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LNG MARKET AND FLEET ANALYSIS

Summary. This paper is part of larger research on the impact of present and future air emissions from the shipping industry and especially the environmental impact of the rapid spreading of the LNG as a fuel in the industry. Therefore, it was important to gather data related to the LNG market and perform an analysis to gain realistic insight into the market behaviour. This paper analyses the situation and trends of the LNG shipping market over a longer period to predict future developments. Data analysis of the several aspects and patterns of the trade has been performed; the results obtained can enable prediction of the market situation for the future. From the data analysis and predictions of the LNG market, continuous growth in the following years is expected, which linked to an increase of the LNG fleet and number of importing countries. Research has shown that new propulsion alternatives such as MEGI and XDF are appearing on the market as the first choice for new builds, while steam turbines are slowly disappearing. Although market growth is projected from all research parameters, the situation has changed due to the COVID-19 pandemic and its impact on the market. Consequently, growth forecasts will not be realized in 2020.

1. INTRODUCTION

Over the last few decades, considerable attention has been paid to environmental degradation as a result of human activity and, consequently, there is considerable focus on responsible and sustainable management of the environment and its resources. The continuously expanding population worldwide, along with the extensive use of fossil fuels, resource exploitation, widespread industrialization and globalization, have led to extreme environmental pollution and ultimately climate change. The consequences of this behaviour are increasingly more visible and ubiquitous, as climate change effects and risks are already present in many parts of the world. Awareness of the need for climate change adaption and the reduction of environmental pollution has triggered a prevailing global trend encouraging the use of renewable and sustainable energy sources that reduce adverse environmental impacts. Because of its flexibility in terms of use in transport, LNG is playing an increasingly important role in the global energy market. Compared to gas transported through pipelines, LNG requires no significant capital expenditures. In addition, its biggest advantage is the lack of close geographical connection to the customer's location [1]. As a result, according to research conducted in 2018, predictions indicate that LNG will account for more than 60% of the global gas trade in 2040. [2] Due to the advancements and innovation of transport and LNG technologies, trade is not limited by the location and reach of pipelines, and therefore allows the transport of natural gas to places where pipelines do not reach or are non-existent. [3] Hence, maritime LNG transport allows exporters to send merchandise to all locations with a functioning liquefaction plant, while importers may collect gas from all locations with liquefaction plants. [4] It is also important to mention that, compared to pipeline gas,

LNG is purer. As LNG must be subjected to the process of liquefaction, it is then purified from most contaminants, a step that is overlooked during pipeline transport. [5]

Since the early 2000s, global LNG production capacities have increased by more than eight times [6]. Moreover, several studies have shown an upturn in the total gas trade [7-9], from 100 million tonnes in 2000 to 354.7 million tonnes in 2019. As reported by M. Galczynski et al. [10], the LNG industry has been growing and represents a significant proportion of the energy market, with more than 30% of total representation. R. Danilov [11] predicts that, because of the continuous population growth, the overall volume of LNG consumption is also expected to increase due to increasing demands. Therefore, increases in both capacity and production rates of LNG can be expected. H. Nikhalat et. al. [12] predicted that future technology advancement would result in a reduction in LNG project investment costs in combination with the development in infrastructure around the world, which will increase business and overall market liquidity for LNG, while S. Razmanova et al. [13], on researching the Russian Yamal project, came to the conclusion that the development of the Northern Sea Route and Arctic regions will assist in increasing gas market trades as well as effectively develop Russia's LNG plant production.

LNG is considered as a replacement fuel in different types of transport [14-16]. Due to tightening of anti-pollution regulations in the shipping industry [17], as a fuel, LNG is increasingly being researched and used, with many authors stressing its benefits [18-20]. Although LNG has some advantages compared with other fossil fuels [21], use of LNG as fuel leads to large quantities of CO_2 emission; this was analysed by Jing, D. et al. [22] and Katebah, M. A., et al. [23].

To analyse and calculate current and future air emissions from the shipping industry (similar to the analysis performed by Dalsøren et al. [24] and Ytreberg et al. [25]) and the impact of the rapid use of LNG as a fuel in the shipping industry, it was important to gather data related to the LNG market and trade (similar to the study performed by Wang. Y. X., et al [26]) and perform an analysis to gain realistic insight into business performance and market behaviours. The aim of this study is to analyse the LNG market and fleet, as well as ships' propulsion systems, by examining the data from 2011 to 2019 to define changes within the LNG market over a period of time and predict trends from the year 2020 onwards.

2. RESEARCH METHODOLOGY

In this paper, Excel (an essential analytical tool that is widely used in almost every industry. [27]) is used to calculate predictions and show market behaviour over a period of time with the results obtained by simple qualitative analysis.

The simple Forecasting technique was performed using an Excel database, where valuable research information mainly from IGU world reports was used to make a prediction and access the trends of the LNG market and fleet behaviour. The results obtained are clear, precise and easy to interpret for most of the readers. In this paper, background information collected over a 10-year period was entered into an Excel spreadsheet [28, 29] to calculate average growth for various LNG market and trade aspects. The same average growth was applied in the computations to predict market behaviour in the following 5 years and therefore predictions until the 2025 have been made. This information has been presented in the graphs accordingly.

3. LNG IMPORTING/EXPORTING COUNTRIES

For the fifth year in a row, the LNG market has experienced an increase in global distribution, which reached 354.7 Mt in 2019 (Million tons in text- Mt), which is 38.2 Mt more than in 2018, indicating an annual improvement of 12 % [7, 30]. The reason behind this is an increase in the number of LNG facilities in the world; Australia stands out with three new projects: Prelude FLNG, Wheatstone and Ichthys launched in 2019. With a total production of 87.6 Mt per year, Australia is becoming one of the leading countries in terms of LNG production capabilities. [31]. Qatar continues to be the highest exporter, with 22 % of world exports [7] (Fig. 1).

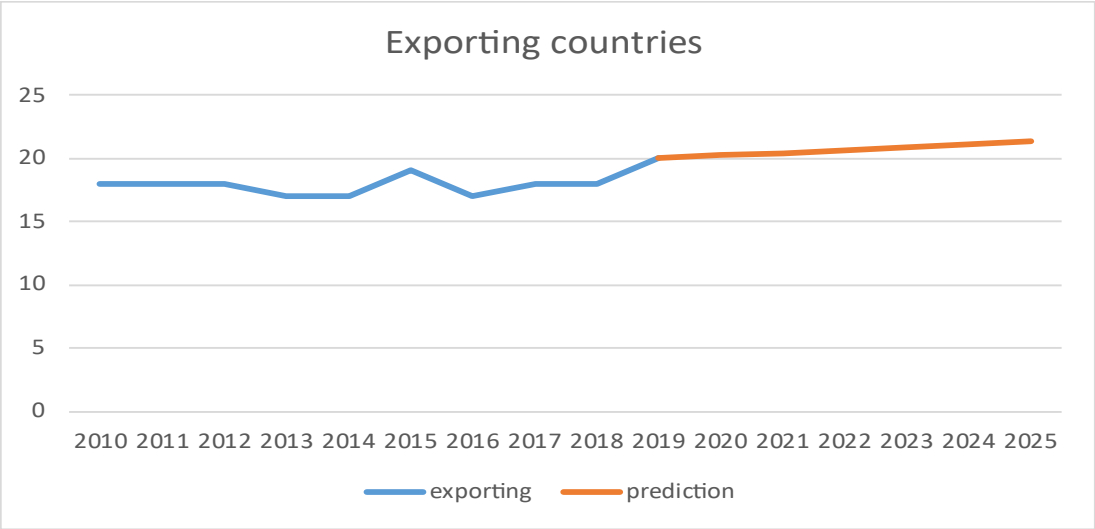

Fig. 1. Number of exporting countries from 2010 to 2019 with future prediction [7, 30, 34-41]

In terms of importing (Fig. 2), 61% of the transported gas was delivered to Asian countries with huge demands: China, South Korea, Japan and Taiwan [32]. Among them, China experienced the largest increase in imports in 2019 with an increase of 6.8 Mt compared to the previous year [7, 30]. Global growth can be linked to the Russian Yamal project in northern Europe, where gas is being exported to European countries in the winter seasons and to the Far East during the summer seasons, when the Northern Sea Route is open for transit. In the past, cargo was mostly transported on the basis of a long-term charter party, where the ship would be chartered for a period of 20 or more years. During this period, mostly same cargo would be transported to the designated fixed destinations. Short-term gas trade reached 99 Mt in 2018, which represents 31% of total gas trade for that year, and compared to 2008, the number of short-term contracts increased by a large 50% [7]. Also, it is important to note that to date, no LNG project has been fully developed in the spot market. It looks like long-term contract is still and will remain the preferable choice on the market for some time, although all projects are designed for spot sales [33].

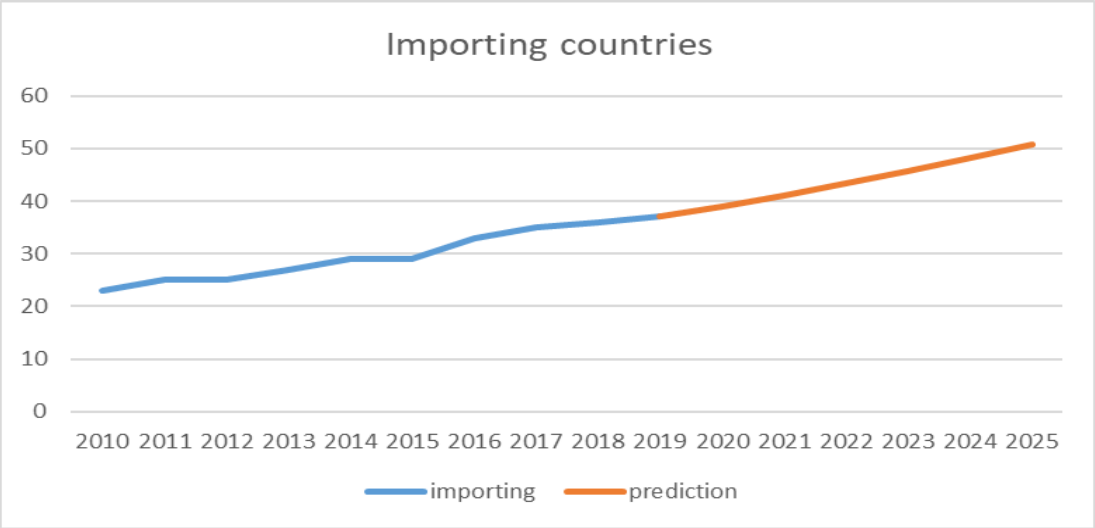

Fig. 2. Number of importing countries from 2010 to 2019 with future prediction [7, 30, 34-41]

The expected trend, obtained using Excel calculations analysing data over a 10-year period, showed that the number of importing countries will continue to increase considerably in the analysed period, while the number of exporting countries will remain almost the same or show slight growth.

3.1. Volume of LNG trade

Predictions of the LNG trade volume can be difficult; they depend on a multitude of factors and the market behaviour in the analysed period. Over the last ten years, the world's LNG trade has not had a steady pattern of behaviour, as can be seen in Fig. 3.

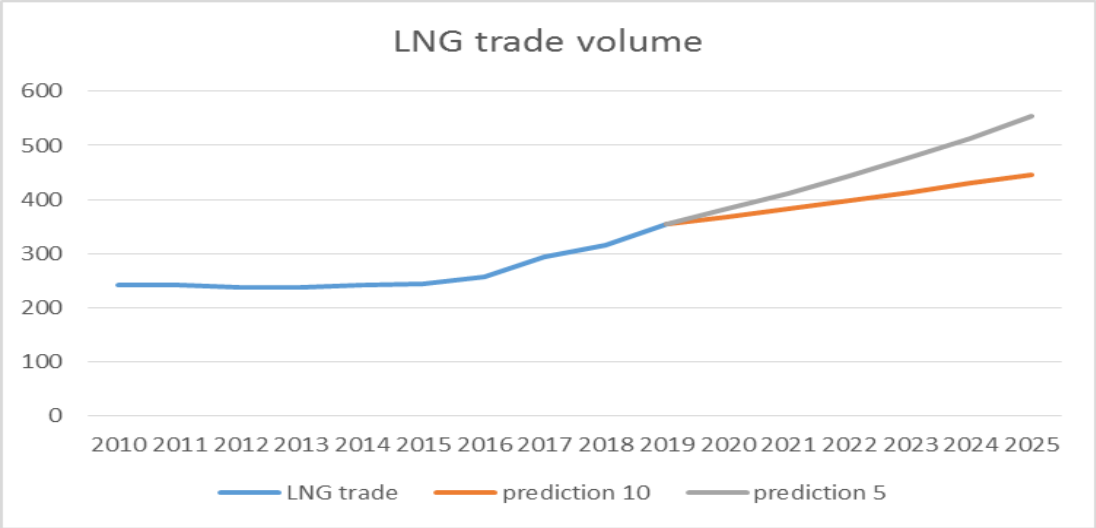

Fig. 3. LNG trade volume in Million Tonnes Per Annum from 2010 to 2019 with future prediction [7, 30, 34-41]

From 2010 to 2015, there was almost no increase in the annual LNG trade, while in the period from 2015 to 2019, there was a large average annual increase of more than 8.2%. Future predictions vary significantly depending on the type of study conducted. Ruszel [42] reports a very optimistic estimate, predicting LNG trade growth in the next five years to follow the last five annual trends (prediction 5 on the Fig. 3.), even increasing slightly more than 8.3% per year. Meza et al. [43] are more conservative in their estimate and predict that annual growth will slow down to a value between 3 and 4% (following a 10-year prediction line).

4. WORLD LNG FLEET

At the end of 2019, the total number of LNG vessels was 541 [7]. This number includes chartered vessels sailing around the world, ships waiting to load and deliver their first cargo and vessels converted into a floating terminal for the reception, storage and regasification of liquefied natural gas (in text-FSRU). Comparing this figure with the one from 2018, it is clear that the global LNG fleet increased by 3% in one year, meaning that the fleet increased by an additional 16 LNG vessels [7, 30].

Predictions for the LNG fleet worldwide indicate continuous growth, which will be fuelled with the increase in the LNG trade, as shown in the previous chapter. Predictions also take into account all vessels ordered.

5. PROPULSION SOLUTIONS ON LNG SHIPS

The decision of the type of LNG vessel propulsion is of key importance as this action affects capital and operating costs, the number of emissions, the size of propulsion compartment, the reliability of the vessel and compliance with important regulations [7].

Steam turbines are often used in the marine industry because they allow for versatile usage, in numerous combinations and systems. Steam propulsion systems are most commonly intended for engine rooms of LNG vessels and are still the dominant propulsion system for these types of vessels [44].

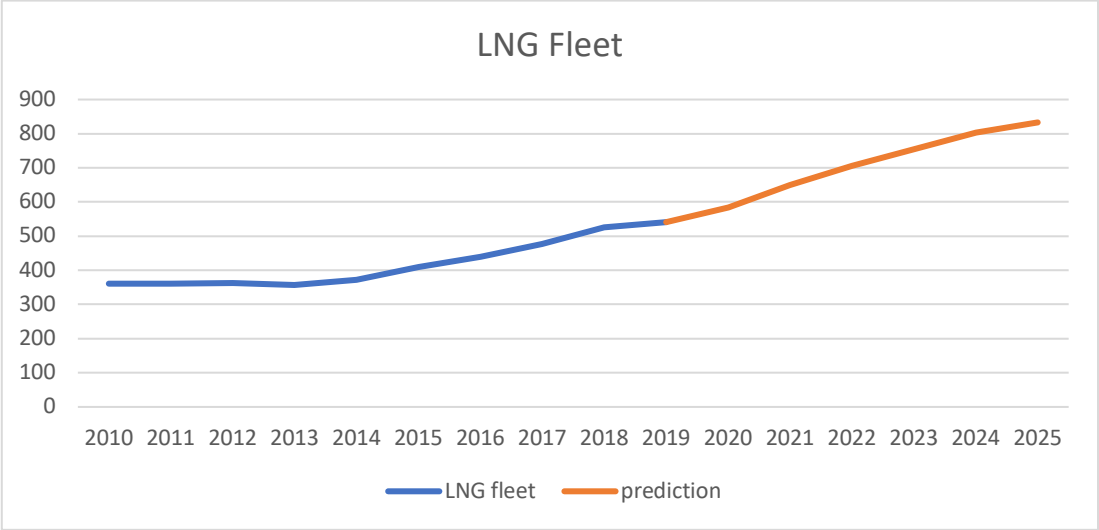

Fig. 4. Number of LNG vessels in use from 2010 to 2019 with future prediction [7, 30, 34-41]

Nearly two decades ago, the only solution on the market for LNG carriers' propulsion systems were steam turbine systems operating on boil-off gas and heavy fuel oil [7]. Today, the steam turbines as a propulsion solution for a vessel are likely to be considered outdated technology. However, one of the main benefits of a marine steam propulsion system, when compared to a diesel engine system, is that traditional steam propulsion systems, in most cases, are less prone to failures, can be quite reliable and require less maintenance. The basic internal control of such a system is simple and cheap, the turbine needs to be overhauled only once in each docking period. Intermediate inspections of steam turbine propulsion systems take place only in cases of obvious failures and thus occur very rarely [45]. As mentioned previously, the main fuel source of a steam turbine is boil-off gas from cargo tanks, or alternatively, heavy fuel oil if the previous method proves inadequate. One of the most fundamental disadvantages of a steam turbine is its low efficiency levels, operating at only 35% efficiency under fully loaded conditions. The total fleet currently consists of 224 steam turbine propulsion vessels, amounting to 41.4% of the complete fleet [7]. Currently, as a result of increased fossil fuel costs and stricter emission regulations, steam turbine ships are not being built, which shows the implementation of new and cleaner technologies within the LNG fleet. New and innovative technologies allow for more flexibility and higher efficiency while also permitting diverse sailing speeds and conditions. When compared to steam turbine propulsion, new modern-generation propulsion systems like Dual Fuel Diesel Electric engines (DFDE)/Tri-Fuel diesel electric propulsion (TFDE), low-pressured Winterthur Gas & Diesel engines (XDF) and M-Type, Electronically Controlled, Gas Injection engines (MEGI) are 25% to 50% more cost-effective and efficient depending on various parameters, but mainly on the load condition [7]. One of the first alternatives to the steam turbine propulsion system was DFDE propulsion. In 2006, it was introduced as being powered by both diesel and boil-off gas. It is able to do so in two separate working patterns, gas mode and diesel mode, powering main generators. The generators then turn electric motors, improving the overall efficiency by more than 20% compared to traditional steam turbine propulsion systems [46]. The following innovation took place in 2008 with the arrival of TFDE propulsion system vessels. This type of vessel significantly improved adaptability, as heavy fuel oil could be used as a supplementary fuel source [46]. Compared to traditional steam propulsion systems, which have the ability to operate and choose various fuel combinations under different sailing conditions, the overall efficiency increased by up to 30%. [46]. In 2019, 17 additional DFDE/TFDE vessels were delivered, resulting in 186 active vessels and comprising 34.4% of the current fleet [7].

Two engine solutions have been introduced recently. The first one is the M-Type, Electronically Controlled, Gas Injection engine (MEGI), followed by low-pressured Winterthur Gas & Diesel XDF. The MEGI engine burns pressurized gas controlled by the boil-off process supplemented with diesel fuel used additionally to increase efficiency. It consumes 15% less fuel than ships of equal dimensions with TFDE propulsion [47]. The XDF propulsion solution introduced by Wartsila injects a low-pressure

mixture of fuel and air at a desirable ratio and according to research [47], this concept leads to additional savings of 20% compared to DFDE.

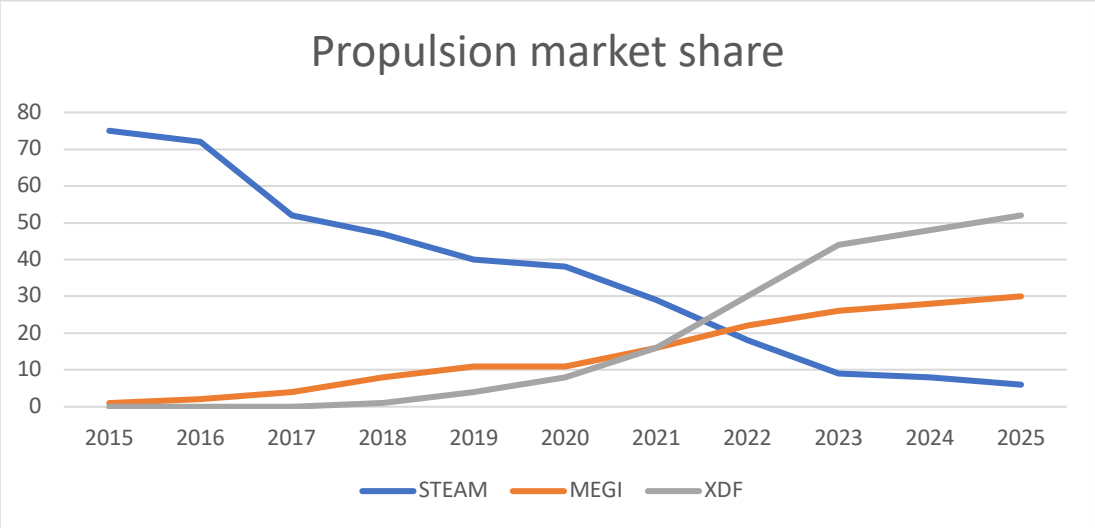

Fig. 5. Market share of different propulsion types in the period from 2015 to 2019 with future predictions [48]

The share of LNG propulsion types has already seen a gradual shift and according to the Rystad Energy forecast [48], the new propulsion types will continue to increase their market share while steam systems will gradually cease to exist as LNG ship propulsion systems.

6. DISCUSSION

The aim of this paper is to analyse the global LNG market and trade, as well as ships' propulsion systems by examining the data mainly obtained from annual editions of World LNG reports over several years. Liquefied natural gas is one of the main factors for achieving more economical and environmentally sustainable energy in the future [7], which is especially evident in the daily increase in its share in propulsion systems in shipping. The global LNG trade is increasing, continuing the trend of consecutive growth for the sixth year in a row. The LNG shipping industry has kept pace with this growth. As of end of 2019, the fleet consisted of 541 LNG carriers trading worldwide, which included 34 FSRU, with a further likelihood to grow in the future. Investment in FSRU facilities means less capital expenditure, prompt manufacture, less maintenance costs and more location flexibility to commence importing gas depending on the demand. Currently, 37 countries around the globe are importing gas, with facilities under construction in three additional countries: Bahrain, Ghana and the Philippines. On the basis of the data analysis using Excel computations, there is a clear tendency that in 2020, the LNG market will continue to grow; consequently, the number of vessels will increase and the number of countries importing the gas will surpass that of the previous year. General market growth will not affect the number of exporting countries, since the distribution of gas fields is uneven and gas production trains and terminals require high investments. The number of exporting countries will remain the same or will increase slightly.

The dynamic LNG market is demanding more flexible and efficient propulsion systems. Steam turbines are still the most prevalent on the market, but due to their low efficiency, no steam turbine vessel has been ordered for delivery at this time, indicating that the industry and market are turning to more innovative, efficient propulsion systems. In Table 1, the correlation between vessel propulsion type and fuel consumption is shown.

Active fleet propulsion types as well as the new fleet orders of LNG carriers are clearly showing which propulsion systems are currently the most preferred ones on the market. Since 2015, 48 MEGI propulsion system vessels have been delivered, with an additional 28 listed in an orderbook awaiting future delivery.[7]. At the same time, there are 16 XDF vessels in service, with an impressive 84 XDF

vessel orders out of a total of 126 LNG new build orders [7]. It is difficult to predict the future trend with certainty, the current market is replacing the steam turbine with more economical LNG fuelled engines. Future prediction implies greater demand for more efficient propulsion systems, where the XDF system and MEGI will have advantages over others and will be represented more. [49] The trends for 2020 are shown in Fig. 6 and 7, where active fleet propulsion type and order book comparisons show that there are no steam ship orders for the year 2020, and this confirms the stated assumption.

Table 1

Propulsion-type characteristics [7]

Propulsion type	Fuel consumption (Tons/day)
Steam	175
DFDE/TFDE	130
ME-GI	110
XDF	108

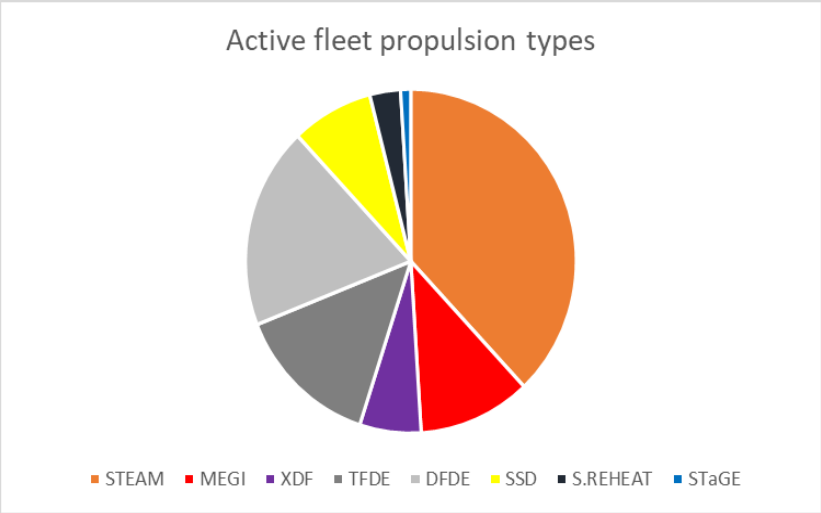

Fig. 6. Market share of different propulsion types for the year 2020 [7, 30]

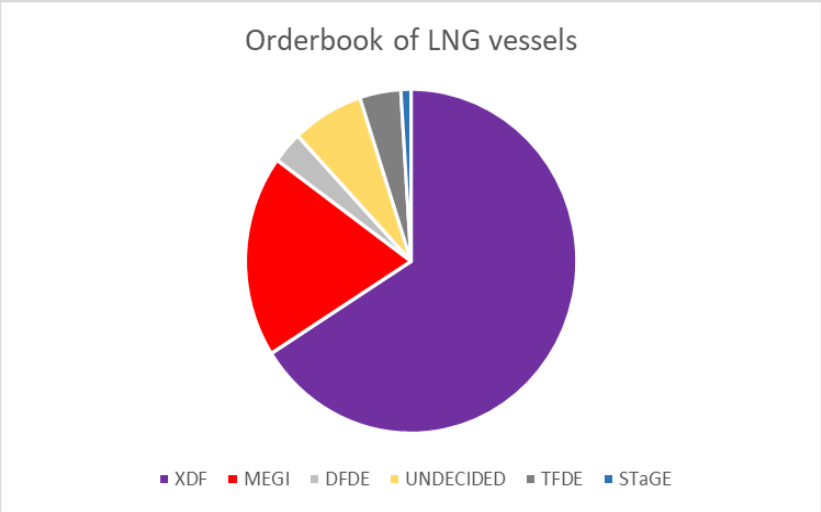

Fig. 7. Orderbook of LNG vessels [7, 30]

7. COVID 19 DISRUPTION

LNG market aspects were analysed for the period up to 2019, creating predictions for the period up to 2025. The market prediction proved wrong during the first year when the market changed due to the impact of the COVID-19 pandemic. Depending on the area, the economy of the countries dropped on average from 1.62% to 5.45%, in some cases close to 10% [50, 51]. Lockdown due to outbreak of the illness affected LNG trade in several areas as shown in Tab 2. LNG trade (Tab. 2) showed a very small increase, down by 3.4 to 6.8% compared with the predicted trade.

Table 2

Predicted vs realized

	Predicted	Realized [52]	Shortage
World LNG trade	368.6 – 382.0 Mt	351.6 Mt	3.4% - 6.8%
World LNG fleet	584	572	2%
XDF propulsion	8.4% of the world market	6.5% of the world market	cca. 2%

The slower increase of the LNG trade also affected the delivery of vessels: where "*12 vessels scheduled for delivery in 2020 to be pushed out to 2021*" [52]. This had a small impact on the propulsion market share, especially on the XDF market share, as shown in Tab. 2.

8. CONCLUSION

Analyses of the LNG market and fleet provide an insight into the overall importance of the gas transport in worldwide trade. Maritime industry is a complex system where LNG market constitutes important part with various companies. They are operating and managing specially designed vessels engaged in variety of tasks associated with LNG transport all over the world, depending on demand. This paper describes and discusses the essential parts of the gas market and trade by analysing and processing reference data taken from previous years, creating predictions for the years 2020 to 2025. The liquefied natural gas market and its global trade reached a level of 354.7 million tonnes in 2019, surpassing the previous year by 38.2 Mt, generating an annual increase of 12 %, and from analysis of the market, continuous growth in the next year can be predicted. From the results obtained, a significant increase in the number of importing countries is evident and it should continue in the near future, which we can relate to the market expansion and investments in new terminals and more financially acceptable FSRU facilities. When looking at energy sources, the share of LNG is expected to grow. According to the forecasts of the world energy agency, renewable energy sources and natural gas will be more desirable than fossil fuels (coal), which will be side-lined due to the emission control regulations, noting that this change will surely be achieved by 2035. From the period 2010 to 2019, it is evident that the worldwide LNG fleet has increased, which is associated with the general growth of the LNG market, and the results obtained confirm that the increase in number of LNG ships will continue in the following years as well. Data processing for LNG propulsion systems shows a clear tendency of the market towards adoption of new technologies that are cheaper to manufacture. Ship propulsion systems have already undergone major changes and in the future, ships will use more innovative and efficient propulsion methods, mostly XDF and ME-GI systems, and ships with steam propulsion systems will gradually disappear from the market. From the results, it can be concluded that the XDF system is slowly becoming the most preferable propulsion system in the LNG industry, which will very soon become the most common type of propulsion engine. This relatively new system is currently installed on 16 vessels in operation. At the same time, this propulsion will be installed on most LNG ships to be built in 2020 (84 XDF orders out of a total of 126 newly built vessels). On the basis of the above-mentioned results, it is evident that the LNG market is growing and thus the demand for qualified specialized operators from a range of industries will increase. All data, future predictions and calculations defined above are

based on the state of the market before the global crisis caused by the pandemic of the Covid-19 virus. The global crisis certainly affected the LNG market and trade. Although the situation is back to normal, consequences of the disruption will be visible in the near future.

The results of the analysis and predictions of the LNG market and fleet that are presented in this paper will enable analysis and prediction of the environmental impact of that sector of the shipping industry. Although LNG as a replacement fuel is increasingly being represented in the shipping industry, its propulsion type still has a significant CO_2 signature, and there is a doubt over the cost-effectiveness of this system in the future.

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