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Logistical opportunities for importing Liquefied Natural Gas to Europe

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Abstract

Liquefied Natural Gas is equivalent to natural gas in terms of calorific value. It has to be chilled down to -162°C in order to increase storage capacity for transportation purposes. With the help of LNG properties, natural gas can be moved more flexibly with significantly lower transportation costs especially between countries which are not connected via a natural gas pipeline. Japan, as the world's largest importer of LNG, can be identified as an example of a region that is totally dependent on LNG in order to satisfy its energy needs due to the lack of alternative sourcing options for natural gas.

Keywords: LNG terminal locations, logistical engineering opportunities, dispatch of green energy, fuel import mechanism

1. Introduction

Over the past number of years, local separation within the international LNG market has been observed, with considerable price differentials between various trading hubs. The price gap between the Asian and the European market especially, is a crucial factor for the geographical distribution of traded volumes [1]. Since 2011, a continuous premium inclination of Asian LNG prices in comparison with European prices has been observed. A tendency towards a convergence of prices can currently be noticed. From a European perspective, price variation and long term security will have a significant impact on future trading of LNG [2].

This paper will characterize the current and future situation of Europe within the international trade with LNG. It will also elaborate on different methods of transport along the supply chain of LNG from its point of extraction up until the end user. In the discourse of this new method of distribution an introduction with its current development and future opportunities will be discussed.

LNG which is the same product source as natural gas in a liquefied state, has the advantage of being able to be shipped overseas via customised gas vessels for distances of thousands of kilometres and no gas network is required [3]. This gas shipment technology has increased its competitivity against conventional gas dispatch within the industry. Nowadays LNG can be shipped from one continent to another at a very low transportation cost.

2. Problem identification and basic principle

Alongside oil, natural gas is one of the most common fuel types in industrial developed countries. Due to geographical considerations, some countries have a massive oil and gas field deposit and others have very limited resources or even none. This uneven distribution of commodities requires the need for delivery via gas pipe lines or in liquid form [4]. Exporting natural gas can be easily done via gas networks similar to water and electricity grids. In order to transport gas, it is normally cleaned, dried, compressed and then enriched with ethyl mercaptan with a proportion of 20 parts per million for odour leak safety. Natural gas is colourless, invisible and almost odour free. Odourisation is, therefore, required in order to detect leaks.

The higher the pressure in the gas network the more gas can be filled into the system. The gas pressure plays a factor on the delivery speed to the end user. Gas can be transported over thousands of kilometres with the help of pressure booster stations, keeping gas pressure topped-up on its initial main traveling routes.

This gas distribution system can only be applied in situations where gas pipe lines are already in place and connected to a customer's network. This system also has its pitfalls due to pressure reduction over its travelling distance caused by friction inside the gas pipes. Another disadvantage is that the end-consumer needs to be connected directly to the gas grid. In the majority of those cases it would not be feasible for isolated businesses or small communities distant from the gas grid to be connected to their network. These factors are proving restrictive for customers outside this system.

To date, LNG is not common place in Germany but with increasing demand for natural gas to supply heat and power generation, higher competition in the energy sector and advanced shipping technology available, logistics of LNG is becoming more viable. LNG and CNG (Compressed Natural Gas) is the same product coming from fossil and non-fossil fuel sources with norm temperature at 25°C and pressure of 101,3kPa. CNG is compressed natural gas which is normally distributed in the gas grid system with a maximum allowable pressure in Germany of 100 bar.

A common pressure for main gas grid routes of those networks is between 25 and 60 bar. LNG, therefore, appears in an unpressurised liquid state which has to be chilled down to -162°C. Liquefaction of natural gas can increase its energy density by 600 times when compared to natural gas. The density of LNG with a temperature of -162°C is 450kg/Nm3 under atmospheric pressure. CNG can increase its energy density to approximately a third of LNG which clearly depends on compression pressure rate of the gas, altitude of the measurement, gas temperature, purity, humidity etc.

(Figure 1 - Marine Transportation of LNG, Intertanko Conference, 2004)

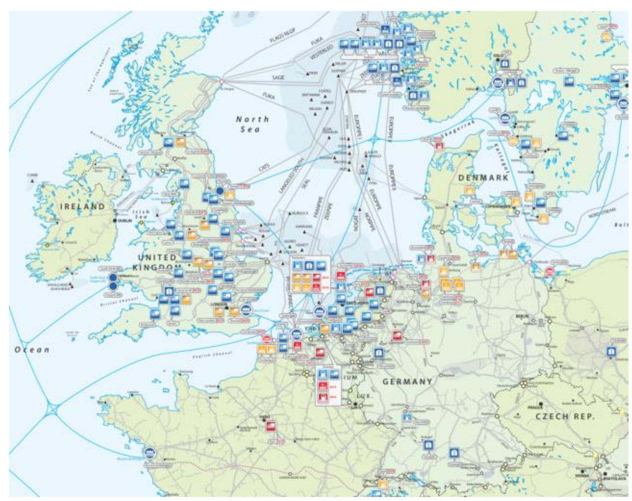
The problem of LNG is that it requires a lot of energy for the chilling process and having only a shelf life which is limited to 10 days. If LNG heats up from its original low temperature of -162ºC it will result in a pressure increase. For that reason, in most cases, LNG transport vessels have a gas engine in place to burn boil-off gases as a fuel without storing it in a compressed form [5].

"With 8.4 million tonnes imported last year the United Kingdom was one of the Europe's leading LNG importers, with a large part of the volumes delivered into South Hook, as a consequence of low demand in Asia and of the redirection of Qatari volumes" [6].

In 2014, 293.2 million tonnes of LNG was produced world-wide, with a total of 75% LNG demand coming from Asia with 110 LNG terminals in operation and 421 LNG cargo ships on sea. Between March and October 2014, a combination of lower energy demand, sharp oil price cuts and crude oil floatation, LNG spot market price had halved. But with stricter legislation on shipping emissions which started in January 2015 in the Atlantic basin helping to stimulate the development of small-scale LNG, new opportunities of growth are emerging which also bring new challenges [6].

(Figure 2 - LNG terminals in Europe, http://www.shannonlng.ie/index.html, Feb. 2016)

As can be seen in figure 2, it will take another couple of years to establish a fully working LNG infrastructure. There are some LNG terminals in place and more planned but this is only the foundation of a new fuel transportation infrastructure. Once LNG terminals have been constructed, gradual development of filling stations is vital in order to get their fuel to the end-customers. Once a working fuel distribution network has been established and fuel prices are competitive, haulage companies should be willing to look into any investment if this type of fuel could reduce running costs.



(Figure 3 - Gas infrastructure Europe, Small scale LNG map terminals, 2015)

Figure 3 illustrates the logistics of LNG throughout the North Sea between neighbouring countries like Ireland, United Kingdom, Netherlands, Belgium, Germany, France, Norway Denmark and Sweden. The map also illustrates installed, planned and commissioned LNG filling stations. It is obvious that optimal investment opportunities for LNG terminals are located near the shore in order to avail access to ship transportation.

3. Methodology

Large scale supply chain of LNG begins with the extraction of natural gas. This is followed by the liquefaction, which is necessary in order to allow the fuel to be shipped economically. At the end of its overseas journey, a large-scale transport vessel arrives at an LNG terminal [7]. The main functions of such a terminal involve the unloading of arriving vessels and the storage of LNG. Furthermore an LNG terminal is the point from where the incoming natural gas has to be distributed towards the end-customers either by a gas pipe line after regasification, which would be the last step within the large-scale supply chain, or in its liquid state [8].

LNG terminals are a highly important part of the LNG-supply chain as they fulfil significant logistical tasks and serve as an interface between intercontinental transport and regional distribution. The fees charged at LNG terminals are an important component regarding the entire financial expenditure along the supply chain of LNG.

The composition of tariffs varies depending on the terms and conditions of the particular terminal. At an LNG terminal at Montoir-de-Bretagne in France, tariffs consist of a fixed rate per unloading process as well as certain components which depend on the exact quantity unloaded. The price structure could also potentially factor in any regasification service option. The quantity is not measured by its volume or mass but instead by its energy content. To evaluate this energy content in a transparent and comparable manner, it is related to fixed standard conditions, e. g. 0° C and atmospheric pressure (101,3 kPa) at the terminal in Montoir-de-Bretagne operated by Elengy. As LNG is usually transported at its boiling point at approximately -162 °C with atmospheric pressure, energy density has to be converted from current state to the conditions used for calculation of the terminal-charges. If an isobaric heating is assumed the following formula describes the mentioned conversion [9].

Energy content (0 °C, p=101,3 kPa)

$$\text{Energy content}(-162\,°C, p=101{,}3\,kPa) + h_v(p=101{,}3\,kPa) + \left(h(0°C, p=101{,}3\,kPa) - h(-162°C, p=101{,}3\,kPa, x=1)\right) \quad (1)$$

Energy content (0 °C, p=101,3 kPa)

$$15{,}64\,kWh/kg + 0{,}142\,kWh/kg + (0{,}159\,kWh/kg - 0{,}062\,kWh/kg) = 15{,}879\,kWh/kg \quad (2)$$

Formula 2 - Conversion of energy content from liquid state [-162° C] to gaseous state [0° C] at atmospheric pressure, data from International Gas Union 2015a and Borgnakke, Sonntag 2013.

Calculation symbol explanation:

p	pressure
x	evaporation content
h	enthalpy
hv	evaporation enthalpy

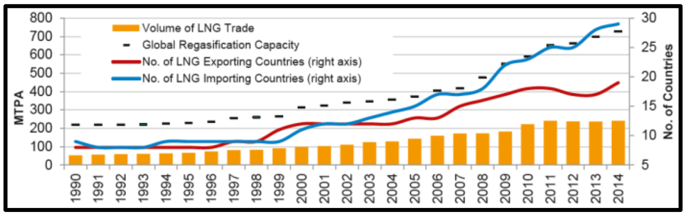
If LNG is regasified, further distribution will take place via pipe line networks. Incoming natural gas can remain as a second application in its liquid form so that distribution will take place by truck, rail or with small-scale ships either by seagoing vessels if the destination is located at the coast or by inland vessels for destinations in the hinterland of an LNG terminal. The distribution of LNG in its liquid state is classified as small-scale distribution [10].

Before elaborating on those different possibilities of small-scale-distribution the possible end-user of natural gas in its liquid state should be identified. There are off-grid customers for example in the industry who would opt to use natural gas for their processes but are not connected to a gas grid so that they are dependent on an alternative method of supply. For those consumers the delivery of LNG can be an adequate option. Moreover, with the preferred use of LNG as a fuel in shipping industry, as well as for transportation fuel for heavy duty trucks, it is necessary to create a LNG filling station network [10] [11].

Regarding heavy duty traffic there is an EU project called Blue Corridors which has developed a model on LNG filling stations for vehicles and trucks using an interactive map. The website illustrates the exact locations of any LNG terminals and installed filling stations in several countries [12]. If those LNG filling stations are adjacent to a haulage company it might possibly generate a further investment opportunity for the operator with a view to reducing their accumulated fuel costs when switching from conventional petro chemical fuels to LNG. On the other hand those interactive maps can potentially open the investment prospects when no sufficient network is in place which means there is no LNG filling station competitor close by.

LNG fuel can also be used to chill any frozen goods at arrival point while LNG is changing its state from liquid to gaseous. This transformation will automatically take place during the heating process still well below -100°C.

Some fast food companies, freezer warehouses and organisations with large cooling processes could potentially benefit in using “cold medium” while liquid fuel is evaporating. Another application could be that LNG will be purposely used for CNG usage, compressed onsite and injected in the gas grid system.



(Figure 4 - LNG trade volume from 1990-2014. International Gas Union, 2015)

Over the last decade, LNG trade volume between countries has significantly increased and exports as well as imports have doubled capacity. Volume trading of LNG has also doubled its share of the market. This evidence shows clearly, that LNG could be one of the fossil fuel alternatives if price structure and supply technology were in place. If technology and investment in terminals are made, this fuel type can be seen as a very competitive rival over the next 5-10 years.

4. Results and discussions

An assessment was carried out with the help of several studies analysing LNG import scenarios to Europe. Transportation and LNG storage technologies were evaluated and a conclusion was drawn that a LNG delivery can only be viable if deliveries of processed LNG have to be transported for more than 400 km [13]. Distance less than that would result in a negative profit return and should effectively be dispatched via a gas grid system instead of a liquefied state.

In comparison to crude oil, CNG and LNG have no fixed market price due to the fact that transportation costs vary greatly [14]. Long distances in the dispatch of gas require gas network systems which, over thousands of kilometres, are extremely expensive and can only justified if a high volume of gas combined with long term supply contracts are in place.

The transport of LNG over long distances is usually achieved by special large-scale transport vessels. Intercontinental shipping is already established nowadays so that there are many suitable ships, the largest models with a capacity of up to 266.000 Nm3 [15]. These ships are equipped with isolated tanks which are capable of maintaining the extremely low temperature of liquid natural gas during the whole duration of transport [5].

A document from the European Parliament and the Council of the European Union has stated in its legislation: “LNG is an attractive fuel alternative for vessels to meet the requirements for decreasing the sulphur content in marine fuels in the SO_x Emission Control Areas which affect half of the ships sailing in European short sea shipping, as provided for by Directive 2012/33/EU of the European Parliament and of the Council. A core network of refuelling points for LNG at maritime and inland ports should be available at least by the end of 2025 and 2030, respectively”. The same document also sets an aim concerning the number of LNG filling stations for heavy duty vehicles by mentioning a benchmark of approximately 400 km between two refuelling points [16].

In order to supply the re-fuelling points which are requested for the European Union in the areas of shipping and heavy duty traffic an operational distribution system is essential. In this regard it is necessary to establish mature technology solutions as well as the corresponding infrastructure. Regarding Europe, distribution by tank truck is already available and widespread over the continent as the possibility of truck loading exists at 18 European terminals and there is also no shortage of suitable artic trucks [17].

As far as distribution by rail is concerned, it can be noted that there is still a significant infrastructural obstacle as unfortunately nowadays none of the European LNG terminals is connected to the rail network [17]. However in May 2015, a German company called VTG Aktiengesellschaft has exhibited an LNG rail tank car in Munich in conjunction with their project partner Chart Ferox. It was 25 metres long and had a storage capacity of 111 Nm^3. This double skinned tank car has been certified and approved for liquid fuels and is able to store the chilled medium at very low temperature for several days [18]. This was the first time that a European produced and certified LNG rail tank car has been approved for certification for the rail network usage. The missing connection of LNG terminals to the rail network can be identified as one of the crucial reasons that the rail tank cars by VTG Aktiengesellschaft are still in the prototype state and are not realized into serial production [19].

There is also another option to transport LNG by rail, namely, the use of LNG ISO containers which offer the advantage of being compatible with several methods of transport. They can make use of the already existing infrastructure for standardised containers so that intermodal transport is possible. This means that the missing connection to the rail network can theoretically be bridged with the help of other methods of transport action such as haulage trucks. This solution is also applicable to customers who are not connected to the rail network and, therefore, have to rely on alternative means of delivery [20].

Besides distribution of LNG by rail there are also certain obstacles when it comes to transporting the cryogenic medium by small-scale vessels. Nowadays there are 12 LNG terminals in Europe in operation, which allows loading of small-scale ships [17]. Suitable vessels, however, up to present time only exist in the area of ocean shipping. According to the ADN directive, transport of LNG is officially allowed on several European inland waterways since the beginning of 2015 but there is still a nonexistence of sophisticated vessels for inland shipping [21].

5. Conclusions

The main incentive for European countries to consider LNG as a possibility to import natural gas is the prospect for security of supply concerning the resource of natural gas. LNG offers the theoretical chance to import natural gas from every part of the world so that dependence on single suppliers can be reduced by diversification of supply sources [22]. Furthermore, there is a tendency towards diminishing European production of natural gas so that prospectively the share of imports in the fulfilment of total demand will necessarily rise over the next few years. According to a future forecast of British Petroleum the demand for natural gas in Europe will increase in absolute terms so that total fuel import will grow accordingly.

In addition to this, the share of LNG in this growing market will increase accordingly [23]. This trend towards higher LNG imports into Europe is supported by the current development of worldwide LNG prices. The convergence between Asian and European prices contributes to a growing attractiveness of the European market from the perspective of exporters [1]. All these factors can finally lead to a higher relevance of LNG in the European energy balance.

As far as the distribution of LNG in Europe is concerned, there are still several obstacles in the way of achieving a mature distribution system and up to the present time delivery by artic truck is the only option which is actually used to a greater extent. On one hand this can obviously be due to the fact that other distribution alternatives like transport by rail or by inland vessel are not far enough developed to be viable alternative options. On the other hand the demand for natural gas in its liquid form is not high enough to ensure a satisfying capacity usage of trains or inland vessels as nowadays customers of LNG-fuelling stations for heavy duty vehicles are usually supplied individually, so that rather small quantities are required [24].

For the future an increasing demand can be expected in the small-scale-sector as environmental guidelines in the shipping industry and heavy duty traffic become stricter and force the usage of LNG as a fuel due to its lower emissions in comparison to conventional fuels like crude oil [11]. This increasing demand could encourage the further development of distribution alternatives which are not yet fully developed. Demand, technical realization of distribution alternatives and the associated infrastructure are mutually dependent so that they can only realistically develop simultaneously [25]. The aim should be that finally several means of transportation are available for the distribution of LNG so that for every particular situation the optimal solution can be chosen.

Abbreviations

° C	degree Celsius
CNG	Compressed Natural Gas
e. g.	exempli gratia (for example)
EU	European Union
hv	enthalpy of evaporation
ISO	International Organization for Standardization
km	kilometre
kPa	kilopascal
LNG	Liquefied Natural Gas
m^3	cubic metre
MTPA	Megatons Per Annum
Nm^3	Norm cubic metre (Standard temperature and pressure measured with temperature of 273.15 Kelvin)
SO_x	Sulphur oxide

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The 1st International Conference on Energy, Environment and Economics (ICEEE 2016) was held at Heriot-Watt University, Edinburgh, EH14 4AS, UK, 16-18 August 2016. ICEEE2016 focused on energy, environment and economics of energy systems and their applications. More than fifty eight delegates from 31 countries with diverse expertise ranging from energy economics, solar thermal, water engineering, automotive, energy, economics and policy, sustainable development, bio fuels, Nano technologies, climate change, life cycle analysis etc. made conference true to its name and completely international. During conference total 51 oral presentations and six posters were shared between delegates. The presentations showed the depth and breadth of research across different research areas ranging from diverse background. ICEEE2016 aimed:

- To identify and share experiences, challenges and technical expertise on how to tackle growing energy use and greenhouse gas emissions and how to promote sustainability and economical, cost effective energy efficiency measures.

In total 11 technical sessions and two invited talks both from academia and industry provided insight into the recent development on the proposed theme of the conference. Preparation, organisation and delivery of the conference started from July 2015 and further co-ordinated by vibrant team of Conference Centre, Heriot Watt University. Conference organisers would like to acknowledge support from the sponsors particularly World Scientific Publication ltd and its team members for the delivery of the conference. Organisers are also thankful to all reviewers who contributed during peer review process and their contributions are well appreciated. At the end and during vote of thanks following awards have been announced and we would like to congratulate all well deserving delegates.

- Best Paper –Academia: Amela Ajanovic, EEG, TU Vienna, Austria
- Best Paper – Student : Christian Jenne,University of Duisburg-Essen, Germany
- Best Poster – Student: Yoann Guinard, University of New South Wales, Sydney, Australia
- Best Poster – Academia: E. Salleh, Universiti Kebangsaan Malaysia, Malaysia
- Active Participation Award - Yoann Guinard, University of New South Wales, Sydney, Australia

At the end we would like to extend our gratitude to all of you for your participation and hopefully welcome you again during ICEEE2017.

Editors:

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