LNG AS A FACTOR OF DEVELOPING INNOVATIVE TECHNOLOGIES IN SEA TRANSPORT

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Abstract

Restrictive environmental regulations related to the entry into force of Directive 2012/33 / EU of the European Parliament and of the Council encourage the search for alternative energy sources for currently used fuels by ships. An alternative to the traditional fuel is the use of LNG - liquefied natural gas. LNG is determined as the fuel of the future and is gaining in popularity among shipowners as shipping fuel. An important aspect for using LNG as shipping fuel is the economic aspect. The aim of this article is to analyze and evaluate the potential of using LNG liquefied natural gas as fuel in propulsion of the ships. The article discusses the challenges posed by the use of LNG in ship propulsion systems other than tankers. Highly advanced solutions of innovative ships using LNG propulsion were presented - projects completed as well as those in the development phase. The solutions concern projects from the world market and the Polish market. Also described activities carried out in seaports of the Baltic Sea aimed at developing a network of terminals and LNG bunker stations. The sources of changes and market needs were also presented and the sources of regulations for LNG-powered vessels were focused on.

Keywords: SECA, Sulphur Directive, LNG-fuelled vessel, marine fuels

1. INTRODUCTION

An important reason for the development of the LNG - fuelled fleet was the introduction of the Sulphur Directive, which adapts EU law to the new regulations of the International Maritime Organisation IMO. According to the MARPOL Convention, the sulphur content of marine fuels is to be 3.5 % by 2020 and 0.5 % after 2020. Sulphur Directive 2012/33/EU (the amendment to Directive 1999/32/EC concerned Annex IV to MARPOL, which sets a maximum permissible standard for the sulphur content of bunker fuels) from 1 January 2015 imposed on shipowners the obligation to reduce the sulphur content to 0.1 % of fuels used by ships sailing in the Baltic Sea, North Sea and English Channel, the North Coast and the areas of the United States of the Caribbean Sea - SECA's (Sulphur Emission Control Areas) as you can see on **Figure 1**. From 2020, the zone will extend to the Irish Sea. The aim of this article is to present the rationale and challenges of implementing LNG as a marine fuel in the SECA zone and to indicate the state of development of an innovative fleet of LNG-fuelled vessels [1,2].

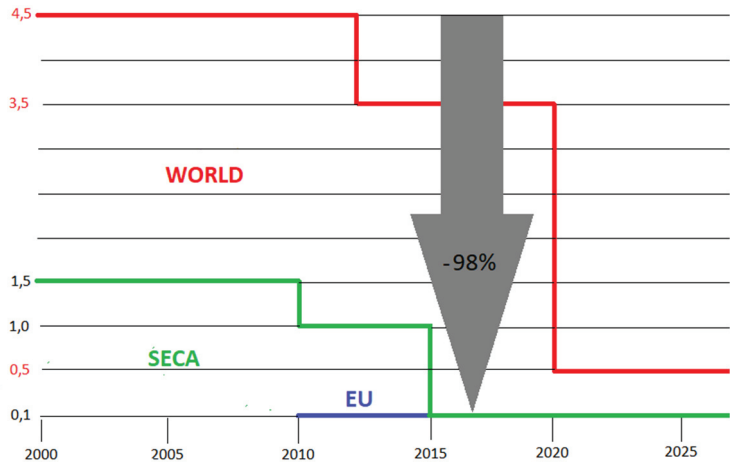

Figure 1 Sulphur limit (%) [own study based on 1,2]

2. SOLUTIONS FOR REDUCING EMISSIONS NOx AND SOx IN THE CONTEXT OF IMPLEMENTATION SULPHUR DIRECTIVE

Shipowners choose different solutions to meet the new constraints, but they also have to choose the most cost-effective method. The most frequently considered alternatives to the fuels used so far are:

- use of fuels with lower sulphur content, i.e. Marine Gas Oil or sulphur-free fuels,
- installation of fuel purification technologies - scrubbers, which desulphurise fuel fumes,
- investment in new LNG-fuelled vessels or LNG-fuel system installation on existing vessels,
- investment in hybrid vessels.

Each of the above solutions has advantages and disadvantages, and the choice of the right one depends on factors such as:

- ship size,
- swimming area of the vessel,
- type of the work carried out by the vessel,
- possibility of modernization of the vessel,
- the distance between ports to be covered by the vessel,
- return on investment (ROI).

It is also worth explaining the costs of implementing the above solutions (**Table 1**).

Table 1 Costs of alternative solutions [3]

Solution	**Cost**
Sulphur-free fuels	About 220 €/MT
Scrubber	5 milion €
New LNG-fuelled vessels	270 milion €
Hybrid vessels	14 milion €

There are at least three alternative approaches to meeting MARPOL Annex VI requirements but particularly attractive alternative seems to be the use of LNG propulsion, not only because it allows to achieve the required reduction in emissions, but also turns out to be the cheapest solution in the long term. Despite the fact that LNG transport has been taking place for many years, LNG-fuelled ships are quite a new concept and the scale of investments in LNG technologies is already in initial state.

- The choice of low sulphur fuel brings with it a number of costs, related not only to the cost of fuel itself, but also to the modification of existing fuel systems on ships. One of the possibilities of adapting marine engines to meet the standards of the Sulphur Directive is to supply the ship's engine with light fuel oil (MGO - Marine Gas Oil) instead of MDO (Marine Diesel Oil). However, fuel prices are not the only problem. Changing from heavy, high-sulphur fuels to low-sulphur fuels is also a challenge for marine equipment. Equipment such as engines and boilers must be modernised. The use of low-sulphur fuels requires the use of new types of engine lubricating oils in accordance with the manufacturer's specifications, which generates further costs for shipowners [4].
- In the context of implementation of Sulphur Directive shipowners are looking for ways to reduce sulphur emissions from ships and to be able to use cheaper traditional fuel by installing scrubbers. Scrubber is a fuel purification technology that works on the same principle as catalytic converters in cars. Ships installed with scrubbers can burn bunker fuel with high sulphur content. The use of scrubbers eliminates almost all harmful emissions from ships. The main producers of scrubbers are Alfa Laval, DuPont and Wärtsilä. Scrubbers are equipped with systems eliminating 97-98 % sulphur oxides (SOx) and 70-80 % particulate matter (PM) [4,5].

- Third alternative - investment in new LNG-fuelled vessels will be describe below.

3. ANALYSIS OF LNG POTENTIAL AS A FUEL FOR VESSELS

For several years, the number of vessels using LNG as a fuel is growing rapidly and further infrastructure projects are planned in ports serving LNG powered vessels. The use of liquefied gas in ship propulsion has been known since the 1960's. For many years now, tankers also known as LNG carriers adapted for transporting LNG, have been using the steam generated from the transported cargo in order to supply the main propulsion system, burning and using them as fuel. On the other hand, the use of LNG as a fuel on ships other than LNG carriers has a much shorter history. Liquefied natural gas is a clean, odourless and colourless fuel, non-toxic and non-corrosive. After the liquefaction process, the LNG contains a small amount of heavy metals, such as mercury, lead, cobalt and sulphur - it is an unquestionable advantage, harmful sulphur oxides, dust or soot are not formed during combustion [6]. An LNG fulled ship reduces the emission of NOx by 85 - 90 %, SO_x close to 100 % and 15 - 20 % reduction in net GHG emissions. The main producers of marine engines using LNG fuel are Wärtsilä, Rolls-Royce, MAN Diesel and Mitsubishi. There are two types of engines available on the market - mono- and dual-fuel configuration. Mono-fuel engines are characterised by spark ignition and are powered only by natural gas. Dual-fuel engines use natural gas as the main fuel and diesel for ignition. A dual-fuel engine is a more complicated solution and particularly suitable for areas not covered by sulphur restrictions [7]. In addition, the economic aspect of LNG as a shipping fuel is very important for shipowners. The use of LNG due to the higher calorific value of approximately 50 kJ/kg by comparison to heavy IFO 180 fuels (approximately 42 kJ/kg) is related with lower fuel consumption. Another advantage argument for LNG is the price, which is currently lower than traditional fuels [8]. In Rotterdam, the price of IFO 180 fuel is 527 USD/MT, while MGO is 682 USD/MT. On the other hand, LNG prices in Europe range from 9.39 USD/MMBtu in Spain to 10.75 USD/MMBtu in Belgium, which means that the price of LNG ranges from 456.35 to 522.45 USD/MT [9,10]. The **Table 2** shows the fuel prices in Europe 30.10.2018.

Table 2 Marine fuel prices in Europe 30.10.2018 [own study based on 9,10]

Type of fuel	Price
IFO 380	468.5 $/MT
IFO 180	527 $/MT
MGO	682 $/MT
LSMGO	674.5 $/MT
ULSFO	656 $/MT
LNG	10.75 $/MMBtu = 522.45 $/MT

Unfortunately, it is difficult to estimate how LNG prices will develop in the future, but according to DNV research the operating costs of an LNG-fuelled vessel may be 35 % lower than the operating costs of an MGO-fuelled vessel over a 10-year horizon. However, over the next 20 years the costs of an LNG- fuelled vessel may decrease by as much as 45 % when using MGO or by 22 % in comparison to heavy HFO fuels using scrubbers. Research show that the high costs related with the construction of LNG-fuelled vessels can quickly return through savings in fuel consumption [5].

4. DEVELOPMENT OF THE MARITIME FLEET USING LNG FUEL

Since 1 May 2018, the fleet of LNG- fuelled vessels has 253 vessels, including 121 vessels in operation and 132 vessels ordered. Among LNG vessels are 4 segments - tankers and bulkers, container and cargo, passenger and supply ships and services vessels. Over the last year the order book for LNG-fuelled ships has increased by 36 %. Most of the vessels ordered are large size vessels with bunker tanks of unprecedented

size. The most dynamic segment in last year was tankers and bulk carriers. Orders related Aframax and Suezmax tankers of 110 000 DWT and above. In the segment of passenger and container vessels orders were also for large size vessels. In the last year most of the cruise ships ordered were dual-fuel ships. Changing the requirements for LNG fuel accelerates the development of bunkering infrastructure around the world. Investments are carried out on ships, LNG fuelling depots and the adaptation of existing LNG receiving terminals [11].

An example of innovation LNF-fuelled vessel from the world market is AIDANova. That is the world's first cruise ship powered only by liquefied natural gas. Ship was built by the German shipyard Meyer Werft in Papenburg. The ship was built to order for the Aida Cruises cruise line owned by Carnival Corporation. As a pioneer in the cruise industry, AIDA Cruises is an example of environmental protection through its advanced project “Green Cruising”. AIDA will be the first cruise line in the world to operate new fleet of ships with 100 % LNG. The German shipyard Meyer Werft plans to build two more liquefied natural gas cruise ships for the Aida Cruises cruise line by 2023. The innovative ship is 337 m long and 42 m wide and can hold up to 6,600 passengers on 22 decks. Ship was launched on 21 August 2018 and on 18 October 2018 the first bunkering of the vessel AIDAnova with liquefied natural gas LNG took place. The operation was carried out in Eemshaven, the Netherlands, using the Cardissa bunker, operated by Shell. Three liquefied natural gas tanks are installed on the AIDAnova ship - two of them are tanks with a diameter of 8 m and about 35 m in length, each of them additionally holds 1.5 thousand m^3 of LNG. The third tank is smaller than the others, reaches 5 m in diameter and 28 m in length and 520 m^3 capacity. The ship is expected to arrive at the Hamburg Steinwerder Terminal on 1 December. AIDANova will sails on maiden voyage to the Canary Islands on 2nd December [12,13].

Another example of using LNG as a fuel is the fleet of ships built in Poland. 4 ferries powered by LNG - Moldefjord, Fannefjord, Romsdalsfjord, Korsfjord, belonging to the shipowner Fjord1 - were built in the Gdańsk Shipyard Remontowa Shipbuilding S. A. Shipyard started built the construction of LNG-powered ferries 9 years ago. On 27th February 2009 the hull of the two-way passenger-car ferry Moldefjord was launched. The vessel was built for the Norwegian shipowner Fjord1 and was the first in a series of ferries powered by LNG. The ship was a success. Constructors won the Green Ship Technology Awards from Informa Maritime Events of Informa, the publisher of one of the world's most important marine journals, the Lloyd's List. This fact proves the position of the Gdańsk shipyard in the elite group of shipyards building not only innovative but also prestigious ships. Sister ships of the Moldefjord - also powered by liquefied natural gas are: Fannefjord, Romsdalfjord and Korsfjord. Ships were placed in service between 2009 and 2010. Each ferry is equipped with one medium-speed diesel generator and two internal combustion engines powered by LNG. They generate electricity for main propulsion as well as for all other ship's systems and receivers. The ferry Moldefjord is more than 122 m long and can hold up 390 passengers, 128 cars or 12 truck combinations with semi-trailers and 55 cars on two decks. Moldefjord, like the 3 twin structures is characterized by a symmetrical hull and during the cruise passengers have a specially separated rest area. Shipyard Remontowa Shipbuilding S. A. is one of the largest European manufacturers of offshore vessels and passenger-car ferries with various types of modern propulsion systems. On the American market Remontowa Shipbuilding competes mainly with Chinese shipyards and Norwegian shipyards in Europe [14,15].

5. INVESTMENTS IN LNG TERMINALS AND BUNKER STATIONS IN THE BALTIC SEA

The develop of maritime transport using LNG as a marine fuel requires appriopriate fleet and also well-established network of terminals and bunker stations. Currently there are more than 100 LNG terminals in the world - in Europe are 23 LNG terminals. On 19 August 2008 Council of Ministers adopted a resolution to build LNG terminal in Świnoujście. It was recognized as a strategic investment for the interest of Poland because terminal guarantee Poland's energy security. The terminal in Świnoujście enables the off-take of liquefied natural gas from any direction in the world. The current technical regasification capabilities of the LNG Terminal at the level of 5 billion m3 of gas make it possible to satisfy 1/3 of the needs of the Polish economy. The

operators authorised to call at the LNG Terminal in Świnoujście are shipowners such as Shell Trading and Shipping Company, Blue Ocean Marine, K Line LNG Shipping [8,16].

Port of Gdynia Authority S. A. signed an agreement with PGNiG Obrót Detaliczny Sp. z o. o. and Gas-Trading S. A. on the use of LNG fuel. The agreement assumes, among other things, the construction of a barge adapted to bunkering other ships with LNG. The project will be implemented within the framework of the National Centre for Research and Development - INNOSHIP programme. According to the Sulphur Directive, by the end of 2025 at the latest, a sufficient number of LNG bunkering points will be established in seaports. Bunkering points will allow inland waterway vessels or LNG-powered seagoing vessels to travel across the entire TEN-T core network. In the case of Poland, it will be polish port: Gdynia, Gdańsk and Szczecin and Świnoujście. The possibility of bunkering LNG fuel in the Port of Gdynia is another example that ports must constantly invest and create such port infrastructure that will satisfy the requirements of shipowners and individual terminals. The Port of Gdynia recognizes the growing demand from shipowners to use more LNG fuel. Through the development of ecological fuel bunkering technology, the Port of Gdynia Authority S. A. wants to build competitiveness on the international arena [17].

6. CONCLUSION

Certainly, this article does not exhaust the subject, but it is only a contribution to further discussion about LNG as an innovative method of ship propulsion. Innovative technology for propelling seagoing vessels with LNG fuel is currently in the implementation phase. This is confirmed by the significant increase in the number of orders for modern LNG-fuelled vessels, as well as further highly advanced LNG terminal projects in world and Baltic ports. The use of LNG is such a versatile solution that it can be used in many areas of the economy, including ship propulsion. The **Figure 2** printed beneath shows the SWOT analysis for the use of LNG fuel as an alternative to the heavy fuels used so far.

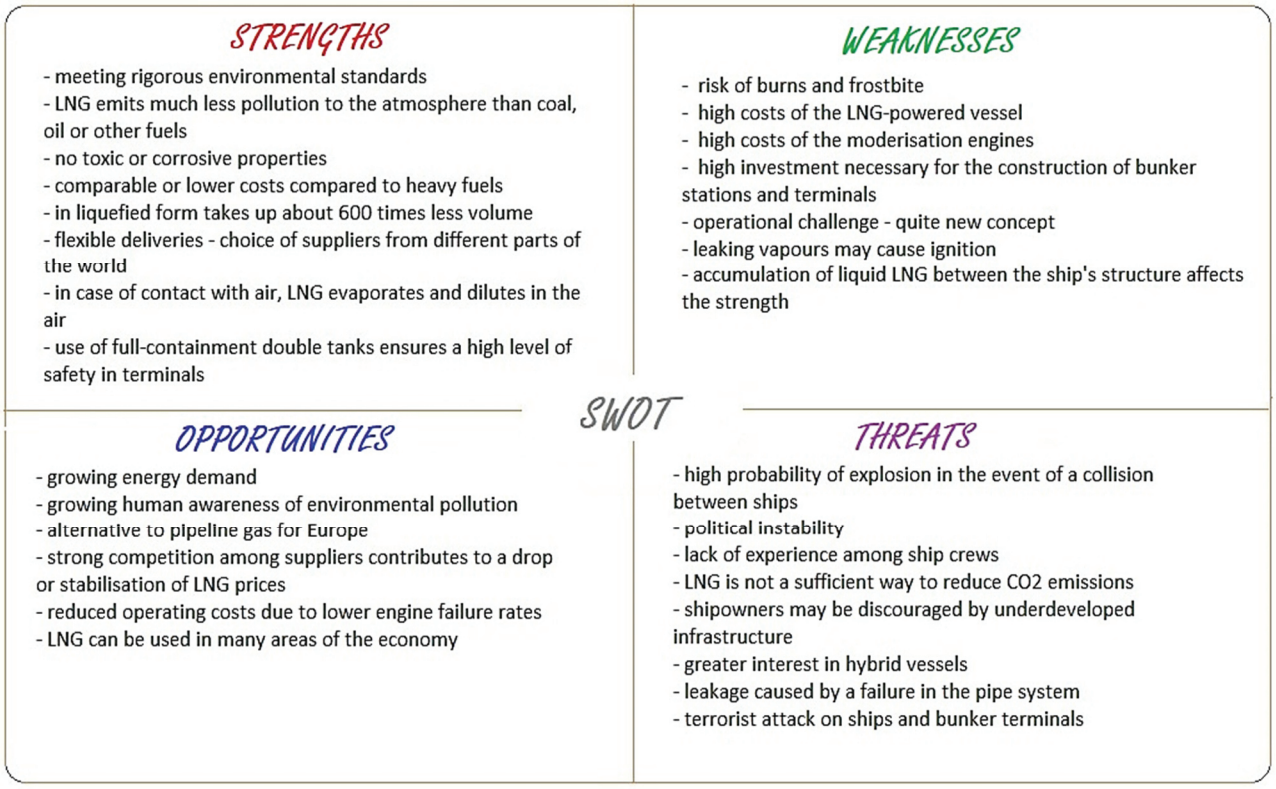

Figure 2 SWOT analysis for the use of LNG fuel as an alternative to the heavy fuels [own study]

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