



UNIVERSITY OF  
NORDLAND

# MASTER THESIS

EN 310 E

Master Thesis in Energy Management

**The drivers and obstacles for the adoption of LNG by  
various companies in an Arctic context**

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**Abstract**

This thesis analyzes the obstacles and drivers of LNG adoption in Arctic region. Because of economical benefits, minimization and solution of environmental problems, technical solutions, LNG is more and more used in shipping, oil, transportation industries. The current researches show the trend of LNG usage increase in various regions of the world.

The thesis analyzed the statistical data from various sources and compared the LNG usage situation in different parts of the world. The main drivers and barriers for LNG adoption were presented in the paper. As well small scale LNG situation is analyzed and new technology adoption feature described.

For supporting the theoretical analysis, empirical research was carried out. The respondents from various companies related to LNG usage participated in the interview. The empirical research results confirmed the LNG adoption drivers and barriers revealed in theoretical part of the thesis.

## **Sammendrag**

Denne oppgaven analyserer hindrene og driverne for økt bruk av LNG i nordområdene. LNG brukes i økende grad i shipping og annen transport, på grunn av de økonomiske fordelene, lavere miljøutslipp og nye teknologiske løsninger. Nyere forskning viser at LNG bruk stiger i flere deler av verden.

Denne oppgaven analyserer statistiske data fra forskjellige kilder og sammenligner LNG-bruk i nordområdene med situasjonen i andre deler av verden. Hoveddriverne og barrierene for økt bruk av LNG presenteres. Småskala bruk av LNG analyseres spesielt og hvordan ny teknologi tas i bruk.

Analysen støttes av empiriske data. Respondenter fra forskjellige selskaper som er relevante for LNG bidro med intervjuer. De empiriske dataene bekreftet analysen av barrierer og drivere i den teoretiske delen av oppgaven.

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### **Glossary of concepts**

LNG Liquefied natural gas

CNG Compressed Natural Gas

LPG Liquid petroleum gas

NGL Natural gas liquids

ESD Emergency shutdown

EPS Expandable Polystyrene

GIE Gas Infrastructure Europe

PSV Platform Supply Vessels

MENA Middle East and North America

GIGNL The International Group of Liquefied Natural Gas Importers

USGS U.S. Geological Survey

IFC the International Finance Corporation

IMO International Maritime Organization

CCGT Combined Cycle Gas Turbine

NOC National oil company

IOC International Oil Company

NSR Northern Sea Route

ECA Emission control areas

SECA Sulphur Emission Control Area

IGU international gas union



## Chapter 1: Introduction

LNG is the fastest growing element in the global natural gas market. “LNG contributes an increasing share of trade. LNG production grows by 4.3% p.a., accounting for 15.5% of global gas consumption by 2030”<sup>1</sup> (BP, 2013:53). Gabriel and Smeers (2005)<sup>2</sup> provide the common operations of the natural gas market models that link ordinary schemes to countries with different natural gas infrastructure systems operating in natural gas market, the authors considered a simple scheme, which consists of three parts: production, transportation and consumption.

In the old global gas model dominated not only the transportation of gas, but as well the gas monopoly. Almost each European country had vertically integrated company managing the transmission, distribution, supply and sometimes even the production, not allowing any form of competition and dictating terms for countries and regions. Therefore, the old world is characterized by long-term natural gas contracts, the conditions dictated production and transport company with a monopoly (duration of contracts 5, 10 or even 15 or more years) and natural gas price indexation to oil and petroleum product prices<sup>3</sup>.

However, the monitoring of the current processes in the world (especially in Europe), it could be noted that more and more powers natural gas customers are acquiring. The long-term natural gas contracts have the benefit of all countries for natural gas - mining companies, suppliers and customers. Mining companies have secured long-term customers, suppliers secured the long-term natural gas volumes and consumers uninterrupted gas supply, but the problem was the high price. As mentioned above, the price of raw materials has led (and many countries are still leading) of oil and petroleum products. However, it was considered that in the long period this indexing should disappear. These trends can be seen already existing in liberal Europe (United Kingdom, Germany, Holland, France ) and the U.S. markets. These countries had as well the monopoly in the old gas model. At the moment they have settled in the New World natural gas model, where natural gas prices are determined on liquid exchanges where infrastructure developed in such way that the buyers can compete with each other almost all the world's natural gas producers, and transport operators are constantly trying to reduce their costs to the defeat their competitors.

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<sup>1</sup> BP Energy Outlook, 2013 [http://www.bp.com/content/dam/bp/pdf/statistical-review/EnergyOutlook2030/BP\\_Energy\\_Outlook\\_2030\\_Booklet\\_2013.pdf](http://www.bp.com/content/dam/bp/pdf/statistical-review/EnergyOutlook2030/BP_Energy_Outlook_2030_Booklet_2013.pdf) [Accessed May 18, 2014]

<sup>2</sup> Gabriel S., Smeers Y. Complementarity problems in restructured natural gas markets. Core Discussion Paper, 2007, No. 37, p. 84.

<sup>3</sup> Stern J. The future of Russian Gas and Gazprom. Oxford: Oxford University Press, 2007, p. 67.

It should be noted that infrastructure in Europe is not so well developed. Dieckhoner C., Lochner S, Lindenberger, D. (2012)<sup>4</sup> who analyzed the existing natural gas infrastructure in Europe and found the natural gas system undeveloped or developed inefficient (due to a bottleneck effect) in Eastern Europe, where at any time may lead to overloading and can severely affect not only just a specific country, but the entire region. So Europe is currently undergoing a transitional phase in which the natural gas sector is being transformed and new infrastructure and linkages built. Every country is going through this in the way which depends on the adopted political, economic, strategic decisions and the quality of their implementation. For many countries, expanding the capacity to draw on LNG is an important component in this transition.

## **1.1 Problem statement**

The world economy is increasingly using natural gas as an alternative to expensive oil resources. The main challenge is that much of the natural gas resources are located in hard to reach remote and undeveloped areas. Therefore, transporting it to the consumer is not only expensive, but technologically challenging. The chosen region for research analysis is Arctic region. Seeking to define the problem it is necessary in short outline the main features of the region.

Arctic is an area with an unique environment and energy resources. Arctic defines the region as the land and sea area north of the Arctic Circle. For surface locations within this zone, the sun is generally above the horizon for 24 continuous hours at least once per year and below the horizon for 24 continuous hours at least once per year. Eight the countries have territory north of the Arctic Circle: the United States (Alaska), Canada, Russia, Norway, Denmark, Finland, Sweden and Iceland. These eight countries are often referred to as the Arctic countries<sup>5</sup>. (O'Rourke R, 2014). There exist only four large scale LNG plants in the Arctic and the small scale LNG is spreading around the world due to favorable conditions and it can be successfully adapted in these region areas and to use the experience of Norway, where the small scale LNG has already spread successfully in Norway. Comparing the Arctic with other lands, there exist harsher obstacles than Europe, Asia. The disadvantage of the region is infrastructure which is poor and solution can be a small scale LNG. The joint solution, LNG and pipeline are a key driver for developing natural gas

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<sup>4</sup> Dieckhoner C., Lochner S., Linderberger D. European natural gas infrastructure: The impact of market developments on gas flows and physical market integration // Applied Energy, 2012. URL: [www.elsevier.com/locate/apenergy](http://www.elsevier.com/locate/apenergy) [Assessed March 1, 2014]

<sup>5</sup> O'Rourke R. Changes in the Arctic: background and issues for congress. Congressional research service, 2014. <http://www.fas.org/sgp/crs/misc/R41153.pdf> [Accessed March 1, 2014]

sector. The small scale LNG lets company to get LNG for companies without help of pipelines. New reserves are expected in the Arctic and improving technologies let to deal with harsh conditions more efficient and small scale LNG can be solution, due to limited structure and environment issues in the region. The LNG is a useful to mitigate impact to environment, biodiversity and CO2 emission.

## **1.2 Research question**

The research question of this thesis is:

*“What are the drivers and obstacles for companies to make an LNG business in Arctic.”*

Sub-tasks

1. To outline the main drivers and barriers to adoption of LNG as an energy carrier.
2. To find out the opinion of companies on the drivers and obstacles to LNG adoption.
3. To assess the prospects for LNG adoption in Arctic region.

The methods will be used as theoretical and practical analysis of scientific literature, interview, statistical analysis, graphical presentation of statistical data, conclusion.

## **1.3 Structure of the thesis**

The thesis is divided into two main parts: theoretical and empirical. The theoretical part describes the LNG concept, analysis the drivers and obstacles for LNG implementation as well the LNG situation in the world and Arctic region. The empirical part details the research methodology, outlines the selected respondents and describes their companies. The empirical part provides detailed analysis of the research results. Based on theoretical and empirical research results the future prospects of LNG adoption are provided.

## 1.4 The background

“LNG is liquefied natural gas, a clear, colourless, non-toxic liquid that forms when natural gas is cooled to  $-162^{\circ}\text{C}$  ( $-260^{\circ}\text{F}$ ). This shrinks the volume of the gas 600 times, making it easier to store and ship to energy-hungry towns and cities overseas”(Shell)<sup>6</sup>. The history of LNG started in the 19<sup>th</sup> century, the technology of LNG evolved a lot and due to technology and other factors such as the reduced price of natural gas the LNG spread around the world. It is very convenience to use LNG where pipelines can't be used. There exist the large scale and the small scale LNG plants around the world. The LNG can be transported by large and small ships in the local areas. There happened many innovations, the constructions costs reduced, ships became more safer, etc. Sophia Ruester and Anne Neumann (2008) used the porter's strategic positioning framework and identified what type of market position is taken by the LNG firms. There exist companies, which use the flexibility strategy and those companies which prefer this kind of strategy are such as BG Group, Exxon Mobil. Those are big firms. Companies invest in a portfolio of LNG export and import. Other companies use chain optimizer strategy and focus only on one country in which import. The example is the France Company Gaz de France. Also national oil companies are interested in the natural gas. And due to shale gas and Fukushima accident there opened a place for small scale LNG companies in the natural gas market. The small scale LNG can be adopted by various companies in islands or stranded markets. All in all, the LNG is used by various companies and the demand is rising what foster the supply increase.



**Picture No. 1. The LNG value chain**

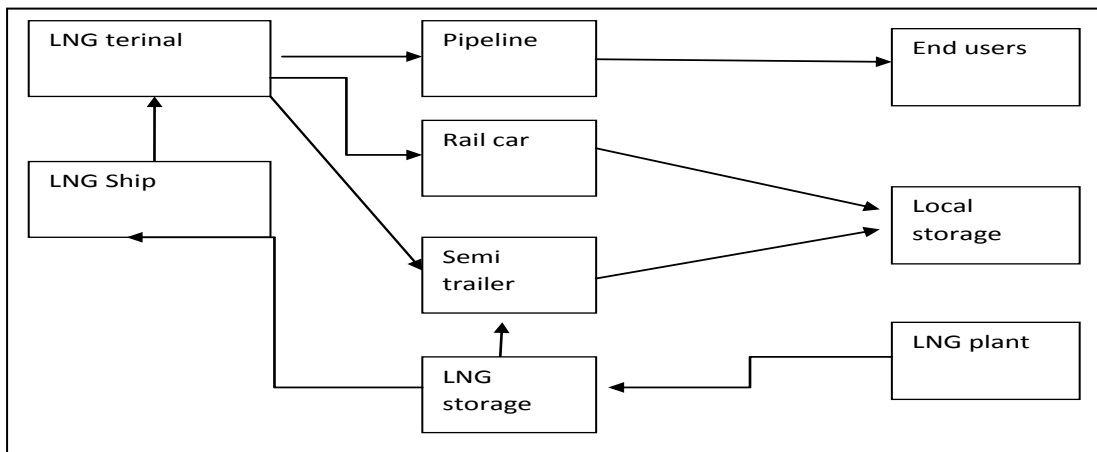
The companies that work in the upstream sector focus on production on the natural gas fields and liquefaction. Midstream companies focus on LNG transportation; it is shipping and downstream companies on regasification, sales and store. Countries that focus on upstream are natural gas producers such as Norway, Qatar, etc.

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<sup>6</sup> Shell, 2014, what is the LNG, <http://www.shell.com/global/future-energy/natural-gas/liquefied-natural-gas/what-is-lng.html> [Accessed March 10, 2014]

The natural gas can be transported by pipelines and LNG and the distance is important factor. The literature gives the different numbers of cost of pipelines and LNG. “The costs of pipelining natural gas benefit substantially from economies of scale, since large diameter pipelines are not that much more expensive to lay than smaller lines but carry much greater volumes. Pipeline costs rise linearly with distance, but LNG – requiring liquefaction and regasification regardless of the distance travelled – has a high threshold cost but a much lower increase in costs with distance. Thus shorter distances tend to favour pipelining, but longer distances favour LNG” <sup>7</sup>(Jensen, 2004: 7). In many sources is stated that transportation of LNG is possible when the distance reach more than 4000 km.

In this work will be more focused on small scale LNG, what are benefits and drawbacks. Here down you can see the small scale LNG supply chain.



**Picture No. 2 Small scale LNG supply chain**

LNG is transported by ships than it goes to end users by rail cars or semi trailer. Companies must built LNG storage, where would be possible to have compressed natural gas. The natural gas goes to industrial user, residential sites and can be used as fuel for vehicles.

<sup>7</sup> Jensen, J., 2004, The development of a Global LNG Market. Is it Likely?If So, When.(Oxford:Oxford Institute for Energy Studies) <http://www.oxfordenergy.org/wpcms/wp-content/uploads/2010/11/NG5-TheDevelopmentofAGlobalLNGMarketIsItLikelyIfSoWhen-JamesJensen-2004.pdf> [Accessed January 30, 2014]

## **Chapter 2: Theory**

### **2.1 Introduction**

This part describes the situation of LNG in global market, analyzing statistical data of LNG usage, as well the main prospects of future development. This part deals with drivers for LNG adoption such as economical benefit of LNG, the environmental issues. The small scale LNG is described, providing the barriers for LNG adoption.

### **2.2 The situation of LNG in global market**

The LNG has enough long history, however the business is adopting LNG not for a long time and still some barriers are arising for LNG adoption. This chapter describes the main features of LNG market globally and in Arctic region.

Concerning the historical facts and analysis of scientific researches it can be stated that LNG was almost solely traded under inflexible long-term contracts. Since 2000, nevertheless, the amount of LNG traded spot and contracts of less than four years duration have grown significantly. As well it should be noted that the long-term LNG contracts have become more flexible. For example, some of contracts regarding LNG are allowing adjustments due to quantity because of a multitude of circumstances, destination flexibility reason, a much broader range of pricing options and price review provisions. Contract provisions let parties not only to deal with short-term operational disruptions but also to exploit profitable temporary trading opportunities<sup>8</sup>.

The LNG industry history is reaching for nearly fifty years. The first LNG supply contract was made for the export of gas from LNG plant GL4Z in the Algerian port to Great Britain and France in 1964. After 5 years another three contracts were signed. It was the supplementary supply from Algeria to France, the second supply was from Libya to Italy and Spain and the last supply was from a plant in Alaska to Japan.<sup>9</sup> The development of LNG market is detailed in Table No.1.

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<sup>8</sup> Weems, P. R.. "Evolution of Long-Term LNG Sales Contracts: Trends and Issues." *Oil, Gas and Energy Law*, 2006, 4(1).

<sup>9</sup> G. Vygon, M. Belova. The development of a global LNG market: challenges and opportunities for Russia. Energy center, Moscow, 2013

**Table No 1. The development of LNG market**

<b>Key figures</b>	<b>1995</b>	<b>2000</b>	<b>2005</b>	<b>2012</b>
Number of liquefaction trains	44	56	68	89
LNG production capacity, millions of tons	89	122	171	282
Number of LNG regasification terminals	31	40	51	93
Capacity of LNG regasification terminals, millions of tons	280	334	380	668
Number of tankers	66	104	167	378
LNG trade volume, millions of tons	74	92	130	236
LNG share of international gas trade, %	20,5	26	26,2	30

Source: G. Vygón, M. Belova, 2013

Analyzing the provided data, it can be stated that during analyzed period the number of liquefaction trains increased twice, from 44 in 1995 till 89 in 2012. As well LNG production during the indicated period increased almost three times and in 2012 reached 282 millions of tons. Three times increased LNG regasification terminals. LNG accounts for 30% of the world trade in gas, its export involves 18 countries, and 26 countries have regasification terminals. Furthermore, in just the last seven years the number of exporting countries has increased by 40%, and importers by 70%.

First of all the situation of LNG in global market will be shortly overviewed. LNG trade decreased in 2012 after 30 years of continuous increase. Global flows reduced by 1,6% from 241,5 MT in 2011 to 237,7 MT in 2012 according IGU and the contraction was mainly due to supply side problems in Southeast Asia and in the Middle East and North America (MENA) region, where domestic and political challenges were going on. The world's dominant LNG importers are Japan and Korea. The market share accounted for 52%. It increased by 4% from 2011.<sup>10</sup>

The increasing world's energy demand is one of the biggest challenges for the 21<sup>st</sup> century. The natural gas is considered as the substitute of oil. Maritime transport can be described as a pillar of world trade, is expected to face the challenges ahead. Certainly, the natural gas markets for decades were localized and isolated, the LNG trade of natural gas by seas has contributed to the development of global market, which shows similarities to the oil market, yet there exist many differences as well<sup>11</sup>.

“Changes in regional demand patterns and the emergence of so many new importers created a large swing in import patterns in 2012 relative to 2011. Seven countries (UK, France, Spain, US,

<sup>10</sup> World LNG report. International Gas union: news, views and knowledge on gas – worldwide, 2013. [http://www.igu.org/gas-knowhow/publications/igu-publications/IGU\\_world\\_LNG\\_report\\_2013.pdf](http://www.igu.org/gas-knowhow/publications/igu-publications/IGU_world_LNG_report_2013.pdf) [Assessed March 10, 2014]

<sup>11</sup> Gkonis K., Psaraftis H. The LNG market and game theory approach to competition in LNG shipping. Maritime Economics and Logistics, Palgrave-McMillan, in press, 2009.

Belgium, Italy, and Canada) saw imports fall by 1.0 MT or more, whereas six countries saw imports increase by 1.0 MT or more (Japan, Brazil, China, India, Turkey, and South Korea). In spite of increased interregional trade, there is still no “global” LNG market with a single price structure. Rather, there are strong regional LNG supply and demand dynamics. But the increasing prevalence of divertible LNG contracts and the emergence of portfolio traders together facilitate greater inter-basin trade”.<sup>12</sup>( IGU, 2013:8)

The use of natural gas as an energy source for the electricity production fostered the development of the international LNG trade, in order to meet the rising demand across developed and developing countries. Natural gas powered stations introduce economic benefits, are faster to construct and more environmentally friendly, when compared to electricity production from other fossil fuels. Furthermore, natural gas can be burned directly as a fuel in the industrial and the household sectors with very high efficiency and minimal losses<sup>13</sup>.

A major player in the market of short-term LNG sales (36% of total spot supplies) is Qatar, which is also the largest of world's producers of liquefied gas. Activity of this country on the spot gas market is largely due to the fact that a significant portion of liquefaction facilities focused on the U.S. market, but were no longer needed because of the North American shale revolution. In second place in terms of LNG sold at spot prices, is Nigeria with 15 % share of this market. Also important suppliers to the spot market are Trinidad and Tobago, Indonesia, Egypt and Equatorial Guinea. Russia is also involved in spot trading LNG in 2012 with LNG plant Sakhalin-2 in the framework of spot and short-term transactions, according GIGNL, has sold 1.3 million tons of LNG (2 % of the spot market and 12.5 % of Russian exports LNG)<sup>14</sup> (Fig. 1)

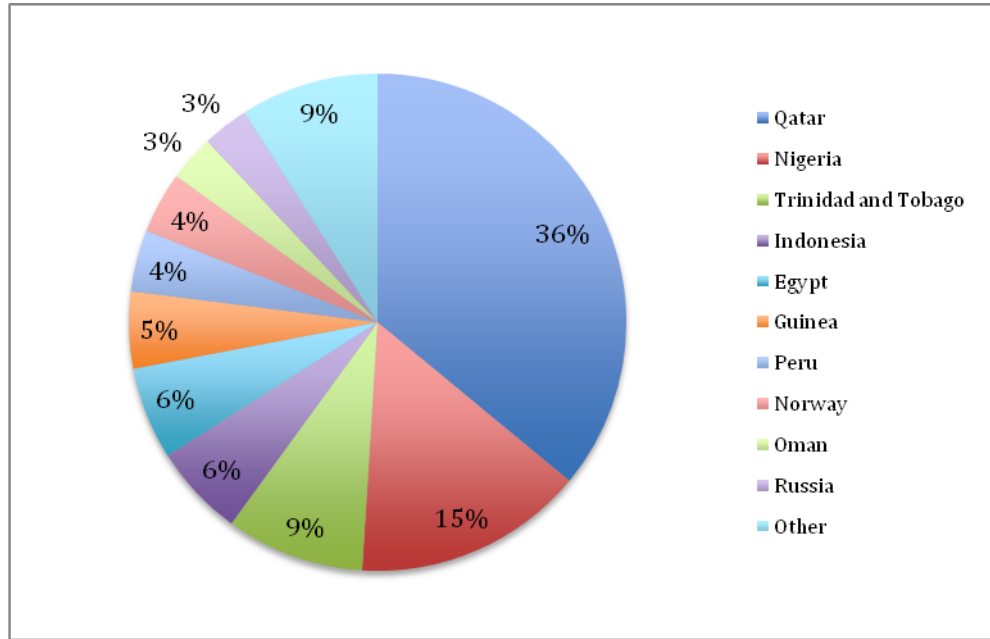
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<sup>12</sup> World LNG report. International Gas union: news, views and knowledge on gas – worldwide, 2013. [http://www.igu.org/gas-knowhow/publications/igu-publications/IGU\\_world\\_LNG\\_report\\_2013.pdf](http://www.igu.org/gas-knowhow/publications/igu-publications/IGU_world_LNG_report_2013.pdf) [Assessed March 10, 2014]

<sup>13</sup> Gkonis K., Psaraftis H. The LNG market and game theory approach to competition in LNG shipping. Maritime Economics and Logistics, Palgrave-McMillan, in press, 2009

<sup>14</sup> Belova M., Vygon G. The development of LNG world market: the perspectives for Russia. Russia: Skolnovo, 2013.

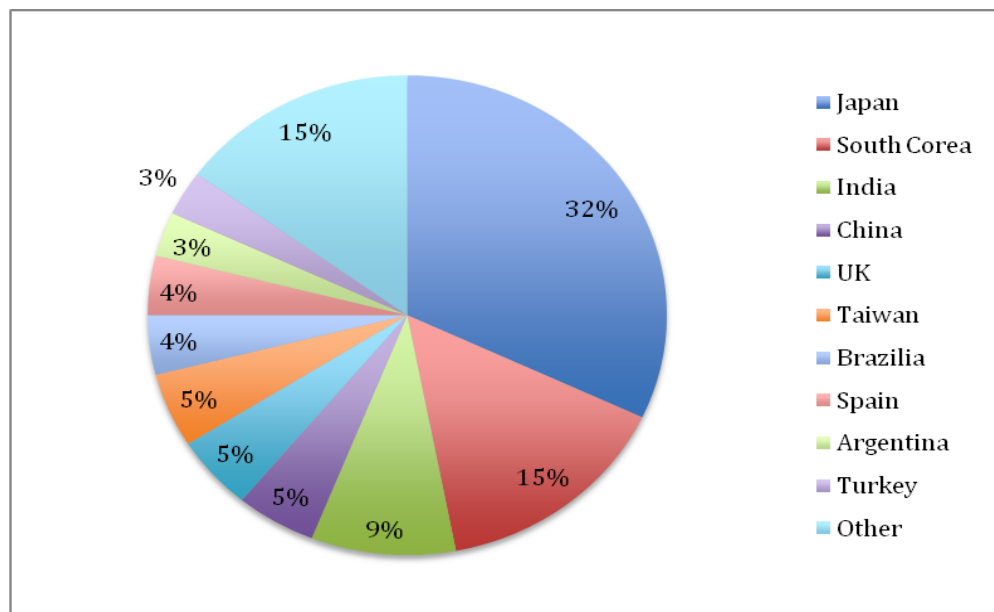




**Picture No. 3. The exporters in LNG market**

Source: GIGNL, 2013.

On the demand side the largest buyer of spot cargoes of LNG is Japan (32 % of total traded volume of spot and short-term), then South Korea (about 15%), which is due to spot transactions satisfy the needs of their peak in the winter. Among the patrons of spot LNG cargoes also include India (9 % of the market ) , China, Brazil and Taiwan ( 5 %) (Fig. 2)



**Picture No. 4. The importers in LNG market**

Source: GIGNL, 2013.

### 2.3. The situation of LNG in Arctic region

“A primary driver for the increased interest in exploring for oil and gas offshore in the Arctic region shrinking Arctic ice cap or conversely the growing amount of ice – free ocean in summertime. Reduced sea ice in the summer means that ships towing seismic arrays can explore previously inaccessible regions of the Arctic Ocean, Chukchi Sea, Beaufort Sea and other offshore regions for longer periods of time without risk of colliding with floating sea ice. Less sea ice over longer periods compared to previous decades also means that the seasonal window for offshore drilling in the Arctic remains open longer in the summer and increases the chances for making a discovery”<sup>15</sup> (O’Rourke,2014: 25).

In addition to the improved access to larger portions of the Arctic afforded by shrinking sea ice, recent interest in Arctic oil and gas was fueled by a 2008 U.S. Geological Survey (USGS) “appraisal of undiscovered oil and gas north of the Arctic Circle. The USGS assert that the extensive Arctic continental shelves may constitute the geographically largest unexplored prospective area for petroleum remaining on Earth. In the report USGS estimates that 90 billion barrels of oil, nearly 1,700 trillion cubic feet of natural gas and 44 billion barrels of natural gas liquids may remain to be discovered in the Arctic”<sup>16</sup>. (O’Rourke,2014: 26).

USGS (2008) announced that the total amount of undiscovered petroleum resources in the Arctic is 413 bboe. It consists of 22 per cent of the global undiscovered conventional oil and gas resources. Moreover, they figure that the Arctic holds 134 bboe of oil what composes around 15 per cent of total global oil resources. Therefore 279 bboe or close to 70 per cent of the arctic petroleum is gas<sup>17</sup>.

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<sup>15</sup> O’Rourke R. Changes in the Arctic: background and issues for congress. Congressional research service, 2010. <http://www.fas.org/sgp/crs/misc/R41153.pdf> [Accessed March 1, 2014]

<sup>16</sup> USGS Circum Arctic Resource Appraisal website at <http://energy.usgs.gov/arctic/>. [Accessed March 1, 2014]

<sup>17</sup> Lindholt L. The role of the arctic in the future global petroleum supply. Statistics Norway, Research Department. Discussion papers, 2011, No. 645. <http://www.ssb.no/a/publikasjoner/pdf/DP/dp645.pdf> {Assessed March 2, 2014}

**Table No 2. Distribution of oil and gas resources among the Arctic five<sup>18</sup>**

Rank	Country	Total estimated resources equivalent (billion barrels)	Percentage
1	Russia	215,94	52
2	USA	83,31	20
3	Norway	47,46	12
4	Denmark/Greenland	44,49	11
5	Canada	22,08	5
	Total	413,28	100

According to the data provided in the table above Russia has the greatest potential for development of oil and gas resources in Arctic region. At the moment Russia takes 52% of all resources. But the global gas market is changing and USA has developed new technologies to extract huge amount of unconventional gas.

The natural conditions in Arctic is harsh, thus the Liquid Natural Gas (LNG) solution is the best option to transport natural gas from the region. The infrastructure is poor and need more than one decade to change situation. The best LNG perspectives has Norway and Russia in Arctic, there are good conditions for it development. The small scale LNG terminals in Norway and geographical conditions led that is easier to have LNG instead pipelines for natural gas distribution in local areas. The smaller LNG tankers and trucks can bring this fuel to regions that are not connected by natural gas pipelines. Norway is one of the first country where a small scale LNG where adopted due to harsh geographical location and poor infrastructure due to that transportation of natural gas by LNG is the most appropriate method, this is a reason why there are spread small scale LNG receiving terminals. Also Russia is moving forward, planning to open the LNG plant in Yamal peninsula.

There exist North Sea Route and Northeast passage in Arctic from which LNG can be transported by ships and reach Asia market, where are the highest LNG prices. The LNG is useful to mitigate an impact to the environment and reduce CO2 emission, because LNG can be uses as alternative fuel for ships too. Moreover, it can bring sustainable development. The regional development has good perspectives regarding LNG. The aim of this master thesis is to find what are the drivers and obstacles for companies to use LNG in Arctic.

The LNG trade is rising quickly in the Atlantic Basin market which may probably overtake the Asia-Pacific market. Large natural gas fields are to be exploited in the Arctic zone by Russia and Norway. Russia, also with the development of its fields in Siberia, may play a role in the natural gas market, similar to that of Saudi Arabia in the oil market. The Middle East (especially

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<sup>18</sup> Keil K. The Arctic – a new region of conflict: The case of oil and gas. Cooperation and conflict, 2013, p. 1-29.

Qatar) will increase its exporting role to both the Atlantic and Asia-Pacific market. Furthermore, the energy demand in China and India will make new challenges<sup>19</sup>. Security of supply considerations, through the diversification of sources, will influence the choices for the supply of energy to markets around the globe in the coming future.

## **2.4 The drivers and obstacles of new technology adoption: LNG case**

### **2.4.1 Economic benefits of LNG**

LNG as fuel has good perspectives in transport industry. In nowadays, the transport sector mostly uses a diesel and oil. LNG demand should rise in the future because of stricter emission regulations for ships and positive price development of gas compared to oil. The use of LNG in the transport sector leads to important economic growth and employment<sup>20</sup>.

As well the scientific researchers recognized the main factors motivating the renewed interest to LNG<sup>21</sup> (Jensen, 2004: 11):

- “Combined cycle power generation from growing electric power markets;
- The effects of technology on cost reduction making previously uneconomic trade attractive;
- Environmental concerns;
- The embrace of gas by previously gas poor economies;
- The growing concern for traditional supplies in the face of growth;
- The stranded gas phenomenon.”

In recent years, LNG has grown significantly as a share of both gas production and trade. Since 2000, global LNG trade has more than doubled while pipeline trade has increased by one – third. In part, this reflected falling costs in the 1990s and early 2000s, as technical advances facilitated larger trains and transport tankers. The growth in LNG trade has been supported by large capital investments in global stage, with further projects under way or being planned. As investment

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<sup>19</sup> Gkonis K., Psaraftis H. The LNG market and game theory approach to competition in LNG shipping. Maritime Economics and Logistics, Palgrave-McMillan, in press, 2009

<sup>20</sup> The economic impact of small scale LNG, 2013. [http://www.nationaallngplatform.nl/wp-content/uploads/PwC-Economic-impact-of-small-scale-LNG\\_STC.pdf](http://www.nationaallngplatform.nl/wp-content/uploads/PwC-Economic-impact-of-small-scale-LNG_STC.pdf) [Assessed March 10, 2014]

<sup>21</sup> Jensen, J., 2004, The development of a Global LNG Market. Is it Likely? If So, When. (Oxford:Oxford Institute for Energy Studies) <http://www.oxfordenergy.org/wpcms/wp-content/uploads/2010/11/NG5-TheDevelopmentofAGlobalLNGMarketIsItLikelyIfSoWhen-JamesJensen-2004.pdf> [Accessed January 30, 2014].

has raise in recent years, costs have climbed as projects needed skilled workers; the situation became more complex, and required more time to complete<sup>22</sup>.

The LNG price lies at core of the economic discussion on the use of LNG as a ship fuel. The researchers showed that current low natural gas price in comparison with traditional oil fuel are a main economic driver for the LNG application. Beside this LNG engine developments highlight the lower maintenance and repair costs comparing to oil engines, because of more clean and efficient system and long lifetime of machine.

“Total demand of natural gas is projected to increase from 3,149 billion cubic meters in 2008 year to 4,535 bcm in 2035 year. This is 44 % increase over the period at an average annual growth rate of 1,4%. 84% of the increase in global gas use in the period to 2035 is expected to come from non-OECD regions. Chinese demands is expected to grow by 5,9%, more then any other region, driven by booming demand in the power, residential and industrial sectors”<sup>23</sup> Kamalakannan og Madhavan,2012:4).

Another research results introduced that small scale LNG can create 8000 additional job, what should foster additional economic increase to 2,7bn Euro in the period up to 2030. It should consist of 0,4% of current GDP and 0,1% of the current amount of job years. In future scenario which supposes stricter emission regulations and favorable price developments, the economic impact could raise to 3,4bn Euro and 11000 job years<sup>24</sup>.

As well the pattern of global LNG trade should change in the future. Recently LNG trade has been focused in the Asia-Pacific region with gas sourced from Asia and the Middle East. Though the market will keep on expanding, LNG demand from the Atlantic basin is expected to enhance<sup>25</sup>.

In British Columbia LNG strategy there is noted that building of LNG projects create thousands of jobs over the next 10 years , works will be related to field preparation work, trade service, heavy equipment operators and engineering positions. Afterward, skilled and technically

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<sup>22</sup> Jacobs D. The global market for liquefied natural gas. Bulletin, September quarter, 2011.

<http://www.rba.gov.au/publications/bulletin/2011/sep/pdf/bu-0911-3.pdf> [Assessed February 20, 2014]

<sup>23</sup> Kamalakannan S., Madhavan B. Drivers for demand of liquefied natural gas in a growing global market. AMET International Journal of Management, 2012, Jul-Dec <http://www.ametjournal.com/attachment/ametjournal-4/Dev-Article-1-Kamalakannan.pdf> [Assessed March 1, 2014]

<sup>24</sup> The economic impact of small scale LNG, May, 2013. Via internet: <http://www.rijksoverheid.nl/documenten-en-publicaties/rapporten/2013/09/02/the-economic-impact-of-small-scale-lng.html> [Assessed March 1, 2014]

<sup>25</sup> Kamalakannan S., Madhavan B. Drivers for demand of liquefied natural gas in a growing global market. AMET International Journal of Management, 2012, Jul-Dec

qualified employees will be needed in operation to deal with and operate the LNG processing and shipment<sup>26</sup>.

As well six economic effects that play role in the use of LNG in the transport sector were known<sup>27</sup>(PWC,2013:12):

- “Investments in ships and trucks that operate on LNG. Ship-owners and truck owners will need to decide to switch to LNG. In that case they need to invest in new ships or trucks that are able to operate on LNG. End user’s decision to switch to LNG determines how fast the small scale LNG market will develop. In the road transport segment, several owners already switched to LNG. The shipping sector lags behind, partly driven by the fact that inland and short sea ships face longer depreciation periods than trucks.
- Investments in LNG infrastructure. Engine producers and ship owners and truck owners will only invest in LNG if they are confident that LNG infrastructure will be built.
- Investments in bio – LNG. There are still debates about the economic impact of bio – LNG usage.
- Diversification of the fuel mix. LNG has been introduced as a new (alternative) fuel only recently. First of all, this development increases the available amount of fuels, which can lead to oil prices increasing at a lower rate or declining oil prices. This will positively impact economic growth.
- Countries’ competitive position can be improved by early participation.
- Health effects as result of emission reduction.”

“The costs of pipelining natural gas benefit substantially from economies of scale, since large diameter pipelines are not that much more expensive to lay than smaller lines but carry much greater volumes. Pipeline costs rise linearly with distance, but LNG – requiring liquefaction and regasification regardless of the distance travelled – has a high threshold cost but a much lower increase in costs with distance. Thus shorter distances tend to favor pipelining, but longer distances favor LNG” (Jensen, 2004:7)<sup>28</sup>.

The production and transport of liquefied natural gas consist of a three-step: firstly, liquefaction process, after that tanker transport and re-gasification. Here we don’t need to focus on

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<sup>26</sup> British Columbia’s Liquefied natural gas strategy. One year update. 2013.

<sup>27</sup> The economic impact of small scale LNG, May, 2013. Via internet: <http://www.rijksoverheid.nl/documenten-en-publicaties/rapporten/2013/09/02/the-economic-impact-of-small-scale-lng.html> [Assessed March 10, 2014]

<sup>28</sup> Jensen, J., 2004, The development of a Global LNG Market. Is it Likely?If So, When.(Oxford:Oxford Institute for Energy Studies) <http://www.oxfordenergy.org/wpcms/wp-content/uploads/2010/11/NG5-TheDevelopmentofAGlobalLNGMarketIsItLikelyIfSoWhen-JamesJensen-2004.pdf> [Accessed January 30, 2014]

the transport of natural gas from the field to the liquefaction plant, because it is frequently located on the coast, because this stage is needed for both pipeline and LNG transport and will not make a difference in the comparison. The costs of LNG projects are hard to simplify because they vary considerably from location to location, and hinge on whether the project is greenfield or an expansion of an existing facility”<sup>29</sup>.

#### **2.4.2 Environmental policies**

LNG production has the prospective to decrease or eliminate the need for the wasteful process of flaring (burning off) of associated natural gas in oil field and the causing environmental impacts. Import LNG can be vaporized to produce natural gas, which can be used in the high efficiency, combined cycle power plants instead of old ones. On the other hand, LNG can be used as a transportation fuel, changing import oil, and is cleaner fuel. In effect, LNG production has recovered a low carbon fuel to displace the high carbon oil and coal, and contribute considerably in decreasing the environmental impacts. Due to positive result, LNG plant construction and plant operation may produce pollutions and effluent, which can be environmental, concern if not correctly addressed in the project execution, plant design and operation<sup>30</sup>.

Besides economic benefits, small scale LNG can lead to environmental advantages compared to currently available transport technologies. Also based on the latest (newest) technologies, LNG leads to significant environmental benefits. Recent TNO, CE and ECN research shows that the environmental effects are biggest for PM, NO<sub>x</sub>, and SO<sub>x</sub> emissions. Regarding CO<sub>2</sub> emissions, LNG presents positive outcomes for road transport; yet in the shipping sector, results introduce a small emission enhance, almost certainly caused by the “methane slip”. But, it can be expected that in the future, LNG will also score positive in the field of CO<sub>2</sub> as engine technology is constantly being improved<sup>31</sup>.

“The construction of LNG facilities, whether liquefaction or regasification/import terminals, gives rise to numerous social, environmental and economic effects. While the issues and regulations vary depending from country to country, the International Finance Corporation (IFC) has issued

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<sup>29</sup> Ulvestad M., Overland I. Natural gas and CO<sub>2</sub> price variation: impact on the relative cost efficiency of LNG and pipelines. *International Journal of Environmental studies*, 2012, vol. 69, issue 3.

<sup>30</sup> John S. *Handbook of Liquefied natural gas*. Oxford, 2014.

<sup>31</sup> The economic impact of small scale LNG, May, 2013. Via internet: <http://www.rijksoverheid.nl/documenten-en-publicaties/rapporten/2013/09/02/the-economic-impact-of-small-scale-lng.html> [Assessed March 1, 2014]

guidelines that are illustrative of the many issues faced by all countries when assessing the environmental impact of proposed LNG facilities”<sup>32</sup> (Susan, 2010:4).

The upcoming alter of environmental regulations created by International Maritime Organization (IMO), the most of interest is focus on the level of emission control areas, serve as a main stream for exploring the use of LNG as a marine fuel. Evaluating to other ship fuels, LNG promises better environmental performance.

“In recent years, LNG has begun to penetrate the fuels market for both marine (bunker) and road transportation. Compared to conventional fuels used in the transport sector, LNG requires more volumetric space to generate the same energy but it requires approximately 3 times less volume than compressed natural gas (at 200 bar). As a consequence LNG and CNG have different development opportunities. Despite the need for more tank space than other transportation fuels, gas alternatives provide a cheaper and more environmentally-friendly option”<sup>33</sup> (IGU,2013:41).

The trend that could influence not only the LNG market but the whole bunker fuel market is the harder line taken due to environmental requirements in emission control areas (ECA). Relative to these requirements, beginning in 2015 only fuel with a sulphur content no greater than 0.1% will be possible to use in the Baltic and North Seas (the current level is 1%)<sup>6</sup>, which will cause an raise in the use of LNG as a bunker fuel in the Baltic region. Thus, by the assessment of the Russian marine shipping registry, by 2020 LNG may consist of 20% of the bunker fuel market<sup>34</sup>.

“Environmental concerns are clearly a driving force in developing interest in natural gas and in LNG. Not only is gas essentially free of sulphur and particulate matter, but the increasing concern for global warming also benefits gas. Not only does gas have a higher hydrogen-to-carbon ratio, minimizing CO<sub>2</sub> emissions, but CCGT’s higher thermal efficiency requires less fossil fuel per MWH generated. By comparison with a coal-fired boiler, gas-fired CCGT units can cut CO<sub>2</sub> emissions by about 40 per cent”<sup>35</sup> (Jensen,2004:12).

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<sup>32</sup> Susan L. The globalization and environmental sustainability of LNG. Is LNG a fuel for the 21<sup>st</sup> century. World energy congress, 2010. <http://www.worldenergy.org/documents/congresspapers/120.pdf> [Assessed February 20, 2014]

<sup>33</sup> World LNG report. International Gas union: news, views and knowledge on gas – worldwide, 2013. [http://www.igu.org/gas-knowhow/publications/igu-publications/IGU\\_world\\_LNG\\_report\\_2013.pdf](http://www.igu.org/gas-knowhow/publications/igu-publications/IGU_world_LNG_report_2013.pdf) [Assessed March 10, 2014].

<sup>34</sup> G. Vygon, M. Belova. The development of a global LNG market: challenges and opportunities for Russia. Energy center, Moscow, 2013

<sup>35</sup> Jensen J. The development of a global LNG market. Is it likely? If so when? Oxford Institute for energy studies, 2004. <http://www.oxfordenergy.org/wpcms/wp-content/uploads/2010/11/NG5-TheDevelopmentofAGlobalLNGMarketIsItLikelyIfSoWhen-JamesJensen-2004.pdf> [Accessed January 30, 2014]



The first and most vital factor that triggered the appearance of technology LNG has become a increasing demand for natural gas and the fact that its service to the region of the largest consumer was not always available. It became clear that pipeline technologies are not sufficient to meet the increasing demand in the world market, and scientists were searching for the methods of transportation of natural gas. One of the newest technologies, which became to be cost-effective and competitive, this technology called the transportation of liquefied natural gas. Another important indicator was the invention of an innovative cryogenic technologies on which an opportunity to cool the gas to extreme temperatures and its subsequent liquefaction voltage. The British scientist Michael Faraday has converted first natural gas to liquid form in the early 19th century, later in 1873, the German engineer Carl Van Linde built the first refrigerant compressor. The first experimental LNG plant was built in America in 1912, while the first commercial plant was put into operation in the same place, but already in 1941<sup>36</sup>.

#### **2.4.3. Small scale LNG benefits**

The concept of small – scale LNG is effective solution to provide natural gas energy consumers who currently do not have access to the pipeline network. Consequence of the application of this concept - the growth of the LNG market due to supply liquefied natural gas or with liquefaction plants, or with regasification terminals, either directly with the vehicles intended for the carriage of LNG. This applies when combined scheme delivery by sea and land directly to the end consumer<sup>37</sup>. (Skangass,2013:2).

Natural geography of clients under this concept - the industrialized countries with rather low population density, such as the Scandinavian countries or island states of the Caribbean, the Mediterranean and South- East Asia. In short period the small scale LNG are modern technologies that transport natural gas to consumers in the isolated markets, which eventually means the beginning there the most environmentally friendly form of fossil fuels.

Furthermore, since under this concept are feasible LNG supplies small and medium volumes, emerging as a promising development of new markets for natural gas, such as island regions or markets the market of heavy vehicles that will in the long run lead to a important decrease in emissions of nitrogen oxides and other harmful substances.

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<sup>36</sup> G. Vygon, M. Belova. The development of a global LNG market: challenges and opportunities for Russia. Energy center, Moscow, 2013

<sup>37</sup> Skangass, Reaching Stranded LNG Markets.

The small scale of LNG involves the use of technologies used in large-scale LNG supply. Tonnage supplies are done between continents and are transported million tons of LNG from the LNG facility for regasification terminal where the supply of the product is in the national pipeline system. In contrast, the supply of LNG in small quantities limit the scope of some regions where LNG carriers are made in volumes of hundreds of thousands of tons of LNG from the supplier dir to end customers, using a range of schemes of transportation, delivering LNG by ships to transport tankers. It helps the development of energy supply results that were impossible. The main aim is to make LNG and, as a result, natural gas as easily reached and easy to use as any other kind of liquid fossil fuels used in the present moment<sup>38</sup>.

In the isolated markets where are supplied small quantities of LNG, it can be as alternative for small companies in those regions. Isolated market means that they are located at a distance from the gas pipeline systems, or so small that connection to the gas pipeline network is hardly achievable. As a result, all the industrial regions where a gas pipelines network are available focus on pipelines, but not LNG. For instance, Scandinavia, where investment in gas pipeline systems are not considered as a main concern by any topographical or demographic motives, focus on small scale LNG. Also in the Mediterranean and Caribbean seas or in Southeast Asia, there are many islands, which will never be connected to any of the pipeline systems and gas consumption that is so small that the building of the traditional infrastructure of large LNG supplies is not logically. Recently, there are found practical solution in the form of gas supply of LNG technology small quantities, the chance to retool power in these islands economical and environmentally friendly combined cycle plant turbines instead of operating on diesel fuel or fuel oil<sup>39</sup>.

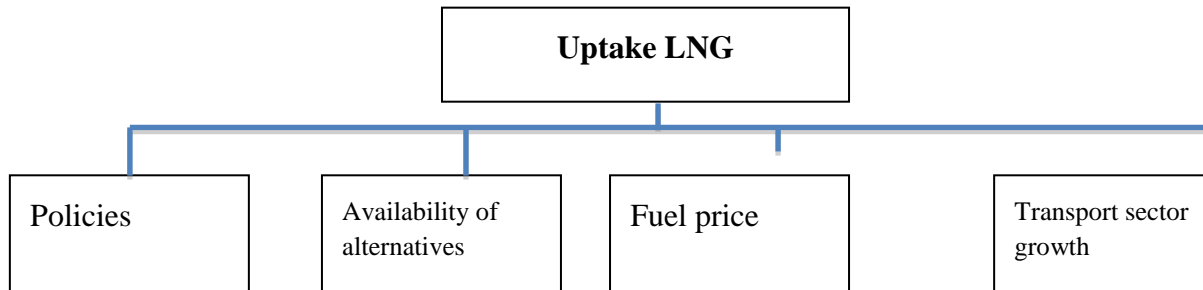
Another big section of the market where technology smaller quantities of gas supplies has important prospects - is a market fuel for bunkering ships. Legal rules to limit polluting emissions from ships, day by day become stricter. First they touch control for emissions of nitrogen oxides and sulfur, but in the future obviously follow limitations on CO<sub>2</sub> emissions and particulate matter. Natural gas is the fuel that meets all these requirements and lets doing without any extra pollution control equipment such as scrubbers or upgrading selective catalytic decrease. Gas used as fuel for ships, can remove emissions of sulfur oxides, reduced by 80 - 90% of emissions of nitrogen oxides, as well as a 20-25 % decline in emissions of CO<sub>2</sub>. The core problem of the supply of gas will be in a liquid state (LNG) as a fuel bunker. It can be resolved by a sequence of small quantities of LNG for the organization of supply of bunker fuel. This market sector is in its early years and is at

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<sup>38</sup> Lochner S. Modeling the European natural gas market during the 2009 Russian-Ukrainian gas conflict: Ex-post simulation and analysis // Journal of Natural Gas Science and Engineering 3, 2011

<sup>39</sup> Belova M., Vygon G. The development of LNG world market: the perspectives for Russia. Russia: Skolnovo, 2013

present being developed mostly in Norway. Though, after the entry into force in 2010 of Annex IV to the International Convention for the Prevention of Pollution from Ships, a increasing figures of ferries, tugs for oil platforms, cargo and passenger ro-ro plying in the areas of environmental monitoring, multi-fuel gas or retooled propulsion<sup>40</sup>.



**Picture No. 5. Key drivers of small scale LNG**

The small scale LNG provides not only economic benefits, but also environmental benefits. It can lead to environmental benefits compared to presently accessible transport technologies. According to the newest innovations, LNG leads to significant environmental advantages. Recent TNO, CE and ECN research presents that the environmental effects are largest for PM, NO<sub>x</sub>, and SO<sub>x</sub> emissions. Regarding CO<sub>2</sub> emissions, LNG introduces positive outcomes for road transport; yet in the shipping sector, results introduce a small emission raise, almost certainly resulted by the “methane slip”. But, it can be expected that in the future, LNG will also score positive in the field of CO<sub>2</sub> as engine technology is constantly being improved.

The main factors determining the pace of small scale LNG uptake are as follows<sup>41</sup>(PWC,2013:15)

1. “Policies. The government plays a key role as it can either stimulate or discourage the use of LNG via regulations and fiscal schemes. Especially, during the market development phase, it is key that the use of LNG is not being negatively impacted by changing (excise) tax policies. European, national, regional and local governments have a variety of tools which they can use to

<sup>40</sup> Lochner S. Modeling the European natural gas market during the 2009 Russian-Ukrainian gas conflict: Ex-post simulation and analysis // Journal of Natural Gas Science and Engineering 3, 2011

<sup>41</sup> The economic impact of small scale LNG, 2013. [http://www.nationaallngplatform.nl/wp-content/uploads/PwC-Economic-impact-of-small-scale-LNG\\_STC.pdf](http://www.nationaallngplatform.nl/wp-content/uploads/PwC-Economic-impact-of-small-scale-LNG_STC.pdf) [Assessed March 10, 2014]

impact relative attractiveness of LNG compared to other fuels. Examples are emission regulations, safety and noise regulations and, excise tax, subsidy and permit regimes. Once the industry has passed the development phase, stimulation measures will not be needed anymore. We expect that the small scale market will be a profitable industry.

2. Availability of alternatives. A second driver is the availability of “clean” and cost-effective alternatives. These include, for example, increasingly clean diesel based technologies and scrubbers (cleaner for oil-based fuels) in the shipping industry. Current oil-based engines are expected to further improve in the field of energy use and emissions.

3. Fuel price differential. A third driver is the relative price of LNG compared to alternative fuels which transport companies in north-west Europe can make use of. The figure below shows that for the market to be successful, the LNG price must be below the oil price and, that the small scale LNG price will lie above the LNG import price. The exact price level will depend on the profit margins of LNG suppliers, the fiscal regime, the additional costs that need to be made to roll out LNG infrastructure and the global LNG price. The dynamics between these drivers will change as the market develops further, both at a global LNG level and at a regional level (up to the refueling stations).

4. Growth of the transport sector. A fourth key driver is the growth of the transport sector and the economic growth in north-west Europe. In general, a growing economy results in a more than proportionate growth of transport movements. High growth of the transport sector will, in general, also drive faster depreciation of ships and trucks, thereby implying relatively more flexibility to invest in new ones. In case the three factors above are positive, ship-owners and truck owners will take an LNG-based vehicle into account.”

After the invention and testing of LNG technologies further innovative development of the maritime industry was stimulated by the need to reduce the cost of technology and make it competitive with alternative pipeline. Thus, the economic factor was the most important stimulus for innovative LNG transportation.

#### **2.4.4 The obstacles and barriers for LNG adoption**

Project developers frequently assert that small-scale liquefaction suggest cost-competitiveness on an absolute and unit-cost basis. On the other hand, there exist only few data points, and cost is complicated to simplify for the broader industry.

“A major challenge to developing LNG projects for independent players has been a lack of company expertise in the liquefaction business. There are few cases where a company that is not a major IOC or NOC has developed a project on its own. This same challenge applies to small-scale LNG. Many companies are involved in this sphere, but not all have experience in large-scale LNG. The early slate of projects in the 1960s and 1970s was largely promoted by NOCs. Many of the new projects are operated by new entrants”<sup>42</sup>.(IGU, 2013,21)

For any innovative and developing business perceptions characterized many issues - and this concept is no exemption. At the same time, all the troubles showed surmountable. What is more, the pioneers will gain considerably and the potential advantages. The main component of questions concerns the first and final phases of the supply chain - but not intermediates. Transportation of LNG seems rather basic, no matter whether it is by sea or by land. Much more effort is needed in order to convince clients to change to a new type of fuel - and will have to switch and supplier, as well as construct a new supply chain. Here it will not work the traditional method of LNG with its long-term contracts, opaque pricing and widespread use of the principle of " take or pay ". Few of the customers is prepared to spend money on buying up until the provider itself choose to start a new model and initiate to construct a supply chain. Lastly, another issue at this phase are funding problem. At the other end of the supply chain there exist another problem - the supplier of LNG. The apparent solution would be to a large LNG terminal or in a straight line from the LNG plant, but it should resolve the issues of suitable equipment, such as cranes, mooring equipment, ladders; besides, it will be necessary to consider the performance of pumps and other features. Moreover, at high load terminal very great significance timetable loading any violations that may unfavorably affect the functioning of the entire chain<sup>43</sup>.

Problems on stage LNG supplier show obviously that the business model for large-scale and small cargoes of LNG is very different from one another. There is a high logistical obstacle to application solution for large-scale LNG supply for supplying small buyer markets. Lastly, frequently will have to form the necessary infrastructure where either no skill or practice using gas as a fuel or a shortage of equipment for handling LNG; where the legal framework and the significant principles are regularly either absent or not well developed and where few people want

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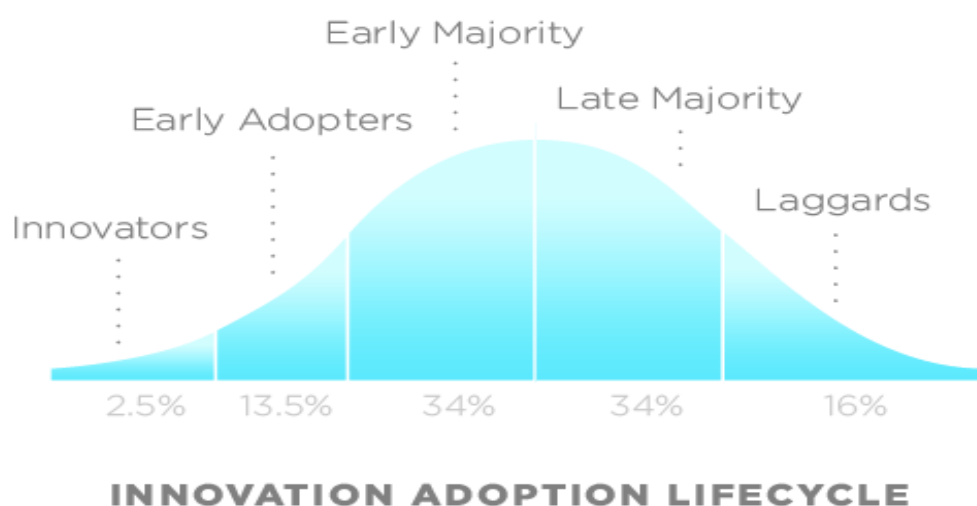
<sup>42</sup> World LNG report. International Gas union: news, views and knowledge on gas – worldwide, 2013. [http://www.igu.org/gas-knowhow/publications/igu-publications/IGU\\_world\\_LNG\\_report\\_2013.pdf](http://www.igu.org/gas-knowhow/publications/igu-publications/IGU_world_LNG_report_2013.pdf) [Assessed March 10, 2014]

<sup>43</sup> Lochner S. Modeling the European natural gas market during the 2009 Russian-Ukrainian gas conflict: Ex-post simulation and analysis // Journal of Natural Gas Science and Engineering 3, 2011

to work directly with the relevant authorities. Finally, completes the list of feasible issues is that most of the existing technological base is relying on work with large quantities of LNG and cannot be rapidly adapted to the supply of small quantities of LNG<sup>44</sup>.

## 2.5 The adoption of LNG technology

There are many models and theories that try to uncover the reasons that will influence the adoption of new technologies. The adoption of LNG technology as all technologies has phases of technology spread and that very clearly explain Everett Rogers Technology Adoption Lifecycle model.



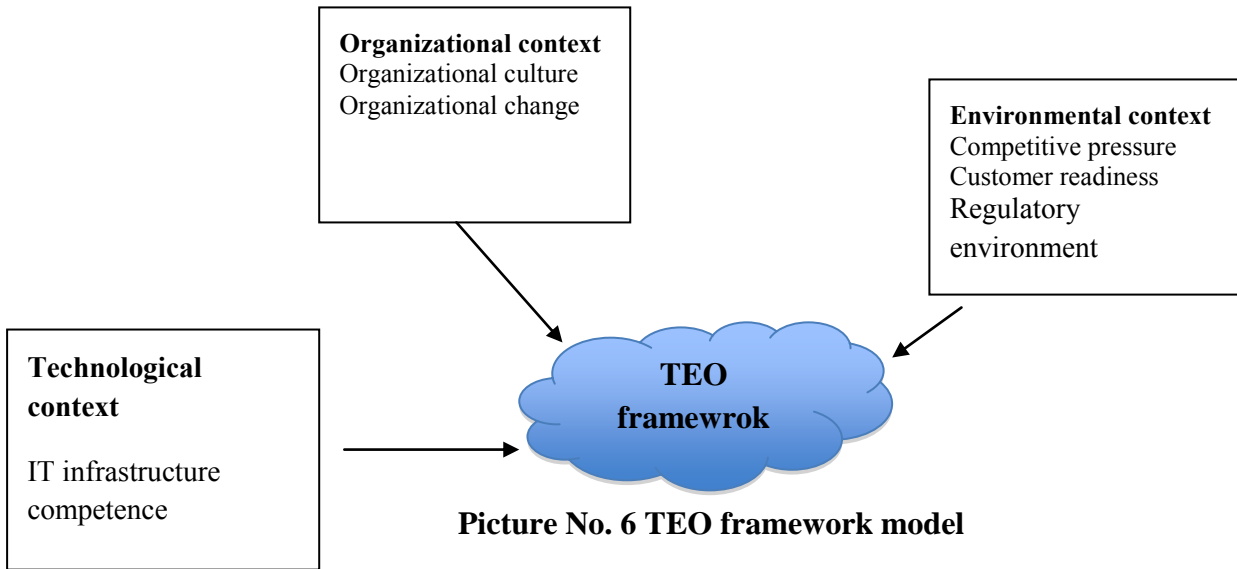
## 2.5 TOE framework

The original idea of technology – organization – environment (TEO) was developed for the adoption of various innovations.

TEO framework model is presented in Picture No.6

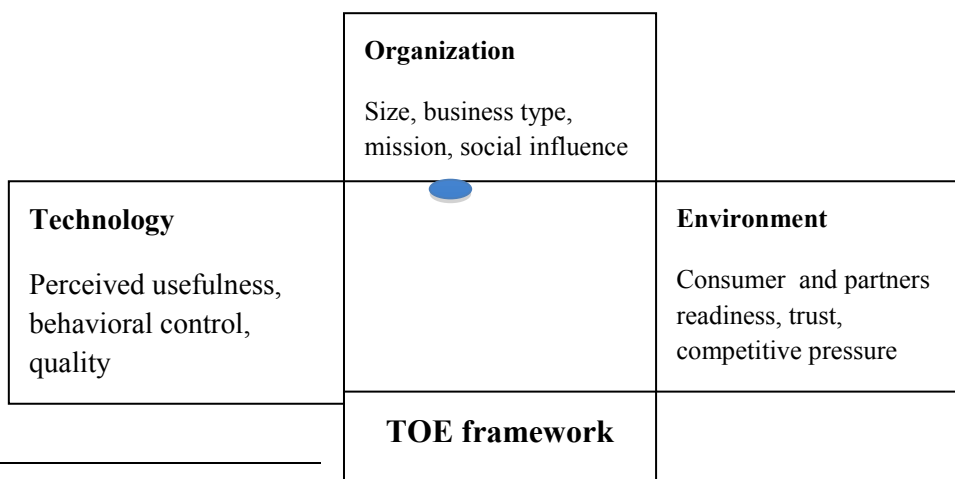
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<sup>44</sup> Belova M., Vygon G. The development of LNG world market: the perspectives for Russia. Russia: Skolnovo, 2013.



TEO framework model presented in the picture above contains three main dimensions or in other words called context: environmental, organizational and technological context. The technological context covers internal technologies and available technologies in the market. Organizational readiness and competence for adoption of new technologies is the vital in TEO framework. The organizational framework is focusing on the openness of organizational culture for innovation. The environmental context covers customer readiness, regulations of environmental issues, as well competitive pressure<sup>45</sup>.

The other model of TEO framework is completed of 3 adoption drivers such as technology, organization and environment.



<sup>45</sup> Scott E.J. An e-transformation study using the technology – organization – environment framework. Merging and Emerging Technologies Processes and Institutions, 2007, No. 4(6).

### **Picture No 7. TEO Framework model**

The other research discovered that environmental context relates to facilitating and inhibiting indicators in areas of operations. Important amongst them are competitive pressure, trading partners' readiness, socio-cultural issues, government encouragement, and technology support infrastructures such as admission to quality ICT consulting services. It should be noted that TOE framework includes three groups of adoption predictors such as leader characteristics relating to change; organization internal characteristics (centralization, complexity, formalization, size), and external characteristics (system's openness, readiness)<sup>46</sup>.

The recent growth of LNG in various parts of the world has led to different developments in liquefaction technology such as AP-X process and the adoption of Frame 9 gas turbine drivers. Process design of natural gas liquefaction plants in arctic climates presents some unique challenges. The features of a mixed refrigerant liquefaction process mean they can easily be adapted to this environment. Although arctic conditions have a low average annual temperature close to zero degrees Celsius the temperature variation over a year can be more extreme than warm climates.

## **2.6 Conclusion**

Summarizing the analyzed chapter it can be stated that LNG has the long history in the world. The usage of LNG during the fifty years period increased more than 3 times. Such situation occurred because of changes in political, economical and environmental spheres. The development of the international LNG trade was favored by the turn to natural gas for electricity production, in order to meet the ever growing demand across developed and developing countries. The LNG trade is growing rapidly in the Atlantic Basin market which is likely to overtake the Asia-Pacific market. Large natural gas fields are to be exploited in the Arctic zone by Russia and Norway.

The main factors determining the adoption of LNG are: policies in different countries, availability of alternatives, fuel price differential, growth of the transport sector. As well the major challenge to developing LNG projects for independent players has been a lack of company expertise in the liquefaction business.

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<sup>46</sup> Awa, H., Eze, S., Urieto, J., Inyang, B. (2011). Upper echelon theory: A major determinant of information technology (IT) adoption by SMEs in Nigeria. *Journal of Systems and Information Technology*, 13(2), 144-162.



### Chapter 3: Methodology

The aim of this part is to introduce the research methodology used by the research to gather data, to evaluate it and to make valid and reliable findings. The methodology shows how data is collected, in which methods it is systemized, what kind of analysis is used and how the information is interpreted or “the way research techniques and methods are grouped together to provide a coherent picture” (Mark Easterby-Smith, Richard Thorpe, Paul Jackson, 2012: XV) In this chapter I will present the reasons regarding philosophical position and provide methodology description, which will present qualitative or quantitative approaches and case analysis.

#### 3.1 philosophical Position

Philosophical position is used to choose research design. There exist many philosophical approaches that can be adopted for research in which way it should be done. According to management research book the main philosophical approach are positivism and social constructivism, of course there are many others, which can perfectly fit for research such as: hermeneutics, critical realism, etc. I chose between social constructivism and positivism. The first approach is used to conduct research when it looks at the world from theoretical perspectives, whereas the positivism relies on statistic. Mark Easterby-Smith, Richard Thorpe, Paul Jackson ( 2012) argue that those two approach can be seen as contrast of each other by 8 features.

	Positivism	Social constructivism
Observer	Independent	Piece of research what is being monitored
Human interests	Mostly not important	The core factor of science
Explanations	Cause and effect	Understanding of data
Research progresses through	Hypothesis and deduction	Collecting data from which thoughts are used
Concepts	Necessary of frame to measure	Inclusion of stakeholder perspectives
Unit of analysis	Simpler as possible terms	Looking at whole puzzle, not only one part
Generalization	Through statistical data	Through theory
Sampling	Large number, chosen accidentally	Small numbers of cases selected for concrete reasons

Figure: The differences between the positivism and the social constructivism

The table shows in which way those approach are different and the best suitable philosophical position for this work is the social constructivism, because in this work is focused on LNG adoption in arctic context and in this case better chances to make this work from this philosophical position by looking to whole view, not to concrete picture.

## **3.2 The research methodology**

### **3.2.1 The research method**

There are two methodological approaches or methods - quantitative and qualitative - available to researchers. In the qualitative approach there is an emphasis on procedures and they are not measured in terms of quantity. In the qualitative approach there is a profound perceptiveness of the phenomenon in its circumstance. Furthermore, quantitative researchers emphasize the measurement and analysis of causal relationships between variables, not processes<sup>47</sup>.

Qualitative data have a strong advantage over quantitative data in drawing insights that could not be gained with “hard” data only. Qualitative data are rich and holistic, with strong potential for revealing complexity. “The more the study is a qualitative study, the more emphasis will be placed on the experience of people in the program or with the phenomenon”.

Case studies supply explanatory evidence as to the reasons and motivations behind small firm internationalization. It is recommended focusing on more narrowly defined groups of firms, generating rich data. The case study method for permitting researchers to study exporting as a dynamic process. Its strength lies in facilitating the study of the internationalization process from numerous perspectives and consequently facilitating a more thorough analysis of each firm than is possible in survey research. Case studies should not be confused with qualitative research and they can be based on any mix of quantitative and qualitative evidence<sup>48</sup>.

This study conducted exploratory case studies to provide support for the research strategy (case study). Results of exploratory case studies assist the researcher to provide some clarification for the research design. A “case” could be an individual, or some event or entity that is less well defined than a single individual, e.g., a process or an organization. Accordingly, the case study could presume a single-case or a multiple-case design, and both types of design may have either a single unit or implanted multiple units of analysis that can be the case itself. A single-case study is considered appropriate for testing a well-formulated theory (critical case), in clinical psychology

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<sup>47</sup> Hollensen, S. *Global Marketing. A decision-oriented approach*. 3rd edition. Pearson Education, 2004

<sup>48</sup> Rundh, B. ‘International marketing behavior amongst exporting firms’, *European Journal of Marketing*, 2006, Vol. 41 No. 1/2

(extreme or unique case), or observing unreachable phenomenon (revelatory case), it involves some potential problems such as misrepresentation<sup>49</sup>.

The interview method was chosen for the research. The interview method is most widely employed method in qualitative research. Telephone interviews using interview schedules are becoming increasingly efficient with developments in computer technology. It can be used as a powerful form of formative assessment. That is, it can be used to explore how a respondent feels about a particular topic before using a second method (such as observation or in- depth interviewing) to gather a greater depth of information. Structured interviews can also be used to identify respondents whose views you may want to explore in more detail (through the use of focused interviews, for example).

The organization of the research: the research was carried out in following steps:

- The literature analysis was done concerning LNG usage, limitations and future prospects.
- The interview questions formed based on literature review;
- The selection of the companies;
- The interview arrangements;
- The results analysis and evaluation.

### **3.2.2. Data collection**

To gather data for the research analysis were chosen sources as primary and secondary data. I tried very hard to get interviews and got some, but then came up with the idea of supplementing with interviews from other sources and it is a reason that both categories of data were used.

- Primary data : the information that was gathered in the research are based on individually responds. The interviews were got from respondents by phone calls one on one. The disadvantages of this type of method that it takes time to get interviews and need to adapt to the interviewees people and it takes time to find person or company which would like to share their time and answer the questions. Many email where sent and only few replies came. The collection and analysis also require additional time.
- Secondary data: The information was collected from web sources about small scale LNG.

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<sup>49</sup> Ibid.

The primary data as interviews were done by asking interviewee question according to interview guide, the respondents are :

- Karin Sund the founder of Sund Energy
- Gudrun B. Rollesfsen – Barents Naturgass
- Morten Christophersen- Connect LNG AS
- BioMAR company didn't find a time for interview, but send written answers to interview guide questions

These respondents provided their general knowledge, thoughts about LNG and small scale LNG, what helped to have a valid data together with the secondary data.

### **3.2.3. Data analyses**

Data analysis was carried out in 2 main ways. First of all the primary data is analyzed, concerning the interview from 4 companies results. The interview results were interpreted giving own opinion and using secondary data. LNG is analyzed in various forums, where experts opinion is given to prove the LNG benefits and barriers. The primary data was analyzed in comparison with secondary data, supporting our research results and respondents opinion.

### **3.2.4. Validity and reliability**

Validity and reliability give the weight from scientific perspective. When carrying out the research Validity means “the extent to which measures and research findings provide accurate representation of the things they are supposed to be describing”<sup>50</sup> (Mark Easterby-Smith, Richard Thorpe, Paul Jackson, 2012:347). Validity can be internal and external.

The internal validity aim is to help to assure that findings are right, in the other words “truth” and results are correct in the study. In this work is used qualitative method, a case study, the respondents were asked and each one have subjective opinion, what complicates the situation. On the other hand, interviewed people are related with LNG business, one respondent is known as consultant, other work with technologies that should be implemented in small scale LNG. It ensures that they know about their work. Moreover interviews from other sources as secondary data were added of small scale LNG experts and organizers of small scale LNG that should guarantee validity for the work. It can be noted, that small scale LNG development started not a long time ago, what

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<sup>50</sup> Mark Easterby-Smith, Richard Thorpe, Paul Jackson (2012). Management research, 4<sup>th</sup> edition. London, UK: Sage Publications

provide new findings, solutions which let easier to operate for companies which activities are related with small scale LNG.

The external validity presents how results from work can be adopted and used. The work focus on small scale LNG in Arctic, but the findings can be used globally, because small scale LNG face the same problems that are found locally and globally and can help to see how small scale LNG is adopted in various situations when exist different conditions.

In this work isn't highlight generalizability criteria, but some part of theory that was used can be applicable to other context that are not related with small scale LNG.

### **3.2.5. The research limitations**

The master thesis about drivers and obstacles for the adoption of LNG by various companies in an Arctic had limitations. It was really difficult to get interviews from companies due to that, to give more weight for the research part were added the secondary data as interviews from other sources. The interviewed companies basically were Norwegian companies, which are located in Arctic region. The author tried to get interviews from Northern Canada, Arctic part where small scale LNG trend is moving up, to get broader perspectives about drivers and obstacles for LNG adoption by companies, but didn't manage to get any interviews and again secondary sources were used to enrich the work.

#### 4. Empirical data

In this following chapter has been concentrated secondary data, which was collected from case studies and LNG small scale LNG conferences. There will be provided companies in the Arctic, which were interviewed. Also other companies that use LNG in this region and companies than can adopt LNG in the future. SWOT analysis, which shows small scale LNG advantages and drawbacks. Moreover, the information about LNG drivers and barriers globally. The experts opinion from different other researchers are provided to support the data analysis.

##### 4.1 The characteristics of selected companies

For the research respondents of 4 companies were selected: Sund Energy, Barents NaturGass, Connect LNG and Bio Mar. The short description of the companies is provided in this chapter. The analysis covers the main areas of activities and the companies' situation of LNG usage.

Sund Energy Company was founded in 2007 by Karen Sund. The main activities are related to the different projects for diverse and international clients. The main areas of activities are presented in Table No. 3

**Table No. 3. Sund Energy main activities**

<b>The activities</b>	<b>Description</b>
Partner selection	Various projects: electricity projects, gas players, industry providers. The company use special knowledge for the companies and people selection.
Strategy and business	Business skills and understanding of market dynamics are used for supporting electricity, gas and oil companies.
Second opinions	Provide the opinion about technologies, energy forms, future projects development.
Contracts and negotiations	Mainly confidential support
Country studies	Prices, players, market dynamics and future outlook
Clean tech business	Biogas, CCS, offshore wind, LNG to ships, fuel cell and more.

By understanding diverse stakeholders and their preferences, Sund Energy often assist clients with:

- Structuring deals where risk and rewards are split according to risk comfort, position and

skills

- Assisting market players understand each other and build well-functioning partnerships
- Making strategies, business models and infrastructure robust to future developments
- Designing concepts with technologies that allow for additional future upside
- Improving clients' business cases by anticipating future needs
- Moving from words to action with measurable results

The second company is Barents NaturalGass. Barents NaturGass AS (BNG) is a regional gas company that sells and distributes natural gas (LNG, liquefied natural gas) in tank-truckers. Relevant users for natural gas are industry, ships, cars, buses and energy to households. Natural gas reduces emissions of CO<sub>2</sub>, NO<sub>x</sub>, sulphur and dust compared to oil. Natural gas is usually cheaper than oil. Natural gas is delivered directly to the customer, BNG is responsible for the construction works and transportation. Barents NaturGass AS is located in Hammerfest, north of Norway. Natural gas comes from the Barents Sea and LNG is produced at Melkøya, close to Hammerfest. BNGs trucks are loaded at Melkøya and go directly to our customers. This makes the transportation short and easy in the north. BNG is an effective organisation, with high expertise.

Connect LNG develops Universal Buoyancy System (UBS), a transfer system which enables cost efficient fluid transfer between small scale distribution vessels and onshore terminals. The construction of small-scale LNG infrastructure in Norway was initiated decades ago. Now, the rest of the world is following. This implies that the construction of several small-scale LNG terminals is planned and being build, in order to meet the booming LNG demand. The use of LNG is rapidly increasing due to the fact that natural gas is a competitive and environmental friendly alternative to oil, diesel and gasoline. The typical small-scale LNG terminal serves the industry with LNG for power generation and functions as hub for ship and truck bunkering.

The third company is BioMar is a company that was created in Denmark in 1972 and later with the help of merges the company growth to the international company. This firm supply fish feed to the aquaculture industry. Company management is located in Denmark. BioMar has factories in Northern Norway in Myre city in Arctic region and in the Western part of Norway Karmoy. Factories produce a fish feed for various species of fish (salmon, trout, cod, etc). BioMar is environment friendly company which focuses on clean technology. The company use gas-powered cargo ship which use LNG as fuel, it helps to reduce NO<sub>x</sub> and CO<sub>2</sub> emissions. Company is efficient and guarantees a complete range of health feed. Company has a charter with NSK shipping which take care of maintenance of gas-powered cargo ship. In factories are used LPG as

energy source for fish feed production and LNG can be used as alternatives, if some changes would be done.

#### **4.2. The characteristics of other companies that use LNG in Arctic**

Bewi Polar and Lovold Industry As are companies in the Arctic region that use LNG. Both companies' activities are the same and participate in the Polystyrene Foams/EPS production business. Firms need heat for the production and LNG is one of the best options, which also ensure environment protection and reduce cost. Bewi Polar has build LNG terminal and LNG is distributed by the Barents naturGass. The products are made by companies such as fish boxes or building insulation to builders' merchants. Companies are modern and present high quality of all products.

Other companies that use LNG are ferries companies such as Fjord1 and Torghatten Nord. Fjord1 own the biggest share of market in Norway, it is the largest ferry company that operate this type of ferries in Scandinavia. LNG ferries are popular in Norway because of government help and incentives. In 2001 two ferries operators merged and was created a company Fjord1. It is the first ferry company that builds ferry that is fueled by LNG. Company aim is to take care of environment. Fjord, company own ferry fleet which consist of 12 ferries. The use of LNG guarantees smaller emission (CO<sub>2</sub>, NO<sub>x</sub>). Company has built bunker station, where LNG as fuel is filled to ferries.

Torghatten Nord is smaller company than Fjord, which operate in the Norhern Norway. The LNG is supplied by the Barents naturGass to company's ferries. It has a ten-year contract to serve the Lofoten archipelago, this ferry operator has a series of LNG-powered ferries which were built in Poland.

#### **4.3. The characteristics companies that could use LNG in Arctic**

Yukon Energy Corporation, it is a company established in the Arctic are in 1987. It is public company that operate in Yukon area in Canada Northern, Arctic region. Company provides electricity and energy services for local people. Company values are to ensure safety and foster the growth of a company. Yukon considers LNG and other options in the region, because of the need of energy source for heating and electricity instead a diesel. Energy needs of fossil fuels consist of 80% in the region. Company is in the deliberations regarding energy sources. There is the option to transport LNG by trucks from Alberta LNG facilities or other places.



Other company, which could use, but isn't using LNG is a Troms offshore company that offers offshore services; it is the biggest contractor of the North Norway. Company operates all over the seven seas but their specialty is the Arctic Sea. They are working with their own fleet and management contracts. The company operates the six PSVs and five offshore services vessels on management contracts. Company always search for improve the safety skills of personnel ashore and aboard ships. Have a good maintenance on the vessels to be safe what means also almost zero accidents or damage to the people or the vessels.

#### 4.4. Small scale LNG

Companies focus on small scale LNG in Arctic areas. Comparing small scale LNG with large scale LNG, it can't ensure constant quantity, but the Arctic region is affected by harsher conditions and there are only four LNG large plants in the Arctic. Moreover, the small scale need less time than large scale LNG and create a chance to adopt it easier for companies; there aren't many large companies in the Arctic. The main users of small scale are marine industry companies, industrial user, local companies and production companies.

The SWOT analysis below represents advantages and drawbacks of small scale LNG

Strengths	Weakness
<ul style="list-style-type: none"> <li>• Can be used where infrastructure is weak such as Arctic region</li> <li>• Can be used where pipeline is impossible or cost too much (stranded LNG market)</li> <li>• Efficient distribution, flexibility and it creates niche market.</li> <li>• Can be used for transport, fuel, power generation, heating</li> <li>• Distribution via LNG tanker, feeder vessel, truck</li> <li>• Simplified storage requirements</li> <li>• Synergy with operations (storage, transport sector)</li> <li>• Less emissions</li> <li>• Focus on maritime and heavy industrial users</li> <li>• Cost and capital efficient</li> </ul>	<ul style="list-style-type: none"> <li>• Limited quantity of natural gas</li> <li>• High investment cost</li> <li>• small scale oriented for domestic area</li> <li>• harder to find investors in project, due to small scale, high investing cost</li> <li>• LNG bunkering issue</li> <li>• In the large scale terminals, small scale LNG can't load.</li> <li>• The cost per unit aren't reducing proportionally with the volume of production</li> <li>• Long planning and construction time</li> </ul>
Opportunities	Threats
<ul style="list-style-type: none"> <li>• Energy diversity</li> <li>• Abundant resources of natural gas (</li> </ul>	<ul style="list-style-type: none"> <li>• Volatility of energy prices</li> <li>• Shale gas, reduce natural gas price (</li> </ul>

<p>250yr)</p> <ul style="list-style-type: none"> <li>• Lower emission for transport and shipping</li> <li>• Growing LNG market demand</li> <li>• Shale gas, will ensure security of supply</li> <li>• Environment protection</li> <li>• New technologies, that reduce the cost of small scale LNG</li> </ul>	<p>higher cost)</p> <ul style="list-style-type: none"> <li>• Large scale enter small scale LNG segment</li> <li>• Pipeline connections in Arctic Harsher conditions in Arctic than in other regions</li> <li>• Substitutes such as propane/butane-synthetic gas(LPG), diesel and oil, renewable energy</li> </ul>
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**Strengths:**

- **Can be used where is weak infrastructure such as Arctic region-** in the regions where is lack of infrastructure, the small scale makes it possible to deliver gas by small ship or by road with semi trailers
- **Can be used where pipeline is impossible or cost too much (stranded lng market)-** it is very convenience to use small scale in the areas such as islands or without roads, where exist harsh conditions.
- **Efficient distribution, flexibility and it creates niche market-** small scale more easily let to reach end users than large scale and efficient distribution is guaranteed by LNG distribution companies.
- **Can be used for transport, fuel, power generation, heating-** has wide spectrum of customers
- **Distribution via LNG tanker, feeder vessel, truck-** on land and on the waters, for example Norway, due to geographical conditions it is more easier to distribute locally by ships than by roads.
- **Simplified storage requirements-** companies that what to use LNG need to build storage tank in which the natural gas can be injected.
- **Synergy with operations( storage, transport sector)-** in the small scale LNG, one company can engage in activities as LNG production, transportation and taking care of storage tank/
- **Less emissions-** pollute less than coal and oil, LNG is environmental friendly, It reduce CO2, NOX, especially environment criteria is empathized in ECA areas.

- **Cost and capital efficient-** LNG projects shows lower levels of total cost (capex and opex), small scale require decreased building times and in the same way reduced risks of non-completion

**Weaknesses:**

- **Limited quantity of natural gas-** impossible to get large quantities
- **High investment cost-** it takes some time to pay off, comparing with large scale, the investment cost consist of small portion, while for small scale LNG, those cost are huge.
- **Small scale oriented for domestic area-** it isn't used for LNG export globally.
- **LNG bunkering issue-** chicken and egg problem; Owners are afraid to invest in new fuel systems because of lack of infrastructure, whereas supply-side seek to see the proof of demand.
- **In the large scale terminals, small scale LNG cant load-** the small scale LNG vessels can only use ports for small scale LNG.
- **The cost per unit isn't reducing proportionally with the volume of production-**focus on end users such as individual customers, not big players and profit isn't big.
- **Long planning and construction-** the example is: "For example, it was recently used 65,000 engineering hours on a small terminal in Sweden and it took four years before the terminal was completed."<sup>51</sup> (Forskningsradet, 2014)

**Opportunities:**

- **Energy diversity-** LNG can be used instead oil or conventional fuels, it also can be used as a mix together with diesel for example, for power generation.
- **Abundant resources of natural gas( 250yr)-** There exist huge volumes of natural gas in the world. The Arctic is a region where are forecasted that will be found many natural gas fields.

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<sup>51</sup> Forskningsradet, 2014 More gas for most people, [http://www.forskningsradet.no/no/Nyheter/Mer\\_gass\\_til\\_folk\\_flest/1253993545428?WT.mc\\_id=nyhetsbrev-ForskningsradetNorsk](http://www.forskningsradet.no/no/Nyheter/Mer_gass_til_folk_flest/1253993545428?WT.mc_id=nyhetsbrev-ForskningsradetNorsk)

- **Lower emission for transport and shipping-** environment issues, the ECA areas in the Arctic region and other region foster to change fuel to LNG because every years the restrictions increase.
- **Shale gas, will ensure security of supply-** due to shale gas price of natural gas is low and due to that LNG demand increase, what foster to rise and the supply side.
- **Environment protection-** Climate, sulphur, particles and protection of oil spills , smaller impact to the global warming, Arctic region is very sensitive to environment disasters.
- **New technologies, that reduce the cost of small scale LNG-** there exist companies that create advanced technologies, that will make small scale more flexible, with much lower investment cost, which will be almost half of it.

#### **Threats:**

- **Volatility of energy prices-** the natural gas price is currently low and the price may rise and the oil price will fall, in which case LNG will become less attractive to consumers.
- **Shale gas, reduce natural gas price-** it is the threat for the LNG in the Arctic region, because there the cost is higher than in USA and that can affect the demand from the Arctic region. Mainly, it has impact for large scale, whereas, the small scale will feel smaller effect.
- **Large scale enters small scale LNG segment-** large scale LNG companies buying small scale companies. For example, The Shell bought Norwegian Gasnor Company.
- **Pipeline connections in Arctic-** Alaska, Arctic Canada, Barents Sea are areas where are planned pipelines projects and in that case the LNG relevant will reduce.
- **Harsher conditions in Arctic than in other regions-** It is especially seen in winter season.
- **Substitutes-** such as propane/butane-synthetic gas (LPG), diesel and oil, renewable energy, when exist incentives from government side. It is foster the use of alternatives.

In conclusion, SWOT analysis shows capabilities of small scale LNG as well as external indicators that influence or will change the option of small scale LNG adoption by various companies. Small scale LNG can be in stranded markets, where due to geographical location to build pipelines is difficult. Also, there exist abundant resources of natural gas. The technologies advanced, the cost of opex and capex reduce and become more attractive for

companies. On the other hand, there are weakness and threats that should be forgotten such as limited quantity, high investment cost and pipelines connection in Arctic.

#### **4.5. High Level and local technology development**

“Technology development happens at two levels: a high- level process and a local- level one. At the high level, there are global and national processes where scientific and industrial research and development is carried out by specialized, often well- resourced, groups of engineers and scientists. Formal institutions, active at national or sub- national level, are vital ingredient here, as they can foster and support knowledge creation, learning and capacity building. But there are rarely strong, viable and vibrant connections between these high- level processes and local ones. Those adopting the technology struggle to access the knowledge created at higher levels”<sup>52</sup> (IIED, 2013:4).

Norway is one of the leading countries in the small scale LNG and shares their experience in the global market. The quickly raising LNG industry is looking forward to draw on support from firms, because the demands for technologies and innovations open new opportunities. “Possible areas of cooperation between Chinese and Norwegian companies identified by the study include LNG regasification solutions, small scale LNG distribution, LNG as marine fuel, LNG bunkering and ship to ship transfer, maritime technologies and standardization activities. Norwegian companies could make use of their unique experiences to benefit Chinese companies by supplying vessels and onboard equipment, steering joint development of advanced maritime technologies and providing advisory services to better manage safety and environmental risks that come with the rapid growth and change in paradigm of the LNG value chain in China.”<sup>53</sup> (DNV, 2011).

High level technologies need time in order to expand in local level one and knowledge from experienced experts such as Norway will help faster to adopt LNG for local companies in countries such as China.

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<sup>52</sup> IIED, 2013, Driving new technology adoption in South Africa’s energy sector <http://pubs.iied.org/pdfs/17178IIED.pdf>

<sup>53</sup> DNV, 2011, Potentials identified for foreign companies in China’s fast growing LNG sector [http://www.dnv.com/press\\_area/press\\_releases/2011/potentialsidentifiedforforeigncompaniesinchinasfastgrowinglngsector.asp](http://www.dnv.com/press_area/press_releases/2011/potentialsidentifiedforforeigncompaniesinchinasfastgrowinglngsector.asp) [Assessed March 1, 2014]

#### **4.5.1 Small- mid scale LNG development**

The islands and stranded markets have the same problems as the Arctic region and companies faced with the same issues regarding the liquefactions plants, LNG carriers, LNG receiving terminals. Small- mid scale LNG summit 2013 has made a survey about small scale LNG development, the graph you can see below. Hence, the reason that leading countries such as Norway that has adopted LNG technologies and focus in Asia, because as was mentioned in this work, China and other Asian countries are huge countries and they need energy, the restrictions for fossil fuels regarding environment is increasing every year and foreign companies started to pay attention on LNG . “As with many Asia-centric trends, the People’s Republic of China is setting the agenda with LNG adoption. In order to meet the goal of 8.3 per cent LNG power generation by 2015 as outlined in the last Five Year Plan, China will be adding a further nine import terminals to the five it currently operates, expanding its import capacity to 4.19 million cubic metres in total by 2014.”<sup>54</sup> ( Small-mid scale LNG summit 2013 ). In 2011 China had more than a few small-scale liquefaction plants. According to Gastech (2011) there were at least 28 liquefaction Plants with the capacity to produce approximately 2.2 mtpa, and 14 new trains are planned to build in 2 next years.

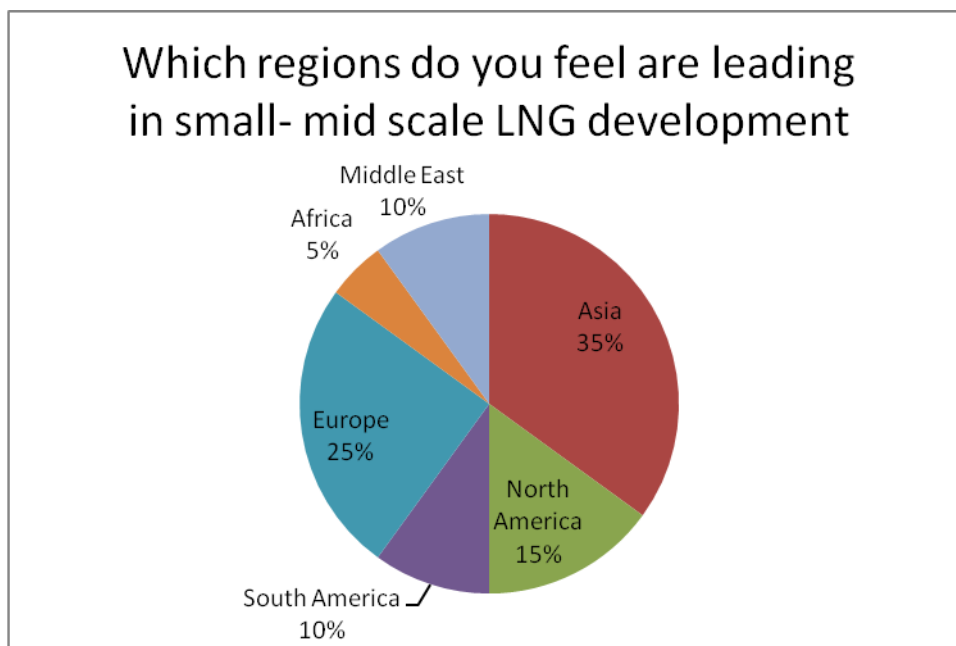
The actions in China territory shows that investors are willing to invest in LNG sector, because country need energy sources.

#### **4.5.2 Small mid scale LNG spread globally**

The most attractive regions, where the innovations spread the fastest are Asia, Europe and North America. Below is a figure from Small- mid scale LNG summit. The survey about small scale LNG was conducted during the year 2013 and finished before summit, which was in 2013 on May. The survey was done by small scale LNG summit organizers, who interviewed the oil and gas industry's key players in small-mid scale LNG.

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<sup>54</sup>Small- mid scale LNG summit 2013,<http://www.smallmidlng.com/media/7175/5291.pdf>



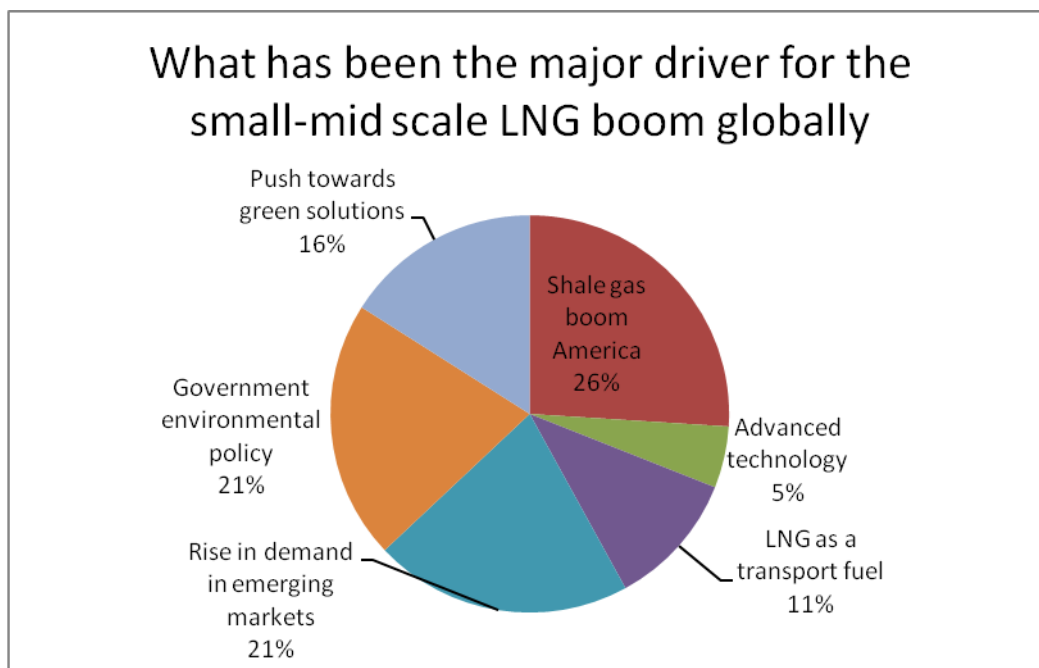
**Picture No. 8. Small- mid scale LNG development**

Source: Small- mid scale LNG summit 2013

In this work research part is analyzed what are the drivers of adoption of LNG in the Arctic Area and it is important to look not only to one particular region, but and globally, in order to see the wider view. The best conditions for small scale and mid scale LNG exist in Asia continent. The survey results showed that interviewed respondents indicated that the best investment climate is in Asia. That pointed 35%. Hence, the best conditions for small scale and mid scale LNG exist in Asia continent. The second place were environment for small-mid scale LNG development is in Europe. 25% participants in survey noted that and the least attractive was Africa continent.

#### **4.5.3 Drivers of small scale- mid scale LNG development in global stage**

Small-mid scale summit, they made the survey and indentified major drivers of small mid scale LNG adoption. Below, the figure present what type of factors that are.



**Picture No. 9. Drivers for Small-Mid Scale LNG adoption**

Source: Small- mid scale LNG summit 2013

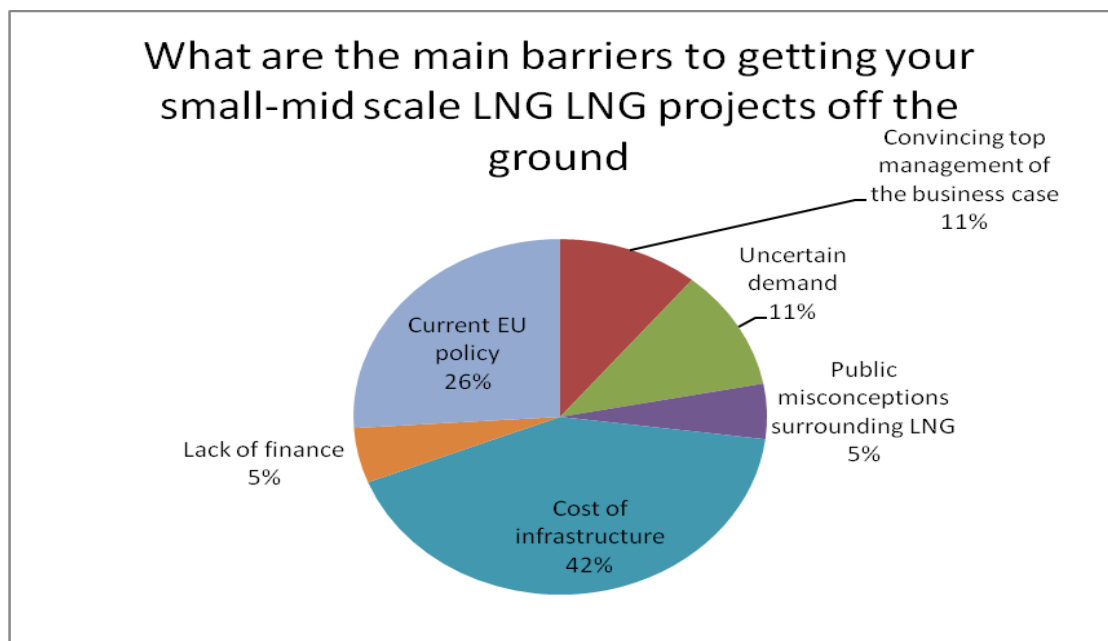
The respondents highlighted as the import factor for LNG growth globally is a “shale gas boom in America”. It is seen that the second driver is the growing demand in emerging markets, whereas advanced technology got only 5 % votes. Arctic region is located in areas where conditions are harsher than in other region, due to that the shale gas creates a treat for Arctic LNG development, because the price remains the higher. The environment solution is effective in globally and in locally. It makes impact for LNG development in Arctic and fosters companies to adopt LNG and safe environment. The example is Norway government which helps to evolve the Northern Norway and High North areas. According to media such as “High North News” the Foreign ministry allocated 150 million NOK for the projects in North. The attention of state creates facilitations for industry and companies, what opens new opportunity. Those were the drivers of LNG adoption. On the other hand, there exist many obstacles for LNG adoption and it is significant to pay attention to barriers.

#### **4.5.4 Barriers of small scale- mid scale LNG development in global stage**

Small- mid scale LNG summit conducted survey and emphasized the obstacles of LNG adoption globally. The figure below illustrates it. The biggest issue is the infrastructure. It consists of 42%. It is a huge problem globally and in local areas. It especially affects Arctic. Due to sophisticated



conditions, there difficult to build the large scale LNG and even small scale, because it is hard to reach the areas, where aren't roads, etc. "The capital-intensive infrastructure is much more expensive than that of similar value chains (e.g. oil) and as a result, infrastructure costs constitute a large share of the cost of energy compared to competing energy carriers"<sup>55</sup>. For example, "With countries like the USA needing to spend an estimated \$210 billion through 2030 on midstream infrastructure in order to meet projected market requirements, it is likely that cost will remain a key factor if the same question were put to the LNG community a decade from now."<sup>56</sup> (Small- mid scale LNG summit 2013). I won't go deep about arctic region in this chapter, because the will be separate section about LNG perspectives in Arctic.



**Picture No. 10. Obstacles for Small-Mid Scale LNG adoption**

Source: Small- mid scale LNG summit 2013

In the Article of poyry about "What are the challengers", there are revealed the issues that happen in the small scale industry<sup>57</sup>(Poyry,2013:6)

1. "For buyers (i.e. shipping and transport companies and local businesses): delivered

<sup>55</sup> Poyry, How can small scale LNG help grow the European gas market, 2013, [http://www.poyry.com/sites/default/files/imce/smallscale\\_lng.pdf](http://www.poyry.com/sites/default/files/imce/smallscale_lng.pdf) [Assessed Marc 1, 2014]

<sup>56</sup>Small- mid scale LNG summit 2013,<http://www.smallmidlng.com/media/7175/5291.pdf>

<sup>57</sup> Poyry, How can small scale LNG help grow the European gas market, 2013.

LNG prices must be low enough compared to the relevant oil alternative, taking into account all investment costs for conversion or new equipment compared with the cost of continuing with the dirtier fuel;

2. For infrastructure developers: the return on investments (e.g. LNG tankers, barges, road tankers, bunkering tanks, specialist loading and unloading facilities, etc.) must be at least as good as other available investment options, taking into account the opportunity cost of losing market share in existing operations if someone else develops it;
3. For LNG producers or importers: who will want to make sure they earn a market price for their LNG. This is creating a ‘chicken and egg’ situation – who will make the first move? Customers hesitate to commit to using LNG unless there is a cost effective supply and suppliers hesitate to invest in costly supply infrastructure unless there is a market.”

There exist also few implications such as:

1. Adequate price differential among LNG and petroleum based substitutes to pay for the structure which is needed to transport the fuel from import terminals to distribution places and afterward to pump it from bunker barges into fuel of ships that need supply.
2. The differential must also be adequate big to offset the added capital and operating costs of storing and burning LNG.
3. Market parity price will also change hinge on local demand and supply – side structures. (poyry, 2013)

There still exist many obstacles and challenges for small- mid scale LNG. The biggest problem remain infrastructure, where is needed huge investments. Also need to get trust from buyers side, when new things, technologies come, it needs patient and time.

#### **4.6. Key markets for small scale LNG**

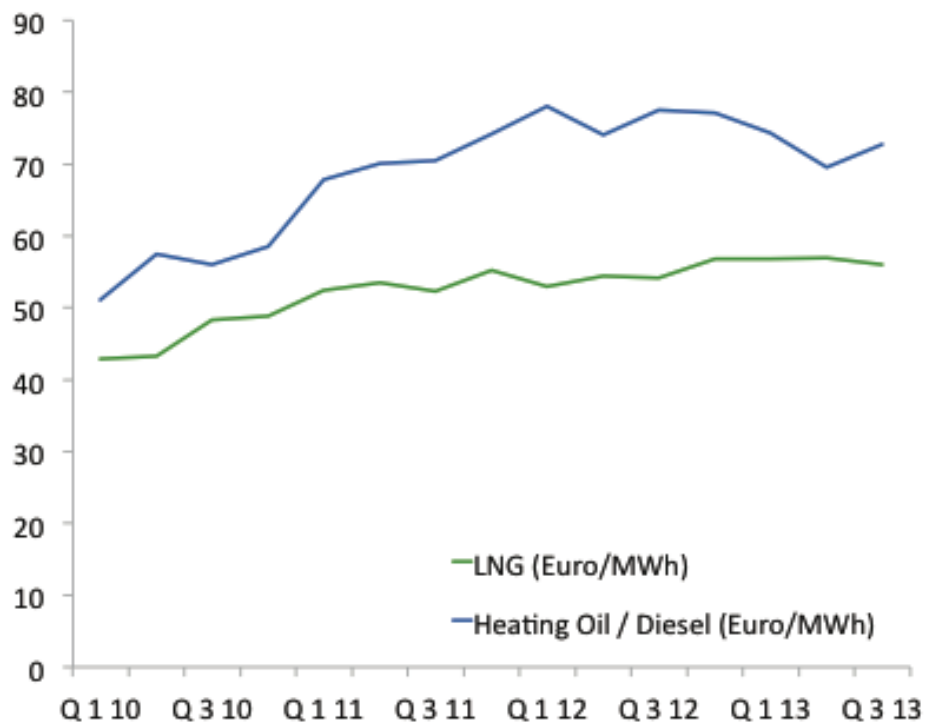
Natural gas is more and more becoming the most abundant, cost effective and environmentally friendly substitute to conventional transportation fuels in road transport, marine bunkering, mining and off-grid.

#### 4.6.1 LNG as fuel

The problem of natural gas to use for fuels was the lower energy density. Comparing with the diesel, the natural gas has 25% of energy content than diesel fuel has. In other words, the energy consumption becomes lower. The significant factor to mention is that moving from oil to natural gas frequently cause higher efficiency regarding optimal combustion. There are manufacturers who test LNG engines for land transport. According to poyry ,The U.S. is the first one who established long distance Trucking routes and cheaper gas, while LNG filling station infrastructure is started to develop not only in USA, but also in Europe. The technical indicators are proven, but the market is still at the beginning stage. Small, but quite well created markets already exist in Japan, USA, and Nordics and are used locally for LNG-based gas consumption.

#### 4.6.2 LNG as fuel perspectives

There was a research by German company who got results that LNG is 15% cheaper than diesel. The data are from 2010 to 2013. The picture is seen below. The LNG is used as fuel in the marine sector and in the future should be uses broadly as fuel instead of conventional fuel for inland transport.



Picture No. 11. LNG vs diesel in german 2010-2013

Source: titan LNG

During the whole period from 2010 to 2013, LNG remain cheaper than diesel. Thus LNG has huge perspective in the inland transport, but as was mentioned it is in the beginning stage and nowadays companies adopt LNG which is related more with LNG transportation by ships as using LNG as fuel, especially as ECA regulations become more and more stricter. It also makes the impact for Norway and also areas in Arctic.

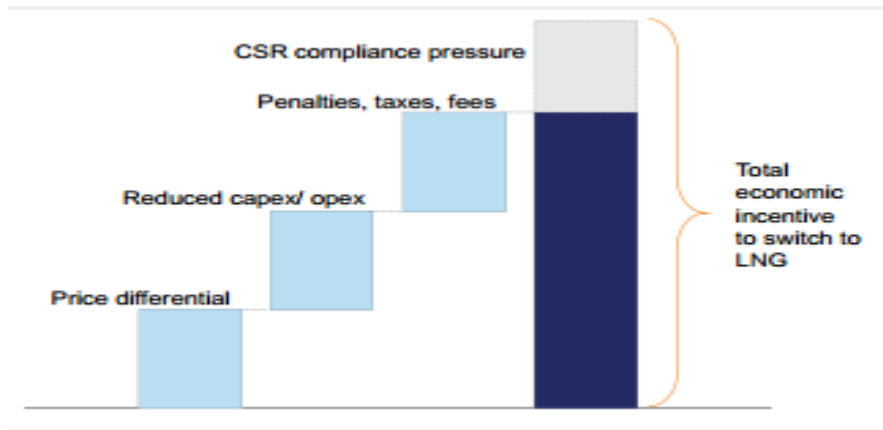
#### **4.6.3. LNG in Arctic waters**

There are good opportunities for big companies with large scale LNG concept such as Golar Hoegh, because according to forecasts about Arctic waters and global warming, the situation should get better and transport LNG in NSR should be safer. Ships need special construction (building and design) in Arctic waters and there are companies that take care of maintenance of ships, for instance the Novatek has order 30 lng tankers, which would help to transport LNG in Arctic waters. And there are expected to be found other big natural gas reserves as USGS mentioned that Arctic own huge reserves of natural gas, and only drawback that the cost of getting natural gas is high. Warsuwa, the company which build ships, made analysis about ships, and are testing prototypes models such as LNG vessel and iceberg as one with LNG as fuel which can travel in Arctic waters in winter without icebreaker. The technology and innovation reduce costs, fuel consumption and increase safety.

#### **4.6.4 LNG economical incentives as fuel**

Local companies use small scale concept, where isn't possible to reach the stranded market by large scale, the LNG can be transported with trailers or semi trucks. I would like to highlight what are the economic incentives for LNG fuel.

Those are such as price differential, reduced capex/opex, penalties, taxes, fees, CSR compliance pressure. It is presented in the figure below.



**Picture No. 12. the economic incentives for LNG fuel**

Source: POYRY,2013

Due to fuel and emissions restrictions at sea, ship-owners will knowledge growing cost inducements to discover cheaper solutions such as LNG. The LNG advance over time. The degree to which it does will hinge on market developments, but the essential drivers are apparent. The three fundamental cost drivers are:

- 1) Growing price differential due to oversupply of gas and a tightening market for low sulphur petroleum products, particularly diesel fuels.
- 2) Declining capex and opex regarding LNG use in fuel engines because of technological development, learning curve implementations and large scale production.
- 3) Beginning of punishments, taxes, environmental surcharges and other barriers for break rules against use of sulphur-rich fuels, ship owners will experience rising constrain from driver of performance. For instance, clearly display behavior in line with Corporate Social responsibility regarding adoption of technology. (poyry, 2013)

It shows, that cost factor such as increasing prices for fuels of low sulphur petroleum or diesel fuels force ship-owners to think more seriously about LNG. Using LNG is protected environment and need to pay smaller taxes or be punished that does not comply with the requirements. Due to technology development the capex and opex decrease also what is an important indicator too.

#### 4.7. The drivers for LNG fueled ferries

Norway is a country where is highlighted environment. It is leading in the numbers by LNG fueled passenger vessels. The company such as Fjord operates from South to North Norway, in the Arctic region too. Consultants of Fjord1, Tide Sjo, and Gasnor have made findings what are the reasons of using LNG, adopting it to ferries:

- Capital cost. The construction cost for LNG ferries is higher than for diesel ferries. It is higher by 15-20 %. The Norwegian government makes incentives such as a subsidy, which can reach 80% of the cost for projects that decrease NOx emissions from the NOx Foundation.
- Carbon tax credits. When Norwegian ferry operators use LNG fueled ferries, they are exempted from carbon taxes on natural gas, while diesel owners need to pay tax.
- Maintenance and operation cost. The maintenance costs are higher for LNG vessels comparing with the diesel ferries.
- Crew size and training. Crew size remains the same for both the diesel-powered ferries and LNG fueled ferries, but there exist gas training or gas course. The crew must know the risk aspects, emergency shutdown (ESD) philosophy, gas plant, demonstration of gas explosions.
- Cost of LNG. Norway is a country where the cost of LNG and diesel are almost the same or just above the diesel. The cost goes up and down mutually in Norway, whereas in The USA is different.
- LNG Supply. The LNG is distributed by supply vessels to coastal storages.
  - Testing. It is essential to check the LNG vessel engines with LNG.
  - Shoreside fixed fueling facilities and tanks. “Shoreside fixed fueling facilities can save money and ease concerns about on-time delivery, but it only makes sense if there is enough LNG consumption to justify the capital expense”<sup>58</sup>.( Joint Transportation Committee, 2012: ii)
- Vessel design. Ferries is constructed in emergency shutdown standards (ESD).( Joint Transportation Committee, 2012)

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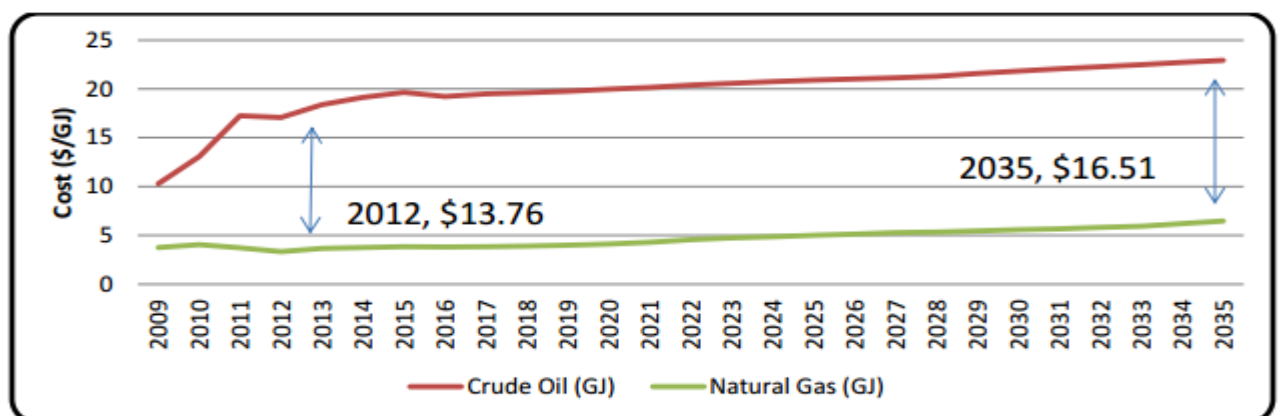
<sup>58</sup> Evaluating the Use of Liquefied Natural Gas in Washington State Ferries, Final Report, 2012  
[http://www.leg.wa.gov/JTC/Documents/Studies/LNG/LNG\\_FINALReport\\_Jan2012.pdf](http://www.leg.wa.gov/JTC/Documents/Studies/LNG/LNG_FINALReport_Jan2012.pdf) [Assessed April 12, 2014]

To sum up, the maintenance cost remain higher for the LNG vessels, also building cost are bigger for ferries with LNG comparing with diesels ferries. On the other hand, there aren't necessary to pay carbon taxes, because these types of ferries are environmentally friendly. Also, there exists training due to safety requirements for LNG vessels. When governments emphasized environment factor and give subsidy until 80%. More and more companies should start to operate in waters with LNG ferries globally and in the Arctic region too.

#### 4.8. Small scale LNG in Northern Canada

Small scale LNG is moving far to the Northern Canada. It can be described as the new phase of LNG, because North America is a continent where started a shale gas boom and Canada can feel now the advantages of cheap natural gas. It fosters LNG growth to the Arctic area even more. Three communities started showing the interest to the small scale LNG. Those communities are Yukon, Inuvik, and Northwest. In those regions where planned pipelines projects, but they still haven't seen the daylight. The projects such as Mackenzie pipelines where postponed and gave a place for LNG.

There exist good possibilities to transport LNG by trucks from the regions such as British Columbia and Alberta in Canada, where exist LNG plants. According to US Energy Information Administration, the figure can be seen below; it forecast that the gap between oil and natural gas only increase. It means that price of natural gas will growth slower upward than oil prices. What is one of the main factors which foster companies to adopt LNG.



Picture No. 13: Long Term Oil and Gas Trend - US Energy Information Administration<sup>59</sup>

<sup>59</sup> US Energy Information Administration (2012) Total Energy Supply, Disposition, and Price Summary, Reference Case.

#### 4.9. LNG for heating and electricity

To start a project of LNG requires high investment cost and another barrier or problem arises for LNG adoption is the heating factor. Comparing infrastructure for electricity and heating, the heating cost is much higher than electricity due to storage criteria. For instance, capital investment for LNG projects in the Inuvik would be : “storage for electricity is in the \$3/GJ range while storage for heat is more likely to be \$10/GJ. If LNG is to be seriously considered for Inuvik, options to reduce the seasonal road outages on the Dempster Highway (Hwy 8) at the Mackenzie River Crossing near Fort McPherson and the Peel River near Tsiigehtchic should be considered. As well the general condition and upkeep of Highway 8 should be reviewed for approved and proposed LNG truck transport.”<sup>60</sup>.(Interdepartmental Energy Coordinating Committee, 2012: 12).

#### 4.10 Small scale LNG projects

It shows that there exist investment cost that isn't small and external factors need to be considered. Moreover, other thing is that the Arctic is a territory with huge areas and people live scattered and an amount of population is quite small and because of that LNG projects that can be distributed by trucks could be a good option for companies and people. It is an attractive solution present the planned projects of LNG in the Arctic. For instance, “the Alaska Legislature in 2013 approved a cash-and-loan package for an anticipated \$430 million”<sup>61</sup>( Alaska natural gas transportation projects,2013). Hence, even expensive projects attract companies to choose LNG, because Arctic is an area where is difficult to get new fields, the finished oil and natural gas resources, no more new fossil fuel reserves were extracted recently and considering the pipelines and LNG. The cost for LNG remains smaller and the projects can be implemented faster.

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<http://www.eia.gov/oiaf/aeo/tablebrowser/> [Accessed May 5, 2014]

<sup>60</sup> Interdepartmental Energy Coordinating Committee, 2012; Concept Study of Inuvik Energy Supply Options, <http://ntenergy.ca/wp-content/uploads/2013/03/Inuvik-Energy-Options-FINAL-DRAFT-V14-Dec-18-20123.pdf> [Accessed May 5, 2014]

<sup>61</sup> Alaska natural gas transportation projects,2013; Small-scale LNG makes in-roads in Canada's far north; <http://www.arcticgas.gov/small-scale-lng-makes-roads-canada-far-north> [Accessed May 5, 2014]



To sum up, Arctic region, especially in the Northern America part, where natural gas price is very low and due to environment benefit, companies more easily choose to adopt the small scale LNG projects. The forecast of oil and natural gas price introduced findings or assumption that the gap between natural gas and oil will become wider and gas will be cheaper. Due to conditions people live in distances and in small population what is another driver for the LNG adoption.

#### **4.11.Conclusion**

The situation analysis of various countries and statistical data it can be stated that LNG has a wide range of possibilities in the inland transport, nowadays changing situation, environmental policies as well as ECA regulations influence more wider usage of LNG as fuel, especially in Norway and also areas in Arctic.

Summarizing it can be stated that Arctic region, especially in the Northern America part, where natural gas price is very low and due to environment benefit, companies more easily choose to adopt the small scale LNG projects. The forecast of oil and natural gas price introduced findings or assumption that the gap between natural gas and oil will become wider and gas will be cheaper. Due to conditions people live in distances and in small population what is another driver for the LNG adoption.

## **5. Chapter: The research results analysis**

Previously, the introduction, theory, methodology, empirical data were analyzed; in addition, both primary and secondary data has been used. In this chapter, the aim is to analyze the interview results.

1. To outline the main drivers and barriers for LNG adoption.
2. To find out the companies opinion about the drivers and obstacles for LNG adoption.
3. To assess the prospects for LNG adoption in Arctic region.

The interview materials will help to answer those questions. The interview questions were divided in the groups covering the situation of LNG usage, the barriers and drivers as well the points for the LNG future evaluation.

### ***Which industries can benefit from LNG adoption in Arctic?***

The one respondent noted that shipping, oil and gas in the Arctic waters, it depends on how far to the circumpolar north you are looking. Also in Northern Norway, Northern Sweden and Northern Finland part of Arctic, it would be the mining sector and transportation onshore.

The other respondent agreed that the adoption on LNG is increasing and in the nearest future the LNG volumes should raise. For instance the number of Coast Guard vessels or LNG powered ferries that will use LNG, should enhance in Arctic. There are also perspectives for the supply ships and cargo ships to become the users of LNG in the future in the arctic, so the LNG as maritime fuel volumes should go upward.

As well the respondents agreed that it would be production companies with large energy consumption, if they switch to the natural gas, they will save expenditure on the energy. It will be the main benefit, diversity. So the Arctic area, of course the local industries will benefit, marine industry which can use LNG as fuel. For instance, Northern Norway companies, producing fish, fish industry can benefit on the diversity. And companies that produce equipment for the oil and gas sector.

Summarizing it can be stated that the industries can get benefit from LNG usage in different areas, such as shipping industry, transportation services and marine industry.

Wim Groenendijk, Vice President, GIE( Gas Infrastructure Europe) who participated to “Small Scale LNG Forum in Istanbul” said that : “the use of LNG as a fuel for marine propulsion, heavy

trucks, buses and railways may offer tremendous potential”<sup>62</sup>. It means that LNG perspectives in Europe and in Arctic are promising. Europe regarding better geographical location than Arctic has better perspectives in heavy trucks, busses and railways.

### ***What are the perspectives for LNG as a maritime fuel in Arctic?***

The respondent noted that the perspectives are seen and good, especially in the long term and especially from China, but it depends from price and availability and from places where LNG isn't available. It depends on which year you are looking. The best perspectives are in Northern Norway and Northern Canada, while there isn't so much focus on small scale LNG in the Russia's Arctic, because there is the interest in the large scale LNG, but the LNG as a maritime fuel perspectives in long term is promising, more and more ships will be build in the nearest future globally and it also growth in Arctic, what will rise the use LNG as maritime fuel. Thus, the potential is huge, especially, when it is cheaper than oil.

Second respondent indicated, that the growth of natural gas market depend on natural gas fields that will be found, by the United States Geological Survey (USGS) estimation the Arctic is rich by resources such as the natural gas, so the growth of natural gas market should be expected and another factor will be the cost of natural gas in Arctic, comparing with other regions. Industries, which need the heat, can be interesting in LNG adoption in Arctic. Also, mining sector in the nearest future in Arctic region, which need energy and LNG can be one of the option. The transport and off-grid sectors can be interesting in the future, but everything depends on the price, availability, etc.

Another idea during interview was revealed that the situation depends on ECA regulations, it is the main driver effecting LNG use in the Arctic area. It seems that some of large oil and gas companies want to switch oil to LNG for the fuel for the environment factor and to show that they have the green profile. For instance ABS ship owners, supply vessels going on LNG, the same thing is seen on Caribbean Sea. The Shell, they also have some supply ships that goes on LNG. Thus, the main driver would be ECA regulation, because Statoil, those companies want that ships owner switch to LNG, because they want to show that there is the agreement and it is a bit of a pressure for the

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<sup>62</sup> Small Scale LNG Forum, 2012 . <http://oilgas.flemingeurope.com/small-scale-lng-forum-201210/interview-with-wim-groenendijk> [Assessed May 2, 2014]

heavy vessels. Moreover, we are also talking about fish industry and fish vessels switch to LNG and it is happening because of ECA regulations.

***Are the Northern Sea Route and the Northwest Passage, one of the factors that can contribute to the development of LNG in Arctic?***

The research results revealed that this sea route passage contribute for LNG development as it will open new development of production of the LNG in Northern Sea Route and the Northwest Passage, but it definitely need more demand and it should be looked to the areas where the ships are going, some of ships will be Chinese that can use LNG as maritime fuel and some ships won't have ability to use LNG in Arctic.

Another respondent thinks that the volume will go up a bit, talking about transport by ships. If we talk about the technology which ConnectLNG is developing, it will enable transition to distribution by ships more easily than today and new technologies as our will make the transition easier so that that you don't need to get the volume that much off before to get economically viable to switch. The LNG shipping in Arctic through The Northern Sea Route, it will increase the distribution from the Melkoya to Asia and it will benefit the local constructions as well and cause some other effect as well.

***What are LNG shipping perspectives in Arctic?***

One respondent noted that it is already very positive for the supply ships and coast guards and can be much more, but again it needs the availability. There is also a potential for cargo ships, but they need large scale LNG.

As well it should be taken into account that it is the cost saving to switching for the natural gas, the LNG. Also it is the green profile.

***What are the main drivers for adopting of LNG by companies in Arctic?***

Firstly, it would be the environment reason and then it depends on LNG volumes that is needed and the price and also availability factor. For instance, Canada the natural gas is cheaper than oil, because of that, the smaller price open new perspectives for LNG in Canada and Northern Canada Arctic areas.

The main drivers are costs, supply and environmental issues/regulations. The price indicator is significant, If LNG be cheaper than ordinary fuel, there will open more opportunities in the Arctic for LNG in the future. The price indicator is important show the example of LNG adoption in Caribbean region, where the LNG comes from USA. “Julio Bravo, vice president of CC1 Companies, explained, “We are very pleased to start working with Crowley towards bringing alternatives for cost effective sources of energy into our island and in the process provide a better footprint in our industrial projects by lowering our emissions.”<sup>63</sup> If the price is lower, more companies will use LNG. The driver for marine sector for LNG is the environmental regulations, because LNG meets ships reductions requirements- environmental regulations criteria for ECA areas in Arctic waters. Talking about cost, LNG has advantage such as fuel cost and operating cost comparing with traditional bunker fuels. While, the supply volumes; it will increase if there be customers/demand.

### ***What are the main obstacles for adopting of LNG by companies in Arctic?***

The main obstacles for the adopting LNG are availability and sometimes the price, infrastructure, small volumes, not many customers.

The other respondent commented that knowledge about the possibilities in the marine sector, again a price factor, it can be driver and obstacle, the price fluctuations will lead. The availability also shouldn't be forgotten, because if no infrastructure and due to harsher conditions it also can be the obstacle factor.

There are companies, those would could use LNG, but don't use, for instance, Hurtigruten Company, ferries companies. The secondary data source was used to see broader view what are barriers of not using LNG from the article about BC Ferries Company that operates in Canada, it uses diesel fuel. Greg Peterson, Director of Engineering Services at BC Ferry Services Inc stated: “factors which may be attractive to other shipping companies looking to make the switch to LNG, such as fuel cost and environmental compliance, were not as significant for BC ferries.”<sup>64</sup>. According to Peterson, the ultra- low sulfur diesel, has very low sulfur level, LNG is the benefit when it is used in the areas where NOX reduction is valid. It means that diesel is still convenient to

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<sup>63</sup> PRWEB, 2014 <http://www.prweb.com/releases/2014/03/prweb11643789.htm> [Assessed May 2, 2014]

<sup>64</sup> Ship & bunker, Ferry Company Could Switch to LNG Despite Love of Diesel,2013 <http://shipandbunker.com/news/am/955559-ferry-company-could-switch-to-lng-despite-love-of-diesel> [Assessed May 3, 2014]

use as fuel in the areas where ferries operate and environmental rules for NOX is invalid, it creates brakes for LNG adoption, unless the state is giving incentives for LNG adoption.

Summarizing it can be stated that availability, infrastructure and small demand are essential barriers for LNG adoption.

***What are the main small scale LNG concept adoption problems in Arctic and stranded markets?***

The main points of attention are the price and infrastructure.

As well it should be noted that the main problem is the large investment cost for the LNG terminal. And the main challenge for the small scale LNG industry is high cost for jetties, berthies, piers, compared to other scale LNG terminal, transfer solution, a point between a ship and the onshore and it cost the large portion of the total investment for a small scale, while for the large scale it consist on only a small portion of the investment.

***What are the risks for switching to LNG for marine and industrial users such as ferries companies, factories, etc?***

The price is the main factor; the infrastructure must be created, if there is no infrastructure companies can come. For instance when ships come for maritime fuel the infrastructure should be there such as bunkers.

As well another respondent noted that it is necessary to know about supply of the LNG. That LNG needs to be available for them. They need to know that they can get LNG from the Melkoya or other places in Europe and need to get the long-term LNG supply.

Secondary data source was found from small scale LNG forum. It is a conference, which is going every year; the forum aim is to follow small scale LNG trends, especially in Europe. The participant was asked about Safety training in a small scale LNG supply chain. The question is:

***“A lot has been made of the “Safety” training and cargo/fuel management necessary to enable a Small Scale LNG supply chain. Do you believe this is a major hurdle? (After all we are dealing with a mature technology in many senses)”<sup>65</sup>.***

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<sup>65</sup> Small Scale LNG Forum, 2012 . <http://oilgas.flemingeurope.com/small-scale-lng-forum-201210/speakers-lounge>

Alexander Harsema-Mensonides, Senior Engineer Project Development, Marine Service GmbH in the small scale LNG forum in Istanbul noted that accidents occur “once LNG is going from the confines of a well supervised and regulated industry into mainstream applications. It will be very hard to make all systems completely idiot-proof, so as to eliminate all chances of unfortunate human error or plain stupidity. Over the years incidents happen in any industry, the objective is to minimize the amount of casualties”<sup>66</sup>

***Are Norwegian government incentives such as the NOx fund a reason for companies in Northern Norway to adopt LNG?***

There is no restriction of NOx fund in the Northern Norway. It is a fund where various enterprises get financial help regarding NOx decreasing measures. The fund aim is to reduce NOx emissions and one of the option is the adoption of LNG, which ensure lower sulphur emission.

It should be noted that LNG is an easy way to reach the ECA regulations. Another example can be the NOx fund that can foster LNG adoption in Northern Norway, Arctic. There are good perspectives for companies in maritime industry in the nearest future to adopt LNG in the Arctic region.

The third respondent confirmed that it is the main driver, it is seen for the 15 years that it is one of the main driver for the whole small scale LNG infrastructure in the Norway and European Union is adopting the same model, but I believe NOx fund is schedule to be close in 2017.

***What impact will ECA regulations in the Norwegian Sea and areas around Canada can have for LNG in Arctic?***

As one respondent thinks, it will make people more look for the LNG. Once more, it will also depend on price, it can be as alternative for NGO, but the price shouldn't be high. If the LNG fuel prices will be high, companies will use oil fuel.

Another respondent indicated that it is the main driver for the LNG as fuel, but not so much for industrial users, because LNG already much cheaper, but you need mutts and clots in the LNG engine. So the anchor regulation is very important for the LNG as fuel and anchor regulation, it will affect ECA and will affect industrial users to switch to the natural gas too.

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<sup>66</sup> Small Scale LNG Forum, 2012 . <http://oilgas.flemingeurope.com/small-scale-lng-forum-201210/speakers-lounge>

### ***Does LNG use in Arctic can reduce emission impact? From scale 1 to 5***

It depends on what kind of emission, if it is it nox emission or sulphur, because LNG reduce sulphur by 90%, so the range scale can be big, while decrease of Nox emission is smaller for LNG, which let to comply with IMO Tier III limits. Moreover, LNG also reduces carbon dioxide (CO2) emissions around 20 %.

Compared to marine diesel, CO2 emission is reduces by 25%, NOx by about 90% and there are no emissions of sulphur and dust.

Yes, it will reduce emission in the boats sail and LNG industry's users. Emission factor depend on criteria are you looking. For instance nox emission, the reduction is small comparing with sulphur emission. Also LNG reduces CO2 emission. From scale from 1 to 5 for CO emission the grade would be arround 3, and for sulphur 5 for the reduction of the emission. The great benefit of natural gas is that it is relatively cheap. The best way for the greener future is to do everything step by step; it isn't economically viable to switch only for the natural gas.

There are alternatives for LNG such as CNG and LPG. The secondary data give the answer about LNG substitutes from "Small scale LNG Forum" in Istanbul in 2012. The question was asked for two participations in small scale LNG forum:

***"Are there any distinct advantages of LNG over CNG or LPG?"***<sup>67</sup>

The participant (Wim Groenendijk) indicated that "For large vehicles, particularly fleet vehicles, LNG becomes attractive because of reduced on-board weight and space requirements; 1,8 litres of LNG is equivalent to 5 litres of CNG. For small vehicles, CNG is generally more appropriate because space and weight are not critical and the cost per vehicle system is less. Some distribution systems have been developed that simply convert LNG to CNG for this purpose. The theoretical reduction of CO2 emissions, compared to gasoline, in vehicles with identical properties and with identical engine efficiency, is around 30% for Natural Gas (LNG/CNG) and 15% for LPG."<sup>68</sup>

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<sup>67</sup> Small Scale LNG Forum, 2012 . <http://oilgas.flemingeurope.com/small-scale-lng-forum-201210/interview-with-wim-groenendijk>

<sup>68</sup> Small Scale LNG Forum, 2012 . <http://oilgas.flemingeurope.com/small-scale-lng-forum-201210/interview-with-wim-groenendijk>



While the other participant of “Small scale LNG forum” (A. Mensonides) answered to this question that LNG cost less than LPG and the main different between LNG and CNG is in the amount of energy per litre.

Again, the secondary data present another interesting question which was asked for respondents in “Small scale LNG Forum”.

*“Can small scale LNG be realized without the regulatory push given by ECA-SECA enforcement?”<sup>69</sup>*

The first respondent (A. Mensonides) thinks that “If the price and the distribution are right, yes. If it’s not available or too expensive, no, it will not be interesting”<sup>70</sup>

The other entrant of conference Wim Groenendijk (small scale LNG forum) believes that “The introduction of Sulphur Emission Controlled Areas was of big help for the development of small scale LNG in the Baltic Sea, where it demonstrated its benefits. This successful example can be followed in other areas to foster the use of small scale even beyond the SECA zones.”<sup>71</sup> Over all, the environment rules remain significant factor.

## 5.1. Summary

In this chapter, interviews, the primary data together with the secondary data show the view of LNG perspectives in the Arctic area. What type of drivers and barriers companies see for the LNG adoption. The drivers were mentioned such as cost, the price of LNG, supply and environment indicators. The big impact makes environment rules, restrictions and that natural gas is more environmentally friendly than oil or coal. It helps to reduce CO<sub>2</sub>, NO<sub>x</sub> and sulphur. Barriers were listed as availability, price, infrastructure and low demand. Arctic region has good perspective for maritime fuel as the shipping is going in the Northern Sea Route. LNG is attractive for industries

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<sup>69</sup> Small Scale LNG Forum, 2012 . <http://oilgas.flemingeurope.com/small-scale-lng-forum-201210/speakers-lounge>

<sup>70</sup> Small Scale LNG Forum, 2012 . <http://oilgas.flemingeurope.com/small-scale-lng-forum-201210/speakers-lounge>

<sup>71</sup> Small Scale LNG Forum, 2012 . <http://oilgas.flemingeurope.com/small-scale-lng-forum-201210/interview-with-wim-groenendijk>

such as mining sector, transportation onshore, maritime industry, production companies, that need diversification LNG, industries that need heat and local companies.

## Chapter 6: The prospects of LNG usage in an Arctic

Energy is one of the most mythologized parts of the world economy. One of these myths is the imminent end of the era of hydrocarbons due to depletion of their reserves. Once these rumors were dispelled, used other conjectures: soon the world will move to renewable fuels, hydrocarbons and then just leave in the past. Oil and gas are also made responsible for global warming, rising carbon emissions.

In fact, the world still for a long time will be dependent on a hydrocarbon economic lifestyle. Revolutionary changes require a lot of time to rebuild our lives and our economy. Even if you believe in the success of "green energy" (the so-called renewable fuels - solar and wind power, bio-fuels), it is still a technological shift would be too great. Radical innovations take root in society too slow. Production of green energy is growing very slowly over low base accepted figures that even slightly increasing in absolute terms and as a percentage relative or show growth of 200-300%. As a result, a positive example swells and becomes grotesque.

Along with the growth of energy consumption is increasing the share of natural gas in the global energy mix. Gas is younger fuel than oil. Period of natural gas, in fact, began with the opening in 1959 of Groningen in the Netherlands and the ensuing discovery of gas reserves in the UK southern North Sea basin in the mid of 1960s. Two oil crises in 1970s dramatically increased the interest to the gas. Since then, gas consumption in the world is steadily growing, and the economic crisis has not broken this trend. According to the International Energy Agency (IEA), since the early 1970s the share of gas in the global energy rose from 16 to 21% in 2008. According to the BP Statistical Review of World Energy, this share in 2008-2010 in world energy consumption was even higher - about 24%<sup>72</sup>.

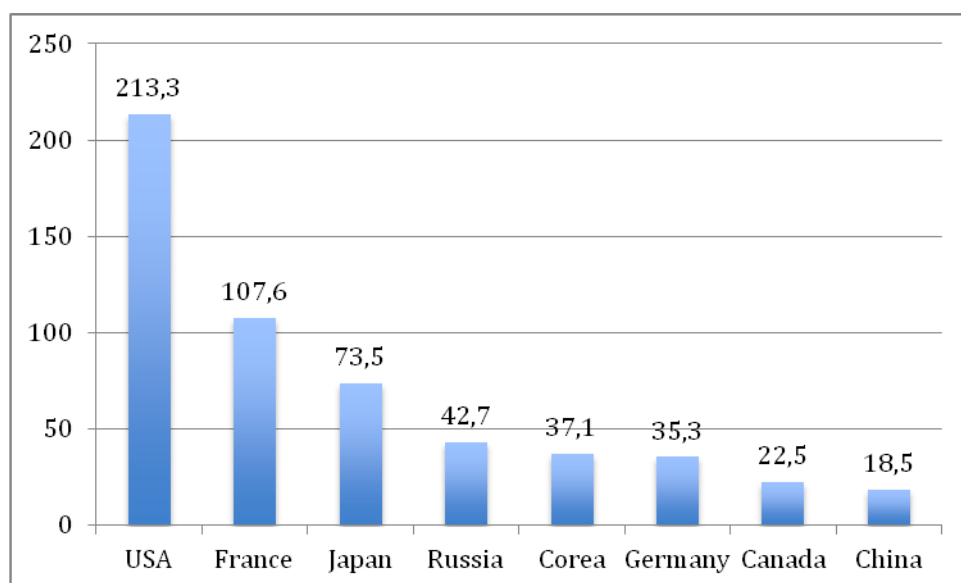
In the future, the trend increase in the share of natural gas will only be strengthened. This is due to several factors. First reason is LBNG more favorable environmental properties in comparison to oil and coal.

Secondly, the end of the "nuclear renaissance" after the accident at the Japanese Fukushima. Again because of environmental properties nuclear power will steadily be changed by gas generation. Germany has decided to close nuclear power plant before 2022, it will be reduced production of nuclear energy in Japan, and similar decisions can be made in Switzerland and the Scandinavian countries. Consumption of electricity produced by nuclear power plants in Germany in 2009 was 135/hour. This means that the closure of nuclear power plants in Germany may

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<sup>72</sup> Belova M., Vygon G. The development of LNG world market: the perspectives for Russia. Russia: Skolnovo, 2013.

increase its demand for hydrocarbons by 30 million tones of oil equivalent - at quite realistic scenario that they would be major substitutes for nuclear generation.



**Picture No. 14 Gas consumption (billion m3) in a scenario of complete replacement of nuclear power generation gas**

Source: EB Statistical Review of World Energy, 2011

Third, actively being replaced power plants using liquid and solid hydrocarbons on gas turbine combined cycle power plant being in the moment is a current most cheap (in terms of unit costs per unit of energy), efficient and environmentally sound electricity. Effectiveness of newly installed combined cycle power plants, expressed attitude produced them electric energy to heat, reached 60 % and continues to grow. The energy division of Siemens already makes turbine plants with air-cooled blades 375 MW. There are plans to launch an industrial combined cycle power plant with capacity of 570 MW, and already with efficiency over 60 %.

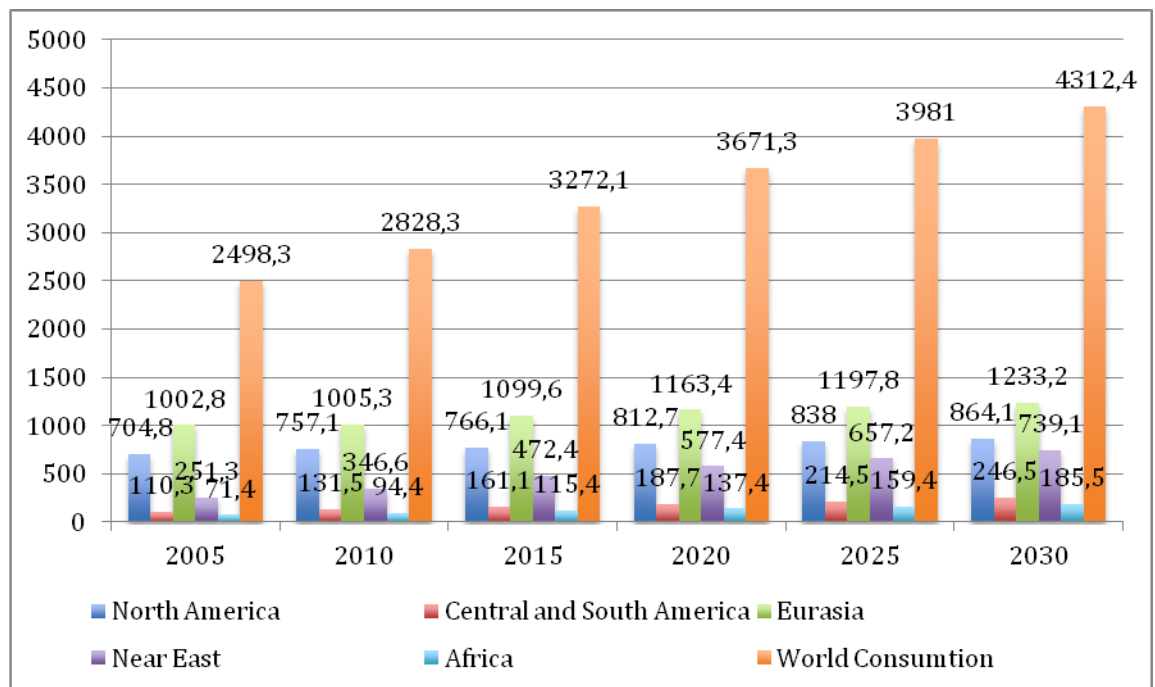
Fourth, the gas chemistry is developing rapidly, which has long been very far behind in terms of growth petrochemicals. Today, as a chemical feedstock used only about 6% of the extracted natural gas, but this figure will increase rapidly.

Fifth, it is important revolution in the field of gas transportation, namely the rapid expansion of technology liquefaction of natural gas and its transportation by sea worldwide.

New countries are involved in the gas business; natural gas becomes available to more and more consumers. As a result of the decline in gas consumption in Europe and North America during the crisis was offset by the growth in gas demand in the developing countries of the Asia - Pacific

Region (APR) , which become the locomotive of global demand for the output of the gas stagnation caused by the global financial crisis. Thus, in 2009 on the back of a decline in demand for gas in the world in Asia Pacific, according to the BP Statistical Review 2010, natural gas consumption increased by 3.4%. It is possible marine LNG volumes allowed to send gas temporarily stagnating market in Atlantic region and continued growth in Asia-Pacific market. In 2010, at least out of the recession, demand for gas in the world began to recover rapidly - and as a result increased by 7.4 % immediately, putting a new historical record of consumption - 3.169 trillion m<sup>3</sup>.

More optimistic outlook for gas producers demand for "blue fuel" made by BP in January 2011 year.



**Picture No. 15 The consumption of natural gas**

Source: BP report of gas consumption, 2011

Of course, there are other predictions about future consumption of LNG. So, BP in January 2011 predicted that the growth of LNG production would be 4.4% per year, which is twice more than the annual production of natural gas (2.1%)

Current and prospective volumes Pacific gas market, as well as the current price of it is very attractive for LNG suppliers. In Asia today sent more than 70 % of the volume of LNG.

By 2030, LNG demand will more than double to about 500 million tons per year. LNG demand in Europe will increase by almost 3 times from the current 47 million tons to 130 million

tons per year. Countries in Asia (primarily Japan and South Korea) in this period expected increase in LNG consumption by 40%. The leader will be the growth of South- East Asia, a relatively new player in the LNG market - China, India, Pakistan, Vietnam, Indonesia, Malaysia, Thailand. Their needs for LNG by 2030 will increase by 8 times.

## **6.1. Conclusions**

The research analysis showed that the main drivers for LNG usage in Arctic region are economical benefits of LNG, environmental solutions, new technologies adoption. The main industries, which can obtain the benefit from LNG usage, are shipping industry, transportation services and marine industry. The LNG amount in such industries are much more higher comparing to others. The LNG usage situation as well depends on various aspects: the situation in the country, legal issues, the international requirements and changing technology. The research analysis revealed that the main obstacles for LNG adoption are availability and sometimes the price, infrastructure, small volumes, not many customers, the lack of people competence and knowledge.

## **Chapter 7: Conclusions and further research studies**

Summarizing it can be stated that history of the development of maritime transport for LNG was triggered by various factors such as: development of related industries, economic and geographic challenges global regulation and technology development.

LNG is considered as a real revolution in the gas market, which changes the image of modern energy, evidence that the raw materials industry is able to generate modern high-tech solutions. LNG opens new markets, involvement repents-increasing number of countries in the gas business, helping to solve the puzzle of global energy security. The term "gas pause", meaning active gas consumption and the possible transformation into a fuel number one, becomes an empty shell.

Liquefied natural gas chain covers several industries, such as shipbuilding, transport engineering and chemistry. Liquefied natural gas generates even the aesthetics of modern highly industrialized society.

At the same time as the share of liquefied natural gas as a method of transportation is increasing most rapidly. World LNG trade is growing at about 6-8 % per year. If this trend continues, in 2020 the share of LNG in global gas trade will be about 35 %, while in 2030 the share of LNG can come up to 60% natural gas trading. It's quite an ambitious task - in fact in 2010 the share of LNG in global gas trade was 30.5 %. It is liquefied natural gas can claim long-term successor to the status of oil as the main product of the global energy exchange.

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- 43.

## **Appendix**

### **Appendix 1**

Sund Energy- Karen Sund

Interview via mobile phone 2014 04 01

### ***Interview guide***

1. Which industries can benefit from LNG adoption in Arctic?

Shipping, oil and gas in the Arctic waters, it depends on how far to the circumpolar north you are looking. Also in Northern Norway, Northern Sweden and Northern Finland part of Arctic, it would be the mining sector and transportation onshore.

2. What are the perspectives for LNG as a maritime fuel in Arctic?

It is good, especially in the long term and especially from China, but it depends from price and availability and from places where LNG isn't available. It depends on which year you are looking. The best perspectives are in Northern Norway and Northern Canada, while there isn't so much focus on small scale LNG in the Russia's Arctic, because there is the interest in the large scale LNG, but the LNG as a maritime fuel perspectives in long term is promising, more and more ships will be build in the nearest future globally and it also growth in Arctic, what will rise the use LNG as maritime fuel. Thus, the potential is huge, especially, when it is cheaper than oil.

3. Are the Northern Sea Route and the Northwest Passage, one of the factors that can contribute to the development of LNG in Arctic?

Yes, it will open new development of production of the LNG in Northern Sea Route and the Northwest Passage, but it definitely need more demand and it should be looked to the areas where the ships are going, some of ships will be Chinese that can use LNG as maritime fuel and some ships won't have ability to use LNG in Arctic.

4. What are LNG shipping perspectives in Arctic?

It is already very positive for the supply ships and coast guards and can be much more, but again it needs the availability. There is also a potential for cargo ships, but they need large scale LNG.

5. What are the main drivers for adopting of LNG by companies in Arctic?

Firstly, it would be the environment reason, then it depends on LNG volumes that is needed and the price and also availability factor. For instance, Canada the natural gas is cheaper

than oil, because of that, the smaller price open new perspectives for LNG in Canada and Northern Canada Arctic areas.

6. What are the main obstacles for adopting of LNG by companies in Arctic?

It is availability and sometimes the price, infrastructure, small volumes, not many customers.

7. What are the main small scale LNG concept adoption problems in Arctic and stranded markets?

Again it is the price and infrastructure.

8. What are the risks for switching to LNG for marine and industrial users such as ferries companies, factories, etc?

The price is the main factor; the infrastructure must be created, if there is no infrastructure companies can't come. For instance when ships come for maritime fuel the infrastructure should be there such as bunkers.

9. Are Norwegian government incentives such as the NOx fund a reason for companies in Northern Norway to adopt LNG?

There is no restriction of Nox fund in the Northern Norway, the aim of this fund is to reduce NOx emissions and the adoption of LNG ensure lower sulphur emission.

10. What impact will ECA regulations in the Norwegian Sea and areas around Canada can have for LNG in Arctic?

It will make people more look for the LNG. Once more, it will also depend on price, it can be as alternative for NGO, but the price shouldn't be high. If the LNG fuel prices will be high, companies will use oil fuel.

11. Does LNG use in Arctic can reduce emission impact? From scale 1 to 5

It depends on what kind of emission, if it is it nox emission or sulphur, because LNG reduce sulphur by 90%, so the range scale can be big, while decrease of Nox emission is smaller for

LNG, which let to comply with IMO Tier III limits. Moreover, LNG also reduces carbon dioxide (CO<sub>2</sub>) emissions around 20 %.

## **Appendix 2**

Barents NaturGass AS-Gudrun B. Rollefsen

Interview via mobile phone 2014 04 04

### ***Interview guide***

1What are the perspectives for LNG as a maritime fuel in Arctic?

Increasing and in the nearest future the LNG volumes should raise. For instance the number of Coast Guard vessels or LNG powered ferries that will use LNG, should enhance in Arctic. There are also perspectives for the supply ships and cargo ships to become the users of LNG in the future in the arctic, so the LNG as maritime fuel volumes should go upward.

2. Does the growth of natural gas market is expected in arctic, where company see opportunity regarding LNG in the nearest future in Arctic region? What type of industries, companies can be interesting in LNG adoption in Arctic?

The growth of natural gas market depend on natural gas fields that will be found, by the United States Geological Survey (USGS) estimation the Arctic is rich by resources such as the natural gas, so the growth of natural gas market should be expected and another factor will be the cost of natural gas in Arctic, comparing with other regions.

Industries which need the heat can be interesting in LNG adoption in Arctic. Also, mining sector in the nearest future in Arctic region, which need energy and LNG can be one of the option. The transport and off-grid sectors can be interesting in the future, but everything depends on the price, availability, etc.

3. Barents gas distributes LNG, what procedures and facilities are needed to develop LNG distribution for small scale LNG Company in Arctic?

We distribute so far by car, with an isolated tank. We build a isolated tank close to the customer as well.

4. Company transport LNG by truck, ships?

So far by truck and in the future if there will be the demand there can be the chance of distribution by ships.

5. What are the main drivers for adopting LNG in Arctic?

The main drivers are costs, supply and environmental issues/regulations. The price indicator is significant, If LNG be cheaper than ordinary fuel, there will open more opportunities in the Arctic for LNG in the future. For example the driver for marine sector for LNG is the environmental regulations, because LNG meets ships reductions requirements- environmental regulations criteria for ECA areas in Arctic waters. Talking about cost, LNG has advantage such as fuel cost and operating cost comparing with traditional bunker fuels. While, the supply volumes; it will increase if there be customers/demand.

6. What are the main obstacles for adopting LNG in Arctic?

Knowledge about the possibilities in the marine sector, again a price factor, it can be driver and obstacle, the price fluctuations will lead. The availability also shouldn't be forgotten, because if no infrastructure and due to harsher conditions it also can be the obstacle factor.

7. Company just distribute LNG to customers by sourcing LNG, company think about producing LNG by own? Why not?

8. Norwegian government focus on High North area, will it help for maritime industries to adopt LNG in Arctic? ECA regulations in North Sea, can it help for companies faster to decide regarding LNG as fuel in Arctic?

Yes, LNG is an easy way to reach the ECA regulations. Another example can be the Nox fund that can foster LNG adoption in Northern Norway, Arctic. There are good perspectives for companies in maritime industry in the nearest future to adopt LNG in the Arctic region.

9. What kinds of risks exist when distributing LNG for industry and maritime sector in Arctic?

It is the same as for other fuels. There are safety requirements, but those exist for LNG and for the other fuels.

10. What are the alternatives for LNG in Arctic?

Alternatives are ordinary fuels, pipelines, CNG.

11. Does LNG use in Arctic can reduce emission impact? From scale 1 to 5.

Compared to marine diesel, CO<sub>2</sub> emission is reduces by 25%, NO<sub>x</sub> by about 90% and there are no emissions of sulphur and dust.



### **Appendix 3**

Connect LNG AS- Morten Christophersen

Interview via mobile phone 2014 04 14

#### ***Interview guide***

1. Which industries can benefit from LNG adoption in Arctic?

It would be production companies with large energy consumption, if they switch to the natural gas, they will save expenditure on the energy. It will be the main benefit, diversity. So the Arctic area, of course the local industries will benefit, marine industry which can use LNG as fuel. For instance, Northern Norway companies, producing fish, fish industry can benefit on the diversity. And companies that produce equipments for the oil and gas sector.

2. What are the perspectives for LNG as a maritime fuel in Arctic?

It depends on ECA regulations, it is the main driver effecting LNG use in the Arctic area. It seems that some of large oil and gas companies want to switch oil to LNG for the fuel for the environment factor and to show that they have the green profile. For instance ABS ship owners, supply vessels going on LNG, the same thing is seen on Caribbean Sea. The Shell, they also have some supply ships that goes on LNG. Thus, the main driver would be ECA regulation, because Statoil, those companies want that ships owner switch to LNG, because

they want to show that there is the agreement and it is a bit of a pressure for the heavy vessels. Moreover, we are also talking about fish industry and fish vessels switch to LNG and it is happening because of ECA regulations.

3. What are LNG shipping perspectives in Arctic? Can the advantage of distance of the Northern Sea Route against Suez Canal increase LNG shipping in Arctic?

I think, the volume will go up a bit, talking about transport by ships. If we talk about the technology which ConnectLNG is developing, it will enable transition to distribution by ships more easily than today and new technologies as ours will make the transition easier so that that you don't need to get the volume that much off before to get economically viable to switch.

The LNG shipping in Arctic through The Northern Sea Route, it will increase the distribution from the Melkoya to Asia and it will benefit the local constructions as well and cause some other effect as well.

4. What are the main drivers for adopting of LNG by companies in Arctic?

It is the cost saving to switching for the natural gas, the LNG. Also it is the green profile.

5. What are the main obstacles for the adoption of LNG by companies in Arctic?

It is infrastructure and they need technology as ours.

6. What are the risks for switching to LNG for marine and industrial users such as ferries companies, factories, etc?

They need to know about supply of the LNG. That LNG needs to be available for them.

They need to know that they can get LNG from the Melkoya or other places in Europe and need to get the long term LNG supply.

7. Are Norwegian government incentives such as the NOx fund a reason for companies in Northern Norway to adopt LNG?

Yes, it is the main driver, it is seen for the 15 years that it is one of the main driver for the whole small scale LNG infrastructure in the Norway and European Union is adopting the same model, but I believe NOx fund is schedule to be close in 2017.

8. What impact will ECA regulations in the Norwegian Sea and areas around Canada can have for LNG in Arctic?

It is the main driver for the LNG as fuel, but not so much for industrial users, because LNG already much cheaper, but you need mutts and clots in the LNG engine. So the anchor regulation is very important for the LNG as fuel and anchor regulation, it will affect ECA and will affect industrial users to switch to the natural gas too.

9. What are the main small scale LNG concept adoption problems in Arctic and stranded markets?

The main problem is the large investment cost for the LNG terminal. And the main challenge for the small scale LNG industry is high cost for jetties, berthies, piers, compared to other scale LNG terminal, transfer solution, a point between a ship and the onshore and it cost the large portion of the total investment for a small scale, while for the large scale it consist on only a small portion of the investment.

10. How UBC system will help to remove or facilitate the obstacles of adoption for small scale LNG?

You don't need to build jetty for our system, it is like a plug pipeline system that give access for the LNG, and it is less costly. The goal is to adopt this system for the industrial users

which use LNG or would like to switch to LNG and it can help to facilitate the transition faster than today.

11. What would be the drivers of adopting UBC systems for small scale LNG users? Is it easy moved to stranded market?

The driver would be to use UBC for small scale users, who want to use LNG and it is too much costly and take too much time. It is a technical solution and you can move it. When the market change it takes a lot of investment to move to the other locations, conditions change very fast. For instance, we have seen the Fukushima disaster and LNG demand change from the Europe to Japan. Also a shale gas, it is really a short time and UBC is such a technology that you can move.

12. What type of companies can adopt this system? What opportunities this system will create?

The main our customers are internal owners. It also can be a chamber own by several parties such as oil and gas majors that invest together and start a joint venture which invests in internals owns, equipments. Also, large production companies, industrial players which want to switch to the natural gas, LNG. And finally, the large port of LNG that want to provide LNG networks because of the capacity constraints.

13. Does LNG use in Arctic can reduce emission impact? From scale 1 to 5

Yes, it will reduce emission in the boats sail and LNG industry's users. Emission factor depend on criteria are you looking. For instance nox emission, the reduction is small comparing with sulphur emission. Also LNG reduces CO2 emission. From scale from 1 to 5 for CO emission the grade would be arround 3, and for sulphur 5 for the reduction of the emission. The great benefit of natural gas is that it is relatively cheap. The best way for the greener future is to do everything step by step; it isn't economically viable to switch only for the natural gas.

#### **Appendix 4**

BioMar

Written answers to interview guide 2014 04 15

## ***Interview guide***

1. What are the perspectives for LNG as a maritime fuel in Arctic?

The use of LNG could be interesting if the price is competitive to other alternatives.

2. Are Norwegian government incentives such as the NOx fund a reason for companies in Northern Norway to adopt LNG?

Yes.

3. What are the main drivers for adopting LNG for supplier of fish feed Company in Arctic?

The price and environmentally aspects

4. What are the main obstacles for adopting LNG for supplier of fish feed Company in Arctic?

The price

5. Small scale LNG concept is used in maritime industry, what procedures and facilities are needed for BioMar Company to adjust LNG as fuel that the process of work will go properly without any interruptions?

BioMar factory is today using LPG as an energy source. To adapt for use of LNG we need to change a storage tank designed for LNG

6. How long BioMar use LNG as fuel in gas powered cargo ship? Since the summer 2012

7. How LNG fuel comes to gas powered cargo ship in BioMar plant at Myre in Vesterålen, Northern Norway? Have contracts with LNG distributors? Use Trucking company? Have LNG bunker station? The LNG is supplied by truck directly to the ship when the ship arriving Myre harbour.

8. Is there any problems with bunker station for building and maintenance it in Northern Norway, Arctic? We don't expect special problems with this.

9. Comparing gas powered cargo ship with oil fuel ship, what are advantages and drawbacks? Higher investment costs and limited refueling opportunities

10. Does BioMar use other cargo ships without LNG as fuel for fish feed transportation? Yes  
What are the differences of operating the powered cargo ship in Arctic waters and other?

11. What the risks are when switching to LNG as fuel?

12. Could repairs and spare parts be more difficult for LNG than for more widespread diesel engines?

13. Do you believe that BioMAR example will foster other companies to adopt LNG in Arctic context, as Norway has competitive aquaculture and marine sectors? Yes

14. Cost of buying LNG cargo ship, from economic side is it right decision, does it pay off?
15. Does using LNG cargo ship increased profit, company efficiency comparing with diesel cargo ship?
16. Does LNG use in Arctic can reduce emission impact? From scale 1 to 5