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Identification of Cost- and Time-efficient LNG Transportation Methods from the US to Finland in the Existing Political and Economic Situation

Bachelor's Thesis

Business Logistics

December 2016



KYAMK
University of Applied Sciences

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Thesis Title Identification of Cost- and Time-Efficient LNG Transportation Methods from the US to Finland in the Existing Political and Economic Situation		
Commissioned by		
Supervisor Eva-Lisa Kauhanen, Senior Lecturer		
<p>Abstract</p> <p>The thesis was focused on the analysis of the global LNG market and description of the existing situation on the US and Finnish domestic LNG markets.</p> <p>The main objectives were to examine the present situation on both markets and to find the most efficient way to deliver LNG from the US to Finland. The theoretical framework was completed by researching literature that is related to the chosen topic. The empirical part is based on analyzing the information from the theoretical research and calculating the potential expenditures of different possible delivery routes. After that, the expenditures were compared, and it was discerned that the most theoretically efficient way of LNG transportation from the US to Finland is the delivery by LNG tanker to the LNG terminal with the following transportation to the end customers using pipe-line transport.</p> <p>Considering the fact that for both countries that were studied in this thesis external LNG activity is a new and rapidly growing field of action, this thesis is a good source of information for companies that are going to enter the markets of LNG trade or transportation.</p>		
<p>Keywords:</p> <p>natural gas, liquefied natural gas, LNG, US, Finland, import, logistics, transportation</p>		

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1. INTRODUCTION

Nowadays, fuel consumption and polluting emissions are becoming an outstanding problem for logistics service providers worldwide. Such a trend exists due to a combination of different circumstances such as growing importance of ecological situation, increasing taxes and gasoline prices. In the current situation, the use of gases seems to be an efficient solution for a range of reasons. First of all, applying gas as a fuel for cars and vessels reduces the formation of emissions. Secondly, the usage of gas provides fuel costs reduction because the prices for LNG in the EU are nearly two times lower than for petroleum. This accounts for the tendency of annual smooth growth in gas demand. Another reason for improvement LNG transportation processes is the aggravation of politico-economical situation between the European Union and the Russian Federation, which makes it important for the European countries to become more independent of Russian suppliers and transit countries. The choice of the US as a supplier is motivated by two reasons. First of all, the US started exporting LNG in 2016, which means that it is a new market for them. The second reason is the forecasts of main analysts who predict that the US is going to become the third biggest provider of LNG in the world market in the next decade because of their big natural gas deposits and low gas prices. As a consequence of the collection of facts that were mentioned before, it is possible to foresee that the reliance on experienced logistics companies that are able to organize the LNG transportation from the USA to EU-member countries in the most cost- and time-efficient way grows slowly but steadily.

Main objective

The main objective of this thesis is to determine the most cost- and time-efficient way to deliver liquefied natural gas from the US to Finland in the existing political and economic situation.

For the purpose of achieving this objective it is necessary to consider the following sub-questions:

- What are the main suppliers and consumers of LNG?
- How political and economic situation affects global and Finnish primary energy markets?
- What are the main conditions and trends at the Finnish and US LNG markets?
- Why is LNG growing in popularity?
- How healthy is the LNG infrastructure in Finland and in the US?
- How LNG supply chain is usually organized?
- What are the possibilities for importing LNG to Finland?

Research methods

For theoretical part, the desktop research was chosen as a research method. Generally, it means that LNG application and transportation related literature, different economic reports and other officially published information will be used as resources of data. This method is the most suitable option for this type of graduation work due to the necessity for analyzing the existing market situation which is impossible without large amounts of relevant and adequate information.

Another method that will be used for collecting data is an interview with the representatives of shipping company specializing in transportation of energy resources. The importance of using this method consists in the lack of information based on practical experience in available information sources.

The empirical part of this thesis will be based on a comparison of calculations of logistical costs and time expenditures for different ways of LNG transportation to Finland. These calculations will include prices for LNG from different supplying countries. As a consequence of this comparison, it will be possible to define the most effective way of LNG import. The information about costs and other data that is needed for calculations will be taken from official information sources or requested from logistics service providers in the industry.

2. NATURAL GAS

Natural gas is a gaseous mixture which consists of mostly methane, propane, butane, ethane and other gases, represented in Table 1, that was formed in Earth's bowels as a result of anaerobic decomposition of organic matter. It is one of the most environmental-friendly, non-hazardous and consumable natural energy resources. (Theodoropoulos, 2010, p. 229).

Gas	Composition	Range
Methane	CH_4	70-90%
Ethane	C_2H_4	0-20%
Propane	C_3H_8	
Butane	C_4H_{10}	
Pentane and higher hydrocarbons	C_5H_{12}	0-10%
Carbon dioxide	CO_2	0-8%
Oxygen	O_2	0-0.2%
Hydrogen sulfide, Carbonyl sulfide	H_2S, COS	0-5%

Table 1: Composition of Natural Gas (Theodoropoulos, 2010)

LNG as a cargo is a cryogenic liquid. It is transported at a temperature of -160 °C and at atmospheric pressure. The LNG has a density of 430-470 kilos per cubic meter. The volume of LNG is circa 1/600 of the value of the natural gas in atmospheric conditions. LNG is odorless, non-toxic and non-rusting cargo. At the same time, LNG is flammable and explosive cargo when its vapor concentration in the air is more than 5%. (LNGas.ru, 2016).

2.1. AREAS OF LNG IMPLEMENTATION

In order to understand how important LNG is, it is necessary to describe the spheres of LNG implementation and level of consumption rates. First of all, gas is the most popular fossil fuel for electrical power production. Generally, the electricity production of gas process is based on using gas and steam turbines or different combinations of them. The popularity of gas is the result of its ecological combustion characteristics. It is proved that the

burning of natural gas is nearly 30% cleaner than the burning of petroleum and 45% cleaner than the burning of coal in terms of carbon dioxide emissions. (Theodoropoulos, 2010, p. 270).

Another area of natural gas implementation is to use it as a fuel for central heating as well as heating of residential and commercial buildings. It is one of the reasons for seasonal demand and price fluctuations for LNG. The growth in natural gas consumption is a result of growing need of heating in the winter season. (James G. Speight, 2007, p. 142).

Natural gas is also used as a fuel for internal-combustion engines in trucks and vehicles. (US Alternative fuels data center, 2016). The usage of natural gas gives a range of advantages over using petroleum or diesel fuel. The main advantages are almost one third lower fuel prices, less ecological footprint and lower car-taxes in case of emission-based taxes. (Harris, 2005, p. 5).

Because of the benefits from using natural gas that were mentioned before, the tendency of implementing gas-fired engines in other modes of transport has arisen. For example, BNSF Railway in cooperation with GE Transportation are testing a locomotive equipped with a dual-fuel engine kit that works on a mixture of diesel fuel and natural gas in the 20/80 pro rata. (Vantuono, 2014). The locomotives of this type are going to be used at railways that are not provided with electrical power grids. The example of growth of LNG-fuelled engines popularity is an existing trend of implementing gas-fueled engines for merchant fleets. Nowadays, an increasing number of articles about using LNG as a ship fuel are being published in professional web-sources and magazines. It seems to be a result of the 2015 European laws that limited the sulfur emissions from merchant vessels. From the point of DNV GL, the usage of LNG as a ship fuel is one of the most affordable alternatives that will partly solve the problem of emission limitations in the near future. (Wuersig & Chiotopoulos, 2015, pp. 6-7).

2.2. LNG SUPPLY CHAIN

Generally, the supply chain is a sequence of activities and organizations that products pass on their way from initial suppliers to consumers.

(Waters, 2009, p. 9).

According to Waters (2009, 10), the former professor of management at the Calgary university of Canada, any product has its own unique supply chain.

Naturally, The LNG is not an exception. In compliance with the LNG supply chain article in Gas in Focus magazine, LNG supply chain usually consist of four segments: production, liquefaction, transportation storage and regasification. (gasinfocus.com, 2016).

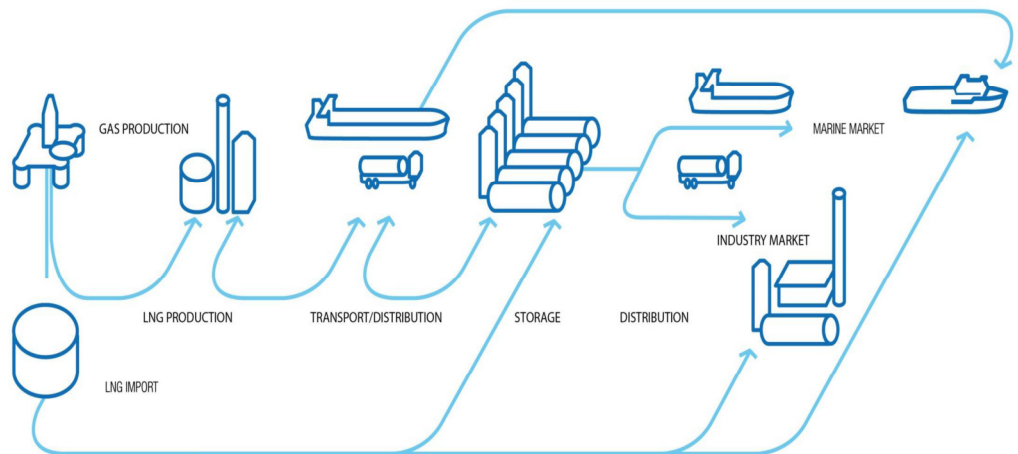


Figure 1: LNG supply chain. Available at:
http://www.kaasuyhdistys.fi/sites/default/files/pdf/esitykset/20150423_kevatkokous/Osmundsen.pdf

2.2.1. PRODUCTION OF THE NATURAL GAS

The process of the natural gas production starts from geological explorations of territories where gas accumulations can potentially be found. After the geological explorations, different kinds of tests take place. The most used tests are seismological studies, geodetic studies and orientation drilling followed by chemical tests. In case of receiving positive inspection results, the special gas production equipment is installed at the optimum place, and extraction process starts. Natural gas is usually

recovered from oil deposits where it exists in a form of gas cap, gas occurrences and coal beds. After the extraction, gas is transported to the places when it will be liquefied by pipe-line transport. (Speight, 2007, pp. 73-87)

The process of Natural gas liquefaction

Liquefaction means the gas-to-liquid transformation of physical form of matter. In the context of working with natural gas, this process is always conducted at special plants. The whole process is usually divided into five successive steps. First of all, it is necessary to refine the natural gas, delivered from gas production fields, from unwanted contaminants by using condensate drips. This process helps to remove light oil distillates and other components that can provoke problems at the following stages. The second step is removing harmful admixtures such as carbon dioxide and hydrogen sulfide. This step is accomplished by using special amine absorbers and desulfurization units. Then, using the adsorbing agent, water is removed from natural gas in order to prevent the formation of ice during the liquation itself. After that, it is necessary to remove mercury from natural gas. The last stage – liquation – is made by freezing gas up to the temperature of -160°C . (Mokhatab & Mak & Valappil & Wood, 2014, pp. 7-9).

2.2.2. MODES OF TRANSPORT USED FOR LNG TRANSPORTATION

The most commonly modes of transport used for LNG transportation are special LNG-carrier vessels and trucks. (Mokhatab & Mak & Valappil & Wood, 2014, p. 40). Despite this, nowadays logistics companies are creating facilities that will make it possible to deliver LNG by railway transport and using tank containers. (Standaert, 2016, p.13).

Examples of these inventions with main technical solutions that were implemented are described below.

Construction of LNG vessel

Vessels for LNG transportation have to meet specified requirements. First of all, they must be built with double-hull pressure-tight construction in order

to prevent leakage of cargo in case of first insulation layer breakdown. In other words, the second hull is destined exactly to prevent the loss of cargo from the tanks and to protect the vessel if the first hull was damaged. It is important because LNG is transported in nearly extreme conditions: the temperature inside the tank must be approximately 160 degrees below zero, which influences the iron of the inner hull negatively and accelerates metallic wear that enhance the risk of accidents. That is why hulls are usually made of special materials that are resistant to low temperature, such as stainless steel, aluminum or special alloy of iron and nickel. Most of LNG vessels can carry 145-155 thousand cubic meters which is nearly equal to 90 million tons after regasification process. Tankers of this type are faster than most oil-tankers, their commercial speed is circa 20 knots per hour in comparison with 15 knots per hour for oil-tankers. Another peculiarity of LNG carriers is the construction of their engines. Due to the high cargo refrigeration costs, its temperature is maintained at the most economically-efficient level which, in turn, means that cargo is transported in evaporating condition. By installation of special equipment inside tanks, gas from fluidized bed can be used as a fuel for the engine of the vessel. That is why, commonly, turbine steam engines are used in LNG vessels due to their fuel flexibility. Alternatively, engines of this type can run on gas as well as on residual oil. It is important also to emphasize that some amount of natural gas is also contained in tanks because of a necessity to keep hulls cooled on empty runs and to minimize the number of thermal discontinuities, which would negatively impact the technical condition of the vessel. (Mokhatab & Mak & Valappil & Wood, 2014, pp. 13-18).

Construction of LNG trucks

The transportation of LNG by trucks is usually performed by using special tank-containers (Mokhatab & Mak & Valappil & Wood, 2014, p. 22) that are loaded to a flat trailer truck in the same manner as standard ISO container. The main characteristics of these containers are presented below.

Containers for LNG transportation

Due to low capacity and limited storage time, tank containers are usually used for transportation of small batches. (cimc.com, 2016). Tank-containers

for LNG transportation have a double-hull airproof structure. The inner hull is usually made of stainless steel while for the outer hull carbon steel is mostly used. (Ingglobal.com, 2015). These materials in conjunction with insulation matters provide energy self-sufficient storage time of up to 65 days. (Zeus Development Corporation, 2013, p. 3).

For the purposes of delivering LNG, 40 and 20ft. containers with a capacity of 47 and 22 cubic meters respectively can be used. These containers must have special frames that meet the ISO standards in order to enable transportation, loading and fastening operations using standard equipment and to keep safety parameters at a desired level. (Ingglobal.com, 2015). This feature makes LNG-containers flexible in the context of using different modes of transport for the delivery and standard flat trailer trucks, flat railcars or containerships can be used for this purpose.

Some of new-fashioned containers can be equipped with complicated real-time computer monitoring systems that provide the container and cargo owners with an ability to control security and safety characteristics. (Ingcontainer.com, 2016).

Construction of LNG railcars

The railway transportation of LNG is not popular for a range of reasons, from strict safety regulations to limited shipment sizes. Nevertheless, this type of transportation can be a good choice both for carriers and for customers because of its environmental performance, low prices and delivery times. Usually, the railway transportation of LNG is performed using tank-containers that were described above, but due to the combination of their small capacity and relatively low speed characteristics of railroad transport, it is economically inefficient. (The US Committee of Foreign Relations, 2005, p. 17).

However, in 2015, VTG Aktiengesellschaft Logistics Company presented a tank railcar for LNG transportation. The wagon has a complex structure. It is equipped with specifically developed suspension which is generally intended to minimize most vibrations and impact forces occurring through the transportation process. The wagon body consists of two tanks with

thermal insulation and vacuum space between them. This engineering design coupled with specific isolation materials results in an isothermal storage period of approximately six weeks without any maintenance and energy expenditures at a temperature of 162 degrees below zero. The wagon has a length of approximately 25 meters and can carry 46 tons of liquefied natural gas which is equal to nearly 110 cubic meters. (Pendt, 2016).

These characteristics make railroad LNG transportation considerably flexible and economically efficient to increase the percentage of LNG cargoes transported by rail transport. (Cockerill, 2015).

2.2.3. STORAGE AND REGASIFICATION OF LIQUEFIED NATURAL GAS

After reaching the point of destination, which is usually a regasification terminal, LNG is unloaded to special storage tanks that must be equipped with air-resistant membrane, special monitoring and cooling equipment to keep a cargo in liquefied state of matter. (Theodoropoulos, 2010, p.258). The capacity of these tanks comprise between 100 000 and 160 000 cubic meters. Their construction must include double walls that are made of nickel steel. They have to be built with a view to different natural calamities in order to prevent any accidents that can be provoked by destruction of storages. Of course, the weight of such constructions is heavy, which implicates special requirements to the tanks' foundations. (freeportlng.com, 2010).

After the unloading process, regasification starts. It can be performed in two different ways. The first way is gradual heating of gas to the ambient air temperature. This method required high pressure internal environment (60 to 100 bar) and salted water gravity filtration heat exchangers. Another way of regasification is burning some amount of cargo in order to heat natural gas. After that, gas is usually modified to meet customer requirements. The modifications are mostly concerned with gas chemical composition and physical characteristics. (2b1stconsulting.com, 2012).

2.2.4. LNG LOADING PROCESS

Because of LNG cargo characteristics, the technology of loading process is very complex and sophisticated. LNG is usually classified as a flammable and high-explosive cargo. That is why there are strict rules that determine the whole procedure for conduction of loading operations. The first step of the loading process is to inspect the service-condition ability of the fire-prevention system, emergency valve closing system, pipelines of onboard cargo handling system air-tightness, mechanical equipment of onboard cargo-handling system, measurement and control equipment, ventilation systems of pump and machine rooms, gas leakage warning and alarm systems, and the alarm system of the tanks filling limit level. After completing this technical commission, a check-list has to be made. Then, cargo tanks must be inertized in order to prevent chemical reaction between the remains of previous cargo and LNG. The loading itself starts from the connection of onboard cargo pipe lines with terminal pipelines by so-called loading arms. Due to the low transportation temperature of LNG (-162 c), the onboard cargo system should be precooled because otherwise rapid temperature change that will happen after the start of loading process can negatively affect the connections of pipelines and pipelines themselves. After the start of loading process, the loading speed has to be increased gradually in order to make the temperatures of cargo and pipe-line system equal and to prevent formation of air bound in the system. Throughout the loading process, the temperature and pressure in cargo tanks should be monitored. In case of increase, their characteristics must be corrected by using special pressure pumps and vessel cooling equipment. The lowering of loading speed must also be done gradually in order to provide the maximum load without risks of accidents. Usually, the message about the end of loading process is sent at least 30 minutes earlier. After stopping loading process, the loading arms and pipelines of the ship's cargo systems must be cleaned from the cargo residues. After that, it is affordable to disconnect loading arms and finish the loading process. (McGuire & White, 1986, p. 89).

2.3. RISKS OF LNG TRANSPORTATION

As it was mentioned before, the LNG is a flammable and explosive cargo. In other words, LNG can be classified as a hazardous cargo. Generally, hazardous cargoes provide a range of specific risks. (Batarliene, 2010, pp. 98-99). The most important of them are described below.

Human factor risks

LNG tankers are equipped with complex loading and cargo monitoring systems. Most of these systems are operated by humans. Crew members are responsible for the cargo condition monitoring and controlling and equipment maintenance. That is why crew members' neglectful attitude to the duties can provoke serious accidents. (Berg, 2013, p. 344).

Technical risks

As it was mentioned, LNG is a dangerous cargo. Because of its transportation characteristics, it must be transported and handled by using specific facilities. These facilities are made to withstand temperature overloads from cargo. Due to the requirements they have to meet, their structure is extremely complex which makes it hard to maintain and control their operable condition. For example, the hulls of vessels are gradually deteriorating and lose their hermiticity. It can provoke two main crisis scenarios. First of them is the complete demolition of the vessel caused by cold LNG leakage which misshapes the vessel's structure. In this case, the vessel may sink and become a cause of an environmental accident. Another scenario seems to be even worse, especially if it takes place when LNG is being transported by truck near the public places. If the inner hull is damaged and the outer hull remains intact, the temperature of the cargo may rapidly increase. As a result of this, the cargo can detonate because of the surge overpressure inside the tank. (Dodge, 2014). Another example of hazardous situation caused by technical malfunction is the breakdown of a spark catcher on the vessel. Considering the fact that evaporations of natural gas are flammable and explosive, the situation can have unpredictable consequences. The most important problem here is that it is

impossible to examine the condition of many identical pieces and there is no chance to fix that kind of problems if the vessel is in operation.

(Sapronov, 2016).

Risk of terrorism

Terrorism has become a severe problem in last decades. In the sphere of energy resources transportation this problem is even more serious. The reason is that terrorists are usually interested in the destruction of infrastructure objects that are vital for a country. (Fay, 2003, p. 3). The eloquent evidence of this is the terrorist campaign that was made in Turkey in 2016 where terrorists fulminated a gas pipeline at the Sinai. (Roberts, 2016). The Terror threat makes it necessary to provide the adequate level of cargo security at all stages of transport process.

Environmental risks

Generally, natural gas contains up to 90% of methane which is one of the primary greenhouse gases. It means that any leakage of the cargo can provide damage to the environment. (US Energy Information Administration, 2016). More specifically, an average LNG tanker capacity is approximately 150 000 cubic meters, but this value is nearly equal to 90 million cubic meters of vaporized natural gas because the LNG compressive ratio is circa 600. (Smith, 2005, p. 3). It is clear that the potential environmental footprint from such an accident is terrible. Consequently, the providers of LNG transportation services should be very careful because any accident will be accompanied with the destruction of their reputation and imposition of hefty penalties.

Climatic risks

Most transport modes are weather-dependent. When taking into account that almost all LNG is transported in the form of sea freight, this dependency becomes even stronger. The weather cataclysms are dangerous for vessels that are in the open sea. Besides that, they pose grave commercial risks because it is unpredictable if a ship will be able to enter or leave a port. In

such situation, the cargo owner can lost his money if the vendor contract is not fulfilled. (The UK Department for Business, Innovation & Skills, 2013).

3. EXISTING MARKET SITUATION

In order to show the timeliness of the topic, it is necessary to describe the present situation on the global LNG market. Also, the important factors that must be considered are the internal and external forces affecting market in the present time and existing trends.

3.1. PLACES OF PROCUREMENT

In accordance with 2016 International Gas Union World LNG Report (2016, p. 7), this year the number of exporters in the world markets decreased. It happened because of the freezing a natural gas production by Angola and Egypt. It was inspired by the necessity of equipment renewal in Angola and lack of feedstock in Egypt, which forced country to turn into an importer. As a result, there are only 17 countries that can be considered as suppliers of Liquefied Natural Gas. These countries and their global market share are presented in Figure 2.

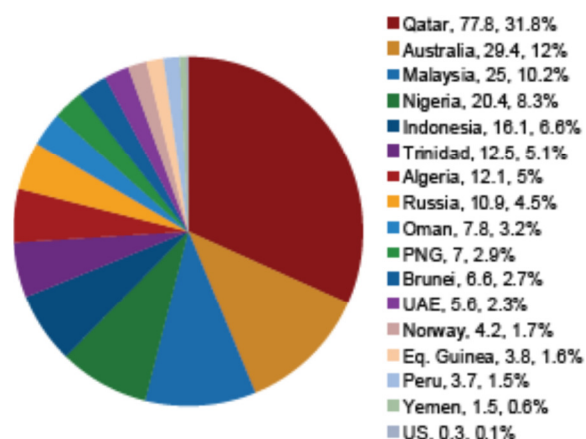


Figure 2: LNG Exports and market share by Country (in MTPA). Available at: www.igu.org/download/file/fid/2123

As can be seen from Figure 2, the main world Supplier is Qatar with a share of nearly 32% of the all LNG turnover. Owing to the completion of

some large LNG infrastructure projects, Australia took a second place with 12% and first time ever outperformed Malaysia.

3.2. MAIN LNG CONSUMERS

In comparison with the export market condition, the situation on the import market is exactly the opposite. In 2015, the amount of consumers increased. This is a result of Jordan, Pakistan, Poland and, as was mentioned before, Egypt entering the market. (IGU, 2016, p. 9). The general information about importing countries and their shares can be seen in Figure 3.

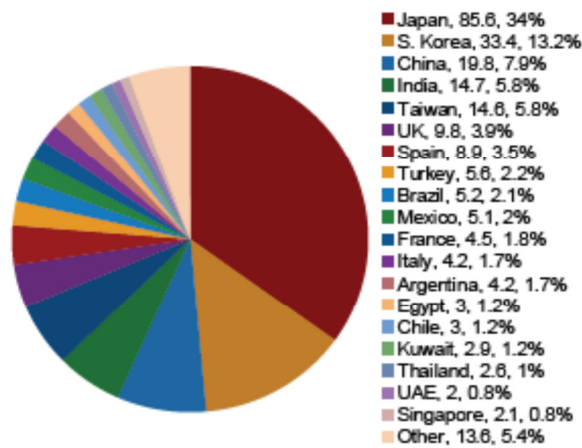


Figure 3: LNG imports and market share by Country (in MTPA). Available at: www.igu.org/download/file/fid/2123

3.3. FREIGHT RATES

In accordance with an article written by Keith Wallis (2015), the market of freight rates for LNG is demoralized and continues decreasing. To be more exact, the LNG transportation market is in its worst business recession for the last 30 years. The reason for this is the combination of 10% annual growth in fleet of vessels that were ordered some years ago and will be built until the middle of 2017, and prevalent volatile economic environment and decreasing demand in some Asian countries in Pacific Basin. This combination of factors resulted in almost 50% decrease of freight rates in comparison with 2014 showings and more than 75% decrease if compared

to 2013. Consequently, the average market freight rate of LNG vessel with 160 000 cubic meter capacity falls inside the limit of \$32 000 per day, which is lower than their break-even point. (Wallis, 2015). In the circumstances concerned, the sea transportation of LNG becomes increasingly profitable and advantageous for customers.

3.4. POLITICAL SITUATION

According to Jonathan Hoogendoorn (2016), a geopolitical and energetic industry analyst from Massachusetts, the European Union's aspiration of becoming independent from Russia in the sphere of gas supply is rising. After the political conflict between Russia and Ukraine, gas transit has become more difficult. As a result, it has become an unsteady way of gas transportation to the European countries. (Hoogendoorn, 2016). Moreover, the economic sanctions affect the Russian gas industry through the limitations of oil and gas production and processing equipment's import. It means that Russian gas suppliers have no ability for the replacement of fixed assets. Consequently, the efficiency of using equipment will decline gradually, which, in turn, can provoke a shortage in amounts of gas production. (Angelina Kolomeytseva, 2016, p.184). Against this background, the necessity of different energy commodity sources and ways of transportation becomes apparent.

3.5. THE IMPACT OF EU LEGISLATIONS ON LNG MARKET

In recent years, the global energy resources market was strongly influenced by the political ambitions of the EU government. These ambitions were presented in a form of environment-related legislative initiatives that are described below. (Van Nuffel, Rademaekers, Yearwood Travezan, Post, Hoogland, Lopez, Ortega, Amon, Fülöp, Barta&Hegedus, 2016, p.15).

Alternative fuels strategy

Greenhouse emissions from commercial transport are becoming a more serious problem every year. According to the data that was collected by Eurostat, the European Union's annual production of greenhouse gases in

2014 was circa 4.5 million tonnes of CO2 equivalent. Despite of the annual lowering of this rate trend, which can be seen in Figure 4, the problem of environmental footprint from the European Union countries is still serious. (ec.europa.eu, 2016).

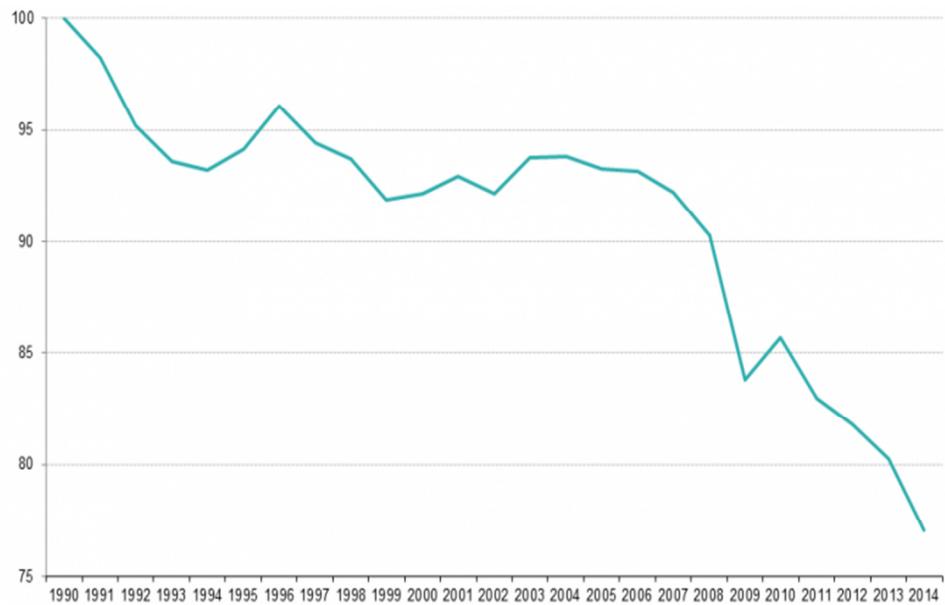


Figure 4: Greenhouse gas emissions from the European Countries 1990-2014. Available at: http://ec.europa.eu/eurostat/statistics-explained/index.php/Greenhouse_gas_emission_statistics

Of course, the exhausts of combustion engines are not the only source of pollution. However, in reliance on the European Climate Policy Info Hub, it accounts for approximately 20% off all emissions. (Karakosta, 2015).

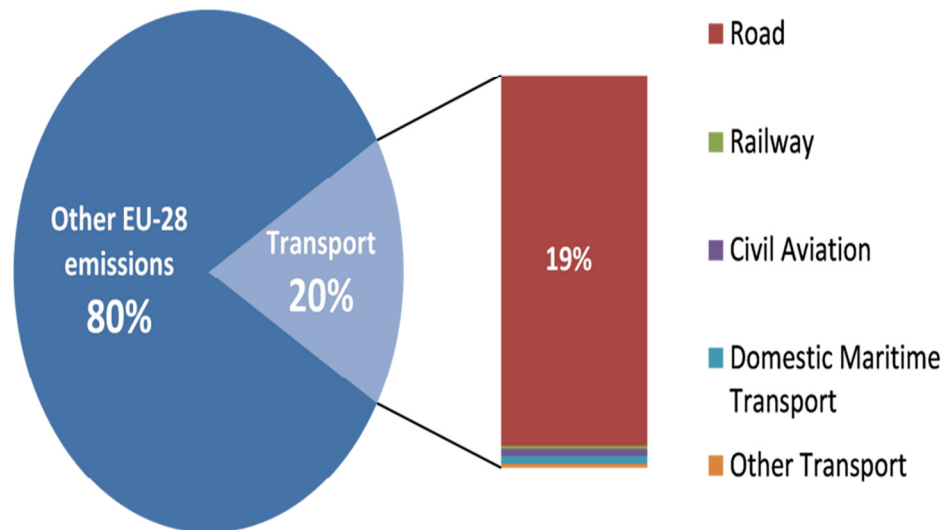


Figure 5: Greenhouse gas emissions of the transport sector. Available at: <http://climatepolicyinfohub.eu/are-transport-emissions-mobilizing-eu-policy-response>

That is why in 2013 the European Commission presented a new alternative fuels strategy. This strategy comprehends the reduction of greenhouse emissions up to 60% before 2050 in comparison with 1990 level. (Golinska & Hajdul, 2012, pp. 11-12). It is planned to achieve this purpose by using alternative energy sources with lower CO₂ percentage as well as development of electric vehicle solutions and implementation of biofuel-operating engines. Liquefied Natural Gas plays a great role in this strategy. It is regarded as one of the main alternatives for diesel fuel that is used in heavy trucks involved in long distance deliveries. Moreover, LNG seems to become a good alternative for most of ship bunkering fuels used in the industry because of its comparably low price and high energy-efficiency. (Kearns & Kidd, 2013, p. 2). The implementation of this strategy is going to exponentially increase the gas consumption in the European Union and in Finland. As a result of growing consumption, the LNG transportation market will also stop its stagnation phase. (DG MOVE, 2015, p. 83).

Liquefied natural gas (LNG) and gas storage strategy

In order to meet the increasing demand and to improve energy self-sufficiency, the European commission developed a strategy of the European Liquefied Natural Gas and gas storage network modernization. In

accordance with Itkonen & Bockstaller (2016, pp. 1-2), the main aims of this strategy are:

- Development of LNG and natural gas infrastructure inside all EU-member countries in order to give them an exposure to the international LNG market. Most of energy infrastructure projects that are of great importance are included in projects of common interest list (PCIs).;
- Creation of domestic LNG market in the European Union to provide the market environment that will be oriented on compensation of deficit as promptly as possible in case of its formation and to encourage investments that are necessary for building the infrastructure;
- The improvement of storage efficiency that is essential to undercut the influence of market fluctuations on sufficient continuous flow of supplies;
- Broadening of international market activity aimed to finding new partners and reducing the vendor-locking level.

The stands of strategy that was mentioned above show that EU is steadily preparing for increasing LNG consumption. At the same time, plans of internal market creation and sprawling the LNG supplier base provide an opportunity for new companies to enter this market and take part in a fair competition.

3.6. FACTORS AFFECTING LNG CONSUMPTION

The most important factor that has an impact on LNG consumption and market prices is weather conditions. As was mentioned before, natural gas is one of the most usable energy resources for electricity production and heating. That is why the connection between climatic action and LNG consumption exists. Generally, it is just seasonal fluctuations that are dependent on how many consumers need to heat their industrial buildings and houses and what is the amount of heat needed. Practically, the amount of heat consumed is usually governed by weather conditions. For example, in accordance with U.S. Energy Information Administration, in Northern

countries in the winter season the consumption of natural gas can be up to 30% higher than in summer.

One more reason for the growth in natural gas consumption in winter season is the performance degradation of car fuel economy. It was proved by the US Department of Energy that in cold weather conditions the mileage per liter rate can be up to 22 per cent lower if the car is mostly used for short-distance runs.

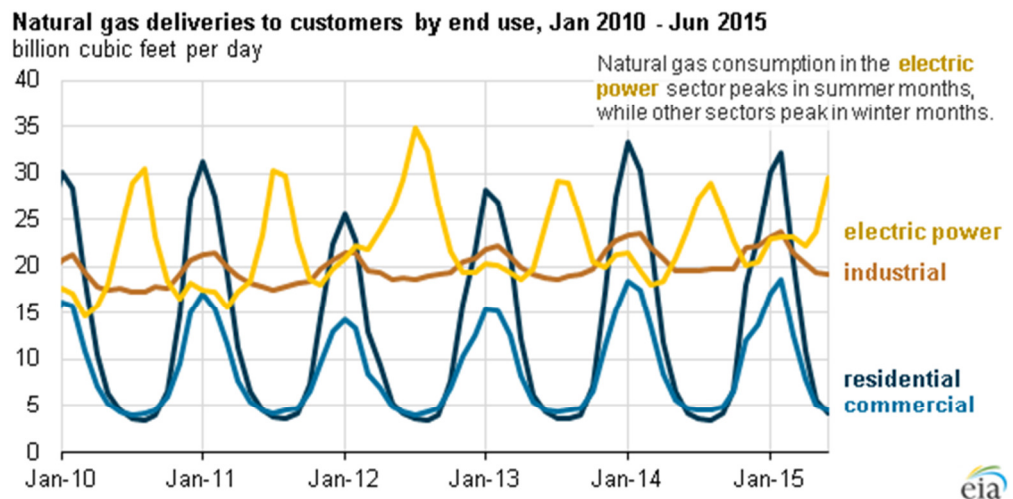


Figure 6: Consumption of Natural Gas in Finland. Available at: <http://www.eia.gov/todayinenergy/detail.php?id=22892>

Analyzing Figure 6, it becomes clear that besides the winter demand pull, in the US there is also a summer peak. The summer peak usually takes place in the middle of July. It is caused by hot weather that leads to growing electricity consumption. The main reason of this is the usage of air-conditioning systems in residential houses and commercial properties. (Bradley, 2015). It is important to emphasize that although Figure 6 gives a statistics of annual natural gas consumption fluctuations in the US, the global picture is absolutely identical.

According to the general principles of market performance, in the situation when the speed of demand growth is much higher than that of supply, the price increases (Parkin & Powell & Matthews, 2012, p.72). Consequently, the worldwide growth in natural gas demand provokes the growth of prices. It can be clearly seen from Figure 7 that the natural gas prices in Finland

are changing in the full compliance with consumption capacity fluctuations.

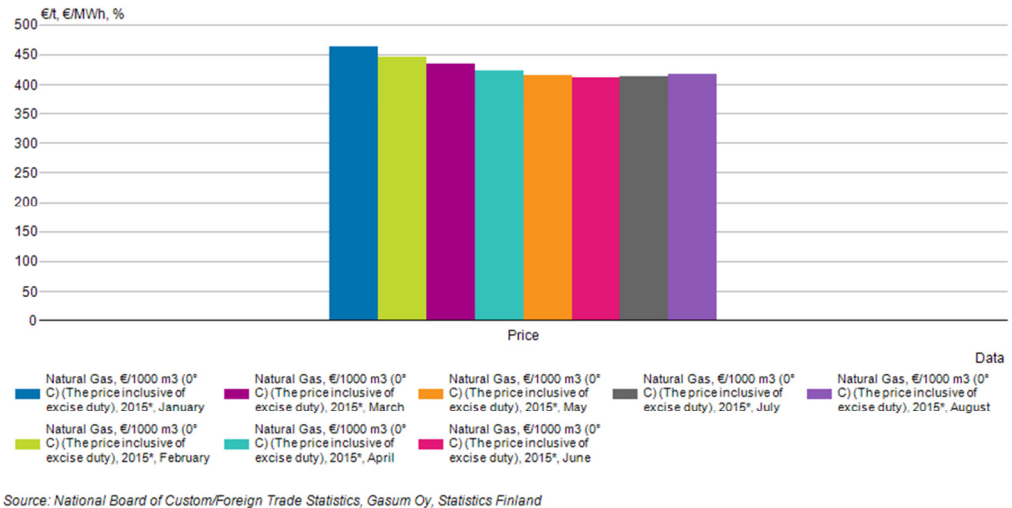


Figure 7: Natural Gas Price fluctuations in Finland. Available at: http://pxnet2.stat.fi/PXWeb/pxweb/en/StatFin/StatFin__ene__ehi/030_ehi_tau_103_en.px/chart/chartViewColumn/?rxid=50da8783-d3a6-4601-a114-e533ae7cb0b7

Another factor that influences LNG market is the face of cycle in which economics remains. If it is in a prosperity phase, the level of business encouragement is usually high. It means that manufacturing industry works more and produces more goods to meet the growing demand. In its turn, the growth in production involves larger energy consumption. As far as natural gas is one of the most efficient and widespread energy sources, the demand for it grows rapidly. (Lee, 2016).

It is also important that competition among energy resources can impact the natural gas consumption rate. It is possible because many manufacturing companies use specific power systems that are able to work on different depletable fuels. Usually these systems can use three types of fuels: natural gas, crude oil and coal or the combination of them. The implementation of multi-fuel systems gives business owners an opportunity to improve their economic efficiency and increase their profits by ordering fuel for the lowest price at the moment. At the same time, it affects the demand for natural gas every time the prices of alternative fuels become lower. (Lee, 2016).

3.7. COUNTRIES IMPORTING LNG TO EUROPE

In accordance with the European Parliament Liquefied Natural Gas in Europe briefing (2015, p. 4), the main countries that supply LNG to the European Union member countries are Qatar, Algeria and Nigeria. At the same time, it is predicted that before 2020 the European Union will have more supply options due to the rapidly growing LNG production in Australia which is going to outwork Qatar and Papua New Guinea and become the new leader in this field. Moreover, notwithstanding that USA officially entered international LNG market only in February 2016, world leading analysts predict that until 2020 US will become the 3rd biggest supplier in the world, after the Australia and Qatar. (Pedersen, 2016) In that case, collaboration between the European Union and US suppliers in this sphere is inevitable mostly because of the need to diversify the suppliers on the European internal gas market. (Leifheit, 2016). In addition to that, in accordance with world bank information, the US have the world's lowest LNG prices and the most efficient production activity which makes them a perspective business partner for the European Union. (Baffes, 2014, p. 7).

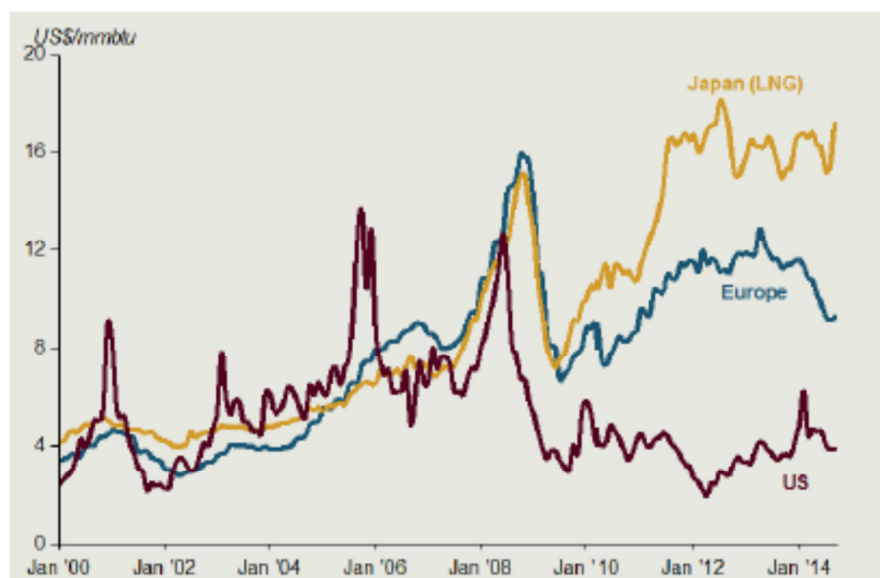


Figure 8: World gas prices. Available at:
http://www.worldbank.org/content/dam/Worldbank/GEP/GEPcommodities/commodity_markets_outlook_2014_october.pdf

4. LNG IN FINLAND

4.1. LNG MARKET IN FINLAND

In accordance with Statistics Finland research center, the consumption of natural gas in Finland decreased by 5 per cent in 2016.

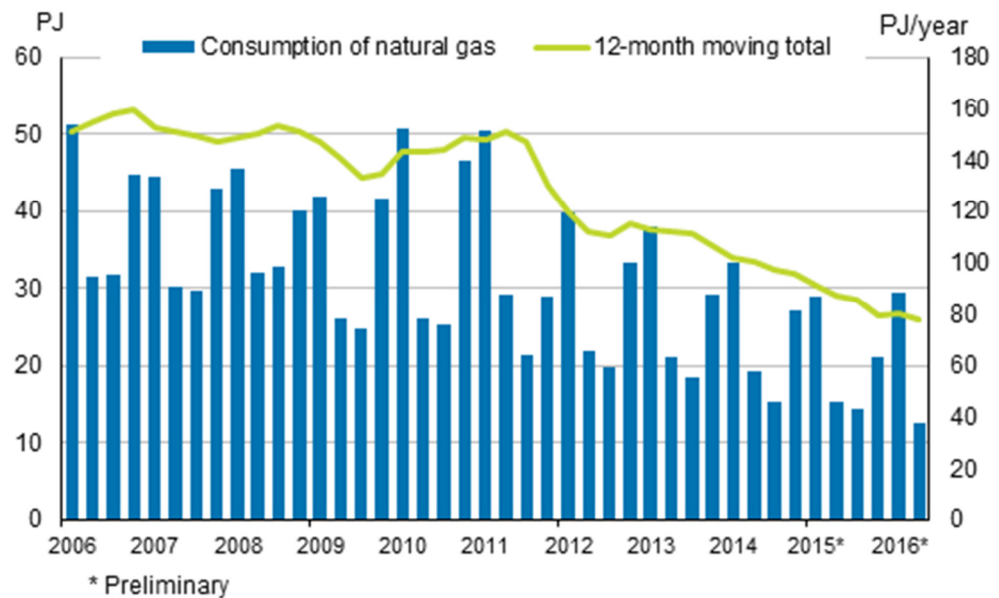


Figure 9: Consumption of Natural Gas in Finland. Available at: http://www.stat.fi/til/ehk/2016/02/ehk_2016_02_2016-09-21_kuv_004_en.html

In spite of the strong trend of decreasing natural gas consumption in Finland, which is shown in Figure 9, the EU Parliament's alternative fuels strategy, that was described above is going to increase the demand significantly until 2020. (DG MOVE, 2015, p. 83).

4.2. LNG INFRASTRUCTURE IN FINLAND

Nowadays, the LNG infrastructure in Finland is growing rapidly. In September 2016, the main Finnish natural gas supplier Skangas, the control interest (51%) of which is owned by Gasum Oy, launched the first LNG terminal in Finland. The terminal is equipped with all regasification equipment, 30 000-cubic meter storage tank and 12 kilometers of pipeline that is made for delivering degasified natural gas to the industrial customers. The new terminal also owns the equipment that gives an ability

to reload LNG directly from one vessel to another and from the vessel to the truck. (hydrocarbons-technology.com, 2015)

Another great project that will help Finland to become more energetically independent from Russia is an LNG terminal in Tornio, Finland. This project is being executed by collaboration of Gasum Oy, EPV Energy company, Outokumpu and Ruuki Metals industrial companies. The terminal is going to be launched in 2018. It will be equipped with a 50 000-cubic meter storage tank and will be able to accommodate vessels with capacity of at least 18 500 cubic meters. The terminal will be primarily oriented on meeting the demand from industrial customers. (torniomangalng.fi/en , 2015).

Yet, LNG transportation by sea is not the only business dimension that is being developed by Finnish government and companies. Another type of project is so-called "Baltic connector". It is a project of 150-kilometer long bi-directional underwater pipeline that will cross the Baltic sea and give Finland an access to the Estonian part of the European natural gas system. The expected pipeline flow efficiency will be circa 7.2 million cubic meters per day. The estimated time of project completion is the December 2019. The main stakeholders of this project are Finnish government company Baltic Connector Oy and Estonian company Elering AS. One of the main project aims is to make Finland more independent from Russian natural gas suppliers and to create a competitive environment on the LNG market in Finland. (Plit H, 2013).

4.3. POTENTIAL BOTTLENECKS FOR IMPORTING LNG TO FINLAND

Lack of infrastructure

As was mentioned before, the LNG infrastructure in Finland is in the phase of development. At the moment, there is only one regasification plant and LNG terminal owned by Gasum Oy in whole Finland. It is situated in Pori, in the south-western part of the country. The limited capacity can provoke problems through import process, especially in the winter season, when the LNG consumption grows.

Monopolized market

Another potential bottleneck is the condition of internal market. Gasum Oy is the only supplier of LNG in Finland and, at the same time, the owner of all infrastructure in the country. Moreover, Gasum's largest stakes are owned by the Finnish government (24%) and Russian company Gazprom (25%). (Talus & Guimaraes-Purokoski & Rajala, 2010, p. 90) It means that nowadays, the Finnish gas market is fully monopolized. (energiavirasto.fi, 2015, p. 13). This problem makes it really difficult to enter the market without comprehensive financial injections.

5. LNG IN USA

5.1. LNG MARKET IN USA

Most of US natural gas is being produced from shales. This technology helps to decrease production costs and improve the efficiency of production processes. It would seem that such an improvement have a solely positive effect on the market situation. However, as a result of this technology implementation, the main producers increased their productivity for more than 50% in only 10 years, which, in turn, provoked the overfilling of internal market and sharp decrease in prices. This situation negatively influenced gas producers especially taking into account the statutory bar for the export of natural gas. In 2016, the statutory bar finally was overturned and US suppliers entered the world market. Unfortunately, because of limited capacity of existing LNG infrastructure facilities and, therefore, limited export volumes, this opportunity will not change a situation sharply. It means that in a long-term perspective, USA is going to become the LNG supplier with the lowest prices. (England & Slaughter, 2016)

5.2. LNG INFRASTRUCTURE IN USA

Most of natural gas in USA is being produced in the north-eastern part of the country at the Marcellus shale. In order to decrease handling and

transportation costs, the main LNG infrastructure is also situated in this region. (Oil & Gas 360, 2016). These facilities are presented in Figure 10.

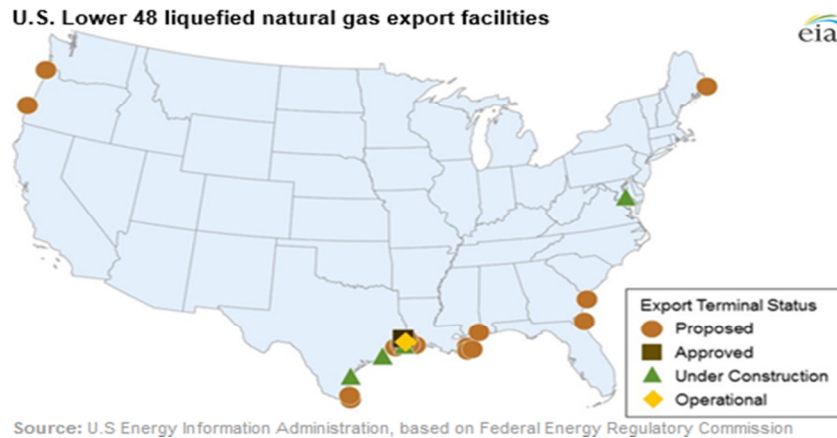


Figure 10: US LNG export facilities. Available at: <http://www.oilandgas360.com/lng-update-u-s-export-terminals-and-infrastructure-in-the-works/>

As can be seen, at the moment USA have only one operational LNG export terminal owned by Cheniere Energy Company. This terminal has a production capacity of approximately 27 million tons per annum. (Business Wire Inc., 2015).

However, it is scheduled to put four more terminals into operation until the end of 2018. Also, more than 15 export terminal construction projects are approved by the US government and will be built before 2022. (OilOnline Press, 2015).

Such a growth in number of LNG facilities and infrastructure objects gives a good opportunity for development of relations between the US government and the European Union as a part of EU alternative fuels strategy.

6. CASE STUDY

In the existing political situation and situation on LNG transportation market, as well as geographical location of the parties, the sea carriage with the subsequent road transportation or pipe-line delivery seems to be the only possible way of delivering LNG to Finland.

However, both sea and road transportation can be accomplished using special LNG trucks and vessels or special tank containers. That is why it is important to find out which of these schemes will be cheaper and faster.

The usage of containers can be reasonable because of the lower time expenditures and costs of cargo handling operations as well as transport freight rates.

The first way of transportation that will be considered is container carriage from Port of New York to Port of Helsinki with the subsequent road transportation to the regasification terminal in Pori. The overland transportation part is going to be completed by using trucks with flat trailers that are designed for the carriage of ISO containers. The implementation of these trucks will help to decrease cargo handling costs and to shorten the time needed for handling operations.

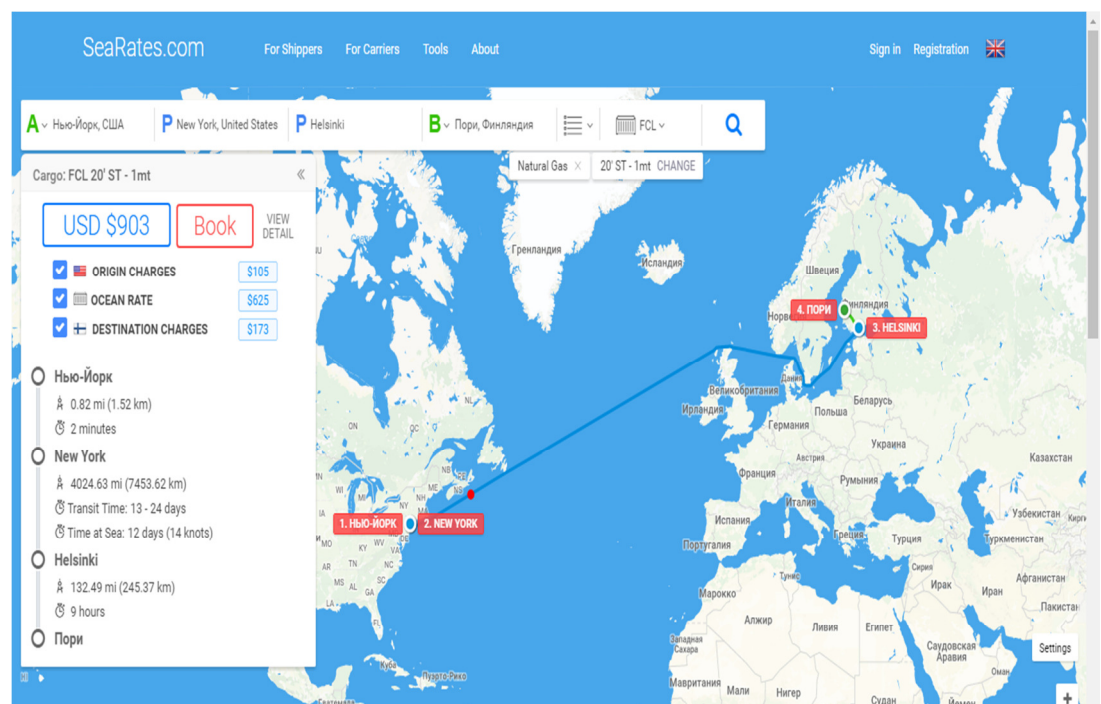


Figure 11: The route, time expenditures and price of one 40-ft LNG container transportation from US to Finland

The figure above shows the route and official price for transportation of one 40-ft LNG container. The price includes freight itself as well as all origin and destination charges that usually consist of:

- agent surcharge;
- terminal handling charges;
- release fees;
- international port security charges;
- ship security charges;
- harbor charges;
- towage charges;
- APEX declaration of loaded and empty container.

The posted price also includes road hauling from Helsinki container terminal to the regasification terminal in Pori, Finland, which is 173 dollars per container.

Unfortunately, LNG is a cargo that is usually delivered in large amounts in order to increase the profitability of business transaction. This is a result of the economies of scale principle implementation. Generally, for sea carriage this principle means that the larger the capacity of vessel, the lower the shipping charges per unit of weight, and the larger a profit for the supplier, by extension. That is why the average capacity of a LNG tanker is approximately 150 thousand cubic meters. It means that to deliver the same amount of cargo it is necessary to freight 3200 40-ft LNG containers. As a result, the transportation cost will be more than 2.5 million dollars. At the same time, as can be seen from Figure 11, the time of transportation is up to 24 days which is 5 days more than in LNG tanker carriage because of the container ship's lower speed characteristics.

Another option is transportation by a LNG tanker with the following distribution using pipeline infrastructure.

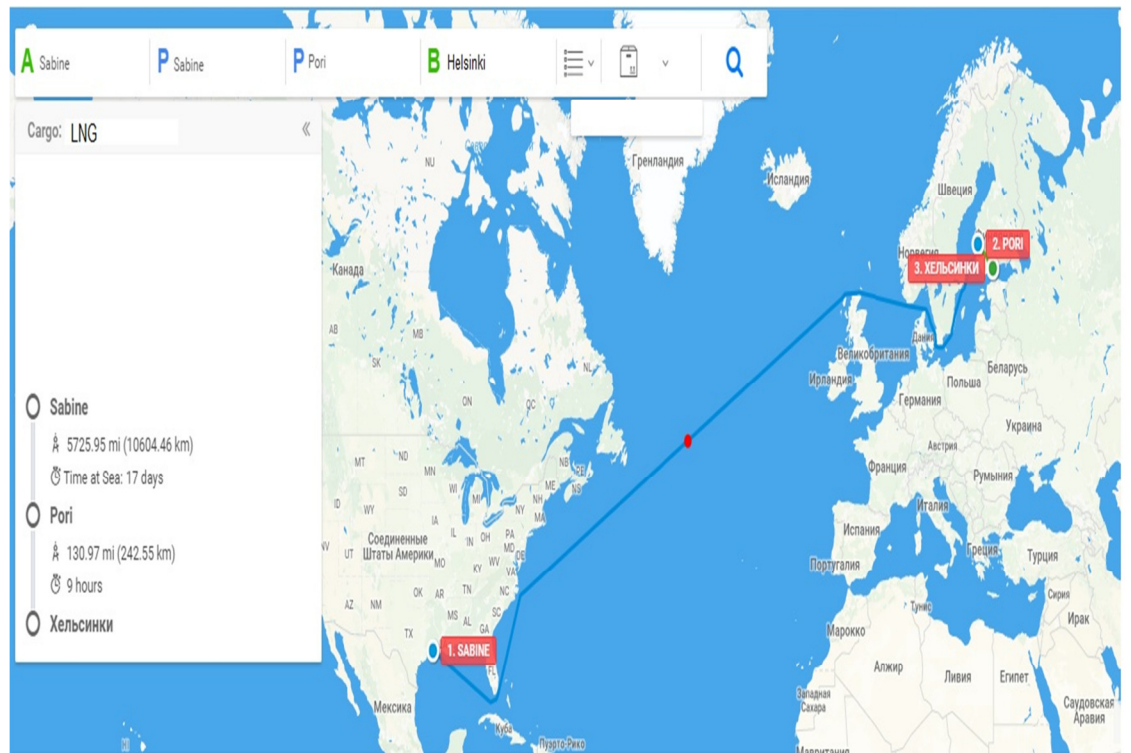


Figure 12: The route and time of transportation cargo by LNG tanker from US to Finland. Available at: https://www.searates.com/reference/portdistance/?K=ChIJkQYhIscLkkYRY_fiO4S9Ts0&D=17838&G=21370&shipment=2&weight=8000&volume=1&weight_unit=KG&volume_unit=CBM&

In accordance with searates.com, the estimated hauling time is 17 days. The normal speed of loading and unloading operations is 10-15 thousand cubic meters per hour, so it is necessary to add 2 days if cargo is being delivered by a LNG tanker with 150 000-cubic meters capacity.

Using the freight rates given by Reuters News Agency, the current freight rates for this type of vessels with the equal capacity are circa 32 thousand dollars per day. It means that the transportation costs will be approximately 610 thousand dollars.

7. CONCLUSION

To sum up, it is possible to make a conclusion that in the existing political and global market situation, the most efficient way to deliver LNG from the US to Finland is transportation by special LNG-tankers.

Apart from the advantages of lower transportation costs and time expenditures, the transportation of LNG by a special tanker directly to the

regasification terminal in Finland provides also an opportunity to perform the subsequent gas distribution through the natural gas pipelines that are connected to the gas storage facilities. It accelerates the delivery of gas to final consumers. Moreover, in the long-term perspective, when the Baltic Connector project will be completed, this scheme of transportation will enable US suppliers to obtain access to the pan-European LNG market by using the Estonian part of the European natural gas system.

Generally, the results of this thesis are not absolutely reliable for practical application by companies. There are two main reasons for that. First of all, the calculations may have inaccuracies caused by the impossibility of current freight rate identification. This impossibility is a result of differences in general prices of each particular transportation agreement. Another reason is the deficiency of current assets in the calculations, which is caused by the fact that they could not be calculated against the background of continuously changing situation in the global market.

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APPENDIX 1: SPHERICAL LNG TANK STRUCTURE

