Technical University of Crete

Dissertation Title:

Liquefied Natural Gas as an alternative fuel and opportunities for Greece

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Abstract

As the environmental crisis demands for alternative fuels, one of the most promising and growing energy sources is Liquefied Natural Gas (LNG). The objective of this thesis is to study LNG as an alternative source of energy to oil, as well as to examine investment and upgrade opportunities for Greece, and more specifically, for the Skaramagkas shipyard.

In subject study, it is examined how Greece can be affected and potentially benefited from the shift towards LNG based on its long standing background and leading role in the maritime industry. In addition, it is examined how ports and shipyards can cope with the changes and with accommodating the emerging needs and vessels.

The aim of subject paper is to detect and discuss investment opportunities in the LNG market, which is growing rapidly, challenges and necessary adaptations based on requirements and technical, institutional, logistics, financial aspects in combination with information of the energy market and potential of the Greek maritime industry.

Table of Contents

1. Introduction 5
1.1. Opportunities in the LNG market 5
1.1.1. Liquefied natural gas 5
1.1.2. Maritime industry and the shift towards LNG 5
1.1.3. LNG and shipping companies 9
1.2. Greek shipping industry 12
1.2.1. History of Greek shipping 12
1.2.2. Greek shipping in numbers 12
1.2.3. Challenges in shipping 14
1.3. Shipbuilding in Greece 15
1.4. Scope and motivation 16
2. LNG as energy source 18
2.1. Technical aspects in shipping 18
2.1.1. Technical difficulties 18
2.1.2. Infrastructure 18
2.2. Logistics aspects of LNG use 20
2.3. Cost and efficiency of LNG-powered ships 20
2.4. LNG Regasification Terminals & Shipbuilding 22
2.5. Loading Base Liquefaction Procedures 23
2.6. Transportation, Storage and Distribution of LNG 25
3. Framework & Competitive Analysis 28
3.1. Institutional framework 28
3.2. Financial framework 30
3.3. The case of POSEIDON MED and POSEIDON MED II 32
3.4. International competitive analysis 33
4. Opportunities for Greece 35
4.1. Skaramagkas shipyard 35
4.2. Shipbuilding opportunities 36
4.3. Investment opportunities 37
4.4. SWOT analysis of the LNG industry 39
5. Conclusions 41
5.1. Concluding remarks 41
References 43

Table of Figures

Figure 1. 1 – Orders for LNG-ready Ships 10
Figure 1. 2 – GHG Emissions of Natural Gas compared to coal 11
Figure 1. 3 – Global LNG Trade.. 11
Figure 1. 4 - Top Ten Shipping Nations 13
Figure 1. 5 – Evolution of the Greek fleet from 2001 to 2019... 14
Figure 2. 1 – LNG import terminals in Europe ………………………………………………………… 19
Figure 2. 2 – Cost vs capacity ……………………………………………………………………… 21
Figure 3. 1 – Regulations and standards ...…………………………………………..……………..29
Figure 3. 2 – Regulations and standards concerning the liquefied natural gas supply chain …....…. 30

Table of Tables

Table 1. 1 – IMO GHG emission reduction strategy 9

1. Introduction

1.1. Opportunities in the LNG market

1.1.1. Liquefied natural gas

Liquefied natural gas or LNG, as it is frequently called, is a gas which is transformed through cooling down into a liquid form (Economides et al., 2005). In this liquid form it is easier for it to be transported safely in a non-pressurized storage. In comparison to other types of fuels, natural gas was regarded as unimportant financially in the past, because it was not as easy to transport or store in comparison to other fuels (Langevin, et al., 2004). Oil, for example, which is in liquid form, has been a lot easier to store and transport and gas was reduced to a local product where it could be consumed within the local network and community where it was produced (Cheng & Duran, 2004).

As global warming and its consequences have become an important issue within human society, industries are turning towards alternative fuels and they are moving away from oil and coal to minimize their emissions and to follow new governmental guidelines. These guidelines were set originally by the Kyoto protocol, and currently by the Paris Agreement (Grubb et al., 1999; Savaresi, 2016). Furthermore, LNG supplies have increased over the years and with the need to reduce harmful emissions the interest of the maritime industry has shifted towards using LNG as an alternative marine fuel (Kumar, et al., 2011). Federal agencies of different countries are now interested into researching and funding projects with regards to the use of LNG as an engine fuel (Parfomak et al., 2019).

1.1.2. Maritime industry and the shift towards LNG

The International Maritime Organization (IMO) in 2008 created a timeline, as presented in Table 1.1, which required vessel fuels to reduce their sulfur content to 0.5% (Sulphur I.M.O, 2020). This requirement had to be implemented prior to January 1, 2020 (Nengye, & Maes, 2010). This was decided in the International Convention for the Prevention of Pollution from Ships, and it can be found in Annex IV of that convention (MEPC, 2011). The requirement stated that the vessel fuel had to have only 0.5% of sulfur in it and there was a suggestion to install exhaust-cleaning systems (Endres, et al., 2018) such as scrubber systems. These systems would help limit the vessels emissions that were airborne. More specifically, these sulfur oxide emissions would fall to a level of 0.5% from the current sulfur content of 3.5% in the commonly used in the marine industry, Heavy Fuel Oil (HFO), by simply using these aforementioned cleaning systems (Seddiek, & Elgohary, 2014).

YEAR	REGULATIONS	PROJECTS/IMPLENTATION SUPPORT
2011	Adoption of **mandatory energy efficiency regulations** for ships under MARPOL Annex VI – Energy Efficiency Design Index (EEDI) for new ships, Ship Energy Efficiency Management Plan (SEEMP) for all ships (15 July 2011)	**IMO-KOICA** (Korea International Co-operation Agency) GHG project on building capacities in East Asian countries to address GHG emissions from ships
2012		"Mitigation of climate change" Global Programme included in IMO's Integrated Technical Cooperation Programme (ITCP), later renamed as **"Energy Efficiency" Global Programme**
2013	**EEDI and SEEMP** enter into force	**Adoption of resolution on promotion of technical cooperation** and transfer of technology relating to the improvement of energy efficiency of ships (MEPC.229(65))
2014	Approval of the **Third IMO GHG Study 2014** (October 2014)	
2015	**EEDI phase 1 in effect** – 10% reduction in carbon intensity of new ships	**Global Maritime Energy Efficiency Partnerships Project (GloMEEP) launched** with 10 lead pilot countries – a Global Environment Facility (GEF)-United Nations Development Programme (UNDP)-IMO project
2016	**Adoption of a mandatory IMO Data Collection System (DCS)** for ships to collect and report fuel oil consumption data from ships over 5,000 gt	
2017		**Global network of five regional Maritime Technology Cooperation Centres (MTCCs) launched** under IMO-executed GMN project, funded by the European Union **Low Carbon Global Industry Alliance launched under GloMEEP project** to support an energy efficient and low carbon maritime transport system
2018	**Adoption of the IMO Initial Strategy on reduction of GHG emissions from ships**,	**GloFouling Partnerships project launched** with 12 lead countries to tackle biofouling

	with a vision to reduce GHG emissions from international shipping and, as a matter of urgency, aiming to phase them out as soon as possible in this century and setting levels of ambition and set of short-, midand long-term candidate measures (April 2018)	on ships to address bioinvasions and support energy efficiency gains through cleaner hulls. A Global Environment Facility (GEF) -United Nations Development Programme (UNDP)- IMO project
2019	**IMO adopts procedure to assess the** impacts of States of candidate measures First year of **mandatory reporting of fuel oil consumption data** to the IMO Data Collection System	IMO **GHG Technical Cooperation Trust fund** established IMO **Symposium on IMO 2020 sulphur limit** and Alternative Fuels Resolution adopted on **voluntary cooperation between ports and ships** to reduce emissions (resolution MEPC.323(74) of May 2019) **IMO-Norway GreenVoyage2050 Project is launched** to support implementation of the Initial Strategy and pilot project demonstrations (May 2019)
2020	**Approval of the Fourth IMO GHG Study 2020** (November 2020) **EEDI phase 2 in effect** – up to 20% reduction in carbon intensity of new ships	**GloFouling Global Industry Alliance established** to address biofouling **IMO-Republic of Korea GHG SMART project launched** to develop training to support developing States to reduce GHG emissions from shipping (October 2020) Launch of **IMO -EBRDWorld Bank FIN-SMART Roundtable** on Financing Sustainable Maritime Transport (October 2020) Resolution adopted on **Encouragement of Member States to develop and submit voluntary national action plans** to address GHG emissions from ships (resolution MEPC.327(75) of November 2020)

2021	**Adoption of short-term measures (EEXI, CII) to reduce carbon intensity** of all ships by 40% by 2030, compared to 2008 Aggregated **results of the 2019 fuel consumption data collection system** **(DCS)** published for MEPC 76 (March 2021)	**IMO Symposium on alternative low-carbon and zero-carbon fuels** (February 2021) **IMO-Germany Blue Solutions Project** for Asia project established (April 2021) **IMO-Singapore NextGEN project launched** to connect decarbonisation initiatives (April 2021)
2021	**Initiate consideration of mid-term measures** under Phase I of the Workplan (October-November 2021) **Further consideration of assessment of** **impacts on States** of candidate GHG measures (October- November 2021) **EEDI phase 3 in effect for certain ship types** with up to 50% carbon intensity reduction for new build large containerships	IMO-UNEP **Maritime Zero-Low Carbon** **Innovation Forum** (September 2021)
2022	**EEXI survey requirements take effect** (November 2022)	
2023	**Carbon intensity measures** enter into effect **Revision of the IMO Initial GHG Strategy** **Start of carbon intensity data (CII) collection** under the short-term measure	
2024		
2025	**EEDI phase 3 in effect** - up to 30% reduction in carbon intensity for newbuild ship	
2023	**IMO Initial GHG Strategy objective of** **40% reduction** of CO2 emissions per transport work compared to 2008, as an average across international shipping	
2050	**IMO Initial GHG Strategy objectives of 50% reduction** of the total annual GHG emissions and 70% reduction of CO2	

	emissions per transport work compared to 2008 whilst pursuing efforts towards phasing them out - as a point on a pathway of CO2 emissions reduction consistent with the Paris Agreement temperature goals	

Table 1. 1 – IMO GHG emission reduction strategy

Another option that was also identified for ships, so they could meet the criteria and the requirements set by the IMO 2020 in reducing dangerous emissions into the atmosphere was to install engines that would be powered by LNG fuel (Bilgili, 2021). The LNG fuels will only emit trace amounts of sulfur in the atmosphere which is a lot less harmful emissions in comparison to traditional fuels. The main issue with installing new LNG engines is the capital cost, as simply installing a cleaning system is a lot cheaper. Recent studies, though, have suggested that LNG is a cheaper fuel in the long term when it is compared to more traditional fuels such as HFO (Obydenkova et al., 2017; Sharples, 2019). This has slowly pushed shipping companies towards commissioning new ships that will use LNG fuel, and more ports are slowly developing LNG appropriate infrastructure (Zhang et al., 2015).

1.1.3. LNG and shipping companies

Many shipping companies are now shifting their focus on acquiring new vessels that have LNG powered engines (Greer et al., 2005). In late 2017 Unifeeder shipping company were the first to have a container vessel that was powered by LNG and Shell had also followed a similar path by ordering an LNG dedicated bunker vessel. Other companies followed suit with the Maersk Group planning on introducing in their fleet container ships that were fuelled by LNG (Lee, & Nam, 2017). In 2018 and 2019 respectively, another company, Crowley Maritime of Jacksonville had two ship launches, both of which were LNG powered (Adamo, 2018). As presented in Figure 1.1, LNG-ready ships are expected to increase to 141 by 2026, with the orders increasing gradually.

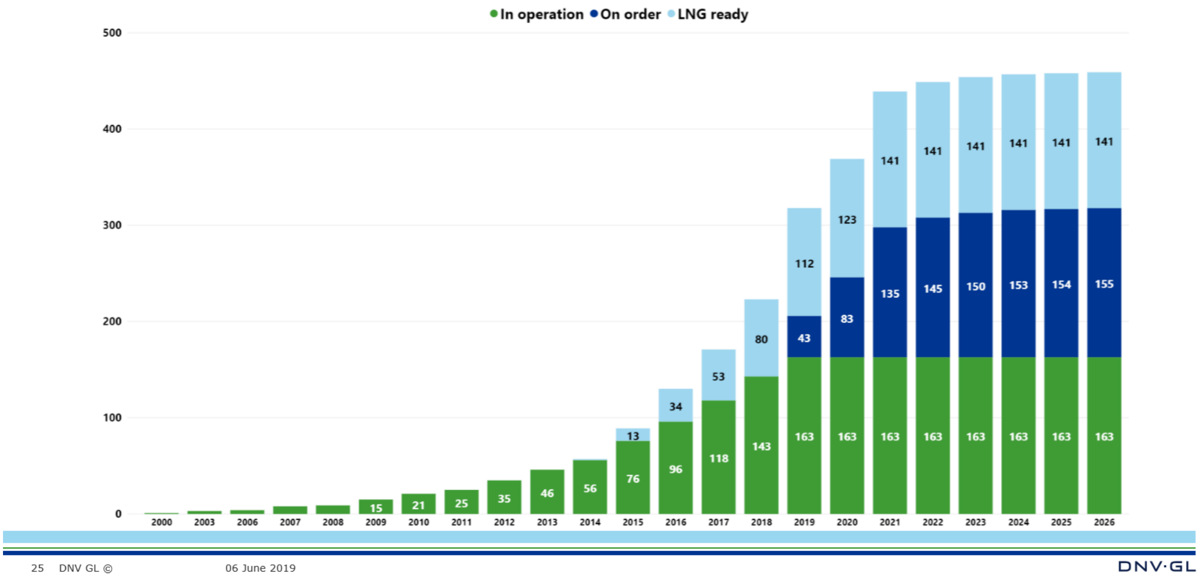

Figure 1. 1 – Orders for LNG-ready Ships

As previously mentioned, the International Convention for Prevention of Pollution from Ships (MARPOL) forced vessels to reduce their sulfur emissions, as adopted by the IMO (Farnelli, 2017). This requirement was not only limited to International Waters, as it was also adopted by different countries for their coastal areas (Sulphur I.M.O, 2020). The current estimations are that by 2030 the LNG bunker fuels will grow to be worth several billion dollars. BHP, which is the world's largest mining company, began commissioning LNG powered vessels at the end of 2012 (Cleary, 2011). New reports stated that in January 2021 there were currently in service 175 LNG powered vessels and 200 more vessels that will use LNG powered engines had been ordered by shipping companies (Purio, 2019).

Figure 1.2, sourced by the International Group of Natural Gas Importers, presents the carbon savings when LNG is used for power generation, compared to coal and indicates its importance as a method towards decarbonisation, on a lifecycle basis. As seen in this chart, the Greenhouse Gas Emissions of LNG are almost half compared to coal, making it a strong alternative to coal.

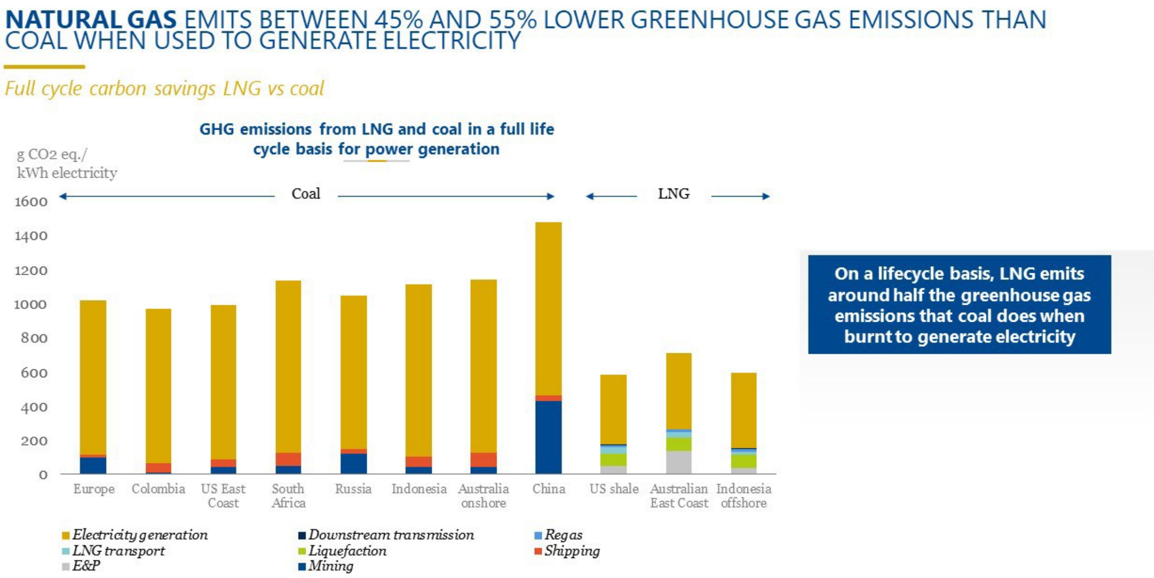

Figure 1. 2 – GHG Emissions of Natural Gas compared to coal

At the same time, according to Figure 1.3, the global LNG trade has been increasing from the year 1971 until 2020. In more detail, LNG trade has grown at approximately 11% per year, as an average. In numbers, this indicates a rise from 2.6 MT to 356.1 MT during the above mentioned period, while the cumulated number of LNG deliveries exceeded 110.000 in 2020.

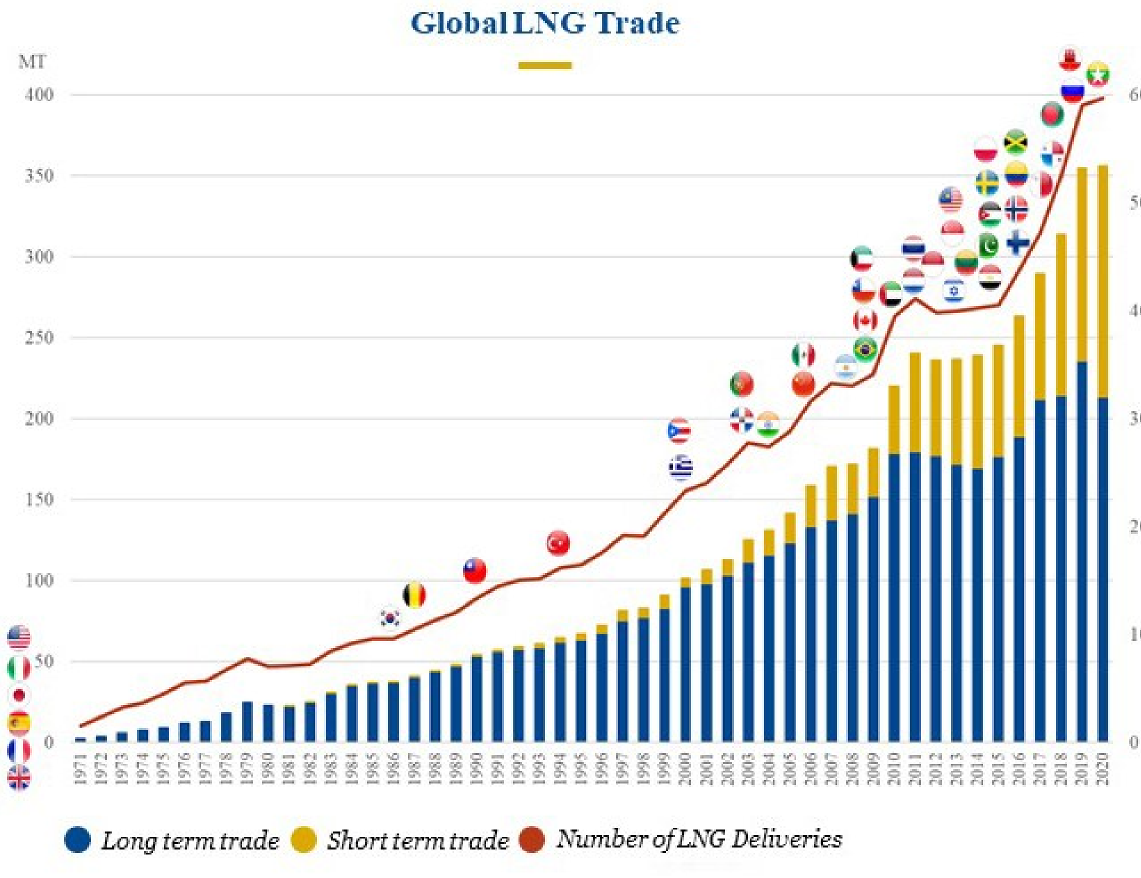

Figure 1. 3 – Global LNG Trade

1.2. Greek shipping industry

1.2.1. History of Greek shipping

Greece is a maritime country and has a longstanding tradition in shipping (Harlaftis, 1993). In Greece, shipping has been a part of the country's history since the ancient times. Due to the country's landscape, which is rocky, but also surrounded by coastline, the locals were pushed towards the sea and shipping (Terkenli, 2004). The unique geopolitical position in the Mediterranean Sea and its proximity to a number of islands were the reasons why Greece became a crossroad for different civilizations and trading roads in ancient times (Bresson, 2015).

During the Bronze era, the Minoans and the Myceneans were amongst the first ancient Greeks to create shipping empires and expand their trade with other civilizations in Egypt, Asia Minor, Phoenicia, the Black Sea, and create colonies in Italy (Reed, 2003). The important role Greece had in shipping, continued during the Byzantine Empire. Despite being under the Ottoman rule for over four hundred years, that did not stop the shipping activities of the Greeks. Any attempts made by the Ottomans to regulate the shipping trade did not deter or effect the Greeks from illicitly continuing their trade (Harlaftis et al., 2008).

The Treaty of Küçük Kaynarca helped the Greek vessels overtake other foreign vessels in the area as they were protected by the Russian Empire (Harlaftis, 2005). The shipping companies and the ports that worked with the Greek shipping families became the hubs of the Greek revolution. The significant role these hubs had in the revolution has been well documented (Wrigley, 1987). In more recent times and during the Second World War, Greek companies would work in areas controlled by the allies and the Greek fleets were under the control of the British Merchant Marine (Harlaftis, & Chlomoudis, 1993). Currently Greece continues the long tradition of being a maritime nation and has a significant role in the current shipping industry.

1.2.2. Greek shipping in numbers

Between the years of 2010 and 2011, Greek shipping companies owned 23.8% of the world's bulk carriers and 32.5% of tankers (ECSA, 2011). When new orders for ships were accounted for, Greek shipping companies had ordered 14.1% of the new bulk carriers that would be built and 20.05% of the new tankers to be built. In addition, the Greek shipping industry earned €35.4 billion in 2014 and there is an estimation that, between the years of 2000 to 2010, the Greek industry earned a total of €280 billion (Bragoudakis et al., 2013). The European Community Shipowners' Associations in their report for the years 2013-2014 stated that the Greek flag in international shipping is the most used flag. Making it the number one European flag used in international shipping and the report also revealed that there were 950 Greek shipping companies in operation during the time of the report (Artuso, et al., 2015).

According to figures released in 2018, the shipping industry in Greece is valued at $21.9 billion and the value increases further when other businesses that are related to shipping are added to this amount to $23.7 billion (Papathanasiou et al., 2020). The shipping industry in Greece is an important employer for the country with 392.000 people working in this industry. This number of employees in the shipping industry translates to 14% of the Greek work force and it contributes to 1/3 of the country's deficit for trade (Argyriou, 2021). Furthermore, in 2018 the Greek Merchant Navy was said to control the largest merchant fleet in the world, with an estimate Deadweight tonnage (DWT) of 834,649,089 tons. According to Lloyd's List, the Greek-owned fleet consisted of 5.626 vessels in 2018. In addition, Greece is found in the top positions in all the different types of ships which also includes the first position for Greek owned bulk carriers and tankers (Bissias, Kapetanakis, 2018). More information on this is presented in the Figure 1 that follows.

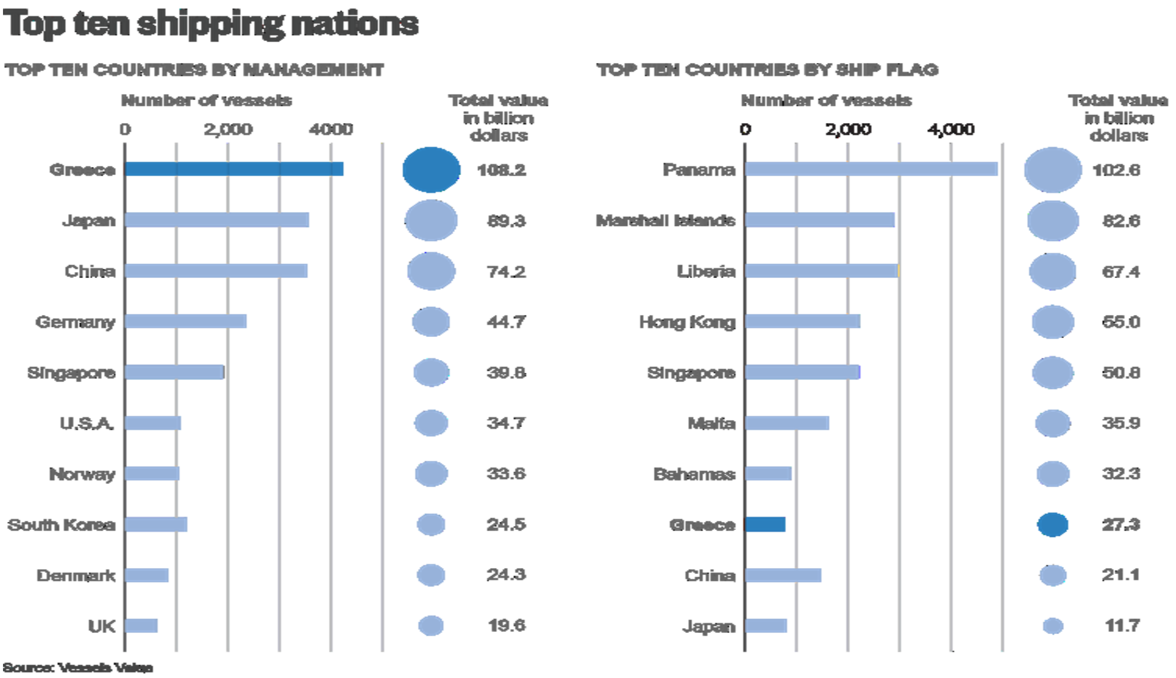

Figure 1. 4 - Top Ten Shipping Nations

As per Figure 1.5, the Greek fleet has shown a tremendous increase in DWT from year 2001 until 2019, with a high of 427m, when the starting point was 150m in 2001. At the same time, there has been gradual increase also in the number of vessels in the Greek fleet, with a highest amount of 75.922 ships in operation in 2019. The age of the Greek fleet tends to decrease in the latest years, which makes it more energy efficient and therefore, competitive.

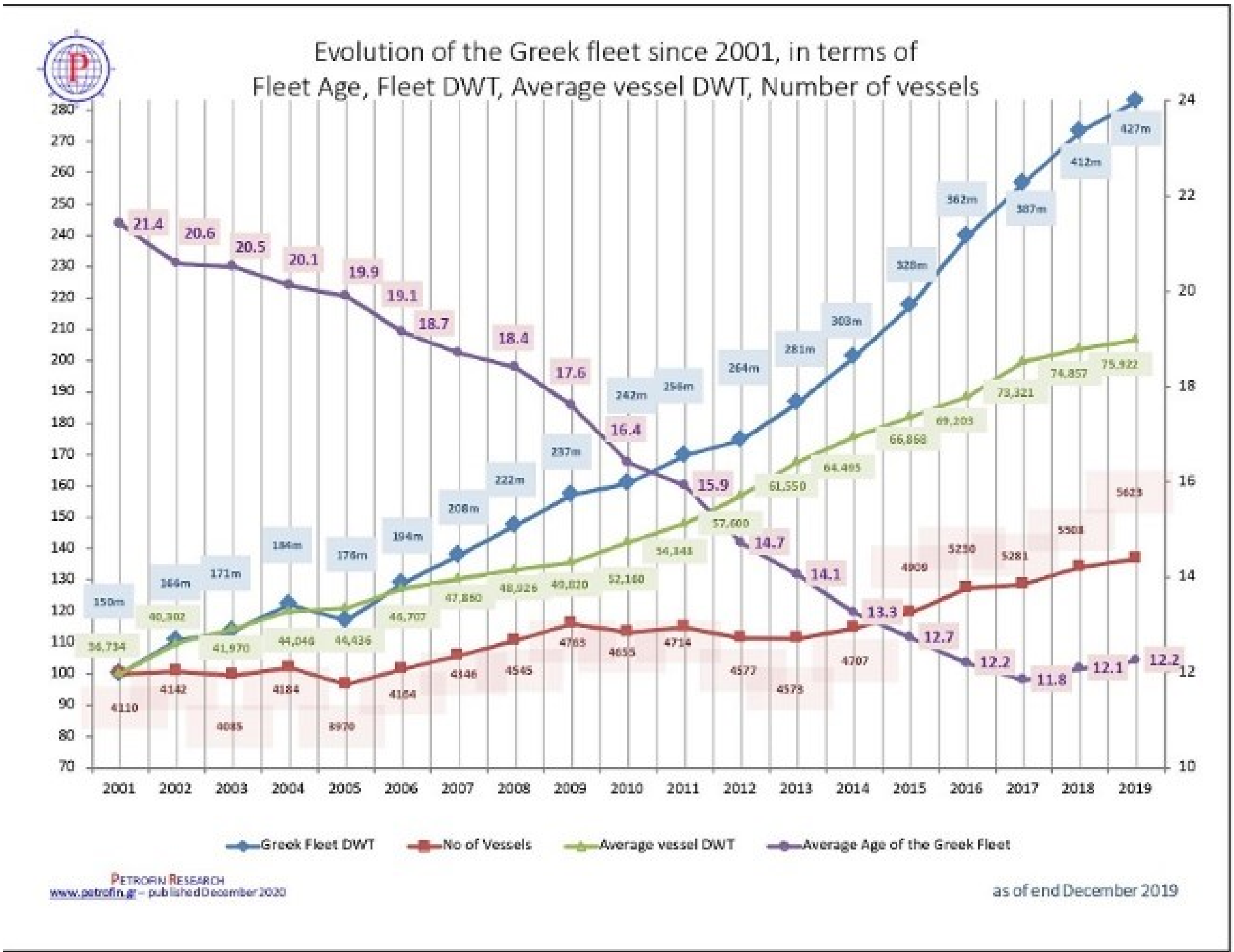

Figure 1. 5 – Evolution of the Greek fleet from 2001 to 2019

1.2.3. Challenges in shipping

Climate change in recent years has become the greatest environmental threat that the world is dealing with, due to the devastating consequences of the earth's rising temperature (Change, et al., 2006). The United Nations and the Framework Convention on Climate Change have stated the need for effective measures to be put into place so that the Greenhouse Gas (GHG) concentrations that are released in the atmosphere can be stabilized and reduced to a level that could potentially prevent the impact of climate change (O'Neill, & Oppenheimer, 2002). The first step that was taken to combat climate change was the Kyoto Protocol (1997) that created certain targets that were binding and limits that were mandatory for GHG emissions for the European Union and for the most prominent industrialized countries in the world (European Council, 2002). These targets for reducing GHG emissions were also enforced into different industries.

For the marine industry, proposals were made for both operational and technical measures to ensure their co-operations with the Kyoto Protocol (Oberthür, 2003). The International Maritime Organization (IMO) and the Marine Environment Protection Committee (MEPC) were the agencies responsible for taking into account the Kyoto Protocol and regulating the GHG emissions for the shipping industry. They were tasked with creating incentives for shipping companies to comply with the new measures to reduce GHG emissions (IMO, 2009). The necessity to reduce GHG emissions in the maritime industry has pushed for the creation of a framework for regulation by the IMO (Van Dender, & Crist, 2009).

1.3. Shipbuilding in Greece

In this chapter it was discussed that Greece has had a long history in the maritime industry and it also has a long history in shipbuilding. There are different shipbuilding companies in Greece, from smaller ones, such as Motomarine, which was founded in 1962 and is focused predominantly on boats used for recreational purposes and coastal patrol vessels. The latter vessels mentioned are used by the Greek Coast guard (Akkerman, 2019). Other shipbuilding companies in Greece have been a part of Greek shipping prior to the Greek revolution and all of this will be discussed in the following sections.

One of these historic companies is Basileiades, which was founded in 1859 in Piraeus and was the largest company in its field in Greece before World War II (Deligianni, 2018). It was one of the largest shipyards in the country during the beginning of the 20th century. This company played a significant role in the Industrial Revolution that occurred in Greece.

Chalkis Shipyards, which was founded in 1971, has two floating docks and in Greece it is considered one of the largest shipyards currently in operation (Kotrikla, 2009). Furthermore, the company is aiming to invest more than €100 million as it works closely with both the Hellenic Centre for Marine Research and the National Technical University of Athens to create new turbine technologies.

Another shipbuilding company that was founded in 1968 was Elefsis Shipyards, which has constructed many different types of vessels (Spyridakis, 2006). In 1997 it acquired Neorion shipyards in Syros, which was a traditional shipyard that constructed ships for the Greek revolution. Neorion was founded officially in 1861 and its main purpose was to support the Greek Steamship Company (Tzamouzakis & Spathi, 2017). The acquisition of Neorion by the Elefsis Shipyards helped the company improve their struggling financial situation, but the financial crisis affected them significantly once more.

The Hellenic Shipyards or otherwise called Skaramagas Shipyards, which took its name from its location, was founded in 1937 to build warships for the Royal Hellenic Navy and originally the shipyard belonged to the Royal Navy (Spyridakis, 2006). The shipyard was destroyed in 1944 during the Second World War after it was bombed by the Allied. Prior to this, a significant investment had been made in the shipyard. An order of submarines and 12 destroyers was under construction prior to it being bombed. It started its operation again in 1957 after it was purchased and rebuilt by Stavros Niarchos, and the facilities were significantly expanded (Vlachos, & Lazopoulos, 1998). It continued to build military ships but their work also expanded to other areas beyond the maritime industry. The company was later sold in 2002 to

German investors and specifically to the German shipyard Howaldtswerke-Deutsche Werft (HDW) (Papaioannou, 2003).

The company was not managed appropriately by the German investors which caused not only for the number of employees to be reduced significantly from an all-time high of 6700 employees in 1975 to only 1300 in 2009, but also for the shipyard to enter into a period of constant decline (Spyridakis, 2016). In 2010, the majority of the shipyard and specifically 75.1% was sold by the German investors to the Abu Dhabi Mar company (Spyridakis, 2018). It is evident that Greek shipbuilding companies have a long history which started prior to the Greek revolution and continues to present day Greece. Over the years the different shipyards have faced challenges from World Wars to financial crises and some have withstood the test of time, while other have been bought out or merged with other companies.

In addition, the Greek shipbuilding industry has been in crisis due to the competition from countries with low labour costs. Because of international competition, efforts towards implementing structural changes in Greek shipyards have been made, in order to increase competitiveness and, eventually, enjoy high profitability.

The main factors fuelling these changes are privatisations, programmatic agreements with the Greek state, the move towards building vessels not easily built in low-labour-cost countries, and technological and organisational modernization (Soumeli, 2000). Important aspects in this improvement are changing the sector's relationship to the financial system, as well as creating a unified policy at European level, in order to compete at international level.

1.4. Scope and motivation

It is evident that Greece has a significant place in the maritime industry and its shipyards have over the years built ships both for commercial use but also for military use. The impact Greece has on the maritime industry is continuous, but as global warming came to the forefront for the global community, the changes needed and legislations put in place to help the ecosystem fromcollapsing have had an impact on the maritime industry. The Kyoto Protocol and the Paris agreement require drastic changes from countries and industries in the years to come and the maritime industry took this into account and changes are slowly being made. The LNG is slowly becoming a promising future fuel for the maritime industry and more and more companies are commissioning new LNG fueled ships.

The importance of this study is found in examining how these changes towards a more environmentally friendly fuel can affect Greece and its position in the LNG industry. How the existing shipyards can cope with the ever-changing landscape and what the future holds for them. How LNG became the future of maritime fuels and the necessary changes that need to be addressed for both the port and the shipyards to accommodate these new vessels. Each aspect of the study that will be examined can potentially show what the expectations for the future of the maritime industry are.

The aim of this study is to examine these new emerging changes in the maritime industry with a specific focus on the Greek maritime industry and Greek shipbuilding. More specifically the objectives of the study are the following:

- To examine LNG as an alternative energy source and marine fuel
- To examine investment and upgrade opportunities for the Skaramagkas shipyard

2. LNG as energy source

2.1. Technical aspects in shipping

2.1.1. Technical difficulties

Using LNG in ships as fuel is not something new for some operators as they have been using this type of fuel to power their vessels for more than 40 years. LNG as ship fuel has become more prominent and mainstream as was stated in the previous chapter due to environmental pressures placed on shipping companies by the IMO in order to reduce the harmful emissions that they release. The use of LNG as fuel for ships has been tested on more than 35 non-LNG carrier gas-fuelled vessels that sail predominantly in Northern Europe (McFarlan, 2020).

One issue that was identified was that the tanks used to store LNG fuel can be space-consuming and have an effect in the ship's productivity but also the ships transportation earnings. The space that is needed to accommodate the whole system for an LNG engine with the cylindrical-shaped fuel tank onboard is three to four times larger than an oil system which is commonly used in vessels. Furthermore, in comparison to diesel fuel, LNG volume is 1.8 times larger, so space is once again an issue for LNG vessels (Thomson et al., 2015). Another technical issue that has been identified in the use of LNG-fuelled vessels or dual fuel engines is that they emit in the atmosphere unburnt methane (CH4) (Greer, Richardson & Sandstrom, 2005).

These emissions diminish the overall "good" environmental performance of LNG fuel powered ships. It is important to take into consideration the potential safety risks that are associated with operating LNG fuel powered vessels and to establish approaches for safety risk assessment that will be common for all LNG ships. Furthermore, certain risk acceptance criteria for vessels that are LNG powered and bunkering procedures need to be established to protect the crews on board but also the environmental impact these new vessels will have (Greer, Richardson & Sandstrom, 2005).

2.1.2. Infrastructure

Currently the literature surrounding the use of LNG as a fuel to power vessels has come to a consensus that the main challenge faced for the further development and establishment of LNG as marine fuel is the lack of infrastructure. The lack of bunkering infrastructure in combination with the lack of a distribution networks that can deliver LNG to the ships affects the use of LNG fuel in vessels (Lee & Nam, 2017). The problem lays with bunker suppliers currently being unwilling to invest money into the infrastructure that is needed until they are sure that there is a sufficient demand to supply LNG fuel in commercial shipping. Simultaneously, the shipping companies and ship owners will not invest money into purchasing ships powered by LNG fuels if LNG suppliers are limited (McFarlan, 2020).

The number of LNG bunkering methods that are in use today are four, which are the following. Ship to ship, LNG portable tank, terminal (loading arm)-to-ship and truck to ship. For the LNG market development to start there needs to be at least the minimal bunkering infrastructure. The European Commission suggested that LNG refuelling stations need to be installed in every port both inland and maritime in the European core network. The date that these refuelling stations needed to be implemented was 2020 for the maritime ports and for the inland ports the year is 2025 (Bithymitris & Spyridakis, 2020). The aim of the above measure is for 139 EU ports which amounts to 10% of EU ports to have the above refuelling stations.

It is believed that the issue of investments being made in the LNG infrastructure can be solved by government initiatives and involvement. This involvement can be through finding LNG projects, tax reduction and subsidies (Grubb et al., 1999). Over the past few years, the EU has invested into the development, support and introduction of LNG bunkering infrastructure. The funding for the aforementioned project came from Trans-European Transport Network (TEN-T). Some public port authorities in European cities (Rotterdam and Antwerp) have taken the initiative and created their own emissions regulations within the port which gives discounts to owners who use clean fuels to power their vessels (Schinas & Butler, 2016).

The financial support and initiatives that governments now offer to build LNG infrastructure have also helped move the process forward and support the use of LNG as a ship fuel (Grubb et al., 1999).

Based on Figure 2.1, import terminals in Europe were in operation in Q4 of 2022, with Spain holding the first position in such infrastructure, while projects for new terminals had been planned, in order for Europe to become more autonomous regarding its energy supply. This has been a result also of the war between Ukraine and Russia, as the latter used to be the main natural gas vendor for LNG supply in Europe.

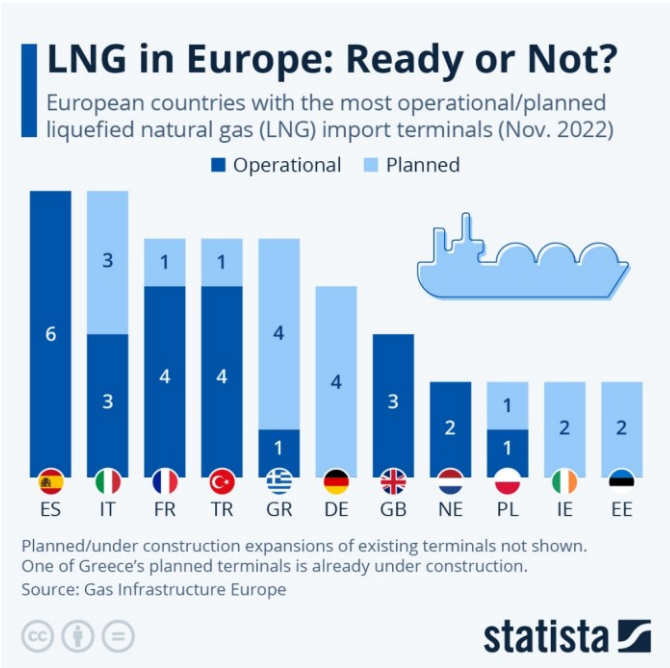

Figure 2. 1 – LNG import terminals in Europe

2.2. Logistics aspects of LNG use

A route that a ship takes is usually regulated and it is on a specific schedule. However, changes can happen to the route due to competition but most of the time the route remains the same. The European LNG bunkering landscape is concentrated in northern Europe as all the LNG bunker opportunities are located in that area and very few can be found in the Mediterranean ports. It is important to have these facilities available at different ports not only in Europe but throughout the world, as shipowners would then invest on vessels powered by LNG fuel. This would mean that the reliance on pipelines to transfer LNG would be reduced and it would boost the development of LNG receiving terminals which cost less than pipelines (Thomson et al., 2015). The current methods of LNG bunkering which have been discussed previously, have certain benefits which is why they are used in certain ports instead of creating new bunkering infrastructure (Grubb et al., 1999).

The ship-to-ship fuelling method is carried out using barges, as there is no need for infrastructure to be built and the bunker barges are also very flexible. These barges can be moved to different locations depending on where the demand is found and their flexibility is useful in ports where manoeuvring is difficult. The barge can supply the ship with LNG fuel without the vessel having to move from its location. This type or refuelling LNG ships can be found in some European ports, for example Spain, the Netherlands, France, Belgium, and the UK (Bithymitris & Spyridakis, 2020).

Furthermore, there is the method of using portable tank containers which are stored on board and are often identified by the 'LNGPac' which is written on them. It is another interesting concept that was founded in 2010 by Wärtsilä. The issue with the above innovation is that it has not been tested sufficiently, which could cause some concern over safety issues (Langevin et al., 2004). However, this has not stopped the company from signing different agreements to fit this type of technology on existing vessels and buildings that operate in different European rivers. The company revealed that in 2012 they had carried out 14 LNGPac installations.

2.3. Cost and efficiency of LNG-powered ships

In 2005, the prices of newly built ships exceeded \$200 million each, while in mid-2008 the prices reached \$250 million, the highest point of all time. The \$250 million price of an LNG carrier was driven by factors ranging from a weakening dollar exchange rate and tightening monetary policies to a lack of capacity for shipbuilding and high steel prices. At the end of 2005, prices were expected to be seen to have fallen to \$160 million per ship (Herdzik, 2011). Shipowners' capital expenditures fell by about 10% compared to ship orders in 2009 when prices ranged from \$225 million for a 173,000-cubic-meter vessel. From Figure 2.2 it is visible that the capital cost per ship decreases as capacity increases, resulting in more appealing deals for vessels with greater tonnage.

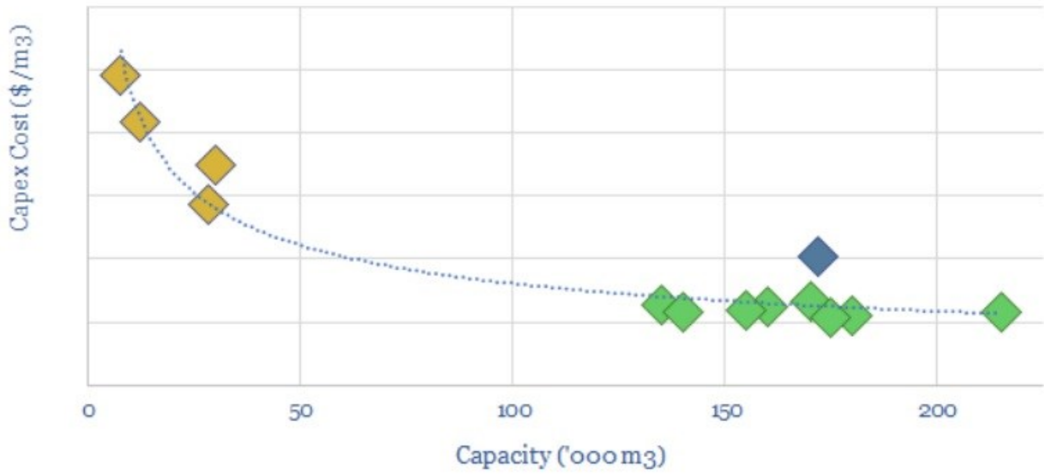

Figure 2. 2 – Cost vs capacity

Korean shipyards, due to suffering from the overall decline in shipping, were quite aggressive in their pricing, forcing Japanese and Chinese shipyards to also offer competitive bids for new ships. The cost of capital has a large share in the total cost of the project and low prices during periods of low fares lead shipowners to place new orders (Yoo, 2017). Before referring to the tendency of shipowners to order such ships, the costs arising from their purchase will be identified. Operating costs, which are included in the variable costs are related to the ship's staff, repairs and maintenance, insurance, supplies, spare parts and finally management costs. The amount of operating costs, depending on the ship, ranges from 15% - 35% of the total cost of the ship and is independent of the type of charter (Najm & Matsumoto, 2020).

The structure of these costs depends on factors such as its size, the nationality of the crew, the political maintenance of the ship by the shipowner, the age and insurance value of the ship as well as the administrative efficiency of the company's management. Liquefied natural gas transport vessels are advanced vessels that require highly qualified, specialized crews. The costly procedures concern the maintenance and repair of the ship especially when an old ship is under discussion. These costs can be divided into three categories which are routine maintenance, repairs resulting from mechanical or other damage and the periodic mandatory maintenance required by the classification society to maintain the ship in its class (Herdzik, 2011).

In terms of insurance costs, this varies between 15% - 40% of the operating costs and the largest percentage is determined by the insurance of the vessel and the engine. Finally, we have the travel costs which is the most expensive category of expenses for a ship and consists of fuel costs, port costs, canal charges, cargo handling costs and the cost of additional insurance (Schinas & Butler, 2016).

Regarding the supply and demand of liquefied natural gas in 2020 and more specifically in the second quarter of 2020, the demand for liquefied natural gas amounted to 86 million tons compared to 87 million tons for the corresponding period of 2019. Based on this, there was a reduction of about 2%. Chinese demand rose by 20% year-on-year, to 16 million tonnes, while demand from the Middle East rose by 39% to 5 million tonnes (Najm & Matsumoto, 2020).

On the other hand, demand from Asia, excluding China, fell by 8%, while demand from Europe slipped by 3% (Najm & Matsumoto, 2020). In the USA there was a 39% increase as a result of enhanced production from large projects. This growth was offset by declining production in the Middle East and North Africa by 2 million tonnes or 8% (Najm & Matsumoto, 2020). It is estimated that a 174,000 m^3 LNG corresponds to approximately 80,000 DWT. Therefore, its price is comparable to the corresponding Panamax for Bulk carriers and the Aframax for tanker vessels. In 2021 a newly built 174,000 m^3 LNG ship will cost $186 million, while in 2019, 2018 and 2017 it would cost $186 million, $181 million and $186 million respectively (Wan, Yan, Zhang & Yang, 2019).

In the Bulk Carriers category, the LNG can be compared to the Kamsarmax (type of the Panamax category) where it costs the yards $26 million, while for the years 2019, 2018 and 2017 the prices were $29 million, $28 million and $25 million dollars, respectively. In the tanker category it is possible to compare to the Aframax of 115,000 DWT, as there is no data for a smaller ship of around 80,000 to 85,000 DWT. An Aframax cost $47 million at the beginning of 2021, while for the years 2019, 2018 and 2017 the prices were at $49 million, $47 million and $44 million dollars, respectively (Najm & Matsumoto, 2020). An order announced in early 2021 for a LNG ship valued at $182.9 million was ordered by Russian shipowners at Hyundai shipyards in Korea. The delivery of the ship will take place in 2023 and it is already time chartered by Total. Based on the above data, i.e. for comparison of ships with similar carrying capacity, the LNG ship is clearly the most expensive of all (Wan, Yan, Zhang & Yang, 2019).

Over the life cycle of an LNG vessel, there are lower maintenance costs, in comparison to a traditional oil powered vessel, as the fuel system is easier to maintain, more efficient, clean and the machinery has a longer lifespan. In addition, due to the environmental benefits of using LNG fuel there is lower taxation or tax reliefs, saving the shipping company money in the long term. As governments are offering business initiatives to become more energy efficient and to use technologies that are less pollutant for the planet, companies often take advantage of these initiatives in order to build new fleets. Currently, only Norway has deployed a NOx taxation system, but more countries are looking into developing similar system in the following years.

2.4. LNG Regasification Terminals & Shipbuilding

In recent times there are import terminals which are also known as regasification or receiving terminals. These terminals have turned into important parts of the LNG chain of supply, as they offer more advantages in comparison to pipelines. As was stated in the previous chapter, these pipelines are costly investments, they have limited flexibility with regards to their geographical location and the security of the supply is also an issue. The LNG carriers will discharge the LNG and the ports must have cryogenic storage tanks in order to keep the LNG at very low temperatures (-163 °C). The gas is then sent into a regasification plant where temperature is above 0°C, the LNG can then be loaded into the trucks and the process of the distribution to the different locations can begin (Kotrikla, 2009).

Currently, the LNG imports in Europe have minimized due to the high demand for LNG in the Asian continent as the region is now responsible for importing 75% of all the LNG available in the market. The main Asian countries that import LNG is Japan, South Korea, China, and India. In Europe the largest consumers for LNG are Spain (27%), the UK (20%), France (18%), Turkey (13%), Italy (12%), Portugal and Belgium (4% each) and also the Netherlands and Greece (1% each). According to Gas Infrastructure Europe (GIE) in Europe there are currently 22 operating terminals and 6 under construction (Harlaftis et al., 2008). Furthermore, there are proposals and plans for another 24 terminals, as was stated previously in this chapter, without governmental involvement and specifically the European Union's involvement, these infrastructures would not have moved forward, due to the hesitance shown by both shipping companies and bunker suppliers to invest money in infrastructure and new vessels if the other party would not also invest accordingly (Lee & Nam, 2017).

If the aforementioned plans come to fruition and the expected LNG infrastructure is created then Europe will have a regasification capacity of 357 billion m^3 by the year 2022. The storage capacity will also increase to 16.6 million m^3 by that same year. The current regasification capacity is 219 billion m^3, whilst the storage capacity in 2013 is half of what is predicted for the new infrastructure to be able to hold (Kumar et al., 2011). Most European countries for example Italy and Spain are carrying out expansions on LNG infrastructure in the short term to help them expand their capacity and storage capabilities in 2022 and 2023 respectively. This is a direct response to the finding offered by the European Commission TEN-T program to create more LNG fuelling facilities (Lowell D. et al, 2013).

The new LNG vessels are more advanced technologically which also means that the materials used to create them are more expensive and need cargo settings that are more advanced. After the financial crisis which caused several issues, this pushed both the financial and the banking sector to make changes that also affected these new vessels and the LNG shipping sector. Furthermore, there are few shipyards in the world that are capable of creating LNG ships that are of a good quality. Those shipyards can be found in Asia, which are slowly taken over from the old traditional shipyard powers of Europe and America (Najm & Matsumoto, 2020).

2.5. Loading Base Liquefaction Procedures

The liquefaction of natural gas based on large-scale loading is carried out with emphasis on the efficiency of the process. The scale of operations means that production with the lowest installed capacity and the lowest fuel consumption is the most economically advantageous. Because the heat that must be removed from the gas to cool it to -160°C is eventually discharged into air or water, several complex systems have been developed (Herdzik, 2011).

The first gas liquefaction processes used arrays of simple refrigeration units in series. Each refrigerant is used in a separate closed loop that provides cooling in specific temperature areas.

Typically, propane, ethylene and methane are used to provide a wide, balanced cooling range. After compression, three temperature levels for each of the three refrigerants form a nine-step sequence (Harlaftis, 2005). Each of these temperature levels corresponds to a predetermined pressure drop (in the separation vessels) for the refrigerant to evaporate to heat exchange with the gas supply and a separate refrigerant stream requiring cooling. In this way, heat is removed from the gas at successively lower temperatures, that is, the refrigerant boils at successively lower pressures (Yoo, 2017).

Heat is released into the air or water through the hotter refrigerant, usually propane, and the compressor transducers. The cooling cycle of ethane is open as it combines with the gas supply and after the final pressure reduction step, liquid methane forms part of the LNG produced. In-line cooling processes have allowed the use of single-component refrigeration systems at a time when thermodynamic correlations and databases of thermophysical properties were not as well developed as they are at present (Najm & Matsumoto, 2020). In addition, the processes were able to become very efficient (i.e. the amount of irreversibility could be reduced) by increasing both the number of refrigerants used and the degree of evaporation of each refrigerant (Harlaftis & Chlomoudis, 1993).

However, this improvement in performance, had increased economic consequences. Each refrigerant requires a compressor, drive, containers, and heat exchangers, along with the necessary piping, insulation, and control systems. Each additional exhaust step adds to the number of heat exchangers and containers and the number of side currents entering the compressor (Herdzik, 2011).

The problem of complex design, the relatively high investment costs and the limitations in the intermediate stages of the in-line liquefaction process are addressed by the refrigerant liquefaction processes. With the development of equipment and control systems it became possible to combine refrigerants in a refrigeration cycle (Harlaftis et al., 2008). In such processes, a combination of refrigerants such as pentane, butane, propane, ethane, ethane and nitrogen is made in proportions suitable for the cooling gate of the liquefied natural gas to be liquefied, i.e. the gas cooling gate in. This reduces the irreversibility of the process. The refrigerant mixture is then concentrated, partly by air or water, and the remainder at a lower temperature by heat exchange with the mixture itself (Yoo, 2017).

In the latter case, the incoming refrigerant gas is cooled and condensed at elevated pressure against the exhausted liquid phase of the refrigerant mixture, each of which is released at a much lower pressure and, as is, its temperature. The coolant process has performed well in a variety of installations and represents a simplification over the in-line liquefaction process. However, it is not thermodynamically efficient enough to be economical in relation to rising energy prices. In order to meet the cooling gate of the supply gas in a wide range, from the temperature of the cooling water or air, to the temperature of liquefaction, compromises in the composition of the refrigerant are necessary (Wan et al., 2019).

The wide range of boiling points for the refrigerant components also means that some of the heavier components are compressed to higher pressures than actually required for their condensation to ensure the condensation of lighter, lighter and lighter components. Such a decompression clause cannot be avoided without a significant separation of the refrigerant components as seen in pre-cooled refrigeration processes (Yoo, 2017).

In the early 1970s, a third generation of processes was developed, including refrigerants and pre-cooling, from the direct combination of the other two. The most widely used process uses two separate cooling systems, a propane cooling cycle in series, followed by a refrigerant cycle comprising propane, ethane and nitrogen as components. The propane cycle cools the natural gas and serves as an intermediate coolant to dissipate heat from the combustion chamber to the air or cooling water (Spyridakis, 2006).

The propane cooling furnace can be made of lower cost common steel, while the lower temperature furnaces require aluminium or nickel steels. Therefore, the failure of the propane cooling process is compatible with the choice of economical materials (Herdzik, 2011). Finally, by reducing the range of cooling to be achieved by the refrigerant, its composition can be optimized and energy losses due to decompression can be significantly reduced (Schinas & Butler, 2016).

Additional process schemes have been developed that fall into the category of refrigerant and pre-cooling processes. If ethane is added to the pre-cooling coolant to form a double-coolant process, the pre-cooling temperature may be adjusted according to the operating conditions of the cycle and the percentage of ethane added (Lee & Nam, 2017). With this process the refrigerant load can be shifted between the two cooling cycles - a feature that can be useful in dealing with changes in the supply gas or changes in power availability (Papaioannou, 2003).

The change in power availability may occur due to changes in ambient temperature that affect the power generated by the gas turbines. Operating a coolant binary for pre-cooling is more complicated because simple pressure control is no longer sufficient but may be preferred in certain cases (Kumar et al., 2011). Another pre-cooling process has been proposed for installations using gas turbines in the refrigeration plant. In this configuration, the dissipated heat of the gas turbines is used to separate ammonia and water in an ammonia absorption cooler. This system could take on the burden of pre-cooling, eliminating the need for expensive compressors and powertrains. Neither of these systems has been implemented in a functional installation (Wan et al., 2019).

2.6. Transportation, Storage and Distribution of LNG

More than 50% of the world's gas reserves are located in remote areas. For example, most of the gas used in Western Europe is produced in the harsh environment of Siberia or the North Sea (Lee & Nam, 2017). In most cases, the producers ship the gas from the production fields to the borders of the countries in which it is used. Importers buy gas at these points under long-term contracts and resell the fuel to local distribution companies as well as to industrial users and power stations directly connected to the distribution system. Domestic and commercial consumers are normally served by local distribution companies (Schinas & Butler, 2016).

Natural gas is mainly used for heating. Therefore, gas demand varies substantially between winter and summer, working days and weekends, or day and night. The ratio between summer and winter loads in Europe is between 1:5 and 1:10. Production, transportation, storage, and distribution facilities must be designed and constructed to handle these load changes. Of the gas circulating on the international border, 75% is transported by pipeline, and 25% by LNG tankers (McFarlan, 2020).

The development of gas fields and the construction of transmission systems from remote production fields to natural gas importing countries are particularly high-intensity capital projects. As a result, the charge factors to which the gas is introduced are almost always very high. To equalize loads, the gas is stored in underground storage facilities during off-peak hours and transported from storage during peak winter demand periods (Schinas & Butler, 2016). The compression of the pipelines themselves in the transmission and distribution systems, as well as the peak needs installations, also help to handle load fluctuations (McFarlan, 2020). The transport of large volumes of gas is best achieved with large diameter pipelines operating at high pressure.

The conductors can be up to 1400 mm in diameter and operating pressure up to 8 MPa. Such pipelines carry gas over distances of about 1000 km. However, this capacity is insufficient to send gas from remote fields to the markets. Re-compression stations must therefore be constructed to increase the gas pressure in the pipeline. Gas compressors are driven by turbines or motors that are fuelled by pipeline gas for greater reliability and lower cost (Thomson et al., 2015).

The submarine pipelines of the North Sea to mainland Europe are constructed with diameters of pipelines up to 1000 mm that are placed at a depth of 150 m. Italy and North Africa are connected by 500 mm pipelines at a depth of 600 m. The very high operating pressures at which the submarine pipelines can be used, partially compensate for the loss of capacity due to the smaller diameters. If necessary, duct arrays are installed. Underwater compression stations are extremely expensive because they have to be built on platforms (Kotrikla, 2009).

Although the energy required to liquefy natural gas is substantial, the volume advantage makes liquefaction economically viable. Cryogenic LNG is transported by LNG tankers at atmospheric pressure. Liquefied natural gas is transported on double hull vessels specially designed to handle the low temperature of liquefied natural gas. These tankers are insulated to limit the loss of liquefied gas due to its exhaust (Harlaftis et al., 2008). These exhaust losses are used to replenish ship fuels. According to World Gas Intelligence (2008), on a typical trip, it is estimated that approximately 0.1% - 0.25% of the LNG load is evaporated each time, depending on the effectiveness of the insulation and the roughness of the trip (Schinas & Butler, 2016).

LNG tankers are up to 300 meters long, 46 meters wide and require a minimum water depth of 12 meters when fully loaded. There are currently 155 tankers carrying more than 120 million tonnes of liquefied natural gas per year. LNG transport is often the only way to transport gas from distant fields of production to consumer countries. Any cost comparison between LNG transport and pipeline transport must, of course, be linked to the project requirement (Thomson et al., 2015).

In general, an LNG installation is the only answer if pipeline transportation is not possible for technical or other reasons or if the distance is long enough. The cost of LNG transport is lower than that of submarine pipelines even for distances of several hundred kilometres, while transport by land is almost always cheaper than LNG transport unless the distance is extremely long (McFarlan, 2020).

When LNG arrives at the terminals, it is transferred to special individual storage tanks. These tanks can be above or below ground and keep the liquid at a low temperature to minimize evaporation height. If LNG fumes are not released, the pressure and temperature inside the tank increases (Herdzik, 2011). The liquefied natural gas is characterized as cryogenic and is kept in its liquid state at very low temperatures. The temperature inside the tank will remain constant if the pressure remains constant, allowing the exhaust gas to be released from the tank. This process is known as self-freezing (Bithymitris & Spyridakis, 2020).

Exhaust losses are collected and used as a fuel source in the installation or for the transport tanker. The liquefied natural gas is heated to the point where it can be converted to the gaseous state so that it can be used. This is achieved by using a switch-off process with heat exchangers.

Distribution systems pick up gas from regional refuelling centres and transport it to residential, commercial, and industrial users. These systems consist of high pressure and low pressure networks. Distribution systems tend to be used at low load rates because they serve a market in which demand varies considerably. If most of the gas is used for heating, the network is designed for maximum load on a winter day. Distribution networks have increased in many areas over the years because gas facilities have been built in many cities long before gas was available (Thomson et al., 2015).

For this reason, the distribution networks consist of mains of different diameters and different materials that have been installed in different years (Lee & Nam, 2017). The old distribution lines often operate at a pressure of 2-8 kPa, while the new mains are often designed for an operating pressure of 100 kPa. Low pressure distribution networks are usually connected to low pressure or high-pressure distribution systems from which they receive gas to special supply stations (Bithymitris & Spyridakis, 2020).

3. Framework & Competitive Analysis

3.1. Institutional framework

The regulatory framework for liquefied natural gas supply is characterized by important relevant environmental legislation. The significance of this is that by imposing stricter air emissions regulations, the demand for LNG as an alternative fuel will result in an increase (as part of a broader set of technical compliance options). At international level (IMO), MARPOL revised Annex VI (IMO Resolution MEPC.176 (58) and Energy Efficiency Resolution MEPC.203 (62) and set the limit on greenhouse gas emissions (Bithymitris & Spyridakis, 2020). From the European point of view, the legislation with the greatest potential to motivate LNG refuelling initiatives is: first, the Sulphur Fuel Directive (2012/33 / EU), which allows the use of liquefied natural gas as an alternative fuel to comply with stricter emission standards (McFarlan, 2020).

Secondly, the Alternative Fuel Infrastructure Development Directive (2014/94 / EU), which aims to ensure minimum coverage of liquefied natural gas supply points at major offshore and main ports across Europe from 2025 and 2030 respectively with common standards for their design and use. The importance of environmental shipping LNG emissions legislation is crucial and puts the driver for growth on the demand side (McFarlan, 2020). For several years the problem was perpetuated by the fact that ship operators and LNG fuel suppliers were reluctant to take the risk of investing in LNG as ship fuel (Tzamouzakis & Spathi, 2017).

Regulations and their adequate implementation are fundamental to setting a fair level of implementation, while promoting a more sustainable shipping approach that can add value, even with stricter environmental requirements. Standards and guidelines also assume a very important role in the development of liquefied natural gas as a marine fuel (Spyridakis, 2018). International standards ensure that there are sufficient technical reports on the equipment and its operation, allowing the development of harmonized industry initiatives and the manufacture of LNG equipment to be subject to uniform requirements, operational and technical (Bithymitris & Spyridakis, 2020).

In addition, it is important to realize that shipping is an international business. Liquefied natural gas as a fuel for shipping will need international harmonization. The first steps of liquefied natural gas as marine fuel have already been taken in the past (Argyriou, 2021). Regulations, standards, and guidelines should be able to be constantly adapted to new needs, taking into account potential risks, and be able to adapt to existing experience. The table below lists the regulations and guidelines for LNG as a marine fuel (Bithymitris & Spyridakis, 2020).

Title	Responsible	Type	Scope
ISO/TS 18683:2015 - Guidelines for systems and installations for supply of LNG as fuel to ships	ISO	ISO Technical Specification	Systems and installations for supply of LNG as fuel to ships Provisions on Safety and Training Last revision in 2015
ISO/DTS 16901 - Guidance on performing risk assessment in the design of onshore LNG installations including the Ship/Shore interface	ISO	ISO Technical Specification	Risk assessment for LNG facilities onshore and at shoreline (export & import terminals)
ISO 28460:2010 – Standard for installation and equipment for LNG – Ship to shore interface and port operations	ISO	International Standard	Onshore LNG terminals and LNG carriers
EN 1473 – Installation and equipment for liquefied natural gas – Design of onshore installations	CEN	European Norm	Design onshore LNG installations with LNG storage >200t
EN 13645 – Installation and equipment for liquefied natural gas – Design of onshore installations with a storage capacity between 5 t and 200 t	CEN	European Norm	Design onshore LNG installations with LNG storage 5t-200t
EN 13766:2010 – Thermoplastic multi-layer (non-vulcanized) hoses and hose assemblies for the transfer of liquid petroleum gas and liquefied natural gas – Specification	CEN	European Norm	requirements for two types of thermoplastic multi-layer (non-vulcanized) transfer hoses and hose assemblies for carrying liquefied petroleum gas and liquefied natural gas
EN12308:1998 - Installations and equipment for LNG - Suitability testing of gaskets designed for flanged joints used on LNG piping	CEN	European Norm	This standard specifies the tests carried out in order to assess the suitability of gaskets designed for flanged joints used on LNG pipes
Seveso II – Directive	EC	Directive	Control of major-accident hazards for onshore installations involving dangerous substances
ADR – European agreement concerning the International Carriage of Dangerous Goods by Road	UNECE	Convention	Transport of hazardous goods by road
EN 1474-1/2/3 – Installation and equipment for liquefied natural gas – Design and testing of marine transfer systems	CEN	European Norm	Design of LNG transfer systems (transfer arms, hoses and offshore transfer systems)
PGS33-2 - Dutch national guideline for LNG bunkering of ships		Dutch Guideline	Shore-to-ship LNG bunker station design
LNG Transfer Arms and Manifold Draining, Purging and Disconnection Procedure	SIGTTO	Guidelines	Purging and disconnection of rigid transfer arms in terminals
Gas as a Marine Fuel- Safety Guidelines – Bunkering	SGMF	Guidelines	Guidance on LNG bunkering operations.
LNG Bunkering Guidelines	IACS	Guidelines	Guidelines on LNG Bunkering operations. Special focus on Safety and Ship-side.

Figure 3. 3 - Regulations and standards

Figure 3.2, as shown below, summarizes the main regulations and standards concerning the liquefied natural gas supply chain.

Title	Responsible	Type	Scope
IMO Interim guidelines on Safety for Natural Gas-Fuelled Engine Installations in Ships, MSC.285(86)	IMO	IMO Guidelines	Construction, operation and other aspects related to ships using LNG as a marine fuel. Applicable until the IGF code enters into force (January 2017)
International Code for the Construction of Gas Fuelled Ships (IGF code)	IMO	Code	Construction of gas-fuelled, seagoing vessels
International Code for Construction and Equipment of Ships carrying Liquefied Gases in Bulk (IGC Code)	IMO	Code	Vessels transporting liquefied gases
International convention on standards of training, certification and watch keeping for seafarers (STCW Code)		Code	Minimum standards of competence for seafarers
Crew Safety Standards and Training for large LNG carriers	SIGGTO		Requirements for the training of LNG tanker crews
European Agreement concerning the International Carriage of Dangerous Goods by Inland waterways (ADN)	UNECE	Convention	Transport of dangerous goods via inland waterways
International convention for the Safety of Life at Sea (SOLAS)	IMO	Convention	Safety standards in construction, equipment and operation of seagoing vessels
International Convention for the Prevention of Pollution from Ships (MARPOL)	IMO	Convention	Prevention of pollution of the marine environment by ships.
Rhine Vessel Inspection Regulations (RVIR)	CCNR	Regulation	Technical rules and requirements for inland waterway vessels
2006/87/EC – Directive of the European Parliament and the council laying down technical requirements for inland waterway vessels	EC	Directive	Inland waterway vessel requirements for certification, carrying dangerous goods and inspections
SIGTTO Crew Safety Standards and Training for large LNG carriers	SIGTTO	Industry Guidance	Document highlights the salient statutory requirements for the training of LNG tanker crews and the provisions of the International Standards of Training and Watch Keeping Convention, as it applies to gas tankers.
European Agreement concerning the International Carriage of Dangerous Goods by Inland waterways (ADN)	UNECE	Convention	Construction and operation of LNG inland tankers. Include provisions for training.

Figure 3.4 - Regulations and standards concerning the liquefied natural gas supply chain

3.2. Financial framework

The state of liquefied natural gas in the world market will soon be redefined as after 30 years of continuous growth global flows decreased by 1.6% from 2011 to 2012. This contraction is mainly due to supply problems and due to domestic and political developments in Southeast Asia, the Middle East and North America. Nevertheless, Japan and Korea hold the largest share of the liquefied natural gas import market in the world (almost 52%) (McFarlan, 2020). Qatar is the world's largest exporter of liquefied natural gas (36% of the total), followed by Nigeria with 15% of the market and then followed by Indonesia, Egypt, Equatorial Guinea, and Russia (www.igu.org). Global energy demand is one of the biggest challenges of the 21st century (Bithymitris & Spyridakis, 2020).

Gas is considered as a substitute for oil and the trade of liquefied natural gas by sea has contributed to the development of the world market, which has similarities but also differences with the oil market. The use of gas as an energy source for electricity generation has promoted the development of international trade in liquefied natural gas, in order to meet the growing demand in developed and developing countries (Deligianni, 2018). Natural gas provides economic benefits, is processed faster, is environmentally friendly and can be burned directly as fuel (in the household and industrial sectors) with very high efficiency and minimal losses (Bragoudakis et al., 2013).

The reduction of the volume of natural gas, with its liquefaction, allows its transportation on economically competitive terms in relation to the pipelines. Especially for long-distance transport (over 3,000 miles), LNG is generally a cost-effective option. In addition, the LNG allows the development of trade between regions that would otherwise be technically or politically impossible to connect (Tzamouzakis & Spathi, 2017). The more specific reasons that favoured the development of the international LNG market include the shift to natural gas for electricity production due to its environmental, economic and technical advantages. In particular, in the transfer of LNG, cost reduction was achieved at all stages of its supply chain with various technological improvements (Bragoudakis et al., 2013).

In addition, contract terms have begun to become more flexible in the face of the need for greater flexibility to meet growing demand. Gradually a part of the market started to move competitively and to promise opportunities for increased profits (Tzamouzakis & Spathi, 2017). The LNG also serves the countries' demand for security in their energy supply through the diversification of their energy sources. In its early stages, the LNG trade consisted of ships that sailed on specific voyages and were bound by multi-year contracts. These structures began to change in the late 1990s when there was a shift from many countries to electricity generation with natural gas (Spyridakis, 2006). Although most of the world LNG trade is still done on binding terms, a flexible market has been created and is constantly growing, now accounting for about 10% of total trade.

It is now possible to change the destination of the loads depending on market conditions and prevailing prices. Gas prices, traditionally linked to those of oil, are increasingly linked to FA price indices and this is particularly important given current oil price levels (Papaioannou, 2003). Long-term supplier-buyer contracts will continue to dominate the LNG market, but will become more flexible, allowing cargo handling in an expanding short-term market. Although its conservative - inelastic and vertical structures will not be eliminated in the coming years, the market will open up to a certain range of new investors. In the traditional market model, the main players in LNG shipping were large vertically integrated energy companies (Chevron, Exxon Mobil, Shell, BP, TOTAL) and state-owned companies (SONATRACH, GAZPROM) (Bithymitris & Spyridakis, 2020).

3.3. The case of POSEIDON MED and POSEIDON MED II

The Poseidon Med liquefied natural gas development program was successfully completed in its first phase, while at the same time the next phase of Poseidon Med II begins, as announced by DEPA, which is the main LNG development body in Greece and coordinator of the program. Every effort is being made to establish Liquefied Natural Gas (LNG) as a marine fuel in the Eastern Mediterranean basin (Bithymitris & Spyridakis, 2020).

Shipping will be able to put into operation ships which will be equipped through the appropriate infrastructure of the wider area, thus creating cleaner conditions, more efficient transport as well as opportunities for technological and economic development. The actions of the program include (Tzamouzakis & Spathi, 2017):

- Preparation of regulatory framework proposals for the refuelling of ships with LNG as marine fuel
- Plan to upgrade the infrastructure of the LNG Terminal of Revythousa that will ensure the possibility of loading LNG on refuelling vessels
- Technical design approved by the competent Authorities for the conversion / construction of ships with LNG fuel as well as for the creation of the necessary port infrastructure to support the supply of LNG ships
- Design and construction of a special container transport ship that will run with LNG (pilot action in the region of Venice - Italian participation)
- Examining synergies with other uses and sectors (such as energy) that will achieve economies of scale in the use of LNG.
- Development of a sustainable LNG pricing / marketing scheme
- Development of financial tools to support port and ship facilities.

POSEIDON MED II is a European program for designing the legal framework and conditions for the use of LNG as a marine fuel in the Eastern Mediterranean. Through the design of targeted and sustainable infrastructure, the program contributes to the development of the LNG supply chain. In this way, the LNG demand for maritime use is expected to be activated in order to meet the modern international environmental requirements (Bithymitris & Spyridakis, 2020). POSEIDON MED II, which is a continuation of the "Poseidon-Med" and "Archipelago-LNG" programs, is co-financed by the "Connecting Europe" mechanism and will last 5 years. This is an international project with the participation of 26 partners from five Member States (Greece, Italy, Cyprus, Croatia, and Slovenia) (Spyridakis, 2018).

The ultimate goal of the project is the availability of LNG in five main ports (Piraeus, Patras, Heraklion, Igoumenitsa, Limassol). It is a collaboration between gas suppliers, shipping companies, port authorities and technical organizations. 50% co-financed by the European Commission (Mechanism: Connecting Europe / CEF-Transport). The actions of the program have to do with the development of the global infrastructure of nodes (hubs) for the supply of LNG in the growing market demand (Bithymitris & Spyridakis, 2020). Specifically, Piraeus will be transformed into a hub & spoke which will be connected to other ports in Greece and will be established as a refuelling station for ships.

The whole project should assess the risks, review the operations, and create security in the port. This program is not only a commitment to a cleaner fuel for shipping, but it is to build a strong, safe, and efficient way of operating transportation systems (Spyridakis, 2016). Liquefied natural gas as a fuel can meet the threefold challenge of social, environmental, and economic requirements. In addition, it can build a correct perception on the scale of the project and be an excellent method for the profile and prospects of ports. Finally, in this very important project, the participation of the society and the cooperation of all the necessary members (stakeholders) is deemed necessary (Spyridakis, 2018).

3.4. International competitive analysis

With cost savings and market flexibility needed to meet growing demand and new international energy conditions, this closed "club" has opened up to independent shipowners and other investors. LNG is a specialized market and the fastest growing in maritime energy transport. In relation to the related oil market, it differs significantly, as it presents limited liquidity and is not expected in the foreseeable future to reach corresponding levels of mature competition (Spyridakis, 2016). The growth rates of the LNG market and its gradual opening to new players with the adoption of more flexible operating conditions place it in the most promising positions of global shipping.

In this new dynamic environment, the big traditional players of maritime energy transport and the independent tanker companies are claiming their place (Bithymitris & Spyridakis, 2020). Despite low oil prices and a relatively weak outlook for the shipping market, the liquefied natural gas market has a bright future. It seems that there is a need for new LNG trains and a tripling of the fleet in the coming years. A new wave of liquefied natural gas exports is presented in the world market from 2020. In general, the supply in the LNG market will increase by 40% between 2015 and 2020. It is the largest increase in supply volume that the market has seen in a period of five years (McFarlan, 2020).

Given the current demand in the next 5 years, the increase in demand in Asia is likely to absorb all this new capacity. The market appears to be structurally longer by 2022. In order for the market to remain in equilibrium, lost volumes from Europe to Asia will have to flow back to Europe, re-exports will slow down, and vulnerable consumers will benefit from the prices of liquefied natural gas (McFarlan, 2020). The result of the change in trade flows shows that the spot market of LNG will trade at very close levels of European price levels, instead of close to the oil prices recorded in tighter market conditions. In the long run, the LNG market has a very positive outlook.

Demand has been expected to increase on average from 4% to 6% per year until 2030 with an expected rate of 4.5% per year, between 2015 and 2020. Given this long-term design, the market need regards new 20mtpa ships over the above mentioned two and a half years, to hit the market by 2023 and an additional 45mtpa by the end of this decade. Otherwise from 2023 a narrow global market for liquefied natural gas is expected to be seen (Argyriou, 2021). The ever-increasing demand for liquefied natural gas on a global scale leads the US LNG market to an advantage over other proposed projects worldwide. However, diversification of energy sources and political developments can help global projects such as Australia be sustainable. Some consumers will want to differentiate their exposure to different prices (Henry Hub vs Oil indexed) and minimize their dependence on a single country to meet their energy needs (Deligianni, 2018).

In 2013, Qatar the largest supplier of LNG met only 25% of the needs of the three largest consumers (Japan, Korea, China) and only Korea allowed to supply more than 30% of its needs from Qatar (Energy Insights by McKinsey 2015). Finally, the International Energy Agency (IEA) in 2011 had stated that it did not count on a nuclear accident but noted that the share of nuclear energy in the global balance would fall from 13% to just 7% in 2035 with an emphasis on energy safety and in the variety of fuel forms (Bragoudakis et al., 2013). The same report said that the Fukushima nuclear accident shook the countries' energy sector. The prospects for nuclear power plants are much more uncertain than they were before the accident. The growing demand for oil in Japan was estimated at between 150,000 and 200,000 barrels per day when the need for liquefied natural gas will reach 11 billion m 3. The above quantities corresponded to 0.2% and 0.4% respectively of world consumption (Argyriou, 2021).

In February 2022, Russia, which had been the main natural gas supplier for Europe, invaded Ukraine, resulting in record high volumes of LNG which was purchased by the EU to replace the lost Russian supplies. As a consequence, prices increased significantly and the volumes available for developing economies was minimized. In addition, delays and cancellation risks, forced governments to impose new policies with regards to gas imports. Thus, LNG has been considered a costly and unreliable fuel by many Asian nations due to the above described situation.

According to the IEEFA (Institute for Energy Economics and Financial Analysis), global LNG markets will see modest supply additions and prices will be structurally elevated for several years. Despite Europe’s short-term LNG buying frenzy to replace lost pipeline imports from Russia, climate and energy initiatives are likely to cause LNG demand growth on the continent to stabilize and reverse later this decade. After several years of weak supply growth, IEEFA anticipates that the global LNG market will see a tidal wave of new projects come online starting in mid-2025. The wave will likely crest in 2026, with the addition of 64 million metric tons of annual liquefaction capacity—the most in the history of the global LNG industry. The supply additions will boost global liquefaction capacity by roughly 13% in a single year. The current downturn will be followed by the largest supply additions in the history of the LNG industry, driven primarily by new projects in the U.S. and Qatar. In 2026 alone, new liquefaction capacity additions will exceed the preceding five years combined (IEEFA, 2023).

4. Opportunities for Greece

4.1. Skaramagkas shipyard

Skaramagkas is a town in the west side of Athens with a population of 2,606 inhabitants; it belongs administratively to the Municipality of Chaidari (Mari, 2020). The shipyard is located in that area, and it can be accessed by two main highways, the Athens Avenue / National Road Athens - Corinth and the ring road Schistou - Skaramaga which starts from Keratsini (Wilczyński, 2015). Until a few decades ago, the Skaramaga Coast was a place that was used by the locals and citizens of Attica for swimming and recreational purposes. As was stated in the first Chapter, Skaramagas shipyard (or otherwise called "Hellenic shipyards") was originally developed in 1937 as a Naval shipyard until 1956 when it was bought by the shipowner Stavros Niarchos (Goulielmos, 2021).

Niarchos made several extensions to the existing infrastructure expanding the shipyard by paving and expropriating towards the beach (Pistofidi, 2015). The president of the Skaramangas Landscaping Association, Panagiotis Koukoumas, made several complaints about this extension. Today, only a small part of the former beach is left from the northern border of the Shipyards to the Athens-Corinth National Road. The Hellenic Shipyards SA or Skaramaga Shipyards is the largest and oldest modern shipbuilding facilities in Greece and throughout the eastern Mediterranean (Hristoforou, et al., 2016). Formerly publicly owned, it is now controlled by Abu Dhabi State Shipyards, which own 75.1% of the share capital, and the German ThyssenKrupp, which owns 24.9% (Kaisarlis et al., 2015). They are located in the area of Skaramaga, in the west of the prefecture of Attica, in the bay of Skaramaga.

After it was bought by Niarchos in 1958 the shipyards took on the construction and maintenance of the ships, as well as making modifications of the used vessels which were bought by the shipping company (Spyridakis, 2006). An older shipyard of the then Royal Navy was chosen as the site, which had been disused after World War II due to extensive damage that was inflected by the Allied during this time. They work exclusively focused on the above in until 1965, when the shipyard cooperated with the Navy to construct resulted the coastal patrol class "Panagopoulos" (Pilarinou, 2012). At this stage, the shipyards were experiencing special development and were starting to build new civil and military vessels. This period of prosperity lasted until the 1970s. In 1985, shipyards were nationalized. With the crisis in the Greek heavy industry continuing, the shipyards were trying to survive in collaboration with the German Blohm + Voss for the production in Greece of the new frigates of the Navy MEKO 200HN - class "Hydra". Three of the four ships commissioned were built there and delivered in 1992-1994. The cooperation continued with the construction of the new type 214 submarines and the upgrade of the old 209 (Neptune program) (Pardali et al., 2013).

In early 2023, the Skaramangas shipyard was acquired by Shipowner Mr. George Prokopiou and the gradual upgrading of the facilities, the strengthening of the fire safety and firefighting systems and the re-operation of the large tank which has remained inactive for about 20 years are now fully underway (Bellos, 2023). This event shows a promising future for the Skaramangas shipyard, new investments and promotion of Greek expertise.

4.2. Shipbuilding opportunities

After the Golden era of the Shipyard things started to change and the company was privatized by 50%, in the form of a cooperative (Athanasiou & Koutroulis, 2018). The remaining 50% goes to the English Brown & Root, from which they are bought by the German HDW and when the latter becomes the property of the Thyssen steel group (January 2, 2005) the shipyards will follow. The difficult situation in European shipbuilding, however, had raised rumours since 2006 about the sale of the shipyards to an Asian heavy industry group. On 13 October 2009, a decision was announced for ThyssenKrupp to leave the Shipyards. But the Skaramangas shipyards, despite being a private company, continued to receive illegal state subsidies, creating unfair competition.

A complaint was lodged with the European Commission and in June 2008 a fine of €539 million was imposed which was deemed impossible to pay. The Greek government, in order to avoid closure, proposed to the European Union the Skaramanga Shipyard to be sold or disuse the equipment it uses for work on merchant ships of Greek and International Customers and for 15 years to be used exclusively for warships of the Greek Navy. At the end of 2009, the owner company announced its intention to sell the shipyards, due to their reduced profitability. Five companies, including a Greek one, showed interest, with the shipyards eventually ending up in Abu Dhabi Mar from the United Arab Emirates (Varahrami, & Haghighat, 2018). The agreement for the transfer of the Shipyards to Abu Dhabi Mar was signed on March 18, 2010 and is completed in September of the same year with the recognition of the debt of about 1.3 billion euros of the Greek State to the shipyards (Pardali et al., 2013).

Despite the above, the shipyards had multiple roles. In addition, many new constructions were undertaken, from 1986 to 2011 to modernize the infrastructure such as the construction of trains as well as the reconstruction of many old stairwells for OSE and ISAP (Metro). The shipyards also have the facilities and equipment even for the construction of aircraft (Varahrami, & Haghighat, 2018). They cover an area of 832,000m², with 65,000m² of them being covered. They have two permanent tanks of 500 and 250 thousand tons, as well as three smaller floating tanks (72 thousand, 60 thousand and 36 thousand tons). As well as a sloping ship bed for launching ships or parts thereof. They are also equipped mainly with machines of CNC technology (Telerex) and optical work (photocell). As was stated in chapter 2, the EU is currently funding through Trans-European Transport Network (TEN-T) fund a number of projects for ports and shipyards to include LNG refuelling stations and to be able to develop and build vessels fuelled by LNG (Bekaert, 2016). Skaramagas can benefit from the above funding to upgrade their infrastructure in order to be able to compete with other shipyards in the world for building new LNG fuel powered vessels.

4.3. Investment opportunities

In the transport sector, liquefied natural gas presents significant prospects, as its demand is expected to increase in the future, due to stricter regulations on gas and pollutant emissions and the positive evolution of gas prices compared to oil (Omoregie, 2019). The result of the expanded demand for liquefied natural gas in the transport sector is that of economic growth and increase the employment opportunities. More specifically, total gas demand is expected to increase from 3.149 billion cubic meters in 2008 to 4,535 bcm in 2035. That is, an increase of 44% and an average annual growth rate of 1.4%. 84% of the increase in global gas consumption by 2035 is expected to come from outside the OECD, while demand from China is expected to increase by 5.9%, more than any other region (Varahrami, & Haghighat, 2018).

In simpler terms, a small-scale liquefied natural gas activity could create an additional 8,000 jobs, resulting in an additional € 2.7 billion in economic growth by 2030 (Eser et al., 2019). Work in this sector, which is related to the field of preparation, trade in services, equipment, engineering, technical specialization, processing, and transport of liquefied natural gas, etc will expand in the next few years (Mitchell, & Mitchell, 2014). In the transport sector, the use of liquefied natural gas has the following economic implications:

1. Investments in ships and trucks running on liquefied natural gas. In the event that shipowners and truck owners turn to liquefied natural gas, they will have to invest in new ships or trucks capable of running on liquefied natural gas. This decision also determines how quickly the small size of the liquefied natural gas market will grow (Osorio-Tejada et al., 2015).
2. Investments in infrastructure for liquefied natural gas. Engine manufacturers, shipowners and truck owners will only invest in liquefied natural gas if they are confident of completing liquefied natural gas infrastructure (Gritsenko, 2018).
3. Investments in bio-liquefied natural gas (bio-LNG). Discussions are still ongoing on the economic implications of using bio-liquefied natural gas (Pasini, et al., 2018).
4. Differentiation of the fuel mixture. Liquefied natural gas as a new (alternative) fuel can lead to a lower rate of increase in oil prices or even a decrease, which will positively affect economic growth (Carboni, et al., 2021)
5. Countries' competitive position can be improved with timely participation (McBean, & Guthridge, 2013).
6. The effects on health as a result of reduced emissions (Schinas & Butler, 2016).

In contrast to oil, which is priced globally, gas prices are priced locally (Ritz, 2014). As there is a buyer and a seller, prices are negotiated between the two traders. Following the rules of the free market, the seller demands a price that covers his operating costs, the amortization of the invested capital, the risks and the buyer agrees to the price that allows him to have a profit margin. More specifically, as prices are set locally, the price of LNG is formed based on the equilibrium point between supply and demand. Both buyers and sellers react to LNG price fluctuations (Rogers, 2015).

This adaptability to price fluctuations, while normal in goods due to the free market, is not so strong in the LNG market because in this market the demand does not show a high degree of adaptability but is inelastic (Fokkema et al., 2017). This is due to natural gas not being a perfect substitute.

In the recent past, there has been speculation that LNG selling prices will converge. The idea was based on the fact that the transport of gas by sea would connect the regional markets, such as America, Asia, Europe and therefore the way of pricing (Hamedifar, et al., 2015). However, natural gas prices still vary widely around the world and the differences have become even more pronounced since the Fukushima accident in March 2011.

4.4. SWOT analysis of the LNG industry

The SWOT analysis is one of the most important strategic planning tools as it has the ability to break down all the important information of a project and show the viability of said project (GURL, 2017). The following table is focused on the Greek market and analyses the Strengths and the Weaknesses of the LNG industry. Furthermore, the Opportunities that exist in Industry today are presented as well as the potential Threats that can be expected (Fine, 2009).

Natural gas shows advantages compared to other types of fuel, such as the fact that it is a clean fuel, which is the main reason to examine it as a fuel and energy source. The difficulty in its transportation, which was a problem in the past, has been overcome, as technology methods for its liquefaction, storage and regasification are available, therefore it is more cost efficient compared to the past, as stated in Chapter 2 and Greece can benefit from this fact. As LNG is a highly efficient type of fuel, its cost reduction has resulted in its use both for domestic as well as for industrial activities. This strengthens its position in the market, as the potential portfolio for LNG is broad.

As any type of fuel, there are also weaknesses in the use of LNG. The main weakness is the high capital cost which is required in order to create adequate infrastructure for supporting the domestic network. Due to the fact that the energy market is still not fully clear with respect to the type of fuel to dominate, the risk to invest is high, as there is no certainty regarding the return of investment. For this reason, Greece has been observating the market, in order to follow a more secure path.

Based on the available data presented in this Chapter, there are opportunities for Greece to develop in the LNG market, by taking advantage of new technologies, upgrading and expanding the available infrastructure, renewing the LNG fleet and expanding the shipping services to new sea routes.

On the opposite side, threats such as supply deposits, potential also of other alternative fuels which have been under evaluation, oligopoly conditions in the market, as well as prices of oil which might become more competitive, become threats, as they increase the risk of this investment.

STRENGTHS	**WEAKNESSES**
• Clean fuel / energy source • Liquid form can be easily transported • Gas is an attractive source of energy for both domestic and industrial use due to its low price and high efficiency.	• Still high risk industry in terms of profitability • High Capital investment for the acquisition of fixed assets but also the creation of facilities. • Long-term contracts with strict terms prevent entry into the industry.
OPPORTUNITIES	**THREATS**
• Development of technology to minimize costs in the LNG chain. • Need to renew the LNG fleet due to aging but also adaptation to the specifications required by the new naval routes (ship sizes, special characteristics). • Opening of sea routes (Arctic-Asia and USA-Asia via the Panama Canal) that will multiply the transport project.	• Turn to Renewable Energy Sources. • Limited Natural Gas deposits. • Possible increase in oil prices could also affect the LNG prices. • Oligopoly conditions of the world market. Small number of suppliers and buyers.

5. Conclusions

5.1. Concluding remarks

As global energy demand is one of the biggest challenges of the 21st century, natural gas is considered as a dominant substitute for oil and LNG trade by sea has contributed to the development of the world market, which has similarities but also differences with the oil market. In conclusion, natural gas, as a source of energy, occupies a dominant position in the production of electricity and its liquefaction can overcome many obstacles. The most important are allowing its transportation by ships and its use as a source of energy.

The LNG industry belongs to the typical industrial chain, including all stages, from extraction to consumption by the final consumer. The development of technology, for each of these stages, has contributed to significant cost savings and improved productivity and efficiency at each stage, resulting in enhanced LNG competitiveness in global markets. The development of technology and the introduction of strict standards has made LNG installations safer but nevertheless the risks remained as LNG is transported and stored in very large quantities.

Thus, for the smooth operation of the LNG supply chain, there are defined standards of safety regulations. In the transport sector, LNG presents significant prospects, as its demand is expected to increase in the future, due to stricter regulations on gas and pollutant emissions and the positive evolution of gas prices compared to oil. The result of the expanded demand for LNG in the transport sector is economic growth and employment. The structure of the LNG market was initially characterized by an oligopoly, which consisted of a few large state-controlled or regulated oil and gas companies. However, the liberalization of trade in LNG has contributed to the further development of shipping, and more specifically to the proliferation of LNG tankers, to the increase of their size but also to the expansion of the scale of imports and exports.

With the expansion of liquefaction plants, LNG exporters are turning to new markets in order to absorb their surplus. The number of LNG terminals is increasing, not only in the existing export or import countries, but also in the countries that have the ambition to enter the LNG market. Nevertheless, LNG facilities are at the highest level of energy investment and require huge financial commitment and high capital for their construction.

The growth of international trade in LNG is due to the preference for natural gas as a source of electricity, in order to meet the ever-increasing demand in developed as well as in developing countries. LNG trade is growing rapidly while the main factors determining the adoption of the LNG are the policies in the various countries, the availability of alternatives, the divergence of fuel prices and the development of the transport sector.

Reducing costs in all parts of the LNG supply chain has led to many new investments in shipping. The LNG fleet is one of the newest fleets. In addition to the above, LNG carriers are considered to be the safest ships in the merchant fleet today, as they are well designed, constructed, maintained, and operated in such a way as to achieve and ensure safety.

Finally, as far as Greece is concerned, the degree of interest of Greek shipping companies is so great that more than half of the orders of LNG type ships are for Greek interests. Shipping companies in Greece are building one of the largest independent LNG transport fleets in the world, at a time when the US is preparing to be added to the list of the largest gas exporters in the world, along with the Russians, Australians, and Qataris. The EU finding available to help shipyards and ports to have refuelling ports and create the appropriate LNG infrastructure in each one of these locations will help Greece be in the forefront of this new developing industry.

The invasion of Russia in Ukraine in February 2022, has created risks of instability in the Natural Gas supply to the European Union. This has resulted in energy crisis and, thus, in an intensive search for alternative plans in order to feed Europe with LNG for domestic and industrial consumption.

Investments in Greece for LNG infrastructure such as the LNG import, storage and regasification facilities in Revythoussa and the FSRU in Alexandroupolis, which is expected to become operational in Q1 of 2024, give Greece a geopolitically strategic advantage, as part of the solution to the problem risen by Russia regarding LNG supply to satisfy the demand of the EU, is expected to come from Greece.

Based on the SWOT analysis of the LNG industry and the strategic location and maritime force of Greece, funding LNG refueling and shipbuilding projects would strengthen the country’s position further in the energy and maritime industries and would increase employment rate and know-how and attract additional investments.

However, given the risks and threats, such as concern regarding the emission of unburnt methane (CH4) in the atmosphere, as well as uncertainty regarding the return of investment for large LNG-related projects, due to price fluctuations of oil and evaluation of other alternative fuels and also renewable energy sources, further investigation and assessment is required.

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