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Study of the use of LNG in maritime transport by an environment analysis tool

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ABSTRACT

Today's society is a global society, structured on the basis of a global economy, and in this economy maritime transport is essential, as well as the ships and port facilities that support it. Within the maritime business, the transportation of natural resources is of great importance. In this sense, natural gas is considered a good of general interest whose supply must be guaranteed and which, in recent years, is the source of energy that has been growing the most. experimenting since, within the fossil fuels, it is the one with the lowest environmental impact and its number of reserves is higher than those of oil. This paper analyses the situation of LNG with regard to such a product as a fuel for maritime transport. The environmental restrictions demanded at the global level are going to be of great importance for the promotion of LNG. Thanks to the four analyses proposed by PPDC- PESTEL-PORTER - SWOT - CAME, it will be possible to locate the weak and strong points of this fuel and its competition in the market. Regarding ports and their adaptation from the point of view of the European Union, it can be concluded that there is a need and that a great benefit would be obtained by implementing a community gas storage system with greater capacity and better distribution throughout European ports.

***Keywords*:** LNG, PESTEL, PORTER, SWOT, CAME

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1. INTRODUCTION

The purpose of this study is motivated by the well-known importance of natural gas as a fossil fuel, the importance and benefits of its transport in the form of liquefied natural gas and the potential of this fuel in relation to the environmental restrictions that, at a global level, affect emissions caused by ships. (1)

Apart from the advantages of LNG as a marine fuel, the signs of scarcity and the problems of the main fossil fuel used until now, petroleum, have pushed natural gas as an alternative fuel. (2)

Gas fields and reserves are distributed across all continents, with three major producers, Russia, Iran and Qatar, but there are more producing countries that help to provide greater flexibility in the market, which is one of the greatest advantages over oil. (3)

Despite the flexibility in the natural gas market, one of the main concerns of the European Union is security of supply, that is, providing member states with the security and capacity to cope with possible gas supply disruptions. (4) The importance of security of supply is also of paramount importance for the European Union.

Also the importance of this security of supply to ships requiring bunkering services in European ports makes it a vital issue for Europe. (5)

The European Union imports two thirds of the natural gas it consumes, either by pipeline or by ships through liquefied natural gas terminals. (6) Most EU countries are dependent on imports to meet their gas demand, and supply is often dominated by a single supplier country. (7)

The problem of this obvious dependence on a single source or route can pose a risk to supply, which can be affected by a simple technical contingency or by political-economic conflicts. (8)

Another important issue related to the use of natural gas is the growing concern about climate change. (9)

The demand and urgency to reduce carbon dioxide emissions have been decisive for the development and diffusion of natural gas for multiple uses, from domestic and commercial to transport fuel for light vehicles, trains and ships. The use of natural gas is being promoted and encouraged at all scales. (10)

The linkage of natural gas and liquefied natural gas with the pursuit of sustainability is evident in its four fundamental pillars, environmental, social, economic and governance. (11)

The pursuit and finding of environmental and economic sustainability can perhaps be seen most obviously, given that it is known at all levels of society that this fuel, compared to other fossil fuels, generates lower emissions and is an economically viable and competitive fuel due to its flexibility in the marketplace. (12)

On the social and governance aspects, there are some obvious concerns about security of supply issues, but work is underway to remove these concerns. (13)

The decision to carry out a PPDC analysis (PESTEL, PORTER, SWOT, CAME) has been taken in order to carry out a comprehensive study of the use of LNG as a marine fuel in the European Union, so as to link it to the concept of sustainability and to understand the importance and potential of the product.

The advantage and contributions of the PESTEL analysis, allow to investigate in several areas, studying Political, Economic, Socio-cultural, Technological, Ecological and Legal factors. Within these factors, specific issues such as political and governmental stability,

financing and subsidies, economic development, resource distribution, health awareness, technological changes and developments, legislation, access to natural resources or propensity to natural disasters, among others, are studied.

Porter analysis establishes a framework for analysing the level of competition within an industry. The analysis derives from the articulation of the five forces that determine the intensity of competition and rivalry in an industry.

Porter's five forces include three horizontal competitive forces: Threat of substitute products, threat of new entrants or competitors in the industry, and rivalry between competitors, and it also comprises two vertical competitive forces: the bargaining power of suppliers, and the bargaining power of customers.

The SWOT and SCA analyses are complemented by first conducting an analysis of the current situation by examining the weaknesses, threats, strengths and opportunities of the system under study.

The SWOT analysis channels and consolidates the results of the SWOT analysis and transforms them into lines of action, seeking to correct the weaknesses, confront the threats, maintain the strengths and exploit the opportunities.

2. STATE OF THE ART

The natural gas market consists of several companies involved in each stage of the process, from extraction to delivery to the consumer. The four main stages are production, liquefaction, transport and regasification (14). Storage and the logistics chain associated with the supply of LNG to ships will also be the subject of study, since these are two fundamental aspects for studying the use of LNG as a marine fuel.

According to data provided by SEA-LNG (SEA-LNG is a multi-sectoral industry coalition whose members work together to demonstrate the benefits of LNG as a marine fuel along the entire value chain), these are the total global bunkering points, taking into account ship and dockside supply as shown in Table 1.

Table 1. Total global bunkering points

Continent	Docks	Ships	Total bunkering
Europe	18	16	34
America	9	3	12
Asia	10	6	16
Total	37	25	62

Source: own elaboration based on SEA-LNG

The largest LNG bunkering service is in the European Union. For the development and the possibility of shipping companies' decision to build LNG-powered ships, bunkering service should be more present in the rest of the continents. (15)

It is at strategic points, but it is not sufficient security of supply for LNG-powered ships. Investment in more bunkering capacity worldwide would be desirable. As far as the distribution of service in Europe is concerned, it is fairly uniform. (16) It is logical to ensure that the energy model of the European Union will be based on the same energy model.

It is logical to ensure that the energy model demanded by society must guarantee its sustainability. To this end, it is necessary not only to understand the basic pillars that describe it, but also to link it to the energy sphere.

Linking the four dimensions of sustainability to a sustainable energy model gives rise to the following bases, which are essential for bringing sustainability to the energy model: environmental friendliness, social acceptability, competitive costs and security of supply.

In order to implement this new sustainable energy model, society is currently immersed in an energy transformation. There are many international commitments and agreements, such as the Paris Agreement and the European Union's proposals to create guidelines focused on reducing greenhouse gas emissions, establishing energy saving and efficiency quotas, and promoting the consumption of energy from renewable sources.

One of the most important challenges is that of social acceptability, given that it is not simply a matter of striving for the well-being of all people on the planet and of future generations. The transition of the energy model at a global level is a fact, and measures are being taken and agreements are being signed worldwide in order to carry out this necessary transformation. Natural gas plays a very important role as an alternative fuel to the harmful fossil fuels we currently use for the most part.

In some areas, such as vehicular transport, or power generation, natural gas can be considered as a temporary power generation method. In these environments what is being pursued, and the ultimate goal, is renewable energies and the total decarbonisation of vehicles, seeking an electric fleet, without emissions. In other areas, such as maritime transport, natural gas does seem to be an ultimate fuel, the ultimate goal for fuel to be used by sea. Although others are emerging, such as hydrogen, which could replace LNG.

Natural gas and its use may become less important in the future, as the ultimate goal is decarbonisation, but today it is an important subject of study, not only at the environmental level but at all levels.

These levels must not lose sight of the meaning of energy sustainability, which not only entails caring for the environment, but also investigating and researching the best way to carry out all types of management around LNG. Asian demand is set to continue to grow, as is industrial demand for gas. US supplies will also continue to grow and produce large quantities of natural gas. According to the International Energy Agency, these are the two aspects that will drive the market. The LNG market will continue to grow, and this implies that the fleet of LNG carriers and gas liquefaction plants will continue to grow.

In the maritime field, LNG will have a major influence. From the point of view of the ports, they will have to be prepared for the exchanges that will take place in them and therefore have the appropriate infrastructure. As for ships in general, more and more of them will be propelled by gas, because the restrictions on emissions in maritime transport are becoming stricter and stricter. The largest LNG bunkering service is in the European Union. For the development and the possibility of shipping companies' decision to build LNG-powered ships, bunkering service should be more present in the rest of the continents. (15)

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3. ENERGETIC SUSTAINABILITY

Numerous articles and research papers deal with energy sustainability and the need for a transition to more sustainable energies. The main ideas about energy sustainability associated

with natural gas, which have been found in numerous articles related to the subject, are discussed below. The most representative ones are cited and whose content develops the ideas summarised below.

It is worth highlighting a document written in 1997, Sustainable Energy in a Developing World: The Role of Knowledgeable Markets (17) in which the aim is to define and express the need to understand the term sustainability and how to apply it to the energy market and globalisation. It is interesting to see in this document that it is necessary to describe the word sustainability, which was so widely used even at that time, but not always in the right way.

The Kyoto Protocol itself was created in the same year and seeks to tackle greenhouse gas emissions in the world. It proposes the search for alternative energies that each country should apply in order to achieve these goals. With the Kyoto Protocol, the need to reduce emissions harmful to the atmosphere and the planet, which was already known at that time, was formalised and written down at a global level.

The importance of an energy transition to meet these targets puts the oil-based economic model in the spotlight. Alternative energies soon began to gain in importance and develop, and natural gas made its way onto the energy market.

The Challenge and Opportunity of the 21st Century. Towards a low-energy economy"(18) describes the unsustainability of the oil-based economic model and looks at natural gas as an alternative, which, while appearing more flexible and with fewer constraints, is expected to decline even more steeply than oil.

Other documents and papers show more positive perceptions, describing the growth in the use of natural gas, the importance of LNG transport, and the environmental advantages of natural gas as a fuel. These are the main themes that are written up in LNG: An eco-friendly cryogenic fuel for sustainable development. Applied energy. (19)

Many industries benefit from the use of natural gas, Sustainable development, climate change-Kyoto: A challenge for the Spanish process industry. Chemical engineering (20) focuses its paper on the importance of energy change and transition in process industries (chemical and petrochemical, mining, food, semiconductors, water treatment or oil refining among others) to comply with the Kyoto protocol.

One of the issues related to natural gas and which energetically shows a weakness is the security of supply at European level. Many articles show concern about this issue and propose long-term visions to reduce the vulnerability of the gas energy system and increase energy network connections.

For example, The future of gas and the role of Liquefied Natural Gas (LNG): economic and geopolitical implications (21). Economic and geopolitical implications (21) not only discuss the growth of LNG trade, but also the contracts that exist between producers and wholesale traders and the need for more gas inward connections in Europe. Security of supply is also discussed in another interesting document, Energy policies in the EU: security of supply, environment and competition (22).

The geopolitical situation is one of the issues that most concerns Europe and is linked to security of supply; dependence on Russia is currently one of the main concerns in this area. In the article Dilemma and Challenge: For an EU Energy Policy (23). The author discusses in detail the energy dependence on Russia, and the gas crises that have caused Europe to study and worry about energy supply. He comments that all the documents drawn up by the European institutions on this subject are generally based on three principles: competitiveness, sustainability and energy security. And these three principles respond to the two main problems

that the Union has had in the energy field over the years: dependence on the outside world and the fragmentation of Member States' policies.

The institutions have taken initiatives to liberalise the gas and electricity sector. With the creation of a European gas market, the Commission aims to drastically reduce the control that member states have over the energy sector and thus improve its competitiveness by making market logic prevail. In order to reduce energy dependence on Russia, the EU has planned a system of gas pipelines encircling the territory of the Federation. However, Russia's power of influence over certain key countries for the project and the uncooperative behaviour of certain member states have had a very negative impact on the implementation of this strategy.

The following paper, Politics, Markets and the Shift to Gas: Insights from the Seven Historical Case Studies(24), discusses a research programme based on the environmental and economic consequences of energy systems, the ESDP. Those studies examine the global shift to natural gas, the reform of electricity markets, international climate policy, the major geopolitical influence on the gas sector and the influence of this on security of supply. He makes an interesting examination of the issues affecting cross-border trade, which are: transit countries (they want to encourage buyers and sellers to pass through their facilities, not delay or cause problems for other countries), consumption risks and geopolitical relations (in the past the state used to make the commercial decisions, now the state sets the context, but stays more on the sidelines. It is not clear that it is favourable for the state to "disappear" and it seems favourable for the state to plan these gas networks).

4. PORT SUSTAINABILITY

For example, the thesis by Canbulat (25) discusses how ports and maritime transport are key to the sustainable development of this growth and the increased consumption that comes with population growth. At the Spanish level, the following two documents refer to the infrastructures of the Spanish gas system and evaluate the gasification capacity of Spanish terminals, allowing an analysis of future gas demand. An economic assessment of the construction of a new LNG import terminal in Spain is also carried out.

The documents are Maritime terminals and logistics chains for liquefied natural gas (LNG). Assessment of future needs in Spain (26) and Evolution of LNG and technological advances in LNG plants in Spain (27).

Study (28) analyses ports, highlighting the role of port authorities and the pioneering initiatives they are developing through the plans and projects of the ports of Barcelona and Vigo. It also raises, through the blue growth of the EU, the importance of the maritime sector and that the level of technological development for the coming years will mean a transformation of the current model of maritime transport. He talks about maritime spatial plans and how they promote the sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources.

Of particular interest is the vision for such plans, in that they will take into account land-sea interactions and determine maritime transport routes and traffic. The promotion of alternative fuels, such as LNG, is a reality that is being encouraged as a measure to control and reduce greenhouse gases. The action of ports in this respect is key, since, as hubs connecting maritime transport and other complementary means of transport and key parts of the logistics chain, they can act as drivers of these initiatives.

However, this requires prior work on the part of the ports to equip themselves with the necessary infrastructures and supply facilities. In relation to port sustainability, another interesting article is, LNG traffic logistics and its implications for the development of port infrastructures and services: past, present and future prospects (29) which raises the challenges and projects in future LNG logistics and the implications for ports. Some of the comments in this document are the following. If nuclear generation capacity is finally phased out, gas will find an important place and there will be new developments on a global scale.

Floating liquefaction and regasification plants are a reality and can be an opportunity in the port sector. Another transformation in the port sector may come from bi-directional terminals (regasification + liquefaction). Logistical adjustments will come from the emergence of new importing powers. More ships using LNG as fuel is a direct implication for port bunkering facilities. A market may emerge, which we can link to the concept of SSS, in which LNG transport is developed, with smaller vessels that generate business opportunities for importing countries that are logistically well placed.

5. LNG AS A SUSTAINABLE FUEL

The relationship between port sustainability and the use of LNG as a marine fuel was discussed in the previous section. The direct involvement of the port system in the transition to this alternative fuel is noted.

This section has been based on three documents, which describe the current situation of LNG as a marine fuel.

The first of these, Implications of SECAs and SECAs in the port city (30), puts the issues in context and describes why ECA and SECA zones have emerged and links the use of LNG to the creation of such zones. He also compares the advantages and disadvantages of LNG as a fuel, talking about low emissions and economical fuel, but also about the large storage space and the necessary transformation of port infrastructures to make them safe.

It mentions that LNG is suitable for short distance and small vessels, offshore vessels do not yet seem to be a candidate for this fuel. This concept also appears in the following paper Application of artificial intelligence to analyse the use of liquefied natural gas in Short Sea Shipping in Europe: specific analysis of the social and population components (31).

This document describes how short sea shipping was proposed by the EU to decongest the main European corridors (pollution and accidents) and LNG is a fuel alternative with less environmental impact. He proposes two variables when deciding to use LNG as a fuel: the capacity of the LNG regasification terminals under construction and the modal distribution of cargo transport by inland waters. Environmental, energy and population variables are also important.

The third document, The Past, Present and Future of Europe's Motorways of the Sea (32) discusses LNG as a marine fuel and the commitment to the maritime transport chain, linking both aspects to sustainability. It mentions the COSTA project, which aims to study the feasibility and develop the supply of liquefied natural gas (LNG) as an engine for the growth and sustainable development of maritime transport in the Mediterranean, Atlantic and North Sea, in which four Member States (Italy, Spain, Portugal and Greece) are involved.

The conclusion is that LNG is in line with European transport policy and will have a positive impact on the environment, saving costs and strengthening the motorways of the sea.

Table 2. Themes using PPDC methodology

Studies	Type of analysis
The internal and external environment analysis of Romanian naval industry with SWOT model [34]. Introduces shipbuilding, including LNG carriers.	SWOT
Effect of the northern sea route opening to the shipping activities at Malacca straits [35]. How the use of the northern sea route affects the economic activity in the Straits of Malacca and Malaysia.	SWOT PESTEL
Fundamental analysis and valuation of Gas Natural Fenosa [36]. Analysis of the merger between Gas Natural Fenosa and Unión Fenosa in the midst of the crisis.	SWOT PORTER
An analysis of the oil and gas industry's competitiveness using Porter's five forces framework [37]. Competitiveness of the gas industry.	SWOT PORTER
Strategic plan of the distribution company Gas Natural BAN SA 2008-2010[38].	SWOT CAME PESTEL
Entering the German Gas market in Lübeck [39]. It details the strategies of a small Norwegian company with expansion prospects.	SWOT PORTER PESTEL
Impact of PESTLE factors on power generation projects of Bangladesh [40]. Energy crisis where projects have been proposed without meeting targets due to the lack of analysis and planning.	PESTEL
Liberalisation of the Turkish natural gas market: a critical evaluation [41]. Liberalisation of an important natural gas market for introducing competitiveness.	SWOT PESTEL
Macro-environmental Analysis for the Alberta Midstream Oil and Gas Sector [42]. Large gas reserves in Canada, but its weakness lies in the lack of pipeline capacity.	SWOT PESTEL
Strategic analysis for companies in the liquefied petroleum gas commercialisation sector, in view of the change in the energy matrix in Ecuador [43].	SWOT CAME PORTER PESTEL
A technical evaluation, performance analysis and risk assessment of multiple novel oxxy-turbine power cycles with complete CO2 capture [44].	PESTEL
The Brazilian offshore oil and gas industry: potential and market [45]. Comparison of the use of gas and other fuels in power generation cycles (gas=combined cycle).	SWOT PORTER PESTEL
Critical analyse of EU Energy Policy and its impact on market subjects [46]. Critical analyse of current EU policy and its impact on energy commodity market participants, with special emphasis on energy companies and costumers.	SWOT PORTER PESTEL
Emerging LNG-fueled ships in the Chinese shipping industry: a hybrid analysis on its prospects [47]. It analyses the prospects for the development of LNG-fuelled ships in inland waterway transport in China, with the aim of changing inadequate thinking.	SWOT

Source: own elaboration based on SEA-LNG

It is worth mentioning in this section the link between LNG and the use of H2. The document Hydrogen generation in LNG carriers (33) summarises that special attention should be paid to the gas management system in LNG carriers without reliquefaction plant, because the excess BOG (Boil Off Gas) generated is burnt in the GCU (Gas Combustion Unit) without any energy input, so there is a clear need to improve the system.

The gas management system in LNG carriers is a critical element, since the use of the BOG generated is of utmost importance for the overall efficiency of the installation to be as high as possible. At present, LNG carriers without reliquefaction plant consume the BOG generated in the propulsion system, and the excess is burned in the GCU (Gas Combustion Unit) without any energy utilisation, so there is a clear need to improve the gas management system. The excess BOG can be treated in a steam reforming plant to generate H2, a clean fuel with no pollutant emissions. The use of H2 as a fuel allows the ship to sail in areas with strict anti-pollution regulations and during the stay in port avoids the need for the costly Cold Ironing.

6. APPLICATION OF THE PPDC METHODOLOGY IN RELATION TO THE LNG MARKET

The application of the PPDC methodology is not common, but it is common to see studies with one or more of the analyses that make up the PPDC methodology. Mostly in university research and also in documents from organisations, in this case related to the gas sector.

Table 2 below shows the documents where these methodologies have been applied.

7. METHODOLOGY AND RESULTS

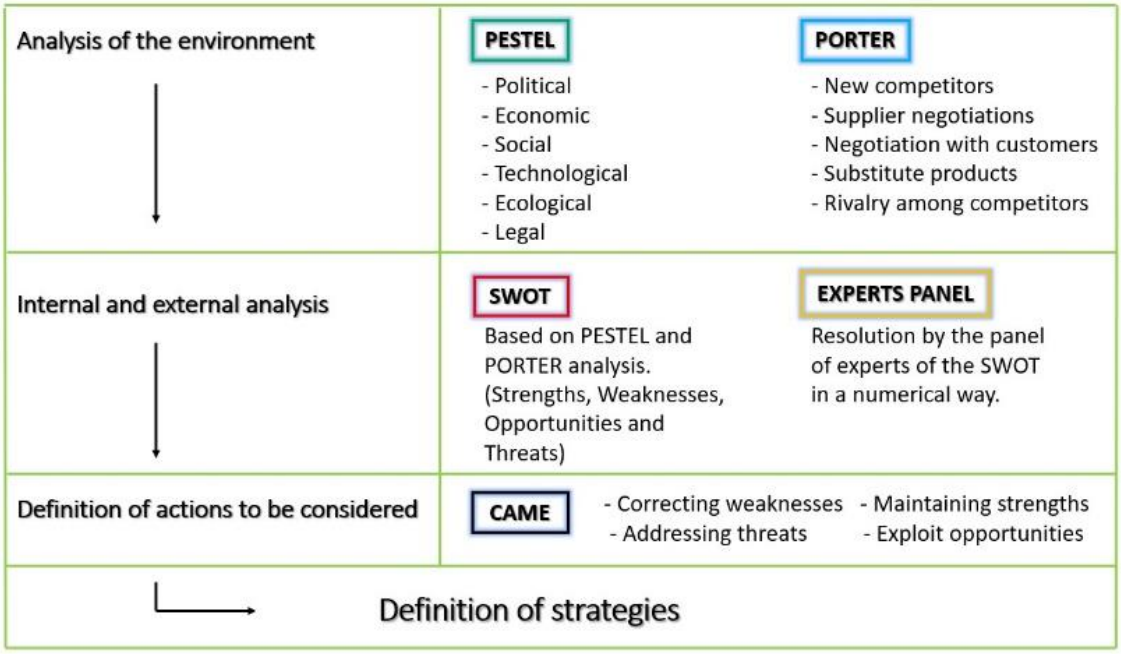

Figure 1. Methodology applied for the study.
Source: own elaboration

The method to be applied consists of a first study on a macroscopic scale, using the PESTEL analysis and Porter's 5 forces analysis. Some of the most important concepts linking these two analyses to the study of LNG use in the European Union will be studied and defined. This will provide an overview of the main features of this study. These concepts will be used in the SWOT analysis. Once the SWOT matrix has been defined, a panel of experts will make the numerical assessment, and the average of all the SWOTs made by each of the experts will be the matrix that will be used to carry out the SWOT analysis. In the SWOT analysis, the two most extreme quadrants of the SWOT (with the highest and lowest scores), which will be analysed in detail, will be selected as the strategies to be proposed in this study.

The methodology is shown schematically in Figure (1).

The following is a brief introduction to each of the four analyses to be used.

7. 1. PESTEL analysis

The PESTEL analysis helps to understand and analyse the macroeconomic environment of the study or research to be carried out, it describes the general environment. The analysis is carried out by studying political, economic, social, technological, ecological and legal factors.

It is a way of knowing and ordering these external factors that are involved in the topic to be addressed. It also helps to recognise and understand these factors, which give valuable information when looking for threats and increasing opportunities. The PESTEL analysis is of great help in carrying out the SWOT analysis.

For this case study, we will focus on the 6 factors mentioned above in Figure (2).

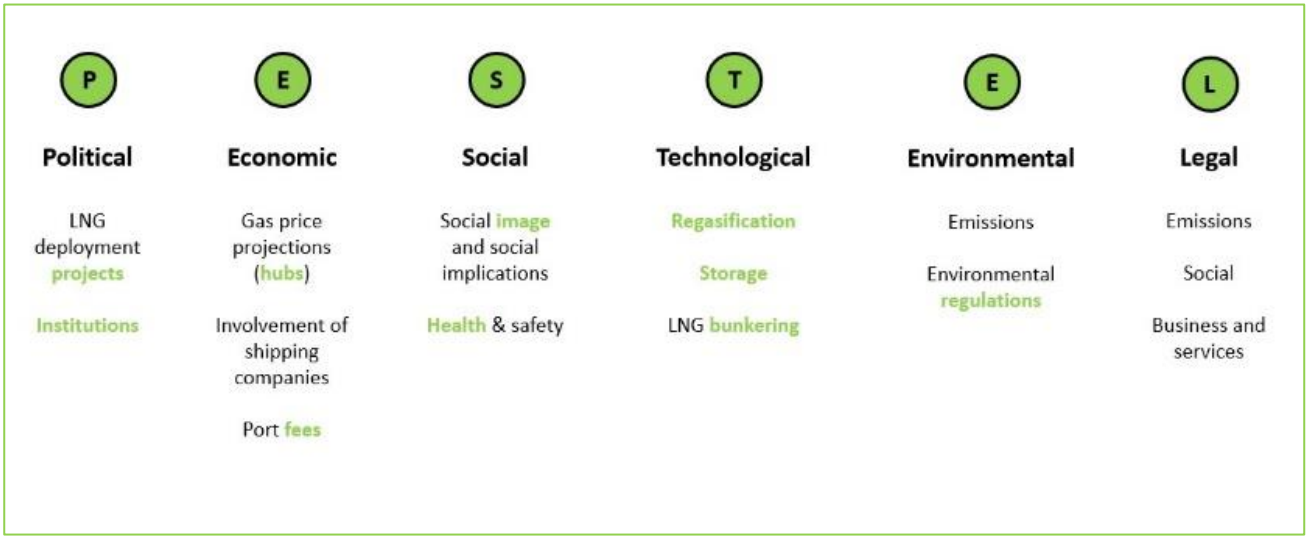

Figure 2. Results of the PESTEL analysis. Source: own elaboration

As an example of how the selection has been made, the following is given under the policy factor: GNL deployment projections PCI (Projects of Common Interest): The European Union has so-called Projects of Common Interest (PCI). These are projects that aim to help the Union achieve climate objectives; affordable, secure and sustainable energy for citizens and long-term decarbonisation. For a project proposal to become a PCI it must have a significant

impact on energy markets, boost competition in energy markets and help energy security through diversification of sources.

Connecting Europe Facility (CEF): PCIs can benefit from accelerated planning and permitting, reduced administrative costs, improved regulatory conditions and access to apply for funding from the Connecting Europe Facility (CEF). The European Commission specifically opens calls for gas and electricity projects, including LNG terminals and energy storage projects. In the current multiannual financial period (2014-2020), investments in LNG deployment projects accounted for almost 12% of the entire maritime portfolio under the CEF.

Institutions

Not only the existence of financial funds, but also the existence of institutions aimed at supporting and deploying LNG-related projects is important.

Some of the most relevant institutions are:

- European Sustainable Shipping Forum (ESSF).
- Connecting Europe Facility (CEF)
- Green Shipping Guarantee Scheme (financial guarantee to the CEF)
- European Fund for Strategic Investments (EFSI)
- European Maritime Safety Agency (EMSA)

7. 2. PORTER analysis

Porter's five forces analysis is a model established to analyse the level of competition within an industry. With this analysis, an examination of the industry in question is carried out at a given time in order to determine the position of one company in relation to another within that industry as shown in Figure (3). In this case, the industry to be considered is that of supplying LNG as fuel to ships, and the company is the European Union as a supplier of LNG.

Figure 3. Analysis of the 5 forces of power.
Source: own elaboration

Five forces are studied and developed focusing on the point of view of this study as shown in Figure (4). Under “new competitors”, as an example of how the selection has been made, the following is indicated: Competitor countries: Countries whose coasts share seas or oceans with EU countries, and which have a bunkering service, could be considered competitors. These are only Morocco and Norway.

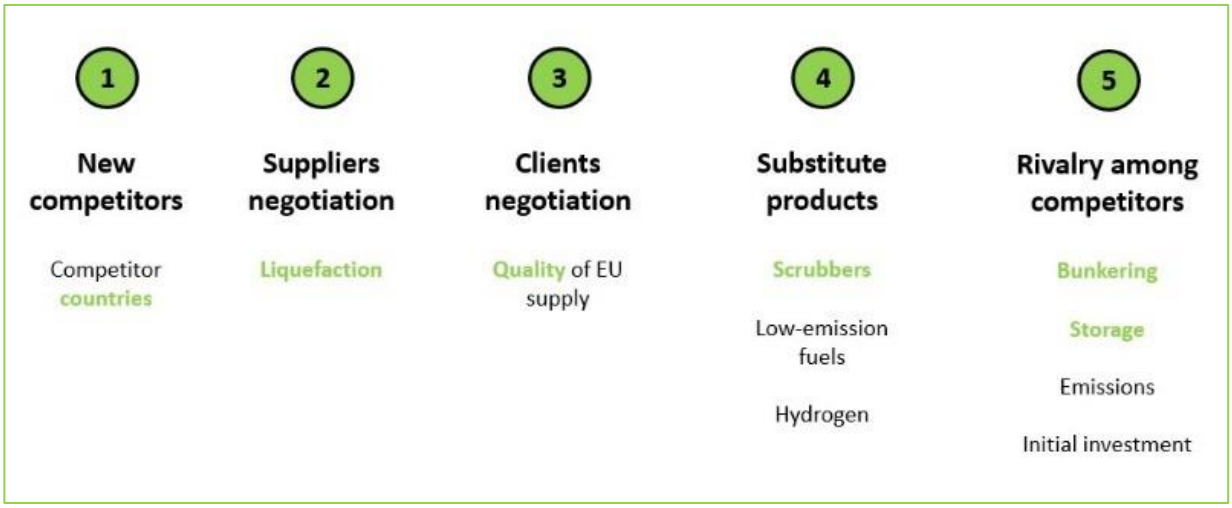

Figure 4. Result of the 5 forces of power analysis.
Source: own elaboration

Environmental restrictions: ECA areas are more restrictive in terms of sulphur than the other areas, which are only affected by the IMO 2020 restrictions. The Mediterranean Sea, and the Atlantic Ocean at its contact with Norway are not currently ECA areas. Therefore, they are less restrictive in terms of emissions and more attractive for certain shipping lines in case they seek to avoid areas with greater restrictions.

7. 3. SWOT analysis

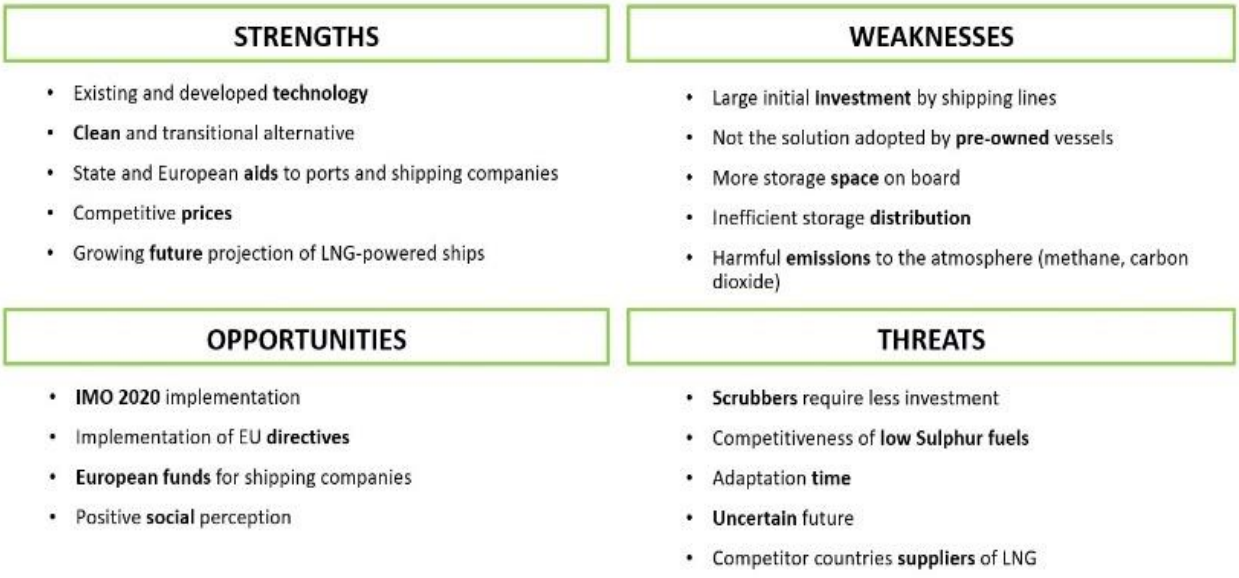

Figure 5. Result of the SWOT analysis.
Source: own elaboration

The purpose of this analysis is to determine the current situation regarding the use of LNG in the European Union. It studies the weaknesses and strengths, and the threats and opportunities of the sector. Knowing one's own weaknesses and strengths is essential, having an internal knowledge of the situation of the sector under study is important in order to be able to make an action plan. In the same way, knowing the external opportunities and threats is important in order to learn how to take advantage of the opportunities and face the threats.

Figure (5) shows the results of the SWOT analysis

As an example of SWOT development: D3 - Need for more storage space on board: Another of the main drawbacks when using LNG as fuel in ships is that the tanks where the fuel is stored require a large amount of space, more than in conventional ships. This amount of space required translates into a reduction of available space for the cargo to be transported. The efficiency of shipping lines can be affected by this fact, which can result in higher freight rates.

7. 4. Panel of experts

In order to carry out the numerical assessment of the matrix, a numerical assessment has been assumed with values between 1 and 5.

This score has the following meaning:

- There is no relationship between the two factors.
- The relationship is slight.
- There is a relationship.
- There is a relationship and it is considerable.
- Both factors are completely related.

A panel of experts in the field was used to carry out the numerical SWOT analysis. The mean and deviation of each of the four quadrants of the matrices solved by the experts was then calculated. After 2 rounds of the SWOT, the values are considered correct, given that the standard deviation of the matrices does not exceed 1 in any of the cases. The result of the final SWOT matrix is the average of the SWOT matrices carried out by the experts as shown in Table 3.

Table 3. Results of the Expert panel

AVERAGE	O1	O2	O3	O4	O5	Subtotal	A1	A2	A3	A4	A5	Subtotal
F1	3,9	3,3	3,0	2,1	1,9	14,1	3,0	3,4	3,5	2,8	3,3	15,9
F2	3,5	3,6	2,5	2,3	3,1	15,0	3,1	3,8	3,1	3,1	2,6	15,8
F3	2,4	3,5	3,8	3,8	2,5	15,9	3,1	2,9	2,4	1,8	3,3	13,4
F4	1,8	2,5	1,8	3,3	2,3	11,5	3,8	3,9	2,8	2,8	3,9	17,0
F5	3,1	3,3	3,3	3,4	1,9	14,9	3,4	3,5	3,1	3,5	3,6	17,1
Subtotal	14,6	16,1	14,3	14,8	11,6	71,4	16,4	17,4	14,9	13,9	16,6	79,1
D1	2,9	3,0	3,0	3,3	1,3	13,4	3,1	3,4	3,4	3,3	3,0	16,1
D2	1,9	2,1	2,1	2,4	1,3	9,8	3,8	3,5	3,8	3,4	2,1	16,5
D3	2,0	1,8	1,8	2,4	1,4	9,3	2,1	2,9	3,1	2,9	2,3	13,3
D4	2,6	2,8	2,6	2,1	1,8	11,9	1,5	2,5	2,0	2,5	3,5	12,0
D5	4,1	4,0	2,4	1,9	2,6	15,0	3,1	4,0	2,6	2,9	2,3	14,9
Subtotal	13,5	13,6	11,9	12,0	8,3	59,3	13,6	16,3	14,9	14,9	13,1	72,8

Source: own elaboration based on SEA-LNG

7. 5. CAME analysis

The CAME analysis can be interpreted as a methodology that extends and supplements the SWOT analysis. CAME stands for different actions that can be carried out; Correct, Address, Maintain and Exploit. Depending on the quadrant, the recommended action will be one of the above-mentioned actions.

Once the SWOT analysis has been completed, the strategies to be adopted can be selected. In this case, the strategies corresponding to the quadrants with the highest and lowest SWOT scores will be adopted. According to the results obtained, the quadrants to be studied and therefore the strategies to be adopted are as follows:

- ✓ Maintain the strengths, by means of a defensive strategy.
- ✓ Correcting weaknesses, through a strategy of adjustment.

8. DEFINITION OF THE STRATEGIES ADOPTED

The main ideas that have been taken into account in the strategies discussed above are set out below. These ideas arise from the study of the strengths and weaknesses set out in the SWOT. Table 4 and Table 5 set out the objectives for implementing the strategies.

Table 4. Defensive strategy

Defensive strategy: maintaining strengths	
Main ideas	
F1 - Existing and developed technology	Continue to invest in improving and adapting to **new technologies** as they emerge.
F2 - Clean and transitional alternative	Promoting the **transition** to alternative fuels
F3 - State and European aids to ports and shipping companies	To give greater visibility to the aid that is offered, in order to keep this aid active, so that it continues to be offered when there is a **high demand and effective results**.
F5 - Growing future projection of LNG-fuelled ships	To place importance on improving the **positive image of LNG as a marine fuel** and to promote the transition to alternative fuels.
Objectives	
The strengths of LNG as a marine fuel must be used to further promote it and to achieve ever better results. Results that will be reflected in an increase in the LNG-powered fleet.	

Source: own elaboration

Table 5. Adjustment strategy

Adjustment strategy: correcting weaknesses	
Main ideas	
D1 - Large initial investment required from shipping companies.	Promotion of LNG to obtain more **European funds**. Possibility of greater discounts on **fees** for LNG-fuelled ships.
D2 - Not the solution adopted by pre-owned ships.	Shorter **adaptation times**, with European funds.
D3 - Need for more storage space on board	Investment in technology and innovation to try to reduce the **size of tanks**.
D4 - Inefficient distribution of LNG storage in EU member states.	Promote the implementation of projects to increase the number of **storage tanks** for better distribution and larger capacities.
D5 - Harmful air emissions.	Guidelines for **methane** use.
Objectives	
The weaknesses of LNG for use as a marine fuel need to be corrected in order to promote the use of LNG in this sector.	

Source: own elaboration

9. CONCLUSIONS

Natural gas market forecasts indicate that prices will fall, and that Asian demand growth will slow down. Europe absorbs this surplus, providing competition for imports and putting pressure on prices.

The many environmental policies being pursued make room for LNG as an energy alternative in a wide range of uses. These two concepts of price improvement and environmental constraints lead to an immediate need for a transition to alternative fuels. In certain sectors, renewable energies have a higher degree of implementation. In the case of bunker fuel, the alternative that meets this transition to clean alternative fuels is LNG.

This work has focused on the transition capacity of European ports and shipping companies, looking at the favourable and unfavourable points of LNG as a marine fuel with high potential.

With regard to ports and their adaptation from the point of view of the European Union, it can be concluded that there is a need and that a great benefit would be obtained by implementing a community gas storage system with greater capacity and better distribution throughout European ports. With this increase in storage efficiency, the security of LNG supply to ships would also be increased, and the fleet of LNG-powered ships would be increased thanks to this security. This concept is directly related to the gas bunkering system, which, although it is true that it is quite extensive in the EU, must be backed up by storage that allows the bunkering service to be reliable and robust.

As far as shipping companies are concerned, the investment involved in building or refurbishing ships to run their fleet on LNG is very high. The fact that on-board LNG tanks take up so much space also has an impact on the viability of these projects faced by shipping companies as shown in Figure (6).

Another of the fundamental effects that prevent shipping companies from opting to have their fleet powered by LNG is that there are cheaper alternatives that are equally valid in terms of atmospheric emissions.

In conclusion, LNG is a suitable and very advantageous alternative because of its fuel economy and environmental conditions. However, it has a high implementation cost for shipping companies, as well as a long adaptation period to convert their fleet.

There is a need for aid to shipping companies and the creation of projects that allow gas supply and bunkering to be efficient, in order to boost fleet growth.

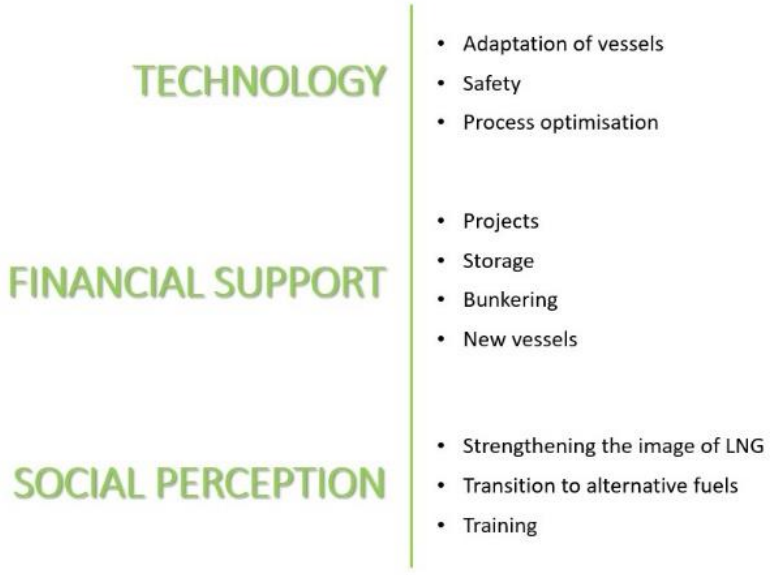

Figure 6. Project feasibility. Source: own elaboration

References

[1] J. Ogden, A. M. Jaffe, D. Scheitrum, Z. McDonald and M. Miller. Natural gas as a bridge to hydrogen transportation fuel: Insights from the literature. *Energy Policy.* Vol. 115, pp. 317-329. 2018. DOI: 10.1016/j.enpol.2017.12.049.

[2] A. R. Shazed, H. M. Ashraf, M. A. Katebah, Z. Bouabidi and E. I. Al-musleh. Overcoming the Energy and Environmental Issues of LNG Plants by Using Solid Oxide Fuel Cells. *Energy.* Vol. 218. 2020. DOI: 10.1016/j.energy.2020.119510

[3] Meza and M. Koç. The LNG trade between Qatar and East Asia: Potential impacts of unconventional energy resources on the LNG sector and Qatar's economic development goals. *Resources Policy.* Vol. 70. 2020. DOI: 10.1016/j.resourpol.2020.101886

[4] O. G. Austvik. The Energy Union and security-of-gas supply. *Energy Policy.* Vol. 96, pp. 372-382. 2016. DOI: 10.1016/j.enpol.2016.06.013.

[5] A. Rubino. The political economy of Euro-Mediterranean cooperation in the gas market: The role of domestic stakeholders and the European Commission. *Resources Policy*. Vol. 70. 2021. DOI: 10.1016/j.resourpol.2020.101883.

[6] L. Langshaw, D. Ainalis, S. Acha, N. Shah and M. Stettler. Environmental and economic analysis of liquefied natural gas (LNG) for heavy goods vehicles in the UK: A Well-to-Wheel and total cost of ownership evaluation. *Energy Policy.* Vol. 137. 2020. ISSN: (0301-4215). DOI: 10.1016/j.enpol.2019.111161

[7] J. Pospíšil, P. Charvát, O. Arsenyeva, L. Klimeš, M. Špiláček and J. Klemeš. "Energy demand of liquefaction and regasification of natural gas and the potential of LNG for operative thermal energy storage". Renewable and Sustainable Energy Reviews. Vol. 99, pp. 1-15. 2019. ISSN: (1364-0321), DOI: 10.1016/j.rser.2018.09.027.

[8] Kuzemko, A. Lawrence and M. Watson. New directions in the international political economy of energy. *Review of International Political Economy.* Vol. 26 N° 1, pp. 1-24. 2019. DOI: 10.1080/09692290.2018.1553796

[9] P. Korkmaz, F. Gardumi, G. Avgerinopoulos, M. Blesl and U. Fahl. "A comparison of three transformation pathways towards a sustainable European society-An integrated analysis from an energy system perspective". Energy Strategy Reviews. Vol. 28. 2020. ISSN: (2211-467X). DOI: 10.1016/j.esr.2020.100461.

[10] Vikara, T. Zymroz, J. A. Withum, C. Y. Shih, S. Lin, H. Hoffman and T. Carr. (2019). Underground Natural Gas Storage-Analog Studies to Geologic Storage of CO2. United States: N. p., 2019. DOI:10.2172/1492342

[11] N. González-Cancelas, B. Molina Serrano y F. Soler-Flores. Seaport sustainable: use of artificial intelligence to evaluate liquid natural gas utilization in short sea shipping. *Transportation Journal.* Vol. 58 N° 3, pp. 197-221. 2019. DOI: 10.5325/transportationj.58.3.0197

[12] B. Molina Serrano, N. González-Cancelas y F. Soler-Flores. Sustainable Short Sea Shipping traffic. Social component analysis through decision networks. *Maritime Engineering,* Vol. 171 N° 4, pp. 135-144. 2019. DOI: 10.1680/jmaen.2017.19

[13] G. Gaustad, M. Krystofik, M. Bustamante and K. Badami. "Circular economy strategies for mitigating critical material supply issues. *Resources, Conservation and Recycling*. Vol. 135, pp. 24-33. 2018. DOI: 10.1016/j.resconrec.2017.08.002.

[14] B. Molina Serrano, N. González-Cancelas and F. Soler-Flores. Analysis of the port sustainability parameters through Bayesian networks. *Environmental and Sustainability Indicators.* Vol 6. 2020. DOI: 10.1016/j.indic.2020.100030.

[15] P. Serra and G. Fancello. Towards the IMO's GHG Goals: A Critical Overview of the Perspectives and Challenges of the Main Options for Decarbonizing International Shipping. *Sustainability.* Vol 12 N° 8. 2020. DOI: 10.3390/su12083220

[16] T. Banaszkiewicz, M. Chorowski, W. Gizicki, A. Jedrusyna, J. Kielar, Z. Malecha and J. Skrzypacz. Liquefied Natural Gas in Mobile Applications—Opportunities and Challenges. *Energies.* Vol.13 N° 21. DOI: 10.3390/en13215673

[17] K. Wilkening, D. Von Hippel and P. Hayes. Sustainable Energy in a Developing World: The Role of Knowledgeable Markets. United Nations University Symposium on Environment. California, United States of America. November 14 and 15th 1997.

[18] Bengoetxea. El reto y la oportunidad del siglo XXI. Hacia una economía baja en energía. *Ingeniería y Territorio.* N° 82, pp. 12-19.

[19] S. Kumar, H. Kwon, K. Choi, W. Lim, J. H. Cho, K. Tak y I. Moon. LNG: An eco-friendly cryogenic fuel for sustainable development. *Applied Energy.* Vol. 88 N° 12, pp. 4264-4273. 2011. DOI: 10.1016/j.apenergy.2011.06.035

[20] R. Aga. Desarrollo sostenible, cambio climático-Kioto: Un desafío para la industria de proceso española. *Ingeniería química.* Vol. 414, pp. 84-94. 2004.

[21] R. Snijder. El futuro del gas y el papel del Gas Natural Licuado (GNL): implicaciones económicas y geopolíticas. *Boletín Elcano.* Vol. 103 Nº 18. 2008.

[22] G. Federico y X. Vives. Políticas energéticas en la UE: seguridad de suministro, medio ambiente y competencia. *Cuadernos Económicos de ICE*. Vol. 79. 2010.

[23] J. Rabadán y L. Baz. Dilema y reto: por una política comunitaria en energía. *Cuadernos Europeos de Deusto.* Vol. 42, pp. 101-123. 2010

[24] M. Hayes and D. Victor. Politics, Markets and the Shift to Gas: Insights from the Seven Historical Case Studies. *Natural Gas and Geopolitics.* pp. 319-354. 2009. DOI: 10.1017/CBO9780511493492.011

[25] O. Canbulat. Brunel Business School (Doctoral dissertation, Brunel University). 1895.

[26] B. Manuel. Terminales marítimas y cadenas logísticas para gas natural licuado (GNL)". Evaluación de las necesidades futuras en España. 2017 (Doctoral dissertation).

[27] C. Iniesta. Evolución del GN y avances tecnológicos en las plantas de GNL de España. *Puertos: información mensual de Puertos del Estado.* Vol. 150, pp. 40-66. 2009.

[28] M. Zamora. La gobernanza de la descarbonización marítima: iniciativas desde los puertos". Revista Catalana de Dret Ambiental. Vol. 9 N° 1. 2018. DOI: 10.17345/2117

[29] de la Peña y M. Elorduy. Logística del tráfico de GNL y sus implicaciones en el desarrollo de infraestructuras y servicios portuarios: pasado, presente y perspectivas de futuro. *Conference: II Mediterranean Days of Coastal and Port Engineering.* Vol. 1, pp. 255-277. 2012

[30] N. González-Cancelas, F. Soler-Flores, A. Orive, A. Camarero. Transporte marítimo y medio ambiente: las implicaciones de las SECAs y las ECAs. *Transporte y Territorio.* Vol 8, pp. 138-156. 2013. DOI: 10.34096/rtt.i8.297

[31] B. Molina, N. González-Cancelas, F. Soler-Flores y A. Camarero. Aplicación de inteligencia artificial para analizar el uso del gas natural licuado en el Short Sea Shipping en Europa: análisis específico de las componentes social y poblacional. *Transporte y Territorio.* Vol. 19, pp. 98-114. 2018

[32] A. Acedo y J. Almazán. Pasado, presente y futuro de las Autopistas del Mar en Europa. *Revista de Obras Públicas: Órgano profesional de los ingenieros de caminos, canales y puertos.* Vol 3565, pp. 31-38. 2015.

[33] Arias-Fernández. Generación de hidrógeno en buques GNL. Repositorio Universidade Coruña. 2017.

[34] A. Gasparotti. The internal and external environment analysis of Romanian naval industry with SWOT model. *Management & Marketing.* Vol. 4 N° 3, pp. 97-110. 2009

[35] N. A. Rahman, A. H. Saharuddin and R. Rasdi. Effect of the northern sea route opening to the shipping activities at Malacca straits. *International Journal of e-Navigation and Maritime Economy.* Vol 1, pp. 85-98. 2014. DOI: 10.1016/j.enavi.2014.12.008

[36] Vázquez. Análisis fundamental y valoración de Gas Natural Fenosa. Repositorio Universidad de León. 2014.

[37] M. A. Hokroh. An analysis of the oil and gas industry's competitiveness using Porter's five forces framework. *Global Journal of Commerce and Management Perspective*. Vol. 3 N° 2, pp. 76-82. 2014

[38] Fernández y R. Pacora. Plan estratégico de la empresa de distribución Gas Natural BAN SA período 2008-2010. Repositorio Universidad del Pacífico. 2014.

[39] A. Amith, K. Finstad and G. Lie. Entering the German Gas market in Lübeck. Norwegian Business School. 2009.

[40] Hussain. Impact of PESTLE factors on power generation projects of Bangladesh. Institute of Governance Studies, BRAC University. 2013.

[41] D. Beyazgul. Liberalisation of the Turkish natural gas market: a critical evaluation. Politecnico di Milano. 2016.

[42] E. Bargorett and B. Williams. Macro-environmental Analysis for the Alberta Midstream Oil and Gas Sector. Athabasca University. 2014.

[43] V. Masache. Análisis estratégico para las empresas del sector comercializador de gas licuado de petróleo, ante el cambio de la matriz energética en el Ecuador. Repositorio digital Escuela Politécnica Nacional de Ecuador. 2015.

[44] F. Climent, G. Martínez-Denegri, B. Soler, H. Darabkhani and E. Anthony. A technical evaluation, performance analysis and risk assessment of multiple novel oxy-turbine power cycles with complete CO2 capture. *Journal of Cleaner Production.* Vol 133, pp. 971-985. DOI: 10.1016/j.jclepro.2016.05.189.

[45] M. Herrmann. The Brazilian offshore oil and gas industry: potential and market entry for Friesland Kabel. Lisbon University Institute. 2015.

[46] P. Mullerová. Critical analyze of eu energy policy and its impact on market subjects. Brno University of Technology.

[47] C. Wan, X. Yan, D. Zhang, D. J. Shi, S. Fu and A. K. Ng. Emerging LNG-fueled ships in the Chinese shipping industry: a hybrid analysis on its prospects. *WMU Journal of Maritime Affairs.* Vol. 14 N° 1, pp. 43-59. 2015. DOI: 10.1007/s13437-015-0080-6