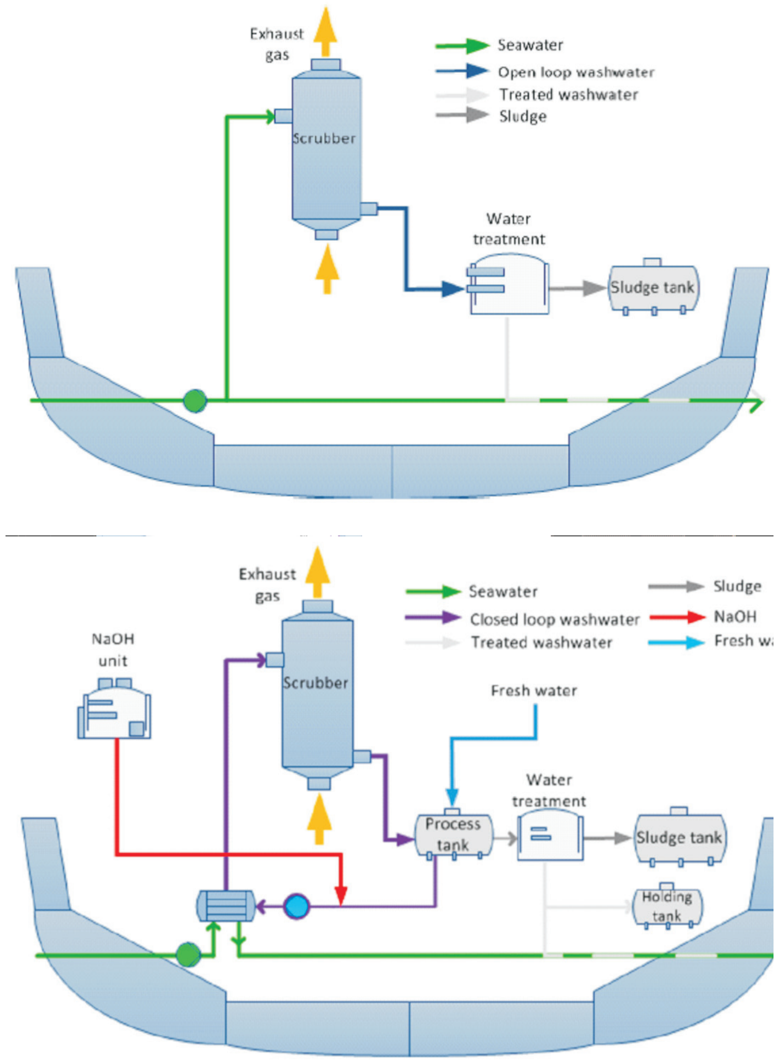

Figure 1.4. Open loop (above) and closed loop (below) scrubber installations
Source: Myśków J.: *Współczesne technologie ograniczenia emisji SOx i NOx w strefie ECA*, presentation of INNO-SHIP Project, http://www.bsrinnoship.am.szczecin.pl

with ammonia or urea before passing through a layer of catalyst at a temperature between 320^0C and 400^0C, whereby NOx is reduced to N_2 and H_2O. This only works, however, if the exhaust gas temperature is correct. If it is too high, the ammonia burns rather than forming a compound with nitric oxide. If it is too low, it forms ammonium hydrogen sulphate and gradually blocks the catalytic converter. The same happens if the sulphur content of the exhaust gas is too high. The minimum temperature required depends on the fuel‘s sulphur content.

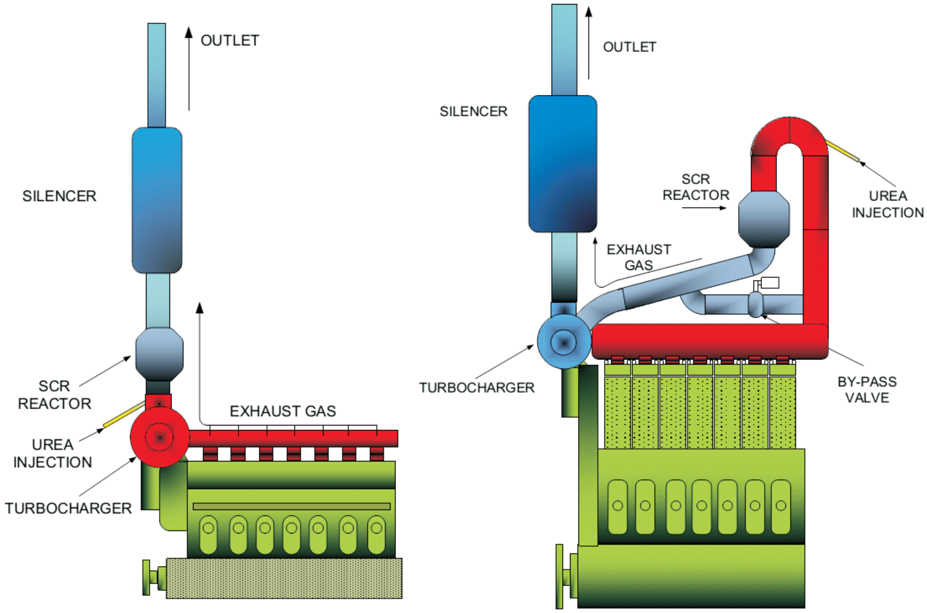

Figure 1.5. Possible locations of the SCR module

Source: Myśków J.: *Współczesne technologie ograniczenia emisji SOx i NOx w strefie ECA*, presentation of INNO-SHIP Project, http://www.bsrinnoship.am.szczecin.pl

The location of the SCR module depends on the engine type. In the case of a medium or high speed four-stroke engine, the SCR module is located in the low pressure part of the outlet gas system, beneath the turbocharger turbine in the exhaust duct. For large bore, slow speed and two-stroke engines, the SCR module is situated between the exhaust receiver and the turbocharger turbine in high pressure zone.

What is important is that SCR installation requires increased investment for procurement, storage space and the large quantities of ammonia or urea that are needed. As a result, the annual expenditure for the use of SCR increases by around five per cent of the usual fuel costs.

In conclusion, it should be noted that there is no proven technology for the purification of exhaust from SOx and NOx. Nevertheless, current research and experience within the shipping industry do allow the search for the most effective solutions to be narrowed down. Currently the most promising four solutions are as follows[8]:

- in the short-term, use of low sulphur fuels,
- in the medium-term, use of closed loop or dry scrubbers installations,
- in the long-term, use of alternative fuels with LNG being most effective one.

[8] Based on: Borkowski T.: *New technologies for reduction of emissions from ships*, presentation of INNOSHIP Project, http://www.bsrinnoship.am.szczecin.pl

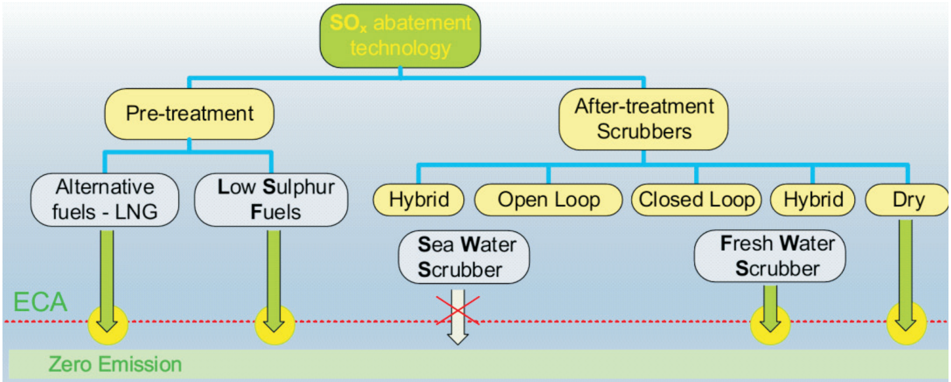

Figure 1.6. SOx reduction technology scenarios

Source: Borkowski T.: *New technologies for reduction of emissions from ships*, presentation of INNOSHIP Project, http://www.bsrinnoship.am.szczecin.pl.

3. Baltic shipping market state-of-the-art report

On our part, it was understood from the very beginning that the reaction of the shipping business to the Sulphur Regulation was of great importance. Through attending a lot of conferences and seminars, participating in different, maritime shipping and transport focused projects it was, however, noted that there relatively little interest in discussion of this topic. Our impression regarding this has remained the same since it was confirmed that the SECA norms will be introduced in 2015.

The following is a list, compiled through research and a review of the current literature, of the most important (but not at all) initiatives and tasks undertaken by science and business (together and separately) as a kind of "preparation agenda":

- A great deal of meetings, debates, conferences and seminars on the "SECA" topic and attempts to work out appropriate solutions for shipping,
- Many applications to national and EU co-financed programs supporting technology innovations in the shipping industry,
- Acceleration of research on alternative vessel supply technologies,
- Alternative Marine Power infrastructure development, especially for cold-ironing in sea ports and LNG bunkering network, LNG terminals network, etc.
- A concerted effort to delay the deadline of the introduction of the SECA norms (failed),
- Rather negatively perceived, simultaneous efforts to establish common procedures for executing new regulation norms by all stakeholders at both a European and national level (mandatory penalties law implementation set for June of 2014, not achieved yet by all),
- An effort to establish national rules of LNG bunkering due to the lack of them at an EU level (esp. in Norway),

- Cost restructuration programs in shipping companies leading to a decrease in operational costs (creating free space for the absorption of additional fuel costs),
- Alteration and optimization of shipping lines schedules – earlier departures from terminal (shortening loading/discharging time) for speed decreasing (fuel cost savings – Stena Line, Finnlines),
- A huge number of small scale cost analysis, especially cost analysis for changing fuel to MGO,
- Scrubber systems development and installation on board (i.e. DFDS, TT-Line, Finnlines, Scandlines, Color Line),
- The most popular suppliers of scrubbers are: Alfa Laval and Wärtsila,
- Design and construction of new ferries supplied by alternative fuel – LNG (Viking Line, Fjord Line, Brittany Ferries, Balearia, Unity Line or Scandlines), but with some cancellations of contracts (Brittany Ferries, STX Finland),
- Development of new, economic and environmental efficient ferries (i.e. Wasa Line will receive new ferry in the 2^{nd} quarter of 2015
- Development of hybrid vessels (Scandlines),
- Development of electric vessels (Norled), also supplied by "green" energy (Scandlines),
- Development of alternative fuel – methanol – Stena Line following more than 2 years lead trials with methanol and all necessary (main engine and bunker supply system) adoptions and reconstructions; Experimental retrofitting of m/s Stena Germanica will be performed by Remontowa Shiprepair Yard [Gdańska Stocznia Remontowa],
- Wide program of route optimalization (DFDS, Stena Line, Finnlines),
- Exploitation costs reduction programs: ecosteaming (ecodriving), electric energy savings systems (Stena Line with whole fleet) and other innovative actions leading to the cutting of costs (Finnlines – Patria Seaways),
- Sharpening (as additional task, besides regular procedure) or new installation of propeller to reach better efficiency (Finnlines, Stena Line, DFDS),
- The sale or charter of older vessels (Tallink, Viking Line, Stena Line, DFDS, Eckero Line) outside the SECA zones (these regions will offer a minimum of 5 or 10 years continuous "normal" sulphur limits) because of economical inefficiency to retrofitting (DFDS, Grimaldi Group, Stena Line),
- Trials and installation of cold-ironing systems (Stena Line, Viking Line, Tallink, Unity Line, Polferries, Faergen).

These are the most important initiatives of Baltic shipping owners and the shipping business in reaction to and in an effort to adjust to the new rules. The majority of these initiatives are supported by examples, which are however intentionally not detailed as the most significant characteristics were used in the following chapters as part of a more thorough and detailed analysis; a case study or example of the most popular solutions.

4. Sustainable waterborne transport „Toolbox" (2011)

European Union politicians perceived risks associated with the implementation of the restrictive sulfur regulations. The Sustainable Waterborne Transport "Toolbox"[9] was the first document on this matter, the goal of which was to support the real maritime economy and protect the industry from the negative consequences of these regulations.

This document consisted of three main parts:

- evaluation of the effects and impact of the Sulphur Directive (Directive 1999/32/EC) - an indication of further actions that should be taken to produce a more significant reduction of emissions of sulphur from the combustion of marine fuels;
- the proposal for a set of actions that can and should be taken by the European Union and by any member state in order to counteract the negative, undesirable consequences of the introduction of the new, more stringent sulphur standards;
- the most important part of this document was a declaration to create a program and deploy tools to facilitate the implementation of the future Directive and accompanying sulphur regulations.

The "Toolbox" contains an indication that, in accordance with the Sulphur Directive, it is possible to use a scope of alternative technical solutions to reduce emissions of sulphur, including:

- desulphured, light marine diesel oil;
- alternative fuels, including LNG;
- use of ship scrubbers.

Ship owners, in order to meet the new standards of ship exhaust quality, at least in the initial stage, should accept one of two solutions: the purchase of new vessels or the reconstruction the ships already in operation. At the same time, it was assumed from the variety of reasons, that in the future the LNG would be the best alternative. However, during the transitional period, the application of scrubbers should be treated as the best solution.

From the point of this paper it is worth paying attention to the issue, which largely determines the shape and scope of the general solutions proposed. It concerns the rules of financial aid granted by the European Union and the member states. The "Toolbox" document suggests that the expenses ship-owners would incur in making changes in the technology used on operated ships is taken into consideration, as well as the financing of the construction of new vessels. Therefore this expenditure must be regarded as the normal costs resulting from the conduct of a company in a commercial environment. As a result of this assumption it is considered that all expenses of this kind should be borne by the ship-owners – hence this must be treated as a principle.

At the same time, the financing of investment in seaport infrastructure: the liquid impurities reception facilities (especially scrubber wastewaters), LNG (import) bunkering and refueling stations, cool-ironing stations and other infrastructure, could be financially supported by the European Union (general rules are binding) or by the public authorities of the country concerned.

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9 SEC (2011) 1052 final; Pollutant emission reduction from maritime transport and Sustainable Waterborne Transport Toolbox; 16/09/2011; Brussels.

It was stated, in the “Toolbox”, that the key elements of the clean technologies development, in terms of exhaust emissions from ships, sulphur emissions in particular, are as follows: the creation of adequate seaport infrastructure, providing the ability to use low sulphur technologies in sea transport and to create unified, international technical standards. Primarily, this should concern the rules and norm of LNG fuel use.

What is most characteristic is that any unified legal rules or standards relating to the technical principles of construction and operation of LNG bunkering systems for marine vessels are yet to be created, both on an EU and international scale. It should be emphasized, that without common and unified, adequate standards, that consider not only the issues of technical parameters of ship and sea port infrastructure, but also the fundamental problems of fuel quality, ensuring safety, certainty of supply, it would not be possible to create a consistent, interoperable system of alternative fuels supply for ships in the future.

Such standards, at least, in its basic formulation, should include and define precisely the issues of:

a. quality characteristics of the fuel (LNG)
b. technical parameters of infrastructure and equipment used for bunkering ships
c. parameters of the vessel (by itself),
d. unified documentation
e. safety requirements and standards in relation to technological processes of:
   - ports supply,
   - storage in sea ports,
   - handling and transport in sea ports,
   - bunkering of ships,
f. the scope of minimum training and education requirements for employed dockers and seafarers[10].

Toolbox, short-term actions and tools

The short-term measures proposed in “Toolbox”, termed ‘actions and tools’, were divided into two groups. The first of them contains tools that should that form part of the EU’s aid and assistance. The second division contains tools that could be provided directly by any of member states.

It was pointed out that the basic tools needed to support the overall changes in the infrastructure of seaports should be:

- the TEN-T;
- multi-annual Program for the Development of Motorways of the Sea;
- Marco Polo II program (Work Program 2011);
- financial instruments offered by the European Investment Bank[11].

In the case of financial aid granted by member states, the general principle should be to use existing standards and principles. Member states may use grants of existing development programs, including financial support, for the types of projects that have

10 ISO; Report of Technical Committee 67 Working Group 10; 1998.

11 Own studies, based on: SEC (2011) 1052 final; *Pollutant emission reduction*...; op. cit.; p. 3-5.

been identified in the document "Guidelines Community on State aid for environmental protection"[12].

Moreover, as was pointed in "Toolbox", in the case of investment projects in the field of port reception facilities for ship impurities and terminals and LNG bunkering station, financial assistance may be provided and funded in accordance with the document Guidelines on National Regional Aid for the period 2007-2013[13]. It should be noted that a document: "Guidelines on National Regional Aid for 2014-2020" is currently in force in this area[14].

With regard to the financial assistance of member states in the field of research, modernization of the fleet and purchase of new ships may be granted in accordance with the principles set out in the document "National Assistance Framework for Shipbuilding"[15].

Among other activities, the importance and need for international dialogue and technical cooperation were indicated. In particular, this should include the European Union's cooperation with Russia, the Baltic Countries and the United States.

Toolbox, medium-term actions and tools

In the "Toolbox", the actions that should be taken in the medium-term were specified separately. Firstly it was highlighted that the priority should be to strive to develop a coherent, sustainable and competitive European maritime transport system in accordance with the assumptions of the White Paper - Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system[16]. The current guidance for TEN-T system development, particular to a specific time period, must be treated as a second fundamental document.

It was also emphasized in "Toolbox", that the activities of the European Union should not rely solely on the transposition of the requirements of international law (the extent of sulphur emissions restrictions) into Community law. It was highlighted, that it is necessary to make every effort to allow the smooth transition of EU maritime transport and multimodal transport to the use of the maritime environmentally-friendly transport technologies.

The proposed actions that should to be taken in the future are divided and presented in several characteristic groups, among them the following:

- regulatory measures - the technical norms of delivering and bunkering LNG on the vessels, due to the lack of relevant international regulations, should be introduced at least at EU level. The EU should strive to shape such legislation in consultation with the European Maritime Safety Agency (EMSA) and the International Maritime Organization (IMO), if possible, and all participating stakeholders. The environmental and economic impact of the IMO and EU further regulations relating to the issue of the utilization of the waters used for ship tank cleaning and purification systems

12 Community guidelines of 1 April 2008 on State aid for environmental protection; OJ C 82; 01/04/2008.

13 Guidelines on National Regional Aid for 2007-2013; OJ C54; 04/06/2003; p. 13.

14 Guidelines on National Regional Aid for 2014-2020; OJ C209; 23/07/2013.

15 Framework on State Aid to Shipbuilding; OJ 317 (11); 30/12/2003.

16 COM (2011) 144 final; White Paper - Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system; Brussels 2011.

of ship liquid wastes from (scrubbers) exhaust gases should be carefully evaluated at the same time;

- non-regulatory measures - should include: the development of platforms for contacts and cooperation with all stakeholders;
- researches and introduction of advanced environmental technologies in maritime transport, especially alternative fuels.

In the long term, the use of alternative fuels should be an option for creating environmentally friendly waterborne transport. The building of supply systems of LNG or other alternative fuels requires time and must be understood as a subject of significant technical changes in the field of fleet operation and the creation of appropriate port infrastructure.

Therefore, the Commission supports initiatives, the undertaking of research and analysis to promote solutions for the reduction of greenhouse gas emissions from maritime transport and the general improvement of transport energetic efficiency. In this matter the EU expect the use of medium term measures to be effective. Of such measures the following were highlighted:

- the development of infrastructure and superstructure - one of the conditions of the use of alternative fuels is to create an appropriate port infrastructure. Therefore, the Commission will take action in order to determine the overall shape of the future systems of logistics, infrastructure and location of bunkering terminals. In addition, the possibility to create supporting tools for the development of the necessary onshore infrastructure facilities shall be examined. The Commission believes that such aid will be able to include support for development: infrastructure, alternative fuel supply, bunkering systems at quayside and offshore bunkering systems. In particular, these actions will include the construction of bunkering infrastructure and the systems of LNG supply. In a similar way the creation of offshore infrastructure and the electrical ship supply should also be considered. The appropriate revision of the Directive on Taxation of Energy Products and Electricity[17] should be particularly useful in this respect. The development of basic infrastructure for marine transport alternative fuels should be based on the shape of the main elements of the TEN-T system. At the same time the Commission recognizes that in the field of complementary infrastructure it will be necessary to involve private sector investment;
- financial and economic instruments – the European Commission highlighted the need for more effort concerning a number of key issues. One of them is to create a general framework for the development of systems for financing infrastructure investments using public-private partnerships, as well as the intensification of activities towards further internalization of all negative externalities generated by transport. Therefore it is expected that the prices of transport services shall fully reflect the real account of the social costs. The Commission will take action towards the creation of a fund supporting the commercial economy and the public sector in research on development and the implementation of appropriate technologies. Such

17 COM(2011) 169 amending Directive 2003/96/EC on restructuring the Community framework for the taxation of energy products and electricity; SEC(2011) 409 final and SEC(2011) 410 final; Brussels; 13/04/2011.

a fund would be created from penalty fees charged to transport operators for generating forbidden emissions[18].

[18] Own study, based on: SEC (2011) 1052 final; Pollutant emission reduction...; op. cit.; s. 7-8.

Chapter 2
Sulphur emissions abatement methods for Baltic shipping

1. Scrubbing technique for maritime vessels

The principal requirement of the Sulphur directive is the reduction of the sulphur content in marine fuels in selected areas (SECA). Similarly, the positive environmental effect (the decrease of sulphur oxide emission into the atmosphere) can be achieved by the implementation of "emission abatement methods". The regulation indicates specific levels of emissions that must be adhered to (Table 2.1).

Table 2.1. Marine fuel sulphur limits

Marine fuel Sulphur Content (% m/m)	Ratio Emission SO_2 (ppm)/CO_2 (% v/v)
3.50	151.7
1.50	65.0
1.00	43.3
0.50	21.7
0.10	4.3

Source: Directive 2012/33/EU.

For the Sulphur Emission Control Area, including the North Sea and Baltic Sea the equivalent emissions value has been set at a level of 4.3% v/v. To achieve the desired environmental effect the following solutions are applicable:

- Mixture of marine fuel and boil-off gas, where the leading solution is implementation of LNG as a marine fuel;
- Equipment of ships with emission-reducing devices (scrubbers);
- Biofuels (as a mixture of biofuels and marine fuels)[1].

The first solution, which results in compliance with the requirements specified in the Directive is to apply desulphurization equipment, that is an onboard exhaust gas treat-

1 Annex II. Directive 2012/33/EU.

ment solution: scrubbers. This technology is already widely used in land-based installations, however, it is yet to undergo widespread application within shipping and as such cannot be considered commercially mature within the maritime sector.

The technology can be based on dry and wet scrubbers. In the first case, the system uses dry chemicals as a scrubbing medium. The absorption phenomenon involving the retention of exhaust components on the surface of a solid absorbent is used in dry cleaning methods. Calcium hydroxide (CaOH2) is a commonly used substance in this type of scrubber. There are two important restrictions associated with the implementation of the dry scrubbing technique. Firstly, due to the weight and elevated location of the scrubber (vessel funnel) it is necessary to use additional stabilizing measures. Secondly, a special waste disposal system must be installed, both onboard the vessel and on land. Unfortunately, the handling of the waste from dry scrubbers in harbors is still an unsolved problems in the European shipping sector[2]. However, this technology does not require additional equipment except for an electrical installation and measuring instruments.

Wet scrubbers use water as their scrubbing medium. There are three main types of wet scrubbers:

- salt-water scrubbers (open loop scrubbers),
- fresh water scrubbers (closed loop scrubbers),
- hybrid type of scrubbers.

In open loop system, outgoing exhaust gases are washed with seawater. The seawater is pumped from the sea through the scrubber, cleaned and then discharged directly into the sea through a process water treatment system. The desulfurization process uses the natural alkalinity of seawater. The sulphur dioxide SO2 readily dissolves in water to form sulphuric acid (IV) - H2SO3, which is then gradually oxidized to sulphuric acid (VI) - H2SO2. Sulphate ions are released together with sea water and some other combustion products in the form of suspended solids, which are separated and discharged into the waste tank. Wash water from the scrubber is treated and monitored at the inlet and outlet to ensure that it conforms with discharge criteria. It can then be discharged into the sea with no risk of harm to the environment. Similarly, such water is more acidic than seawater. Therefore, the widespread use of this method will depend on the assessment of its impact on the environment. A SOx removal rate close to 98% with full alkalinity seawater should be expected, meaning emissions from a 3.5% sulphur fuel will be the equivalent of those from a 0.10% sulphur fuel after scrubbing. An open loop scrubber requires the least investment and has lower operating costs than other options.

In the closed loop system, outgoing exhaust gases are washed with fresh water in the scrubber. The process water is continuously re-circulated. The ability to use a fresh water scrubber for the disposal and neutralization of sulphur compounds is to maintain a suitable pH. PH fresh water circuit which is held close to neutral. Suitable pH is achieved mainly by means of sodium hydroxide (NaOH). Closed loop systems can also be used when the ship is operating in sea areas where the alkalinity would be too low for open loop operation. During the entire process, sulphur oxides are neutralized and converted into harmless sulphates, which together with water, are excreted into the sea. Drop water has

2 *Reducing the sulphur content of shipping fuels further to 0.1 % in the North Sea and Baltic Sea in 2015: Consequences for shipping in this shipping area*, ISL, Bremen, 2010.

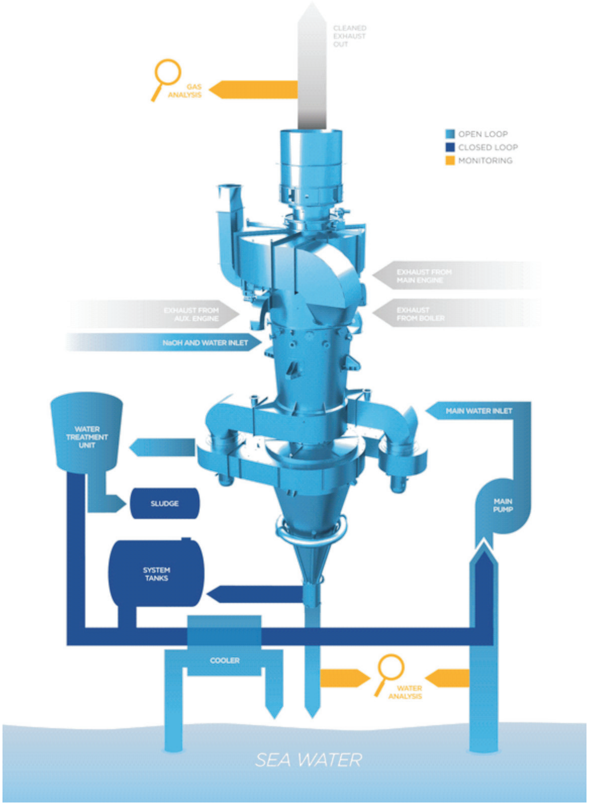

Figure 2.1. Operation scheme of the open and closed loop scrubbers
Source: http://www.cleanmarine.no/product_and_technology/allstream.

a pH of close to neutral, and therefore is slightly different to seawater. A closed loop can operate anywhere but has higher operating costs.

The final solution – hybrid scrubbers, is a combination of the closed and open loop systems, thanks to which it offers flexibility and the advantages of both solutions.

Scrubbing technology is a relatively new technology, which was firstly applied in the power industry (stationary installations). Companies such as Wärtsilä and MAN worked on the application of this solution on ships in recent years. In the year 2008, Wärtsilä began tests of this scrubber installed on the tanker Suula, which operates in the Baltic Sea region. The process was completed in 2010. The installation has been certified by two classification societies: Germanischer Lloyd and Det Norske Veritas (DNV) and finally has received a certificate of conformity for SECA. In December 2010, Wärtsilä received its first commercial order of scrubbers from the Finnish company Containerships Ltd Oy.

Currently engineering companies are providing the research activities underway on the development of the most effective, technologically and economically feasible equipment to capture sulphur compounds from exhaust gases. Above all, the creation of, competition should lead to the rapid diffusion and absorption of this type of innovation and hopefully a reduction in the cost of installation and its subsequent maintenance can be achieved. Nevertheless within the maritime sector scrubbing technology has to be consid-

Figure 2.2. Scrubber on the tanker vessel Suula
Source: http://worldmaritimenews.com/archives/20080.

ered a relatively new development, and therefore the final effectiveness and maintenance requirements are not specified (the oldest installations are currently approx. 7 years). It is therefore difficult to assess comprehensively the global costs of the solution.

Table 2.2. Selected producers of scrubber devices and its main clients

Company	Nationality	Client
Wärtsila	FI	Ignazio Messina & Co, Color Line, Wilhelm Wilhelmsen ASA, Algoma Central Corporation, Containerships, Finnlines, Royal Caribbean, TT-Line, Solvang ASA, Dorian-LPG Ltd.
Alfa Laval	DK	DFDS, Finnlines, MAN, Viking Ocean Cruises, Spielthoff,
Clean Marine	NO	Torvald Klaveness, Dorian LPG, Hyundai Shipyard,
Green Tech Marine	NO	Norwegian Cruise Line
DeltaLangh Ltd	FI	Langh Ship, Bore Ltd
Belco Dupont	US	Maersk (testing)
Saacke	DE	MT Levana (chemical tanker)
Marine Exhaust Solution (MES)	CAN	-
Couple Systems	DE	-
MAN Diesel & Turbo Green Technology	DK	-

Source: D. Gregory, Exhaust Gas Scrubbers. Cleaner Air-The Hurdles. 1st Ad-Hoc Expert Meeting on Scrubbing Technology, Brussels 3.06.2013; websites of the companies.

Scrubber devices are offered by different manufacturers in the world. Importantly, Europe is undoubtedly the centre of technological development. These developments should be supported by public authorities as, on top of positive environmental effects, regional and national development (including technological development, an increase in the attractiveness of the export economy) can also be achieved. The leading company in terms of market penetration is Wärtsilä. It is estimated that the company order book consists of about 100 units installed or on order for 51 vessels[3]. Positive market experiences are also obtained by companies such as Alfa Laval, Clean Marine or Green Tech Marine (Table 2.2).

Currently, 92 vessels are reported to have SOx scrubber technology fitted and 37 ships on order are due to have scrubbers installed. The majority of these units are Ro-Ro and cruise/passenger vessels (50%) and offshore units (18%) that typically spend a high proportion of their time operating in SECA zone. Just 0.1% of the fleet is reported to have scrubbers fitted and 75% of these vessels are younger than ten years old. Meanwhile, a slightly larger share of the order book (0.7%) is due to have scrubbers fitted. Interestingly, bulkers account for 22% of the units on order compared to 3% of the fleet. Scandinavian owners, mainly Norwegians, account for 50% of the scrubber equipped fleet whilst 'other' European owners account for 41% of the order book in numerical terms[4]. The main recipient of the devices are European companies (29%) including Scandinavians (40%). According to the forecasts over 6,000 scrubbers could be in operation by 2025 and this figure could be doubled by 2035[5].

The decision to invest in the installation of scrubbers on a vessel need a relevant comparison of the costs of available options. A shipping line may use an expensive fuel with a low-sulphur content or install the scrubber and still bunker traditional fuels (IFO, HFO). Therefore, the following factors affect the economic calculation:

- investment cost (device and installation),
- annual cost of operation and maintenance,
- daily vessel fuel consumption,
- difference in low and high sulphur content fuel prices (price gap) at the time of the investment and in subsequent years,

The cost of installation depends mainly on the power of devices emitting exhaust gases (main vessel engines power) and the number of the emission sources (fumes) as each of them should be equipped with separate scrubber[6]. These costs will also depend on the type of vessel and the type of scrubber installed. Research conducted by the ship-owners, institutions related to maritime transport, the shipbuilding industry or companies involved in this issue indicate that the cost of the device is about EUR 1.9 - 6.5 mln. As an example of such calculations the outcomes of USDT (US Department of Transportation),

3 *Finnlines Orders Wärtsilä Emissions Scrubbers* (http://gcaptain.com/finnlines-orders-wartsila-emissions-scrubbers/.

4 *2015 SOx Limits: Is The World Fleet Scrubbing Up?* (http://www.hellenicshippingnews.com/2015-sox-limits-is-the-world-fleet-scrubbing-up/.

5 GLOBAL: Scrubber order book set for dramatic rise. (http://www.bunkerspot.com/global/37394-global-scrubber-order-book-set-for-dramatic-rise.

6 *Techniczno – eksploatacyjne aspekty redukcji emisji SOx na statkach,* G. Kidacki, P. Krause, P. Rajewski, Zeszyty Naukowe Nr 10 Akademii Morskiej w Szczecinie, 2006.

EMSA (European Maritime Safety Agency), Brittany Ferries, or the Green Ship of the Future project can be presented.

In the case of the calculation undertaken by the USDT for a container ship with a capacity of 2,000 TEU and 16 MW engine the costs of a scrubber device may vary between EUR 2.3-2.8 mln. (Table 2.3.).

Table 2.3. Comparison of the costs of scrubber device for container vessel of 2000 TEU capacity (mln. EUR)

Main engine power	Type of scrubber			
	Open loop	Closed loop	Hybryd	Dry
36 MW	2.4	3.0	2.8	4.7
16 MW	2.3	2.8	2.4	2.5
10 MW	1.4	1.7	1.5	1.2

Source: USDT, 2011.

According to an estimation prepared by EMSA for a scrubber device installed on a passenger ferry with an engine power of 40 MW, the cost can vary between EUR 3.4-4.3 mln. for a used ship and EUR 2.4-3.8 mln. for a newly built vessel. In the case of cargo vessels with an engine capacity of 20 MW, these costs vary accordingly from EUR 2.4 to 3.0 mln. for a used ship and from EUR 1.9 to 2.6 mln. for a new ship The costs for newly built ships are lower, due to the fact that the installation of the existing scrubber on a ship requires additional modifications in order to adapt it to the scrubbing system, which generates additional costs.

Table 2.4. Costs of scrubbers for selected typed of vessels (EUR mln.)

	Used vessel	New vessel
Open loop		
Passenger ferry (approx. 40 MW)	3.5	3.0
Cargo vessel (20 MW)	2.4	2.1
Closed loop		
Passenger ferry (approx. 40 MW)	3.4	2.4
Cargo vessel (20 MW)	2.4	1.9
Hybryd		
Passenger ferry (approx. 40 MW)	4.3	3.8
Cargo vessel (20 MW)	3.0	2.6

Source: The 0.1% sulphur in fuel requirement as from 1 January 2015 in SECAs – An assessment of available impact studies and alternative means of compliance. Technical Report. EMSA, 13.12.2010.

A very interesting example of the calculation is also that prepared by the shipping company Brittany Ferries. A Study prepared for Ro-Pax ships shows that in addition to the basic characteristics of the units (of various sizes), other important factors also affect the global cost of this solution. Use of a scrubber requires extra energy consumption, and creates impurities, which must first be collected (to provide adequate space), and then be disposed of in an environmentally-friendly manner, which entails additional costs. Furthermore, the study distinguishes between CAPEX and OPEX costs, and specifies the cost of installation.

Table 2.5. Estimation of implementation of scrubbing technique on the Ro-Pax vessels by Brittany Ferry

		Ro-Pax 1	Ro-Pax 2	Ro-Pax 3
Vessels characteristics				
Passengers capacity	(PAX)	1200	2011	1500
Road units capacity	(units.)	547/75	648/85	500/110
Main engines power	(MW)	16,3	25,2	53,5
Selected effects of scrubbers operation				
Energy consumption	(kWh)	300–410	300–600	600–850
Chemical consumption	(tons/day)	3–12	4–18	6–36
Sludge emission	(m^3/day)	2–2,4	0,2–36	6–7,2
Bleed water emission	(m^3/day)	82–100	86–150	240–300
Costs of scrubbers and their installation				
OPEX (*closed loop*)	EUR mln.	5,6–5,8	5,8–8,7	16,2–17,0
OPEX (*open-loop*)	EUR mln.	0,6–1,4	0,8–2,0	1,2–4,1
CAPEX (only device)	EUR mln.	3,5–4,8	3,3–5,2	4,4–6,5
CAPEX (device + installation)	EUR mln.	5,5–7,6	5,3–6,4	7,0–10,4

Source: F. Pouget, Scrubbers retrofit: Ferry case study. 1st Ad-Hoc Expert Meeting on Scrubbing Technology, Brussels 3.06.2013 r.

In the framework of the Green Ship of the Future project it was estimated that the cost of installing a scrubber is about 5.84 mln. USD[7], of which:

- scrubber machinery and equipment 2.6 mln. USD;
- steel (150t) / pipe / electrical installation and modification 2.4 mln. USD;
- design and classification costs 0.5 mln. USD;
- loss of service 20 days) 0.34 mln. USD.

The cost is estimated as above, with return on investment (with reference to the change in fuel to MDO) about 4-6 years. Experts estimate that only 10% of the units operating in the zone will be equipped with this type of technology. It can be assumed that the process of adaptation of vessels to the requirements of the Directive will be connected with a significant increase in demand for the shipbuilding industry, especially after 2015.

Costs associated with the operation of the system are also a crucial element in the calculation of global costs. According to estimates by DMA (Danish Maritime Authority) costs associated with the operation and maintenance of scrubbers may reach 0.0025 EUR

7 *Green ship of the future.* Green Ship Technology Conference, Copenhagen 2012.

per kWh[8]. This means that for a container with a capacity of 2,000 TEU with an engine power of about 16 MW, annual operating costs of a scrubber can amount to EUR 260 thousand.

A key factor, in addition to the size of vessels, which determines the possibilities of the use of scrubbing technology, is their age and technological advancement (equipment). In the EMSA calculations the difference between the cost of scrubber installation on used and new ships was evident. In the case of used vessels the possibility of depreciation of the investment is critical. Increasing the frequency of renewal of a fleet limits the possibility of retrofitting to relatively new ships, which are permanently present in SECA. In the case of smaller units, which are older than ten years the cost of installing a scrubber may be equal to the total value of the ship (Table 2.6.).

Table 2.6. The ratio between the costs of scrubber installation and the value of ship

Type of vessel	Size	Value of vessel	Scrubber
Chemical tanker	12 000 DWT	13 m USD	44.6%
Container Ship	500 TEU	6 m USD	96%
Bulk carrier	Panamax	12.5 m USD	46%
Tanker	Aframax	17 m USD	34%

Source: Alkis John Corres, LNG : The fuel for the Green Corridors of Europe? (www.academia.edu).

Among other challenges facing ship owners who are considering this path in order to meet the requirements of the Directive, the following issues are also relevant:

- the size and weight of the device can prevent the installation,
- the device and the necessary installations take up cargo and/or passenger space,
- the system needs a space for water tanks and/or pollution containers,
- the production of additional engine power for the scrubber may the necessary, which will increase costs and cause further constraints on cargo space [9].

An additional solution to the sulphur problem is the use of hybrid propulsion on maritime vessels. The technology is based on the installation of systems consisting of a traditional diesel engine equipped with a small scrubber, supporting electric engines and a set of batteries. The combustion engines produce energy used for electric propulsion with any surplus being stored in the batteries. On occasions when energy is in high demend (e.g. acceleration, maneuvers) the stored energy will also be used for electric propulsion. This type of solution is planned to be implemented by Scandlines on a relatively small ferry that runs between the port of Puttgarden, and Rødby (45 minutes). The removal of one of the five generators has freed up sufficient space for the installation of the batteries and the scrubber. The batteries are used for the balancing of the engine load, which ensures their optimal activity (mainly in terms of the level of emissions). As a result, it is possible to install smaller scrubbers, thereby reducing capital expenditures. If the pilot installation functions efficiently, the company plans to upgrade other ships. There is no information

8 *North European LNG Infrastructure Project. A feasibility study for an LNG filling station infrastructure and test of recommendation.* Danish Maritime Authority, Copenhagen, 2012.

9 Alkis John Corres, LNG: The fuel for the Green Corridors of Europe? (www.academia.edu).

available on the cost of the solution, as well the possibility of the use of such technology on large units of Ro-Pax.

To summarize, the main advantages of the scrubbing technique seem to be the lack of a necessity to develop new fuel tanks or fuel logistics, the relatively straightforward and less costly process of retrofit (in comparison with the LNG solution). Nevertheless, the following disadvantages should also be highlighted: sludge reception facilities, space requirements and the issue of stability, large installation/interface onboard, the improvement of operational costs, the necessity of fulfillment of wash water criteria. Similarly, other important challenges require further assessment: performance on all engine loads, performance documentation, integration with boilers or corrosion.

2. LNG as an alternative fuel for vessels

2.1. Technology and market for LNG marine fuel

The need to adapt to the new IMO regulations for the reduction of emissions from ships, stimulates the search for alternatives to the traditional fuel currently used. This alternative is the use of a mixture of traditional fuels (IFO, HFO) and liquefied natural gas (LNG) as fuel in ship propulsion units. LNG is currently considered the "fuel of the future" in shipping. Liquefied natural gas is produced by lowering the temperature of natural gas to about -162 °C. Liquefaction of natural gas associated with the high level of purification, mainly from carbon dioxide. Liquefied natural gas has a volume about 600 times smaller than in its gaseous state. Condensation results in a very clear, colorless and odorless fuel, free from toxins and corrosives. The main component (about 90-95%) of liquefied natural gas is methane (CH4). Despite this, the following components are recognized: ethane, propane and very small amounts of higher alkanes. LNG has virtually no sulfur and heavy metals like: cobalt, lead, mercury. In effect, the combustion process does not generate sulphur oxides, dust and neither does it form, through solid waste incineration, slag, ash or soot.

Compared with traditional fuels used in the shipping sector combusted LNG emits significantly less nitrogen oxides and carbon dioxide. As a result of combustion LNG produces up to 90% less emissions of nitrogen oxides and 5% less carbon dioxide emissions than the combustion of conventional fuels. Table 2.6 shows estimates of emissions for the four types of fuels.

Engines for ships using LNG as fuel are offered among others by manufacturers such as: Wärtsilä, Rolls-Royce, MAN Diesel, and Mitsubishi Heavy Industries. Two main groups of internal combustion engines powered by liquefied natural gas can be distinguish: mono-spark ignition and dual fuel burners. Mono-ignition engines are engines powered only by gas. The development of this type of engine began in the early 1990s. The use of mono engines can be a good solution for vessels operating in areas with a well-developed network of LNG bunkering stations. While dual-fuel engines using natural gas as the main fuel and oil as fuel additives initiating ignition. The motor may also be switched from gas mode to oil mode at any time without stopping the engine. These motors have a more complicated structure in comparison to mono engines but prove a good option for ships operating in regions where the bunker station network is not sufficiently developed.

Table 2.7. The level of reduction of emissions from combustion processes of LNG (in comparison with traditional fuels IFO)

	CO_2	NO_x	SO_x	PM
DNV[1]	15-25%	85-90%	-	-
COSTA[2]	25%	85%	95%	-
GASNOR[3]	25%	90%	100%	100%
DMA[4]	15-30%	80-90%	100%	-
MAN[5]	20-25%	80%	90-95%	-
IMO[6]	15-25%	90%	~100%	-

Source: own elaboration.

An important technological issue constituting the challenge of using LNG as fuel for ships is the fact that much more space is required for LNG fuel tanks and relevant cryogenic installations. The volume of LNG tanks must be about 1.8 times greater than the volume of the tanks for MDO with an equivalent energy value. Furthermore, the use of vacuum insulation required for LNG tanks means that 2.3 times more space is required. In addition, there is a need for tanks of a cylindrical shape, which in effect means that the required space on the vessel is approximately 4 times greater. It can be expected that due to the relatively large space required for fuel tanks, LNG as fuel will be used primarily by ships operating on short distances. In order not to take up too much space on the ship, the volume of the tanks will be limited, and thus LNG-powered ships will require frequent bunkering. LNG as fuel is therefore most suitable for short-sea vessels such as ferries, ro-ro, as well as for individual offshore patrol vessels or tugs. Typical tanks for LNG fueled ships used currently do not exceed the capacity of about 200 m^3.

Research conducted by MARINTEK shows that the cost of construction of LNG-powered ships could be around 10-15% higher than the cost of construction of ships powered by conventional fuel. For a typical ro-ro ship with a capacity of 5,600 DWT the additional cost may therefore amount to about 3.2 mln. It is mainly associated with the construction of the LNG storage tanks and fuelling systems. In addition, DNV has estimated that the operating costs of the LNG-powered vessel may be about 35% lower than the operating costs of a ship powered by MGO during a period of 10 years. In contrast, within 20 years, the cost can be reduced by as much as 45%[10].

The estimated costs associated with the installation of LNG have been presented, inter alia, in the report by the *DMA North European LNG Infrastructure Project - a feasibility study for an LNG filling station infrastructure and test of the recommendation*. The document presents the unit costs of particular methods of abatement of sulphur emissions in respect of the main engine power (Table 2.8).

10 *The age of LNG is here. Most cost efficient solution for ECAs,* DNV presentation, June 2010.

Table 2.8. Estimated unit costs of implementation of sulphur abatement methods in shipping industry

Investments (€)= N (€/kw)* P main (Kw)	Unit	Retrofit	New builds	Other invest costs[7]	Total new builds
HFO/Scrubber	€/kW	429	375	420	795
MGO	€/kW	54	45	420	465
MDO motor conversion/fuel cooler/fuel pumps	€	130 000	100 000	-	100 000
LNG: Spark Ignition 4-stroke	€/kW	570	345	750	1 095
LNG: 4-stroke dual fuel	€/kW	570	345	750	1 095
LNG: 2-stroke high-pressure diesel dual fuel	€/kW	489	390	680	1 070

Source: North European LNG Infrastructure Project. DMA 2012. Appendix 3.

Other estimates are presented in the publication of the conference on Green Technology on Ships, held in 2012 in Copenhagen. The materials referring to the costs of LNG facilities in the cargo vessel with a liquid capacity 38.5 thousand. tons. The cost of such reconstruction has been estimated at 7.56 mln., which includes the following:

- 4.38 mln. USD devices LNG tanks and equipment, and the conversion of the main engine,
- 2 mln. USD for steel and steel works (300 tons)
- 0.5 mln. USD for the project and the classification of the vessel,
- 0.68 mln. USD as the cost of exclusion of the vessel (40 days) [11].

Currently, in terms of LNG there is no ship fuel market, therefore it is difficult to predict what will be the difference in prices between the fuel and traditional fuels (IFO, MDO, MGO). Consequently, prices can only be compared with traditional LNG fuel hubs.

The history of LNG as a marine fuel began in 2001, when a Norwegian ship-owner Fjord 1 first introduced an LNG powered vessel into service (other than a vessel for transporting LNG). It was a small ferry 'Glutra', which only serviced the coast of Norway. The key motivation behind the use of LNG as a prime fuel source in shipping is to reduce emissions from the vessel's engine. The ferry built in 2000 has two LNG tanks with a capacity of 32 m^3.

On a global scale, there is currently a fleet of 50 LNG-powered ships (in addition to gas carriers) in operation. Among existing ships powered by LNG can mainly be found coastal car-passenger ferries, ro-ro, PSV offshore units serving oil rigs, tugs and Ro-pax ferries. Also noteworthy is the geographical distribution of the fleet. Currently, the world's largest shipping market, which uses LNG propulsion is Norway, where liquefied gas is now being used for the first time. Shipping company Fjord 1, with twelve LNG-powered ships, is currently leading the way. The majority of other such vessels are also owned by Scandinavian companies.

11 *Green ship of the future.* Green Ship Technology Conference, Copenhagen, 2012.

Table 2.9. Fleet of vessels propelled by LNG (7.2014)

Vessel type	number
Car-passenger ferries	22
PSV	12
Tugs	5
Ro-Pax vessels	3
Chemical tankers	1
General cargo	2
Patrol vessels	3
Harbor vessels	1
HSV	1
Total	50

Source: H. Mohn, An overview of compliance strategy of ship-owners in the SECA area. BPO Conference, Ronne 4.09.2014.

The majority of LNG powered vessels are typical short-sea ships with a restricted range of operation. This is due to the relatively small size of cylindrical LNG fuel tanks, which require more space onboard than conventional fuel tanks. In the case of long distance shipping more cargo space should be sacrificed in order to allow for the space required by LNG tanks. Similarly, this results in the a decrease in the effectiveness of thesolution in areas of poorly developed LNG bunker infrastructure.

Currently, two ships propelled by LNG fuel operate within the Baltic Sea Area. The first one is a large LNG powered vessel, ferry 'Viking Grace' owned by Viking Line. The ferry, in the operation since January 2013, should be regarded as a benchmark within Baltic shipping. It operates between Turku in Finland and Stockholm in Sweden. It has a length of 214 meters, a width of 31.8 meters and can accommodate 2,800 passengers. The ferry is equipped with four Wärtsilä dual fuel (LNG/diesel) engines with a combined

Figure 2.3. LNG fuelled Ro-Pax vessel - M/S Viking Grace

Source: http://www.stxeurope.com/sites/Finland/Products/Pages/Cruise%20Ships%20and%20Ferries/NB-1376-Viking-Grace.aspx.

power of 30400 kW. Viking Grace is expected to consume about 60 tones of LNG a day and about 22,500 tons per year. The ferry cost about 240 mln. Euro, 28 mln. Euro of which was funded by a Finnish Government subsidy[12].

The second vessel is a border guard patrol unit 'Turva' from Finnish Border Guard. The LNG/diesel-powered dual engine vessel with a length of 96 meters entered into service in 2014. The ship was constructed by the STX shipyard in Rauma and is the largest vessel ever commissioned by the Finnish Border Guard. The almost EUR 100 mln patrol vessel is also ice-classed and is able to brake up ice up to 80 cm thick. In addition to standard border duties 'Turva' will undergo search & rescue operations, assist during environmental affairs such as oil spills as well as towing ships in distress[13].

Figure 2.4. LNG patrol vessel Turva
Source: http://www.baltictransportjournal.com/lng/lng-patrol-vessel-for-the-finnish-border-guard,1606.html.

An analysis of the Baltic Sea should also take into account LNG powered vessels operated by Fjord Line on routes between Norway and Denmark. These include new environmentally-friendly cruise ferries MS Stavangerfjord and MS Bergensfjord. The first vessel entered into service in July 2013, the second in March 2014. The ferries are 170 meters long and are able to accommodate 1500 passengers[14]. An important characteristic of the vessels is the implementation of a single-fuel engine, hence they run solely on LNG fuel.

Ship-owners operating in the western part of the Baltic Sea and the adjacent part of the North Sea are also planning to use LNG-powered ships. This type of unit are, amongst others, in service with the following companies: Scandlines, Fjord 1, containership and SamsøFærgen (Table 2.10).

Information provided by owners concerning plans to build LNG-powered ships are also worth mentioning. Among such examples are the Polish Steamship Company, whose ferry vessels are operated by Unity Line on the ferry route Poland – Sweden as well as

12 http://www.reuters.com/finance/stocks/VIK1V.HE/key-developments/article/2672646.

13 LNG patrol vessel for the Finnish Border Guard. (http://www.baltictransportjournal.com/lng/lng-patrol-vessel-for-the-finnish-border-guard,1606.html.

14 http://www.fjordline.com/Our-ships/MS-Stavangerfjord/Ship-facts/Facts/.

Maersk Line[15] and CMA CGM[16] who are both evaluating the possibility of using LNG propulsion on container ships.

Table 2.10. Selected orders for LNG fuelled vessels from the Baltic and North Sea ship-owners

Company	Number	Type	Main features	Year of delivery	Shipping service
Scandlines[8]	2	Ro-pax	1300 pax., 72 truck/382 cars	2015	Rostok-Gedser
Fjord Line[9]	1	Ro-Pax	1500 pax., 1350 line meters	2014	Berger-Stavanger- Hirtshals-Langesund
SamsøFærgen[10]	1	Ferry	600 pax., 160 cars	2014	Samso-Hou (DK)
Containership[11]	2	Container	1368 TEU	2016	SSS Baltic

Source: Own elaboration based on http://www.baltictransportjournal.com/lng.html.

Future development plans for LNG fuelled ships show that a further 66 orders for this type of units have already been placed. As a result, a minimum fleet of 116 ships should be in operation from the year 2018 (Table 2.11). This group also contains the ships currently in operation with plans to retrofit with LNG. However, in this case the vessel types are slightly different, PSV (14) and container (14) ships being those which dominate. What is also important to note in this case is the action of Dubai ship-owner UASC who ordered

Table 2.11. Order book for vessels propelled by LNG (7.2014)

Type of vessel	Quantity
PSV	14
Container	14
Car-Pax Ferry	8
Ro-ro	7
Ro-Pax	4
Chemical tanker	4
Tug	3
LEG Carrier	3
General cargo	2
Gas carrier	2
Car Carrier	2
Product tanker	1
Bulk ship	1
Icebreaker	1
	66

Source: Own elaboration based on *H. Mohn, An overview of compliance strategy of ship-owners in the SECA area. BPO Conference, Ronne 4.09.2014.*

15 http://shippingwatch.com/carriers/article6263287.ece.

16 http://shipandbunker.com/news/world/261288-cma-cgm-daewoo-to-develop-lng-powered-container-ship.

five container vessels with a capacity of 14 thousand TEU and another 5 with over 18 thousand TEU, which will be adapted for use of LNG as an alternative fuel[17]. On the following positions car-passenger ferries (8) and ro-ro vessels (7) are listed. LNG fuelled propulsion systems will also be installed on gas carriers, car carriers, and icebreakers. This confirms the versatility of LNG propulsion technology and the widespread possibilities of its application, regardless of a vessel's type or size.

Taking into account the spatial distribution of the order book, Norwegian (19 units), US (12 units) and Danish (8 units) companies should be highlighted. Several ships have also been ordered by companies from Germany, the Netherlands, UK and Canada. The structure presented does not determine the areas in which the ships will operate but their domination of Europe is visible. European owners ordered a total of 41 ships, hence it is more than probable that they will be put into operation in the European part of the SECA zone.

Similarly, it should be emphasized that a significant growth of orders for new LNG powered ships has been noted. In the period May 2014 - July 2014 another five additional orders for such vessels were submitted[18]. In the following years more and more orders for LNG powered ships should be placed. According to a DNV survey, in 2020, there will be approximately 1,000 LNG powered vessels worldwide. Offshore vessels and ships operating in regular shipping (ferries, ro-ro ships, container vessels) will dominate the future LNG fuelled fleet and may account for about 60% of that fleet. In Europe, there will be about 400 such ships. Consequently, the world LNG bunkering demand in 2020 may reach a total amount of 4-7 mln. tones. In Europe demand may be at around 1.4-2.2 mln. tones.

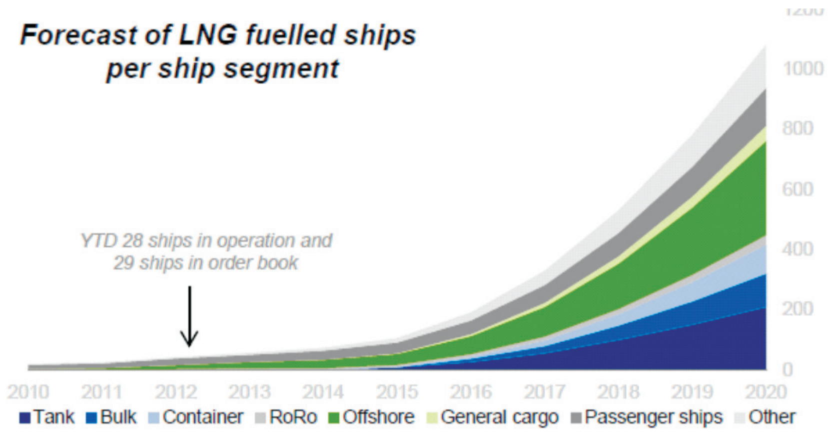

Figure 2.5. Forecasts of LNG fuelled ships (per ship type and per region)

Source: Shipping 2020, Technology investments in the new market reality, Claus Winter Graugaard, Poland, March 2013

By the year 2013 the total global production of natural gas had reached 3,369.9 billion cubic meters. At the same time, global reserves were estimated at 185.7 trillion cubic meters, so the Ratio R/P could be estimated at 55 years. Production counting on the fact that

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17 M. Borkowski, *Skazani na LNG*. „Namiary na Morze i Handel" November 21/13.

18 *LNG – a cost-effiient fuel option*. DNV-GL (www.sjofart.ax/files/oceaneballand2014.pdf.

1,035.9 billion cubic meters are traded globally. The majority of trade (68.6%) is done via pipeline systems and the rest of the volume is transported in LNG form. The total volume of LNG trade in the year 2013, could be calculated as follows:

- 523.15 mln. m^3 of liquid LNG,
- 236.91 mln. of tones of LNG,
- 298.79 billion m^3 of gaseous (produced from LNG).

Through analysis is may be estimated that the global demand of LNG will develop further and reach a level of about 500 mln. tons in the year 2030[19]. In terms of export, Qatar is leading the way on the LNG market with a volume of 78.02 billion tons of LNG, which constitutes 1/3 of global trade (Table 2.12). The main importer of the LNG is Japan and South Korea. These countries possess of 54% of the global import market.

Table 2.12. Top exporters and importers of LNG in year 2013

No.	Exporter country	10^6 m^3 gaseous	10^6 tones	Importer country	10^6 m^3 gaseous	10^6 tones
1	Qatar	98.21	78.02	Japan	109.61	87.98
2	Malaysia	31.04	25.14	South Korea	51.03	40.39
3	Australia	27.29	22.41	China	23.39	18.60
4	Indonesia	23.49	18.36	India	16.49	13.05
5	Nigeria	20.82	16.47	Taiwan	16.02	12.72
6	Trinidad & Tobago	18.45	13.67	Spain	11.69	9.13
7	Algeria	13.68	10.81	United Kingdom	8.72	6.91
8	Russian Federation	13.55	10.69	France	7.51	5.94
9	Oman	10.37	8.35	Mexico	7.23	5.67
10	Yemen	8.90	6.82	Argentina	6.17	4.72
11	Brunei	8.56	7.01	Turkey	5.57	4.40
12	United Arab Emirates	6.16	5.08	Italy	5.09	4.05
	Total	280.5	222.83	Total	268.5	213.56

Source: own elaboration based on The LNG Industry 2013. GIIGNL. France 2014.

Investigation of the characteristics of global demand on LNG indicates that the market could be divided into three geographical areas: Asian (75%), European (14%) and American (9%). Similarly, the market could be shared between long and medium-term contracts and the spot market sector. It could be stated, that the crucial part of trade is operating on the basis of long and medium term contracts within the abovementioned geographical areas. Seen in this way, the demand-supply ratio on the particular markets is balanced. The spot market should be regarded as supplementary to long term contractors without any geographical restrictions.

The main effect of the spatial isolation of the markets is different LNG prices. The highest, estimated at about 17 USD/1mmBtu is observed on the Asian market. The lower

[19] http://www.ey.com/GL/en/Industries/Oil---Gas/Global-LNG--New-pricing-ahead---LNG-demand-growth.

Figure 2.6. The main global maritime routes of LNG trade in 2013
Source: The LNG Industry 2013. GIIGNL. France 2014.

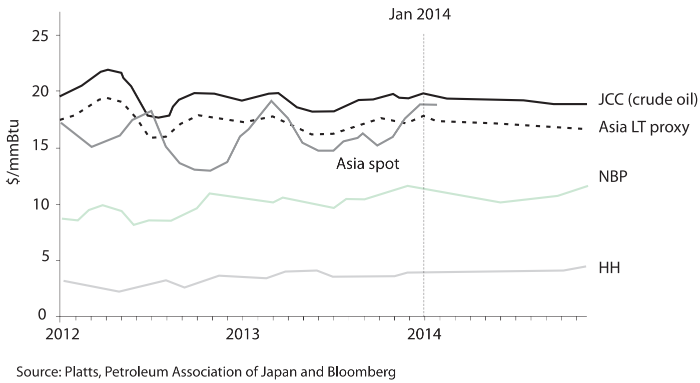


Figure 2.7. LNG prices development in the main global markets[20]
Source: Global trade summary for 2013. BG Group 2014 (http://www.bg-group.com/assets/files/cms/A3319_BG_LNG_flyer_v6.pdf).

prices (approx. 5 USD/1mmBtu) are in the US sector. The European part of LNG trade is on average, 10-11 USD/1mmBtu, in terms of global prices. Despite the process of gradual integration of the presented markets variance in pricing is likely to be maintained, (Fig. 2.7) although, the differences will decrease. The future situation will be defined by the balance between supply and demand on LNG on a global and regional scale.

On the one hand, development of new facilities for liquefaction (e.g. Australia, Angola, USA, Russia) will improve the supply side of the market, on the other, growing demand for LNG in Asia and Europe will create an additional demand for gas. Although a long term prediction is more difficult some basic assumptions are possible:

- the known available resources of natural gas are higher than those of crude oil, so it is clear that the future availability of natural gas looks more promising,
- crude oil is used as a raw material for many industrial processes and therefore is able to carry a payment an additional premium compared to only energy production,

[20] *HH – Henry Hub*, USA; *NBP – National Balance Point*, U.K.

- since the hydrogen/carbon ratio is much more preferable for natural gas compared to crude oil the contribution to global warming is much less when burning natural gas than crude oil related products, so the higher attractiveness of gas could result in the development of higher prices than for crude oil.
- depending on future national and international policies addressing the issue of climate change, the reduction of prices is more plausible since any reduction of the basic market price of crude related products is likely to be offset by taxation and other initiatives that focus on the reduction of emissions of greenhouse gases.

The crucial issue is a price gap between the LNG and traditional fuels for maritime transport. A comparison of historical prices of LNG and heavy (HFO, IFO) or distillates (MDO, MGO) fuel prices indicates that in general LNG prices were lower. In the period 2009-2011 LNG was 40-60% cheaper than HFO, whereas compared with MGO, the price was about 60-70% lower[21]. However, it should noted that future LNG fuel prices will depend not only on the price of LNG in the hubs (although it will be a major component of the price), but also on the cost of storage, transport to local terminals and distribution. There are currently no LNG common market in the Baltic Sea area. This means that if an accurate price for LNG should be calculated, cost for regional distribution as well as small scale LNG terminal operations have to be added to the European Hub price. According to DMA (2012) the estimated additional cost is between 100 and 140 USD/tone. The market observation based on Western European practice (Spain) shows that the distribution costs are about 1.5 USD/mmBtu of LNG (approx. 70 USD/tone). As a result, the level of bunkering prices of LNG fuel should include 11.5 USD/mmBtu (536 USD/tone).

In the case of LNG the future level of the prices will be influenced by the following elements:

- balance between supply (e.g. increase of the capacity of liquefaction plants and LNG tankers fleet development) and demand (e.g. level of utilization of LNG technology in transport, implementation of diversification policy for energy resources, seasonal consumption of gas by households and industry) of the source,
- level of separation of main global LNG markets (North America, Europe, Asia).

As a result, it is estimated that return on investment (In terms of a change in fuel from MGO) may be achieved in 3 to 9 years (depending on the difference in prices between LNG and MGO and the time that the ship spends in the region of SECA in relation to the total operating time throughout the year).

2.2. LNG terminals and bunkering stations development in the Baltic Sea region

Development of LNG shipping requires that an adequate amount of the gas is available for final users. Currently 22 large import LNG regasification terminals are operating in Europe. Most of them are located in Spain, the United Kingdom and France. The total installed capacity of LNG tanks is more than 8.6 mln. m^3. Re-export operations based on maritime transport are possible in ten locations constituting approx. 12% of the turnover LNG terminals[22].

21 *Costs and benefits of LNG as ship fuel for container vessels* -Key results from a GL and MAN joint study, Germanischer Lloyd, 2012.

22 T. Deschuyteneer, *LNG import potential to Europe.* GIE, Brussels 04.2014.

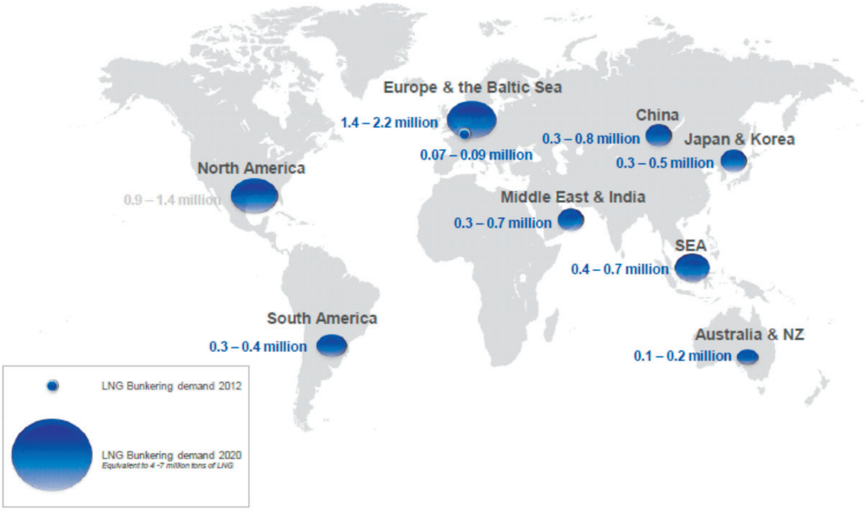


Figure 2.8. Forecast of world demand for LNG

Source: Shipping 2020, Technology investments in the new market reality, Claus Winter Graugaard, Poland, March 2013.

Table 2.13. LNG import and regasification terminals in Europe

No.	Country	Port/Terminal	Number of tanks	Capacity [thou. m^3]
1	Belgium	Zeebrudge	4	380
2	France	Fos-Cavaou	3	330
3		Fos-Sur-Mer	3	150
4		Montoir-de-Bretagne	3	360
5	Greece	Revithoussa	2	130
6	Italy	Offshore Livorno	4	103
7		Panigaglia	2	100
8		Rovigo	2	250
9	The Netherlands	Gate LNG	3	540
10	Portugal	Sines	3	390
11	Spain	Barcelona	6	760
12		Bilbao	2	300
13		Cartagena	5	587
14		Huelva	5	619,5
15		Mugardos	2	300
16		Sagunto	4	600
17	Turkey	Aliaga/Izmir	2	280
18		Marmara Ereglisi	3	255

19	United Kingdom	Dragon	2	320
20		Isle of Grain	8	1000
21		South Hook	5	775
22		Teesside		138

Source: own elaboration based on The LNG Industry 2013. GIIGNL 2014.

The four LNG import terminals designated above operate in the European area of the SECA zone. These are Zeebrugge (Belgium), Grain LNG, Teesside (United Kingdom) and the Gate LNG (Netherlands). In addition, there is also a small terminal in Nynäshamn in Sweden, which having entered into operation in 2011, is the first of its kind in the Baltic region. The Terminal operator is AGA Gas AB. The first supply of gas to the terminal was delivered by the ship Coral Methane from a liquefaction plant in Risavika/Norway. Currently, the terminal is equipped with a tank with a capacity of 20,000 m^3, however the next stage of development assumes the construction of a second tank. The terminal has one vessel stand for handling LNG tankers with a maximum length of 160 m, draft of 9 m and a capacity to 15,000 m^3. Gas is supplied to a nearby refinery, as well as the city gas grid in Stockholm. The terminal also serves the first ro-pax ferry powered by LNG on the Baltic - Viking Grace. For this purpose, the company AGA Gas Seagas built an LNG bunker barge, which allows for a single delivery of 70 tons.

Important projects concerning the development of LNG import terminals in the Baltic Sea are terminals in Świnoujście/Poland and Klaipeda/Lithuania.

In August 2008, the Polish Government adopted a resolution in which the construction of the LNG terminal has been recognized as a strategic investment in the interest of the country. The plan of diversification of energy sources and supply routes of natural gas to Poland has been regarded as an important factor in this decision. A preliminary analysis has indicated that an optimum location for the project is the port of Świnoujście. The technical project has been completed and the works began in 2010. Completion of the terminal is scheduled for the beginning of 2015. The LNG terminal in Świnoujście with the tanks capacity of 320 thousand m^3 will receive 5 billion cubic meters of natural gas per year. At the same time there will be an opportunity to increase the operational capacity of up to 7.5 billion m^3, without expansion of the area. The basic functional elements of the terminal are as follows:

- a pier equipped with an unloading position and security installations (the depth of the port areas amounting to 14.5 meters),
- two LNG storage tanks with a capacity of 160 thousand. cubic meters each,
- an LNG regasification station.

The port's infrastructure will enable support for LNG tank vessels ranging in capacity from 90 to 200 thousand m^3 and a draft of 12.5 meters.

Currently, plans for establishment of a second loading/unloading pier are under development. The planned investment is focused on the development of the distribution function of the terminal in the Baltic Sea region, also for LNG shipping.

In the Lithuanian port of Klaipeda the construction of the LNG import terminal based on the technology of FSRU - Floating Storage and Regasification Unit - has been just completed. FSRU unit is an anchored tanker adapted to receive gas from ships and equipped with an onboard regasification system. According to the initial assumption, the FSRU can also serve as a distribution point for the LNG small scale terminal located in the Baltic region. Similarly, there is no possibility to load LNG bunkering barges, hence there are additional plans to develop a small LNG bunkering station in Klaipeda. FSRU vessel - a floating terminal has been built in the Korean Hyundai Heavy Industries shipyard in Ulsan. The unit has been commissioned by the Norwegian company Hoegh LNG but will be transferred to the prospective operator (Klaipedos Nafta) under a charter agreement for a period of 10 years. The cost of construction of the vessel will be approximately 330 mln. USD (Hoegh[23]), while the freight rate will be 156 thousand USD per day for ten years[24]. There is also the option for Klaipedos Nafta to purchase the units after the charter period. A ship of length 294 m, a width of 46 m and a draft of 12.6 m will have a capacity of 170 thousand m^3 of LNG. As a result, FRSU terminal capacity is estimated at 2-3 billion m^3 of gas per year[25]. In august 2014, the LitGas company signed a LNG delivery contract with Norwegian Statoil for the import of 540 mln. m^3 of gas. Thus, the completion of the work and the launch of the terminal should therefore coincide with the first deliveries of LNG to Lithuania.

Figure 2.9. FSRU unit in the port of Klaipeda (visualization)
Source: http://www.lei.lt/energy-security-conference/index_files/Masiulis.pdf.

In addition to the Polish and Lithuanian projects, other plans are in place for the construction of LNG import terminals, namely in Sweden, Finland, Latvia, Estonia and Russia (liquefaction plants). In most cases, these are small import terminals built for the needs of regional industry and society. Obviously, due to the significantly smaller storage capacities the import of LNG is likely to take place from one of the major European hubs.

23 http://www.hoeghlng.com/regas/Pages/Lithuania-FSRU.aspx.
24 http://www.highbeam.com/doc/1G1-285471767.html.
25 http://www.lei.lt/energy-security-conference/index_files/Masiulis.pdf.

In Sweden, the LNG small scale terminals are planned in Lysekil, Gävle, and Sundsvall. In Lysekil near Gothenburg, the Linde Group will build a terminal on behalf of the Norwegian company Skangass, which will supply gas to the nearby Preem refinery as well as other industrial customers. There are plans for the capacity of the tanks to amount to around 30,000 m^3. The LNG will be fitted in the Risavika liquefaction plant in Norway. The expected cost of construction is about EUR 44 mln. Skangas is also an investor in the LNG terminal in the port of Gävle, construction of which is scheduled to begin in 2015. The terminal, which will have a LNG tank capacity of 30,000 m^3 will serve two major industrial producers in the region, Sandvik and Ovako. At the same time the use of LNG is planned within the transport sector (land and sea). A similar activity is planned in the port of Sundsvall. As in other cases, the terminal is built for the needs of local industry.

Figure 2.10. LNG terminals in the Baltic Sea Region
Source: Baltic Ports Organization, Gdynia 2014.

A similar process can be observed in Finland, where the national pipeline operator Gasum plans to build several LNG small scale import terminals. The following ports are indicated: Pori (Tahkoluoto), Inkoo and Tornio. In the first case, the terminal will have a capacity of 30,000 m^3, which will serve surrounding industry and transport applications. The construction phase is expected to start in 2014 and the first deliveries should be completed in 2016. The second terminal is planned in the port area of Fjusö Joddböle (Inkoo). In this case, the possibility of building an underwater pipeline (Balticconnector) connected to the port of Paldiski in Estonia is also being investigated. As a result, the terminal would not only serve the Finnish market, but also that of the Baltic States. The third project is for a terminal in the port of Tornio, construction of which is planned to start in 2017. In this case, plans have been drawn up for a terminal with a storage capacity of 50,000 m^3 connected by a pipeline of 22 km in length with the Röyttä industrial area. In addition, the Tornio LNG will distribute the LNG by trucks or rail to customers in northern Finland and Sweden. Construction of a terminal is also planned in the Finnish port of Rauma[26]. It is worth noting that the Finnish government decided to offer support for the development of a network of LNG terminals. By 2014, the budget of the program will amount to EUR 90 mln. State aid amounts to 20-30% of the total costs of investment, including planning and construction, purchase of equipment storage and handling. The initiative aims to help in the creation of a network of small-scale LNG terminals (5,000-70,000 m^3) along the coast of Finland. Each project must pass through the State aid notification procedure, in addition to being approved by the European Commission.

In Estonia two LNG terminal projects are also under consideration. The first of which is overseen by the LNG Holding BV, Estonian power network operator Elering and the management of port of Tallinn. Muuga port is regarded as its likely location. According to preliminary assumptions, the terminal would be equipped with a tank of a capacity of 90,000 m^3. The second project is that of the Balti Gaas (Alexela Group). The company chose the port of Paldiski for the location of its LNG terminal. The construction of an LNG terminal in Riga is estimated to cost around EUR 710 mln.[27].

In the year 2010 the Latvian state energy company Latvenergo JSC was obliged to investigate the possibility of building an LNG import terminal in Latvia, with Riga, Ventspils, Liepaja and coastal areas of Vidzeme all indicated as possible locations. Riga likely to be the most appropriate location for the port However, all options are still being considered and the final decision on the location has yet to be made. It is worth mentioning that the construction of the LNG terminal in the port of Riga is planned for the port development program for 2009-2018 (Free Port of Riga Development Program 2009-2018). The terminal would be built at the mouth of the river Daugava and its area would amount to 34 ha, with an annual capacity in the region of 5 billion m^3 of gas. As a result the terminal would begin operations no earlier than 2017.

As a complementary element for large and small scale LNG import terminals planned in the Baltic Sea region a number of LNG bunkering stations have been planned and designed. All mentioned above points will create an LNG bunkering network, due to which the availability of LNG will be increased.

LNG bunkering stations are currently being developed in the ports of Gothenburg, Hirsthals, Turku, Aarhus, Copenhagen-Malmö, Helsingborg, Helsinki, Stockholm, Tallinn, Turku, Trelleborg, Sundsvall, Rostock, Klaipeda, Kaliningrad, St. Petersburg, Risavika. Each of these projects is at a different stage of planning and development. In some cases, the project agreements (letter of intent) between seaports and the companies involved in the gas market have already been signed (i.e. Turku, Hirtshals, Gothenburg).

26 http://www.tem.fi/en/energy/press_releases_energy?89521_m=116057

27 M. Rozmarynowska, *LNG supply in the Baltic Sea region.* “Port Technology International” www.porttechnology.org.

Figure 2.11. LNG bunkering stations on the Baltic Sea
Source: Baltic Ports Organization, Gdynia 2014.

At the same time, a number of projects are currently in the conceptual phase, preparing feasibility studies and market investigations or beginning to design the terminals. With regard to the other cases the potential locations for terminals that would allow customers to receive an optimal service, both active in the field of maritime and land are given in the table below (2.14).

It should be emphasized that most of the identified projects are predicted (or analyses) to provide more functions than bunkering. Currently, it seems unlikely that the terminals will be used exclusively to serve maritime transport, and therefore other ways of managing their potential are being sought. The exception to this rule are those ports with a high volume of shipping traffic, where the demand for LNG fuel is likely to be significant (i.e. Hirtshals, Trelleborg, Rostock). It should be also noted that the bunkering function is available in any location, using truck-to-ship (TTS) technology.

An important issue concerning LNG small scale import terminal development is also its model capacity for the Baltic Sea area. Through analysis of the development plans it can be said that the reference capacity of the terminal is about 30,000 m^3 of LNG. This effects the size of the ships that can be handled at the terminal, as supply vessels or bunkering barges. Other projects for larger terminals are still in the conceptual stage (excluding Świnoujście and Klaipeda).

Table 2.14. Relevant actions and initiatives of the Baltic Sea ports in development of LNG terminals and bunkering stations

Maritime port	Actions and initiatives
Aarhus	– Feasibility study – Approval from the authorities (EIA, risk assessment, location studies), – Pre-design of LNG terminal
Copenhagen-Malmö	– Gathering data related to shipping activities and estimating future bunker volumes within the area, – Localization study including preferred location and layout of the terminal, – Cost and market analysis study including operational and investment cost.
Helsingborg	– Market study is ongoing including discussions with important stake holders (ship owners, ports, bunker companies e t c), – LNG terminal location study, – Develop a design for a multi-purpose LNG bunker ship.
Helsinki	– Feasibility study
Stockholm	– Safety Manual – Feasibility Study (Strategic planning for infrastructure, localization and ship bunkering)
Tallinn	– Feasibility Study – General and Detailed Plan tender – Environmental Impact Assessment
Turku	– Intention letter: Port Turku - Gasum – LNG bunkering arrangements in the harbor area – Safety manual for bunkering and use of LNG in port areas
Trelleborg	– Basic design of LNG terminal berth, – Complete technical design of LNG storage and bunkering facility.
Sundsvall	– Technical design of berth for LNG terminal – Detailed LNG infrastructure planning.
Rostock	– Obtaining all related LNG bunkering permits – Technical Design of LNG bunker station
Klaipeda	– Technological design study for LNG bunkering station, – Front end engineering design (FEED) and QRA, – Environmental procedures and permits.
Gävle	– Agreement with Skangass for development of LNG terminal
Goteborg	– Intention letter: Swedegas – Vopak – Market studies – Permissions – Construction of the LNG small scale terminal (2013-2017)
Hirtshals	– Agreement between Port Hirtshals and Gasnor – Design and construction agreement with Liquiline company.
Pori	– LNG small scale terminal development - Gasum
Inkoo	– LNG small scale terminal development - Gasum
Torino	– LNG small scale terminal development - Gasum
Risavika	– LNG Skangass bunkering station development

Source: E. Arolski, LMH in Baltic Sea Ports II. BPO Conference, Ronne, Denmark 5.09.2014; P.O. Jansson, E. Arolski, LNG in the Baltic Sea Ports. INEA meetings, Brussels 9.07.2014 r.; http://www.skangass.com/index.cfm?id=408969; Fjord Line to have an LNG terminal in Hirtshals, http://www.baltictransportjournal.com/denmark/fjord-line-to-have-an-lng-terminal-in-hirtshals,1677.html.

2.3. LNG tankers and bunkering barges for the Baltic

An important challenge in the process of the development of the LNG bunkering network on the Baltic Sea is also the availability of a appropriate fleet of LNG tankers. As was mentioned before, the small scale LNG terminals require the use of a fleet with suitable technical parameters that allow it to call at selected ports.

In year 2013, the LNG tanker fleet consisted of 393 vessels with a total capacity of 55.4 mln. m^3 of LNG. The majority of the ships (301 units) have a capacity of 90–170 thousand m^3, and therefore, they could be handled only in large LNG import terminals with the appropriate navigation parameters and tanks capacity.

The evident domination of large LNG tankers, and therefore the limited availability of the fleet of small vessels suitable for regional markets should be regarded as a significant restriction for the development of the LNG market in the Baltic. Only 24 LNG tankers with a capacity of up to 50 thousand m^3 are globally available (Fig. 2.12).

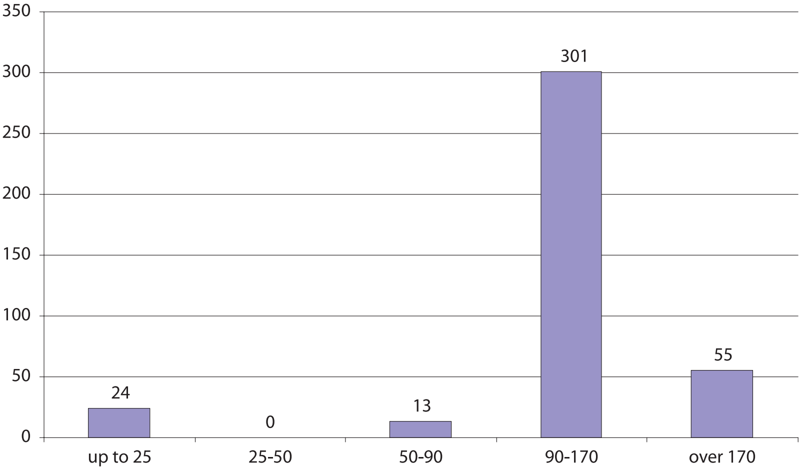


Figure 2.12. Capacity structure of the global LNG tankers fleet.
Source: Own elaboration: The LNG Industry 2013. GIIGNL. France 2014.

The limited engagement of ship-owners in the development process of the fleet of small LNG tankers is also confirmed by records of orders for new vessels. The yard's order history of 123 units contains only ten ships of a capacity below 50,000 cubic meters. As a result of the planned investments, the capacity of the world fleet of LNG tankers should be increased by 11.2 mln. m^3 by 2016.

Taking into account that the model capacity of the LNG terminals planned in the Baltic Sea area amounted to approximately 30 thousand cubic meters of liquid gas, a point of reference in terms of LNG tankers can be defined. A vessel of an approximate capacity of 10-15 thousand cubic meters should not exceed a draught of 7 meters and longitude of 160 meters. Ships of these parameters are currently operated by Norgas company (Table 2.15).

The development of the LNG Baltic market will require investment in new ships for the supplying of gas. Based on the information available, it could be indicated that the cost of building a LNG carrier with a capacity of around 12,000 m^3 is approximately 43 mln. USD.[28.]

[28] http://www.platou.com/.

Table 2.15. Main technical parameters of selected small LNG tankers

Vessel	LNG capacity [m^3]	Length [m]	Beam [m]	Draft [m]
Coral Energy	15 600	155	22	6,9
Norgas Unikum	12 000	115	20	6,8
Norgas Invention	10 030	130	20	7,2
Norgas Conception	10 030	130	20	7,3
Norgas Creation	10 030	130	20	6,4
Norgas Innovation	10 030	130	20	6,4

Source: Own elaboration based on: http://www.vesselfinder.com/vessels.

Another type of vessel to operate LNG as a marine fuel are LNG bunkering barges. These type of vessels could be used for the LNG bunkering process[29]. There is currently only one barge is operation in the Baltic – AGA Gas. Originally the ship was a Norwegian ferry, which was rebuilt in the years 2012-2013 for the amount of 1.7 mln. USD, with the support of TEN-T funding of EUR 261 thousand. Utilization of LNG bunkering barges in the process of vessel fuelling is determined by two main issues: the necessity to maintain safety zones and the acceleration of the bunkering procedure. According to European standards (internal regulations implemented by port authorities in Sweden, Belgium or the Netherlands) the safety zone during LNG bunkering should reach 25 meters. In the case of a STS (ship-to-ship) procedure, the majority of the zone is on the waterside, therefore the transshipment processes are able to continue even during the LNG bunkering process.

Another important condition for the use of the process involving LNG bunkering barges is the significant reduction bunkering time. This is due to the possibility of more efficient pumping of fuel into the tank of the vessel by connecting hoses of a larger diameter. This is confirmed by the fact that the transshipment of LNG from a car to a ship is undertaken in three hours, while the STS bunkering process takes only 60 minutes, taking 40-45 minutes to pump fuel from the maximum throughput. It should be added that the process of loading LNG fuel from a LNG bunkering barge is providing by a flexible hose of about 6 inches in diameter, which allows for pumping at a rate of 3000 liters per minute. In comparison, the process of reloading the LNG from a truck is completed at around 600 liters per minute.

2.4. Implementation of LNG fuel in other modes of transport

The European transport policy focused on the sustainable development of the transport system through the promotion of clean fuels as alternative fuels for modes of transport. For this reason, LNG fuel is also used with land transport (road, rail) as well as inland navigation.

29 See: M. Rozmarynowska, *LNG jako alternatywne paliwo dla statków- aspekty techniczne, ekologiczne, ekonomiczne i regulacyjne.* „Logistyka” 5/2012, s. 746.

In the case of land transport LNG fuel is mainly used with heavy vehicles such as trucks and buses (urban transport). The majority of truck and bus manufacturers (e.g. Iveco, Scania, Mercedes, MAN) offer the natural gas propelled vehicles equipped with both mono-fuel (100% natural gas) or diesel (a mixture consisting of 50-95% natural gas) engines. A fleet of this kind is operated by companies such as DHL, UPS, Coca-Cola, Tesco or VOS Logistics. LNG fuelled trucks are already operating successfully in the Netherlands, Spain, UK and Sweden. The Netherlands is leading the way in the LNG truck market with 231 LNG fuelled trucks (0.3% of the total truck fleet) in 2014. An increase in the LNG fleet by up to some 40 thousand is expected by 2020. Approximately 150 LNG vehicles are in operation in Spain. Forecasts indicate a growth of up to 5 thousand LNG vehicles by 2028 (3% of the total fleet)[30].

Figure 2.13. LNG propelled city bus in city of Olsztyn
Source: cng.auto.pl.

In the case of LNG powered urban buses Poland is currently the pioneer (both in construction and utilization of LNG buses). In October 2013 Gazprom Germania and Solbus introduced Europe's first 11 LNG-fuelled city buses in the city of Olsztyn. In the 1st quarter of 2015, 35 LNG fuelled buses will be introduced in Polish capital, Warsaw[31].

Inland navigation is another mode of transport currently looking to use LNG as a fuel. Europe's first new-built LNG-fuelled inland vessel MTS Argonon was introduced into service in December 2011. The barge is a dual-fuel driven chemical tanker owned by Deen Shipping and operated by its subsidiary, Argonon Shipping. The vessel is designed to run on LNG and diesel at a ratio of 80:20. The vessel, with a tonnage of around 6100 tones, is equipped with an LNG fuel tank of 40 m^3 capacity due to which the ship can travel the

30 http://www.ngvglobal.com/.
31 http://www.ngvaeurope.eu/solbus-lng-fuelled-buses-to-hit-the-streets-of-warsaw-early-2015.

route Rotterdam-Basel- Rotterdam without bunkering (approx. 1,600 km). Another two single-fuelled new-build LNG tanker barges, the GreenStream and the GreenRhine were put into operation in 2013. The ships of overall length of 110 meter have a tonnage of around 2,877 tones. The vessels have LNG fuel tanks with a capacity of 80 m^3.

Figure 2.14. „Green Rhine" the LNG propelled inland barge
Source: www.maritime-executive.com.

Another LNG propelled inland vessel is Eiger-Nordwand. In this case an retrofit procedure has been implemented. The vessel equipped with a Wärtsilä dual-fuel drive system gets 95 to 99% of its power from LNG. Its 60 m^3 capacity tank ensures an operational range of about 1600 km[32]. LNG propulsion was also used on inland tanker barge MS Sirocco in 2014. Sirocco's primary cargo is LPG-propane but the vessel is able also to carry ammonia or other chemical products.

In addition to the examples presented concerning the use of LNG fuel with inland traffic, several new projects can be listed. Kooiman Marine B.V. builds an LNG propelled pusher. The vessel will be equipped with a Wärtsilä duel-fuelled engine with a total power of 4,240 kW and LNG fuel tanks of 160 m^3. Preliminary tests, trials and the maiden voyage of the unit is planned for 2015. The pusher will operate between Rotterdam and Duisburg[33]. Another example is the 1,145 Eco Liner, the inland tanker barge developed by Damen[34]. The vessel equipped with a total engine power of 896 kW will have an fuel tank capacity of 45 m^3. Similarly, Romanian inland waterway operator Navrom have plans to retrofit three existing pushers with LNG propulsion. Pilot operations are scheduled for the

32 http://www.shortseashipping.de/de/branchennews/news-detail.php?id=10042&year=2014.
33 Kooiman Marine B.V. presentation.
34 http://www.damen.com/news/2012/09/damen-ecoliner-concept.

third quarter of 2015[35]. Similar activities are planned by next inland shipping companies, such as: Bodewes Binnenvaart B.V, Chemgas Barging S.a.r, DCL Barge B.V[36].

The limited availability of LNG fuel is regarded as a primary constraint in the development of LNG technology in road or inland transport. However, according to the EU Directive on the deployment of alternative fuels infrastructure,[37] an appropriate number of publicly accessible LNG refueling points should be put in place by 31 December 2025 at the latest, at least along the TEN-T Core Network in existence at that time, and after 2025 on other parts of the TEN-T Core Network where they are made accessible to vehicles. The directive indicates that the necessary average distance between refueling points should be approximately 400 km. This allows for the assumption that in the future LNG is likely to grow in popularity as a fuel for land transport.

2.5. Biofuels in the shipping sector

Biofuels also have great potential for use as a low sulphur technology. Moreover, it is said that "Biofuels stand out as the best option, considering the overall environmental, safety and security impacts"[38]. Biofuels are produced from living organisms or from metabolic by-products (organic or food waste products). In order to be considered a biofuel the fuel must contain over 80 percent renewable materials. These fuels are made by a biomass conversion (biomass refers to recently living organisms, most often referring to plants or plant-derived materials). This biomass can be converted to convenient energy containing substances in three different ways: thermal conversion, chemical conversion, and biochemical conversion. This biomass conversion can produce fuel in either solid, liquid, or gas form. This new biomass can be used for biofuels. Biofuels have increased in popularity due to of rising oil prices and the need for security within the energy industry.

Biofuels can be grouped into four main "generations". First generation biofuels are made from sugars, starches, oil, and animal fats that are converted into fuel using existing processes or technologies. This generation is so-called conventional biofuel technology. These fuels include biodiesel, bio-alcohol, ethanol, and biogas, like methane captured from landfill decomposition. Second generation biofuels are made from non-food crops or agricultural waste, especially lingo cellulosic biomass like switch grass, willow, or wood chips. Third generation biofuels are made from algae or other quickly growing biomass sources. The final generation of biofuels are made from specially engineered plants or biomass that may have higher energy yields or lower barriers to cellulosic breakdown or are able to be grown on non-agricultural land or bodies of water[39]. Advanced biofuel technologies, which cover generations two to four, are conversion technologies which are still in research and development (R&D), pilot or demonstration phase. This category includes hydrotreated vegetable oil (HVO), which is based on animal fat and plant oil, as well as

35 http://www.lngmasterplan.eu/pilots/overview.

36 http://www.lngmasterplan.eu/masterplan/activities/16-masterplan/108-pilot-deployment.

37 DIRECTIVE 2014/94/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 22 October 2014 on the deployment of alternative fuels infrastructure.

38 D*NV: biofuels are key to meeting marine emissions targets*. (http://www.biofuelsdigest.com/bdigest/2013/01/28/dnv-biofuels-are-key-to-meeting-marine-emissions-targets/.

39 http://www.greenchoices.cornell.edu/energy/biofuels/.

biofuels based on lignocellulosic biomass, such as cellulosic-ethanol, biomass-to-liquids (BtL)-diesel and bio-synthetic gas (bio-SG)[40].

First generation biofuels have a crucial importance for the transport sector. Three types of fuels should be indicated as a potential source of energy transport: ethanol, biodiesel and biogases. Ethanol is biologically produced alcohol derived through the fermentation of sugars or starches (easiest), or cellulose (which is more difficult) which are acted upon by microorganisms and enzymes. This type of biofuel is commonly used in the USA and Brazil. Biodiesel is the most common biofuel in Europe. It is produced from oils or fats using transesterification and is a liquid similar in composition to fossil/mineral diesel. Chemically, it consists mostly of fatty acid methyl (or ethyl) esters (FAMEs). Pure biodiesel (B100) currently reduces emissions by up to 60% compared to diesel. Biogas can be produced through the anaerobic digestion of feedstocks such as organic waste, animal manure and sewerage, or from dedicated green energy crops such as maize, grass and crop wheat. Biogas can also be upgraded to biomethane by removing CO2 and hydrogen sulfide (H2S) and used as fuel in natural gas vehicles.

The International Energy Agency has forecasted that the proportion of biofuels used within the transportation industry should reach 27% by the year 2025. The majority of biofuels will be used within road passenger transport. The shipping sector is likely to constitute about 11% of the biofuel transport market by 2050[41]. Six types of biofuels can be highlighted as potential energy sources for the shipping sector:

1. Biodiesel – to replace MDO/MGO in low to medium speed engines (used in tug boats, small carriers or cargo ships);
2. DME (Di-methyl ether) – used as a replacement for MDO/MGO in all types of engines (all sizes of carriers or cargo ships);
3. Straight Vegetable Oil (SVO) used to replace IFO or heavy fuel oil in low speed engines (all sizes of carriers or cargo ships);
4. Bio-LNG or bio-methane in gas engines using LNG;
5. Bio-ethanol used in high speed main or auxiliary engines (short distance ships, ethanol tankers, or for electricity production on board vessels such cruise and passenger ships);
6. Pyrolysis bio-oil in low speed engines (all sizes of carriers or cargo ships)[42].

Of those biofuels listed three would fulfill the requirements of the sulphur directive. These are bio-methane, methanol (M85) and pure biodiesel (B100). Taking into account the technological, market and operation specifity of maritime transport, the most important bio-solution for vessel fueling is bio-methane or methanol.

Biogas technology is regarded as a future source of energy for the European market. According to the analysis, the level of production of biogas in Europe should increase from 14 billion m^3 in 2012 to 28 billion m^3 in the year 2020. This is due to the following advantages of biogas utilization:

- based on varied, renewable, "self-made" sources of raw material, e.g.: sewerage, organic municipal waste, waste from the food industry;

40 *Technology Rroadmap. Biofuels for Transport.* International Energy Agency, Paris/France 2011.
41 *Technology Rroadmap. Biofuels for Transport.* International Energy Agency, Paris/France 2011.
42 *Potential of biofuels for shipping.* Final Report, ECOFYS 2011.

- reduces the storage of organic waste and solves the problem of storage of sewerage in municipal wastewater treatment plants;
- a unique combination of low-carbon, low-emission with low levels of noise from transport;
- biogas production in order to improve the eco-efficiency of waste treatment processes;
- high efficiency of biogas production from acreage, reducing competition for arable land.
- enriched biogas is similar to natural gas, hence ability to use the existing infrastructure and CNG vehicles,
- increase in the security of the supply of gas.

The principal element of the utilization of biogas in the transport sector (incl. shipping) is the rapid development of the production capacity for biomethane. More than 13,8 thousand biogas facilities operated in Europe in 2012.

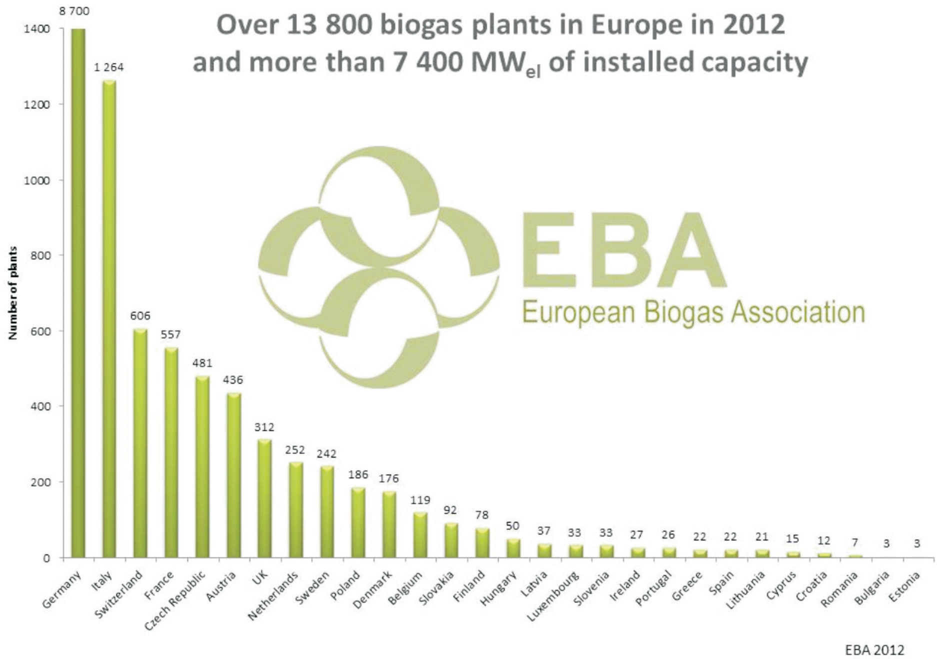


Figure 2.15. Biogas plants in Europe in year 2012
Source: http://european-biogas.eu/biogas/.

This area of fuel market development is also strictly connected with another analyzed fuel option for the shipping sector – LNG. Biomethane can be liquefied, creating a product known as liquefied biomethane (LBM). Two of the main advantages of LBM are that it can be transported relatively easily and be used in either LNG vehicles or CNG vehicles. Liquid biomethane is transported in the same manner as LNG, that is, via insulated tanker trucks designed for the transportation of cryogenic liquids. Therefore, the aforementioned development of the LNG facility within the Baltic Sea region can be also an important incentive for the development of biogas (biomethane) production and utilization[43]. Development of the LBM market will require similar improvement of the liquefaction capacity. The best practices for the development of small scale liquefaction plants could be based on Norwegian experiences (e.g. Snurrevarden LNG Production Plants, Kollsens LNG Terminal, EGE Biogass Oslo). The technology of biomethane liquefaction is offered by various producers, such as Wärtsilä Hamworthy[44] (Norway) or CrioStar (USA)[45].

Anther possible solution is methanol. Methanol has come to be known as "wood alcohol" because it was once produced chiefly as a byproduct of the destructive distillation of wood. Modern methanol could be also produced in a catalytic industrial process directly from carbon monoxide, carbon dioxide, and hydrogen. Methanol is used on a limited basis to fuel internal combustion engines in transport. The use of pure methanol is required in motorsports, such as: Monster Trucks, USAC sprint cars or Speedway. Hence, the solution can be regarded as being tested in practice.

This approach to the sulphur problem has been choose by Stena Line. According to the analysis of Stena Teknik[46], the basic advantages of this solution for the shipping industry are:

- required reduction of SOx and NOx emissions and additional particulates,
- possibility of production by using different raw materials,
- safety and security requirements similar to those of gasoline and crude oil,
- liquid state without high pressure,
- high availability (approx. 55 mln. tons per year);
- low retrofitting costs (estimated at EUR 300 per 1 kW),
- biodegradability.

Nevertheless some problems are also defined: low ignition temperature, toxicity and large volume (2x larger than conventional fuels). According to Stena's plans, if the technology works out as envisaged, 25 ferries will be adapted by the year 2018.

43 http://www.bioenergyconsult.com/tag/liquified-biomethane/.
44 http://www.wartsila.com/fi/gas-systems/lng-handling/lng-liquefaction.
45 http://www.cryostar.com/web/small-scale-lng.php.
46 P. Stefenson, *Studies of scrubbers and alternative fuels.* Stena Rederei. Presentation EMSA 2013.

Chapter 3. MGO – fuel change solution and its economic impact

1. Change of fuel type from HFO/LSHFO to MGO

It is quite clear for all stakeholders of a ship, that the easiest solution to the Sulphur Regulation is to change the fuel type, currently (until the end of 2014) HFO (in general, regardless of the type: 180 or 380, the very classic marine Heavy Fuel Oil, used above all nowadays outside SECA zones) or LSHFO (currently used in all SECA zones Low Sulphur Heavy Fuel, regardless of the type: 180 or 380) to MGO (Marine Gas Oil), which, due to ISO standards, is the only type of marine fuel to meet the maximum limit of 0.1% Sulphur. (in practice there are several sub-types of MGO fuel, differing from each other by the viscosity ratio or density or flashing point, but still with a norm of 0.1%).

However, there are several tasks to be completed before the ship will be fully refitted and switched to MGO.

The decision to switch to MGO has multi-aspectual consequences due to the following:

- after conversion to the new fuel only a single use of the system is possible (a dual use is possible if a double system was provided, including tank space. This can be recommended in cases where the ship is also operating outside the SECA region);
- engines remain equally reliable with no need for any major changes in their construction;
- the availability of MGO – if unavailable is the use of marine diesel also an option for the converted system configuration.

It may be assumed that thus far vessels have only used LSHFO, engines and all connected system parts were designed to use heavy fuel oil with a sulfur content of 1.0 up to 3.5. In particular, the main engine must have the maximum operational reliability, soft ignition and low ignition forces and moments are of importance. Some recent ships has already updated engines on board which allow the use of MGO and HFO from the design stage, these ships are particularly suitable for engine conversion. Older and slow speed engines <400 rpm should invest in a scrubber solution as well as being adjusted and tested in order to rule out the risk of not finding an optimum solution for this specific type of engine.

For modern engines the following parts and equipment are needed:

1. Fuel cooler to keep the fuel temperature low enough and integrated between the main engine and the mixing tank (return piping line from the engine) or direct in line to the fuel supply pipe to the main engine to be sure that the engine gets the correct lubricity. In some cases a special chiller is necessary, because the cooling is insufficient.
2. Change of fuel pump (or additional) which can operate with lower viscosity and density fuel.
3. Upgrade of fuel volume in order to ensure the correct fuel ignition to the engine (adjustment of fuel supply)
4. Change over to cylinder oil BN40-50
5. Different additional tanks or modification of HFO tanks (service and setting tanks)
6. Clean up of pipes and the tank system as well as adjustment of the whole system
7. In some cases the boilers should be adjusted to the new fuel (preheating of the fuel)

Changing to MGO is not without its complications as it may bring some technical problems, e.g. leaks in engine parts (due to the different viscosity and density of HFO and MGO) or other operating risks. Some vessels need to be modernized with special equipment for mixing fuels, as well as a steering system compatible with other engine management systems. Furthermore, the crew will require additional training as it will result in the need for them to carry out additional tasks. Last (but definitely not least), constant fuel changing is nothing more than another factor leading to technical failures or human errors. For those ships where fuel changing leads to the use of new or additional fuel types, it will mean the transformation of one or more tanks to MGO and an additional necessity for holding more samples of fuels for testing and evaluation. This also requires increased fuel monitoring and reporting.

Due to the relative simplicity of the fuel change solution, further analysis concerns the economical impact on shipping efficiency.

Global shipping consist in general of two different types the shipping: tramping and liner. From the characteristics of both types we know, that tramping shipping, which also strongly depends on the regulation of Sulphur Regulation, has a specific method for calculating the freight rate where for each separate voyage an individual CBA is conducted. Thus, the potential increase in the cost of fuel will have a relative small impact on the final rate in this type of shipping as it depends on the following:

- Share of the distance covered by the SECA zone on the whole voyage (fuel costs increasing ratio),
- Average and individual share of the fuel cost (only for the main engine) of the total cost of the voyage (in tramping shipping varying between 15% and 25%),
- Place or port of bunkering, which leads directly to fuel price differences,
- Frequency of entering SECA zones (yearly or other periodical ratio).

As a result of the of the above mentioned aspects this type of shipping should, due to the comparative analysis, be affected only to a minor extent by the Regulation. However, it will still be impacted negatively. A more detailed economic analysis will be undertaken in chapter 6, yet for the time being we may assume that further analysis concerning this type of shipping is not required . Far more important, in the opinion of the author, is liner shipping in the Baltic Sea Region, due to the following:

- The entirety of the region comes falls within the SECA zone, thus it is fully dependent on the Regulation,
- The average share of fuel costs as a percentage of the total cost of functioning of a shipping line vary from 27% up to 50% (see p.3. Microeconomic assumption),
- The bunker suppliers market has limits as far as the Baltic Sea Region and therefore there is generally the need to bunker in one of the Baltic sea ports, which excludes regional shipping lines, especially small and medium, from the global bunker market; Only the biggest shipping companies have enough market power and potential to purchase bunkers globally with deliveries directly to selected ports for direct bunkering;
- This type of shipping operates within the SECA zone 100% of the time.

The above are taken as initial assumptions, which form the basis for extended analysis in the next section. The explanation of specific aspects has also been taken into account.

2. Fuel characteristics and assumptions

In order to carry out a cost analysis, it vital to determine the average fuel consumption of each ship mentioned in the Appendix I. This required detailed research using the burning calculations method, which was problematic due to the sensitivity of the data, which practically all ship owners endeavor to maintain private, As it will be shown in the next part of the paper, this is due to the fact that the cost of bunker fuel is one of the most important factors in liner shipping and, therefore, is crucial for calculating tariff rates – the greatest area of competition on the shipping market.

Therefore, in this case an alternative methodology was adopted with the average bunker fuel consumption calculated as a ratio of the main engine power and the average theoretical value of fuel consumption by each kW of engine power per working hour against the average speed. Naturally this raises the following questions:

- What is the main engine power?
- What is the average utilization of engine power?
- What is the average fuel consumption and by what speed is it calculated?

The first question can be answered with relative ease – this data is commercially available on the market and can be also verified by independent research using fleet descriptions appearing in appropriate literature and professional magazines.

The second question is related to the average speed of the ship serving in the line. This required special research on the actual speed shown in some commercial electronic platforms, mainly based on GPS (Global Positioning System) or AIS (Automatic Identification System) or VTS (Vessel Traffic System). Each ship specified in table 2 has undergone a 4-time trial in terms of actual speed under the assumption of not being more than 15 NM before or behind sea port (to avoid mistakes coming from the first and last phase of the trip – speed accelerating and speed reducing, which could negatively affect the final, average result of the measurement). Therefore, the speed of each ship was individually calculated. For the simplification of the calculation it was assumed, that the speed remained constant throughout the trail run. This aspect does not exclude any other average speeds measured by the owner in any other period.

The final question is probably the most difficult to answer clearly and concerns a ship's engine characteristics. Some commercial available data shows such information in official ships particulars. Others result from multiplying the average power use and value of grams of fuel for each kW engine power per working hour. The value ranges between a minimum of 160 and 185 g/kWh depending on the engine power utilization ratio and the type of engine. At extreme moments it might even reach 250 g/kWh[1].In order to avoid the problem of the vast range of engine types and the permanent diversity of current vessel speeds values taken from theoretical calculations and the function of fuel consumption of one of the biggest ships engine suppliers (MAN B&W and Wärtsilä)[2] have been assumed and, thus, the following average values have been used in the next calculation:

- HFO – 186 g/kWh (by 100% engine power utilization), 172 g/kWh (by 80%), 167 g/kWh (by 70%) and 162 g/kWh (by 60%), while
- MGO – 184 g/kWh (by 100% engine power utilization), 170 g/kWh (by 80%), 165 g/kWh (by 70%) and 160 g/kWh (by 60%).

Average fuel consumption is shown in fig. 3.1.

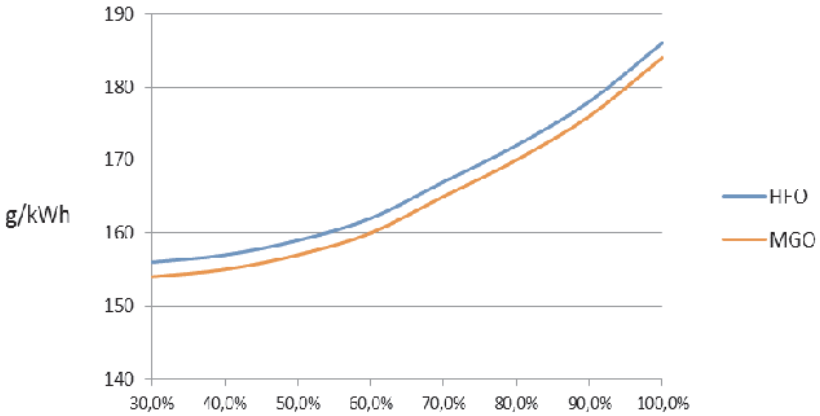


Figure 3.1. Marine fuel consumption function (in g/kWh) depending on the level of engine power utilization (%)

Source: own calculation based on assumptions and average fuel consumption of ship: K. Kuiken, *Diesel engines for ship propulsion and power plants*, TGET, Onnen, 2012.

This has been helped by the next calculation; namely the total yearly marine fuel consumption by the ro-ro & ro-pax shipping market segment given in metric tons. In addition a calculation of the yearly value of fuel consumption in this segment was also carried out. This required additional calculations for the average price of bunker fuel. Based on limits mentioned in the second part of the paper, as of 2012 on the Baltic Sea all ship

1 K. Kuiken, *Diesel engines for ship propulsion and power plants*, part II, TGET, Onnen, Netherlands, 2012, p. 177.

2 www.mandieselturbo.com/0000684/Products.html.

owners are obliged to use LSHFO (Low Sulphur Heavy Fuel Oil) 180 or 380 class (the differences between the most important kinds of bunker fuel are described in more detail in table 3.1.) and MDO (Marine Diesel Oil) in all sea ports. All ships are equipped with auxiliary engines running only on distillates like MDO or MGO. Since 1st of January 2015 all ships are obliged to reduce Sulphur content in their emissions by up to 0.1% due to the aforementioned IMO Regulation. As assumed, the calculations conducted were based on a single solution as a way to meet the new limit – a change of fuel to MDO.

The next task is to look at the potential economical impact of IMO Regulation on the ro-ro & ro-pax shipping market segment on the Baltic Sea after 2015, expressed by the value (in EUR) of additional fuel costs. This can be based on the data previously calculated. The result of this calculation might be understood as a macro economical impact of the IMO Regulation to the international trade and Baltic Sea Region economy.

In order to obtain a more detailed answer on the potential impact of the IMO Regulation on tariffs and rates on the Baltic Sea, ro-ro & ro-pax shipping lines will be the subject of a final calculation. Based on average cost structures in liner shipping (depending on the type of shipping), a suitable share of fuel costs will be recalculated by the percentage increase of fuel prices. As a result the potential percentage increase of tariff rates in this type of shipping in the BSR will be obtained.

Table 3.1. Chemical features characteristic of chosen marine fuel types

Type of marine fuel	Full name	Viscosity max. mm^2/s	Density kg/l	Flash point	Sulphur content
380 HFO	Heavy fuel oil	Max. 380	Max. 0.957	Min. 86°C	> 4.5%
380 LSHFO	Low sulphur heavy fuel	Max. 380	Max. 0.949	Min. 90°C	Max. 1,0%
380 IFO	Intermarine fuel oil - residual oil, 2% distillate	Max. 380	Max. 0.99	Min. 60°C	Max. 3.5%
180 IFO	Intermarine fuel oil - residual oil, 12% distillate	Max. 180	Max. 0.99	Min. 60°C	Max. 3.5%
DMX	Very light gas oil with good low temperature characteristics almost only for emergency use	5.5	-	Min. 43°C	Max. 1.0%
DMA (MGO)	Medium gas oil (Marine Gas Ool)	6.0	Max. 0.89	Min. 60°C	Max. 0.1%
DMB (MDO)	Relatively heavy gas oil (Marine Diesel Oil)	11.0	Max. 0.9	Min. 60°C	Max. 1.5%

Source: own prepared based on "Reducing the sulphur content of shipping fuels further to 0.1 % in the North Sea and Baltic Sea in 2015: Consequences for shipping in this shipping area", Final report, Institut für Seeverkehrswirtschaft and Logistik ISL, Bremen, September 2010, s. 27.

3. Calculation assumption

Liner shipping

In conducting the research, due to the large diversity of lines and ships operating on those lines it has been stated that the calculation model used needs to undergo some simplifications:

The shipping line must meet conditions of: constant and frequent operation with official publication of schedules, tariffs and booking conditions;

Baltic shipping lines include all relations between Baltic ports and also between Baltic and North Sea ports, which is a serious part of the Baltic RO-RO & ferry market;

Excluded from the research are all other than RO-RO and RO-PAX lines, such as car-carrier lines, bulk lines, chemical lines etc;

The number of weekly departures and voyages are taken from official timetables and schedules published by operators;

Technical breaks and voyages not performed due to bad weather conditions, which gives a total yearly number of voyages from multiplying the above mentioned weekly departures and 52 weeks a year;

Excluded from the analysis is the possibility of introducing an additional vessel to the line at a time of increased demand, to later remove it when the demand diminishes;

In calculations only the main engines and their fuel consumption are taken into account due to the fact that all auxiliary engines are running only on MGO or MDO and the IMO Sulphur Regulation discussed does not envisage any changes in this area of a ship's technical exploitation;

The consumption of HFO and MGO measured in grams per each kWh of engine power is different; it comes from the difference in the calorific value of those two types of marine fuel, an average net specific energy of HFO is 40,4 MJ/kg, while of MGO is 42,6 MJ/kg.[3] In average, it might be treated as a constant difference in energy efficiency of 5% (by MGO advance) between both types of marine fuel.

Main engine power and consumption

The power values of all main engines are taken from official published ships particulars and compared to existing lists of engine types by supplier.

The most controversial aspect may occur with the assumption of the lack of change in marine fuel prices as of 1/01/2015. Although we could expect some price decreases for HFO, which will come from the reduction of market demand to almost zero (normal HFO may be purchased by the owners only in the case of a long, outbound SECA zone voyage and on the condition that prices are lower than in the port of discharge or in cases that ship owners will equip their vessels operating in SECA zone with scrubbers). However, quite to the contrary MDO and MGO may be sold for increasing prices due to increasing demand. This may be a serious and important market change, which looks likely to be the most frequently used solution of fuel changing due to the IMO Sulphur Regulation. Until

3 International standard – ISO 8217:2005, table 2, *Fuel handbook*, VISWA LAB, Houston, USA, 2012, p.19.

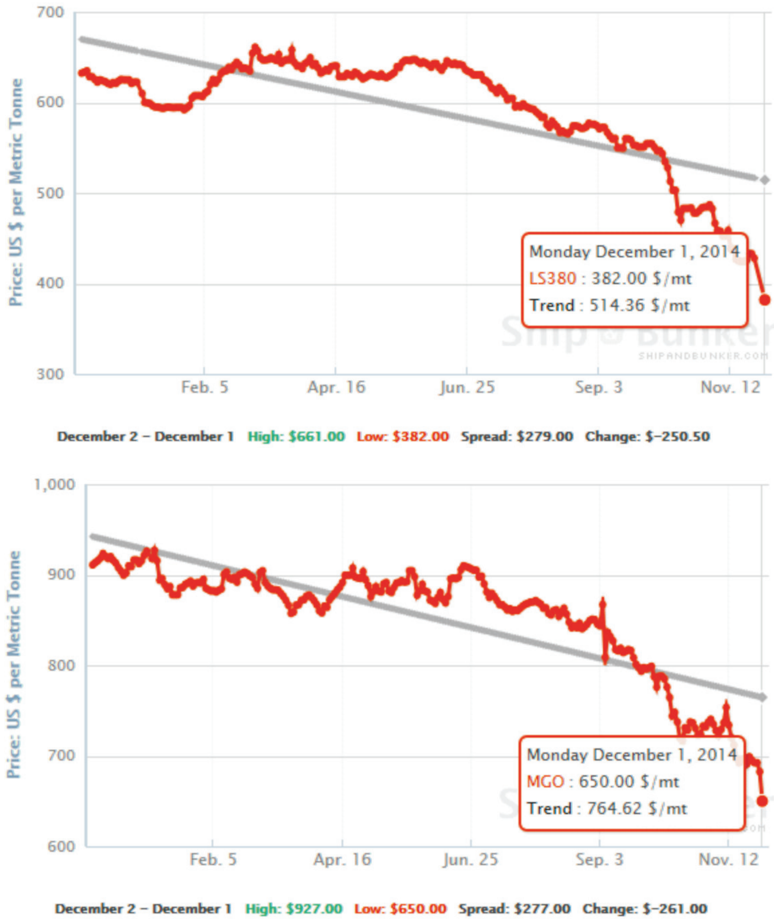


Figure 3.2. Last 12 months trend line for bunker (LSHFO left, MGO right) price index on Rotterdam stock

Source: Ship & Bunker 2014, Vancouver, Canada, www.shipandbunker.com.

now, there were only a few other cases where different were employed, such as the LNG propelled m/s Viking Grace, the very first LNG ferry on the Baltic Sea introduced into the Stockholm – Turku line. Another example are the various types of scrubbers already installed on a few ships operating on the Baltic Sea, of which the majority were pilot projects, readily co-financed by EU funds, rather than commercial, business adaptations to the new market conditions. However in general, the potential change in fuel price is a separate research topic. For the proposes of this paper it may be assumed that this aspect is a serious occurrence, which is likely to have an important impact on increasing the intensity of the general process – increasing prices in maritime transport as of 2015. The question remains as to whether it will it will have an equally strong impact on the main process.

Fuel price

A further question that may be posed is will the petroleum industry be able to meet the increased demand for MDO/MGO? Is it technically easy to solve such to solve such an issue by switching fuels? According to interviews with senior representatives of the EU[4] the industry is prepared for new market conditions and to ensure an adequate supply of low sulphur marine fuels. However, there are serious doubts about this claim given the following two facts:

Figure 3.3. Last 12 months trend line for bunker (LSHFO left, MGO right) price index on Gothenburg stock
Source: Ship & Bunker 2014, Vancouver, Canada, www.shipandbunker.com.

[4] In reference to Magda Kopczynska, Head of Unit Maritime Transport and Logistics, DG MOVE, European Commission, presentation *"EC policy helping industry to meet new sulphur limits"* on the *TransportWeek 2014* conference in Gdansk, Poland, 4/03/2014.

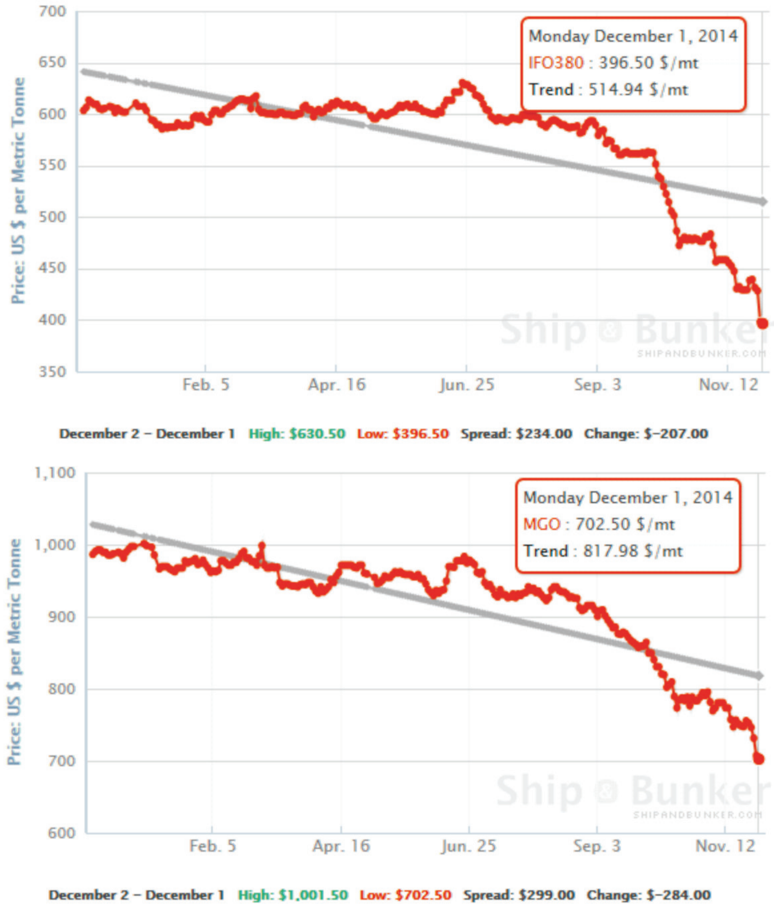


Figure 3.4. Last 12 months trend line for bunker (LSHFO left, MGO right) price index on Gdynia/Gdansk stock
Source: Ship & Bunker 2014, Vancouver, Canada, www.shipandbunker.com.

With global 300 mln. tones of HFO yearly consumption[5] by the maritime transport, a potential loss of 2.5 mln. tones may not prove a difficult problem for all producers, as it is almost 0.87% of total world HFO consumption,

From behavioral economy we know, that all market stakeholders have the tendency to use the opportunity to increase their profits following any circumstances where a price increase may be justified.

The above described overview may be complicated further when taking into account the next four graphs which illustrate the tendency for LSHFO and MGO price to continually decrease in the four selected sea ports of Rotterdam, Gothenburg, Gdynia and St. Petersburg. Special attention should be given to St. Petersburg's stock and its variable trend – most probably caused by current political conflict due to Russia's imperial aspira-

5 S. Aakre, *Wärtsilä Exhaus gas clearing system*, presentation on the *TransportWeek 2014* conference in Gdansk, Poland.

Figure 3.5. Last 12 months trend line for bunker (LSHFO left, MGO right) price index on St. Petersburg stock

Source: Ship & Bunker 2014, Vancouver, Canada, www.shipandbunker.com.

tions and aggression towards Ukraine, official EU and USA sanctions, as well as by the global trend of the equation of Russian oil and oil product prices to average global prices.

However, for the Baltic shipping market Rotterdam's stock is the most important determinant and therefore further calculations will be based on its marine fuel prices.

Microeconomic assumptions

Other economic related assumptions concern the structure of the total costs of liner shipping with a special indication of the share of fuel costs. Maritime transport economics distinguishes many kinds of cost calculation methods, especially for liner shipping. Clearly the most important figures are taken from the "ex post" analysis. In accordance with this, after taking into consideration a great deal of published data, it has been decided that in subsequent calculations fuel costs within each type of liner shipping will be represented by the following values as a percentage of the costs structure as a whole:

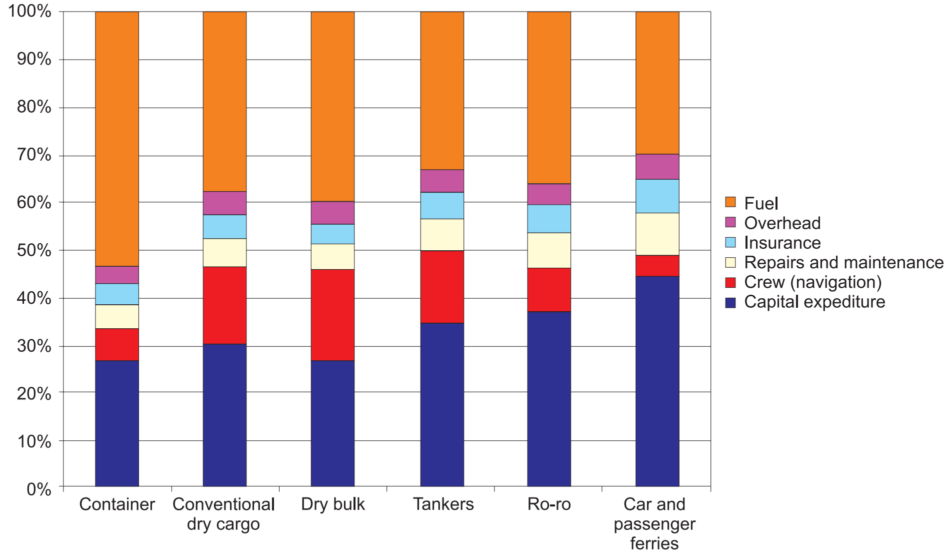


Figure 3.6. Structure of costs of shipping within chosen fleet types

Source: Sulphur content in ships bunker fuel in 2015. A study on the impacts of the new IMO regulations on transportation costs, Ministry of Transport and Communications Finalnd, Helsinki, 2009, p. 8.

- in pure RO-RO shipping – 37.0%, and
- in RO-PAX shipping – 30.0%,
- in container shipping – 27%
- due to real calculation assumptions and clear justification (see fig. 3.6.).

The final, assumption concerns the solution adopted by all shipping owners operating on the routes connecting the Baltic Sea with the North Sea due to adhering to the IMO Sulphur Regulation in the future. When taking into account three possible options (despite the lack of reaction and the allowance of penalties in sea ports, which, in some special cases might be a short-term solution), all further calculations were performed based on 100% fuel changing. This study could be extended in the future once concrete figures and the names of vessels being equipped with scrubbers or retrofitted to the LNG supply are known. Due to the small number of scrubber installation examples and only single cases of LNG supplying, it was decided to simplify the calculations using this assumption.

4. Calculation of fuel changing costs

Based on the abovementioned assumption and taking into account all correlations and dependencies explained, the studies have shown a lot of interesting results and tendencies. According to the methodology the most important conclusions are as follows:

1. Bunker prices taken into account have varied on a large scale. I.e the Rotterdam bunker stock noted its lowest price in 2014 at 581,00 USD (23/04/2014) and highest at 635,00 USD (4/12/2013), which gives a variability almost 10%.

2. For a more complex overview table 3.2. is presents a more detailed bunker price analysis for the beginning of the year 2014 and at the end of the study (31/03/2014). This provides the additional conclusion that on the Baltic Sea the LSHFO and MGO is available for varied prices, where St. Petersburg's index is the lowest; up to 30% lower than Gdynia's LSHFO rate and up to 19% than Gothenburg's MGO rate.
3. The average price spread on the Baltic Sea between LSHFO and MGO equals 326,00 USD or 318,13 USD including Rotterdam rates and determine a huge share in the base LSHFO price from 44.6% (Gdynia) up to 68.4% (St. Petersburg). This might have an important impact on the increase of future costs, depending on the sea port where the owner carries out the bunker purchase.

Table 3.2. Overview of chosen marine fuel prices in the Baltic Sea range (as for 31/03/2014)

Port of bunkering	Marine fuel type	Fuel price [USD/t] at:		Spread
		7/01/2014	31/03/2014	
Rotterdam	LS380	599,50	643,00	43,50
	MDO/MGO	894,00	875,00	-19,00
	difference	294,50	232,00	-62,50
Gothenburg	LS380	614,50	665,00	50,50
	MDO/MGO	973,50	957,00	-16,50
	difference	359,00	292,00	-67,00
Gdynia	LS380	668,50	709,50	41,00
	MDO/MGO	966,50	947,50	-19,00
	difference	298,00	238,00	-60,00
St. Petersburg	LS380	469,00	489,50	20,50
	MDO/MGO	790,00	818,50	28,50
	difference	321,00	329,00	8,00

Source: own calculations based on quotes on Ship & Bunker statistics, Vancouver, Canada, March 2014.

4. Baltic RO-PAX fleet, utilized in liner shipping, counting 117 ships performs weekly 31.297 NM on 3.612 voyages (almost 31 voyages per ship weekly on av. 8,66 NM distance) represents a total lane capacity for RO-RO cargo units of up to 3.78 mln. meters, which gives a yearly transportation capacity of 643.5 mln. km of lanes/NM;
5. Baltic RO-RO fleet, utilized in liner shipping, counting 61 ships performs weekly 19.343 NM on 186 voyages (3 voyages per ship weekly on average 104 NM distance) represents a total lane capacity for RO-RO cargo units up to 462.571 m, which gives an annual a transportation capacity of 116.45 mln. km of lanes/NM;
6. Baltic RO-RO fleet, according to performer direct studies, is used with an average speed equal to 79.2% of the maximum technical speed, while RO-PAX ships are operated using 72.5% of their maximum speed. Therefore, current introduced schedules are quite dense and leave only a small margin for potential decreases in speed without affecting the timetable.

7. The most utilized lines are in the RO-RO shipping market: Service 1, Mann Lines (Paldiski/Turku/Bremenhaven/Cuxhaven) serving on 96%, German – Finland Service, Finnlines (Travemünde/Rostock/Helsinki) serving on 93.5% and Gothenburg – Zeegrugge line. CLdN, serving the above on 90%.
8. Yearly HFO consumption in the Baltic Sea shipping RO-RO & ferry lines in 2013 was estimated at 926,079 hours which gives an average operating time at the sea of 5202.7 hours in one year (almost 60% of whole yearly time), but with clear dominance of RO-RO ships which are ca. 5,617 hours at sea in a year, while RO-PAX ships only 4,830 hours. This comes from the important difference between routes and the special character of each shipping type: RO-PAX lines are serving the shorter and most frequented routes and need more time for loading and discharging and boarding/un-boarding of passengers; RO-RO lines are serving on rather longer routes and need much less time to be loaded / unloaded.
9. Baltic RO-RO shipping consumes yearly (2013) 796,092 metric tons of HFO for steaming at sea (excluding other types of fuel used in sea ports), and RO-PAX shipping consumes 1.55 mln. metric tons of HFO accordingly. This corresponds to the relation between transportation capacity and work performed annually by both types of shipping.
10. By current ship's exploitation conditions (see assumptions) annual cost of HFO burning at sea by ships operating on chosen RO-RO & ferry lines on the Baltic Sea and lines related to the Baltic Sea with North Sea reaches 1 509.1 mln. USD (see tab. 3.3), in which 2/3 is accounted in ferry shipping, in terms of Rotterdam bunker stock.
11. On the assumption of exploiting all ships at full speed it would reach up to 1,681.7 mln. USD annually at market value.
12. The theoretical calculations summarized in the table above also show the possible volume and value of HFO consumption if all vessels would sail at full speed. This would give an annual increase of HFO consumption of 83,471 metric tons more in RO-RO shipping and 184,689 metric tones more in RO-PAX shipping. In total it would gives additional 268,160 metric tones of HFO. In value dimensions it would look accordingly: additional 53.7 mln. USD for RO-RO shipping and 118.8 mln. USD for RO-PAX shipping (according to Rotterdam rates from 31/03/2014).
13. The additional cost of changing fuel from LSHFO to MGO on the RO-RO and RO-PAX market under by conditions reported in 2013 may amount to as much as almost 196 mln. USD.
14. The difference measured as growth may reach in average +13.0% of fuel costs for the total fleet (15.7% for RO-RO and 11,6% for RO-PAX shipping lines).
15. This type of shipping services 8.3 mln. tons per annum, which may suppose an additional cost of transportation of 23.60 USD per ton. For a typical truck (with a payload of 22 tones) it means an average increase in cost of almost 520 USD.
16. Maximum additional cost, assuming sailing at full speed (100% engine power utilization) potential increase of maritime RO-RO and RO-PAX shipping on the Baltic Sea may reach up to 582.2 mln. USD (195.9 mln. USD in RO-RO and 386.3 mln. USD in RO-PAX shipping).

Table 3.3. Aggregated indicators for RO-RO, RO-PAX and CONTAINER shipping on the Baltic Sea

Indicator	Unit	RO-RO	RO-PAX	Cont.	Total
by real measured exploitation conditions					
Time at sea	h	360 932	565 147	512 672	1 438 751
Yearly HFO consumption	MT	607 100	1 180 600	677 800	2 465 600
Yearly MGO consumption (alternatively)	MT	600 000	1 166 700	669 700	2 436 400
Fuel volume difference	MT	7 100	13 900	8 100	29 100
Yearly HFO costs*	USD	390 400 000	759 100 000	435 800 000	1 585 300 000
Yearly MGO costs*	USD	525 000 000	1 020 800 000	586 000 000	2 131 800 000
Fuel value difference	USD	134 600 000	261 700 000	150 200 000	546 500 000
by full ahead speed (100% engine power utilization)					
Time at sea	h	291 563	411 025	380 253	1 082 841
Yearly HFO consumption	MT	879 859	1 735 583	744 118	3 359 560
Yearly MGO consumption (alternatively)	MT	870 399	1 716 921	736 117	3 323 437
Fuel volume difference	MT	9 461	18 662	8 001	36 124
Yearly HFO costs*	USD	565 749 591	1 115 979 727	478 468 118	2 160 197 436
Yearly MGO costs*	USD	761 598 723	1 502 305 524	644 102 468	2 908 006 715
Fuel value difference	USD	195 849 132	386 325 797	165 634 350	747 809 279

* – in accordance to Rotterdam bunker prices on 31/03/2014.
Source: own calculation.

17. Assuming that in RO-RO shipping fuel cost represents 37% of all operational cost, an additional fuel cost increase of 15.7% should have an impact on total shipping costs of no more than. 6%. In RO-PAX shipping 30% of the total cost of the route is made up of fuel costs. An increase in fuel price by 11.6% translates to a total cost increase of ca. 3.5%.
18. By this assumption growth may reach +34.6% on average in both types of shipping. Then the total cost of RO-RO shipping might increase by 12,8% and in RO-PAX shipping by 10.4%.
19. Contrary to RO-RO and RO-PAX operators, where we can see investment in scrubbers and alternative fuels like LNG or methanol, there is no news about such changes within the container sector. Therefore, the analysis has been based on the assumption of all the operators changing LSHFO to MGO on all their vessels, at least for the first part of 2015.
20. A total of 138 container ships have been studied (both, feeder and short sea) currently deployed in feeder/shortsea lines (status for 7th of June 2014), deliberately skipping 7 direct ocean lines that use the Baltic Sea ports. This is due to the fact, that the region is still served in vast majority of cases by feeders, and ocean lines appear mostly as temporary or niche market solutions (e.g. banana service or trade exchange with

Greenland). The ocean loops feature low stability in the employment of the vessels (quite often the given ship is introduced for one trip only and then sent to another area or even to another operator). The two main full-year lines (Far East loops by Maersk Line) feature the biggest container ships in the world with a capacity of as much as 18,000+, which do not fit the other Baltic sea fleet parameters.

21. All analyzed container ships perform transport work of 7.2 mln NM on an annual basis.
22. The analyzed box fleet performs a total of 4,581 voyages a year (ca. 33 voyages per ship, each taking 10 days on avg.). The average annual distance of one vessel exceeds 52 thousand NM. The fleets of feeder/shortsea vessels are operated on average at 75% of their maximum technical speed, which indicates that the current schedules are quite dense, but still allow a sizable margin for potential acceleration without affecting the timetable. Nevertheless, there are high differences among the lines and single services. Tschudi Lines is the most 'exploited' provider with its both ships sailing at almost 90% power, while the vast majority go between 68-70%. This is of course very much dependant on the given route's distance and weekly schedules, therefore, the units quite often slow down to the minimum awaiting the scheduled time to enter the next port. A great operational challenge of such action is to have larger space for maneuver and in case of unexpected port congestions or other types of delays, the next terminal can be approached without delay thanks to an increase in speed in between.
23. At present, steaming at sea in the Baltic container sector is estimated at 512,672 hours, which gives an average time of 3,715 hours per one vessel. This is ca. 42.4% of the whole year, supposing that each ship could sail 24/7/365. However, it should be mentioned that time spent in ports has a crucial impact on handling operations.
24. The whole container sector consumes 0.68 mln tons of LSHFO annually (excluding other types of fuel used in the ports). Given the current exploitation conditions of the ships (see above mentioned assumptions) the annual cost of LSHFO used by the whole Baltic container fleet reaches 434.6 mln USD (in Rotterdam bunker stock prices). However, under the assumption that all ships are sailed at full speed, the amount would grow up to 478.5 mln USD a year.
25. Taking the Baltic container shipping market perspective as a whole, the additional costs of a fuel change from LSHFO to MGO in this sector (based on the current prices spread) would be around 395 mln USD and might reach on average a growth of 34.5%. If we assume steaming at full speed with 100% engine power utilization on all ships all year round, we are talking about a maximum 166 mln USD add-up. Taking into account a 54% fuel share in the overall costs structure of container lines, the Baltic 'fuel revolution' should raise the total operational costs by 18.6%.
26. If all 26 Baltic feeder/shortsea operators changed their fuel from LSHFO to MGO today, the total cost would amount to 150 mln USD extra annually, with a growth rate of 34.5% in average. This would raise the tariffs by almost 19%. The model analyzed does not, of course, include fuel prices changing due to new market conditions, which may in fact impact not only LSHFO and MGO, but also other fuels and lubricants (at least in the short term) due to the new structure of oil production.

27. Yet, if we add this result to the previously analyzed ro-ro & ferry market with ca. 400 mln USD add-up (for a consumption of 1.8 mln tons), it totals 550 mln USD in additional fuel costs. The purchasing structure will also change significantly with LSHFO demand almost disappearing and MGO growing by almost 2.44 mln tones.
28. A Sensitivity analysis shows additional aspects of the trend, namely the decreasing trend for additional costs for both types of shipping lines with the increase of LSHFO fuel (near the MGO price level), where the Break Even Point for RO-RO market lies at 744,18 USD pre 1 metric tones and BEP for RO-PAX market lies at 717,43 USD/metric tones of LSHFO (see fig. 3.7.).
29. For MGO price (fig. 3.8.) the trend for additional costs is increasing which translates to an immediate increase in conversion costs for each shipping line. The BEP for RO-RO market lies at 756,05 USD pre 1 metric tones and BEP for RO-PAX market lies at 784,22 USD/metric tones of MGO.

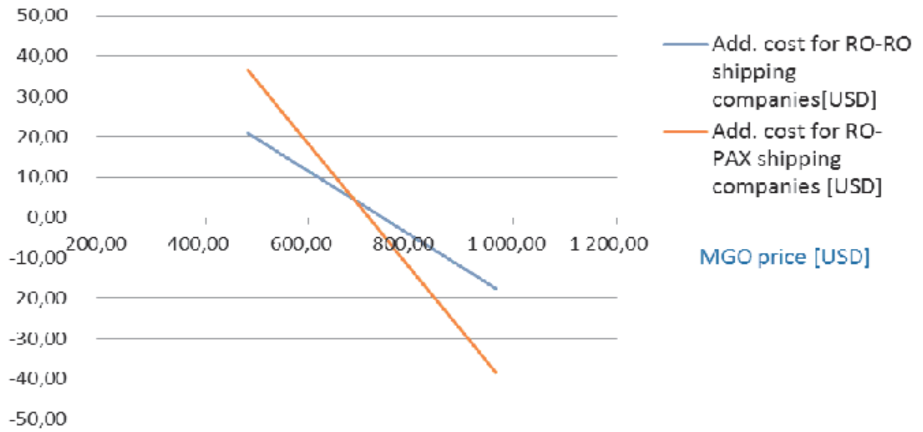


Figure 3.7. Additional cost function due to LSHFO price changing (by Rotterdam rates)
Source: own preparation.

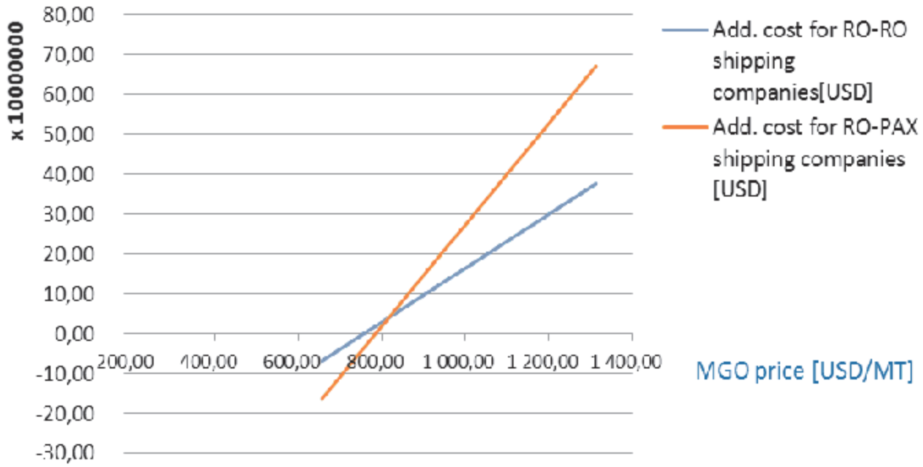


Figure 3.8. Additional cost function due to MGO price changing (by Rotterdam rates)
Source: own preparation.

5. Results and conclusions

The introduction of the Sulphur Regulation has an important influence on shipping costs due to the substantial fuel cost increase. Most important for all market stakeholders is that of price. Due to the studies and calculations described above, it is most probable (assuming that all ship owners will react to this regulation with only fuel changing from LSHFO to MGO), that the total cost of selected shipping lines will amount to an additional 196 mln. USD per year – a growth rate of no more than 13% on average. This could cause a 3.5% - 5% increase in tariffs rates.

However, the model analyzed does not include any marine fuel price changes due to new market conditions (increased demand for MGO and almost reduced demand for LSHFO). According to all theoretic micro economical rules this trend has most probably. This may have also a small impact on other fuels and lubricant prices, at least in the short term, due to the change in the structure of oil production. The general question is, will the industry meet the new market expectations?

Changing to MGO in special cases may have also caused technical problems such as leaks in engine parts (due to totally the different viscosity and density of HFO and MGO) or other operating risks. Some vessels need to be modernized using special equipment for mixing fuels. As it is impossible to simply change to another fuel source, the need arises to modernize the vessel by installing mixing tanks which combine both fuels before entering the SECA zone. This also requires a steering system compatible with other engine management systems. Furthermore, the crew will need additional training and will be responsible for carrying out further tasks. Moreover, the constant change of fuel provides a further window of opportunity for any type of technical failures and human errors to occur.

For those ship owners who do not meet the new limits a penalty system is foreseen by the European Commission and will be integrated into the national law systems. If this aspect will, in some countries be delayed or introduced disproportionately to other ones, with, i.e. very low penalties, it may create a new trend – the avoidance of fuel changing with conscious, intentional breaking the law. In these circumstances the BEP is almost equal to the lowest possible profit that might be achieved by switching to MGO from HFO. If only small penalties will be introduced there is the risk of the continued use of HFO in SECA zones.

For those ships where a change of fuel will lead to use of a new, additional fuel type, this will result in the necessity to transform one or more tanks in preparation for MGO and the additional necessity of holding more samples of fuels for testing and evaluation. This also requires increased fuel monitoring and reporting.

For those ships who cannot be modernized and adapted to MGO burning the aforementioned issue will mean a reduction in the route's flexibility or its total cancellation, where at least one part of the voyage runs through the SECA zone.

Broadly speaking, this leads the market based on maritime transport via SECA zones to increasing delivery costs and final product prices or, according to some experts, a so called "back-shift" of the cargo from sea to road (in some special supply chain configurations). Some reports cite a potential back shift of between 14% and 46% of existing cargo flows realized from German sea ports via maritime transport to Baltic sea ports (see table 3.4).

Table 3.4. Expected back shifts caused by IMO Sulphur Reg. on the Baltic Sea

market	estimated volume in 2015 (1,000 trailers)	expected shift in 2015 in %	expected shift in 2015 (1,000 trailers)
German Baltic Sea ports			
- Western Sweden / Norway	230	14%	31
- Southern Sweden	1,220	15%	181
- Finland	790	27%	215
- Russia / Baltics	300	46%	138
Belgium - Western Sweden	160	24%	38
Gesamt	2,700	22%	604

Source: Reducing the sulphur content of shipping fuels further to 0.1 % in the North Sea and Baltic Sea in 2015: Consequences for shipping in this shipping area", Final report, Institut für Seeverkehrswirtschaft and Logistik ISL, Bremen, September 2010

Another, similar trend is the "re-routing" of current trade flows, where in special configurations it may be more cost-efficient to bring the cargo from Adriatic sea ports (Both the Adriatic and the Mediterranean Sea is excluded from the SECA zones) via European rail system to Poland or Scandinavian countries, instead of carriage via sea to the Baltic Region.

Table 3.5. Aggregated values of additional cost of fuel by type of shipping line

Comparison criteria	Type of liner shipping			
	Ro-Pax	Ro-Ro	Container	Total
Number of vessel operating on 31/03/2014	117	61	138	316
Av. main engine utilization ratio (%)	72,5	79,2	75,0	ca. 75%
Total time at sea (h/year)	565 147	360 932	512 672	1 438 751
Total LSHFO consumption (mt/year)	1 180 600	607 100	677 800	2 465 500
Est. MGO consumption (mt/year)	1 166 700	600 000	669 700	2 436 400
Total cost of LSHFO (mln. USD/year) *	759,1	390,4	435,8	1 585,3
Total est. cost of MGO (mln. USD/year)*	1 020,8	525,0	586,0	2 131,8
MGO – LSHFO cost difference (mln. USD)	261,7	134,6	150,2	546,5
Av. share of fuel costs in total operational cost of the line (%)	30,0	37,0	54,0	x

* – by the assumption of Rotterdam bunker index from 31/03/2014
Source: own calculations.

All of the examples presented above should draw our attention to the possible further consequences of the IMO Sulphur Reg. which result in, among others, a dramatic increase in price.

Subsequently analyzed and concluded possible, are the most important impacts on specific market's levels: marine fuel, shipping freights and shipping owners.

5.1. Marine fuel market

Total marine fuel consumption within Baltic liner shipping up until the end of 2014 consist of approximately 2.5 mln. tones, mainly of LSHFO. Since 2010 it is obligatory for all ships berthing in the EU sea ports longer than 2 hours to switch the main engine to MGO. This has caused many lines and schedules to be reorganized, shortening the time of staying in the port less than 2 h, which requires increased terminal services efficiency. However, this part of the fuel demand will not be included in further calculation and analysis.

By theoretical assumption of 100% steaming of all ships in the BSR, the consumption would increase by up to 3.36 mln. tones. This is, however, verified by economic realities, where neither 2.5, nor 3.36 mln. tones have a noticeable impact on the world's fuel market, considering its annual production of 300 mln. tones. Nevertheless, on a regional scale, it may pose a challenge or question in terms of the strategic decision making of the producers: how should they go about changing the fuel type production structure in the case of a sudden appearance of demand on 2.5 mln. tones of MGO and sudden the disappearance of an equal volume of LSHFO, despite the fact, that some part of the Baltic liner fleet will be retrofitted with scrubbers and a small number of vessels will receive alternative propulsion systems.

Therefore, theoretically, the replacement of the LSHFO with MGO would generate from one side a marginal decrease of fuel consumption in terms of volume (ca. 30 thousand tones annually), but seriously increase fuel costs for all shipping owners, to the value of ca. 546.5 mln. USD a year. In case of 100% capacity steaming the value will reach as much as ca. 748 mln. USD.

The next aspect of the cost analysis concerns the sensitivity of the shipping market on fuel price changes. As of 1/01/2015 shipping owners will pay special attention to the MGO price and its dependency on crude oil price and the port of delivery. Comparing to data from table 3.2. we can see a visible difference between the MGO (as well as all other fuel types) price in St. Petersburg (the cheapest stock), Rotterdam (worlds marine fuel stock determinant) and Baltic sea ports, i.e. Gothenburg or Gdynia/Gdansk, where the price can vary between 818,50 USD up to 957,00 USD on one day (spread 138,50 USD/metric tones). An annual consumption of 2.44 mln. tones can equate the value of 337.4 mln. USD, which is equal to 60% of the previously calculated annual additional cost of fuel changing (from LSHFO to MGO). This means actually, that normal, day-to-day market changes and differences may have almost the same impact on the economical efficiency of maritime shipping, as far as so called „Sulphur Revolution" is concerned. In the Baltic Sea region we can see the general tendency for prices of marine fuels to remain high than 60–70 USD/metric tones. The port of St. Petersburg is exceptional in this respect as it offers the lowest price in the whole Europe, if not worldwide (due to Russian's crisis in recent months the sale of cheapest marine fuel has been removed to Nahodka/East Sibiria).

The most important conclusion is that shipping owners can react quite flexibly to the new coming market conditions by:

- Looking for new fuel suppliers and stocks (restructuration of fuel logistics) – spreads utilization,
- Integration for consolidated purchase of marine fuel with larger deliveries and, therefore, lower prices,

- Restructuring the contract periods of shipping industry fuels in order that they better take into account seasonal changes.

In specific cases potential savings may be crucial for each company. I.e., taking a ship (m/v ER Riga) with a main engine output of 10.000 kW, with average 75% capacity utilization and an annual distance performer of 52.000 NM, the potential saving may reach 300.000 USD a year. This can absorb 29% of the additional cost of changing fuel as of 1/01/2015, which will cost 983.100 USD.

Another factor with potential important impact on the absorption of additional costs is the daily price of the fuel. Figures 3.2–3.5 shows the fluctuation that has taken place within the chosen stocks in the last 12 months. In Rotterdam the maximum fluctuation reached 277,00 USD and in Gdansk/Gdynia 299,00 USD. At certain points it is more than 40% of the lowest MGO price. This is the second solution to find an amortization factor for the cost consequences of the SECA implementation.

The third indicator influencing the efficiency is the spread between the price of LSHFO and MGO. For this analysis, consequently calculated by the market conditions of 31/03/2014 this spread has been established at 232,00 USD/metric tones.

This seems to be the most crucial aspect, as the additional cost is directly taken from the price difference of both types, only marginally decreased by a small, 5% lower fuel consumption. From the above mentioned figures we can calculate also the changes of the spread, which on some days has been decreased to 90 USD/metric tones. Such a small difference no longer represents a cost revolution, because it has less impact of the final price of the service than the normal market trends. This may be a case for daily bunkering logistics management.

However, when all of these indicators go extremely wrong, the aggregated impact may be serious for the owner. Returning to the example of ship (m/v ER Riga) and the increase in cost of fuel by 232 USD/metric tones, an additional 170 USD/metric tones caused by a price increase due to an increase in demand may cause a total additional annual cost of 1,76 mln. USD. In this aspect the accumulated increase factor on 46% may cause a complete line cost increase of 25%, which may be transferred directly to the tariffs and rates and produce an increase of the same value.

5.2. Shipping freight market

The external symptom of market changes for shipping owners are rates changes. A calculation performer for liner shipping in the Baltic Sea Region shows that only the fuel change solution (LSHFO for MGO) should directly increase the tariff rates by ca. 10.4% in ferry shipping, ca. 12.8% in ro-ro shipping and ca. 18.6% in container shipping.

This can be, however, modified both negatively and positively by other aspects. Commonly shipping owners and forwarders are claiming double or triple and, therefore, a high increase in rates. The justification of such assumptions poses a serious problem

From market analysis we know that a lot of shipping lines do not have any reasonable alternative or competition, i.e. the routes Stockholm – Tallinn or Stockholm – Helsinki (for freight). On such routes we can expect at least a redoubling of the abovementioned increases due to the ambiguity of rates calculation methods by each owner. This will be a good opportunity for all to increase rates more (more or less) than it should be increased due on account purely of the fuel change solution. Additional benefit can be devoted to the owner's investments fund or to cover losses from previous periods or simply to increase benefits for the owner. We should keep in mind, that in the last few years (and it continues to be the case) the shipping market is experiencing declines and in some specific aspect even crisis. This situation generates losses, costs owners a lot and prevents new investments. Hence the reason such actions should clearly not be evaluated as negative. From the point of view of market fluctuation and behavioral economy, those shipping owners on an upward trend or in the position of reasonable price increases should include future reserve funds. This is especially important for Baltic owners, as the EU direction clearly shows the LNG-direction in vessel propulsion, which will require a lot of investments in next 5-10 years. This would be satisfactory justification for greater rates increases than the calculation shows.

However, on routes consisting of alternative – land corridors, the abovementioned increase will, in practice, require less force. Of utmost importance here is the principle "what the traffic can bear", which sets the maximum limit of the final price of the transport service, beyond which starts the efficiency of another solution, another transport mode and supply chain. Following this logic, a regularity stating that in a case of the exstence of many alternative services the closure of one is immediately compensated by another, comes into place.

This leads us to the third aspect of the Sulphur Regulation shipping market – the so called "cargo back-shift" from sea to land described previously, which has real potential to appear.

The next aspect of the market is a situation where already existing routes serviced by one shipping line (i.e. Gdansk – Nynashamn) are on the border of economic efficiency, very close to the break-even point. Here additional costs will certainly influence the financial condition of the owner in the short-term and results in a medium-term perspective in the risk of closing the line. This is caused by the lack of profit in previous periods, which, in turn, does not allow for new investment to be undertaken. There is currently a fleet consisting of a mixture of new and old vessels which, from an economical point of view, do not warrant retrofitting (their value is near the price of a scrubber or LNG supply system).

Chapter 4
Economic speed as a factor affecting the efficiency of shipping in the BSR area

1. Introduction

Container shipping within the limited area of the BSR has its own specificities. It differs greatly in comparison to ocean container shipping. Firstly, container lines are almost exclusively feeder lines, serviced by ships up to 3000 TEU. The standard loops connect North Sea container hubs (Hamburg, Rotterdam, Bremerhaven) with 2-4 Baltic Sea ports. The round trip for one feeder vessels takes approximately 1 week. Ship-owners and vessel operators are in competition with each other and with other modes of transport, with economic success depending on the ability to adapt to changing demands and the effectiveness of links with hinterland of ports. Frequent, reliable sea-land container services are mostly desired by customers. The low profitability of such intermodal services is often compensated by the revenue from other than pure shipping logistics services.

More detailed information is needed to build the model required for economic analysis of specific container shipping. Taking into consideration the BSR container market, the following internal and external determinants seem crucial for further analysis:

1) Baltic Sea countries are serviced by regular feeder lines transporting containers to/from Hamburg, Bremerhaven, Antwerp and Rotterdam (fig. 4.1). An exception to this rule are ocean connections: A10 (Asia-North Europe) and ECUBEX (South America-Russia) of APM Maersk. The first of the lines has called regularly at the port of Gdansk (DCT) since 2010. This case promises the gradual diminishing of the importance of feeder connections to that region of Europe.
2) Feeder connections to the BSR are serviced by over 20 ship-owners and container operators. The most important being: Unifeeder (41 ships), MSC (16), Maersk Line (15), Team Lines (17), FESCO-ESF (7), Containerships (9) and OOCL (6). The dense network of connections is serviced by ships with a capacity of between 500 to almost 3000 TEU. In 2011, 6 ship-owners offered feeder vessels with a capacity greater than 1200 TEU: 12 were owned by MSC, 8 by Maersk Line and 7 each were the property of Unifeeder, Team Lines and FESCO-ESF respectively.

3) Container handlings at BSR ports underwent considerable fluctuations during the period 2008-2012 (tab. 4.1). BSR countries reacted by restricting trade to include only business greater than that of Western European countries. The exception to this rule is the port of Gdansk and to some extent the port of Gothenburg, which during the period analyzed serviced ocean-going vessels and was involved in "transshipment"[1].
4) As the biggest market Russia operates a policy of handling its own cargo within its own ports, hence the dynamic development of container handling in St.Petersburg and construction of the new port at Ust-Luga. These ports are, however, disadvantaged by the freezing of the Northern Baltic. Thus, only one ship-owner, i.e. APM Maersk within the ECUBEX line has decided to make St. Petersburg a port of call, using ocean-going ice classed container ships of 2,500 TEU. The Russian market is serviced by the ports of St. Petersburg (2365 thou. TEU in 2011) and Kaliningrad (318 thou. TEU in 2010), with the role of Lithuanian, Latvian and Estonian ports is diminishing in this respect. The share of Russian ports in the container turnover of the BSR increased from 10% in 2010 to 28% in 2012 (fig. 4.2).

Figure 4.1. Container lines in BSR
Source: www.baltictransportmaps.com [date 06.07.2013].

[1] In "transshipment" it is easier to generate substantial container turnover as containers are included in the statistics with every cargo operation undertaken by a ship.

Table 4.1. Container throughput in the biggest ports of the BSR [1000 TEU]

No.	Port	2008	2009	2010	2011	2008/2012
1	St. Petersburg	1983	1344	1931	2365	+19%
2	Gothenburg	862	824	891	914	+6, %
3	Gdańsk	186	240	512	686	+269%
4	Gdynia	610	378	485	617	+1%
5	Aarhus	453	385	447	431	-5%
6	Helsinki	420	357	400	394	-6%
7	Kotka/Hamina	666	345	397	612	-8%
8	Klaipeda	373	247	295	382	+2%
9	Riga	211	182	254	303	+44%
10	Kaliningrad/Baltijsk	213	94	231	318	+49%

Source: own elaboration on the basis of the ports' statistics.

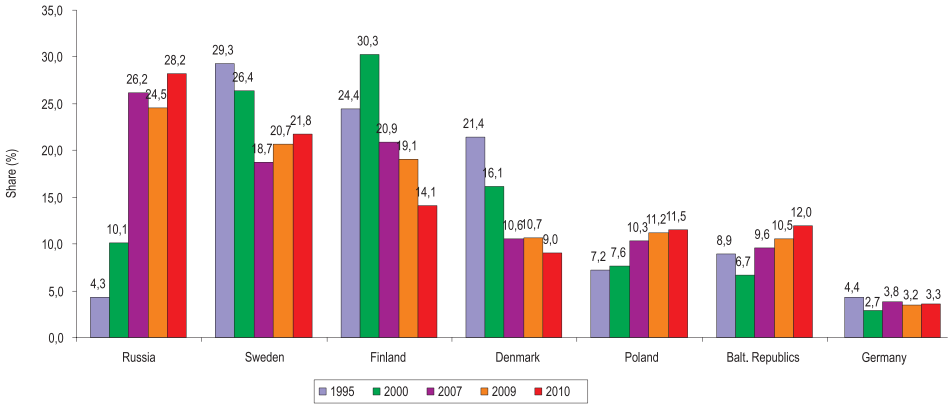


Figure 4.2. Structure of container throughput in BSR in 1995-2010
Source: Karl-Heinz Breitzmann, Baltic maritime transport after the recession – future challenges, Presentation of Baltic Ports Conference 2011, Rostock 2011.

2. Assumptions for the BSR container shipping model

There are several possible approaches to the optimization of a vessel's economic performance. The exploitation parameters crucial for economic efficiency calculations are very much market dependent. Considering the volatility and the uncertainty of the shipping market, the most influential assumptions at the first stage of research include:

1) macro-economic data (charter rates, freight rates, fuel prices),
2) the category and number of ships (TEU, power),
3) the period of shipping performance (voyage, year),
4) port rotation (no of ports, distances),
5) economic strategy of the ship operator (profit-maximizing, profit margin, lean logistics, etc.)

The main aim of the following research is to develop the economic speed of the feeder vessels operating in the BSR. The economic speed is defined as the speed that allows the ships' operator to achieve the greatest profit from a sea voyage. Therefore, further research is to based on the following model assumptions:

1) mathematical models for vessel economic speed will be developed,
2) two alternative models comprise:
   a) model of efficiency based on a single voyage with maximum profit,
   b) model of efficiency based on a one year account period with maximum profit.
3) the models will be examined based on data of containerships representative for BSR, e.g. 1,000 TEU, 1,700 TEU, 2,500 TEU and additional 4,500 TEU (future option),
4) the models will be based on feeder line Hamburg- St. Petersburg-Hamburg with two destinations ports (Hamburg and St. Petersburg),
5) the most reliable and universal model will be recommended for further research dedicated to BSR shipping.
6) the economic strategy of the ship operator (profit-maximizing, profit margin, lean logistics, etc.).

3. Description of the models

3.1. Model of voyage efficiency with maximal profit

A vessel's economic performance presupposes maximization of the profit, that is the difference between income and cost of sea voyage. For the sake of simplicity, the port costs are ignored. Therefore, the model can only be applied to the road-to-road section of the sea journey.

$$P_v \rightarrow max$$
$$P_v = I_v - C_v$$

P_v – profit per vessel per year
I_v – income per vessel per year
C_v – costs per vessel per year

$$I_v = Capacity \times Freight$$

Capacity – 0,6÷0,8 × $Capacity_{max}$ [TEU]
Freight – based on the current freight rate for the trip Hamburg-St. Petersburg [EUR/TEU]

$$C_v = C_{time\,charter} \times T_{sea} + C_{fuel_{sea}} \times T_{sea}$$
$$C_v = [(C_{time\,charter} + C_{fuel_{sea}}) \times T_{sea}$$

$C_{time\,charter}$ – cost of time charter per vessel per day [EUR]
$C_{fuel_{sea}}$ – costs of fuels per vessel at sea per day [EUR/day]
T_{sea} – number of days at sea [days]

$$C_{fuel_{sea}} = C_{heavy\ fuel_{sea}} + C_{diesel\ oil_{sea}} + C_{lubricating\ oil_{sea}}$$

$C_{heavy\ fuel_{sea}}$ – cost of heavy fuel at sea [EUR/day]
$C_{diesel\ oil_{sea}}$ – cost of diesel oil at sea [EUR/day]
$C_{lubricating\ oil_{sea}}$ – cost of lubricating oil at sea[EUR/day]

Through simplification of the above formula it can be assumed:

$$C_{fuel_{sea}} = C_{heavy\ fuel_{sea}}$$

$$C_{fuel_{sea}} = Consumption_{heavy\ fuel_{sea}} \times Price_{heavy\ fuel}$$

$$Consumption_{heavy\ fuel_{sea}} = Consumption_{design\ speed} \times \left(\frac{v_{sea}}{v_{design}} \right)^3$$

$Consumption_{heavy\ fuel_{sea}}$ – consumption of the heavy fuel IFO at sea [t/day]
v_{design} – contract speed of the vessel
$Price_{heavy\ fuel}$ – current price of heavy fuel [EUR/t]

$$T_{sea} = \frac{D_{sea}}{v_{sea} \times 24}$$

D_{sea} – distance Hamburg St. Petersburg via Sund [Nm]
v_{sea} – vessel's average speed at sea [kts]

$$P_v = Capacity \times Freight - [(C\,(time\,charter) + Consumption\,(designspeed)$$
$$\times (v_{sea} / v_{design})3 \times Price(heavy\ fuel)] \times D_{sea} /(v_{sea} \times 24)$$

$$P_v = Capacity \times Freight - [C(time\,charter) / v_{sea} + Consumption\,(design\,speed)$$
$$\times v_{sea} 2\ v_{design} 3 \times Price\ (heavy\ fuel)] \times D_{sea} / \times 24$$

Economic speed is calculated by examining the maxima and minima of the above functions. Therefore, a differential equation will be calculated.

$$\frac{dP_v}{dv_{sea}} = 0$$

3.2. Model of efficiency based on a one year account period with maximum profit

A vessel's economic performance presupposes maximization of the profit, that is the difference between income and cost during one year of a ships' exploitation. For the sake of simplicity, the ships multiples of the same loops as well as a standard, static freight and cost are assumed.

$$P_v \rightarrow max$$
$$P_v = (I_v - C_v) \times n$$

P_v – profit per vessel per year
I_v – income per vessel per year
C_v – costs per vessel per year
n – number of round trips Hamburg-St. Petersburg-Hamburg per year

$$I_v = Capacity \times Freight$$

Capacity – 0,6÷0,8 × $\text{Capacity}_{\max}$ [TEU]
Freight – based on the current freight rate of the round trip Hamburg-St. Petersburg--Hamburg [EUR/TEU]

$$C_v = C_{time\,charter} \times T_{round\,trip_{total}} + C_{fuel_{sea}} \times T_{round\,trip_{total}} + C_{port} + C_{owner} \times T_{round\,trip_{total}} + C_{fuel_{port}} \times T_{port}$$

$C_{time\ charter}$ – cost of time charter per vessel per day [EUR]
$C_{fuel_{sea}}$ – costs of fuels per vessel at sea per day [EUR/day]
$T_{round\ trip_{total}}$ – number of days of round trip Hamburg -St.Petersburg-Hamburg [days]
$T_{round\ trip_{sea}}$ – number of days at sea of round trip Hamburg -St.Petersburg-Hamburg [days]
C_{port} – port costs per vessel in Hamburg and St. Petersburg [EUR]
C_{owner} – owner's variable costs (shipbroking, cargo planing, etc.) [EUR/day]
$C_{fuel_{port}}$ – costs of fuels per vessel in port per day [EUR/day]
T_{port} – number of days in Hamburg and St. Petersburg [days]

$$C_{fuel_{sea}} = C_{heavy\,fuel_{sea}} + C_{diesel\,oil_{sea}} + C_{lubricatng\,oil_{sea}}$$

$$C_{fuel_{sea}} = Consumption_{heavy\,fuel_{sea}} \times Price_{heavy\,fuel} + Consumption_{lubricating\,oil_{sea}} \times Price_{lubricating\,oil}$$

$C_{heavy\ fuel_{sea}}$ – cost of heavy fuel at sea [EUR/day]
$C_{diesel\ oil_{sea}}$ – cost of diesel oil at sea [EUR/day]
$C_{lubricating\ oil_{sea}}$ – cost of lubricating oil at sea[EUR/day]
$Consumption_{heavy\ fuel_{sea}} = f(V_{sea})$ [t/day]

$Price_{heavy\ fuel}$ – current price of heavy fuel [EUR/t]
$Consumption_{diesel\ oil_{sea}} = f(V_{sea})$ [t/day]
$Price_{diesel\ oil}$ – current price of diesel oil [EUR/t]
$Consumption_{lubricating\ oil_{sea}} = f(V_{sea})$ [t/day]
$Price_{lubricating\ oil}$– current price of lubricating oil [EUR/t]

$$T_{round\,trip_{total}} = T_{round\,trip_{sea}} + T_{port}$$

$$T_{round\ trip_{sea}} = \frac{D_{round\ trip_{sea}}}{v_{sea} \times 24}$$

$D_{round\ trip_{sea}}$ – distance of round trip Hamburg -St. Petersburg-Hamburg [Nm]

v_{sea} – vessel average speed at sea [kts]

$$C_{fuel_{port}} = C_{diesel\ oil_{port}} \times Price_{diesel\ oil} + Consumption_{lubricating\ oil_{port}} \times Price_{lubricating\ oil}$$
$$\ldots + C_{lubricating\ oil_{port}} C_{fuel\ port} = [Consumption]_{diesel\ oil_{port}}$$

$C_{diesel\ oil_{port}}$ – cost of diesel oil at port [EUR/day]

$C_{lubricatng\ oil_{port}}$ – cost of lubricating oil at port [EUR/day]

$Consumption_{diesel\ oil_{port}}$ – consumption of diesel oil at port [t/day]

$Price_{diesel\ oil}$ – current price of diesel oil [EUR/t]

$Consumption_{lubricating\ oil_{port}}$ – consumption of lubricating oil at port [t/day]

$Price_{lubricating\ oil}$ – current price of lubricating oil [EUR/t]

$$n = \frac{365}{T_{riound\ trip_{total}}}$$

$$P_v = (Caapacity \times Freight - C_{time\,charter} \times T_{round\ trip\,total} + C_{fuel_{sea}} \times T_{round\ trip\,sea}$$
$$. - C_{port} - C_{owner} \times T_{round\ trip\,total} - C_{fuel\ port} \times T_{port}) \times \frac{365}{T_{roiund\ trip\,total}}$$

$$P_v \left[\begin{array}{l} Capacity \times Freight - C_{time\,charter} \times \left(\frac{D_{round\ trip\,sea}}{v_{sea} \times 24} + T_{port} \right) \\ - C_{fuelr_{sea}} \times \frac{D_{round\ trip\,sea}}{v_{sea} \times 24} - C_{port} - C_{owner} \times \left(\frac{D_{round\ trip\,sea}}{v_{sea} \times 24} + T_{port} \right) - C_{fuel\ port} \times T_{port} \end{array} \right]$$
$$\times \frac{365}{\frac{D_{round\ trip\,sea}}{v_{sea} \times 24} + T_{port}}$$

$$C_{fuel\,sea} \approx C_{heavy\ fuel\,sea}$$

$$C_{fuel\,sea} = Consumption_{heavy\ fuel} \times Price_{heavy\ fuel}$$

$$Consumption_{heavy\ fuel\,sea} = Consumption_{design\,speed} \times \left(\frac{v_{design}}{v_{sea}} \right)^3$$

$$P_v \left[\begin{array}{l} Capacity \times Freight - C_{time\,charter} \times \frac{D_{round\ trip\,sea}}{24 \times v_{sea}} - C_{time\,charter} \times T_{port} \\ - Consumption_{design\,speed} \times \left(\frac{v_{sea}}{v_{design}} \right) \times Price_{heavy\ fuel} \times \frac{D_{round\ trip\,sea}}{24 \times v_{sea}} \\ - C_{port} - C_{owner} \times \frac{D_{round\ trip\,sea}}{24 \times v_{sea}} - C_{owner} \times T_{port} - C_{fuel\ port} \times T_{port} \end{array} \right]$$
$$\times \frac{8760 \times v_{sea}}{D_{round\ trip\,sea} + 24 \times T_{port} \times v_{sea}}$$

The economic speed is calculated by examining maxima and minima of the above functions. Therefore, a differential equation will be calculated.

$$\frac{dP_v}{dv_{sea}} = 0$$

4. Models' exploration

4.1. Vessel's data

The models will be used for calculations of the economic speed of the vessel *Nordic Philip/ Nordic Star* 1,036 TEU, which is representative for the BSR container fleet.

1) Vessels' construction data

Table 4.2. Vessel construction data

Name	Nordic Philip/Nordic Star
IMO	9483669/9483671
Year of built	2010/2011
Capacity	1036 TEU (250 reefers)
GT	10318 t
DWT	13031 t/10600 t
Contract speed (v_{design})	19,0 kts
Rated power	9000 kW

2) Vessel exploitation data from the BRS shipping market for the voyage Hamburg-St. Petersburg-Hamburg via Skaggerak

Table 4.3. Vessel exploitation data

Operator	OOCL
Service	Scan Baltic Express 1 (SBX1)
Capcaity	0,6×1036 = 622 TEU
Freight	475 EUR/TEU (Hamburg – St. Petersburg) 165 EUR/TEU (St. Petersburg – Hamburg) 640 EUR/TEU (round trip)
$C_{time\ charter}$	5100 EUR/day
$D_{round\ trip_{sea}}$	2×1219 = 2438 Nm – round trip
$Consumption_{design_{speed}}$	1,6 t/hr×24 = 38,4 t/day
$Price_{heavy\ fuel}$	460 EUR/t ± 50%

$Price_{diesel\ oil}$	690 EUR/t ± 50%
C_{port}	35700 EUR - Hamburg 20400 EUR –St. Petersburg 56100 EUR – round trip
C_{owner}	6000 EUR/month (200 EUR/day)
T_{port}	40 hrs – Hamburg 27 hrs – St. Petersburg 67hrs (2,79 days) – round trip
$Consumption_{diesel\ oil_{port}}$	2,0 t/day

4.1.2. Calculations of voyage economic speed

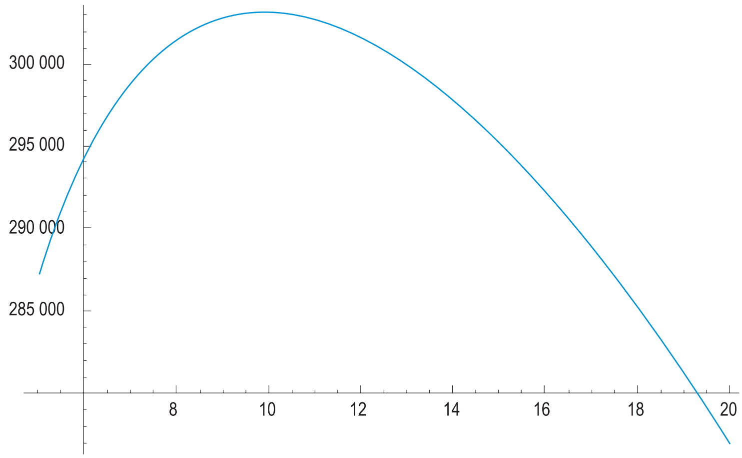
$$P_{\downarrow}v = Capacity \times Freight - [C_{\downarrow}(time\,charter)/v_{\downarrow}sea +$$
$$[Consumtion]_{\downarrow}(design_{\downarrow}speed) \times [v_{\downarrow}sea]^{\uparrow}2/[v_{\downarrow}design]^{\uparrow}3 \times [Price]_{\downarrow}(heavy\ fuel)] \times D_{\downarrow}sea/24$$

$$\frac{dP_v}{dv_{sea}} = 0$$

a) $Price_{heavy\ fuel} = 460$ EUR/t

$$P_v = 342100 - \frac{1219}{24\left(\frac{5100}{x} + 2{,}57x^2\right)}$$

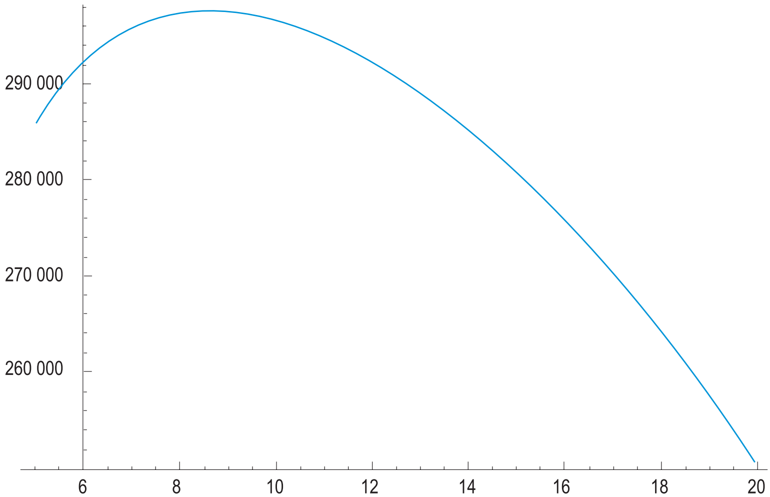
$x = 9{,}97\ kts$



b) $Price_{heavy\ fuel} = 690$ EUR/t

$$P_v = 342100 - \frac{1219}{24\left(\frac{5100}{x} + 3{,}86x^2\right)}$$

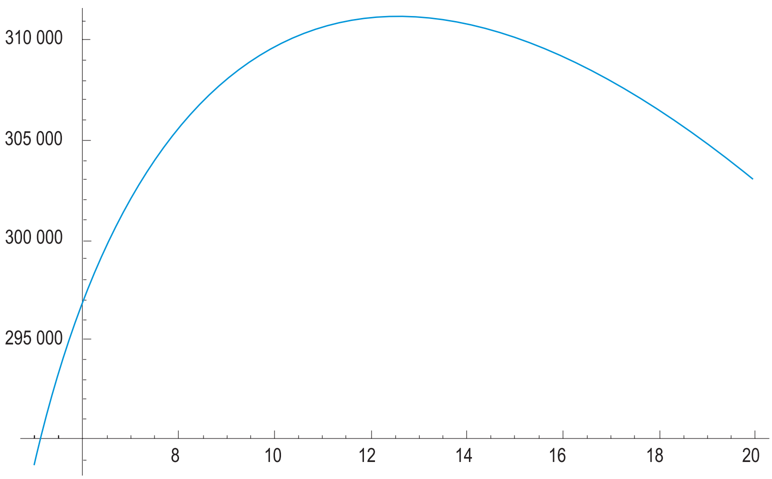
$x = 8{,}71$ *kts*



c) $Price_{heavy\ fuel} = 230$ EUR/t

$$P_v = 342100 - \frac{1219}{24\left(\frac{5100}{x} + 1{,}29x^2\right)}$$

$x = 12{,}56$ *kts*



4.1.3. Calculations of long term economic speed

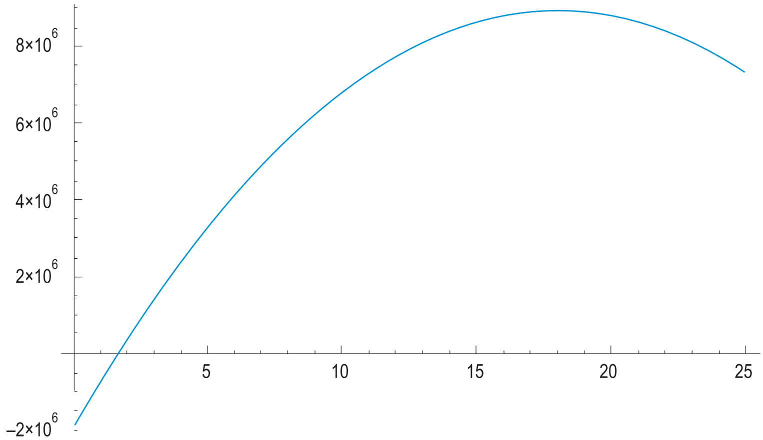
$$P_v \left[\begin{array}{l} Capacity \times Freight - C_{time\,charter} \times \dfrac{D_{round\,trip\,sea}}{24 \times v_{sea}} \\ - Consumption_{design\,speed} \times \left(\dfrac{v_{sea}}{v_{design}} \right)^3 \times Price_{heavy\,fuel} \times \dfrac{D_{round\,trip\,sea}}{24 \times v_{sea}} \\ - C_{port} - C_{owner} \times \dfrac{D_{round\,trip\,sea}}{24 \times v_{sea}} - C_{owner} \times T_{port} - C_{fuel\,port} \times T_{port} \end{array} \right]$$

$$\times \frac{8760 \times v_{sea}}{D_{round\,trip\,sea} + 24 \times T_{port} \times v_{sea}}$$

a) $Price_{heavy\,fuel}$ = 460 EUR/t, $Price_{diesel\,oil}$ = 690 EUR/t

$$P_v = \frac{8640x \left(323342{,}8 - \dfrac{1615175}{3x} - 261{,}61x^2 \right)}{2438 + 66{,}96x}$$

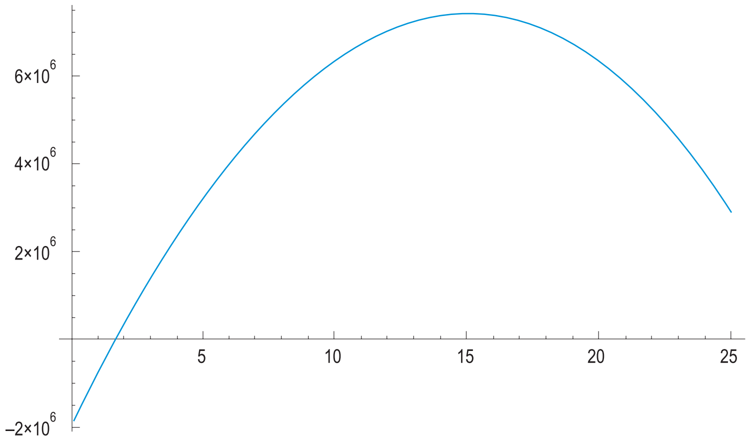
x = 18,00 *kts*



b) $Price_{heavy\,fuel}$ = 690 EUR/t, $Price_{diesel\,oil}$ = 1035 EUR/t

$$P_v = \frac{8640x \left(224110{,}7 - \dfrac{670450}{3x} - 392{,}41x^2 \right)}{2438 + 66{,}96x}$$

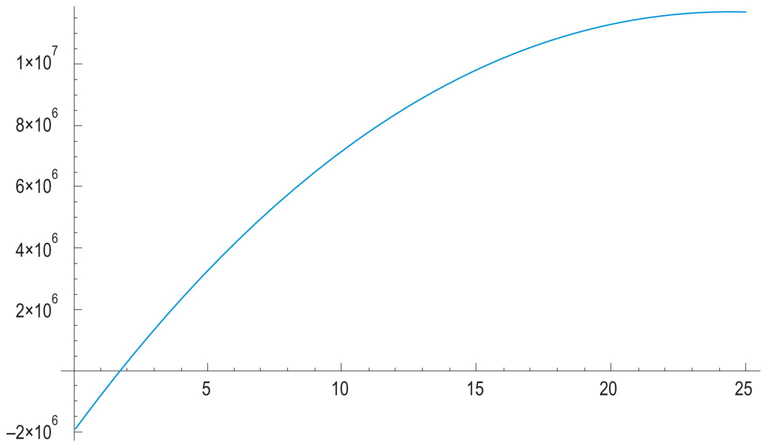
x = 14,97 *kts*



c) $Price_{heavy\,fuel} = 230$ EUR/t, $Price_{diesel\,oil} = 690$ EUR/t

$$P_v = \frac{8640x\left(325267{,}9 - \frac{1615175}{3x} - 130{,}80x^2\right)}{2438 + 66{,}96x}$$

$x = 24{,}46\ kts$



4.1.4. Discussion of results

Tables with calculation results are shown below.

Table 4.4. Economic speed in relation to fuel price [kts]

Fuel price	Voyage	One year
150%	8.71	14.97
100%		18.00
50%	12.56	24.46

Table 4.5. Economic speed in relation to freight [kts]

Freight	Voyage	One year
150%		22.08
100%		18.00
50%		12.05

The main conclusions are as follows:

- voyage economic speed and long distance economic speed is very much dependent on fuel price
- voyage economic speed is not dependent on freight but very much dependent on a vessel's costs at sea (characteristic of tramp shipping scheme)
- long term economic speed is dependent on freight and the vessels' total costs (characteristic of liner shipping scheme)

A detailed conclusion should be based on a greater number of results obtained with regards to changes in key parameters.

5. Conclusions

The analysis of economic efficiency with respect to BSR container shipping has a simplified character. The analysis does not take into account cash flows arising from shipping alliances in the framework of the specified shipping line or financial settlements between carriers in the land-sea logistics chain. This simplification is, however, essential as in temporary transport economics costs generated by one mode of transport are losing their importance with door-to-door logistics costs being more important. The assumptions for the calculation of a vessel's economic speed relied on traditional profit-maximizing criterion. The two calculation models analyzed comprise: the model of voyage efficiency and the model of long-term operational efficiency.

The results confirmed the economic rationality of slow-steaming in shipping. In the case of a short distance voyage, characteristic for RMB container shipping, the calculated ship's economic speed is up to 50% less than the ship's contract speed. The main cost factor that determines this speed is current fuel prices. A similar relationship was observed based on the model of long-term operational efficiency. In this model, port costs and freight rate are additional factors, which have a substantial influence on the financial result of the shipping business. In particular, the agreed freight income is very often key when deciding to increase the vessel's average speed on the specified round-trip container line in the RMB. The results show that, assuming market conditions for shipping, the vessel's long-term economic speed is higher than that calculated for a single trip.

A detailed calculation of vessel emissions was based on a simpler model, which is the voyage efficiency model, mainly due to the limited availability of detailed financial data. The results obtained showed that by navigating at the economic speed the vessel reduces its emissions from 5 to 30% in relation to the contract speed. Therefore, slow-steaming results in dual benefits; greater operational profit and lower external costs of transport. Further study on the basis of t real financial data will allow more accurate calculations of the operational efficiency depending on the vessel's predicted speed.

Chapter 5
Economical impact and comparative risk and costs analysis

1. Analysis of the pros & cons of each solution

Measurement of the economical impact of the Sulphur Regulation consists of a few different, but important elements. In this chapter all the main positive and/or negative aspects of specific solutions matching the new limits have been collected and collated. Positive aspects ("pros") and negative aspects ("cons") have been presented in table 5.1 according to the criteria of specific solutions: installation of scrubber, fuel type change from LSHFO to MGO, alternative fuels and investment in entirely new ships.

Assigning a specific value to all chosen aspects should be done by each company separately, therefore, it has been decided that the summary should go no further. Each company calculates using its own methodology the importance of different solutions due to the development strategy, current financial conditions, market competitiveness, available resources, know-how, expected demand, scale of services performance (daily, weekly, monthly and annually) etc.

2. Risk analysis

The probability of the occurrence of a specific event can vary greatly, for instance an explosion on a LNG Ship is very likely, however it cannot be ruled out (high risk and low probability). The policy can influence the availability of fuels, the imposition of duties or an embargo. This is a risk for the ship-owner, which varies depending on the kind of fuel.

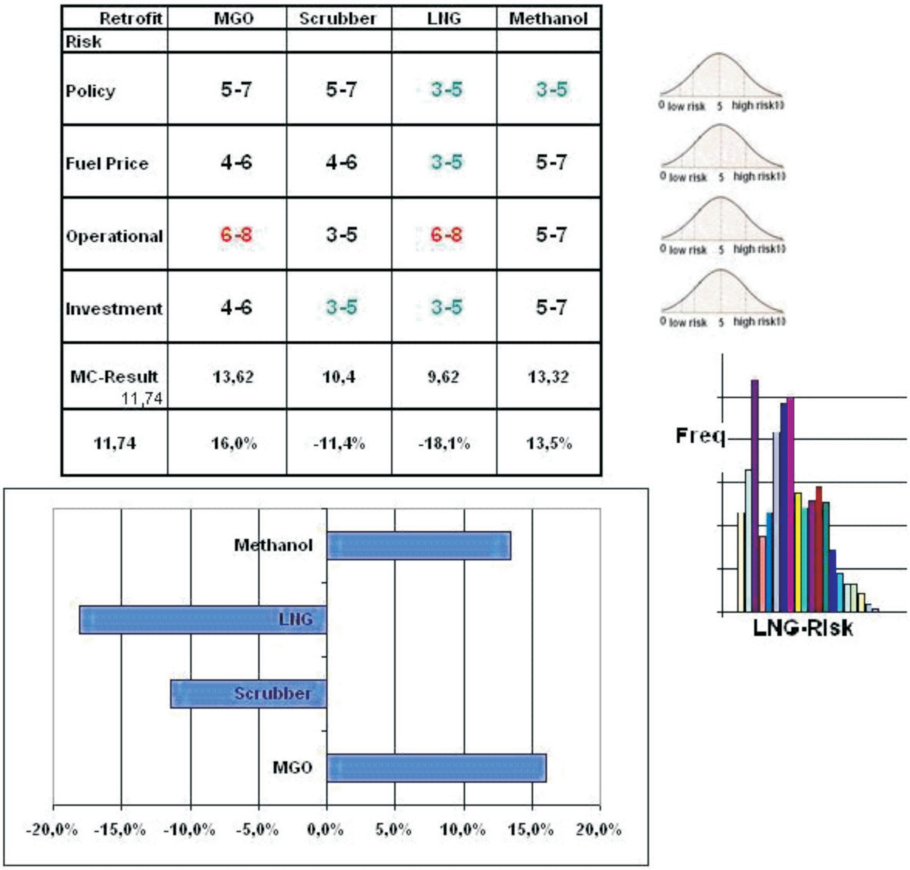
That all events occur at the same time is unlikely but not an impossibility. these occur with a definite probability, hence a simple summary in this context is unhelpful and does not take into account different probabilities for each single risk. The following table shows the results of a MC-Simulation and the risk aggregation (Monte Carlo, 10,000 runs each, own programming).

Table 5.1. Summarized overview of pros and cons of specific solutions

Solution	Con's	Pro's
Scrubbers	➲ Sudden cost of 4–6 mln. USD investment for one ship; High cost of maintenance and cleaning installation; ➲ Uncertainty and potential high cost of filter's waste delivery at the port, especially NaOH (15% of fuel cost); ➲ Additional space for installation in engine room and above; ➲ Ship's cargo capacity reduction; ➲ Short-term exclusion of the ship from the business (for retrofitting tasks); ➲ Crew training and additional responsibilities; ➲ Additional officer/ crew member for the installation; ➲ Short term limitations in the shipyards capacity for retrofitting; ➲ Potential risk of further limitation for open loop scrubbers (limits for S water injection);	➲ Continuous LSHFO using – no further investment in bunker area – for the open loop systems in sea areas with low salinity; ➲ Lower prices for LSHFO due to demand decreasing; ➲ Theoretical short period of capital return (4–5 years) given by suppliers; ➲
MGO	➲ Reconstruction of the fuel supply installation (lower fuel heating, no wires) – est. cost per ship by 100–150 thousand USD; ➲ Real danger of MGO price increase due to the serious growth in demand – use of normal diesel when not available; ➲ Supply limits – new brake-event point for production volume;	➲ Relatively lowest cost per unit of investment; ➲ Easiest solution for implementation ad hoc by the owner; ➲ Lower norm of consumption – longer distances to perform using the same capacity of bunker holds or increasing cargo capacity;
Alternative fuels (LNG, methanol, hybrid, electricity)	➲ High costs of investment; Long period of technology development; ➲ Partly, reduction of ship's cargo capacity (for LNG bunkering); ➲ Reconstruction or cleaning of bunker holds for new fuel; ➲ Not sufficient LNG bunkering network; ➲ Lack of specific LNG bunkering regulations – in particular the prohibition of LNG bunkering during pier operations (loading/discharging);	➲ Independency from the crude oil and fuels market; ➲ Potential area of cost reduction in the long-term;

New orders	➲ Extremely high cost of investment; ➲ Risk of new technologies (not sufficiently approved in practice) ➲ Rerouting old fleet to the regions excluded from the SECA or chartering outside the SECA or demolition of the ship;	➲ Competitive advancement through high quality services;

Source: E. Czermański, *Dyrektywa siarkowa – ekonomiczne skutki jej wdrożenia na przykładzie żeglugi liniowej na Bałtyku*, Sopot, 24/10/2014.



Retrofit / Risk	MGO	Scrubber	LNG	Methanol
Policy	5-7	5-7	3-5	3-5
Fuel Price	4-6	4-6	3-5	5-7
Operational	6-8	3-5	6-8	5-7
Investment	4-6	3-5	3-5	5-7
MC-Result 11,74	13,62	10,4	9,62	13,32
11,74	16,0%	-11,4%	-18,1%	13,5%

Figure 5.1. Risk-Matrix for different retrofit options
Source: own elaboration.

Risk Matrix values are assumptions

Scaling of risk (0 up to 10):

4-6 average risk 5-7 moderate higher risk 6-8 high risk 3-5 low risk

Policy:	For LNG and methanol the dependency on the policy is low e.g. an embargo of fuel.
Fuel Price:	Prices follow a certain supply-demand relation. The LNG price is more stable than e.g. HFO or MGO (compare to 6.5.).
Operational:	The use of MGO is not adequately tested. There is a higher risk of shut-down of the engines. LNG Methanol is toxic and LNG leakages with definite oxygen concentration are flammable.
Investment:	The return risks for LNG and the Scrubber solution are much less than for MGO (see chapter 6.5)

Analysis Result

The results reflect the assumptions and calculation results on the volatility of fuel prices of chapter 6.5. Conservative estimates have been taken for the assumptions and extreme values have been avoided (a risk value of 5 represents a medium risk).

The LNG retrofit displays as a result the lowest risk value. The scrubber variant is the 2nd best solution. The total risk for both variants could be 19.0, the probability for this special case is very low, much more likely are one or two simultaneous events. The simulations take into account the probability for single event and the aggregation of more than one risk. The result shows a reduced risk for the LNG solution than for the scrubber version (9.6 < 10.4).

The average risk of all variants is 11.74, based on this value the relative differences for each possible retrofit option can be determined.

MGO with the noticeably highest risk value of 13.6 reflects high operational risk, it is assumed that the measures for the retrofit are relatively small and modifications have been made only for essential parts due to costs.

3. Investments overview in the Baltic Sea Region shipping market

Despite the general impression we may have following the market review concerning all initiatives and planned investment undertaken by Baltic shipping owners, the picture of the market is seriously worrying. The main conclusion is, that not all owners are prepared sufficiently for the new limits or even at all . What follows is a breakdown of the major investments that Baltic shipping owners have declared, begun to carry out or analyze:

- DFDS – is realizing a general investment program of installing 21 scrubbers on board with app. value of 700 mln. DKK (~94 mln. EUR),
- Stena Line – had declared an estimated additional cost of new fuel (MGO) purchase instead of previously used LSHFO of 455 mln. SEK (~49.5 mln EUR) but now decided to use Methanol propulsion,
- Scandlines – has started the installation of hybrid systems and cleaning at a cost of 15 mln. EUR,

- Viking Line – has to great acclaim introduced the m/s Viking Grace into service at a cost of 230 mln. EUR,
- Fjord Line – has introduced two new ferries: m/s Stavangerfjord and m/s Bergensfjord at a cost of 206 mln. EUR,
- Brittany Ferries – had in 2013 launched, and since temporarily sidelined a project (Pegasis) with a total budget of 270 mln. EUR, currently running several installations of on board scrubbers,
- Color Line – has invested 28.4 mln. EUR in scrubbers on 4 vessels,
- P&O Ferries – has declared an additional annual fuel costs of 30 mln. GBP (~38 mln EUR) due to changing to MGO,
- Finnlines – plans to invest 50 mln. EUR in a mains engine integration system, steering system „Promas Lite" and also installations of 14 scrubbers,
- Balearia – retrofitting one main engine for LNG supply with expected costs of 3 mln. EUR on board of m/s Abel Matutes,
- TT-line – installation of one scrubber with an expected cost of 7 mln. EUR on board of m/s Robin Hood.

The above listed investments of 17 ship-owners opearting in the Baltic Sea Region, amounting to a total value of almost 920 mln. EUR, illustrate the enormous additional costs brought about by the Sulphur Regulation. Nevertheless, it represents only the cost of some chosen investments. It is also know with certainty that 41 vessels will be retrofitted with scrubbers and an additional few (exact number unknown) have already ordered. It is assumed that no more than 20% of all currently running vessels on the Baltic Sea in liner shipping will be equipped with scrubbers in 2015.

Based on the calculation performed in Chapter 3 we can estimate using an additional method the possible cost of compliance with the Sulphur Regulation.

4. Freight rates and increase of tariffs

A detailed analysis and prediction of the increase in tariffs and rates for all Baltic shipping lines is not possible being as it is outside of the main aim of this monograph. However, an attempt has been made establish a basis for the potential increases both for liner shipping (this point) and tramping shipping (p.5).

The following list of announcements by specific shipping owners may serve here as background information:

- *Scandlines* – has decided to introduce the „Marpol Surcharge" to the rates, although they are already generally using MGO. For example: Rodbyhavn – Puttgarden 41 eurocents/m, Rostock – Gedser oca. 94 eurocents/m, Helsinborg – Helsingor 29 eurocents/m.
- *Color Line* – will combine the BAF surcharge with the Marpol Surcharge. The expected increase will reach on average 13% of the BAF value, depending on the route. This amounts to a tariff increase of approximately 2% of the grand total.

- *Tallink Silja Line* – introduces a constant surcharge of 2 - 4,5 EUR per 1 lane meter. I.e. on route Tallinn – Helsinki it will cost an additional 34,00 Euros for a regular, 17 m truck with trailer).
- *Stena Line: the* currently used BAF and LSS (Low Sulfur Surcharge) will be integrated into the total sea freight. Subsequently a new surcharge - "SECA BAF" will be introduced due to the increase in fuel cost. All changes, as declared, will be adequate to the route distance.
- *DFDS* – calls rates will increase by an average of 15% of the current rates, depending on the route distance.
- *TT-Line* – will introduce the „Marpol Surcharge" at a rate of 2,00-2,50 EUR/m. This is based on the price difference between LSHFO and MGO.
- *Unity Line* – initial calculations lead them to call for an increase of 24-28 SEK/m as a result of the LSS surcharge (previously value of 3 SEK/m).
- *Finnlines* – has reorganized its tariffs by implementing BAF into freight rates and introduced a new additional surcharge for bunker costs of approximately 10% of the freight. Per lane performance can reach an additional 4,00 EUR/m on the Gdynia – Helsinki route.
- *Hapag-Lloyd* – has from an early date declared the introduction of a Sulphur Surcharge within container shipping of 50 USD for 1 TEU on USA – Europe routes.

The above are facts concerning the introduction of the sulphur regulation within Baltic liner shipping. Some of the above figures are very close to the calculations made in this analysis and meet expectations of an increase in rates of no more than 10 – 12% in total.

In addition, some examples of increased tariff rates on selected routes are shown below (table 5.2). In order to provide truly representative results a number of ferry lines, ro-ro lines and container lines servicing the most popular destinations have been selected.

To extend the scale of the analysis, we have assumed 3 different utilization ratios of a line/ship. The results are given for an entire cargo unit (one 17 m trailer or one TEU). The prediction are based on real navigation and port conditions. Within ferry shipping the potential cost increase due to the SECA zone has been divided in half, which means that half of the additional costs will be covered by the increase in freight rates and the second half by passenger booking rates. This may vary for each specific route and thus far the analysis has yet to show any objective trend.

Table 5.2. Examples of tariff rate increase by chosen shipping line, according to the established line utilization ratio

Shipping line	Speed	MGO consumption	fuel cost increase	Cargo unit	Additional value of the tariff rate (by chosen line utilization ratio)		
[port-to-port]	[kn]				50%	60%	75%
Lubeck – Hanko	16	44,7	10 817,00	Trailer (115)	189,77	156,77	125,78
Kiel – Oslo	17,8	66,8	16 173,00	Trailer (68)	137,84	98,61	79,28
Rostock – Gedser	14,5	6	1 454,00	Trailer (60)	24,23	20,19	16,15
Świnoujście – Ystad	15	9,7	2 314,00	Trailer (119)	19,61	16,30	13,00

Stockholm – Turku	15	14,2	3 443,00	Trailer (61)	57,38	47,82	37,42
Tallinn – Helsinki	16,5	12,4	2 995,00	Trailer (50)	59,90	49,92	40,47
Gdansk – St. Petersburg	14,5	56,7	13 721,00	1 TEU (868)	31,62	26,39	21,11
Klaipeda – St. Petersburg	13	40,1	9 700,00	1 TEU (966)	20,08	16,72	13,40
Hamburg – Ust Luga	14	71	17 181,00	1 TEU (1660)	20,70	17,25	13,80
Gdynia – Helsinki	14,5	36	8 700,00	1 TEU (1349)	12,91	10,75	8,60

Source: own calculations.

As can be seen, the most dramatic increases should be expected on ro-ro lines, the core business of which is freight carriage rather than passenger travel. This is due to the low unit capacity of ro-ro ships, which is average 60 – 80 trailers at once. Much better conditions are offered by container shipping, where even feeder ships are able to take hundreds of units (containers) at once. The biggest container vessel taken into account here has a capacity of 1,660 TEU and therefore, the greater additional cost is divided between more cargo units and thus equates to a lower value per unit. Furthermore, crucial here is the speed and capacity utilization factor.

5. Rates increasing in tramping shipping

Tramp shipping is characterized by a lack of regularity of sea routes and the fact that each subsequent voyage must be planed. Each voyage has two legs, the first is the ballast leg - from the discharging port to the loading port and the second is the laden leg - from the loading port to the discharging port. The Baltic Sea Region is usually the area where sea voyages end or begin, therefore ships spends more time in ports.

The most important economic factor affecting the choice of the ship-owner in tramp shipping is the freight rate. Freight rate is charged for sea voyages in terms of USD per tone or USD per cubic meter of cargo. During the freight rate calculation for a particular voyage one takes into account all ship-owner costs including variables and constants. Fuel costs account for a significant share of total voyage costs.

In order to evaluate the effect of new sulphur regulations on freight rates, simulated tramp voyage costs, wholly or partially within the ECA, will be calculated. Voyage costs converted into freight rates will allow the competitiveness of tramp shipping in the ECA in comparison to entirely outside of the ECA to be calculated.

The calculation of voyage costs is based on the following assumptions:

- Two variants of full ship cargo:
  1) coal (SF=31,0 cbf/t, loading/discharging rate 3,000 metric tones)
  2) wheat (SF=59,0 cbf/t, loading/discharging rate 6,500 metric tones);
- Two variants of ship routes:
  1) 7500 Nm (including 500 Nm at ballast);

2) 2500 Nm (including 300 Nm at ballast);

- Three variants of time sea time spent in ECA:
  1) 100% of ship's route in ECA, 2 loading/discharging ports in ECA;
  2) 50% of ship's route in ECA, 1 loading/discharging port in ECA;
  3) 25% of ship's route in ECA, 1 loading/discharging port in ECA;
  4) 0% of ship's route in ECA, no loading ports in ECA;
- Bunker prices:
  1) in ECA: MGO – 640,00 USD/t;
  2) outside ECA: 380 IFO – 380,00 USD/t, MDO – 640,00 USD/t;
- Three bulk cargo ships as described in table 6.2.

Table 5.3. Vessels operational data for calculations

Vessel's name	m/v Mielec	m/v Kopalnia Halemba	m/v Rodło
Cargo capacity	204 762 cbf	513 873 cbf	1 519 533 cbf
DWT	4 456 mt	11 715 mt	33 742 mt
Speed laden	14,0 knots	11,0 knots	12,5 knots
Speed balast	15,0 knots	12,5 knots	14,5 knots
Fuel consumption: IFO/MGO laden IFO/MGO ballast IFO/MGO port MDO/MGO sea MDO/MGO port	 13,5 t/day 11,0 t/day 1,4 t/day 0,6 t/day 0,5 t/day	 15,0 t/day 14,0 t/day 1,9 t/day 0,9 t/day 0,5 t/day	 41,0 t/day 38,0 t/day 5,5 t/day 4,3 t/day 3,2 t/day
T/C Value (daily cost)	2 500 USD	4 000 USD	9 000 USD
Port costs	8 000 USD	12 000 USD	21 000 USD
Agency commissions per port	2 000 USD	2 000 USD	4 500 USD
Miscellaneous cost per voyage	500 USD	1 000 USD	1 500 USD

Source: Polish Steamship Company fleet.

The tables show summary results according to ship type, cargo type, the whole voyage distance and the share of which is within the ECA. The results allow the following conclusions to be drawn:

- Taking into account all calculation variants, freight rates for ship voyages through the ECA should be up to 30% higher than freight rates for voyages beyond the ECA.
- The most important factor in the increase of freight rates is the distance travelled in the ECA. For short distances in the ECA less than 1,000 Nm the rates increase should be less than 15%. The exact difference depends on the ratio of the distance in the ECA to the total voyage distance. In cases of very long ship voyages e.g. Europe-South Asia the freight rate increase should be less than 5%.
- The size of the ship also has an impact on the freight rate increase, the smaller the larger percent increase in its costs.

- The freight rates depend largely on the type of transported cargo. Volumetric cargo, such as wheat, have a more likely to increase the price of carriage. This is definitely is more pronounced for smaller ships.

Table 5.4. Calculations of freight rates for a voyage distance of 2500 Nm

Distance in ECA	100%		50%		25%		0%	
Cargo type [cbf/t]	SF=31	SF=59	SF=31	SF=59	SF=31	SF=59	SF=31	SF=59
m/v Redło (33742 t DWT)								
Total voyage cost [USD]	731137	503797	670948	454434	650644	434129	607647	401953
Freight rate [USD/t]	21,67	19,56	19,88	17,64	19,28	16,86	18,01	15,61
Freight rate increase against non-ECA voyage	20%	25%	10%	13%	7%	8%		
m/v Kopalnia Halemba (11715 t DWT)								
Total voyage cost [USD]	217193	186088	197456	167666	189013	159223	175636	147165
Freight rate [USD/t]	18,54	21,36	16,85	19,25	16,13	18,28	14,99	16,90
Freight rate increase against non-ECA voyage	24%	26%	12%	14%	8%	8%		
m/v Mielec (4456 t DWT)`								
Total voyage cost [USD]	121368	113725	108148	100866	102180	94896	93890	86966
Freight rate [USD/t]	27,24	32,76	24,27	29,06	22,93	27,34	21,07	25,06
Freight rate increase against non-ECA voyage	29%	31%	15%	16%	9%	9%		

Source: own calulations.

A general observation is that the competitive position of the shipping markets of Northern Europe in relation to the other destinations will be weakened by the requirements of the ECA. The introduction of larger vessels for tramp shipping in the BSR and North Europe allows freight rates to be partially reduced. An extremely important factor here is fuel consumption. Hence it seems reasonable to adjust the speed of the ship and other parameters to match ECA operating conditions.

Table 5.5. Calculations of freight rates for a voyage distance of 7500 Nm

Distance in ECA	50%		25%		0%	
Cargo type [cbf/t]	SF=31	SF=59	SF=31	SF=59	SF=31	SF=59
m/v Redło (33742 t DWT)						
Total voyage cost [USD]	260358	253079	241365	234084	219227	212305
Freight rate [USD/t]	58,43	72,91	54,17	67,44	49,20	61,17
Freight rate increase against non-ECA voyage	19%	19%	10%	10%		
m/v Kopalnia Halemba (11715 t DWT)						
Total voyage cost [USD]	442396	412606	415533	385746	382482	354009

Freight rate [USD/t]	37,76	47,37	35,47	44,29	32,65	40,64
Freight rate increase against non-ECA voyage	16%	17%	9%	9%		
m/v Mielec (4456 t DWT)`						
Total voyage cost [USD]	260358	253079	241365	234084	219227	212305
Freight rate [USD/t]	58,43	72,91	54,17	67,44	49,20	61,17
Freight rate increase against non-ECA voyage	19%	19%	10%	10%		

Source: own calculations.

6. Comparative investments cost analysis

In this analysis three important ship types will be investigated: a handy size containership, a ro-ro and a ro-pax vessel. The fuel change to MGO is the baseline for all comparative calculations. Previous comparisons refer to the part on IFOcSt1.0% or IFOcSt3.5%.

The sulphur directive requires a cut in sulphur emissions, therefore vessels may only operate using MGO or equivalent abatement technology (scrubbers, LNG, Methanol).

The above mentioned vessels are not equally suitable for adjustment (retrofit), especially in the case of an older ship or one that is not entirely new. Above all, the following points are to be taken into account:

- what are the impacts of dynamic stability, trim, stress change on the ship
- is there enough space and volume for additional equipment, tanks, pumps, pipes and parts

The installation of a scrubber in a RoPax ship for example is nearly impossible as stability is tight and additional volume does not exist on the upper decks.

In most cases, only after having answered all of these questions can economic aspects be taken into account and the start of an economical investigation makes sense. Technical feasibility does not form part of the following calculation. The objective is first and foremost to answer the question whether a cost-effective operation is generally possible under the adoption of certain investment costs and reductions in the performance of the ship.

The amount to be invested, operating costs and later on in particular the fuel costs are all of interest when deciding upon an investment.

Table 5.6. SD and Mean comparison

	Oil-Price Brent	eqv-LNG*	eqv-Methanol**
SD	100,48 l	57,36 l	180,94 l
Mean	720,20 l	429,05 l	1006,04 l

Source: own elaboration.

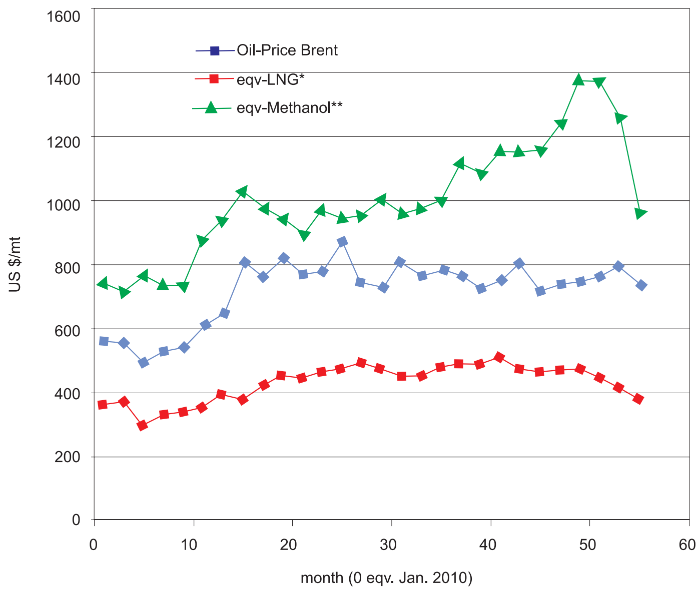


Figure 5.2. Fuel price volatility

Source: own elaboration based on www.ycharts.com LNG,www.onvista.de Fuel Price Brent, www.methanex.com Methanol.

The comparative Return for a hypothetical Ship (Containership) is as follows:

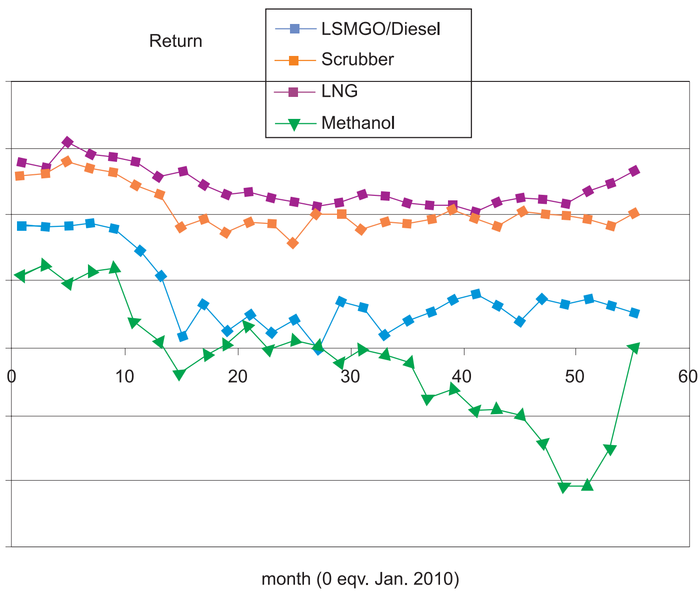


Figure 5.3. Dependency of the Return influenced by fuel price

Source: own elaboration.

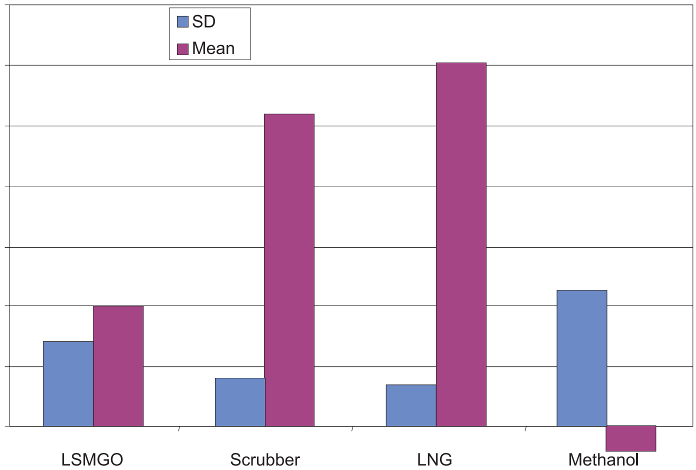


Figure 5.4. Return (Mean) and Risk (SD) for different retrofit options of investment
Source: own elaboration.

The economical risk analysis

The LNG solution poses the smallest risk, closely followed by the scrubber variant.

Use of MGO is risky as the oil price represents a higher percentage of the total cost. This also applies for methanol.

Analysis of different retrofit investments

The problem of choosing an optimal retrofit is one of the main issues faced by each ship owner and operator of ships as criteria for obtaining an efficient solution, technical feasibility, investment costs, operating costs and transition costs during the retrofit phase in the shipyard are to be taken into consideration. Finally the net present values are calculated for different retrofit solutions.

The standard solution is conversion to MGO. This is also the basis for comparison with other options such as LNG, scrubber and methanol. In the scrubber variant the actual machinery remains unchanged, while all the other variants require an adaptation of the main engine, the efficiency and reliability of the system will be worse in general, depending on the type of the engine. Dual use engines pose no problems in this context. Methanol is an exceptional case as it will be increasingly important in the future,. It is environmentally friendly and requires no changes in on board handling procedures, other than the fact that more than twice as much tank space is required.

Different retrofit examples are presented below:

RoPax vessel

Figure 5.5. RoPax Finlandia in the Helsinki-Tallin range (distance 45nm)
Source: www.eckeroline.fi.

Technical Data: Lpp= 175 B=27,6 T=7,0; Main engine: 4x Wärtsilä 12V46 each 12600 kW; Vmax=29kn (38500 kW) Hotel Load: 1500 kW, V travel~20kn (12700 kW) Seastate < 3 transit time 2-2,5 h 180nm daily

Yard: Fincantieri 2001 Operator: Eckerö Line (since Jan.2013)

Passenger: 2000 Cars:660 Lane: 1950 m

Scrubber (closed system) retrofit (Price Difference MGO-IFOcSt3.5%=300 USD/t)

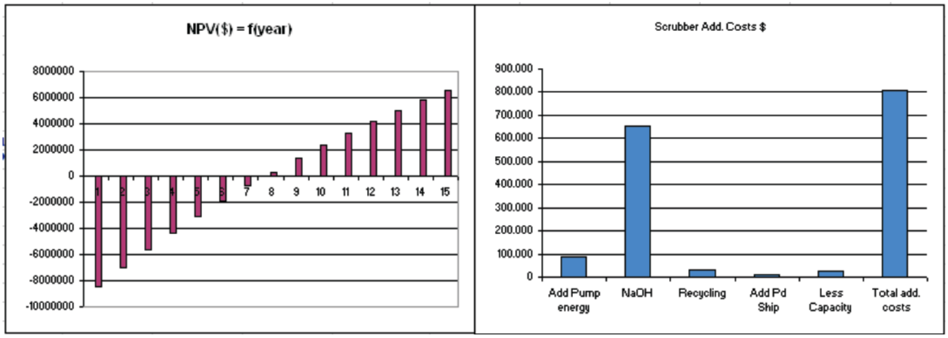


Figure 5.6. Scrubber retrofit NPV calculation result RoPax Finlandia Investment 10 mln. USD
Source: own elaboration.

LNG retrofit (Price Difference MGO-eqv-LNG=289 USD/t)

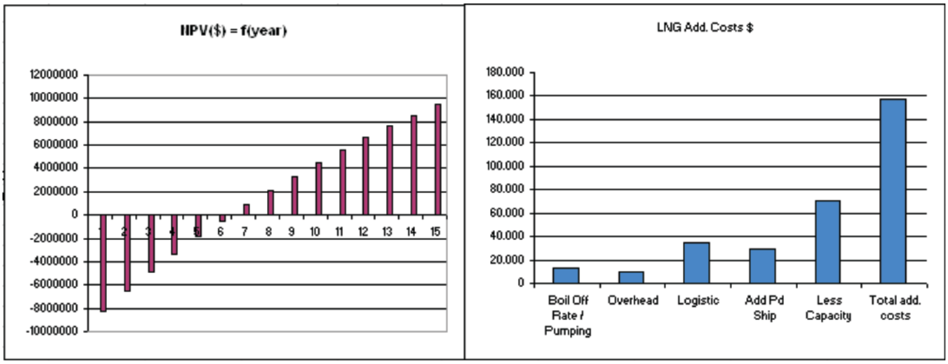


Figure 5.7. LNG retrofit NPV calculation result RoPax Finlandia Investment 10 mln. USD
Source: own elaboration.

Methanol Retrofit (*Fictive* Price Difference MGO-Methanol=70 USD/t)

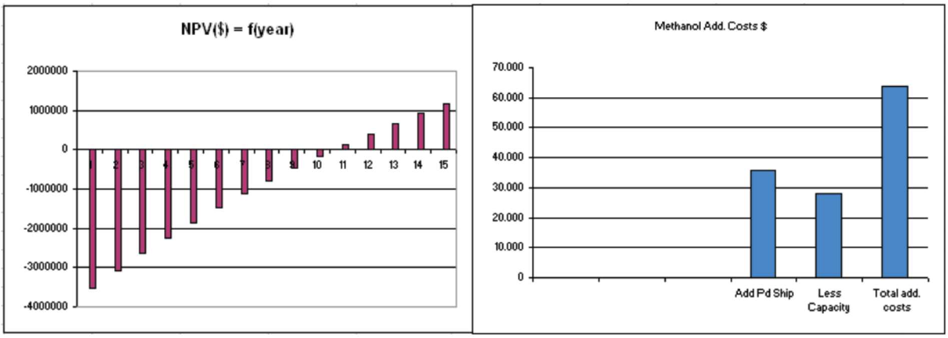


Figure 5.8. Methanol retrofit NPV calculation result RoPax Finlandia Investment 4 mln. USD
Source: own elaboration.

The conversion of the RoPax vessel presents a big challenge. There is hardly any free space available and in the case of the scrubber solution bulky equipment is required to be installed on the upper deck near the funnel. The additional weight must be compensated by the replacement of other components with those of a lighter weight. The stability of the ship and the drafts and trim are to be observed. The scrubber solution is more complicated than other solutions and correlates with the maximum possible engine output. The best solution is to integrate an additional section of 5m and to lengthen the ship. The LNG variant is more flexible as components can be integrated into more areas of the ship and stability and trim are largely unaffected.

The NPV calculation takes into account the high investment (interest rate 5%) and all relevant operating costs like caustic soda (NaOH) which is an relatively high cost factor (15% of the fuel costs or 0,02 USD/kWh). The LNG solution is in comparison to the scrubber solution much more preferable assuming there is the possibility to refuel the gas after all passengers have left the ship.

Conversion to methanol or MGO proposes fewer technical problems and requires few physical changes. The machinery can be changed in turn during normal operation, as only day-to-day operation they both required simultaneously. However, since the operating costs are high, should there be plans to replace it in the next 5 years by a new vessel, a LNG retrofit is in this case unprofitable.

RoRo vessel

Figure 5.9. RoRo Finhawk in the Hull-Helsinki range (distance 1300 nm via Gothenburg)
Source: www.finnlines.fi.

Technical Data: Lpp= 162,2 B=20,6 T=6,7; main engine 12600 kW; Vmax=20kn; Vtravel~17kn (7,750 kW) Seastate < 3; Lane Length=1,890 m Container=185+206 Reefer=50;

Scrubber (open loop system) (Price Difference MGO-IFOcSt3.5%=300 USD/t)

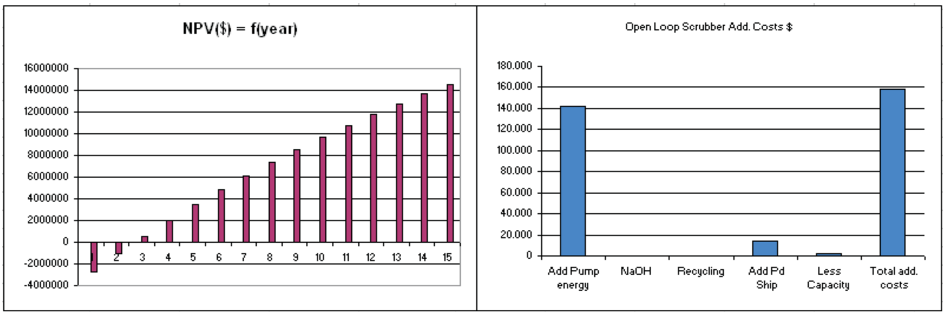


Figure 5.10. Scrubber retrofit NPV calculation result RoRo Finhawk Investment 4,5 mln USD
Source: own elaboration.

LNG retrofit (Price Difference MGO-eqv-LNG=289 USD/t)

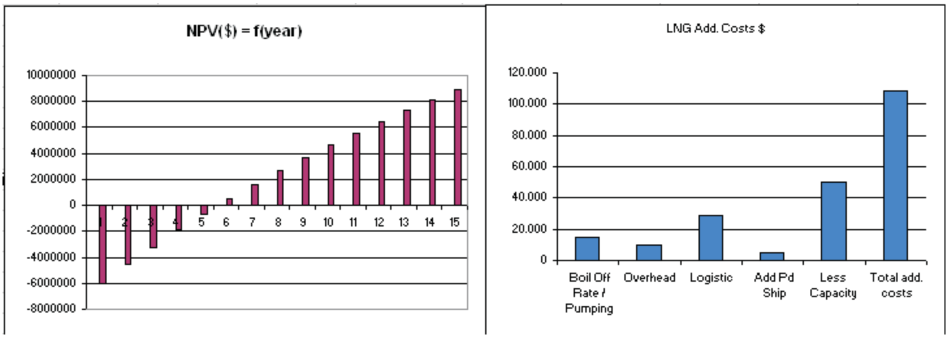


Figure 5.11. LNG retrofit NPV calculation result RoRo Finhawk Investment 7,5 mln USD
Source: own elaboration.

Methanol Retrofit (*Fictive* Price Difference MGO-Methanol=75 USD/t)

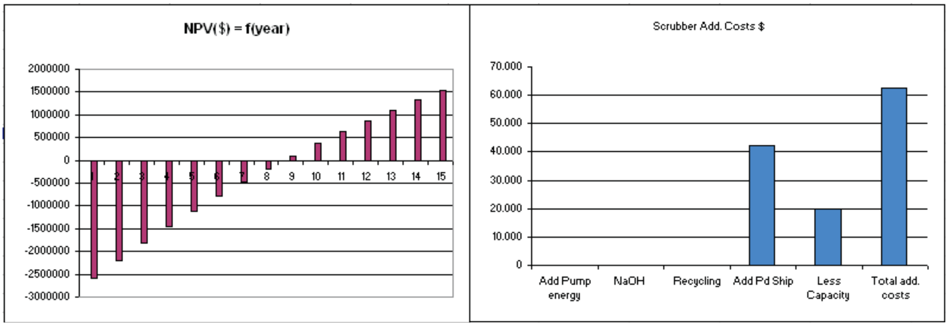


Figure 5.12. Methanol retrofit NPV calculation result RoRo Finhawk Investment 3 mln USD
Source: own elaboration.

The RoRo vessel and the retrofit with an open loop-scrubber are the solutions with the slowest return on investment time (2,6 years) in comparison to the other options. The open loop system makes use of the salinity of sea water for the process. Expensive caustic soda need not be taken into account.

The water must be alkaline enough (ph value is high enough), which in the Baltic can prove a problem. In this case the use of low sulphur fuel is recommended, or otherwise the water flow rate would have to be increased which, in turn, would lead to the need for an additional pumping power. The wash-water can be discharged into the sea after filtering the residuals out of the water. In such critical sea areas and for environmental reasons the discharge of the wash-water is not permitted.

The retrofit investment for the LNG option is approximately 50% higher. LNG tanks are to be installed in the double bottom (mobile LNG Container tanks could also be an alternative, simplify and shorten the refueling process, but reduce the payable "Lane Length" of the ship).

The Methanol option is not suitable as this will cause the endurance of the ship to be reduced to half of that of the MGO solution (the energy content of methanol is only 44% of MGO).

The equivalent Methanol price is on average about 30% higher, whilst the volatility is nearly double in comparison to MGO (see Table 5.6). For ships with a high transit-share the use of Methanol is uneconomical at this time.

Containership (1000TEU)

Figure 5.13. Containership VII Helsinki-Teeport(GB)-Rotterdam Kiel-Canal Option via Skagen
Source: www.marinetraffic.com.

Technical Data: Lpp= 158,1 B=22 T=8,9; Wärtsilä W7L64 12600 kW, Vmax=20,4 kn Vtravel~19,3kn (10700 kW) Seastate < 3; Container=969 TEU (656 TEU (14t)) Reefer 126; Shipyard: Sietas Type 168 Build 2002, Operator: Containership

Scrubber (closed system) retrofit (Price Difference MGO-IFOcSt3.5%=300 USD/t)

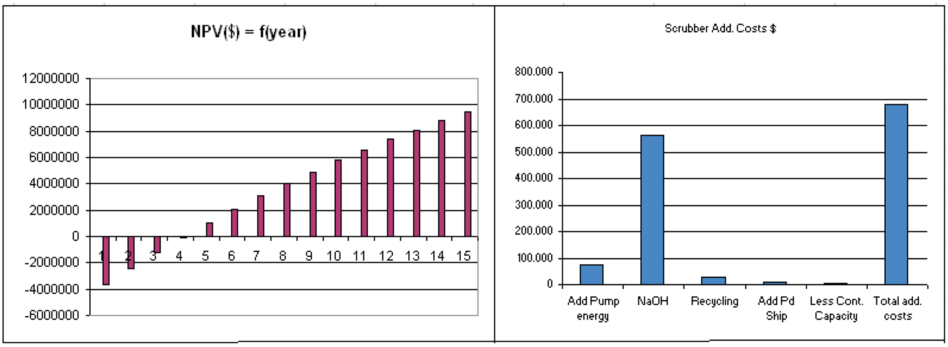


Figure 5.14. Scrubber retrofit NPV calculation result "ContainershipVII" Investment 5 mln. USD
Source: own elaboration.

LNG retrofit (Price Difference MGO-eqv-LNG=289 USD/t)

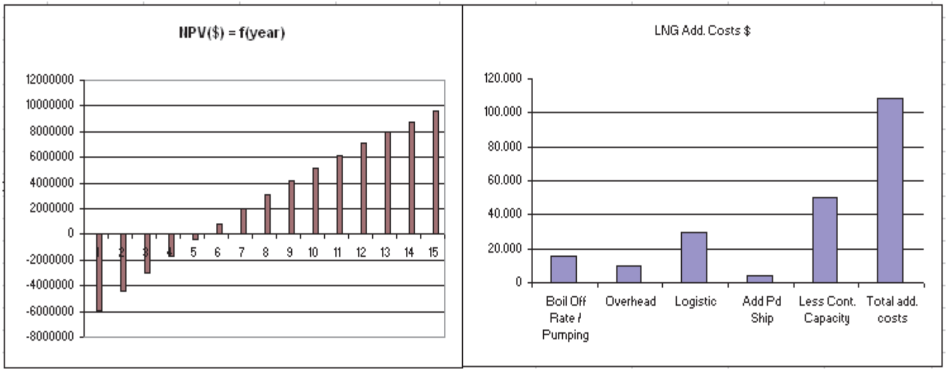


Figure 5.15. LNG retrofit NPV calculation result ContainershipVII Investment 7,5 mln. USD
Source: own elaboration.

Methanol Retrofit (*Fictive* Price Difference MGO-Methanol=75 USD/t)

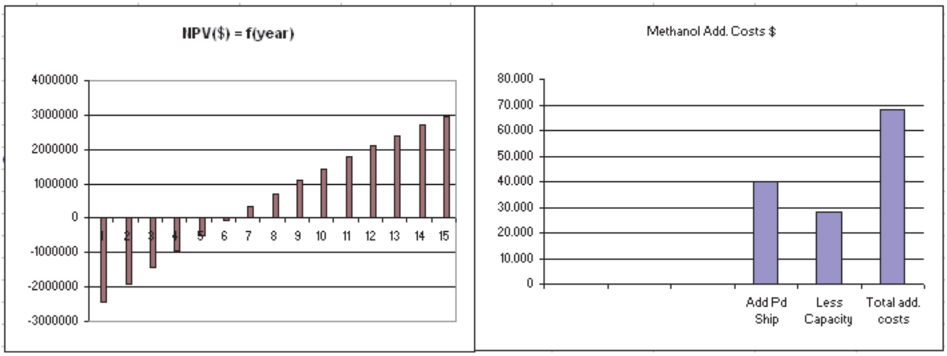


Figure 5.16. Methanol retrofit NPV calculation result ContainershipVII Investment 3 mln. USD
Source: own elaboration.

The differences between the scrubber (closed System) and LNG retrofit options are relatively small. A generally valid statement cannot be made, however if the vessel remains in service for a longer period the LNG solution produces higher revenues and return than the scrubber retrofit. The risk of the return (SD) is equal (see Figure 5.16.). On the other hand the retrofit measurement is much more complicated than for the scrubber solution. All parts of the engine must be modified, the main engine needs to be updated and the availability of LNG is not ensured in all ports.

The methanol option and its conclusion very little from that of the RoRo analysis.

Summary of the calculation results

The RoPax vessel with an estimated 10 mln. USD investment requires about 7.8 years to produce a return on investment (Scrubber closed system). It requires a great deal of conversion work and the downtime of the vessel is approximately 4 weeks in the shipyard (6.4 years for the LNG solution). A con-version is not recommended.

For the RoRo vessel a conversion is profitable. It can reach the breakeven point in as little as 2.6 years (Scrubber solution open system), whilst the LNG version is also acceptable, producing a return on investment after 5.6 years.

The containership also favors conversion with a suitable scrubber as well as LNG. The investment has already been paid after 4 (Scrubber) and 5,2 years (LNG).

The use of methanol can in most cases be overlooked on account of its cost. Only if the price difference is more than USD 70 in comparison to MGO can it be considered. However, this is a fuel for the future, provided that it is produced from biomass.

Chapter 6.
European Union political activity and legislation to support the implementation of Sulphur Regulations

1. New European Union strategy for transport fuels

The European Union is putting in place a number of initiatives to counteract the negative effects of anti-sulphur restrictions and to ensure a smooth transition to the new requirements, without overly affecting the real maritime economy.

The European Union is taking action to support the real economy, including adapting certain seaports to the requirements of the sulphur regulations. These activities relate primarily to the development of seaport infrastructure. In fact, it will be the foundation for a future system of onshore and offshore supply of alternative fuels for vessels. The EU's vision of the alternative, low-sulphur engine technologies for maritime transport is based on the assumption that the LNG is most predisposed, economical and promising fuel.

In 2013 the European Commission published a considerable dossier, mostly referred to as "Package: alternative fuels for transport".

The documents included are related directly or indirectly to the Sulphur Directive (2012). The general assumption of solutions contained in the dossier was the creation of a foundation for the development of a comprehensive strategy to increase the use of clean fuels and alternative technologies in transport.

The European Commission's Communication entitled "Clean Energy for Transport: A European Alternative Fuel Strategy"[1] was the most fundamental document included. It states that the countries of the European Union, and in particular their transport, are largely dependent on the use of petroleum fuels derived from processed crude oil, especially gasoline and diesel fuels. Hence the existence of many significant problems, primarily economic dependence on foreign oil suppliers, excessive pollution of the environment, and the dependence of transport within the EU on fuels generating significant amount of carbon dioxide.

1 COM(2013) 4 final; Clean Power for Transport: A European alternative fuels strategy; Brussels; 24/01/2013.

Therefore, the enforcement of changes in EU transport technologies enabling the significant, in terms of volume, replacement of petroleum fuels by alternative fuels is considered to be necessary. What is fundamentally important is the consideration that large-scale action in this area should lead to:

- substantial cost savings resulting from the release of the EU economy from crude oil suppliers monopolizing markets;
- costs reduction of the import of conventional fuels, currently in use;
- reduction (up to 60%) of CO2 emissions from the transport sector;
- generating approx. 700,000 new jobs[2].

The European Union's anticipates the following estimated savings arising from the use of alternative fuels:

- 4.2 billion EUR annually by the year 2020;
- 9.3 billion EUR annually by the year 2030;
- additional 1 billion EUR annually after the year 2030[3].

The document states that the new European strategy for transport fuels should focus on increasing the degree of use of alternative fuels. LNG and electricity are primarily considered as alternative fuels. At the same time, LPG, CNG and bioethanol as alternative fuels could be treated as desirable but would remain likely a niche market.

The important parts of the document states that LNG is the most economically and environmentally sound alternative available and suitable to be used in shipping. Furthermore, the development of LNG propulsion technologies should also be considered by the European maritime carriers as a tool for the construction and improvement of their international competitiveness. It is especially important in the context of expected further tightening of international regulations concerning the reduction of greenhouse gasses and other exhaust pollutants which will be gradually implemented as of 2020 for all the seas.

The priority actions that must be taken are:

- creation of infrastructure for supply, distribution and bunkering of alternative fuels, mainly LNG;
- the creation of uniform technical standards and norm for fuels and technologies;
- the action on creation of trust and social acceptance (consumers);
- promoting the development of scientific programs, research and development institutes, experimental centers[4].

The report states that the costs of creating the basic Community infrastructure for LNG bunkering in seaports will probably reach an approximate amount of 10 billion EUR. Assuming this, member states will skillfully use existing tools to support the development of transport infrastructure, direct funding by these countries will not be necessary.

At the same time member states should prepare for the intensification of political action and the use of indirect support tools (non-financial) in the areas of: licenses, permits, warranties, research and development, transportation charges, fees and taxes[5].

2 COM(2013) 4 final; Clean Power for Transport...; op. cit; p. 1.
3 COM(2013) 4 final; Clean Power for Transport...; op. cit; p. 2.
4 COM(2013) 4 final; Clean Power for Transport...; op. cit; s. 8-10.
5 COM(2013) 4 final; Clean Power for Transport...; op. cit; s. 9.

2. European Union strategy to promote and use LNG in shipping

The most important document of the described package (in the presented scope) is a Commission Staff Working Document Actions towards a comprehensive EU framework on LNG for shipping[6].

This document provides strategic solutions for supporting activities that should be taken to implement the plan of introducing LNG into shipping. Above all, this document mostly refers to the issues and problems of LNG bunkering infrastructure development.

Analysis of the document shows four substantive parts to its content: These are as follows:

- identification and justification of need, costs and the benefits that should result from the introduction of LNG use into maritime transport;
- recognition of the degree of the project implementation (especially in terms of actions that should be taken by the European Union itself);
- identification of hazardous factors and delays in the implementation of the program;
- indication of the actions that have to be taken in this area in the future and establishing a timetable for their implementation.

The document states strongly that maritime transport largely, negatively affects the natural marine environment. Moreover, it affirms that the European Community should seek to significantly increase its energy security. Refraining from the use of conventional marine fuels is understood to be the primary measure to be taken in tackling such issues.

Therefore, specific, stringent requirements of environmental and economic objectives must be designated. They should help to create the conditions for improving the environmental performance and competitiveness of EU maritime transport in future. In particular, they should include:

- the reduction of greenhouse gas emissions (in particular CO2). in accordance with the provisions of the Transport White Paper, the reduction within maritime transport must reach 40% by 2050;
- the reduction of gaseous pollutant emissions negatively influencing the local marine environment and coastal belt. This applies in particular to the compounds of sulfur, nitrogen and particulate matter;
- increased energy security and the independence of the European Union through diversification of the supply of raw fuel sources.

It was recognized that in this regard, the best and most reasonable applied solution, is the use of LNG as a marine fuel. The use of LNG should allow a significant reduction of harmful combustion emissions. In particular, emissions can be reduced by:

- sulphur compounds – almost completely;
- solid particles – almost completely;
- nitrogen – 90%;
- carbon dioxide – about 20-30%[7].

6 SWD(2013) 4 final; Commission Staff Working Document Actions towards a comprehensive EU framework on LNG for shipping; Brussels; 24/01/13.

7 SWD(2013) 4 final; Commission Staff Working Document Actions towards a comprehensive...; op. cit.; p.1.

Common use of LNG in maritime transport (as well as in other transport modes) should also bring significant benefits in economic terms. Average prices of this fuel in the European Union are 300 - 400 Euro/1tonne. Therefore, in the context of LNG prices the prices of other marine fuels should be considered as much higher. In the case of MGO the average price reaches 480 Euro/1tonne. In contrast, the purchase and use of light diesel, desulphured oil in shipping, with parameters consistent to the requirements of the sulphur regulations (including SECA norms), amounts to a cost of 730 EUR/1tonne[8].

What is important, according to conducted research, is that a substantial volume of the world's supply of raw materials could be used in LNG. It creates a significant opportunity to increase the global production of alternative fuels. In the long term, this is likely to affect the reduction of the prices of LNG. It is considered that the increase in LNG demand should encourage exporting countries, including in particular the United States, Australia and Russia, to increase output. This should, as a consequence, allow these countries to benefit from the positive effects of the production scale. All of that should accelerate the trends of global supply growth and cut LNG prices.

Another issue is that global trends in the lowering of LNG prices, resulting from an increased demand and an increase in supply, should not be wrongly associated with the continually observed increases in the prices of conventional fossil fuels that are currently in use[9].

In addition, it is considered that the requirement followed by the transformation of European maritime transport and the widespread use of LNG should significantly stimulate economic growth.

All of these issues show the significant benefits and positive effects that may be gained from the use of LNG as a marine fuel.

However, in this context a number of very important questions may be raised: what are the costs of the this change? In accordance with research results, the, costs, that the European Union's economy will have to bear in this respect are not, when taking into account the associated benefits, significantly high. The second question is: what are the costs that the shipping companies will have to bare? In reply it is estimated that the prices of new vessels (LNG fuel use) should not differ significantly from the current prices of the new, currently built conventionally powered ships. In the case of ships that are already in operation and thus undergo modification, working under the assumption that the amount of freight will remain the same, a return on investment is estimated in up to 2-4 years[10].

A significant drawback, other than the costs of modernization, will result from the need to reduce the loading capacity of the ships. This results from the fact LNG fuel requires an increase in the capacity of the fuel tanks.

Nevertheless, those ship-owners who first decide to carry out upgrading or invest in new ships will be able to discount the significant economic benefits resulting from a competitive advantage over other ship-owners.

8 SWD(2013) 4 final; Commission Staff Working Document Actions towards a comprehensive...; op. cit.; p. 2-4.

9 SWD(2013) 4 final; Commission Staff Working Document Actions towards a comprehensive...; op. cit.; p. 3.

10 Danish Maritime Authority, Trans-European Network (TEN-T) Program; North European LNG Infrastructure Project; Copenhagen; March 2013; Appendix 3.

More importantly, the implementation of the infrastructure development program of LNG bunkering in ports will be expensive and technically complex. It is estimated that the cost of investment in infrastructure, respectively, will amount up to 10 billion EUR in the ports of TEN-T network and approximately 15 billion EUR in the case of smaller sea ports and terminals[11].

It should be emphasized that in order to create a spatially fulfilled and coherent LNG supply network for marine vessels it will be necessary to shape and construct the composition of large import-bunker terminals and medium and small bunker terminals. In the case of large terminals located in the major ports, there is the need for investment in infrastructure in order to allow for the unloading and storage of LNG. In addition, it must be expected that many ports require the construction of a very expensive transport infrastructure necessary to transmit LNG in inner port transport processes.

However, it must be assumed that in medium and small size ports or separated terminals it will be necessary to implement systems based on the use of mobile equipment: lorry road tankers and bunker ships.

The most important factor in this regard is that the development of LNG infrastructure in ports is currently only in its initial phase.

Crucially highlighted in this document is the conclusion that the necessary activities of the European Union in the field of development of appropriate legal standards and the defining directions of the expected port infrastructure development, and thus also the conduct and financial support of development programs in seaports are significantly delayed.

At the same time, it is considered that only the European Union's unambiguous definition of such rules will create the necessary impetus for effective implementation and fulfillment of the provisions and requirements of the sulphur regulation.

The implementation of investment projects in LNG import infrastructure in accordance with the provisions of the proposed directive, setting out guidelines and principles for the development of infrastructure of an alternative fuel supply, must be at least in the initial phase subordinated within the framework of a common European alternative fuels infrastructure development program.

The strategic problem is that the directive will be concerned with the realization of fundamental investment projects (in the field of import and LNG bunkering in TEN-T ports). The development of LNG infrastructure in large seaports will be a crucial factor when planning and constructing the entire supplementary system. It must be considered as a key factor for smaller ports authorities, suppliers and distributors of LNG and shipping companies in shaping and initiating business plans and possible investment activities.

Therefore, a clear definition of the rules and directions of development of EU policy in this area, covered by legislation in the form of the relevant directives, is fundamental and necessary.

The new legislation must relate to:

- shape and structure of the planned, promoted and financially supported LNG infrastructure system;
- scope of assistance, including norms and rules for financial aid;

[11] SWD(2013) 4 final; Commission Staff Working Document Actions towards a comprehensive...; op. cit.; p. 12.

- technical norms and regulations;
- legal standards of safety[12].

3. Development of alternative fuels infrastructure

Development of fuel supply infrastructure is a crucial element of the European strategy for alternative transport fuels. As a result, the most important document relating to this issue presented in the dossier analyzed is a proposal for a Directive on the development of alternative fuels infrastructure[13].

Although the document presented does not relate directly and exclusively to the issue of the maritime transport and seaport alternative fuels infrastructure, it must treated as fundamental. This results firstly from the fact that it will be treated as a guideline for future development of all alternative fuels used within EU transport (land transport and waterborne transport). Moreover the proposed directive combines the issues raised in the previously discussed documents. As such, from a logical point of view, it should be treated as an interpretation of the law, which will in future be in force in this regard.

The proposal of the new directive is accompanied by a document containing the results of research on the impact of the above proposal entitle: "Impact Assessment of Directive (Proposal) on alternative fuels infrastructure development"[14]. The proposal for a directive includes a description and analysis of the extent of the measures that are going to be taken, both at Community level and subsequently by individual member states, to create or help to develop the supply infrastructure for alternative fuels for all transport modes across the European Union.

The statement affirms that only the appropriate formation of such an alternative fuels infrastructure will enable the possibility of achieving the objectives of the European Strategy of Alternative Fuels for transport in the future and is the most important provision of this document. At the same time it is also a condition for full social acceptance of the planned measure[15].

In the introduction to the proposal for a directive, as well as in the previously cited strategies, types of alternative fuels, which should be considered as possible alternatives were described. It is considered that the implementation of the new strategy for alternative transport fuels, including any of its elements - the creation of a distribution infrastructure for alternative fuels - should be focused on infrastructure for car refueling and, of particular important for the topic at hand, maritime and inland waterborne transport.

Moreover the contents of the document stress, that future development of alternative fuels, especially LNG infrastructure for heavy road vehicles and shipping, should be coop-

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12 SWD(2013) 4 final; Commission Staff Working Document Actions towards a comprehensive...; op. cit.; p. 2-5.

13 COM(2013) 18 final; Proposal for a Directive on the deployment of alternative fuels infrastructure; Brussels; 24/01/2013.

14 SWD(2013) 6 final; Commission Staff Working Document of the Impact Assessment of the Proposal for a Directive on the deployment of alternative fuels infrastructure; Brussels; 24/01/2013.

15 COM(2013) 18 final; Proposal for a Directive...; op. cit.; p. 2.

erative and spatially coherent. The development programs should be focused on filling the transport network on the main transport routes[16].

A key element of the proposal for a Directive are records concerned with the obligations of public authorities of the Member States. In Article 3 of the proposed directive it is established that all member states are obligated to create and propose national programs of development of transport infrastructure for alternative fuels. They should obligatorily include inter alia:

- the creation of national development programs of supply infrastructure
- of alternative fuels for transport;
- assessment of the possibilities, needs and requirements of shaping the development of infrastructure;
- assessment of the impact of EU and national development programs;
- the scope of regulations necessary to support the infrastructure development;
- the creation of a set of policy tools aimed at the implementation of national policies for the development of green transport;
- the scheme of support programs creation in the field of research, technology and development;
- assessment of needs and opportunities for infrastructure development of LNG fuel bunkering for ships in ports placed beyond the TEN-T corridors. In particular, the creation of legal conditions for non-transport ship bunkering: passenger, off-shore, fishing and recreation ports;
- defining the principles of international cooperation;
- defining the principles needed for cross-border coordination of national programs[17].

One of the most essential issues in this discussion is – in accordance with the proposal of the Directive – the necessity to include information about the types of alternative fuels in the national programs of development of alternative fuels infrastructure. Those types are covered by each program and the basic infrastructure network, which would be developed within such a program. nevertheless, only the enlisted fuels and investments, covered by the national programs of infrastructure development, could be taken into consideration and supported in the national and EU public programs of development of alternative fuels infrastructure[18].

What is of key significance for the analyses in relation to the main subject of the present research is, pursuant to the proposal of the Directive, an obligation taken by the member countries to ensure access to the wharf systems of providing the ships with electric energy until 31st December 2015. This refers to all the quays in maritime and river ports[19]. A similar regulation refers to the obligation to provide access to LNG bunker infrastructure. The member countries should ensure public (unlimited) access to LNG bunker facilities in all the ports (including river and maritime ones) included in TEN-T network until 31st December 2020[20].

16 COM(2013) 18 final; Proposal for a Directive...; op. cit.; Paragraphs 21 i 23; p. 10-11.

17 COM(2013) 18 final; Proposal for a Directive...; op. cit.; Article 3.1.; p. 13.

18 COM(2013) 1COM(2013) 18 final; Proposal for a Directive...; op. cit.; Article 4.5.; s. 13.8 final; Proposal for a Directive...; op. cit.; Article 3.2., 3.3., 3.4.,3.5., 3.6.; p. 13.

19 COM(2013) 18 final; Proposal for a Directive...; op. cit.; Article 4.5.; p. 13.

20 COM(2013) 18 final; Proposal for a Directive...; op. cit.; Article 6.1.; p. 14.

In the above mentioned document assessing the influence of the Directive proposal's implementation, the European Commission presents results of the analyses referring to the effects of choosing one of the four analyzed variants. An explicit assessment of this document is rather difficult, since it is of a general character – it presents solely ultimate conclusions and a comparison of particular variants. However, it is important that as a general conclusion option number three is recommended. This option is formulated in the following way: 'The European Union will present the member countries a set of requirements with respect to the infrastructure of transport alternative fuels. This set will include the criteria (technical ones – author's footnote) and requirements in the field of minimal spatial coverage with infrastructure, including the related goals with respect to the most anticipated fuel technologies. Electric energy and LNG will be preferred for maritime and inland shipping, whereas hydrogen fuels, LNG and CNG – for road transport[21].'

4. Evaluation of Directive on alternative fuels development (proposal)

In March 2014, after stormy discussions in EU political circles and consultancies, as a result of the motions filed by interested economic organizations and taking into account the effects of simulations and scientific research, the European Council and European Parliament reached a consensus as regards the most important solutions which were covered by the Directive concerned. Up to this day (August 2014), the Directive is yet to be published. Nevertheless, on the basis of the above quoted proposal of the Directive and an official press publication issued by EC Press Office conclusions made be made about its final shape[22]. First and foremost, the justification regarding the content and solutions of the future Directive is quite interesting. At present, both the condition and development of the technologies are not sufficient, and self-acting, (driven by free market forces) rapid development is most likely impossible. As a result the general conclusion is that changes in the development and implementation of alternative fuels' technology used in transport require initiation by the EU.

The means of transport using alternative fuels are not commonly applied. They also lack a respectively high demand, which could encourage producers to intensify research works, to introduce new technical solutions and to commence mass production of such fleet. For the main part, this results from the lack of fuel infrastructure. Another key issue is the lack of appropriate regulations referring to the quality parameters of fuels, technical standards in the field of infrastructure and regulations, comprehensive, coherent safety requirements concerning the parameters and principles of the fleet operation as well as distribution of alternative fuels. However, the absence of infrastructure for the distribution of alternative fuels' and its lack of development are caused by the absence of demand for such fuels, as mentioned above.

21 SWD(2013) 6 final; Commission Staff Working Document of the Impact Assessment of the Proposal for a Directive...; op. cit.; Articles 26 i 36; p. 6-8.

22 Press Office; Council of the European Union; Clean fuel infrastructure agreed by the Council and the European Parliament; Brussels; 26/03/2014.

The issue of a relationship between the member countries and the European Community itself should be considered in a similar context. The member countries do not make plans of infrastructure development, because the EU lacks directives in this respect. First and foremost, this refers to the issue of the appropriate saturation of the space with infrastructure, internal, international spatial coordination in the development of the national systems, absence of uniform technical standards regarding its creation and operation, and finally, absence of the principles of supporting the development by means of public financial and non-financial instruments. Despite this, the European Union itself declared to a certain extent that it will act only as a coordinator in the field of providing spatial coherence among the national systems. What is considerable, when discussing the present situation, is that the publication clearly uses the blunt expression: 'a vicious circle'[23].

Therefore, it is generally accepted and it has been strongly emphasized that the most important initiatives of the European Union should undertake, and this should be reflected in the future Directive, to commence intensive development of the infrastructure of supply and distribution of alternative fuels for transport purposes as well as the creation of standards and technical parameters enabling the safe, coherent, inter-operational functioning of such systems. Only those administrative-legislative actions which, pursuant to a logical justification, may be undertaken by the administration at the EU level, will cause the development of commercial investments, production, markets and supplies in the sphere of real economy to commence.

In connection with the above presented issues it is now generally known that the proposals of the future Directive will be considered fundamental. Each member country will be obligated to create and introduce the national policy of alternative fuels' development for transport purposes. In every country the framework of such policy must cover, in the first instance, the national strategic goals in the field of spatial layout of the facilities providing and distributing alternative fuels. In this respect, the appropriate principles concerning the support of the development of such infrastructural facilities should be determined. Each member country will have to prepare such plans of development and make them available to the European Commission within two years' time from the date of the Directive coming into force. Based on the national framework of the alternative fuels' development policy for transport purposes, the European Commission will produce a coordinated, long-term program of safety and support for private and public investments in the field of the fleet, production and distribution of alternative fuels as well as development of the fuels' distribution infrastructure throughout the European Union[24].

At the same time, in order to supplement the general solutions, the future Directive will contain detailed solutions regarding minimal saturation with the fuels' distribution infrastructure and the time of creation and implementation of such plans. With respect to maritime transport each member country will be obliged to do the following:

- ensure access to the wharf systems of electric energy supply as regards electric energy supply for the vessels until the end of 2025. This infrastructure should be installed in all the ports covered by the TEN-T network and other maritime and river ports;

[23] Press Office; Council of the European Union; Clean fuel infrastructure agreed...; op. cit.; p. 2.

[24] Own studies, based on: Press Office; Council of the European Union; Clean fuel infrastructure agreed...; op. cit.; p. 2-4.

- in the case of liquid natural gas (LNG) for vessels – the fleet of water transport driven with LNG should be provided under the condition of unlimited movement (the possibility to bunker LNG – author's footnote) between all the maritime ports covered by the basic TEN-T network until the end of 2025, including LNG bunkering until the end of 2030 in the case of river ports covered by the basic TEN-T network[25].

5. Conclusions, evaluation and discussion

The Directive of the European Union no 2012/33/EC of 21st November 2012, referred to as Anti-Sulphuric Directive II, sets forth the requirements concerning sulphur content in marine fuels applied in the marine waters surrounding the European Union. The Baltic Sea and Northern Sea were designated as areas of increased restrictiveness of the provisions of this Directive. On one hand, the Directive supplements IMO regulations whilst simultaneously fulfilling the obligations accepted by the European Union. On the other hand, it constitutes a logical element of a widely understood policy of protection of the natural environment. Its shape and character require, however, that it be treated as a component of the power engineering policy, internalization of transport external effects, construction of a balanced and energy-saving economy.

The Anti-Sulphur II Directive does not describe clearly the technologies that should be applied in order to reduce the content of sulphur in marine fuels. It only indicates that these technologies may rely on the application of light diesel oil distillers, alternative fuels or usage of fume filtering devices mounted on board the vessels using traditional fuels.

Before the Directive was adopted it was obvious that its implementation would carry serious consequences, first of all, changing the applied solutions in marine engineering. Logically, the other component of the system changes which should take place is adjustment of the maritime ports to serve the technologically modified vessels. This refers to two principal issues, namely, assurance of access to low-sulphur fuels which will be bunkered to the ships and collection of the ship's waste as generated by scrubbers.

The above argument in conjunction with logical reasoning indicate that the changes, which will have to take place in the technique and technology of maritime transport (in both maritime transport and the port industry), are of revolutionary character and scale. It should be emphasized that time is a considerably significant factor. The widely comprehended changes in the applied marine fuels will have to take place within the space of a few years. Therefore, prior to when the Anti-Sulphur Directive came into force, the European Union began to take action aimed at helping the real EU maritime industry as soon as possible, without redundant economic losses and the weakening of competitiveness, in order to help to over come the difficult time of transformation. During the years of 1999–2012 the European Union presented a series of documents and official instruments which may generate some conclusions about the shape of the system solutions which will

[25] Own studies, based on: Press Office; Council of the European Union; Clean fuel infrastructure agreed...; op. cit.; p. 3.

be accepted for implementation of the Anti-Sulphur Directive and IMO regulations as regards restrictions on sulphur emissions from vessels.

Pursuant to logical thinking and theoretical justification for running a policy of external effects internalization, the European Union pointed out that the cost of ship modifications or the purchase of a new fleet must be treated as part of the normal costs of economic activity. As such they should be borne by the ship-owners. However, the issue of the structural cost of the technological transformations, which will have to be incurred in maritime ports as a consequence of investing funds in bunker infrastructure and the electrical ship power supply infrastructure from the land is understood otherwise.

The theoretical, economic, geopolitical and, first and foremost, environmental justifications indicate that the best solution in the field of energy carriers generally known in the contemporary world should be the application of LNG on board the sea-going ships as a low-sulphur fuel during navigation and the application of electrical energy while ships are docked in port. Therefore, the European Union was explicitly in favor of the application of this type of fuel and future aid initiatives will refer to the promotion, development and support of these technologies. This is confirmed by the documents analyzed.

In accordance with the theoretical justification it has been accepted that the maritime port infrastructure is mainly the key component in the system changes, the designer and creator of which was the European Union. The other component must be legally sanctioned technical standards and principles referring to the following issues :

- quality parameters of low-sulphur fuels;
- technical parameters of the ships using low-sulphur fuels,
- technical parameters of the infrastructure and equipment used when unloading the low-sulphur fuels in the maritime ports;
- the storage, transport and bunkering of these fuels;
- uniform, international principles and technical standards also in the field of education and the acquirement of the necessary personal qualifications ensuring safety during all the technological processes related to the application of low-sulphur carriers of energy.

Formation and development of the EU spatially coherent system of LNG bunker infrastructure will rely on programs which will have to be elaborated by particular member countries within their obligations. Only then will the national programs be coordinated at Community level. In the case of maritime ports the national programs will have to include those ports which belong to the EU program of TEN-T network development (transport channels). It is worth mentioning that in this respect the key regulation should impose the obligation to ensure access to the LNG bunker infrastructure and the provision of electric energy in maritime ports of the EU member countries. The infrastructural projects referring to the above must be completed by the end of 2025.

Further to the information included in one of the above quoted documents (Comprehensive Framework of UE Action in favor of Application of LNG in Shipping) the European Commission puts in place international initiatives in favor of creating and introducing the standards and principles in the field of supplies, storage, delivery, bunkering and application of LNG in shipping. Such cooperation is already taking place within the Emergency Medical Services Authority (EMSA), International Organization for Standardization (ISO) and International Maritime Organization (IMO). According to the declarations the works should be completed by the end of 2014[26].

In compliance with the documents analyzed the implementation of the obligation to develop LNG bunker infrastructure by the member countries could be financed from public funds. At the same time the European Union could participate financially in such projects within the already existing instruments supporting the development of transport infrastructure.

To end the analysis it seems desirable to make at least a general assessment of the actions conducted by the European Union. The first and most fundamental issue is the fact that all the initiatives presented constitute an element of widely comprehended policy which strive for the formation of pro-ecological, balanced transport solutions. In this respect, the European Union is regarded as a world-wide leader, almost a propagator of global solutions. Taking into account the civilized approach, as understood within a European mentality, to the issue of protection of the Earth natural environment, all the actions undertaken must be considered justifiable. This opinion appears to be right irrespective of the future financial costs that will have to be incurred, abatement of competitiveness of the European maritime transport and the entire EU economy, and, finally, irrespective of the opinions which may adversely refer to particular partially initiatives.

The opinions which negatively assess the actions undertaken by the EU in the analyzed scope should be regarded more or less justifiable. Fundamentally, one may either partially agree with them or discredit them. They are frequently based on weak grounds as far as the merits are concerned; they are often formulated by branch business groups and as such they should often be regarded as saturated with particularism.

As a result of the analyses conducted and simple logical thinking, one may come to the frustrating conclusion that seemingly all the EU initiatives, regardless of their shape, appear far too late. In 1999 the first Anti-Sulphur Directive introduced certain restrictions. Already then it was generally known that the introduction of more restrictive standards is only a matter of time. Nevertheless, (in August 2014) even the most fundamental system solutions were not proposed as regards creating appropriate conditions for the implementation of the 2012 Anti-Sulphur Directive. In consequence therefore, on 1st January 2015, theoretically, no vessel using conventional fuels will be able to operate on the Baltic Sea and Northern Sea, and the navigation of the ships generating non-sulphated fumes will not be possible either. The only available alternative is that of very expensive, desulphurized light marine diesel oils.

To conclude, it should be emphasized that although the European Union undertakes preparatory actions to implement the Anti-Sulphur Directive II, which should be positively assessed, the fact remains that neither the European Union nor particular member countries are prepared to comply with the EU regulations. As a result, the entire maritime branch, deprived as it is of any adequate legal frames, unable to take advantage of appropriate port infrastructure and to create a coherent system of infrastructure to provide ships with alternative fuels and no comprehensive system of technical standards at its disposal, is also not ready to accept the changes imposed by the Directive.

26 SWD(2013) 4 final; Commission Staff Working Document Actions towards...; op.cit; p. 4-5.

The maritime ports lack the appropriate infrastructure. In SECA areas the bunker terminals operate only in Norway and Stockholm (and it should be remembered that Norway is not EU member state). There are no LNG import terminals and LNG bunker terminals, many ports lack waste collection systems generated by ship scrubbers and, finally, the wharf electric installations lack parameters allowing ships to be provided with energy. The member countries will create the spatial plans of LNG infrastructure development in the future (including maritime ports) and at the same time only those plans are to become the grounds for planning a comprehensive, coherent system in the entire European Union.

Thus far the legal standards governing the technical aspects of the supply, storage and bunkering of alternative fuels are yet to be made public. According to the declarations they are due to be completed by the end of 2014. Therefore, this only serves to confirm the notion that such EU initiatives, including principal, legislative regulations, are undergoing delays,. How can a real sphere of economy be ready to introduce regulations, which although they do not exist, should be in force within a few months' time?

To sum up, two issues, seemingly of lower significance, but equally important in reality should be emphasized. Both IMO documents (Annex VI to MARPOL 73/78 Convention) and the EU regulations (Anti-Sulphur Directive) allow for the application of scrubbers as an alternative method. In case of their usage, liquid pollution containing sulphur appears. In compliance with the Directive number 2000/59/EC on port devices collecting waste produced by the ships and remains of the loads[27], the member countries are obliged to ensure the presence of appropriate devices (infrastructure) to collect waste generated by the ships. This also refers to waste collection from the ship's scrubbers. In the meantime, the analyzed documents referring to the EU vision of Anti-Sulphur Directive II implementation provide no reference to these issues. In many maritime ports such infrastructure is simply missing and this fact refers mostly to small ports ad maritime havens. Another issue is the lack of legal solutions regarding technical parameters with which the devices should comply and similarly, in the case of LNG bunkering, the standards and legal regulations setting forth the principles of waste collection and uniform technical parameters of such waste collecting devices.[28] The analysis of the proposed system of solutions relies on the assumption that LNG will be a commonly used and promoted fuel. The presented documents, however, refer mainly to spatial formation of the bunker infrastructure and the principles concerning the support of financial development of such projects in big maritime ports. Whilst one of these documents mentions that operation of a spatially coherent network of LNG provision conditions the effective functioning of the maritime industry (and what is more important, not only shipping). The LNG provision network has to cover, which is logical and has been discussed in the documents analyzed, both big and small ports. The likelihood that in small ports the provision and bunkering will take place by means of mobile transport solutions is also referred to (road cisterns or bunkering boats). The documents presented do not refer to the problem concerning how the system elements of this type should develop. Therefore, the question arises as to whether the EU politicians can see any possibilities to support such elements of LNG provision and

27 Directive 2000/59/EC of 27 November 2000 on port reception facilities for ship-generated waste and cargo residues; Brussels 2000.

28 Berau Veritas – Marine and Offshore Division; Exhaust Scrubbers; Neuilly-sur-Seine; 03/2014.

bunkering systems? The documents analyzed do not mention the principles, planning or support of development of the LNG ship bunkering systems in small maritime ports. It may be concluded that they will develop automatically and will become a domain of the commercial capital. As a result, a fundamental concern may be raised, namely how will the situation of small maritime ports be affected if the commercial capital is not interested in investing and implementing such projects?

The final conclusion is as follows – the European Union undertakes political and legislative initiatives, which aim to limit the negative consequences of the introduction of restrictive standards as regards the content of sulphur in marine fuels. The solutions should be assessed positively. These initiatives, however, are significantly delayed and in many cases also ambiguous and at least partially incoherent.

Summary

The sum up of the work presented herein is only the beginning. The decision to present for discussion the problem of the Sulphur Regulation was motivated by the uncertain market reaction, varying points of view, the scale of the potential market impact, the vast number of solutions and a distinct lack of debate on both an EU and international scale.

The aim of this work was to show in a condensed form the most important solutions and aspects of the sulphur limits problem on a technical and economical level.

The Sulphur Regulation is the result of a common trend to reduce the negative impact of transport, in this case maritime, on the environment. However it is not the final measure. Consultations and an evaluation of the implementations of previous sulphur limits in SECA zones are due to be carried out in 2018 with the view to the legislation being put into practice globally in 2020 or 2025, depending on results of the evaluation.

It is our intention as authors that the monograph be treated as a voice in the discussion and an analysis of the overview of the possible consequences of the act.

By undertaking this analysis *ex ante* our intention was also to begin preparations for further *ex post* analysis following the specific period of validity of the Regulation. By way of an introduction to such analysis, listed below are some threats and opportunities, which may arise as of 2015 for the shipping industry.

The following are some of the most important threats:

- An increase in direct costs, which causes more expensive ferry transits for trucks and lorries,
- Reduction of a number of ro-ro and ferry services with an associated decrease in competitiveness of the ferry services market (clogging of some routes, dissolution of shipping companies, etc.),
- Unreliability in the prediction of future marine fuel prices (both, LSHFO and MGO),
- Unreliability in the prediction of future freight and tariffs rates (due to a huge number of diverse indicators influencing the market), which lead to unreliable cost calculations of intermodal, sea-land transport chains, especially in a long-term perspective,
- A likely increase in the price of MGO due to the rapid growth of demand from day to day and constant refineries capacity (sharing the same volume of diesel oil production with land transport – MGO and gasoil for trucks),
- Danger of the dissolution of some running contracts (in cases of lower penalties payment in comparison to further losses by the operator),

- Loss of some part of the transportation market in favor of land transport (in specific conditions a possible cargo “back shift”)
- Danger of loss of some cargo for transport due to production shifting to other low staff cost countries, also connected with the increase of maritime transport costs in the final price of the product,
- Insufficient awareness by stakeholders, forwarders and customers concerning the scope of danger and, therefore, lack of acceptance for transport costs increasing and effecting the final price of the product (and looking for other markets, producers),
- Danger of general rerouting of some intermodal relations and services,
- Necessity of recalculation of all contracts for transportation extending to 2015 and beyond, especially after 1/01/2015, when the new market condition will appear,
- Destabilization of the whole transport & logistics market at the beginning of 2015 due to uncertainty,

And to the most important opportunities belong:

- Cargo back-shift to the road or rail transport from maritime shipping,
- New tendering procedures concerning new market conditions, or recalculation and renegotiations of current contracts.
- Intermodal transport will gain in importance.
- Potential rerouting of the cargo flows – favoring the aspirations of South Europe corridors and Adriatic sea ports (not affected by the Sulphur Regulation).
- Verification of current relations and logistics chains – need for revision of transit time due to obligatory driver’s rest time and working time, adoption of regulations by local drivers and companies – all for improving the efficiency of the delivery process.
- Verification of road transport companies of small truckers operating on marginal costs and, in some cases, their closure.
- Expected extended awareness of a forwarder and customer concerning the causes of price increases.
- Advantage of companies with flexible contracts, foreseable changes in rates due to reasonable reasons.

The above is not part of a SWOT analysis, but a summary of what we expect and fear as a result of the Sulphur Regulation.

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Appendix
Working table with Baltic liner shipping per-formance and marine fuel consumption

Operator	Ship's name	Yearly disstance	Av. time at sea		Main Engine Power		LSHFO consumption		MGO consumption	
			full ahead	real measured	by 100%	real measured	by 100%	real measured	by 100%	real measured
		[NM]	[h/year]	[h/year]	[kW]	[kW]	[mt/year]	[mt/year]	[mt/year]	[mt/year]
BALTIC LINER CONTAINER SHIPPING										
APL	Akacia	36 400	1 968	2 889	8 400	5 721	3 074	2 744	3 041	2 711
CMA CGM	Jonni Ritscher	52 000	2 476	3 059	16 980	13 746	7 821	7 232	7 736	7 148
	Rijnborg	52 000	2 476	3 741	15 000	9 929	6 909	6 129	6 834	6 054
	Christopher	52 000	2 694	4 228	11 060	7 049	5 543	4 857	5 483	4 798
	Alsterdijk	52 000	2 600	3 490	14 520	10 817	7 022	6 380	6 946	6 305
	Charlotta B	28 600	1 546	1 634	11 200	10 595	3 221	3 134	3 186	3 099
	Mito Strait	31 200	1 576	2 516	9 730	6 094	2 852	2 499	2 821	2 468
	ER Riga	52 000	2 737	4 370	9 960	6 238	5 070	4 443	5 016	4 389
	ER Visby	52 000	2 737	4 483	9 960	6 081	5 070	4 416	5 016	4 361
	Perseus J	52 000	2 694	3 741	9 600	6 914	4 811	4 345	4 759	4 294
	Pictor J	52 000	2 694	4 031	9 600	6 417	4 811	4 268	4 759	4 216
	Tongan	57 200	2 964	4 333	9 600	6 566	5 292	4 723	5 235	4 666
	Fenja	52 000	2 694	3 969	8 400	5 702	4 210	3 757	4 164	3 712
	Page Akia	52 000	2 694	3 399	8 400	6 659	4 210	3 870	4 164	3 825
	Wega	62 400	2 889	4 078	9 300	6 588	4 997	4 487	4 943	4 433
Containerships	Conatinerships VI	65 000	3 140	3 714	12 600	10 652	7 359	6 884	7 280	6 805
	Containerships VII	65 000	3 250	3 714	12 600	11 025	7 617	7 207	7 535	7 125

	Aila	65 000	3 672	6 075	8 400	5 078	5 738	4 997	5 676	4 936
	Linda	65 000	3 672	4 012	8 400	7 688	5 738	5 522	5 676	5 460
	Containerships VIII	65 000	3 250	3 514	12 600	11 655	7 617	7 330	7 535	7 248
	Jork Ranger	65 000	3 514	4 362	8 400	6 765	5 490	5 076	5 430	5 017
	Jork Ruler	65 000	3 514	4 577	8 400	6 448	5 490	5 017	5 430	4 958
	Sleipner	65 000	3 514	4 362	8 400	6 765	5 490	5 076	5 430	5 017
	Vohburg	65 000	3 514	4 088	8 400	7 219	5 490	5 165	5 430	5 106
Eimskip	Dettifoss	83 200	4 160	5 859	14 800	10 508	11 452	10 282	11 329	10 159
	Godafoss	83 200	4 160	5 073	14 800	12 136	11 452	10 651	11 329	10 528
Green Alliance	Norderoog	54 000	2 842	3 699	13 560	10 420	7 168	6 552	7 091	6 475
	Hooge	54 000	2 842	3 576	13 560	10 777	7 168	6 590	7 091	6 513
	Evolution	54 000	2 842	3 857	10 560	7 781	5 582	5 042	5 522	4 982
Hacklin Seatrans	Ragna	67 600	4 361	4 829	3 825	3 455	3 103	2 969	3 069	2 936
Hapagg-Lloyd	Emotion	39 000	1 970	2 167	12 640	11 491	4 631	4 432	4 581	4 382
	Empire	39 000	2 021	2 868	11 060	7 794	4 157	3 732	4 112	3 688
	Aalderdijk	39 000	1 950	2 635	14 520	10 745	5 266	4 785	5 210	4 728
	Amerdijk	39 000	1 950	2 635	14 520	10 745	5 266	4 785	5 210	4 728
	Thetis D	39 000	2 053	2 422	11 200	9 491	4 276	4 000	4 230	3 954
	Warnow Vaquita	31 200	1 642	2 197	9 600	7 175	2 932	2 664	2 901	2 633
	Astrorunner	39 000	2 167	2 727	7 999	6 355	3 224	2 964	3 189	2 929
	Jessica B	31 200	1 642	2 476	6 600	4 377	2 016	1 788	1 994	1 767
K-Line	Conmar Fjord	88 400	4 911	6 406	7 200	5 520	6 577	6 011	6 506	5 940
	Conmar Hawk	88 400	4 911	6 182	7 200	5 720	6 577	6 047	6 506	5 976
Mac Andrews	Enforcer	67 600	3 756	5 828	7 200	4 640	5 029	4 435	4 975	4 380
	Flintercrown	67 600	3 654	4 934	8 400	6 221	5 709	5 187	5 648	5 126
	Maris	78 000	5 032	6 047	3 825	3 183	3 580	3 349	3 542	3 311
Maersk Line	Annabella S	39 000	2 108	3 305	8 400	5 358	3 294	2 886	3 258	2 851

	Anna Sirkka	39 000	2 108	3 391	8 400	5 222	3 294	2 869	3 258	2 833
	Helmut	39 000	2 108	3 645	8 400	4 858	3 294	2 851	3 258	2 816
	Neuenfelde	39 000	2 108	3 071	8 400	5 766	3 294	2 940	3 258	2 904
Mann Lines	Laura Ann	31 200	1 686	2 419	8 400	5 857	2 635	2 352	2 607	2 323
	Anke Ehler	52 000	3 059	3 910	5 760	4 506	3 277	3 013	3 242	2 978
MSC	HS Humboldt	57 200	2 487	3 739	41 130	27 360	19 026	16 878	18 821	16 673
	MSC Paola	57 200	2 434	3 643	28 800	19 241	13 039	11 567	12 898	11 426
	MSC Sabrina	78 000	3 237	4 588	22 140	15 617	13 328	11 967	13 185	11 823
	MSC Atlantic	51 000	2 372	3 355	21 700	15 341	9 574	8 596	9 471	8 493
	MSC Mandy	78 000	3 714	4 084	21 700	19 737	14 992	14 347	14 830	14 186
	MSC Joy	51 000	2 656	3 188	16 260	13 550	8 033	7 515	7 947	7 429
	Helle Ritscher	52 000	2 476	3 399	16 980	12 371	7 821	7 064	7 736	6 980
	Valentina	57 200	2 724	4 115	16 980	11 239	8 603	7 631	8 510	7 539
	John Rickmers	57 200	2 487	4 301	21 600	12 490	9 992	8 649	9 884	8 541
	MSC Eyra	52 000	2 600	3 355	15 660	12 137	7 573	6 922	7 492	6 840
	MSC Iris	62 400	3 120	4 105	15 660	11 902	9 088	8 306	8 990	8 208
	MSC Lieselotte	51 000	2 550	3 750	15 660	10 649	7 428	6 629	7 348	6 549
	MSC Malin	51 000	2 550	3 517	15 887	11 518	7 535	6 806	7 454	6 725
	Langeness	46 800	2 463	3 000	13 560	11 133	6 212	5 778	6 146	5 711
	Heluan	46 800	2 463	3 228	13 560	10 348	6 212	5 678	6 146	5 611
	Sandy Rickmers	46 800	2 127	3 367	17 700	11 183	7 003	6 137	6 928	6 062
	Hanse Courage	46 800	2 600	3 250	7 902	6 322	3 821	3 534	3 780	3 493
OOCL	OOCL Rauma	54 000	2 769	4 000	11 200	7 754	5 769	5 180	5 707	5 118
	Navi Baltic	54 000	2 842	3 750	11 200	8 488	5 921	5 380	5 857	5 316
	Sonderborg Strait	64 800	3 503	4 263	9 960	8 183	6 489	6 035	6 419	5 966
	Nordic Philip	64 800	3 411	5 143	9 000	5 968	5 709	5 065	5 648	5 003
	Nordic Stani	64 800	3 411	5 102	9 000	6 016	5 709	5 065	5 648	5 003

Samskip	Arnafell	83 200	4 622	5 986	8 400	6 487	7 222	6 601	7 144	6 523
	Helgafell	83 200	4 622	5 299	8 400	7 327	7 222	6 833	7 144	6 756
SCA Logistics	Astrosprinter	52 000	2 889	3 939	7 999	5 866	4 298	3 882	4 252	3 836
	Flintercape	52 000	2 811	3 312	8 400	7 129	4 392	4 132	4 344	4 085
Seago Line	Bomar Victory	52 000	2 385	3 333	16 980	12 151	7 534	6 764	7 453	6 683
	Bomar Valour	52 000	2 385	3 490	16 980	11 606	7 534	6 723	7 453	6 642
	Bomar Vanquish	52 000	2 385	3 291	16 980	12 307	7 534	6 804	7 453	6 723
	Heinrich Ehler	39 000	2 053	2 690	11 200	8 547	4 276	3 908	4 230	3 862
	Petkum	39 000	2 053	2 708	13 560	10 277	5 177	4 704	5 121	4 648
	Mistral	45 900	2 481	3 531	8 400	5 903	3 876	3 480	3 835	3 439
	Ruth	45 900	2 481	2 623	8 400	7 946	3 876	3 772	3 835	3 731
	Kornett	45 900	2 378	3 531	8 400	5 658	3 716	3 296	3 676	3 256
Sea Connect	Borussia Dortmund	60 000	3 636	5 217	5 300	3 694	3 585	3 199	3 546	3 161
	Njord	60 000	3 243	4 688	6 600	4 566	3 981	3 553	3 939	3 510
	Pirita	60 000	3 529	5 000	6 600	4 659	4 333	3 890	4 286	3 844
Sun Lines	Frej (Trans Frej)	39 000	2 635	3 197	2 700	2 226	1 323	1 231	1 309	1 217
	Odin (Trans Odin)	39 000	2 635	3 391	2 700	2 098	1 323	1 210	1 309	1 195
Team Lines	Barmbek	54 000	2 700	4 000	12 640	8 532	6 348	5 631	6 280	5 563
	A La Marine	28 600	1 482	2 167	11 060	7 564	3 048	2 721	3 016	2 688
	Svendborg Strait	39 000	2 053	2 766	9 960	7 391	3 803	3 455	3 762	3 414
	Anne Sibum	39 000	2 053	2 889	9 000	6 395	3 436	3 085	3 399	3 048
	Grete Sibum	39 000	2 053	2 889	9 000	6 395	3 436	3 085	3 399	3 048
	Tina	57 200	2 964	4 028	8 400	6 180	4 631	4 182	4 581	4 133
	Freya	52 000	3 059	3 969	5 760	4 439	3 277	2 995	3 242	2 960
Transatlantic	Jork	46 800	2 530	3 162	8 400	6 720	3 952	3 655	3 910	3 612
	Robert	46 800	2 530	3 441	8 400	6 175	3 952	3 570	3 910	3 527
	Johanna	57 200	3 269	4 807	5 300	3 604	3 222	2 876	3 188	2 841

	Elisabeth	52 000	3 059	3 399	5 760	5 184	3 277	3 136	3 242	3 101
Tschudi Lines	Anke Ehler	72 800	4 282	4 853	5 760	5 082	4 588	4 341	4 539	4 292
	Antje Russ	72 800	4 282	4 986	5 760	4 947	4 588	4 317	4 539	4 267
Unifeeder	Eilbek	52 000	2 600	3 939	12 640	8 342	6 113	5 423	6 047	5 357
	Flottbek	46 800	2 340	3 120	12 640	9 480	5 501	5 028	5 442	4 969
	Adelina D	52 000	2 600	3 688	16 520	11 647	7 989	7 173	7 903	7 087
	Calisto	52 000	2 261	3 377	28 879	19 336	12 144	10 773	12 014	10 643
	Vera Rambow	39 000	2 053	3 277	11 200	7 015	4 276	3 747	4 230	3 701
	Alexander B	52 000	2 613	3 312	11 060	8 726	5 375	4 942	5 318	4 884
	Frederik	39 000	1 960	2 708	11 060	8 003	4 032	3 641	3 988	3 598
	DS Agility	20 800	1 040	1 588	9 730	6 373	1 882	1 660	1 862	1 639
	ER Tallinn	46 800	2 463	2 943	9 960	8 335	4 563	4 269	4 514	4 220
	Sainty Vogue	52 000	2 889	3 662	9 470	7 471	5 089	4 678	5 034	4 623
	Bernhard Schepers	39 000	2 229	3 047	9 600	7 022	3 979	3 594	3 937	3 551
	Conmar Avenue	52 000	2 811	3 490	9 000	7 249	4 705	4 351	4 655	4 301
	Conmar Bay	46 800	2 530	3 367	9 000	6 762	4 235	3 848	4 189	3 802
	Katharina Schepers	52 000	2 737	3 796	9 000	6 489	4 581	4 138	4 532	4 089
	Nordic Bremen	39 000	2 053	3 145	9 000	5 874	3 436	3 030	3 399	2 993
	Nordic Hamburg	52 000	2 737	3 741	9 000	6 584	4 581	4 138	4 532	4 089
	Phoenix J	52 000	2 737	3 333	9 000	7 389	4 581	4 261	4 532	4 212
	Anina	39 000	2 108	2 746	8 400	6 448	3 294	3 010	3 258	2 975
	Ida Rambow	31 200	1 733	2 690	7 900	5 091	2 547	2 246	2 520	2 218
	Aldebaran J	31 200	1 696	2 537	7 200	4 813	2 271	2 014	2 246	1 990
	Andromeda J	31 200	1 696	2 013	7 200	6 065	2 271	2 124	2 246	2 100
	Conmar Island	36 400	2 080	2 779	8 400	6 288	3 250	2 953	3 215	2 918
	Morsum	20 800	1 095	1 475	9 240	6 857	1 881	1 709	1 861	1 689
	Sylt	36 400	1 916	2 379	9 240	7 441	3 293	3 045	3 257	3 009

	Bianca Rambow	36 400	2 080	2 935	8 400	5 952	3 250	2 918	3 215	2 883
	Henneke Rambow	36 400	2 080	2 180	8 400	8 016	3 250	3 180	3 215	3 145
	Larissa	31 200	1 686	2 713	8 400	5 222	2 635	2 309	2 607	2 281
	Hanse Spirit	62 400	3 373	4 913	9 240	6 343	5 797	5 174	5 735	5 111
	Hanse Vision	62 400	3 373	4 692	9 240	6 643	5 797	5 205	5 735	5 142
	Atair J	41 600	2 261	2 849	7 200	5 713	3 028	2 784	2 995	2 751
X-press feeders	WES Amelie	72 000	3 892	6 316	9 000	5 546	6 515	5 674	6 445	5 604
	WES Carina	72 000	3 892	5 414	9 000	6 470	6 515	5 850	6 445	5 779
	Pollux	72 000	3 789	5 950	9 240	5 884	6 513	5 707	6 443	5 637
	Condor	72 000	3 789	4 706	9 240	7 441	6 513	6 023	6 443	5 953
	Marnedijk	59 800	3 518	4 124	7 200	6 141	4 711	4 432	4 660	4 382
	Vega Stockholm	59 800	3 518	4 271	7 200	5 929	4 711	4 382	4 660	4 331
	Katharina B	52 000	2 971	4 094	3 960	2 874	2 189	1 977	2 165	1 953
Total container fleet		7 185 900,0	380 253,0	512 672,1	1 487 236,0	1 097 384,7	744 118,4	675 904,0	736 117,1	667 902,7
BALTIC LINER RO-PAX SHIPPING										
Black Sea Ferry	Petersburg	54 080	3 380	5 302	10 600	6 360	6 664	5 496	6 592	5 429
Color Line	Color Magic	258 440	5 874	7 260	31 200	18 720	34 086	23 375	33 719	23 103
	Color Fantasy		5 874	7 260	31 200	18 720	34 086	23 375	33 719	23 103
	SuperSpeed 2	131 040	4 227	6 011	37 800	22 680	29 720	22 767	29 400	22 494
	SuperSpeed 1	107 744	3 476	4 327	37 800	22 680	24 436	16 880	24 174	16 683
	Color Viking	131 040	3 448	4 282	17 200	10 320	11 032	7 601	10 914	7 513
	Bohus		3 120	4 147	11 472	6 883	6 657	4 824	6 586	4 767
Destination Gotland	Gotland	210 912	2 467	2 992	50 400	30 240	23 125	15 651	22 876	15 470
	Visby		2 467	2 801	50 400	30 240	23 125	14 907	22 876	14 738
	Gotlandia		2 520	3 396	36 000	21 600	16 873	12 398	16 692	12 251
DFDS Seaways	Pearl Seaways	198 016	4 715	6 347	23 760	14 256	20 836	15 291	20 612	15 110
	Crown Seaways		4 605	5 964	23 760	14 256	20 351	14 455	20 132	14 285

	Regina Seaways	247 728	5 630	6 769	23 760	14 256	24 882	16 790	24 614	16 597
	Athena Seaways		5 898	7 038	23 760	14 256	26 067	17 457	25 786	17 257
	Optima Seaways	162 344	3 865	5 340	18 900	11 340	13 588	10 174	13 442	10 053
	Victoria Seaways		3 454	5 340	25 200	15 120	16 190	13 242	16 016	13 081
	Patria Seaways	97 968	2 881	2 969	5 280	3 168	2 830	1 721	2 799	1 702
	Kaunas Seaways		2 969	3 524	10 600	6 360	5 853	3 900	5 790	3 855
	Sirena Seaways	104 208	4 737	6 059	18 900	11 340	16 651	11 748	16 472	11 611
Eckerö Line	Finlandia	54 912	1 894	2 602	50 400	30 240	17 751	13 221	17 560	13 064
	Eckerö	44 200	2 210	3 400	12 484	7 490	5 132	4 177	5 076	4 126
Færgen	Hammerodde	71 344	3 567	4 247	8 640	5 184	5 733	3 831	5 671	3 787
	Povl Anker	17 472	874	1 099	9 173	5 504	1 491	1 034	1 474	1 022
	Lolland	99 840	3 306	4 497	1 492	895	917	676	908	668
	Langeland		3 671	4 580	4 400	2 640	3 004	2 080	2 972	2 055
	Odin Sydfyen	54 080	2 253	2 551	1 280	768	536	347	531	343
	Frigg Sydfyen		2 003	2 504	1 370	822	510	354	505	350
Finnlines	Finnstar	455 000	6 067	6 989	48 000	28 800	54 163	35 427	53 581	35 025
	Finnmaid		6 067	7 022	48 000	28 800	54 163	35 591	53 581	35 187
	Finnlady		6 067	6 832	48 000	28 800	54 163	34 826	53 581	34 432
	Finnclipper	120 640	1 371	1 817	23 040	13 824	5 875	4 245	5 812	4 194
	Finnpartner		1 371	1 676	23 040	13 824	5 875	4 007	5 812	3 961
	Finntrader		1 371	1 997	23 040	13 824	5 875	4 583	5 812	4 528
	Nordlink		1 371	2 024	48 000	28 800	12 239	9 619	12 108	9 502
	Finneagle	237 120	3 576	5 377	23 040	13 824	15 327	12 264	15 162	12 116
	Finnfellow		3 576	5 527	23 040	13 824	15 327	12 531	15 162	12 378
	Finnsailor		3 856	5 377	15 360	9 216	11 015	8 275	10 897	8 176
	Finnhansa	120 640	5 664	6 417	23 040	13 824	24 272	15 701	24 011	15 524
Fjord Line	Oslofjord	44 928	2 429	3 209	16 350	9 810	7 385	5 320	7 306	5 257

Navirail	Liverpool Seaways	33 488	1 674	2 175	15 600	9 360	4 858	3 460	4 806	3 419
Polferries	Wawel	128 440	3 380	4 281	13 020	7 812	8 185	5 719	8 097	5 652
	Baltivia		3 211	4 722	13 240	7 944	7 908	6 227	7 823	6 152
	Scandinavia	73 580	4 088	4 938	21 480	12 888	16 332	11 010	16 156	10 883
Scandlines	Deutschland	341 120	3 411	4 771	12 320	7 392	7 817	5 890	7 733	5 819
	Schleswig-Holstein		3 411	4 805	12 320	7 392	7 817	5 931	7 733	5 860
	Prinsesse Benedikte		3 688	4 980	6 490	3 894	4 452	3 277	4 404	3 238
	Prins Richard		3 688	5 016	6 490	3 894	4 452	3 282	4 404	3 243
	Holger Danske		3 591	6 498	4 420	2 652	2 952	2 757	2 920	2 723
	Tycho Brahe	94 432	1 749	2 385	9 840	5 904	3 201	2 365	3 166	2 337
	Hamlet		1 574	2 337	6 120	3 672	1 792	1 416	1 772	1 399
	Aurora af Helsingborg		1 686	2 409	9 840	5 904	3 086	2 375	3 053	2 347
	Mercandia IV		1 686	2 248	2 750	1 650	863	627	853	620
	Kronprins Frederik	179 712	4 383	6 197	22 000	13 200	17 936	13 661	17 743	13 497
	Prins Joachim		4 383	6 113	22 000	13 200	17 936	13 475	17 743	13 313
Smyril Line	Norrona	62 920	2 996	3 745	22 080	13 248	12 305	8 534	12 173	8 435
St. Peter Line	Princess Maria	53 352	2 425	4 073	22 950	13 770	10 352	9 029	10 241	8 917
	SPL Princess Anastasia	84 864	3 857	6 956	22 950	13 770	16 466	15 326	16 289	15 134
Stena Line	Stena Germanica	171 808	3 996	5 113	23 040	13 824	17 123	12 087	16 939	11 946
	Stena Scandinavica		3 818	5 238	25 920	15 552	18 407	13 686	18 209	13 523
	Stena Danica	221 000	2 763	3 635	25 743	15 446	13 227	9 544	13 085	9 432
	Stena Jutlandica		2 570	3 611	25 920	15 552	12 389	9 379	12 256	9 266
	Stena Scanrail		3 453	4 063	6 400	3 840	4 111	2 730	4 066	2 699
	Stena Saga	105 456	4 793	7 533	22 948	13 769	20 460	16 905	20 240	16 698
	Stena Nautica	70 928	3 733	4 825	12 480	7 488	8 665	6 142	8 572	6 070
	Stena Spirit	209 664	5 667	6 511	29 400	17 640	30 987	20 215	30 654	19 986
	Stena Vision		4 876	6 431	33 098	19 859	30 017	21 585	29 694	21 329

	Sassnitz	116 480	2 912	3 989	18 200	10 920	9 858	7 318	9 752	7 231
	Trelleborg		3 236	3 989	17 650	10 590	10 622	7 266	10 508	7 181
	Mecklenburg-Vorpommern	241 696	5 755	6 945	25 200	15 120	26 973	18 167	26 683	17 957
	Skane		5 755	6 985	28 960	17 376	30 998	20 999	30 665	20 756
	Ask	156 832	4 239	4 901	9 840	5 904	7 758	5 093	7 674	5 035
	Urd		4 239	5 522	8 826	5 296	6 958	4 971	6 884	4 913
	Stena Flavia	86 528	3 605	4 973	18 900	11 340	12 674	9 474	12 538	9 361
	Scottish Viking	86 320	3 597	5 832	21 600	12 960	14 450	12 245	14 295	12 094
Tallink/Silja	Silja Serenade	172 536	4 108	4 740	32 580	19 548	24 894	16 308	24 626	16 122
	Silja Symphony		4 108	6 033	32 580	19 548	24 894	19 576	24 626	19 340
	Baltic Queen	157 976	3 224	4 438	32 000	19 200	19 189	14 314	18 983	14 143
	Victoria I		3 590	5 724	26 240	15 744	17 523	14 689	17 335	14 509
	Baltic Princess	238 784	4 873	7 556	32 000	19 200	29 005	23 794	28 693	23 504
	Galaxy		5 427	7 509	26 240	15 744	26 487	19 861	26 202	19 625
	Isabelle	193 648	4 503	7 226	24 000	14 400	20 103	16 960	19 887	16 752
	Romantika		4 401	7 391	26 240	15 744	21 480	18 735	21 249	18 502
	Star	239 616	2 958	3 413	48 000	28 800	26 411	17 302	26 127	17 105
	Superstar		2 904	3 356	50 400	30 240	27 227	17 861	26 935	17 658
	Silja Europa		3 715	4 812	31 800	19 080	21 973	15 607	21 737	15 423
TT-Line	Huckleberry Finn	172 640	4 316	6 394	14 800	8 880	11 881	9 369	11 753	9 255
	Tom Sawyer		4 316	5 263	14 800	8 880	11 881	8 086	11 753	7 992
	Peter Pan	346 112	5 244	7 902	19 600	11 760	19 118	15 333	18 912	15 147
	Nils Holgersson		5 244	7 443	22 000	13 200	21 459	16 408	21 228	16 211
	Robin Hood		5 916	7 256	13 000	7 800	14 306	9 735	14 152	9 621
	Nils Dacke	69 888	3 584	4 659	13 000	7 800	8 666	6 178	8 573	6 105
ULS Estonia	ULS Ferry 1	31 304	2 033	2 746	7 609	4 565	2 877	2 119	2 846	2 094

Unity Line	Polonia	276 640	3 738	5 361	15 840	9 504	11 014	8 458	10 896	8 356
	Skania		2 561	4 836	34 550	20 730	16 461	15 941	16 284	15 740
	Kopernik		4 462	5 911	5 450	3 270	4 523	3 267	4 474	3 228
	Jan Śniadecki		3 640	4 940	11 840	7 104	8 016	5 896	7 930	5 826
	Gryf	194 688	3 817	4 603	7 920	4 752	5 624	3 784	5 563	3 740
	Wolin		3 605	5 110	13 200	7 920	8 852	6 759	8 757	6 678
	Galileusz		3 135	4 879	11 520	6 912	6 718	5 531	6 645	5 464
Viking Line	Gabriella	172 536	4 012	6 162	23 780	14 268	17 747	14 419	17 557	14 243
	Mariella		3 921	5 016	23 000	13 800	16 775	11 836	16 595	11 697
	Amorella	238 784	5 553	7 753	24 000	14 400	24 789	18 644	24 523	18 420
	Cinderella	69 160	3 144	6 175	28 800	17 280	16 840	16 966	16 659	16 753
	Rosella	65 416	3 238	4 220	17 652	10 591	10 633	7 599	10 518	7 509
	Viking XPRS	69 888	2 796	3 717	40 000	24 000	20 799	15 078	20 575	14 900
Wasa Line	Wasa Express	43 680	2 240	3 260	14 866	8 920	6 194	4 826	6 127	4 768
Total container fleet		8 295 612	386 385	521 421	2 278 523	1 367 114	1 606 552	1 173 565	1 589 278	1 159 694
BALTIC LINER RO-RO SHIPPING										
Anship	Ambal	113 984	6 031	7 861	16 290	9 774	18 273	13 062	18 077	12 908
CLdN	Victorine	34 840	1 787	2 386	10 920	6 552	3 629	2 642	3 590	2 611
	Schieborg	282 880	7 253	8 271	10 920	6 552	14 732	9 538	14 574	9 430
	Slingeborg		7 253	7 902	10 920	6 552	14 732	9 267	14 574	9 164
DFDS Seaways	Fionia Seaways	203 424	4 521	5 558	21 600	12 960	18 162	12 390	17 966	12 245
	Selandia Seaways		4 731	6 054	21 600	12 960	19 006	13 417	18 802	13 260
	Transpulp	120 016	6 155	7 274	21 600	12 960	24 727	16 497	24 461	16 308
	Begonia Seaways	300 040	4 445	5 526	20 070	12 042	16 593	11 445	16 415	11 312
	Freesia Seaways		4 445	4 879	20 070	12 042	16 593	10 516	16 415	10 399
	Ficaria Seaways		4 445	5 264	20 070	12 042	16 593	11 029	16 415	10 903
	Petunia Seaways	308 256	4 567	4 870	20 070	12 042	17 048	10 556	16 864	10 438

	Primula Seaways		4 567	6 343	20 070	12 042	17 048	12 832	16 864	12 679
	Magnolia Seaways		4 567	5 324	20 070	12 042	17 048	11 219	16 864	11 091
	Botnia Seaways	83 200	4 160	5 299	12 600	7 560	9 749	6 851	9 645	6 771
	Corona Seaways	97 344	4 867	6 009	21 600	12 960	19 554	13 395	19 344	13 239
Finnlines	Finnmill	436 800	7 280	7 786	21 600	12 960	29 248	18 163	28 934	17 962
	Finnpulp		7 280	7 828	18 900	11 340	25 592	15 978	25 317	15 801
	Finnwave		7 280	7 786	18 900	11 340	25 592	15 893	25 317	15 716
	Finnkraft	270 400	4 507	5 891	18 900	11 340	15 843	11 357	15 672	11 223
	Finnhawk		4 507	5 891	18 900	11 340	15 843	11 357	15 672	11 223
	Caroline Russ		4 292	5 598	11 030	6 618	8 806	6 298	8 711	6 224
	Finnsun	182 000	2 889	5 465	20 000	12 000	10 747	10 428	10 631	10 297
	Finnsea		2 889	3 527	20 000	12 000	10 747	7 322	10 631	7 238
	Finntide		2 889	4 428	20 000	12 000	10 747	8 715	10 631	8 608
	Finnbreeze	137 904	3 283	3 768	20 000	12 000	12 214	7 958	12 083	7 867
	Finnsky		3 283	3 768	20 000	12 000	12 214	7 958	12 083	7 867
	Baltica	87 360	4 598	5 079	13 575	8 145	11 609	7 364	11 485	7 281
Lillgaard	Fjardvagen	43 680	2 496	2 912	5 884	3 530	2 732	1 799	2 702	1 779
Mann Lines	Estraden	124 800	6 568	6 820	12 600	7 560	15 394	9 435	15 228	9 332
SCA Transforest	Obbola	291 200	6 067	6 983	9 000	5 400	10 156	6 637	10 046	6 561
	Ortviken		6 067	7 354	9 000	5 400	10 156	6 870	10 046	6 790
	Ostrand		6 067	6 884	9 000	5 400	10 156	6 543	10 046	6 468
	Transreel	156 000	3 900	7 500	7 775	4 665	5 640	5 563	5 579	5 493
	Helena		5 200	7 647	7 693	4 616	7 441	5 859	7 361	5 789
Sea-Cargo	SC Ahtela	126 880	3 845	5 565	5 920	3 552	4 234	3 281	4 188	3 242
	Trans Carrier		4 229	4 918	4 500	2 700	3 540	2 324	3 502	2 297
SOL Continent Line	Merchant	40 560	2 318	3 527	13 200	7 920	5 690	4 581	5 629	4 525
	Vikingland	214 240	5 638	6 653	13 200	7 920	13 842	9 169	13 693	9 064

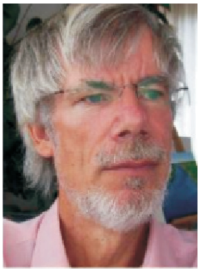
	Vasaland		5 638	5 951	13 200	7 920	13 842	8 531	13 693	8 437
Tallin/Silja	Sea Wind	102 336	6 020	6 822	8 352	5 011	9 352	6 017	9 251	5 949
	Regal Star	65 312	3 628	4 214	8 700	5 220	5 872	3 871	5 808	3 827
Transatlantic	Transtimber	222 560	5 564	6 148	18 000	10 800	18 628	11 819	18 428	11 686
	Transpaper		5 564	7 179	18 000	10 800	18 628	13 181	18 428	13 026
	Transwood	156 000	4 457	5 735	12 600	7 560	10 446	7 371	10 333	7 284
	Transpine		4 457	5 306	12 600	7 560	10 446	6 980	10 333	6 900
Transfennica	Genca	624 000	5 673	8 265	25 200	15 120	26 589	20 744	26 303	20 494
	Stena Forerunner		5 547	6 972	24 000	14 400	24 760	17 168	24 494	16 967
	Stena Forecaster		5 547	6 178	24 000	14 400	24 760	15 747	24 494	15 569
	Stena Foreteller		5 547	8 548	24 000	14 400	24 760	20 187	24 494	19 941
	Seagard		5 943	6 638	15 600	9 360	17 244	10 998	17 058	10 874
	Friedrich Russ	130 000	6 190	7 784	12 600	7 560	14 508	10 063	14 352	9 946
	Pauline Russ	140 400	2 925	6 440	15 600	9 360	8 487	9 525	8 396	9 404
	Kraftca		3 191	3 878	25 200	15 120	14 956	10 145	14 796	10 028
	Plyca	114 400	5 200	7 062	25 200	15 120	24 373	17 938	24 111	17 724
	Pulpca	228 800	5 200	5 897	25 200	15 120	24 373	15 782	24 111	15 603
	Trica		5 200	6 151	25 200	15 120	24 373	16 274	24 111	16 088
UPM Seaways	Misana	197 600	3 293	4 543	15 000	9 000	9 188	6 868	9 090	6 787
	Misida		3 293	3 875	15 000	9 000	9 188	6 102	9 090	6 033
	Mistral		2 994	4 739	12 600	7 560	7 017	5 839	6 941	5 768
Wagenborg Shipping Sweden	Balticborg	153 920	4 664	4 751	9 450	5 670	8 198	5 010	8 110	4 956
	Bothniaborg		4 664	5 458	9 450	5 670	8 198	5 416	8 110	5 354
Total container fleet		5 791 136	291 563	360 932	982 799	589 679	879 859	607 084	870 399	600 049
GRAND TOTAL		21 272 648	1 058 201	1 395 025	4 748 558	3 054 178	3 230 530	2 456 553	3 195 793	2 427 646

Biographical notes

Ernest Czermański, PhD., researcher, graduated from the University of Gdansk (UG, 2007) in Intermodal transport development in globalization, is an Assistant Professor at the Institute of Maritime Transport and Seaborne Trade of the Faculty of Economics. He was a member of the Scientific Advisory Board of the Institute, is an expert for the Ministry of Regional Development and Pomeranian Marshall Office in the field of transport, development, and intelligent transport systems. Expert in consultations for the Baltic Sea Region Program 2014 – 2020. External evaluator of maritime transport in the Baltic Transport Outlook 2030 project. His scientific research focuses on maritime shipping, containerization, intermodal transport and sustainable development in globalization, economics of transport and functioning of transport systems. He co-operates with the bi-monthly "Baltic Transport Journal". He has been an expert and financial manager of several projects in NTERREG III B, Central Europe Program and 7th FP. Currently he is the project manager of TRANSFORuM (7th FP) at the UG.

Sławomir Droździecki, PhD, researcher, academic teacher. Erasmus and Tempus programs scholar, student of the University of Gdansk (Poland) and the University of Leicester (England). Graduated (2004) from the University of Gdansk in the field of financial aspects of maritime ports' infrastructure development. An aca-demic teacher (1996), Assistant Professor (2004) at the Maritime Academy of Gdynia. His scientific interests and research are focused on practical problems of logistics and transport, broader theory and practice of trans-port policy, theory of externalities and their internalization, as well as transport policy of the European Union. Author of articles (20) and monographs: The theoretical aspect of internalization of transport externalities (2013); The internalization of transport negative externalities in European Union's transport policy (2014).

Maciej Matczak, is an Assistant Professor at the Department of Logistics and Transport Systems of Gdynia Maritime University. He is an experienced transport and logistics economist, university lecturer, and project manager with over 15 years of work experience in research, education, and consulting. He worked as a development specialist in the Department of port development of the Gdansk Port Authority SA during the years 1998 – 2005. He received his PhD in 2004, and begun his work at the Gdynia Maritime University a year later. From 2005, Dr Matczak has been working as senior consultant and project manager in Actia Forum Ltd, the leading Polish consultancy company engaged in maritime transport and seaport development in the Baltic Sea Region. In the year 2013 he was appointed Head of the Actia Consulting Department. He has also been working with the Baltic Ports Organisation for many years. As a member of the BPO team he is mainly engaged in research and analysis of the maritime transport market. Dr Matczak is a maritime transport expert and evaluator of the investment and research project proposals in TEN-TEA, EACI and DG MOVE. As a former member of the Polish National Rowing Team, he is also involved in the sporting activities as a Mem-ber of the Board of the rowing club GKW Drakkar.



Eugen Ferdinand Spangenberg is a graduate of the Technical University of Berlin Dipl.-Ing. Naval Architect. He works as an Engineer in various sectors such as offshore, shipbuilding, High Speed Craft and pleasure yachts. In the field of shipbuilding he is mainly concerned with Research and Development for hydrodynamic and structural dynamic. Moreover, he is as lecturer for customer personal and vessel transfer and testing. He works for Thyssen, Babcock, AEG and different shipyards. In 2010 he was awarded the 2nd Innovation Prize of Thyssen Group in advancement of ship propulsion. During his study in NY/New-Jersey he worked on a container Terminal. As of 2013 he began Doctoral Studies at the University of Gdansk, Faculty of Economics, with a special focus on maritime transport development.

Bogusz Wiśnicki, PhD., Eng., a graduate of two Masters Courses: at the Navigation Faculty of the Maritime University in Szczecin, in shipping; as well as at the Transport and Communication Faculty of the University of Szczecin, in economy. In 2001 he defended his doctoral thesis entitled: “Multicriteria Analysis of the Location of the International Multimodal Transport Terminal in the Szczecin Area” written at the Management and Economics Faculty of the University of Szczecin. Since 1993 he has been a researcher at the Maritime University, where he is currently Assistant Professor in the Department of Integrated Transport Technology and Environment. As of 2012 he is the Vice-Dean of the Transport Economics and Engineering Faculty. In addition to his academic activity, during 2007-2013 he was chair of the President of the Association of Maritime Education in Szczecin. Bogusz Wiśnicki is the author of over 60 research publications, numerous business studies commissioned in the area of transport and logistics and has completed several international research internships. He primarily specializes in intermodal transport.