**The Thesis Committee for Sinem Okumus**
**Certifies that this is the approved version of the following thesis:**

# Impacts of US LNG Exports on the Supply Security of the EU Natural Gas Market

**APPROVED BY**
**SUPERVISING COMMITTEE:**

**Supervisor:** ______________________________
**Larry Lake**

**Co-Supervisor:** ______________________________
**William L. Fisher**

# Impacts of US LNG Exports on the Supply Security of the EU Natural Gas Market

by

**Sinem Okumus, B.S.; M.S.**

**Thesis**

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

**Master of Science in Energy and Earth Resources**

**The University of Texas at Austin**

**May 2015**

*I dedicate this thesis to my family*

*for their constant support and unconditional love.*

# Acknowledgements

Many people helped me bring this thesis into existence. I would therefore like to offer my sincere thanks to all of them.

I would first like to express my special appreciation to my advisor, Prof. Larry Lake for accepting me as a MS student, his encouragement, thoughtful guidance, critical comments and correction of the thesis. In addition, I want to thank to my co-advisor Prof. William L. Fisher for his invaluable trust and suggestions.

A special thanks go to Ipek Nese Sener, for her hospitability, joyful gatherings and all her supports. I am also grateful to Sezgin Kucukcoban for his assistance and detailed explanations about Austin daily life.

I also appreciate the financial support of the Energy Market Regulatory Authority of Turkey during my MS study at the University of Texas at Austin.

Last but not least, I have been blessed to have many people in my life who have offered me love and encouragement through all my achievements including the creation of this thesis. My completion of this thesis could not have been accomplished without my parents, my sister, and my friends. Many thanks to all for everything.

# Abstract

## Impacts of US LNG Exports on the Supply Security of the EU Natural Gas Market

Sinem Okumus, M.S.E.E.R.

The University of Texas at Austin, 2015

Supervisor: Larry Lake

Co-Supervisor: William L. Fisher

Advances in drilling technology and production strategies such as hydraulic fracturing and horizontal drilling have made shale gas more accessible and have boosted US natural gas production. The US Energy Information Administration (EIA) expects that indigenous production will exceed consumption and that the US could become a liquefied natural gas (LNG) exporter by 2016. While US natural gas production has boomed, the EU has been increasingly dependent on natural gas imports mainly from Russia. In addition to rising dependency on Russian natural gas, the dispute between Russia and Ukraine has disrupted delivery of Russian gas and has threatened the security of natural gas supply to the EU. This situation has compelled the EU to seek different suppliers to reduce Russian dominance of Russia. Considering 30 percent of EU natural gas imports come from Russia an increase in EU concerns about disruption of the Russian supply has fueled a discussion of US LNG exports.

As an alternative to Russian supply, US LNG exports are considered as a solution to mitigate the effects of supply interruptions and overdependence on Russia. Currently the most important question is whether US LNG exports will or will not be a panacea for the EU natural gas market. This study uses US LNG export scenarios to investigate the effects of US LNG exports on the EU natural gas market. Although I primarily expected that US LNG exports would not impact the EU natural gas market, the main findings are surprisingly different from the anticipation. The consequences are:

1. Although US LNG exports are not an elixir for the EU natural gas market to improve its security supply, they will reduce the dominance of certain exporting countries.
2. US LNG exports will not decrease the EU's dependence on its suppliers due to the EU's preference to import US LNG. This situation prevents any improvement of the security of natural gas supply in the EU.
3. US LNG exports will result in a slump in natural gas prices and a rise in natural gas demand in the EU.

# Table of Contents

## List of Tables

## List of Figures

# Chapter 1: Introduction

Issues related to the supply of primary energy resources have become a major challenge for the European Union (EU) members. A continually increasing energy demand, concerns about climate change and the EU's stringent policies to de-carbonize its energy systems have promoted the consumption of less carbon-intensive fossil fuels (especially natural gas) over the last two decades. In addition, insufficient domestic natural gas production in the member states has created pressure on the EU. For this reason, access to affordable, stable and sustainable natural gas from multiple suppliers is at the top of the EU's agenda.

Although natural gas has been imported via well-connected pipelines from several exporting countries, such as Russia, Norway and Algeria, to supply the EU, some EU countries, such as Estonia, Lithuania, Latvia, Finland, and Bulgaria, completely depend on a single supplier (Russia). The disputes between Russia and Ukraine, causing disruption of Russian gas in 2006, 2009 and 2014, and the expectation of serious reduction in future Russian gas production have threatened the security of natural gas supply at national and the EU level. Also those threats have increased energy expenditures in the EU countries. These hardships have compelled the EU to attempt to mitigate impacts of Russian gas disruption. Therefore, diversification of routes and sources to meet the EU's natural gas demand has been the EU's priority.

According to the EU's Energy Security Strategy (COM/2014/0330), more effective use of the opportunities to import liquefied natural gas (LNG) in the EU member countries is described as one of the measures to strengthen energy independence and to ensure the security of supply. When the construction period of new pipelines and capital-intensive investment are taken into account, US LNG imports have gained importance in last two years.

In contrast to many EU countries who have depended heavily on a single supplier for natural gas supply, advances in drilling technologies and production strategies such as hydraulic fracturing and horizontal drilling have made shale gas more accessible and boosted indigenous natural gas production in the United States (the US). As a result of the shale gas boom, the US Energy Information Administration (EIA) expects that indigenous natural gas production will exceed domestic gas consumption and that the US could become an LNG exporter by 2016. With the emergence of US LNG exports, both the US and the EU see the US natural gas as a remedy for reducing Russian hegemony in the EU natural gas market.

Both sides have made numerous infrastructural and legal arrangements, but it is not yet known whether US LNG exports are a solution to the supply problem of the EU natural gas market. The aim of this study is to analyze the impact of US LNG exports to the EU gas market.

### 1.1. Research Questions

The shale gas boom in the US has had a positive effect on the US economy since 2007. Today, increased US natural gas production provides opportunity to the US to become a net LNG exporter in the foreseeable future. Large capital-intensive investments have been made to maximize impacts of shale gas on the US economy, to be a natural gas exporter and to support the US's allies (especially the EU countries). But some fundamental questions, leading research questions, should be answered before initiating LNG export from the US to the EU countries:

1. What advantages can the EU anticipate from natural gas imports from the US? Will this trade be a panacea for the EU's countries to solve the problem related to the security of natural gas supply?

2. Will the US natural gas export reduce the EU's dependence on its main suppliers?

3. Will the LNG imports from the US change the EU's natural gas demand?

### 1.2. HYPOTHESES

The hypotheses are:

*$H_0$: Natural gas supply security of EU countries will not be affected by LNG imports from the US.*

*$H_1$: Natural gas supply security of EU countries will be affected by LNG imports from the US.*

At the outset, I expected my research to verify the null hypothesis ($H_0$).

### 1.3. STRUCTURE OF THE THESIS

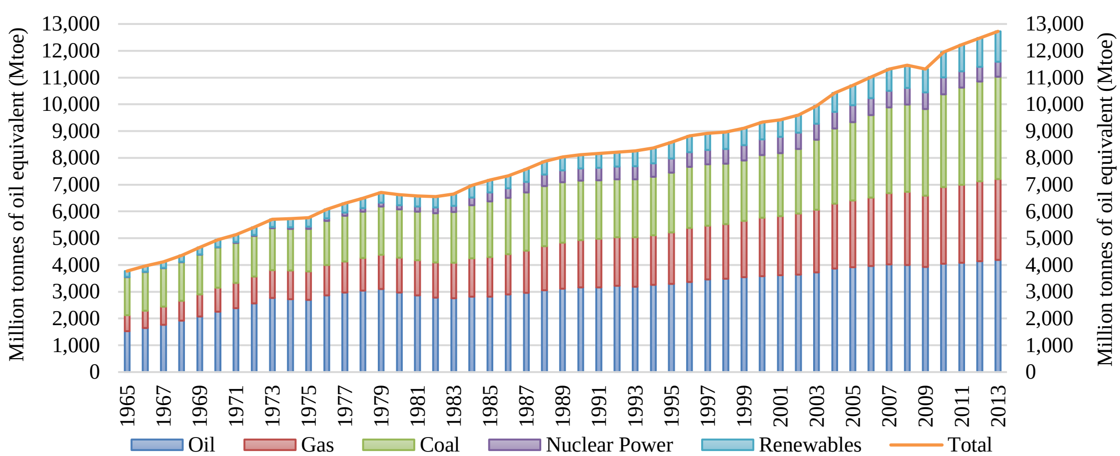
This study in five chapters is an analysis of the impacts of US LNG exports on the EU's natural gas market. Chapter Two is a description of the basics of LNG markets: US, EU, and global. The methods used to accept or reject the hypothesis are explained Chapter Three. Chapter Four is a discussion of the assumptions used to analyze impacts of US LNG imports on the EU's gas market and presentation of the results of the methods discussed in Chapter Three. The final chapter (Chapter Five) summarizes and draws conclusions.

## Chapter 2: Overview of the LNG Market

### 2.1. The Global LNG Market

Energy consumption has grown in recent decades due to significant increase in global population and higher demand by emerging economies. Figure 1 shows global primary energy consumption from 1965 to 2013. In that period, total consumption growth rose 2.6% per year and total consumption jumped from 3,765.1 million tonnes oil equivalent (Mtoe) in 1965 to 12,730.5 Mtoe in 2013 (BP 2014). Also more than 85% of global energy needs was fulfilled primarily by fossil fuels.

Figure 1: Global Primary Energy Consumption (1965-2013)

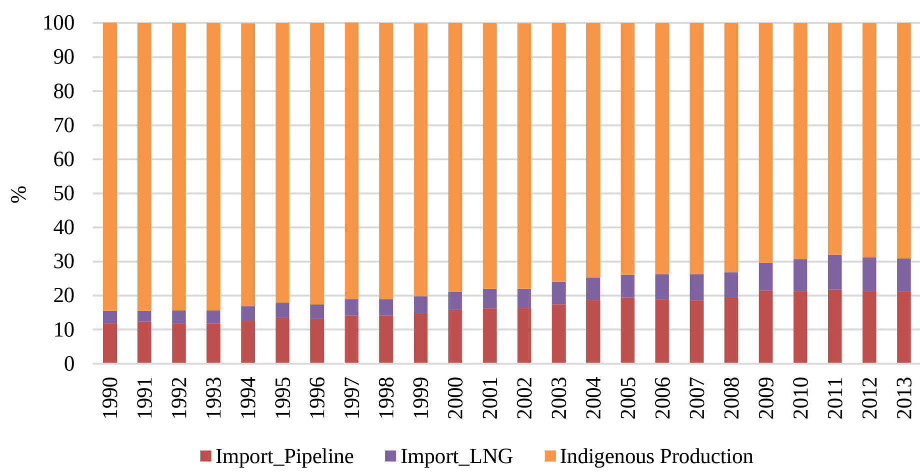



Source: BP Statistical Review of World Energy 2014

Fossil fuels have been at the heart of global energy use, but today, concerns about high energy prices and the energy supplies security are forcing all countries to transform their energy markets; the environmental policies have added to this transformation. For these reasons, the use of natural gas, the least carbon-intensive fossil fuels, has increased dramatically in the last five decades; furthermore, it is expected to be the fastest growing fossil fuel in the near future. While its share of the global energy mix in 1965 was 15.6%, it provided 23.7% in 2013 (BP 2014), and this share is anticipated to grow at a rate of about 1.6% per year until 2040 (ExxonMobil 2015).

The geographical mismatch between resources and consumers has led to significant growth in the international gas trade since the 1990s. To illustrate, while 85% of natural gas demand was fulfilled by indigenous production at the beginning of the 1990s, this rate decreased to 69.1% in 2013 (Figure 2). This abrupt expansion in the gas trade has been dominantly facilitated by pipelines that connect countries and continents. However, the rebalancing of global and local natural gas markets via gas pipelines is often faced with technical, economic, and even political restrictions (Cornot-Gandolphe, et al. 2003). These challenges in natural gas markets have generated intense interest in liquefied natural gas (LNG) since the 1990s (Figure 2). As shown in Figure 2, whereas in 1990 LNG accounted for only 3.7% of total global natural gas consumption, this rate increased to 9.7% in 2013.

Figure 2: Shares of natural gas production and import in total gas consumption (1990-2013)[1]




Source: BP Statistical Review of World Energy, 2014

[1] When compared to total consumption, annual changes in the levels of natural gas storage are very small. For this reason, they are not taken into account while calculating ratios.

LNG, super-cooled (or cryogenically processed) liquid natural gas with approximately 1/600th of the volume of its gaseous state, can easily be stored and transported to energy-hungry locations without using pipeline. In addition to its transportation superiority, there are several reasons for the emergence of the global LNG trade:

- LNG is purer than pipeline gas and has more stable composition, higher methane ($CH_4$) and energy content (European Commission 2009). During liquefaction process, impurities in natural gas are removed from gas mixture.

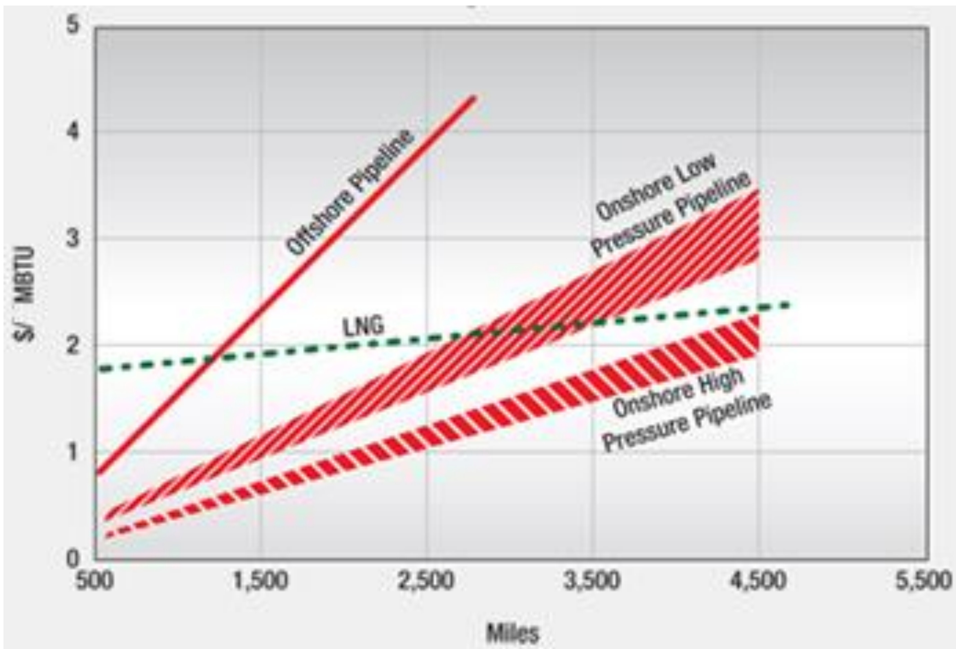
- Generally, natural gas is traded by pipelines, and they cross a number of countries and borders with possibly unstable political situation (Cornot-Gandolphe, et al. 2003). Unlike pipeline gas, LNG helps the importing countries to overcome political restrictions.

- Trading natural gas in a liquid form provides flexibility to both importing and exporting countries. Regarding data from BP Statistical Review of World Energy 2014, feeding key natural gas markets (Asia, North America and Europe) by means of pipelines can create economic and technical problems, and sometimes impossibilities because gas fields in these regions are remote or stranded. Under these circumstances, exporting countries, such as Middle Eastern countries, prefer trade natural gas as LNG to monetize stranded gas fields.

From the aspects of importing countries, LNG offers the supply security. For example, EU has attempted to reduce its dependence on its main supplier (Russia) by importing LNG from various locations/sellers.

- LNG becomes more advantageous than pipeline gas over long distances, especially for overseas when natural gas demand increases and LNG cost along the whole value chain reduces. In the LNG industry, as a rule of thumb, LNG is considered as the more economical alternative compared with a pipeline for distances in excess of 2,000 to 3,000 miles (Rogers 2010). This empirical assumption can also be easily seen in Figure 3.

Figure 3: Comparison of transportation cost ($/MBTU) of natural gas as a function of distance (mile) for offshore pipeline, onshore low pressure pipeline, onshore high and low pressure pipelines and also LNG



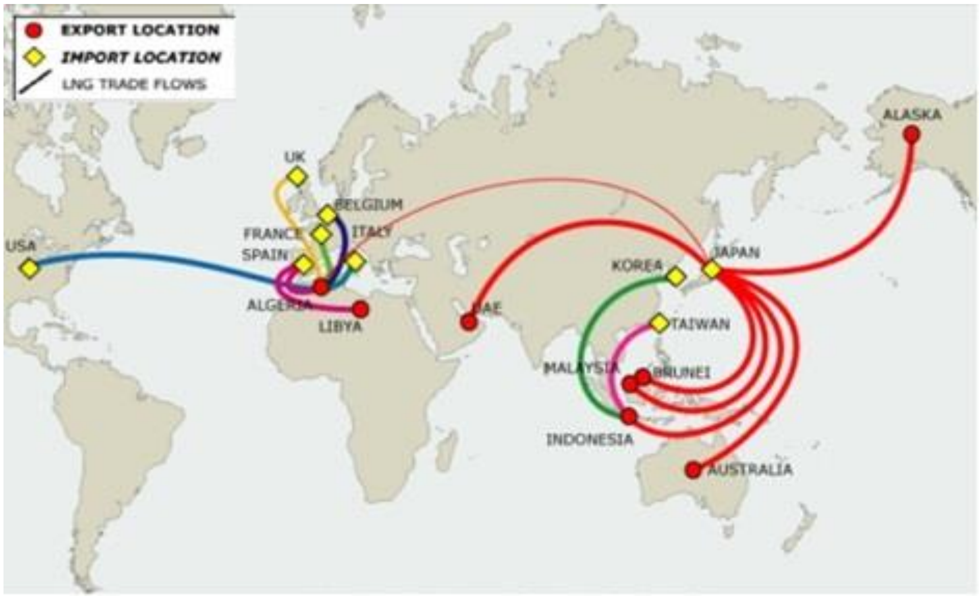

Source: ENI (Economides 2007)

In the following sections, the structure of the global energy market, initially, is examined. The global LNG demand and supply are identified, and then the LNG price formation and the factors influencing the global LNG trade are explored.

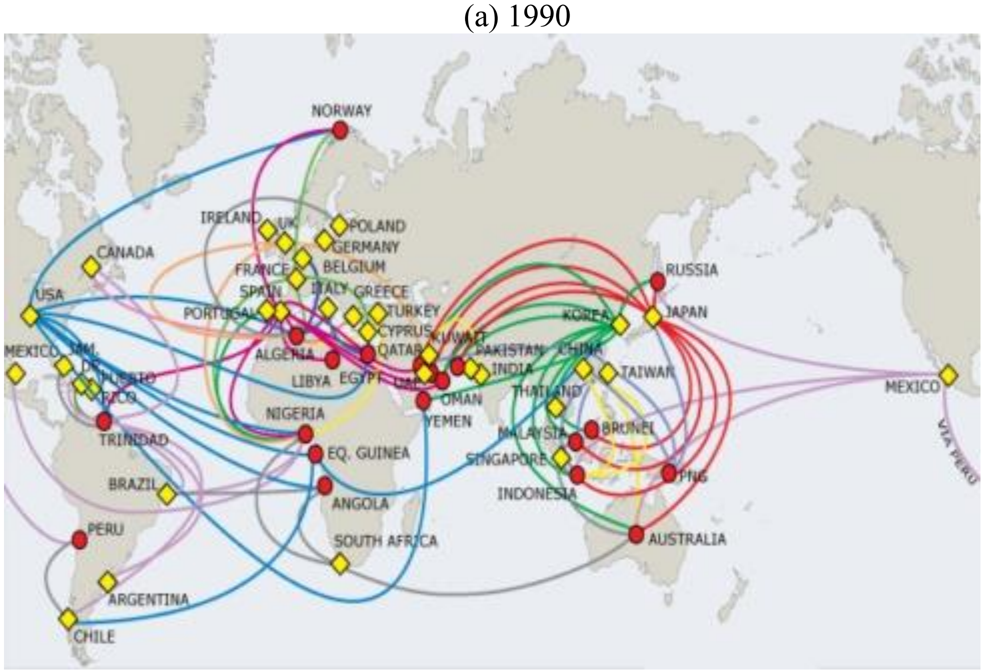
### 2.1.1. Structure of the Global LNG Market

Complexity of the multi-stage LNG production and delivery processes requires capital intensive investment for infrastructure (liquefaction, regasification plants and refrigerated tanker). Therefore, LNG was only traded within defined regions, and the global LNG market became the niche (new emerging) market until the 1990s. Over the last three decades significant alterations were observed in the global LNG market (Figure 4).

Figure 4: The global LNG trade routes in 1990 and 2015




(a) 1990




(b) 2015 (expected)

• LNG exporting countries ♦ LNG importing countries

Source: Poten & Partners, November 2013

Regarding Figure 4, in 1990, the LNG importing countries were located in three regions: North America (US), Europe (UK, France, Spain, Belgium and Italy) and Asia-Pacific (South Korea, Taiwan and Japan). For the delivery part, there were two independent basins (Atlantic and Pacific). On the supply side, LNG exporters were located in North America (the US-Alaska), Middle East/North Africa (MENA) (UAE, Algeria and Libya) and Asia-Pacific (Brunei, Malaysia, Indonesia and Australia). In that year, 3.7% of global natural gas consumption was met by LNG and the LNG market became a fledgling market vis-à-vis other energy resources' markets.

In 1990 the supply chain was driven by long-term buyer and seller relationships due to requiring capital intense investment (Poten & Partners 2013). Purchasing LNG with long-term contracts (20-25 years in duration) mandated the utilization of the oil-indexed LNG prices. Starting from the 1990s the LNG spot market has begun to emerge with the impacts of the start-up new projects, blossoming of infrastructure for spot LNG market and the expiration of old long-term contracts (Alaska Support Industry Alliance 2013).

In the last 25 years (between 1990 and 2015) although exporting and importing regions did not change too much, the global LNG market has become more competitive in both supply and demand sides due to considerable increase in the numbers of suppliers and consumers. For this reason, the LNG trade has become more complicated and more dynamic. In 2015, it is expected that LNG will be traded by 20 suppliers and 29 consumers. In spite of the fact that long-term agreements were dominant at the beginning of the 1990s, spot LNG trade will become between 25-30% of total LNG transaction (Poten & Partners 2013).

In the light of the structure of the global LNG markets between 1990 and 2015, the snapshots of the current LNG market can be listed as follows:

- Expanding LNG trade has created a link between consumers and gas producers who belong to distant reserves.

-The main driver of the market has been the imbalance between indigenous supply and demand, and LNG is generally used as a supplement fuel rather than a primary fuel. Major shift in gas utilization pattern is not expected in the near future.

- Economic development, industrialization, and improvement of living standards are the main determinants of LNG demand. While LNG demand was boosted by developed countries (Japan and South Korea) in the 1990s, primary LNG consumers have recently been developing countries, such as China and India. In the foreseeable future, this demand shift from developed to developing countries will shape the global LNG trade.

-In addition to natural gas demand of developing countries, higher oil prices and the shale gas revolution in the US have spurred the development of the global LNG market. Especially, low natural gas prices in North America (the US Henry Hub) and the UK's NBP (National Balancing Point) compared to oil prices have increased competitiveness of LNG with respect to other energy resources. Therefore, oil price level will become one of the main parameters for the global LNG market.

- Geographically, the global market is segmented among the Atlantic, the Pacific and the Middle East regarding the routes of the global LNG trade. Unlike other two great ocean basins, the Middle East located between them has exported LNG to both markets (Jacobs 2011). Whereas LNG trade was made separately in the Atlantic and the Pacific basins in the 1990s, the growth in global natural gas demand has recently kicked off cross-basin and inter-basin LNG trade.

- At the outset LNG was marketed under the long-term contracts. Starting from early 1990s, spot and short-term LNG markets has emerged, and the share of these markets in the whole trade became about 30% (International Group of Liquefied Natural Gas Importers (GIIGNL) 2014).

- Under the ideal market conditions the LNG prices are expected to be formed regarding the LNG supply chain. But varying LNG prices from basin to basin disproves this anticipation. Whereas the LNG prices in the 1990s were close to each other because of the dominance of long-term contracts and utilization of oil-index price formula, the changes in the natural gas market structure caused LNG price divergence. To illustrate, oil-linked LNG prices in Asia-Pacific, gas-on-gas market pricing mechanism in North America, and hybrid pricing mechanism in Europe have resulted in various LNG prices. This situation has prevented the construction of integrated global LNG market. In the near future, regional gas price mechanism is expected to persist.

- The geographic isolation and inadequate domestic natural gas production have led to higher LNG prices. Asia Pacific countries are the best example for this condition. Remoteness of Asia Pacific countries from main LNG suppliers reduces the possibility of negotiation on the LNG price negotiation.

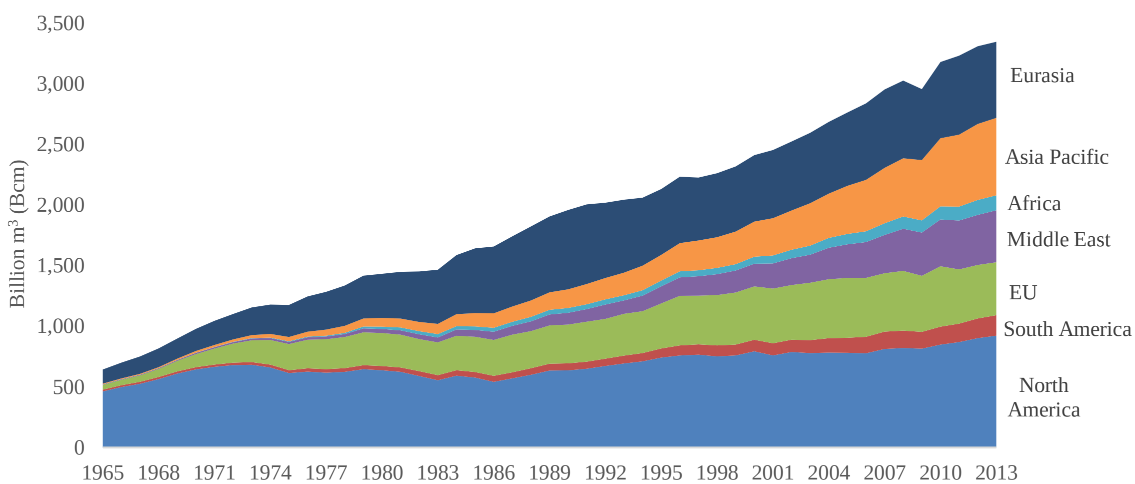
- Emergence of the LNG spot market is directly related to an increase in surplus capacity of long-distance supply. The high entry cost of LNG production has been one of the main reasons preventing the development of the LNG spot market. For this reason, general tendency in the global LNG market is to trade LNG via long-term contracts. Under these circumstances, in the upcoming decades, while spot market is growing, a dramatic shift from long-term contracts cannot be expected (Černoch, et al. 2010).

- On the supply side, a small portion of LNG is re-exported by importing countries, such as Belgium, France, Spain, Netherland and Portugal, located near shore. Re-exportation is anticipated to continue especially in Europe.

### 2.1.2. The Global LNG Demand

The global LNG demand is mainly related to the global natural gas demand, the status of pipelines, and the price of substitute fuels. Since 1965, the natural gas demand has grown substantially due to an increase in global population with a rate of 1.1% per annum, technological development, and stringency of environmental policy. As shown in Figure 5, in 1965, 78% of natural gas consumption was stemmed from developed countries in North America and Europe. In 2013, this ratio decreased to 40% and natural gas demand shifted from developed countries to developing countries (China and India).

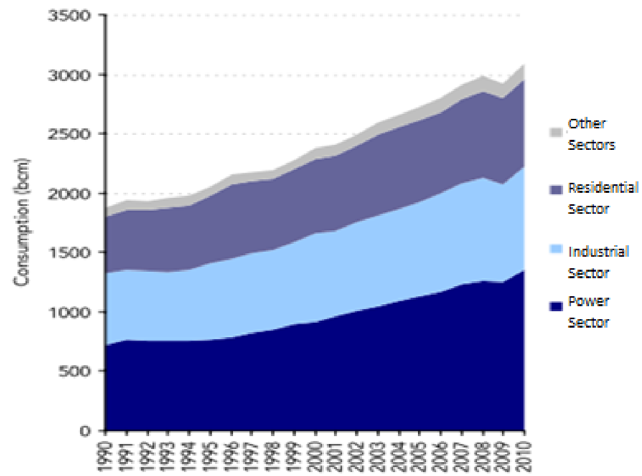
Figure 5: Natural gas consumption by region between 1965 and 2013




Source: BP Statistical Review of World Energy 2014

Much of increase in natural gas consumption is due to the growth in the use of natural gas to generate cleaner electricity. For this reason, the share of natural gas in power generation has risen reasonably (Figure 6), and gas consumption has increased by 63% since 1990. Due to stringent environmental policies in key natural gas consuming countries, natural gas demand is expected to grow. Therefore, natural gas producers, who want to monetize their natural gas resources, have focused on the LNG consumers, such as Japan and the EU countries.

Figure 6: Global natural gas consumption by sector between 1990 and 2010

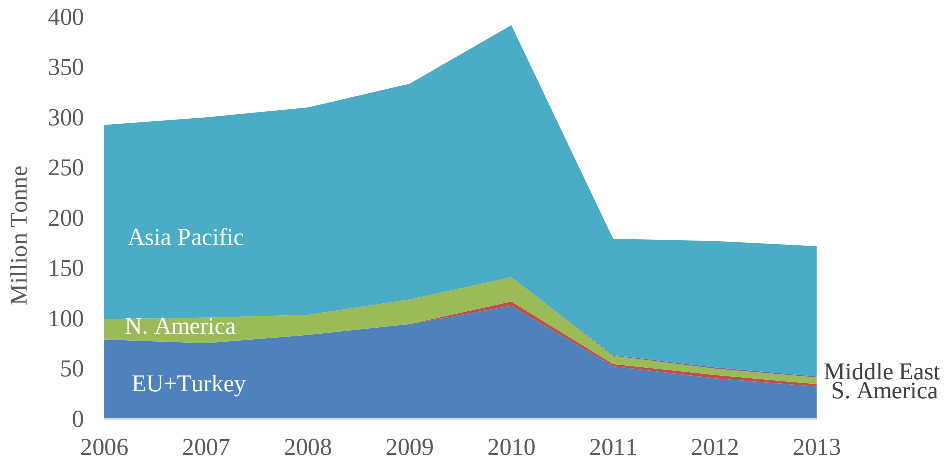



Source: Poten & Partners, January 2013

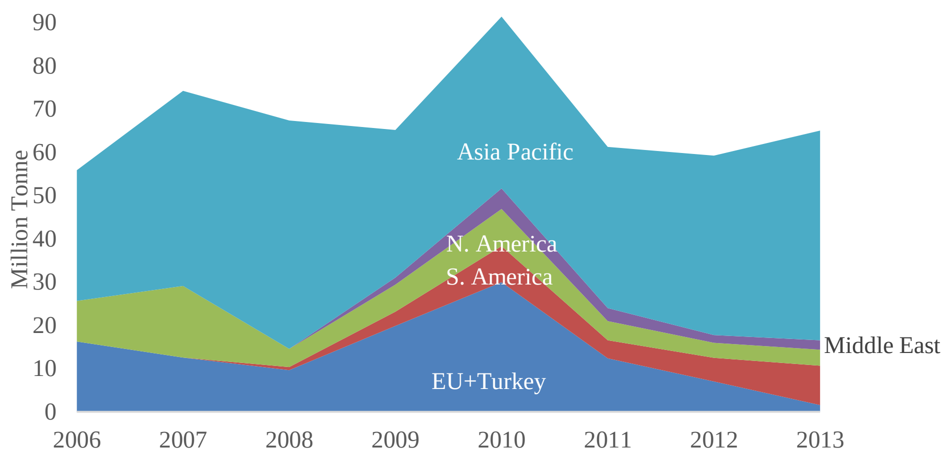
LNG represents 10% of global natural gas trade and is utilized to fulfill both primary and peak natural gas demand. On the demand side, the LNG consumers are generally Asia-Pacific and the European countries. The share of Asia Pacific trade in the global market shown in Figure 7 is 75% of global trade in 2013. In this region, Japan with 30% of total global demand is the largest consumer, followed by South Korea, China, India and Taiwan. In 2014, Japan, South Korea and China comprised 62% of the global LNG demand (Kato 2014). Due to Fukushima disaster in March 2011, especially Japanese LNG imports skyrocketed, so the share of Asian LNG trade in global trade increased significantly and unexpectedly after 2011 (Figure 7(b)). This growth was fulfilled via spot LNG trade by Japan. Regarding GIIGNL data, the share of Japanese LNG spot trade increased 20% in 2006 to 33% of the global LNG spot trade in 2013.

The second vital LNG consumer is Europe. Although the European countries' demand has fallen since 2010, this region is still second most important destination for LNG. The Asia-Pacific and Europe account for 90% of total import of LNG with the balance going to South America (5%), North America (4%) and the Middle East (1%) (PFC Energy 2013).

Figure 7: Global LNG Imports by region between 2006 and 2013




(a) LNG import with long-term contracts




(b) Spot LNG import

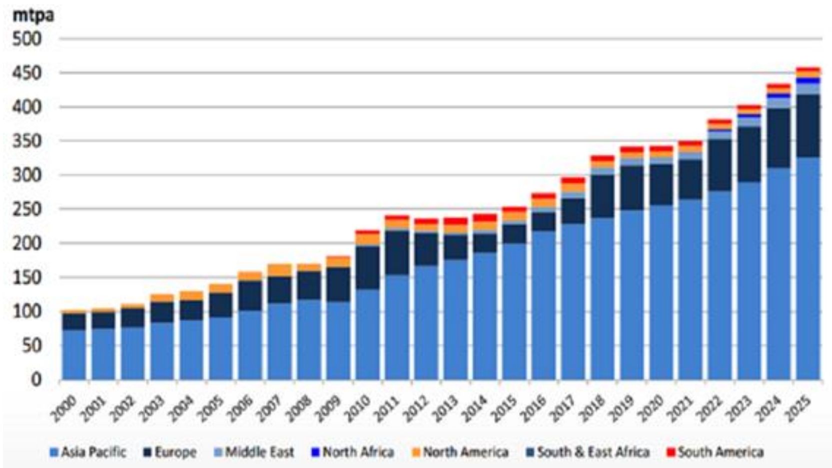
Source: GIIGNL

Countries located in North America were also the LNG importers to balance their indigenous natural gas markets. But an increase in unconventional gas production in this region has caused the reduction of natural gas imports. For this reason, 20% of the global

LNG demand accounted from this region in 2006, it plunged to only 4% in 2013. In the short term this reduction is expected to continue because of the shale revolution in the US.

Since 2011 the conditions of the global LNG market have been changed and tight market conditions have been experienced despite the considerable expansion of liquefaction capacity. In addition to tight market condition, considerable growth in Asia Pacific region ascended the LNG spot prices. This increase in the LNG spot prices affected the global LNG demand growth and LNG demand has stayed on a plateau (240 Mtoe per annum). Environmental policies, depletion of existing gas fields (i.e. reduction of indigenous natural gas production) and an increase in natural gas demand are expected to trigger the LNG trade in the near future. According to Wood Mackenzie's forecast (illustrated in Figure 8), until 2016 global LNG demand will be flat depending on oil and gas prices. If these prices change beyond expectations, graph given in Figure 8 also alters (Market Realist 2014). Regarding Figure 8, Asia Pacific is expected to be the key LNG consumer in the next decade with a growing demand due to having isolated LNG market with scarce resources. Secondly, although the EU's natural gas demand has tightened since 2011, its demand is forecasted to increase starting from 2017 because of plunging of Norway and Netherland's natural gas production and stricter environmental policies.

Figure 8: Projected global LNG demand




Source: Wood Mackenzie Q4 2013 LNG Tool[2] (Market Realist 2014)

Although future of LNG is seen as very bright by many analysis, recent plummeting prices of oil and gas can be game changer for the global LNG investment and trade.

### 2.1.3. Global LNG Supply

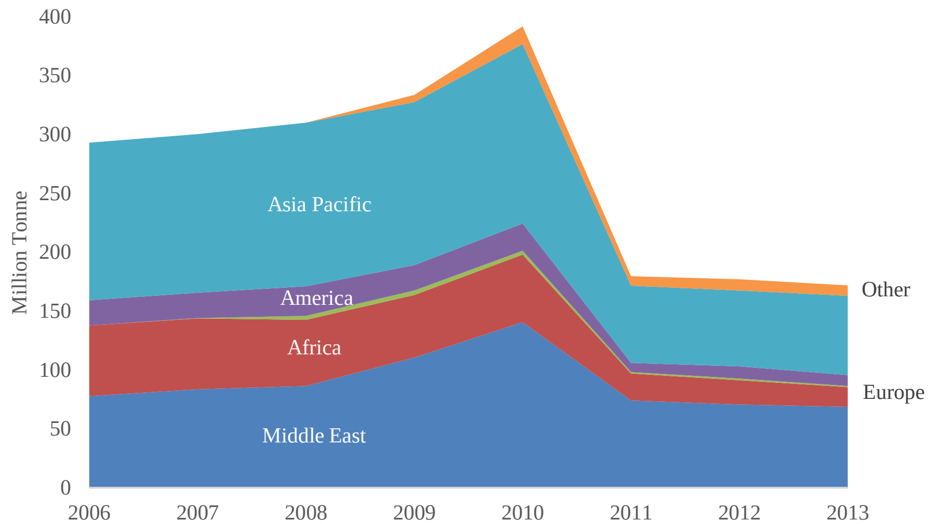
When key LNG customers (Japan South Korea, China and India) are considered, it is not surprising to see the primary LNG suppliers located in Asia Pacific and Middle East regions (Figure 9). Their proximity to key customers provides an advantage for these regions regarding prices.

As mentioned before, the LNG producers with distinct characteristics disseminate globally. Whilst some are key oil and gas producers such as Qatar in the Middle East, the others such as Trinidad & Tobago and Brunei with large stranded gas reserves are generally small but effective players in the global LNG market.

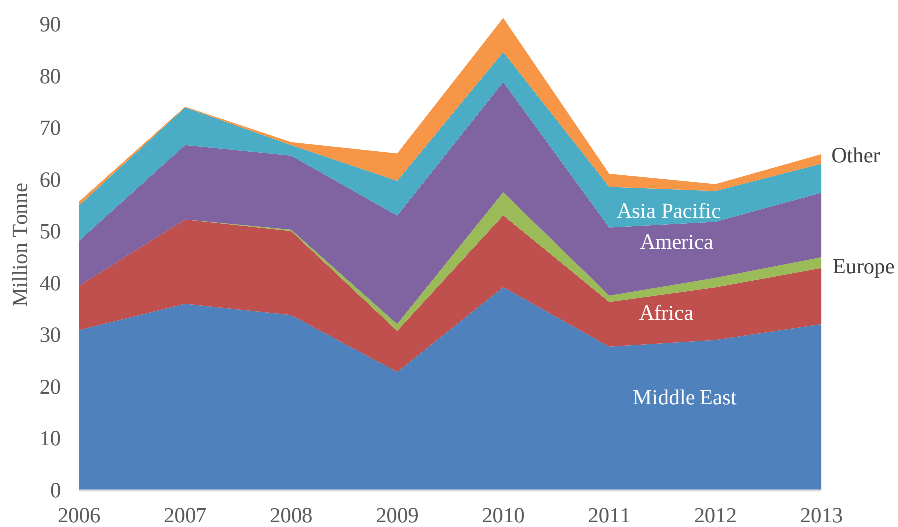
Although small portion of LNG has been re-exported by importing countries (like Spain, Portugal and Belgium), LNG is imported by counties where natural gas is extracted. For this reason, the main providers of LNG are Middle Eastern and Asia Pacific countries.

[2] Utilization rate of nameplate capacity is assumed as 85%.

Figure 9: Global LNG export by type between 2006 and 2013




(a) LNG import with long-term contracts



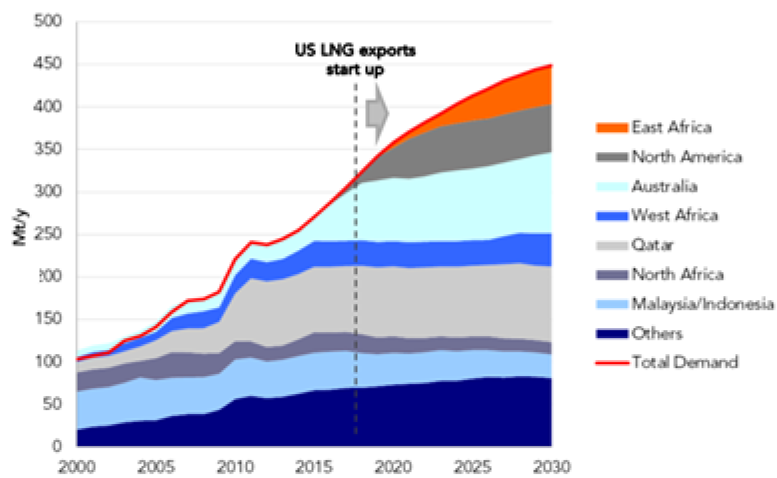

(b) Spot LNG export

Source: GIIGNL

Historically, the Asia-Pacific region was dominant in both long-term and spot LNG markets. New suppliers from Middle East (such as Qatar) led to the reduction of Asia-Pacific region's market share. In 2006 while Asia-Pacific supplied 40% of the global LNG demand, Middle East provided 31% of total. With starting a considerable LNG production by Qatar, Middle East became the world's largest LNG supplier in 2013. Regarding International Group of Liquefied Natural Gas Importers (GIIGNL)'s 2013 report, Qatar supplied 33% of the global LNG need.

According to Australian Government Bureau of Resources and Energy Economics (BREE), the global LNG supply is anticipated to expand rapidly to 2020 with a rate of 6.5 per cent per annum starting from 2013 and total LNG trade will reach to 370 Mtoe in 2020 (Australian Government Bureau of Resources and Energy Economics 2014).

Figure 10: Projected global LNG supply between 2000 and 2030




Source: Poten & Partners, November 2013

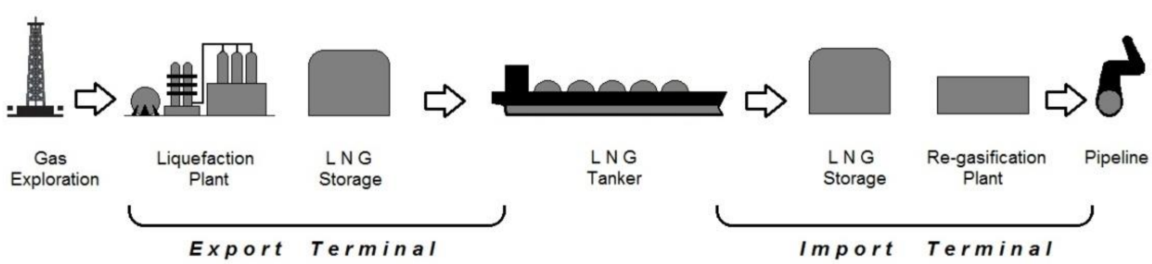
Figure 10 illustrates the global LNG supply between 2000 and 2030. Before 2020, new LNG suppliers, such as the US and Australia, are expected to be an LNG exporter to monetize their unconventional sources. With the entrance of new suppliers into the market, the amount of accessible LNG and competition in the market will increase rapidly, and this market transformation leads to lower the LNG prices. As a result, similar to other healthy energy markets, plunging LNG prices will trigger demand growth.

### 2.1.4. Global LNG Infrastructure

Regarding the International Energy Agency (IEA), natural gas could be the "Golden Age of Gas" due to an increase in natural gas demand by more than 50% that accounts for over 25% of the world demand in 2035. And IEA emphasized that as a result of growth in natural gas LNG would become the "glue" to link the global gas markets. These expectations in the global LNG market has made the LNG infrastructure more essential to gain higher benefits from the LNG trade than before in the foreseeable future, To maximize profit from the LNG trade the entire LNG value or supply chain, backbone of the LNG market, should be understood.

The LNG supply chain given in Figure 11, including conversion of natural gas to liquid and back to its gaseous state, requires multi-step processes. Subsequent to production of natural gas, gas is sent to a liquefaction plant by means of pipelines. In liquefaction facility, natural gas is firstly pre-treated to remove some hydrocarbons (propane, butane and ethane) and impurities (carbon dioxide and water). Under atmospheric pressure pre-treated gas is cooled down to -162 °C (260 °F) to shrink the volume of natural gas. This liquefied natural gas is transported via double-hulled tankers or truck to its destination country (Stage 3) where LNG is altered to its original state by regasification utility. At the final stage natural gas is transmitted to the pipeline system for delivery to end users.

Figure 11: The LNG supply chain




Source: Morosuk & Tsatsaronis, 2012

Due to the complexity of the LNG supply chain, considerable amount of investment and specialized knowledge is necessary to implement this chain successfully. Under the light of the recent technological innovations, the distribution of capital cost of each unit of the chain is given in Table 1. As shown in this table, liquefaction unit comprises 30-45% of all LNG investment. Depending on the distance between supplier and customer, transportation cost of LNG varies.

Table 1: LNG costs by supply chain segment

| Unit | | $/MBtu | % of Capital Cost |
|---|---|---|---|
| Upstream[3] | | 0.17-6.00 | 15-20 |
| Liquefaction | | 1.15-10.53 | 30-45 |
| Regasification | | 0.40-2.00 | 15-25 |
| Shipping (Round Trip) | Intra-Basin | 0.35-0.90 | 10-30 |
| | Cross-Basin | 1.00-2.50 | |

Source: Office of Fossil Energy, U.S. DOE and PFC Energy (U.S. Energy Information Administration (EIA) August 2014)

In the following part, recent status of supply chain units in the global LNG market will be explained.

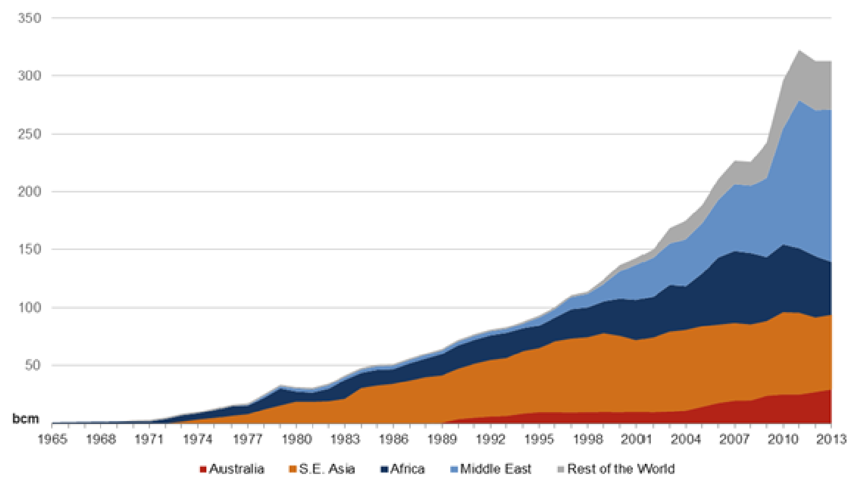
***2.1.4.1. Global LNG Liquefaction Terminals***

The liquefaction plants, generally consisting of parallel processing units (trains), are explained as the heart of the LNG projects and the largest single investment in the LNG value/process chain (Sakmar 2013). Long construction period, fluctuations of the global energy market, as well as the tremendous financial commitment[4], make the building of these plants a challenging business (Du and Paltsev November 2014).

[3] Upstream includes exploration and production (E&P), development, extraction, transportation, and storage of natural gas.
[4] Although at the outset of the 2000s the cost of building an LNG liquefaction plant was average 300 $/tpa, with the emergence of new innovations this amount has risen enormously and has been more than 1,000 $/tpa since 2010 (Du and Paltsev November 2014).

Commercially, first liquefaction plant started to produce LNG in 1964 and others have been on stream since then. As shown in Figure 12, while the LNG production increased slowly depending on the global LNG demand and the LNG infrastructure between 1964 and late 1990s, the growth in production has expedited after this period.

Figure 12: Global LNG production between 1965 and 2013



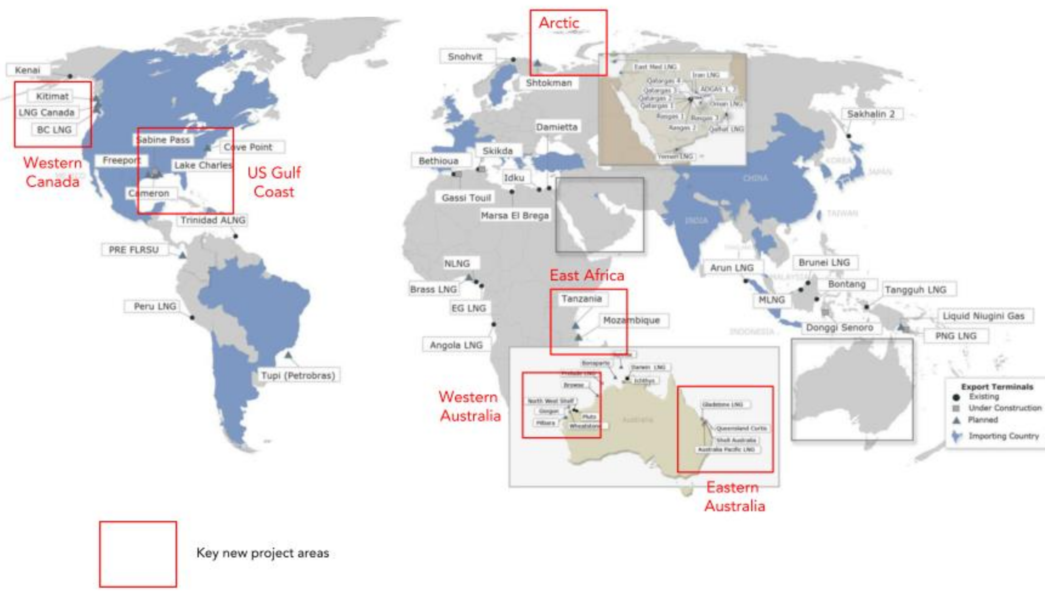

Source: BREE and Petroleum Economist (Australian Government Bureau of Resources and Energy Economics 2014)

As Figure 13 shows that more than 40 liquefaction plants (export plants), located in 17 countries, produce nearly 300 million tonnes per annum (Mtpa) (Songhurst February 2014). Now two-thirds of the LNG liquefaction capacity and production is held by Qatar, Indonesia, Australia, Malaysia and Nigeria. Until 2020 with the growth in Australian and Russian liquefaction capacities and the completion of new plants in the US (Figure 12), the total liquefaction capacity is anticipated to escalate with a rate of 36%[5] (International Gas Union (IGU) 2014). Similar to the growth in capacity, LNG production is expected to rise to 397 Mtpa in 2018 (International Gas Union (IGU) 2014) and approximately 600 Mtpa in 2025 (Songhurst February 2014).

[5] This rate corresponds the period between 2013 and 2018.

In addition to 16 under-construction liquefaction plants, 21 new plants[6] are planned to be constructed as of January 2015. But the plummeting of oil price starting in mid-2014 has made the future of planned plants gloomy.

Figure 13: Existing and new LNG liquefaction plants[7]




Source: Poten & Partners, November 2013

According to the global LNG demand, availability of feed gas or rising domestic gas demand, maintenance of plants, utilization rate of the LNG production plants vary from region to region. For example, in 2013 the utilization rate of the plants in Egypt and Algeria dropped significantly because of rising domestic demand; on the other hand, the utilization rate of plants in Qatar and Malaysia became more than 100% in that year to compensate the production loss resulting from Algeria, Nigeria and Egypt.

LNG producing countries have focused on developing their market share and minimizing their production costs so as to maximize their profits. To achieve these goals,

[6] This does not include suspended and cancelled plants.

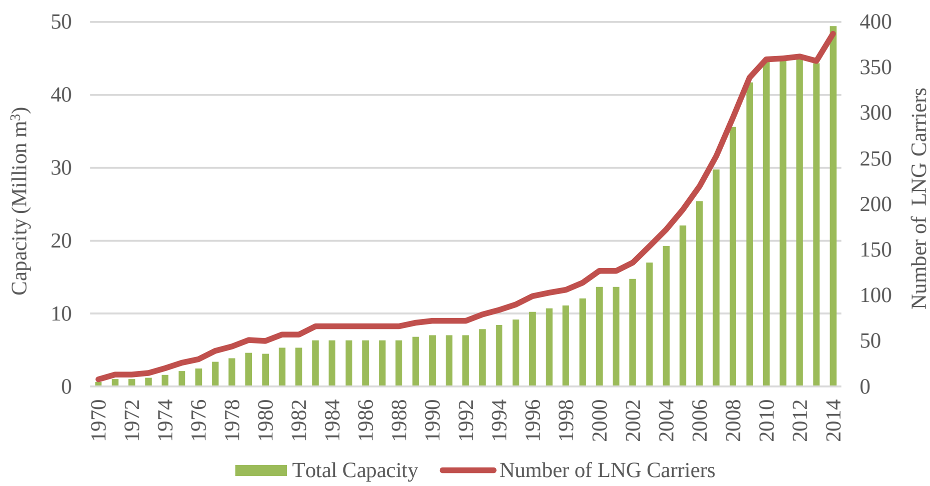
[7] A number of LNG liquefaction plants and their locations have not changed since 2013, so this illustration (Figure 13) can be used to exhibit current situation of the global LNG market as of January 2015.

they have utilized new technological innovations both in onshore and offshore. The advent of floating production units (FPU) and floating production and storage units (FPSU) in offshore projects has created a new horizon to the natural producers who want to monetize their resources more economically.

#### *2.1.4.2. Global LNG Shipping Fleet*

After liquefying natural gas, next step is to transport LNG to customers. Primary transportation modes are by sea and truck and in a few locations by rail (Japan) (International Group of Liquefied Natural Gas Importers (GIIGNL) 2009). The LNG trucking is most widely used for short-distance transportation to regasification facility by double-skinned tank trucks to decrease transportation cost and time. Depending on industry requirements, trucks with the capacity of 6 to 20 tons are generally used in many countries, such as the US, Japan, South Korea, the UK, Germany, Belgium, and Turkey. The LNG trucking, as well as transportation LNG via railroad, accounts for the smaller portion of total LNG delivery.

Figure 14: The capacity of LNG carriers between 1970 and 2014




Source: International Gas Union (IGU) (2014) and HIS Inc.

In contrast to transportation of LNG via truck or train, considerable amount of LNG is transported via sea in double-hulled LNG carriers. At the beginning of the 1970s, LNG shipment was a niche business, with significant growth in the global LNG demand[8] it has developed abruptly. As shown in Figure 14, while the number and capacity of the LNG carriers were only 8 and 649,224 $m^3$ respectively in 1970, 387 ships with the capacity of 49.43 million $m^3$ were in service in 2014.

Today, the LNG carriers ranging in size from 18,000 to 266,000 $m^3$ are used to transport LNG. Typically, vessels, with a capacity of 18,000 to 40,000 $m^3$, are utilized in Southeastern Asia to smaller terminals in Japan. Although common class of the LNG carrier with a capacity between 125,000 and 149,000 $m^3$ has been preferred, more recent addition to the fleet carrier has generally included the largest category including Q-Flex (210,000-217,000 $m^3$) and Q-max (261,700-266,000 $m^3$) (International Gas Union (IGU) 2014).

The main determinant of the charter rate is long- and short-term contracts. But some unexpected events such as the Fukushima disaster can lead to temporary large shipping prices.

Over the last decade the LNG demand of energy-hungry Asia Pacific countries especially China and India has spurred the number of LNG fleet. For this reason, new carriers with an average capacity of 164,000 $m^3$ have been ordered to be in service until 2018. With these carriers, total capacity of the global LNG carriers is anticipated to rise approximately 30% or a compound average annual growth rate (CAAGR) of 7% (Du and Paltsev November 2014).

[8] As a rule of thumb, 1-2 extra LNG carriers (depending on the size of carrier) should be in service for each additional 1 million ton of LNG production per year.

### *2.1.4.3. Global LNG Receiving/Regasification Terminals*

Regasification terminals are the final part of the LNG supply chain. In this part, LNG is gradually re-warmed to return it to its original state (gaseous state). These units have generally been located on shore. Over the last decade, new technological improvements, such as floating regasification unit (FSRU), have allowed prospective and current LNG exporting countries to gain fast and relatively cost-efficient access to the global LNG supply (Teekay LNG Partners L.P. 2015).

As shown in Table 2, 108 LNG regasification/receiving terminals including 18 floating units were in operation at the end of January 2015. The nameplate capacity of these terminals increased by a rate of 1.2% and became 985.8 Bcm/year (729.7 Mtpa). Proportional to regional LNG demand, 52% of global nameplate capacity of LNG terminals is located in Asia-Pacific region. In this region, the capacity of Japanese and South Korean terminals accounts for 78% of regional capacity.

Table 2: The Global LNG regasification terminals (As of Jan. 2015)

| Region | Nameplate Capacity[9] (Bcm/y) | # of Floating Regasification Terminals | # of Regasification Terminals (Total) |
|---|---|---|---|
| Asia-Pacific | 515.2 | 4 | 56 |
| Europe | 192.9 | 4 | 24 |
| Middle East | 20.5 | 4 | 4 |
| North America | 229.7 | 1 | 17 |
| South America | 27.5 | 5 | 7 |
| Total | 985.8 | 18 | 108 |

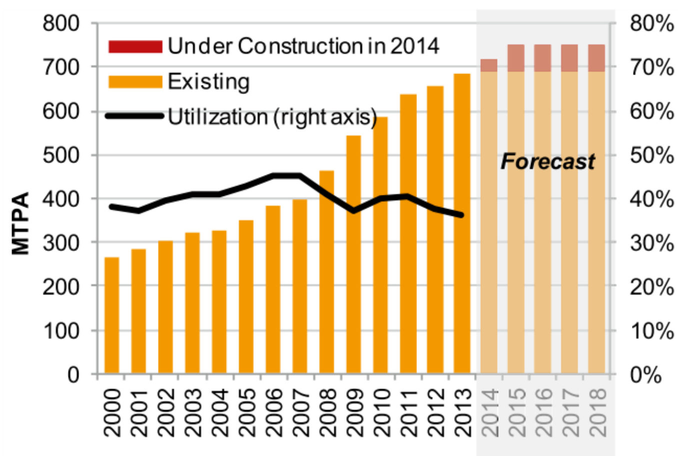
Source: GIIGNL, 2014 and Global Energy Info, 2015

Similar to the existing LNG regasification terminals, 16 new terminals[10], which are under construction as of Jan. 2015, are generally located in Asia-Pacific region. In

[9] Nameplate capacity is nominal/installed capacity of regasification facility.
[10] This does not include stalled and cancelled terminal projects.

addition to traditionally export-oriented Asia-Pacific region, investments on new regasification capacity expansion have started in some Middle Eastern countries. Although considerable amount of expansion in the capacity of LNG regasification terminals is planned to be constructed, many of them have been recently cancelled or suspended due to the unexpected decrease in oil prices and tight global LNG demand (Global Energy Info 2015).

Figure 15: The capacity of global regasification terminals between 2000 and 2018




Source: International Gas Union (IGU), 2014

Figure 15 illustrates the development of the capacity of LNG regasification terminals over the last two decades. Especially, in the last decade a large amount of idle regasification capacity has been observed due to the growth of regasification capacity and gradual decline in the LNG demand of some regions like North America and Europe. In the foreseeable future, developments in the LNG regasification terminals are directly related to the status of terminals in Asia-Pacific and North America. As planned, if many nuclear power plants restart, the LNG demand in Asia Pacific is anticipated to plunge significantly. Also, if the plummeting price of oil continues, this leads to narrow the price gap between Asia-Pacific and the other regions and to make the LNG trade less attractive for the exporting countries. Therefore, a considerable increase in the capacity of global LNG regasification terminals is not expected until 2018.

### 2.1.5. Global LNG Prices

In the global LNG market, dominance of long-term contracts between suppliers and buyers makes the global LNG market illiquid and also leads to form different price mechanisms in Asia Pacific, North America and Europe. Since the 2000s expansion of spot LNG market with a greater traded LNG volume, growth of portfolio traders[11] and liberalization of the natural gas markets in North America and the UK have increased the liquidity of the global LNG market. This market shift has caused the diversification of the LNG prices from region to region. Highly regionalized LNG prices mean that vessels carrying LNG to the same country can deliver LNG at considerably different prices (Australian Government Bureau of Resources and Energy Economics 2014). For this reason, unlike crude oil pricing, there is no global index to characterize the LNG price in the global LNG market.

To understand price mechanism in the LNG market, in the following sections, the regional LNG pricing and arbitrage opportunities will be explained.

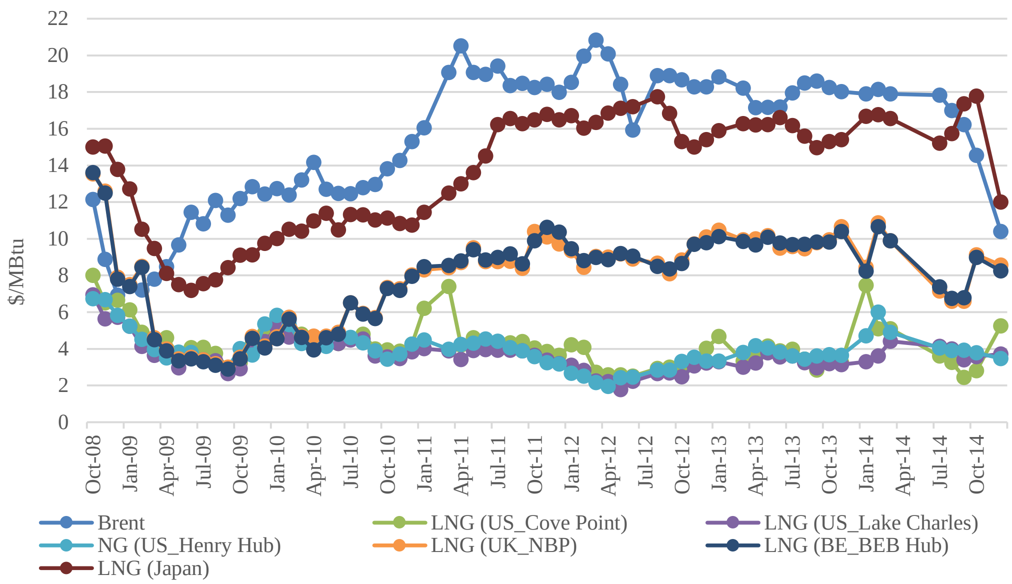
#### *2.1.5.1. Regional LNG Pricing*

On the supply side, the LNG exporting countries have preferred long-term contracts to mitigate the high investment risk related to the high capital costs of LNG supply chain. Similar to the LNG suppliers, the LNG importing countries have generally tended to sign up for long-term contracts to provide energy security. The evolution of contracting practices has become the fundamental determinant of the regional LNG prices. Since the mid-1980s the deregulation of the natural markets in North America and some of the

[11] Portfolio traders provide LNG from various suppliers in their portfolio.

European countries have taken place, competitive forces have affected the market structure and operation. For this reason, the mechanisms of the regional LNG prices have diverged from region to region.

Figure 16: Monthly prices of regional LNG, natural gas, and oil




Source: Federal Energy Regulatory Commission (FERC) and World Bank

As it is illustrated in Figure 16, the price mechanisms (oil-indexed, hybrid pricing and gas-to-gas pricing) lead to significant difference among the regions. While gas-to-gas pricing is resulted in the lowest LNG prices, oil-indexed pricing increases the economic burden on the LNG importing countries using oil-indexed pricing mechanism.

**2.1.5.1.1. Prices in Asia Pacific Countries**

Both historically and currently, Asia Pacific countries (such as Japan, South Korea, China and Taiwan), the key consumers in the global LNG market, have predominantly traded LNG by using oil indexed long-turn contracts lasting for 15 to 25 years. Almost all LNG prices in this region have been determined via the average Japan Crude Cocktail (JCC) that is the monthly average price for crude oil imports into Japan. Although JCC is estimated by taking into account the prices of 200-crude oil from 30 countries, it closely tracks Brent type crude oil price with a one- to two-month lag (Poten & Partners October 2010). The correlation between JCC and Brent oil can be seen easily from Figure 16. The general formula of LNG price[12] in Asia Pacific countries is as follows:

$$\mathbf{P(LNG)\ (\$/MBTU) = \propto + \beta(JCC)}$$

Where α and β are constant and JCC is in $/bbl.

To protect the LNG suppliers and customers, oil-indexed formula was revised but these modifications did not prevent the huge price gap among the regions. As shown in Figure 16, Asia Pacific countries paid average 16 $/MBtu for the imports of LNG in the years between 2011 and 2014, Europe and the US imported LNG with prices of 9 and 3 $/MBtu respectively.

As far as the spot LNG market in Asia Pacific is concerned, the LNG prices are generally benchmarked with Henry Hub (HH) in the USA and NBP in the UK.

**2.1.5.1.2. Prices in European Countries**

Unlike other regions, LNG has been traded via two different price mechanisms in European countries. While the pricing mechanisms in Asia Pacific and Europe (except the UK) are based on the market prices of oil/oil products or oil basket as a commodity to determine LNG prices, different commodity, natural gas, has been used to indicate LNG price in the UK National Balancing Point (NBP). Under this circumstances, when historical LNG prices in continental Europe are examined, prices in the UK have been generally lower than the prices in other European countries. For example, in February 2013 while the LNG price in the UK was 22 Euro/Megawatt-hour (€/MWh), it became 32.7 €/MWh in Italy and 36.3 €/MWh in Greece (European Commission 2013).

[12] This straight line relationship between the LNG price and JCC was used until late 1980s. And then it was modified to mitigate impacts of extreme oil prices on the LNG prices. Now, S-Curve relationship has been used to soften impacts of high oil prices.

Although the LNG prices in the UK have been determined regarding to balance of natural gas supply and demand, in continental Europe the LNG trade has heavily depended on long-term contracts in which prices have been indexed to crude oil and oil products. Generally, oil/oil product indexed contracts, the prices of gas oil and/or fuel oil are considered to estimate LNG prices. Most widely used formula in long-term European contracts is:

$$\mathbf{P_n = P_o + a[Av\,P_{FO}(n - x, \ldots, n - 1)] + b[Av\,P_{GO}(n - x, \ldots, n - 1)]}$$

Where a and b are a constant and multiplied by the average of last (x-1) month's fuel oil and gas oil prices respectively and the key variables in this formula change from contract to contract and are kept confidential by the parties (Rogers 2010).

Figure 16 shows the relationship among LNG prices in the natural gas hubs (Henry Hub, Cove Point and Lake Charles in the USA; NBP in the UK and BEB in Belgium). Luckily the European countries have not paid as much as Asia Pacific countries but they still spend more than North American countries during importing LNG.

Even though majority of the European LNG contracts have been prepared on the basis of oil-indexation, the region has increasingly moved towards the hybrid pricing system (particularly in the Northwestern part of Europe) (International Gas Union (IGU) 2014).

**2.1.5.1.3. Prices in North American Countries**

Until mid-1980s, the natural gas markets of North American countries were regulated and a significant portion of LNG exports to this region took place under long-term contracts where prices were either fixed with some provision for escalation over the contract life or were linked to prices of substitute energy sources, such as crude oil (Canadian Association of Petroleum Producers January 2014). But with the liberalization of gas market as a result of the deregulation of the gas markets, the market players moved away from long-term contracts to short term basis contracting mechanism. Transformation of the gas markets has led to dominance of gas-on-gas market based pricing (hub pricing) system in this region; and LNG like natural gas started to be priced by shifts in supply and demand (U.S. Energy Information Administration (EIA) August 2014). During the evolution of gas-to-gas pricing mechanism the natural gas prices at Henry Hub (HH) in Louisiana have used as a benchmark and LNG prices have estimated according to prices at this hub.

Gas-to-gas pricing mechanism has essential effects on the profitability and risks of a project due to the volatility and lower price of pipeline gas and expected high oil price (Du and Paltsev November 2014). As a rule of thumb, 1 MBtu of natural gas have approximately one-sixth of the energy content of one-barrel crude oil. As far as oil prices and the energy content relationship between oil and gas are concerned, average gas prices are expected to be 1/6 of the oil prices. But the market dynamics in North American countries have been beyond the expectations. The HH natural gas prices have been the lowest gas prices among other regions due to the inclusion of cheap and abundant natural gas into gas-to-gas mechanism. As a result of sudden increase in gas supply in the US, the HH gas prices plummeted compared to the previous periods. To illustrate, regarding the data from U.S. Energy Information Administration (EIA), the average gas prices in the HH in 2014 were between $ 4-5 per MBtu, whereas the same prices in 2008 were about $ 8-9 per MBtu[13]. When these prices in 2008 and 2014 are compared with the prices in other regions that do not produce shale gas, the prices were $ 11-12/MBtu in Europe and $ 18-19/MBtu in Asia Pacific in 2008. In 2014, average natural gas prices, considerably higher than the HH prices, were $ 8-9/MBtu in Europe and $ 13-14/MBtu in Asia Pacific.

---

[13] Whereas the oil prices were close to each other in 2008 (99.67 $/bbl) and 2014 (93.26 $/bbl), natural gas prices were different from each other due to the gas-to-gas pricing mechanism.

In the foreseeable future, considerable natural gas production in the US and its impacts on the LNG prices in North American natural gas market are anticipated to sustain. This production is also expected to make the US a net gas exporter instead of importing natural gas from other regions like South America and the Middle East. Consequently, the LNG markets in other regions will also be significantly influenced (Zelenovskaya 2012).

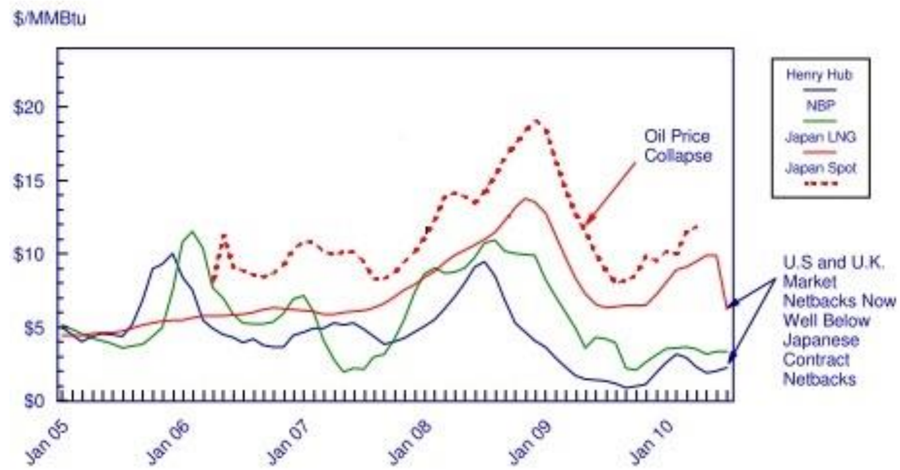
#### *2.1.5.2. Arbitrage in LNG Prices*

Requiring high capital-intensive investment has shaped the global LNG market and forced the LNG suppliers to sign a long-term contract to sell their products as a bulk. For this reason, only limited amount of LNG has been traded in the spot market. Since the 1990s an increase in the volume of spot and short-term transactions has provided arbitrage opportunities. Arbitrage[14] in the LNG market is defined as a physical cargo diversion from one market to another, which offers a higher price (Zhuravleva 2009). In the global LNG market two types of arbitrage mechanism are used: financial and operational arbitrage. The first contains the simultaneous purchase and sale of LNG to benefit from a price difference between the markets. As an alternative to financial arbitrage, operational arbitrage includes selling LNG cargo to hedge the risk of plant outages, overfull storage tanks or force majeure (Holleaux 2006).

Over the last five years, the price differences between three main regions have diversified significantly and prepared the ground for LNG arbitration for especially the Middle Eastern countries. For example, as shown in Figure 17, when LNG supplier from Qatar sent its cargo to Japanese contract market or the UK, it would have netted back \$7.16/MBtu or \$1.21/MBtu respectively. If this supplier delivered its product to Japanese spot market, the added margin would be \$9.54/MBtu (Jensen 2011).

[14] This trade mechanism is limited to a contract, and it is different from the LNG re-export.

Figure 17: Hypothetical LNG netback[15] to Qatar assuming 2008 costs and the availability of receipt terminal capacity[16] at market




Source: Jensen, 2011

Although arbitrage mechanism provides flexibility and highest netback to the suppliers, the structure of the global LNG market restricts frequent utilization of arbitrage mechanism due to existence of uncertainties in regional LNG pricing, contractual limitations, and technical barriers. In the near future, abundant LNG production as a result of entrance of new suppliers to the market is expected to increase arbitrage ability.

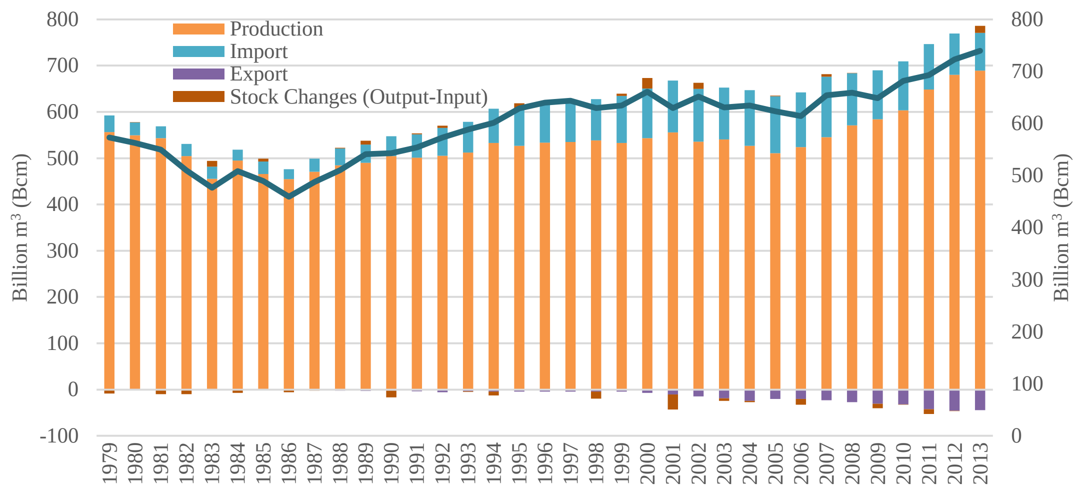
### 2.2. THE US LNG MARKET

The United States has one of the largest natural gas markets in the world and development of the US LNG market has been different from other countries regarding many aspects. Although considerable amount of natural gas was produced in the US, the US became the net gas importer at the beginning of the 1960s due to an increase in share of natural gas in the US energy mix. After peak gas production in 1973, the natural gas

[15] Netback price of LNG at a certain point (i.e. the border or the wellhead) is the comparative value of selling LNG to various markets and used to estimate the worth of producing gas. It is calculated by deducting the costs associated with getting LNG from certain point to the eventual point of sale from its competitive value at that point of sale.
[16] Receipt terminal capacity shows regasification capacity of the LNG terminal.

imports became flat in the following 15 years and then started to rise gradually until mid-2000s.

Figure 18: Changes in natural gas production, import (pipeline and LNG), export and the level of natural gas storage in the US (1979-2013)




Source: EIA

Figure 18 illustrates the balance between natural gas supply and demand in the US natural gas market[17]. Depending on the reduction in indigenous natural gas production, natural gas imports have increased. After 2000, they have started to grow. Because of the shale gas boom in 2007, whereas natural gas imports have shrunk, natural gas exports have risen.

High oil prices, as well as technological advancement (horizontal drilling and hydraulic fracking) used to extract natural gas from gas reservoirs, have provided incentives to emerge the production of shale gas. Since 2010, the US has become the largest natural gas producers in the world by being the frontrunner in the shale gas extraction in mid-2000s. As a result of the shale gas boom, an increase in domestic gas production has

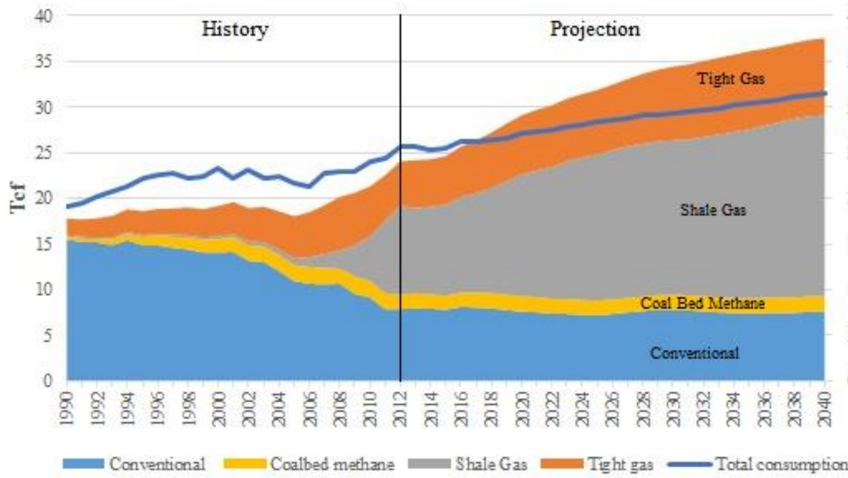
[17] Consumption = Indigenous Production+ Import +Stock changes-Export. In Figure 18, values calculated regarding to this formula are different from natural gas consumption due to the statistical deviations.

caused a continuous decline in LNG imports, the closure of LNG import plant in Alaska, and an increase in US natural gas exports. To illustrate, according to data from the US Energy Information Administration (EIA), while the US in 2007 imported 19% of its natural gas demand, this share dropped to 10% in 2013. The US natural gas exports have risen and reached to 6.5% of the US natural gas production in 2013.

The surge in the shale gas production has led to lower gas prices considerably and this reduction has created an encouragement in domestic natural gas demand and competition among coal and natural gas for electricity generation; and it has impacted the US energy mix and energy independence. As a result of the shale gas production, the share of natural gas in total US energy mix changed from 22.9% in 2007 to 26.9% in 2014 because of utilization of natural gas heavily on electricity generation and industrial sector such as metal manufacturing, chemicals and petrochemicals.

Over the last decade the shale gas revolution has become a game changer in the US energy market and now the US is planning to be a significant LNG exporter to sell its oversupply gas. As shown in Figure 19, the shale gas production, accounting for nearly 1% of US gas production in 1990, is anticipated to rise 53% of total gas production in 2040. When the US natural gas consumption is predicted to grow with a CAAGR of 0.74%, the US could import 6 Tcf/year in 2040. Expectation of considerable amount of gas supply and current low natural gas prices at the HH make the US an attractive natural gas exporter.

Figure 19: US Natural gas consumption and production by source between 1990 and 2040 (Reference Case Scenario)




Source: Annual Energy Outlook (U.S. Energy Information Administration (EIA) May 2014)

In addition to excessive amount of natural gas production and comparatively low natural gas prices, the existence of extensive infrastructure provides many advantages to the US to be a gas exporter in the near future. In the US, existing regasification facilities can be utilized as a liquefaction plant by investing small amount of money. For this reason, several companies have focused on this type of investment to minimize initial expenditure of liquefaction plants.

Although the shale gas boom has provided many opportunities to the US, some requirements, such as retrofitting exiting infrastructure and adapting or amending existing regulations, should be fulfilled to realize US LNG exports. In the following part of this section, current status of US LNG infrastructure, barriers for US LNG exports and the effects of them on both domestic and exogenous energy markets will be discussed.

### 2.2.1. The US LNG Infrastructure

Prior to the revolution of shale gas in the US, significant amount of LNG was imported by the US. As a result of a decline in US conventional natural gas production and an increase in US natural gas demand several US LNG import terminals were constructed. Table 3 given below shows that 11 existing LNG import terminals in the US with the capacity of 18.5 Bcf/d.

Table 3: Import capacity of existing U.S. LNG terminals[18] (As of February 2015)

| **Terminal/Location/Operator** | **Capacity (Billion std. $m^3$/day)** |
|---|---|
| Everett, MA, GDF Suez- DOMAC | 29.3 |
| Cove Point, MD, Dominion-Cove Point LNG | 51 |
| Elba Island, GA, El Paso-Southern LNG | 45.3 |
| Lake Charles, LA, Southern Union-Trunkline LNG | 59.5 |
| Offshore Boston, MA, Excelerate Energy- Northeast Gateway | 22.7 |
| Freeport, TX, Cheniere/Freeport LNG Dev. | 42.5 |
| Sabine, LA, Cheniere/Sabine Pass LNG | 113.3 |
| Hackberry, LA, Sempra-Cameron LNG | 51 |
| Offshore Boston, MA, GDF Suez-Neptune LNG | 11.3 |
| Sabine Pass, TX, ExxonMobil-Golden Pass (Phase I&II) | 56.6 |
| Pascagoula, MS, El Paso/Crest/Sonangol-Gulf LNG Energy LLC | 42.5 |
| Total | 523.9 |

Source: Data from Federal Energy Regulatory Commission (FERC)

An exponential increase in the shale gas production has altered the decline in US natural gas production and reduced the need for importing LNG. Before the shale gas boom, total LNG import volume in the US reached to 800 Bcf in 2007 and dropped to only 100 Bcf in 2013. Some terminals such as Freeport in Texas, Sabine and Hackberry in Los Angeles have applied to receive re-export permission.

Regarding the projection of US natural gas production updated by the US Energy Information Administration, US gas extraction will exceed gas demand before 2020 and 6 Tcf per annum of LNG can be imported by the US in 2040 (U.S. Energy Information

[18] Penuelas in Puerto Rico (PR) is not shown in the Table 3 because it cannot serve or affect deliveries in the Lower 48 US states.

Administration (EIA) May 2014). Considerable growth in natural gas surplus in the foreseeable future has provided some opportunities for new LNG investments. Firstly, some investors applied to DOE to retrofit existing LNG regasification terminals generally located in the east coast of the US. Table 4 shows the applications to DOE so as to export domestically produced LNG to FTA and non-FTA countries. According to this table, total capacity of all application is 2,264.5 million $m^3$ (Mcm)/day (80 Bcf/d).

Table 4: Export capacity of proposed and approved U.S. LNG terminals (As of Dec. 31, 2014)

| **Company** | **Capacity[19] (Mcm/day)** |
|---|---:|
| Sabine Pass Liq., LLC | 62.3 |
| Freeport LNG Exp., LP and FLNG Liq., LLC[20] | 90.6 |
| Lake Charles Exports, LLC | 56.6 |
| Carib Energy (USA), LLC | 2 |
| Dominion Cove Point LNG, LP | 50.1 |
| Jordan Cove Energy Project, LP | 56.6 |
| Cameron LNG, LLC | 48.1 |
| Other Projects | 1,898.2 |
| **Total** | **2,264.5** |

Source: Data from U.S. Dept. of Energy (DOE)

[19] It includes the capacity of terminals that were approved to export to both FTA and non-FTA countries.
[20] Freeport LNG Expansion, LP and FLNG Liq., LLC has two different applications approved by both FERC and DOE.

Figure 20: U.S. LNG liquefaction terminals approved by DOE to export to Non-FTA countries (As of Dec. 31, 2014)


Source: Data from U.S. Dept. of Energy (DOE)

As of December 31, 2014, 48 applications were submitted to DOE for the rights to export LNG to both FTA and non-FTA countries. As shown in Figure 20, only 8 applications were granted LNG export permits. Among these permits, Sabine Pass, the first bi-directional facility in the world, is anticipated to initiate operations in late 2015, with 11% of its export capacity serving the spot market, and the remaining that will be sent to Korea Gas, GAIL India, and BG Group54 under the long-term contracts.

### 2.2.2. Barriers for the LNG Export

Although the LNG export would be very advantageous for the US and the global economy, there are several bottlenecks that can impede the realization of US LNG exports or cause significant reduction in profitability.

#### *2.2.2.1. Financial Drawbacks*

The oil prices, main determinants of LNG prices in Asia Pacific and some European countries, have been declining steadily since June 2014 because the gap between the LNG prices in the US and these regions has narrowed. As of February 1, 2015, they have fallen by nearly 60% and made the LNG trade from the US uneconomic by reducing the US competitiveness against traditional sellers, such as Qatar and Australia.

Plummeting oil price has also threatened to the proposed US liquefaction terminals. When considering the requirement of huge capital intensive investment for constructing LNG liquefaction terminal, dropping oil prices have been increasing the cancelation risk of greenfield LNG projects[21] due to the existence of many financial uncertainties. Depending on oil prices, plunging oil-linked LNG prices do not support profitable LNG exports from the US. To illustrate, in 2015 it is anticipated that the many US greenfield projects may be postponed or sold if they cannot attract customers or necessary development capital[22] (Weems and Hwang 2015).

In the long-run, dropping natural gas prices will hurt the production of shale gas generally used as a feed-gas for LNG production. This reduction may also harm LNG investments due to possibility of feed gas scarcity.

#### *2.2.2.2. Environmental Problems*

Regarding EIA's Annual Energy Outlook 2014, US natural gas production is anticipated to rise from 24.06 Tcf in 2012 to 37.54 Tcf in 2040 by increasing 1.6% annually. This long-term growth in natural gas production is expected to come from the shale gas development. As far as substantial carbon emissions of the shale gas production (i.e. fugitive methane) and the environmental impacts of hydraulic fracturing like water contamination, and also an increase in seismic activities are concerned, the growth in the shale gas production will make environmental regulations much stricter.

---

[21] Greenfield LNG projects include the construction of all facility. Unlike greenfield projects, existing LNG facility is upgraded in brownfield projects. For this reason, the capital expenditure of the LNG projects varies substantially among greenfield and brownfield developments.

[22] Plunging LNG prices cause to decrease high profitability expectations of greenfield projects.

For the LNG production, the price of feed-gas is one of the essential parameters to expand profitability of LNG trade. Stricter health, safety, and environmental regulations will lead to spike in the overall cost of shake gas production and therefore the price of feed gas and the amount of exported LNG will inflate.

#### *2.2.2.3. Current US Policies on the LNG Export*

Under the Natural Gas Act, Department of Energy (DOE)[23] was authorized to export LNG. Exporting LNG to the countries with which the US has Free Trade Agreement (FTA) is directly considered in the public interest and the application for exporting LNG to such countries are approved without any modification or delay (Bobbish 2014). As of February 2015, the US has FTAs with twenty countries: Bahrain, Australia, Canada, Chile, Colombia, Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, Israel, Jordan, South Korea, Mexico, Morocco, Nicaragua, Oman, Panama, Peru and Singapore.

Unlike countries with FTAs, if domestically produced LNG is imported to countries without such FTAs, exporting companies should apply to DOE which analyzes the effects of LNG exporting process on the public interest regarding indigenous natural gas production needs and broader macroeconomic indicators. In this procedure, some flaws that harm possible US LNG exports exist. First drawback is opaque parameters of public interest. During assessment of an application, DOE has looked to a broad range of factors, such as domestic need, domestic natural gas supply, balance of trade and geopolitical considerations (Duncan 2015). Existence of some rebuttable presumptions, unfortunately, can impact DOE's final decision and lead to unexpected results.

Although the US recently has FTAs with twenty countries, certain countries such as Japan, Taiwan, South Korea, China and the EU countries are not in the list. Therefore, LNG exports to these countries requires DOE's approval.

[23] DOE regulates LNG as a commodity in international trade.

Prior to applying to DOE, companies planning to export LNG should have the approval of the Federal Energy Regulatory Commission (FERC)[24] to construct or operate an LNG terminal since the construction and operation of the LNG terminals have more significant impact than the exportation of LNG as a commodity (Brown 2014). Review and approval processes by DOE and FERC take between 18 and 30 months[25] and cost $100 million for proposals to export LNG to countries with which the US does not have FTAs (Collins 2015). This long approval period has caused to hamper the competitiveness of US projects and to rise project cost unexpectedly.

The other vital hardship is the opposition of indigenous natural gas consumers such as Dow Chemical that uses significant quantities of natural gas. Consumers have stressed that LNG exports would cause domestic natural gas price spike and hurt the US economy.

#### *2.2.2.4. Uncertainties in Panama Canal Expansion*

New LNG projects in the US are mainly located to the eastern coast of the US and many export projects are relying on transit through the Panama Canal to access Asia Pacific countries. The expansion of the canal[26] will provide significant amount of time and cost savings for the US LNG exporters. But there are some uncertainties on this project. First bottleneck is insufficient capacity of the canal even after the expansion. Only six ships of any type will be able to enter the canal in each direction in a daily basis (Goncalves 2014). According to Wood Mackenzie's expectations, around 30 million tons of LNG will follow to Asia Pacific region via the Panama Canal (Wood Mackenzie 2014). Carrying this amount of LNG from Atlantic to Pacific will result in serious congestion in the canal. With

---

[24] FERC reviews applications as National Environmental Policy Act (NEPA) agency and regulates the design, construction and operation of a facility and its impact on the surrounding environment.

[25] To expedite DOE's and FERC's review processes, "LNG Permitting Certainty and Transparency Act" was introduced to the 114th Congress. Regarding this regulation, DOE's approval period will not exceed 45 days after the completion of NEPA review.

[26] In spite of the fact that completion of canal expansion project was planned at the end of 2014, the expansion of the Panama Canal has not been finalized. The expected date of completion is in January 2016.

an increase in tanker traffic in the canal, its physical restriction will most probably elongate the transportation period.

Another key uncertainty is the toll rate applied after the expansion of the canal. Recently, Panama Canal Authority proposed toll rate as approximately $700,000 round trip for 173,000 $m^3$ ship. Regarding King&Spalding's estimation, if the proposed toll rate with some extra costs is applied, the transportation cost of the LNG carrier from the US to Japan is $1.75 per MBtu versus $2.5 per MBtu via the alternative route around the Cape of Good Hope (Weems and Hwang 2015).

In the foreseeable future, the concerns related to cost and congestion impact both the US and importing countries. Asia Pacific countries may prefer to import LNG from other sources, such as Qatar or Australia. To mitigate negative effects of the Panama Canal, the US companies exporting LNG can elect to alternative routes to Asia Pacific countries.

### 2.2.3. Impacts of the US LNG Exports

Regarding EIA projection given in Annual Energy Outlook 2014, US LNG exports to both FTA and non-FTA countries have sparked many debates on the benefits of US LNG exports not only in the US but also in possible importing countries like the EU members.

#### *2.2.3.1. Domestic Energy Market*

The US natural gas producers have been very ambitions to take advantage of tremendous price differentials between the US and foreign markets. But US LNG exports are a double-edged sword for domestic energy market and the US economy. Whereas it provides many advantages to the US energy market and economy, it can create some undesired problems.

To estimate the effects of US LNG exports on the US economy, many studies were carried out by considering several scenarios. One of the most contentious studies conducted by NERA Economic Consulting[27], the private consulting firm, conveys two outcomes. First one is that US LNG exports are very sensitive to both internal and external factors (such as supplies of LNG from other regions, the global LNG prices, and the cost of producing natural gas in the US) that make it hard to predict. Secondly, US LNG exports provide net positive macroeconomic takeaways for each scenarios[28] (Montgomery and Tuladhar 2013). As a conclusion, NERA emphasized that the US would obtain net economic benefits from LNG exports and they would increase as the level of LNG exports increased.

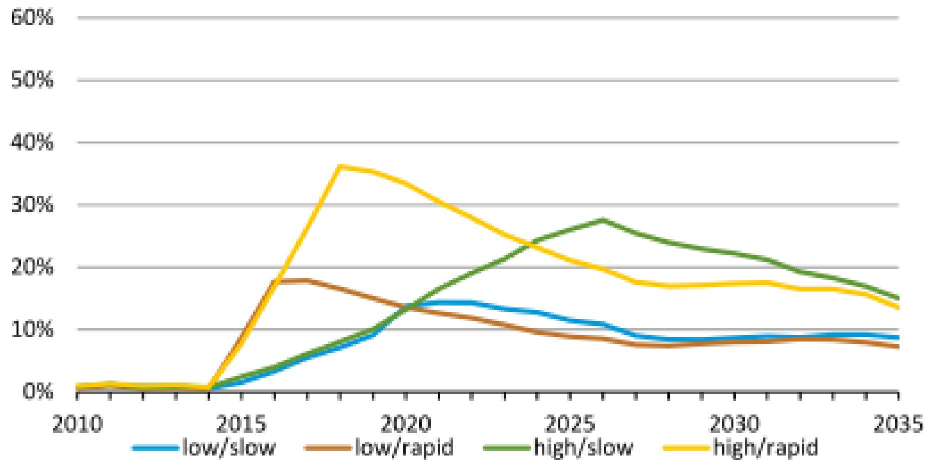
Exporting LNG directly supports thousands of US jobs in engineering, manufacturing, construction and operation of the export infrastructure. Depending on an increase in the LNG production, the shale gas production will be triggered and this will create additional jobs in the upstream part of the gas industry (America's Oil and Natural Gas Industry 2014).

On the other hand, US LNG exports will rise US natural gas wellhead prices in all scenarios analyzed by the EIA. In Figure 21 the impacts of US LNG exports on natural gas wellhead prices can be seen easily. The pattern of price increases changes according to the ultimate level of exports and rate at which increased exports are phased in. While sudden rise is observed for “high/rapid” scenario, moderate growth occurs at “low/slow” scenario. Price settlement for each scenario is nearly seen after 2030.

[27] The study was first conducted in 2012 and updated in February 2014 to verify and extend the takeaways of the previous study.

[28] 16 scenarios, which are incorporated different assumptions about US natural gas supply and demand outlook and LNG export levels, were analyzed by the NERA.

Figure 21: Natural gas wellhead price difference from Annual Energy Outlook (AEO) 2011 Reference Case with different additional export level imposed[29]




Source: Data from U.S. Energy Information Administration, National Energy Modeling System (U.S. Energy Information Administration (EIA) 2012)

Although price spike is observed in the short-term period as a result of NERA's optimistic analysis, this increase will be restricted by the global LNG market in the mid- and long-term period. When US LNG prices rise, exporting countries will be reluctant to purchase US export and this will pressure LNG prices.

#### *2.2.3.2. The Global Energy Market*

If US LNG exports are realized over the next few years, many importing countries as well as the global energy market are benefited in the aspect of geopolitical issues, regional LNG prices and GHG emissions (climate change).

##### **2.2.3.2.1. Geopolitical Benefit**

The US LNG exports can help the US allies especially the countries in Europe and Asia Pacific to diversify their energy sources. In the Central and Eastern Europe, countries

[29] Scenarios are: low/slow (6 Bcf/d, phased in at a rate of 1 Bcf/d per year), low/rapid (6 Bcf/d, phased in at a rate of 3 Bcf/d per year), high/slow (12 Bcf/d, phased in at a rate of 1 Bcf/d per year) and high/rapid (12 Bcf/d, phased in at a rate of 3 Bcf/d per year).

have heavily depended on natural gas imports from Russia. Utilization of natural gas imports as a political weapon by Russia against the EU has harmed the natural gas markets both in country and regional bases. The LNG exports from other sources, such as Qatar, Algeria and Nigeria, have the EU members allowed to cut their dependence on Russia for natural gas. To illustrate, the LNG exports to the EU countries have led to the reduction in share of Russian gas from 75% in 1990 down to 34% in 2013 (Cunningham 2013). In addition to the diversification of resources, US LNG exports will support the EU countries to achieve their 20/20/20 goals to reduce their greenhouse gas emission in the foreseeable future.

Similar to the EU members, key LNG consumers in Asia Pacific, such as Japan and South Korea, are interested in the US LNG to improve their energy security and economies by importing LNG from the US with a reasonable price.

**2.2.3.2.2. Impacts on the Regional LNG Prices**

After implementing US LNG exports, low natural gas prices in the US have started to force main natural gas and the LNG exporters to review their contracts signed with importing countries. To illustrate, Russia accepted spot prices for natural gas exports to the EU countries instead of oil-linked prices (Cunningham 2013). Initiation of US LNG exports will increase pressure on suppliers to re-negotiate their natural gas prices. For this reason, in the short-term after starting LNG exports from the US, the LNG prices in Europe and Asia Pacific are expected to plunge.

The other prospective impact of US LNG exports is the formation of more liquid LNG market. Depending on the volume of LNG imported via both long-term contracts spot prices will reduce. To illustrate, in the study conducted by Deloitte in 2013, impacts of US LNG exports on the LNG price in other regions were analyzed; and Deloitte found that a decrease in the rate of price in importing countries would be very fast. This reduction in LNG prices will reduce the burden on the economies of the LNG importing countries.

#### 2.2.3.2.3. Impacts on GHG Emissions

Although production of natural gas is a controversial because of environmental concerns, US LNG exports are believed to have positive effects on the reduction of GHG emissions of the developing and developed countries. In foreseeable future, Chinese LNG demand is expected to increase rapidly to decrease its GHG emissions. Similar to China[30], LNG need in Germany is anticipated to rise due to the German plans including the replacement of nuclear with natural gas. Lower global LNG prices due to US LNG exports will help countries who want to restructure their energy markets to reduce emissions. Under these circumstances, US LNG exports will encourage importers to displace dirtier sources of energy like coal and crude oil.

## 2.3. THE EU LNG MARKET

The European Union (EU) is a net natural gas-importing region. In 2012 the EU imported 66% of natural gas supply (European Commission (EC) 2014). In spite of its high import rate, natural gas as an important part of the EU's energy mix is made up only 24% of the EU's primary energy consumption in 2012. Because of the EU's stringent policies to de-carbonizing its energy system, the EU natural gas demand has increased abruptly over the last decade and the EU natural gas market has become the second largest natural gas markets after the US natural gas market.

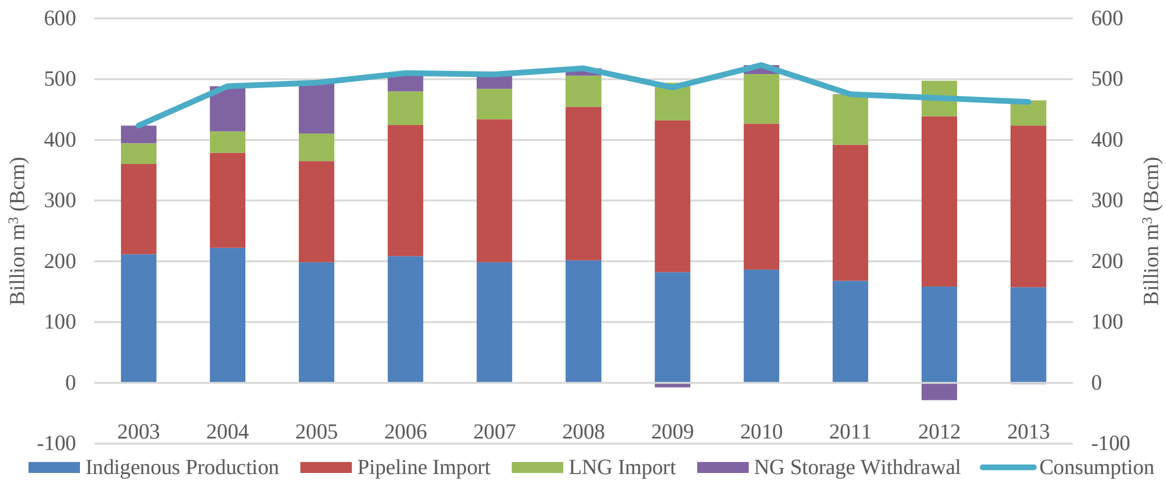
Continuous increase in natural gas demand in the EU countries has been fulfilled by indigenous gas production, natural gas imports and underground storage of natural gas. Even though natural gas has been mainly produced by the Netherland, it has not been

[30] Although China is thought as a major LNG market for US LNG exports, in the medium to long run, the US does not plan to establish FTAs with this country (Hufbauer, Bagnall and Muir 2013).

sufficient to feed the EU's gas glut. To narrow the gap between gas demand and domestic gas production well connected pipelines from main natural gas suppliers (Russia, Norway and Algeria) with a capacity of 530 Bcm/year have been utilized to import natural gas. In addition to pipelines, natural gas has been stored in 130 underground gas storage (UGS) facilities with the capacity exceeding 90 Bcm (European Commission (EC) 2014).

In the supply side, declining gas reserves in the North Sea and the Netherlands, increased production costs, and the EU's desire to diversify the natural gas suppliers (i.e. to decrease dependence to Russia) have been strengthening the role of LNG in the EU natural gas market since the 2000s. Also, in the demand side, the deregulation of the EU's energy markets and transformation of energy sector especially power generation to the utilization of low carbon intensive fuels have supported LNG exports to the EU. Figure 22 shows the balance between natural gas supply and demand in the EU countries in the period between 2003 and 2013. While total domestic natural gas production was 212 Bcm in 2003, it plummeted with a rate of 2.7% per year and became 157 Bcm in 2013. Although total natural gas demand in the EU grew rapidly between 2003 and 2008, it reached its highest amount in 2010. Unfortunately, after 2010 it decreased 9% in 2011 and became flat between 2011 and 2013.

Figure 22: Natural gas production, imports (net) (pipeline and LNG) and storage withdrawal in the EU countries (2003-2013)




Source: Eurogas, Author's Analysis

Depending on reduction in indigenous production, natural gas imports inflated starting from 2003 and the EU dependence on natural gas imports increased to nearly 70% most of which is pipeline gas coming from Russia. Over the last decade, natural gas has been heavily imported via pipelines and its prices were formed regarding long-term contracts varying from 10 to 35 years in the EU countries. But growing tension between Ukraine and Russia, which caused natural gas supply disruptions in 2006, 2009 and 2014, has made the EU energy security one of the priorities of the European Council. To mitigate impacts of high Russian gas prices and Russian political pressure on the EU, alternative form of natural gas delivery was started to be discussed by the EU and its allies. To illustrate, at the EU-US summit held in March 2014, energy cooperation[31], providing ground for exchanging energy across the Atlantic, was on the table (De Micco 2014).

When taking the EU's massive reliance on pipeline gas into account, additional pipeline gas is not seen as a good solution as delivery of LNG via cargo ships to the EU

[31] In this summit, the LNG export was shown as a solution for the long-term period. But in the short term it was emphasized that the EU countries should make better use of their indigenous resources by lifting environmental bans on shale gas and by not phasing out nuclear power plants.

from various sources. Despite high LNG prices and the requirement of additional infrastructure investment, LNG seems as one of the best options.

### 2.3.1. Structure of the EU LNG Market

Contrary to the US natural gas market, liberalized and operating based on supply and demand balance, the EU gas market generally depends on long-term contracts with take-or-pay obligations. Also, the EU has a fragmented market structure regarding country-based policies and markets' dynamics. While the Central and Eastern European countries mainly utilize carbon intensive solid fossil fuels, the northwestern European countries (including Italy) prefer to use less carbon intensive fuels like natural gas to achieve the 20/20/20 targets[32]. In the northwestern part of Europe, the basics of the market are: growing hub-trading (like NBP), liquidity, and spot-based pricing. But this situation is not the same in the Central and Eastern Europe with illiquid market and oil-indexed natural gas prices (Boersma, et al. October 2014).

Divergence between country-based energy markets is one of the major challenges to function the common energy market, maintain the security of energy supply in the EU and to promote energy efficiency and renewable energy. For this reason, the EU legislations and policies have become very active in the EU natural gas market.

Three consecutive directives (Directives 1998/30/EC, 2003/55/EC and 2009/72/EC) gradually created a common framework for liberalizing the EU gas market, based on the general EU rules and promoting competition (Goldthau 2013). In these directives third-party access[33] to gas infrastructure (such as LNG receiving terminals) was regulated to provide fair, transparent and non-discriminatory gas market (King & Spalding

---

[32] These targets have three objectives: reducing the EU GHG emissions from 1990 levels by 20 percent, raising the share of the EU energy consumption produced from renewable energy sources to 20% and improving the EU's energy efficiency by 20 percent by 2020 (Goldthau 2013).

[33] Adaptation of third-party access to LNG receiving terminals varies from member to member. To comply with the EU regulations different approaches were utilized by the member countries.

2006). Liberalized EU natural gas market by the directives has triggered greenfield LNG investments in the EU countries and the utilization of arbitrage process by the LNG seller and buyer.

In addition to three-directive package, some vital policy measures were taken to stimulate and financially support the development or establishment of trans-European energy infrastructure. These measures became very helpful to the EU natural gas market to be more efficient and more resilient in the face of a potential supply disruption. Regarding the data from Gas Infrastructure Europe (GIE) total 15 new LNG regasification facilities with the capacity of 92.2 Bcm/year were added and 7 terminals were under construction between 1998 and 2014[34].

In the EU market nine natural gas hubs are operated. Regarding to data from International Gas Union (IGU), after structural transformation in the EU natural gas market by the EU policies, gas-on gas competition rose from 15% in 2005 to 45% in 2012 and oil-indexed pricing mechanism plunged from 78% to 50%. As a result of reduction in oil-indexed pricing market liquidity also escalated (Institute of Energy for South-East Europe (IENE) July 2014).

[34] In this period the EU LNG regasification capacity has doubled. As of February 2015, the EU's total regasification capacity was 192.2 Bcm/year.

Table 5: The EU natural gas hubs

| **Physical Hubs**[35] | **Country** | **Hub Type** |
|---|---|---|
| Central European Gas Hub (CEGH) | Austria | Transit[36] |
| Zeebrugge (ZEE) | Belgium | Transit |
| Virtual Hubs[37] | Country | Hub Type |
| GasPool | Germany | Transition[38] |
| National Balancing Point (NBP) | United Kingdom | Trading[39] |
| Net Connect Germany (NCG) | Germany | Transition |
| Points d'Echange Nord (PEGS) | France | Transition |
| Points d'Echange Sud (TIGF) | France | Transition |
| Punto Di Scambio Virtuale (PSV) | Italy | Transition |
| Tile Transfer Facility (TTF) | Netherlands | Trading |

Source: Data from Institute of Energy for South-East Europe (IENE)

Table 5 illustrates the physical and virtual natural gas hubs in the EU members. Whereas natural gas is physically traded at only two points (ZEE and CEGH), natural gas is solely traded financially at the others.

### 2.3.2. The EU LNG Trade

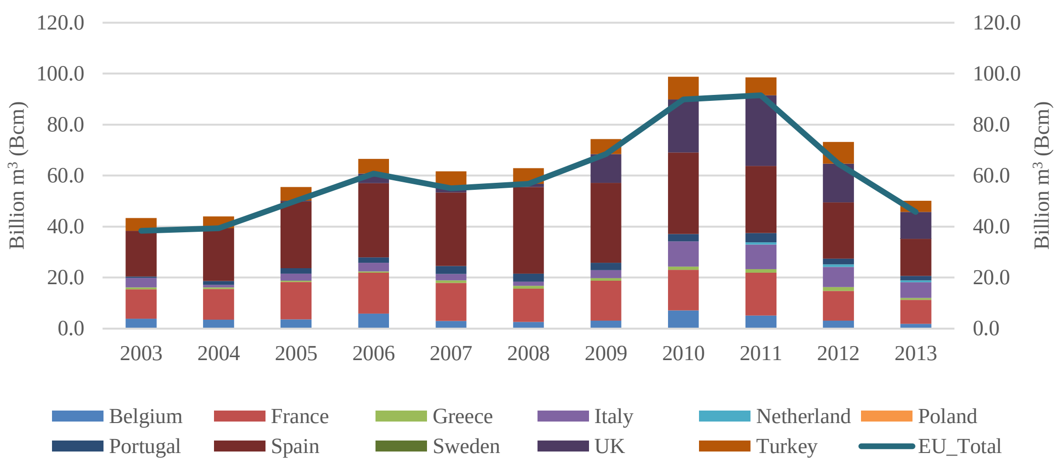
The European Union with 28 member countries has fulfilled 23% of its primary energy needs from natural gas. Total EU natural gas demand has been facilitated by primarily natural gas imports via pipelines or the imports of LNG (see Figure 22) due to reduction in domestic natural gas production. For this reason, the natural gas market in the EU countries has been characterized by depleting indigenous resources and growing dependence on natural gas imports. Whereas considerable amount of natural gas (more than 80% of total import) has been imported via pipelines, rest has been supplied from various LNG exporting countries, such as Algeria and Nigeria.

---

[35] Physical hub (actual transit location) is a point at which several pipelines intersect.
[36] Transit physical hub is a point at which natural gas is physically traded.
[37] Virtual (balancing) point is a trading platform for financial trading of natural gas.
[38] At transition virtual point, trading environment is immature but benchmark prices are set in national natural gas market.
[39] Trading virtual point is a mature hub that let the participants to manage their gas portfolios.

Although the share of LNG in the total EU natural gas supply[40] (averagely 11%) has not been so high, LNG has gained importance especially after dispute between Russia and Ukraine in 2009. It has been traded by Belgium, France, Greece, Italy, Netherland, Portugal, Spain and the UK to feed the EU's natural gas market. As illustrated in Figure 23, LNG was generally traded by Spain, France and the UK between 2003 and 2013. According to data from International Group of Liquefied Natural Gas Importers (GIIGNL), the LNG providers to the EU countries are Algeria, Egypt, Nigeria, Norway, Peru, Trinidad & Tobago, Qatar and Yemen.

Figure 23: The EU's LNG import volumes (2003-2013)




Source: GIIGNL and EIA, Author's Analysis

After 2011 in which the EU LNG imports reached at its highest volume (82 Bcm), it declined abruptly in the following years due to economic stagnation, imports of cheap coal from the US, higher generation level from renewables, and the divergence between pipeline gas and spot LNG prices. In addition to the volume reduction in the LNG imports, only small portion of imported LNG was consumed and the remaining part was re-exported

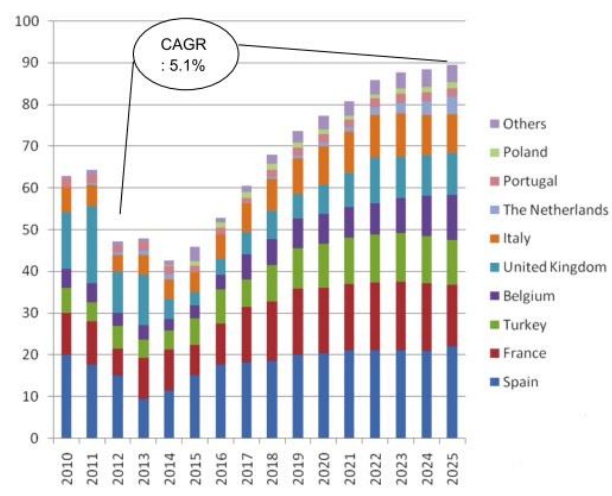
[40] Between 2003 and 2013 this share changed from 7.2% (in 2004) to 17.4% (in 2011) depending on weather condition, LNG spot prices and problems related to suppliers, such as supply disruption.

especially to the Asia-Pacific countries. To illustrate, 41.4 Bcm of LNG were imported in 2013 but only 13.1 Bcm of LNG were consumed by the EU countries. The residual part was traded again.

The European LNG re-export has been directly related to regional LNG prices and importing countries' approach to long-term contracts. As a result of huge gap between the LNG prices in Europe and Asia Pacific region, LNG re-export to Asia Pacific countries becomes attractive. The other essential market for Europe reloads is Latin America. Latin American countries have generally been reluctant to enter long-term contracts and relied on the spot LNG trade (Hellenic Shipping News Worldwide 2015).

In addition to the LNG re-export to Latin America and Asia Pacific, LNG is delivered within the European countries because of the short distance advantage that makes the LNG prices more competitive. But the volume of LNG reload within Europe is very limited with respect to the LNG re-export to Asia Pacific or Latin America.

Figure 24: The EU and Turkey LNG demand outlook to 2025 (Million tonnes per annum (Mtpa))




Source: CERA Global Redesign (Bonhomme, et al. 2013)

Although the EU's LNG market has got smaller since 2012, it is expected that LNG trade will expand after 2015 due to plummeting natural gas prices. Figure 24 shows the EU's LNG demand from 2010 and 2025. Regarding CERA's prediction, the EU LNG market with Turkey will grow with CAAGR of 5.1% per year and it will access to 90 million tons in 2025. Considerable rises in the LNG imports in Spain, France and Turkey are anticipated as the main reason of the EU's LNG market development.

### 2.3.3. The EU Liquefaction and Regasification Terminals

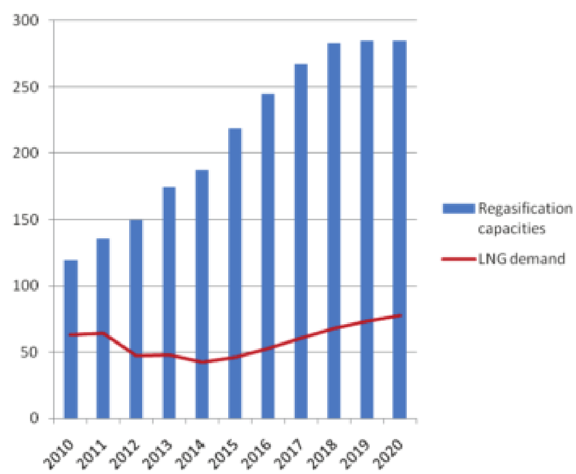
Liquefied natural gas is seen as an alternative fuel to pipeline gas to strengthen the EU's hand against particularly Russia. For this reason, many regasification terminals were constructed all around the Europe.

Figure 25: Existing and planned LNG regasification terminals in Europe


Source: GIIGNL (2014) and Author's Analysis

Country's geographical situation, capacity of the LNG terminals, natural gas demand and downstream market development mainly affect the role of the regasification terminals in the natural gas market. As shown in Figure 25, 21 regasification terminals (excluding Turkey) were on stream as of Jan. 2014 and seven terminals with a capacity of 35 Bcm were under-construction. Total capacity of existing terminals were 190 Bcm. 32 LNG terminals with more than 160-Bcm capacity was planned to be constructed (Renier 2013). Regarding terminals that are under-construction and planned to be built, continuous capacity expansion is expected. As shown in Figure 26, abrupt development in regasification capacity is anticipated in the years between 2015 and 2018. In 2018, total regasification capacity is predicted to be 280 million tons per year.

Figure 26: The European LNG regasification capacities vs. demand outlook to 2020 (Mtpa)




Source: CERA and PFC Energy Inc. (Bonhomme, et al. 2013)

When considering total delivery of LNG in 2014 (given in Figure 24) and total regasification capacity, it can be seen easily the low utilization rate of regasification terminals (around 20%) due to mainly economic stagnation and long-term contracts.

In foreseeable future natural gas demand in the EU is forecasted to experience a limited growth (0.1-0.2% per year between 2010 and 2030). The present economic slowdown, gas-coal competition, and the generation of electricity with increasing rate of renewables are expected to limit natural gas demand (Bonhomme, et al. 2013). Competitive Russian pipeline gas prices as well as economic stagnation will put considerable pressure on the LNG imports. For these reasons, spare regasification capacity is anticipated to be considerably high (this gap is predicted to be 200 million tons according to Figure 26) vis-à-vis the EU's natural gas demand.

Although limited amount of natural gas is produced by few EU members, these countries import natural gas in a gaseous form. For this reason, there is no liquefaction plant in the EU members. In Europe there is only one liquefaction plant located in Norway (Snohvit), not the member of the EU.

# Chapter 3: Method

The aim of this chapter is to explain the methods that will be used to analyze impacts of US LNG exports on the EU natural gas market. Measuring impacts on natural gas market is a complex task because of many uncertainties, such as natural gas prices.

In this study, security supply and economic impact analyses are carried out to determine the correctness of the null hypothesis ($H_0$).

## 3.1. Security Supply Analysis

Security of energy supply -defined by the IEA as an uninterruptible supply of energy at a price which is affordable, while respecting environment concerns- is a multi-dimensional concept with four main dimensions (the 4 A's): availability (related to physical existence of energy resources), accessibility (regarding geopolitical barriers), acceptability[41] (including environmental and safety concerns) and affordability (related to cost of energy resources).

According to studies carried out scholars and several energy-related organizations many simple and aggregated indicators have been used to estimate the energy security. These indicators given in Table 6 can be categorized into nine groups to calculate the security of natural gas supply.

[41] This parameter is usually taken into account by policymakers as constraints and generally is not seen as one of the primary goals of energy security.

Table 6: Indicators for natural gas security of supply

| Group | Indicators |
|---|---|
| Macro-economic indicators | Energy intensity, consumption/capita, import bill indicator etc. |
| Energy balance indicators | Production, imports, exports, transformation, conversion loss, distribution loss, energy industry use, final consumption etc. |
| Reserves indicators | Indigenous production, proven gas reserves etc. |
| Sectorial indicators | Residential, industrial, power generation etc. |
| Diversification indicators | Sources, suppliers, routes etc. |
| Import risk indicators | Import dependency, supplier shares and country risks |
| Infrastructure indicators | Storage, LNG terminal, interconnection pipelines |
| Energy crisis indicators | Storage flexibility, LNG flexibility, fuel switching flexibility etc. |
| Gas flow model indicators | Gas supply margins, pipeline use etc. |

Source: Badea 2010

Estimation of security supply for both short- and long-term is very essential. While long-term energy security mainly deals with timely investments to supply energy in the line with economic developments and sustainable environmental needs (International Energy Agency (IEA) 2015), short-term energy security[42] indicates the ability of market fundamentals to react urgently to abrupt alterations with-in the supply-demand balance. Although US LNG exports affect both short- and long-term security supply in the EU natural gas market, matching the maximum supply (indigenous gas production and import capacity) and the expected demand is very complicated due to a considerable swing in natural gas demand between the summer and winter months in the EU countries (Lajtai, Czinkos and Dinh 2009), and this uncertainty is related to the storage capacity that provides flexibility in the market. Under these circumstances, in this study, estimation of security supply can be made only for long-term.

[42] Regarding the IEA, short-term security supply is defined as hourly or daily security of energy supply. Therefore, measures such as withdrawal of natural gas from underground gas storage facilities, fuel switch and instantaneous demand reduction are seen as a solution to mitigate impacts of supply disruption.

Energy balance and diversification indicators are very helpful to measure long-term security supply. Supply-demand balance in the EU natural gas market can be calculated by using four parameters of market: forecasted indigenous natural gas production, import capacity of pipeline gas based on existing contracts, forecasted natural gas demand and possible import capacity of LNG.

In the second part of this analysis, diversity indicators, market concentration of natural gas suppliers and Shannon-Wiener-Neumann (SWN) index, are quantified to estimate long-term security of supply.

### 3.1.1. Herfindahl-Hirschman Index (HHI)

Herfindahl-Hirschman Index (HHI), a statistical measure of concentration, is used to measure market concentration of gas suppliers in the EU gas market. HHI is important to estimate the degree of market competitiveness. It focuses on characteristics of energy suppliers and availability of the fuel supply in the supplier country, so the market share of each supplier is taken into account to calculate HHI.

$$\mathbf{HHI} = \sum_{\mathbf{n}} (\mathbf{S_n})^{\mathbf{2}} \qquad \text{(Eq. 1)}$$

where $S_n$ is the market share of firm where n=1, 2,.., n

The HHI reaches a maximum value of 10,000 if a monopoly or one firm with 100% of market share exists. HHI moves from 10,000 to 0 if firms have a small portion of market share.

Although different approaches exist to define the structure of markets, markets are commonly classified as; "unconcentrated" if HHI<1,500, "moderately concentrated" if 1,500<HHI<2,500 and "highly concentrated" if HHI>2,500.

### 3.1.2. Shannon-Wiener Index (SWI)

Shannon-Wiener Index measures import supply diversification by considering both the number of natural gas suppliers and their market shares (Von Hirschausen, et al. 2010). The Shannon-Weiner function[43] is:

$$\mathbf{SWI} = -\sum_{i} \mathbf{x_i} \ln \mathbf{x_i} \qquad \text{(Eq. 2)}$$

Where $x_i$ is the fraction share of the imports from supplier i. When natural gas is provided from only a supplier (i.e. complete dependence on a single importer), SWI becomes zero. The index escalates as the number of suppliers rises. Therefore, lower the SWI is, worse degree of diversification in the market is.

Although SWI is used to assess the diversification level of the market, it is insufficient to represent the structure of the market. Because political stability in exporting countries and indigenous production are the other vital determinants for the security of energy supply. To estimate the impacts of domestic gas production and supplier reliabilities on supply diversification Shannon-Wiener Index was adjusted and two distinct indicators have been defined.

The SWI formula is adjusted by including long-term socio-political stability in regions of origin that is one of the main reasons causing supply disruption. For example, one of the main gas suppliers to EU countries, Russia, has a political stability index of 0.22 and this decreases the reliability of this country in the eyes of gas importers. Although political stability of exporting countries is considered as an essential parameter for the security of energy supply, the political stability in the "home" region is not an issue (Jansen, Van Arkel and Boots 2004). When long-term political stability in regions of origin is taken into consideration, modified SWI, called as Shannon-Wiener-Neumann 1 index (SWN-1 or SWN 1), is formulized as:

[43] The formula of SWI consists of negative sign to ensure positivity of the index.

$$\mathbf{SWN\ 1} = -\sum_i \mathbf{x_i}(\ln \mathbf{x_i})\mathbf{b_i} \qquad \text{(Eq. 3)}$$

Where $x_i$: Market share of supplier i

$b_i$: Index of political stability of country i, ranging from 0 to 1 where a high index represents high political stability. For this reason, SWN-1 is lower than the SWI if the energy source is imported from unstable regions.

SWI is further extended to include indigenous production as well, to the so-called Shannon-Wiener-Neumann 2 (SWN-2 or SWN 2) index (Dresden University of Technology (TUD) 2008). By estimation of SWN-2, the shortcoming of SWN-1 is eliminated. To illustrate, when importing country with only one supplier has high share of indigenous production in the whole supply, SWN-1 is calculated zero although its security of energy supply is very high. Adjustment of SWI by taking into account the share of domestic production helps to reflect exact situation of the energy market.

$$\mathbf{SWN\ 2} = -\sum_i \mathbf{x_i}(\ln \mathbf{x_i})\mathbf{b_i}(\mathbf{1} + \mathbf{g_i}) \qquad \text{(Eq. 4)}$$

Where $x_i$: Market share of supplier i

$b_i$: Index of political stability of supplier i

$g_i$: The share of indigenous production in the total consumption

Generally, the relationship among three indices are SWI>SWN-1>SWN-2.

To sum, the higher value of indices shows better supply security. The difference between the indices indicates the effects of parameters (political stability and the share of indigenous production in the total energy supply) on the market.

### 3.2. Economic Impact Analysis

Potential impacts of US LNG exports are expected not to be limited to the security of energy supply. It will also affect natural gas consumers economically. Entrance of the US as a new supplier to the EU natural gas market with low gas prices compared to the prices of other suppliers is anticipated to strengthen the EU's bargaining position, to compel other suppliers to re-negotiate long-term contracts and lower natural gas prices. These prospective advantages may finally trigger the EU natural gas demand.

Estimation of economic impacts of the US natural gas exports on the EU gas market is very challenging task because of the existence of many uncertainties. Natural gas market is very dynamic and many parameters such as harsh weather conditions, EU's economic situation and some exogenous events may lead to unexpected price change and demand jump.

Forecasting natural gas prices in the EU market is a challenging issue because natural gas import heavily depends on long-term contracts. Also, natural gas prices are generally linked to highly volatile oil prices. During importing LNG from the US, the main determinant of natural gas prices will be US natural gas prices that are formed regarding to the Henry Hub Price, liquefaction, regasification and shipping costs, so these components will be used to forecast the EU natural gas prices empirically.

After predicting EU natural gas prices for the period between 2015 and 2030, the EU natural gas demand will be estimated via the formula given in the analysis[44] performed by O. Dilaver and her colleagues (Dilaver, Dilaver and Hunt 2014). In the literature on natural gas demand projections, there are several econometric models with various approaches such as bottom-up[45] or survey-based approaches.

In the following part of this section, the approach used to predict EU natural gas price in the years from 2015 to 2030 is defined. Secondly, the method and the formula obtained from it will be explained.

---

44 The aim of this study is to show the impacts of natural price change on the EU's natural gas demand by using the relationship between natural gas price and demand.

45 Bottom-up approach aims to forecast EU natural gas demand by breaking up EU's natural gas demand into smaller units and then estimating the aggregates of demand. To illustrate, EU's natural gas demand was predicted from natural gas consumption of sectors such as the power and non-power sectors in the EU countries.

### 3.2.1. Predicting European Natural Gas Prices

When US LNG exports with lower LNG prices are initialized, the LNG prices in the US and the EU countries are expected to converge to each other. For this reason, the LNG prices in the EU countries are anticipated to decrease until the LNG prices in the EU countries are equal or close to the US LNG prices that are the combination of the natural gas price at Henry Hub, liquefaction, regasification and shipping costs.

When considering the dependence of the EU countries on pipeline gas, the reduction of the LNG prices in the EU countries will also affect the prices of pipeline natural gas primarily imported from Russia. For these reasons, the average price of imported natural gas in the EU countries will decrease.

To predict average price of natural gas in the EU countries, the formula given below will be used:

$$(\mathbf{P_{av}})_{\mathbf{t}} = \mathbf{X_t} * (\mathbf{P_{pipeline\ gas}})_{\mathbf{t}} + (\mathbf{1} - \mathbf{X_t}) * (\mathbf{P_{LNG}})_{\mathbf{t}} \qquad \text{(Eq. 5)}$$

Where $(P_{av})_t$ : Average price of imported natural gas at year t in $/MBtu

$(P_{pipeline\ gas})_t$: Average price of imported pipeline natural gas at year t in $/MBtu

$(PLNG)_t$: Average price of imported LNG at year t in $/MBtu

$X_t$: The share of pipeline gas in the total natural gas import at year t

As mentioned before, LNG prices will converge in the US and the EU countries as a result of the LNG export from the US. Therefore, LNG prices will be estimated:

$$(\mathbf{P_{LNG}})_{\mathbf{t}} = (\mathbf{P_{Henry\ Hub}})_{\mathbf{t}} + (\mathbf{P_{Liquefaction}})_{\mathbf{t}} + (\mathbf{P_{Shipping}})_{\mathbf{t}} + (\mathbf{P_{regasification}})_{\mathbf{t}} \qquad \text{(Eq. 6)}$$

Where $(PLNG)_t$ : Average price of LNG at year t in $/MBtu

$(P_{Henry\ Hub})_t$: Average price of natural gas at Henry Hub at year t in $/MBtu

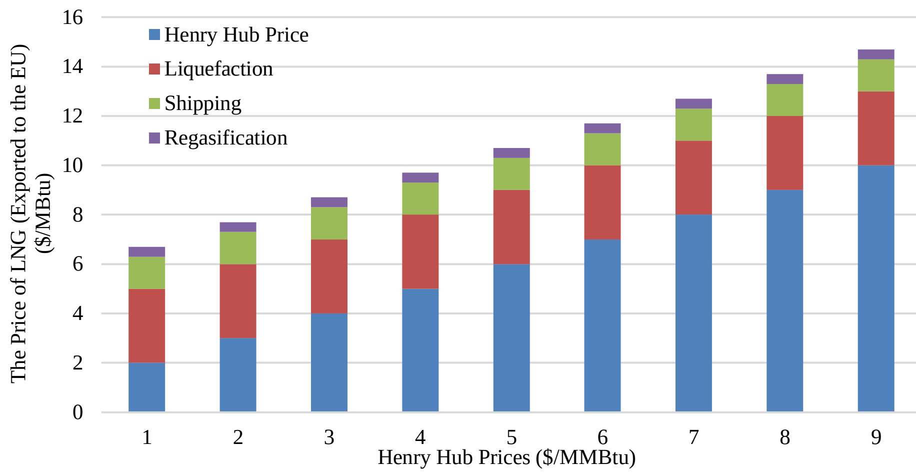
$(P_{Liquefaction})_t$: Average cost of liquefaction process at year t in $/MBtu

$(P_{Shipping})_t$: Average shipping cost from the US to the EU countries at year t in $/MBtu

$(P_{Regasification})_t$: Average cost of regasification process at year t in \$/MBtu

Figure 27 plotted regarding Eq. 6 will be used to estimate LNG prices at year t.

Figure 27: The Price of LNG[46] exported from the US to the EU countries




Source: Cheniere Energy data (Henderson 2012)

### 3.2.2. Projection of European Natural Gas Demand

In the analysis performed by O. Dilaver and her colleagues, European natural gas demand (OECD-Europe) is projected by means of the Structural Time Series Model (STSM) with the Underlying Energy Demand Trend (UEDT) concept. Although many models used by Eurogas and International Energy Agency (IEA) are based on the disaggregate forecast approach, demand in the STSM is predicted via the aggregate approach.

Energy demand is traditionally formulized as a function of economic activity and the energy prices. But many exogenous unobservable factors (such as technological progress, consumer tastes, preferences, demographic and social structure, environmental regulations and economic structure), as well as income, the price of energy sources, affect

[46] The prices given in Figure 27 are estimated by only using the natural gas prices at Henry Hub, liquefaction, regasification and shipping costs and they do not include profit.

the natural gas demand. When these unobservable drivers are ignored or assumed as changing linearly during modelling the energy demand, the forecasted demand becomes poor. It is, therefore, important to take these unobservable factors into account. To overcome this shortcoming, a stochastic UEDT, which allows for the inclusion of all unobservable factors into the model, is used in the prediction of the natural gas demand. This parameter significantly represents non-linear changes in exogenous unobservable factors.

While the UEDT provides flexibility in reflecting the trend and the seasonality of unobservable parameters on the energy demand, the structural time series model (STSM) allows for the estimation of a non-linear UEDT (Hunt and Ninomiya 2003). By benefiting from the advantages of the STSM and the UEDT, OECD-Europe natural gas demand is formulized by (Dilaver, Dilaver and Hunt 2014) as follows:

$$\mathbf{G_t = f(Y_t\,, P_t, UEDT_t)} \qquad \text{(Eq. 7)}$$

Where $G_t$ : Natural gas demand at year t in Billion $m^3$ (Bcm)

$Y_t$: Gross Domestic Product (GDP) at year t (US Dollar 2005= 100 PPP)

$P_t$: Natural gas price index at year t (2005=100)

$UEDT_t$: Underlying Energy Demand Trend for natural gas at year t

In the light of abovementioned definition of the parameters, the relationship between the natural gas demand and GDP, price and unobservable factors is explained as:

$$\mathbf{A(L) * ln(G_t) = B(L) * ln(Y_t) + C(L) * ln(P_t) + UEDT_t + \boldsymbol{\varepsilon}_t} \qquad \text{(Eq. 8)}$$

Where A(L)[47], B(L)[48] and C(L)[49] : Polynomial lag operators

B(L)/A(L): The long run income elasticity of natural gas demand

C(L)/A(L): The long run price elasticity of natural gas demand

---

47 $A(L) = 1 - \lambda_1 L - \lambda_2 L^2 - \lambda_3 L^3 - \lambda_4 L^4$
48 $B(L) = 1 - \varphi_1 L - \varphi_2 L^2 - \varphi_3 L^3 - \varphi_4 L^4$
49 $C(L) = 1 - \sigma_1 L - \sigma_2 L^2 - \sigma_3 L^3 - \sigma_4 L^4$

$\varepsilon_t$ : A random error term

$UEDT_t$: Stochastic and estimated by STSM via below formula

$$\mathbf{UEDT_t = \mu_t} + \text{irregular interventions} + \text{level interventions} + \text{slope interventions}$$
(Eq. 9)

Where $\mu_t$ [50]: Level of the UEDT at year t

By using Eq. 8 and 9, the natural gas demand is forecasted via annual change in natural gas demand:

$$\mathbf{\widehat{\Delta g_t} = \widehat{K_Y}\Delta y_{t-1} + \widehat{K_P}\Delta p_{t-1} + \Delta\widehat{UEDT}_t} \qquad \text{(Eq. 10)}$$

Where $\widehat{K_Y}$ and $\widehat{K_P}$ : Estimated coefficients

$\Delta\widehat{UEDT}_t$: Estimated UEDT

To calculate coefficients ($\widehat{K_Y}$ and $\widehat{K_P}$), the natural gas prices and GDP values of OECD-Europe countries from 1978 and 2011 were used by scholars (Dilaver, Dilaver and Hunt 2014) and the natural gas demand was formulized as follows:

$$\mathbf{\widehat{\Delta g_t} = 1.18964 * \Delta y_{t-1} - 0.15936 * \Delta p_{t-1} + \Delta\widehat{UEDT}_t} \qquad \text{(Eq. 11)}$$

Where $g_t$ : The natural logarithm of natural gas demand at year t

$y_t$: The natural logarithm of Gross Domestic Product (GDP) at year t (US Dollar 2005= 100 PPP)

$p_t$: The natural logarithm of natural gas price index at year t (2005=100)

$UEDT_t$: Underlying Energy Demand Trend for natural gas at year t

In Eq. 11, $\Delta\widehat{UEDT}_t$ is projected as -0.0015, -0.0020 and -0.0025 for the low, reference and high scenarios in the years between 2012 and 2020. While the growth in

[50] $\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t$ ;  $\eta_t \sim NID(0, \sigma_\eta{}^2)$ Where $\sigma_\eta{}^2$: is estimated by using the software package STAMP 8.10
$\beta_t = \beta_{t-1} + \xi_t$ ;  $\xi_t \sim NID(0, \sigma_\xi{}^2)$ Where $\beta_t$: slope of the UEDT and $\sigma_\xi{}^2$: estimated by using the software package STAMP 8.10

GDP is taken as 2%, 1% and 2.5% for reference, low and high scenarios respectively, the increase in the natural gas price is forecasted as 2%, 2% and 0.5% for these scenarios.

In this study, the natural gas demand in the EU countries will be projected by using Eq. 11. After estimating the natural gas demand, a correction factor, 0.91[51], is used to convert projected natural gas demand of OECD-Europe countries to the demand of the EU countries.

---

[51] OECD-Europe countries are Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey and the United Kingdom. To estimate the natural gas demand in the EU countries, the natural gas demand in Turkey, Norway and Switzerland should be discarded and the demand in Bulgaria, Croatia, Cyprus, Latvia, Lithuania, Malta and Romania should be added to the forecasted natural gas demand. In the light of this approach, multiplying projected OECD-Europe's demand by 0.91 is sufficient to determine the demand of the EU countries.

# Chapter 4: Effects of the US LNG Exports on the EU Natural Gas Market

The security of the EU gas supply has become a priority for the EU members since Russia cut off natural gas deliveries to Ukraine in 2006, 2009 and 2014. To mitigate the effects of prospective natural gas disruption the European Commission (EC) released "European Energy Security Strategy" (COM/2014/0330) in May 2014. In this regulation eight key pillars, including concrete actions that need be taken in short, medium and longer terms, were determined. In the natural gas supply side, more effective use of the opportunities to import liquefied natural gas (LNG) in the EU member countries is shown as a major possible solution of diversification (European Union (EU) 2014).

The European Union, as well as the US, believes that the LNG trade from the US to the European member countries will decrease the EU's dependence on Russian gas and be the game changer in the EU's natural gas market. Although existence of many uncertainties makes this thought harder to prove, the impacts of US LNG exports on the EU natural gas market can be analyzed by measuring EU's security of natural gas supply.

## 4.1. ASSUMPTIONS

This section outlines the assumptions used in the security supply and the economic impact analyses.

### 4.1.1. Security Supply Analysis

Three scenarios are implemented: reference, low case and high case scenarios in this analysis. In all scenarios, it is assumed that;

- Indigenous production in the EU countries will decrease 1%, 2% and 1.6% annually over the periods: 2015-2020, 2020-2025 and 2025-2030 respectively.

- Only existing pipeline infrastructure is assumed to be used in between 2015-2030. In other words, total capacity of pipeline transporting natural gas from exporting countries will not change throughout these years.

- Regarding "take-or-pay" obligation, 70% of the gas capacity delivered by Russia under the long term contract is assumed to be purchased by the EU countries.

- According to Eurogas assumptions[52], the compounded average annual growth rate (CAAGR) is taken as 0.6% to estimate the EU natural gas demand in between 2015 and 2030.

- To determine amount of LNG that is required to fulfill the gap between the natural gas demand and indigenous natural gas production, projected natural gas exports by the exporting countries are given Table 7.

Table 7: Projected gas imports to the EU countries by the exporting countries (Bcm)

| | 2015 | | 2020 | | 2030 | |
|---|---|---|---|---|---|---|
| | **Pipeline Gas** | **LNG** | **Pipeline Gas** | **LNG** | **Pipeline Gas** | **LNG** |
| Algeria | 28.0 | 16.0 | 20.0 | 21.0 | 22.0 | 38.0 |
| Azerbaijan | 0.7 | 0 | 10.0 | 0 | 15.0 | 0 |
| Egypt | 0 | 0 | 0 | 0 | 0 | 3.0 |
| Libya | 8.0 | 0 | 10.0 | 0 | 15.0 | 6.0 |
| Norway | 109.0 | | 110.0 | | 100.0 | |
| Other[53] | 0 | <1 | 0 | <1 | 0 | 15-18[54] |
| Qatar | 17.3 | | 20.4 | | 22.0 | |
| Russia | 130.0 | | 119.0 | | 76.0 | |
| Trinidad&Tobago | 2.6 | | 2.6 | | 2.6 | |

Source: Dickel, et al. 2014, Mitrova 2014, Duval 2011 and Author's estimations

52 According to Eurogas data the growth rate of natural gas demand is defined as 0.045%, 1.15% and 0.53% over the periods 2011-2020, 2020-2025, and 2025-2030, respectively. By using these rates CAAGR is calculated as 0.6% by the author.

53 Other includes imports from Israel, Cyprus and Yemen.

54 During calculation of the indices, this value is taken as 15 Bcm.

The LNG demand of the EU countries over the period 2015-2030 is estimated by using Eq. 12.

$$\mathbf{LNG_t = D_t - Q_t - I_t} \qquad \text{(Eq. 12)}$$

Where $LNG_t$ : Projected LNG demand at year t in Billion $m^3$ (Bcm)

$D_t$: Total natural gas demand at year t in Billion $m^3$ (Bcm)

$Q_t$: Indigenous natural gas production at year t in Billion $m^3$ (Bcm)

$I_t$: Amount of imported natural gas purchased under long term contract at year t in Billion $m^3$ (Bcm)

Stability indexes used to calculate of Shannon-Wiener-Neumann 1 index (SWN 1) are illustrated in the following table (Table 8).

Table 8: Political Stability Index (PSI) of the exporting countries to the EU countries

| **Exporting Countries**[55] | **PSI**[56] |
|---|---|
| Algeria | 0.08 |
| Azerbaijan | 0.25 |
| Egypt | 0.06 |
| Libya | 0 |
| Nigeria | 0.02 |
| Norway | 0.96 |
| Oman | 0.68 |
| Other[57] | 0.01-0.73 |
| Peru | 0.2 |
| Qatar | 0.94 |
| Russia | 0.22 |
| Trinidad & Tobago | 0.58 |
| The US | 0.74 |

Source: Cornell University, INSEAD and the World Intellectual Property Organization (WIPO) 2014

[55] Political stability indices of some countries such as Libya are not estimated by Cornell University, INSEAD and the World Intellectual Property Organization (WIPO). Hence, this type of indices is assumed as zero during calculating SWIs.

[56] The political stability index is between 0 and 1. The higher the index is, the more stabile the country is.

[57] The political stability indices of Israel, Cyprus and Yemen are 0.17, 0.73 and 0.01 respectively.

US LNG exports to EU countries are anticipated to initiate at the end of 2015. For this reason, HHI, SWI, SWI-1 and SWI-2 indices are calculated over the period 2016-2030.

In this study, six scenarios, four of which were specified in the EIA's 2011 Annual Energy Outlook, will be analyzed to measure impacts of US LNG exports to the EU countries. These scenarios[58] are:

- No export case (base scenario),
- 6 billion cubic feet per day (Bcf/day), phased in at a rate of 1 Bcf/day per year (low/slow scenario),
- 6 Bcf/day phased in at a rate of 3 Bcf/day per year (low/rapid scenario),
- 12 Bcf/day phased in at a rate of 1 Bcf/day per year (high/slow scenario),
- 12 Bcf/day phased in at a rate of 3 Bcf/day per year (high/rapid scenario),
- Adjustable LNG export (flexible scenario).

#### 4.1.2. Economic Impact Analysis

In the economic impact analysis, the formula (given in Eq. 11) used to calculate the change in natural gas demand over the period 2015-2030 consists of several parameters. The first parameter, natural gas prices, are estimated by assuming that price formation in the OECD-Europe countries and the EU countries is based on the volume-weighted average prices. While the shares of pipeline gas and LNG in the natural gas market are estimated regarding IEA and EIA data for the years between 2000 and 2013, these shares over period 2014 and 2030 are assumed as 90% for pipeline gas and 10% for LNG. The LNG prices for the period between 2014 and 2030 are estimated by assuming that the prices of exported LNG in this time span will be equal to US prices calculated by using Eq. 6 and Figure 27. While the regasification and the shipping costs of LNG, and the cost of the liquefaction of natural gas are assumed as constant between 2014 and 2030, the HH price

[58] To convert daily LNG export rate into annual rate one year is taken as 330 days.

will increase according to the scenarios described in the low (2%), reference (1.5%) and high scenarios (0.5%) described in Section 3.2.1.

US LNG exports are expected to lead to an increase in EU natural gas demand due to natural gas price drop. To measure the growth in EU natural gas demand, the natural gas demands of the OECD-Europe countries in the years from 2000 to 2013 were calculated by using EU's annual natural gas consumption[59] gathered from Eurogas reports, and the natural gas consumptions of non-EU countries such as Norway, Switzerland and Turkey from EIA.

Regarding the Eurogas's report, the expected growth rates of natural gas demands illustrated in Table 9 were defined as:

Table 9: Expected growth rate of the natural gas demand over period 2011-2035

| Period | Growth Rate (%) |
|---|---|
| 2011-2020 | 0.045 |
| 2020-2025 | 1.150 |
| 2025-2030 | 0.530 |
| 2030-2035 | 0.630 |

Source: Eurogas

Data related to the gross domestic product (GDP[60]) are gathered from Organization for Economic Co-operation and Development (OECD). Three different expected growth rates have been used in the model defined by Dilaver, Dilaver and Hunt so as to estimate GDP for the years between 2014 and 2030. These rates are 1%, 2% and 2.5% for the low, reference and high scenarios, respectively.

[59] The EU natural gas demand includes the natural gas consumption of the non-OECD-Europe countries such as Bulgaria, Malta, Cyprus, Romania, Latvia and Lithuania. Hence, their natural gas usage were discarded and the natural gas consumptions of Turkey, Norway and Switzerland were added to find the natural gas demand in the OECD-Europe countries over the period 2000-2013.

[60] For GDP the reference base year is 2005.

Abovementioned in the Section 3.2.2 the natural gas demand in the EU countries has been estimated multiplying projected demand of the OECD-Europe countries by correction factor, 0.91.

## 4.2. Data Analysis

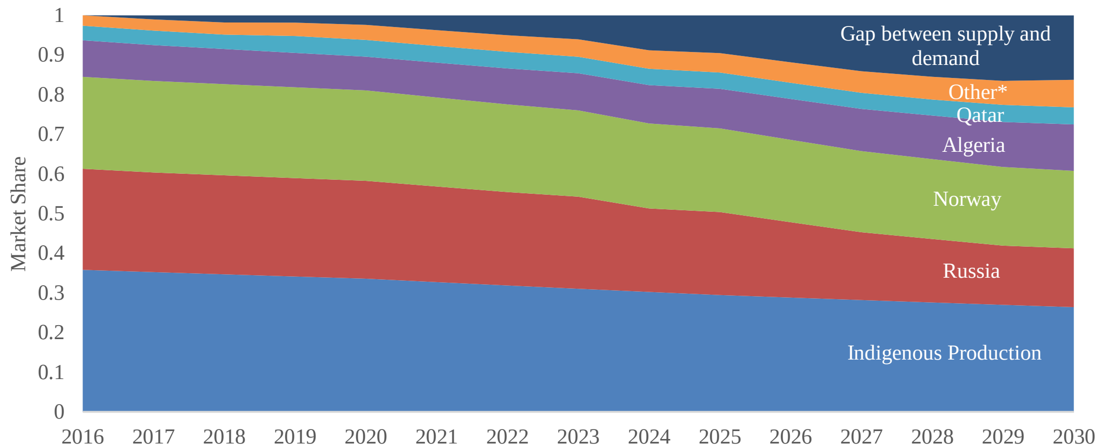
### 4.2.1. Security Supply Analysis

Security supply analysis includes two steps. These steps are the demand-supply balance assessment and the calculation of the indices. In each scenario if the demand-supply balance assessment fails, the indices will not be estimated.

#### *4.2.1.1. Scenario 1: No Export (Base Scenario)*

In Scenario 1, the conditions of the EU natural gas market over period from 2016-2030 are analyzed by assuming that US LNG exports are not implemented. Before calculating HHI, SWI, SWI-1 and SWI-2 indices, balance check between natural gas supply and demand are made to analyze whether current and prospective natural gas and LNG exporting countries could fulfill the EU's natural gas. The supply and demand of natural gas in the EU countries over the period 2016-2030 are illustrated in Figure 28.

Figure 28: The market share of natural gas suppliers in the EU natural gas market from 2016 to 2030 for the Scenario 1




*includes Nigeria, Libya, Trinidad & Tobago, Peru, Oman, Egypt, Yemen, Azerbaijan, Israel and Cyprus.

Source: Eurogas, Dickel, et al. 2014, Mitrova 2014, Duval 2011 and author's estimations

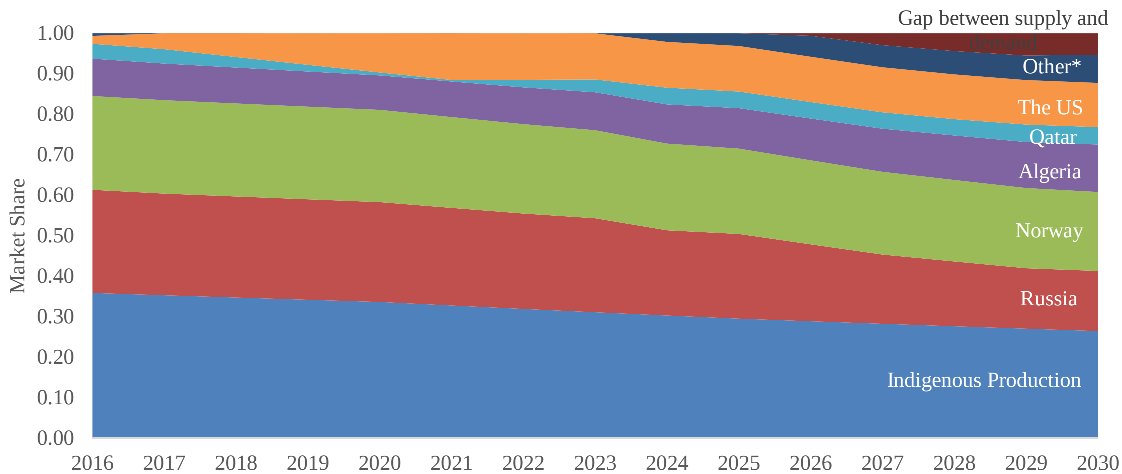
Regarding Figure 28 natural gas supply from existing and prospective suppliers is not sufficient to feed the EU's natural gas market starting from 2017. For this reason, the indices to analyze the EU natural gas market could not be calculated.

As a result, if the EU countries do not diversify their natural gas suppliers as soon as possible, they will face with natural gas deficiency in the following years.

#### *4.2.1.2. Scenario 2: Low/Slow Export Rate*

Scenario 1 shows that the EU countries will challenge the natural gas deficit in 2017 if natural gas and LNG will not be supplied from the new suppliers such as the US. In the Scenario 2, the effects of the LNG exports from the US emerging with 6 billion cubic feet per day (Bcf/day), phased in at a rate of 1 Bcf/day per year starting from 2016 are analyzed. Under these circumstances, the US market share in the EU natural gas market varies from 2% in 2016 to 11% in 2025.

Figure 29: The market share of natural gas suppliers in the EU natural gas market from 2016 to 2030 for the Scenario 2

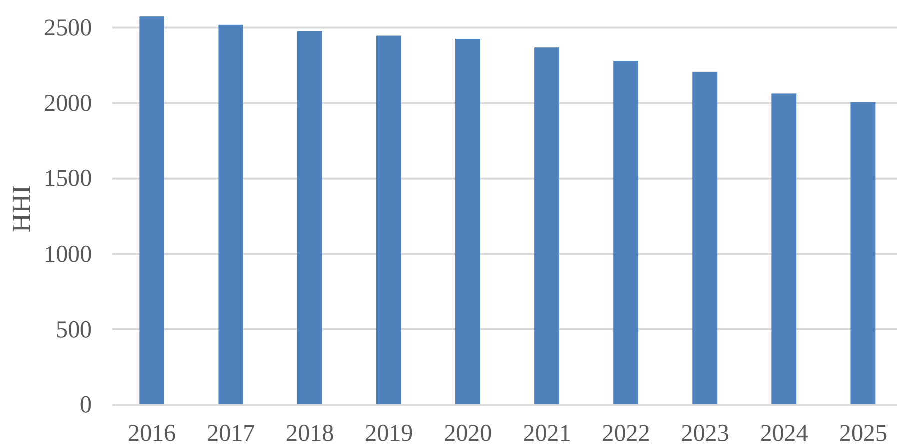



*includes Nigeria, Libya, Trinidad & Tobago, Peru, Oman, Egypt, Yemen, Azerbaijan, Israel and Cyprus.

According to Figure 29, the EU countries could solve shortcoming of natural gas until 2025 by importing LNG from the US. While both indigenous natural gas production and natural gas exports from the existing suppliers decrease, US LNG exports may compensate this reduction until 2025. Also, US LNG exports to the EU countries will impact the EU natural gas market in the period between 2015 and 2025. After 2025 the member states should find new natural gas suppliers or increase the export rate of natural gas under existing natural gas contract. For this reason, the indices, such as HHI and SWI indices, can only be calculated for this timespan.

Although US LNG exports under the condition of low/slow Scenario (Scenario 2) affects the EU natural gas market between 2016 and 2021, market dominance of some exporting countries does not weaken considerably in this period. Therefore, HHI indices do not decrease below 1500 and this situation represents the prevalence of moderately concentrated market condition (Figure 30).

Figure 30: Herfindahl-Hirschman Indices over the period 2016-2025 for the Scenario 2




Similarly, the impacts of US LNG exports can be seen from Figure 31. An increase in SWI, SWI-1 and SWI-2 indicates the improvement of the EU's supply security of natural gas. Also, the effects of the parameters (political stability and the share of indigenous production in the total energy supply) on the market can be seen easily. When the values of SWI and SWI-1 are taken into account, they alter from 1.14 to 1.34 and this rise indicates the diversification of natural gas exporting countries over the period from 2016 to 2025. Unlike SWI and SWI-1, an increase in SWI-2 values becomes comparably lower because of depletion of the EU's domestic natural gas resources.

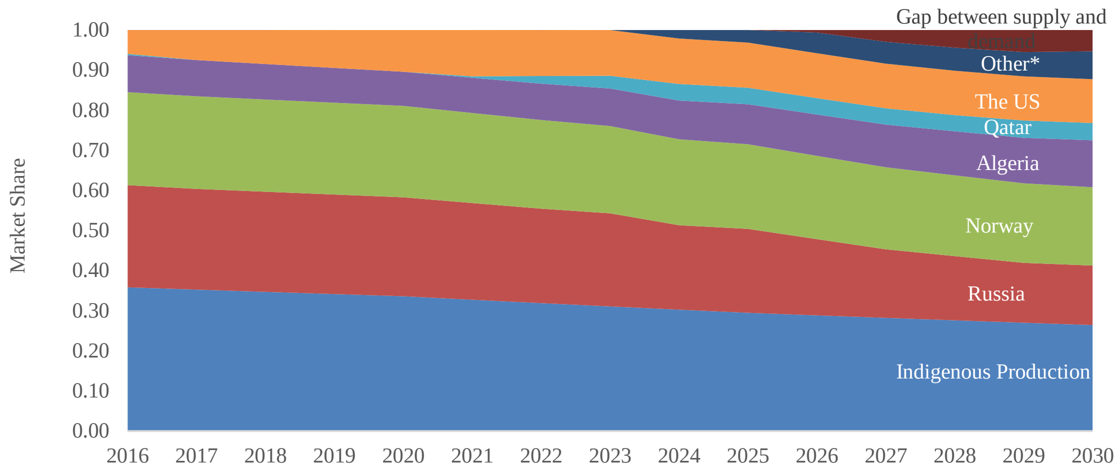
Figure 31: SWI, SWI-1 and SWI-2 over the period 2016-2025 for the Scenario 2


As a result, low/slow scenario affects the EU's natural gas market until 2025. After this year additional volume of natural gas and LNG should be imported by the EU countries to prevent the supply deficiency.

#### *4.2.1.3. Scenario 3: Low/Rapid Export Rate*

When the volume of exported LNG by the rate of 6 Bcf/day phased in at a rate of 3 Bcf/day per year is considered, similar outcomes are obtained with the Scenario 2. Although initial export rate and the market shares of the US in the EU natural gas market are higher in this scenario than the ratios estimated in the Scenario 2, the market share of the US increases up to 11%.

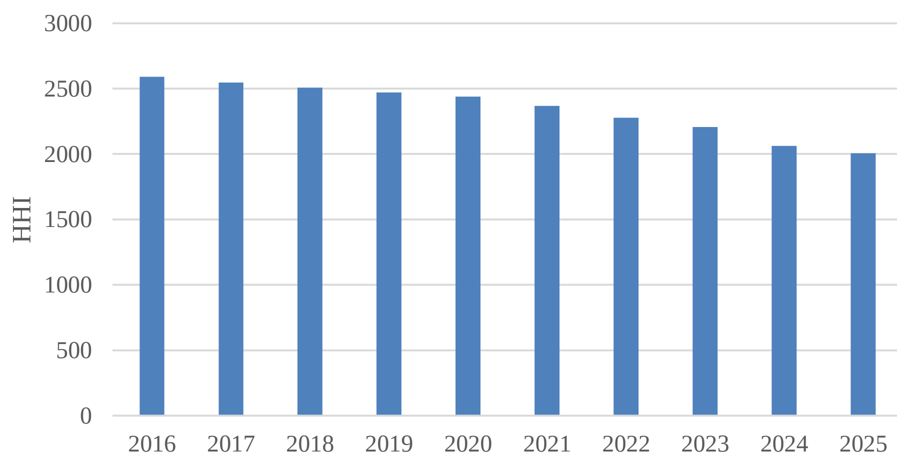
Figure 32: The market share of natural gas suppliers in the EU natural gas market from 2016 to 2030 for the Scenario 3




*includes Nigeria, Libya, Trinidad & Tobago, Peru, Oman, Egypt, Yemen, Azerbaijan, Israel and Cyprus.

As shown in Figure 32, US LNG exports help the EU countries to fulfill the natural gas demand over the period 2016-2025. But total natural gas and LNG supplies become insufficient after 2025. The gap between supply and demand widens between 2026 and 2030.

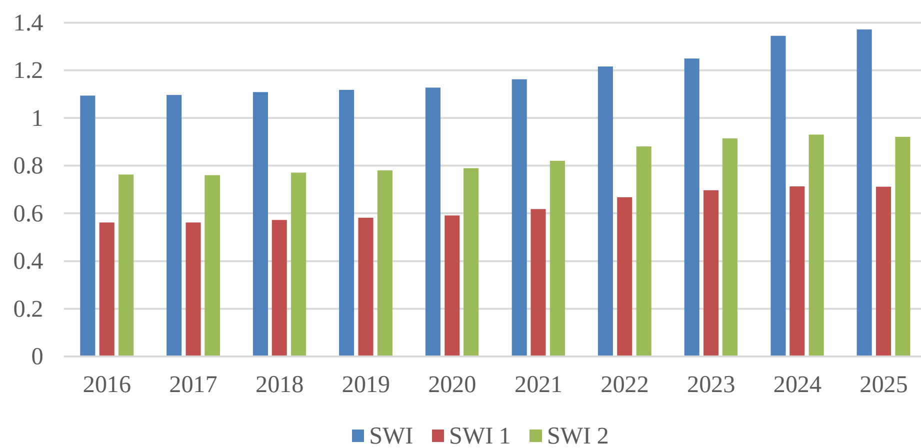
Figure 33: Herfindahl-Hirschman Indices over the period 2016-2025 for the Scenario 3




The market share of the US in the EU natural gas market does not illustrate noticeable differences between the Scenario 2 and 3. As illustrated in Figure 30 and 33, nearly same HHI indices for the period between 2016 and 2025 are obtained from these scenarios. In other words, the LNG trade from the US to the EU countries with the rate described in the Scenario 3 will create nearly same impacts on the natural gas market. The competition in the EU natural gas market ascends incrementally and market conditions do not change too much for these two scenarios.

The decline in the market share of some exporting countries and a rise in the US market share result in some alterations in the EU natural gas market. As illustrated in Figure 34 while SWI and SWI-1 improve significantly, SWI-2 related to the annual rate of indigenous natural gas production grows incrementally.

Figure 34: SWI, SWI-1 and SWI-2 over the period 2016-2030 for the Scenario 3



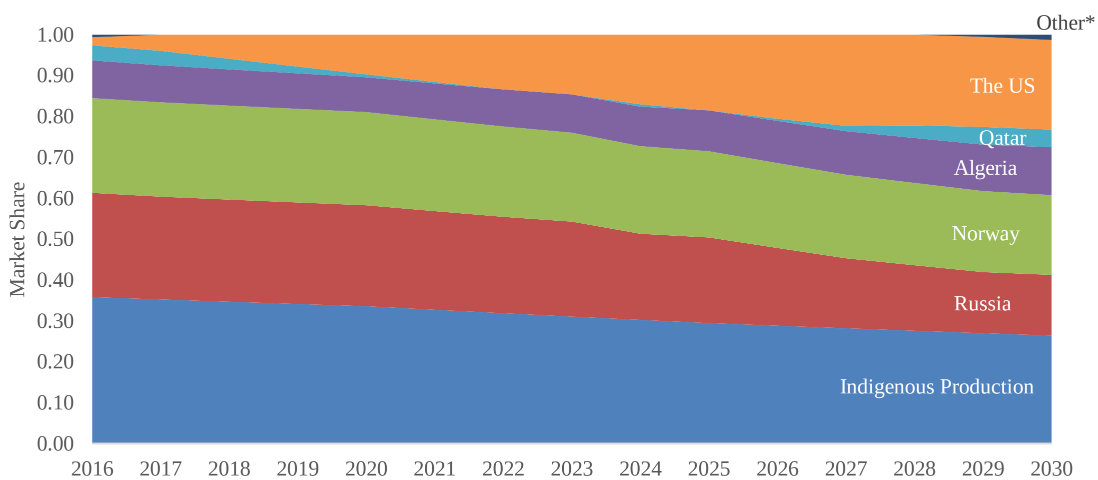

Unlike HHI index, impacts of US LNG exports on the EU natural gas market are felt when SWI, SWI-1 and SWI-2 indices in the Scenario 2 and 3 are compared. Regarding the security of the natural gas supply, the improvement of the EU natural gas market in the Scenario 3 is more than the Scenario 2.

#### *4.2.1.4. Scenario 4: High/Slow Export Rate*

When considering the amount of investment on the liquefaction plants and nameplate capacities of these plants, the US can export more than the volumes described in previous scenarios. In the light of this fact, when US LNG exports with a rate of 12 Bcf/day phased in at a rate of 1 Bcf/day per year (high/slow scenario) are analyzed, the outcomes are different from the results in the Scenario 1, 2 and 3.

Regarding the demand-supply balance assessment, the volume of natural gas found by aggregating indigenous production and natural gas exports could fulfill EU natural gas demand between 2016 and 2030 (Figures 35). While an increase in the export rate from 1 Bcf/day to 12 Bcf/day rises the US market share in the EU natural gas market from 2% in 2016 to 22% in the years between 2027 and 2030, the LNG exports from the US increase competition in the market.

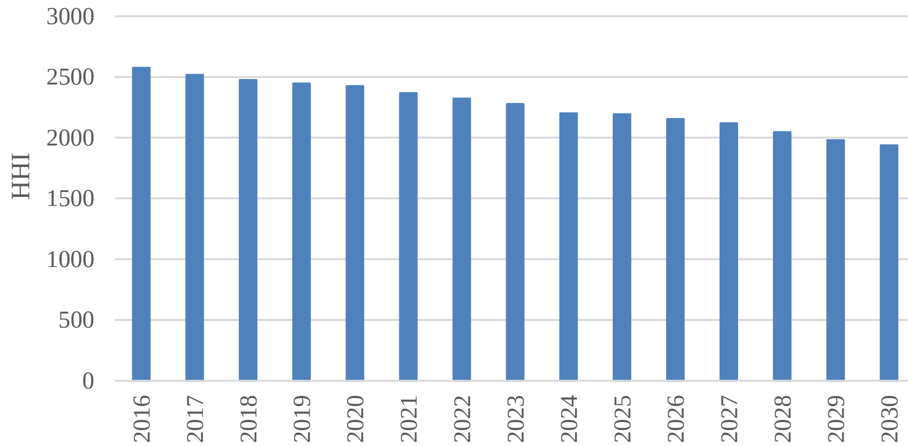
Figure 35: The market share of natural gas suppliers in the EU natural gas market from 2016 to 2030 for the Scenario 4




*includes Nigeria, Libya, Trinidad & Tobago, Peru, Oman, Egypt, Yemen, Azerbaijan, Israel and Cyprus.

With starting LNG exports from the US in 2016 HHI values decrease persistently. While HHI is 2574 in 2016, this value drops to 1937 in 2030 (Figures 36). This decline represents the diversification of natural gas suppliers in the EU natural gas market.

Figure 36: Herfindahl-Hirschman Indices over period 2016-2030 for the Scenario 4




The slump in the market share of certain exporting countries such as Russia and an increase in the US market share affect the EU natural gas market. As shown in Figure 37 while SWI and SWI-1 illustrate similar and considerable improvement, SWI-2 related to the annual rate of indigenous natural gas production increases incrementally.

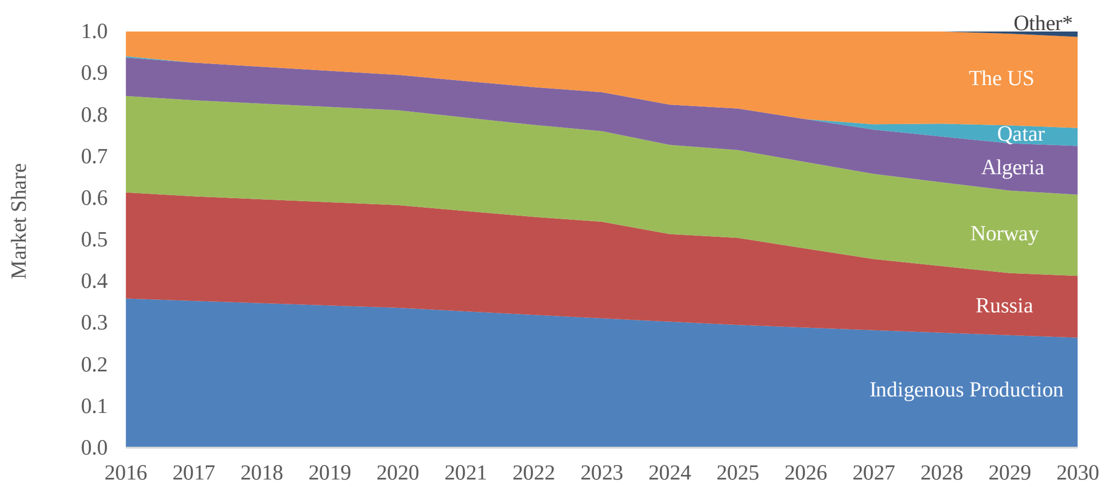
Figure 37: SWI, SWI-1 and SWI-2 over the period 2016-2030 for the Scenario 4


Under these circumstances in the Scenario 4, US LNG exports become more meaningful than previous scenarios. While US LNG exports help the EU countries to feed their natural gas glut, it increases competition in the market and also improves security of natural gas supply.

#### *4.2.1.5. Scenario 5: High/Rapid Export Rate*

When the volume of LNG exports from the US increases, the structure of the EU natural gas market transforms. Due to advantageous US LNG prices the EU countries would prefer to export LNG from this country instead of importing from other suppliers with low political stability indices. In the light of this approach, when LNG is imported from the US with a rate of 12 Bcf/day phased in at a rate of 3 Bcf/day per year, the impacts of this transaction would be higher than preceding scenarios. After initializing the US LNG exports, the US's market share in the EU countries will rise abruptly from 6% in 2016 to 22% in 2022 (Figure 38).

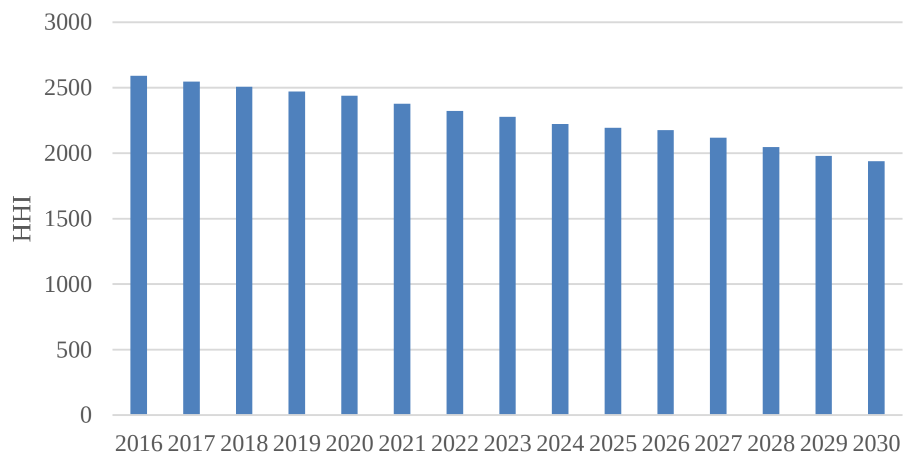
Figure 38: The market share of natural gas suppliers in the EU natural gas market from 2016 to 2030 for the Scenario 5




*includes Nigeria, Libya, Trinidad & Tobago, Peru, Oman, Egypt, Yemen, Azerbaijan, Israel and Cyprus.

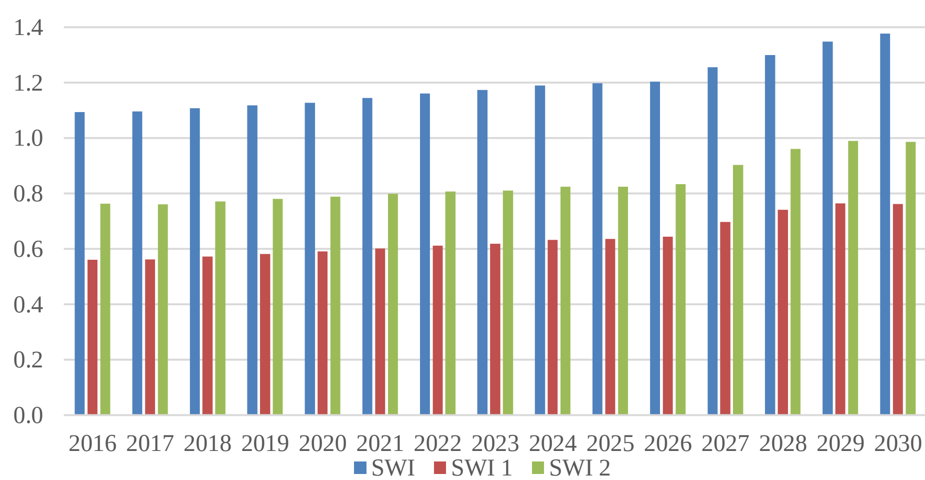
As illustrated in Figure 39 pipeline gas and LNG will be imported from mainly Russia, Norway, Algeria and the US in this scenario. The reduction in the number of suppliers affects HHI indices dramatically. While the structure of the EU natural gas market in 2016 and 2017 is highly concentrated, it becomes moderately concentrated as a result of plunging HHI values after 2017.

Figure 39: Herfindahl-Hirschman Indices over period 2016-2030 for the Scenario 5




Similar to HHI, an increase in the US dominance on the EU natural gas market and a slump in Russian market share affect SWI and SWI-1 indices. Amount of rise in these indices is higher than the Scenario 2, 3 and 4 from 2016 to 2030. As shown in Figure 40 depletion of the EU's natural gas reserves causes a moderate increase in SWI-2.

Figure 40: SWI, SWI-1 and SWI-2 over the period 2016-2030 for the Scenario 5

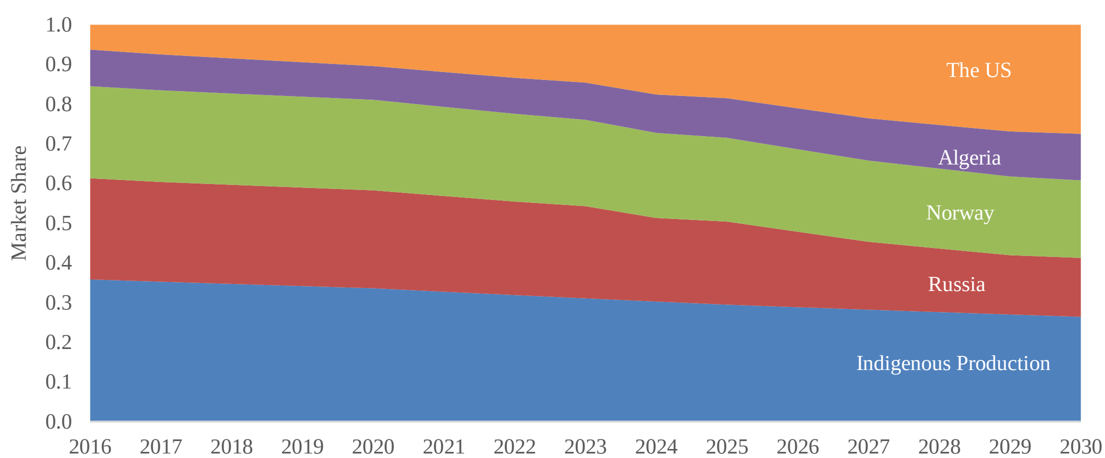


Regarding the outcomes of the security supply analysis for the Scenario 5 the volume of US LNG exports is the primary determinant. The higher volume of US LNG exports is, the more effective US LNG exports on the EU natural gas market are.

***4.2.1.6. Scenario 6: Flexible Export Rate***

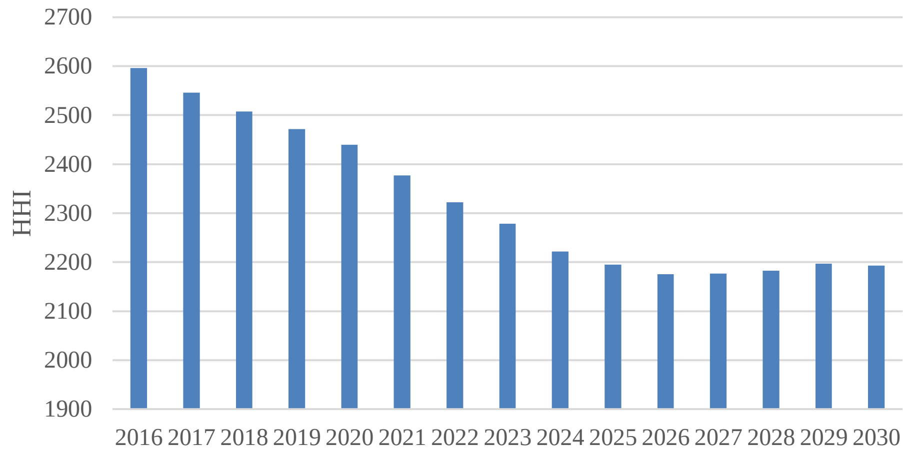
Heretofore limited LNG exports from the US to the EU countries are analyzed. The results of previous scenarios illustrate that high volume of LNG exports helps the EU countries to mitigate Russian dominance in the EU natural gas market and to diversify natural gas suppliers. For this reason, unlimited or flexible LNG export rate is expected more effective than the previous scenarios.

Figure 41: The market share of natural gas suppliers in the EU natural gas market from 2016 to 2030 for the Scenario 6




Similar to other scenarios natural gas supply is equal to an aggregate of indigenous production and imported natural gas and LNG. The EU countries will most probably prefer to import LNG from the US because of comparatively lower natural gas prices in the US; therefore, it is assumed that LNG is only imported from the US for this scenario. According to this assumption the US's market share is 6% in 2016 and increases 27% in 2029 (Figure 41).

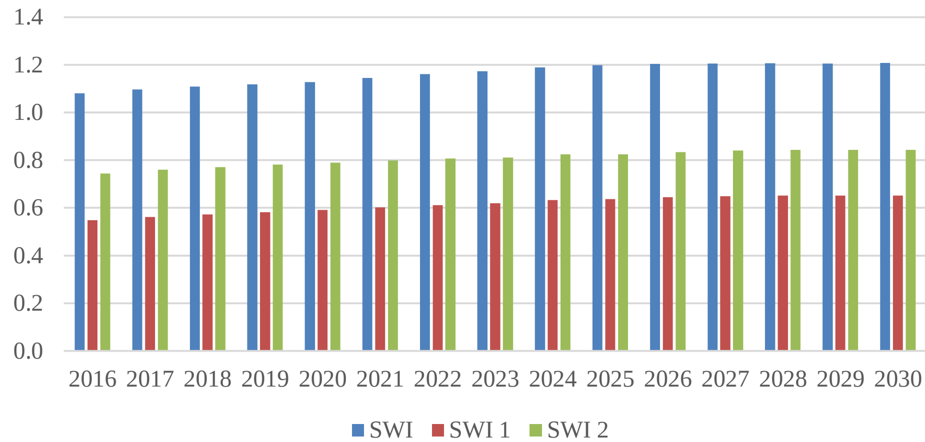
Figure 42: Herfindahl-Hirschman Indices over period 2016-2030 for the Scenario 6




As demonstrated in Figure 41 natural gas is imported from Russia, Norway, Algeria and the US. In other words, the number of suppliers in this scenario decreases and their market shares escalate especially the US's share. Fluctuation of the market share results in reduction of HHI indices from 2016 to 2030 (Figure 42). HHI value in 2016 is 2,596 with the market shares: 36% (indigenous production), 25% (Russia), 23% (Norway), 23 % (Algeria) and 9% (the US). HHI index in 2030 drops to 2,193 with reshaping of the EU natural gas market regarding following shares: 26 % (domestic production), 15 % (Russia), 20% (Norway), 12% (Algeria) and 27% (the US).

In the Scenario 6 a plunge in HHI indices is not as much as in the previous scenarios because the EU countries supply natural gas from only four countries compared to the other scenarios in which there are at least five exporting countries.

Figure 43: SWI, SWI-1 and SWI-2 over period 2016-2030 for the Scenario 6




As exhibited in Figure 43 SWI, SWI-1 and SWI-2 indices, as well as HHI, do not change with introducing US LNG to the EU natural gas market with ascending volume. In other words, LNG exports only from the US in addition to Russia, Norway and Algeria do not impact the EU natural gas market as expected.

As a result, although the volume of US LNG exports is one of the main determinants for diversification of natural gas suppliers, the number of suppliers and their market shares are the other vital parameters for the improvement of the market.

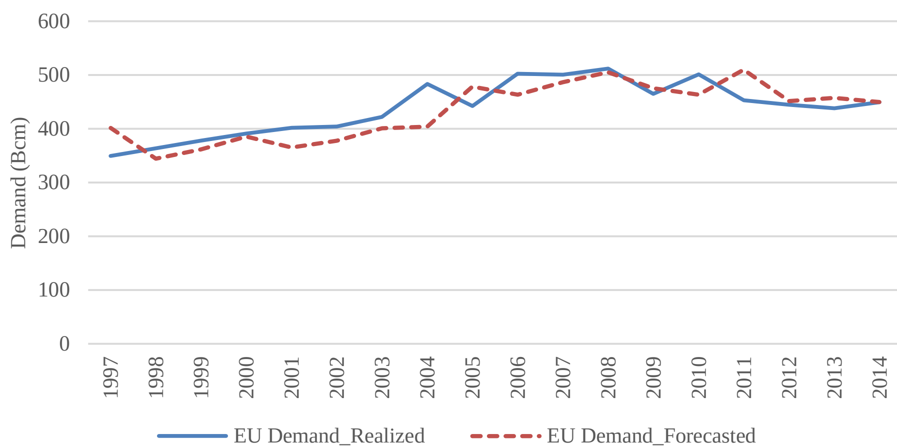
When considering the results of all scenarios, US LNG exports become helpful and meaningful for the EU countries if the considerable amount of LNG is exported to the EU natural gas market by the US. Moreover, variety of the natural gas suppliers is another significant issue that the EU countries should consider. For these reasons, the most effective scenarios are determined as Scenario 4 and 5.

### 4.2.2. Economic Impact Analysis

In the first part of this section, US LNG exports are analyzed whether they do or do not affect the security of natural gas supply in the EU natural gas market. To make final remarks economic impact analysis should be carried out.

Before analyzing impacts of US LNG exports on the EU countries, natural gas demands in these countries over the period 1997-2014 are estimated by using Eq. 11[61] given in Section 3.2.2 and compared with the real demand values to check reliability of the model described by O. Dilaver and her colleagues. The differences between forecasted and realized EU natural gas demand given in Figure 44 fluctuate in the ranges between -10% and 10% in the years between 1997 and 2014. In this period, the average deviation between these values becomes -1.5%.

Figure 44: Forecasted and realized EU natural gas demand over the period 1997-2014




In the second part of the economic impact analysis the change in demand of natural gas in the EU countries is estimated for the years between 2016 and 2030. In these calculations three scenarios (low, reference and high) are analyzed to determine natural gas prices and GDP values that are illustrated in Figure 45 and 46.

[61] UEDT values were taken as 0.01239, -0.00685 and -0.002 for the periods 1995-1998, 1999-2011 and 2012-2014, respectively.

Figure 45: Natural gas prices over the period 1995-2030

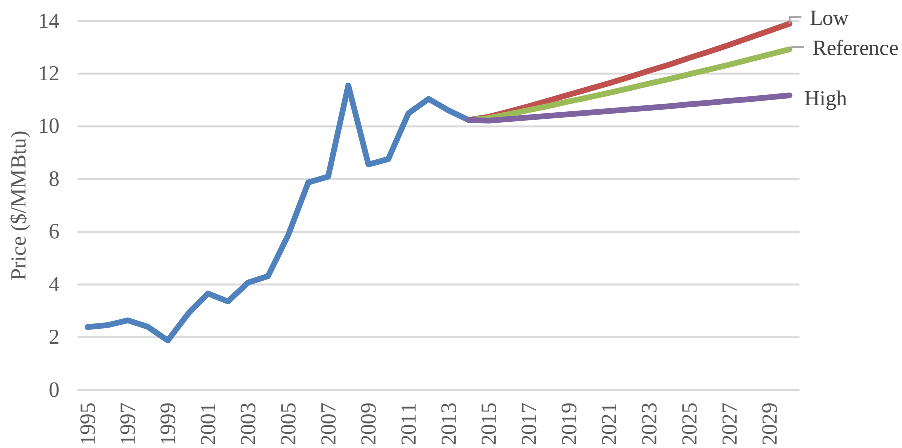
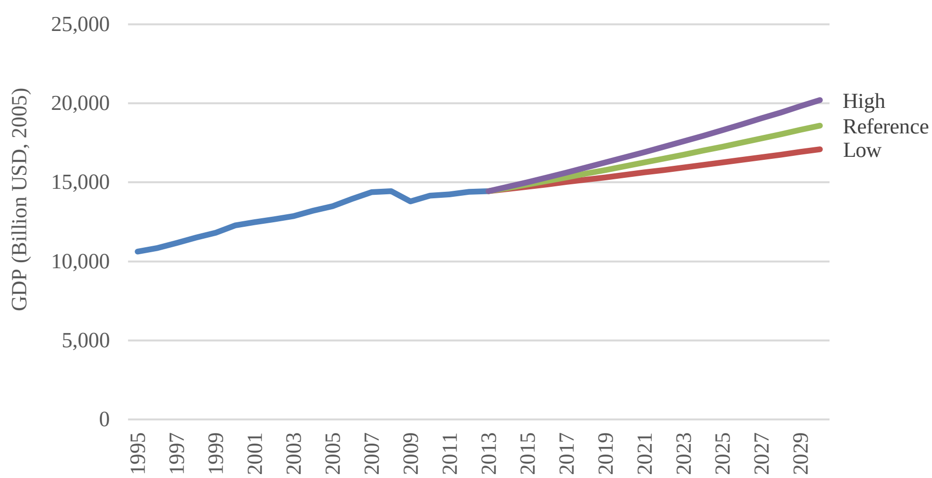
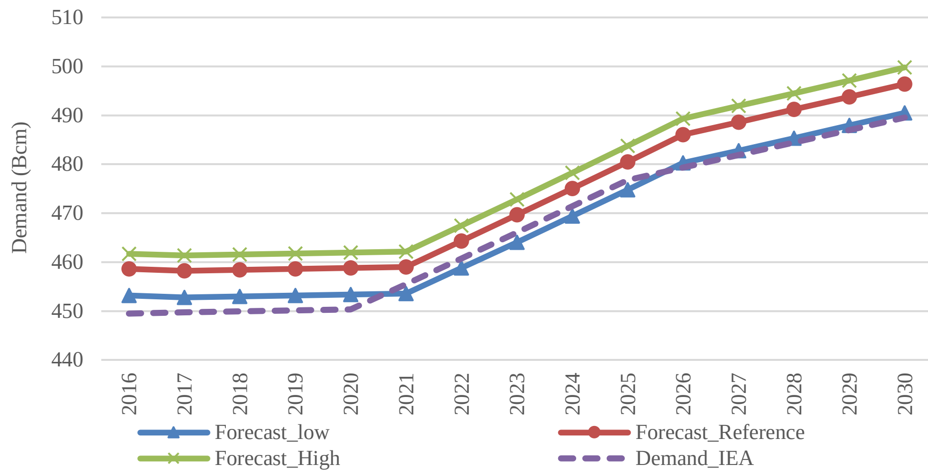



Figure 46: GDP in the OECD Europe countries over the period 1995-2030




After implementing three scenarios the results shown in Figure 47 do not conform to the expected values. At the outset of this study it is assumed that there are no impacts of US LNG exports on the EU natural gas market. But the outcomes of the economic impact analysis exhibit that reduction in natural gas prices will generally cause an increase in natural gas demand in the EU countries.

Figure 47: Natural gas demand in the EU countries regarding reference, low and high scenarios




As given in Table 10 after initialization of US LNG exports the natural gas demand in the EU countries rises gradually. For the low case scenario in which the growth in natural gas price and GDP are defined as 2% and 1% per annum respectively, the natural gas demand will ascend less than 1% in the period 2016 and 2020. In the following five years a slump in the natural gas demand is observed. Unlike the change in the years between 2021 and 2025 the natural gas demand increases incrementally.

Table 10: Summary of the changes in natural gas demand in the EU countries over the period 2011-2035

| **Time** | **Growth in Demand (%)** | | |
|---|---|---|---|
| | **Low Scenario** | **Reference Scenario** | **High Scenario** |
| 2016 | 0.812 | 2.024 | 2.718 |
| 2017 | 0.682 | 1.892 | 2.585 |
| 2018 | 0.681 | 1.891 | 2.583 |
| 2019 | 0.681 | 1.891 | 2.584 |
| 2020 | 0.680 | 1.890 | 2.582 |
| 2021 | -0.420 | 0.777 | 1.462 |
| 2022 | -0.420 | 0.777 | 1.462 |
| 2023 | -0.421 | 0.776 | 1.461 |
| 2024 | -0.422 | 0.775 | 1.459 |
| 2025 | -0.421 | 0.775 | 1.459 |
| 2026 | 0.192 | 1.396 | 2.084 |
| 2027 | 0.192 | 1.396 | 2.084 |
| 2028 | 0.191 | 1.395 | 2.083 |
| 2029 | 0.191 | 1.394 | 2.082 |
| 2030 | 0.191 | 1.395 | 2.082 |

For the reference case scenario, the natural gas price and GDP are assumed to grow 1.5 and 2% annually from 2016 to 2030. Under these circumstances three distinct trends are observed. In the first part including the period 2016-2020 an increase in demand is around 2%. The pace of growth in the second period (2021-2025) is less than the rise in the first part and it becomes 0.78%. In the final portion the alteration in the natural gas demand is approximately 1.4%.

For the high case scenario when the changes in natural gas prices and GDP are taken as 0.5% and 2.5% per annum, the tendency of the growth in the natural gas demand is similar to the reference case scenario. Averagely, the natural gas demand increases 2.6% in between 2016 and 2020; these rates become 1.5% and 2.1% in the periods 2021-2025 and 2026-2030, respectively.

In addition to analyzing three scenarios, the effects of the natural gas price fluctuation are tested. While the growth rate of natural gas price is altered, other parameters specified in the reference case scenario are kept constant from 2016 to 2030. The outcomes are given in Table 11.

Table 11: Annual growth rate of the EU natural gas demand regarding alteration of natural gas prices

| **Annual change of natural gas prices (%)** | **Annual growth in natural gas demand (%)** | | |
|---|---|---|---|
| | **2016-2020** | **2021-2025** | **2026-2030** |
| **0.5** | 2.04 | 0.92 | 1.54 |
| **1.0** | 1.99 | 0.85 | 1.47 |
| **2.0** | 1.84 | 0.7 | 1.32 |
| **3.0** | 1.70 | 0.56 | 1.17 |
| **4.0** | 1.55 | 0.41 | 1.02 |
| **5.0** | 1.41 | 0.27 | 0.88 |
| **10.0** | 0.70 | -0.45 | 0.14 |
| **-0.5** | 2.22 | 1.07 | 1.69 |
| **-5.0** | 2.90 | 1.72 | 2.30 |

The smaller the change in natural gas prices is, the higher the growth in natural gas demand is. For example, if natural gas prices increase 1% annually, a rise in natural gas demand becomes 1.99%, 0.85% and 1.47% for the periods 2016-2020, 2021-2025 and 2026-2030, respectively.

To sum up, the consequences of the economic impact analysis of US LNG exports to the EU countries are as follows:

- If existing price formation methodology based on the HH prices persists in calculating the US LNG prices, US LNG exports will result in convergence of pipeline gas and LNG prices in the EU natural gas market.
- Depending on a rise in natural gas prices in the EU natural gas market, the natural gas demand in the European countries will deviate over the period 2016-2030. For all scenarios, initial market reaction to the LNG exports is an increase in natural gas demand. According to the outcomes of low, reference and high case scenarios, it is expected that

annual growth in the EU natural gas demand will become approximately 0.7%, 2% and 2.6% in the period between 2016 and 2030.

• Although the volume of the US LNG is one of the main determinants for the security supply analysis, this parameter does not impact the EU natural gas market economically. Unlike the volume of US LNG exports, US LNG prices will shape the natural gas market in the EU countries.

• GDP, as well as LNG prices, is another essential variable to forecast the EU natural gas demand. Therefore, the final remarks depend on the growth in GDP. The higher the growth in GDP in the EU countries is, the more impacts on the market are.

### 4.3. VERIFICATION OF THE HYPOTHESES

The aim of this study is to find the answers of the below questions:

1. What advantages can the EU anticipate from natural gas imports from the US? Will this trade be a panacea for the EU's countries to solve the problem related to the security of natural gas supply?
2. Will the US natural gas export reduce the EU's dependence on its main suppliers?
3. Will the LNG imports from the US change the EU's natural gas demand?

To achieve the aim of this study, the following hypotheses were tested:

$H_0$: Natural gas supply security of EU countries will not be affected by LNG imports from the US.

$H_1$: Natural gas supply security of EU countries will be affected by LNG imports from the US.

At the beginning of this research, I expected is to accept the null hypothesis.

When considering the results of the security supply and economic impact analyses, the null hypothesis should be rejected and alternative hypothesis ($H_1$) should be accepted. Depending on the volume of US LNG exports, LNG trade will have an impact on the EU natural gas market. For the economic impact analysis, the implementation of US LNG exports will affect the formation of the EU natural gas prices positively. They will be re-adjusted according to the US LNG prices. This alteration in the prices will cause an increase in the EU natural gas demand.

In the light of these outcomes, the questions can be replied as follows:

1. Conditionally, US LNG exports will provide many advantages to the EU countries. They will give them an opportunity to re-negotiate their long-term natural gas contracts. Secondly, they would cause a slump in natural gas prices in the EU natural gas market. Although US LNG exports are not an elixir for the EU natural gas market to improve its security supply, they will lessen the dominance of some exporting countries on the market.
2. US LNG exports will not decrease the EU's dependence on its suppliers. Because the EU countries will most probable prefer to import LNG from the US and under these circumstance the US market share in the EU natural gas market will rise. This situation prevents to improve the security of natural gas supply in the EU market.
3. US LNG exports will result in a rise in the EU natural gas demand. With an increase in GDP of the EU countries, the initialization of US LNG exports will lead to a decline in the EU natural gas prices. Regarding to reference case scenario the EU natural gas demand is expected to grow 1.9%, 0.8% and 1.4% over the periods 2016-2020, 2021-2025 and 2026-2030, respectively.

# Chapter 5: Conclusion and Final Remarks

## 5.1. Summary and Conclusion

As the cleanest-burning fossil fuel, natural gas has gained ground in the EU energy market for the last three decades due to EU's concerns about climate change and the EU's stringent policies to de-carbonize its energy systems. In spite of the importance of the natural gas demand in the EU countries, natural gas supply and insufficient domestic natural gas production in the member states have become essential challenges that make access to affordable, stable and sustainable natural gas from various suppliers at the top of the EU's agenda.

Even though considerable amount of natural gas is imported via well-connected pipelines from several exporting countries, such as Russia, Norway and Algeria, to fulfill the EU's natural gas need, some EU countries, such as Estonia, Lithuania, Latvia, Finland and Bulgaria import their whole natural gas needs from a single supplier (Russia). Disruption of Russian gas, resulting from the disputes between Russia and Ukraine in 2006, 2009, and 2014, has endangered the security of natural gas supply at national and the EU level. Also cutting off the natural gas supply from Russia has increased energy expenditures in the EU countries. These problems have compelled the EU to take measures to mitigate the impacts of Russian natural gas disruption. Hence, diversification of both routes and sources has been the EU's priority to meet the EU's natural gas demand.

To strengthen energy independence and to ensure the security of natural gas supply in the EU natural gas market, efficient use of the opportunities such as importing LNG is defined as one of the essential measures in recent EU's regulations (e.g. the EU's Energy Security Strategy (COM/2014/0330)). Although the construction of new pipelines is counted as a solution in these regulations, long construction period of new gas transmission system and the requirement of capital-intensive investment have made LNG imports especially from the US important in the last two years.

The EU countries have been facing hardships about the security of natural gas supply. Meanwhile, advances in drilling technologies and production strategies such as hydraulic fracturing and horizontal drilling have made shale gas more accessible and boosted indigenous natural gas production in the US since 2007. The US Energy Information Administration (EIA) expects that the growth in natural gas production in the US, as a result of the shale gas boom, would provide an opportunity to the US to be a net natural gas exporter in the foreseeable future. By exporting LNG to the EU countries the US could help its allies, the EU countries, to reduce Russian hegemony in the EU natural gas market.

Even though both sides have made many infrastructural and legal arrangements, it is not yet known whether US LNG exports are or are not an elixir for the EU natural gas market. For this reason, impacts of US LNG exports on the EU gas market are analyzed in this thesis. During measuring the effects of US LNG exports on the EU natural gas market, three essential issues are investigated:

1. What advantages can the EU expect from natural gas imports from the US? Will this trade be a panacea for the EU's countries to solve the problem related to the security of natural gas supply?
2. Will the US natural gas export reduce the EU's dependence on its main suppliers?
3. Will the LNG imports from the US change the EU's natural gas demand?

At the beginning of this thesis, it is expected that the security of natural gas supply in the EU countries will not be affected from US LNG exports. To accept or reject this hypothesis, this thesis is structured in five chapters to analyze impacts of US LNG exports on the EU's natural gas market. The basics of the LNG markets are described in Chapter

Two. Chapter Three reviews the methods used to verify correctness of the hypothesis. Chapter Four discusses the assumptions used to analyze impacts of US LNG exports on the EU's gas market and presents the results of the models described in Chapter Three. In the final chapter (Chapter 5) some conclusions and final remarks are drawn.

As a result of the security supply and economic impact analyses, main findings are:

-*Security Supply Analysis:* Herfindahl-Hirschman Index (HHI), Shannon-Wiener Index (SWI) and modified SWIs (SWI-1 and SWI-2) are calculated. During estimation of these indices, some parameters, such as the market share of indigenous production and political stability index of the exporting countries, are used. As a result of these calculations, the volume of LNG exports from the US and the number of suppliers are found as two main determinants for diversification of natural gas suppliers and improvement of the market.

To answer the research questions and find impacts of US LNG exports on the EU natural gas market six different scenarios defined by the EIA's 2011 Annual Energy Outlook are analyzed. The results of analyses show that US LNG exports become helpful and meaningful for the EU countries if the considerable amount of the US LNG is exported to the EU natural gas market. Moreover, variety of the natural gas suppliers and their market shares are discovered as other significant determinants that should be taken into account by the EU to solve the problem about security of natural gas supply. In the light of these outcomes, US LNG exports with a rate of 12 Bcf/day phased in at a rate of 1 Bcf/day per year (high/slow scenario) and 12 Bcf/day phased in at a rate of 3 Bcf/day per year (high/rapid scenario) seem as the most effective scenarios.

-*Economic Impact Analysis:* The natural gas demand model formulized by O. Dilaver and her colleagues is used to measure the economic impacts of US LNG exports on the EU countries. To construct this model while the natural gas prices and GDP values of OECD-Europe countries from 1978 and 2011 are taken as primary parameters, the Structural Time Series Model (STSM) with the Underlying Energy Demand Trend (UEDT) concept is used to forecast the European natural gas demand (OECD-Europe). The consequences of this analysis are:

- With initialization of US LNG exports, the prices of pipeline gas and LNG in the EU natural gas market will converge to each other.
- Although the EU natural gas demand will deviate over the period 2016-2030 due to a rise in natural gas prices in the EU natural gas market, generally, the EU natural gas market will react positively to US LNG exports by an increase in natural gas demand. According to the outcomes of low, reference and high case scenarios, annual growth in the EU natural gas demand is anticipated to be approximately 0.7%, 2% and 2.6% in this period.
- While the volume of the US LNG is one of the main determinants for the security supply analysis, it does not affect the EU natural gas market economically. As an independent from the volume of the US LNG, LNG prices always shape the market in the EU countries.
- GDP and the LNG prices are vital variables to predict the EU natural gas demand. In other words, the final remarks on the impacts of US LNG exports on EU natural gas market depend on the growth in GDP and LNG prices. The higher the growth in the GDP of the EU countries is, the more impacts of US LNG exports on the EU natural gas market are. Unlike GDP, an increase in LNG prices negatively affects the EU market and lessen the impacts of US LNG exports.

When taking the findings of the security supply and economic impact analyses into consideration, outcomes contradict the hypothesis about insensitivity of the EU natural gas market to US LNG exports. Depending on the volume of natural gas export and the LNG prices, the LNG trade between the US and the EU countries will provide some benefits, such as a growth in the EU natural gas demand, improvement of competition in the market and convergence of the pipeline gas and LNG prices.

## 5.2. Final Remarks

On the contrary to the initial expectation, analyses exhibit that US LNG exports will have the impacts on the EU natural gas market. Even though these results conform to the studies performed by optimistic scholars and consulting companies, certain concerns still exist about the effects of US LNG exports on the EU market.

Although the LNG markets in the US and the EU countries are well-developed and deregulated markets, they are structurally distinct from each other as mentioned in Chapter Two. Unlike the US natural gas market, the EU gas market generally depends on long-term contracts with take-or-pay obligations. Also, the EU has a fragmented market structure regarding country-based policies and markets' dynamics. While the Central and Eastern European countries with illiquid market and oil-indexed natural gas prices mainly utilize carbon intensive solid fossil fuels, Northwestern European countries (including Italy) prefer to use less carbon intensive fuels like natural gas to achieve the 20/20/20 targets. In the northwestern part of Europe, the market has growing based on hub-trading (like NBP), liquidity, and spot-based pricing. These differences between the natural gas markets cause uncertainties during forecasting improvement of natural gas market in competition and natural gas demand.

In addition to structural perplexities in these markets, models used in the analyses are based on many assumptions. In security supply analysis, many parameters such as the depletion rate of the EU's indigenous production and natural gas (and also LNG) capacity delivered by the exporting countries under the long term contracts over period 2015-2030 are assumed. To illustrate, EU domestic natural gas production is assumed to decrease by 1%, 2% and 1.6% annually over the periods 2015-2020, 2020-2025 and 2025-2030 respectively. Also, US LNG exports to the EU countries are anticipated to implement at the outset of 2016 and only certain scenarios given in the EIA's 2011 Annual Energy Outlook are analyzed.

Similarly, many assumption are made to measure the economic impacts of US LNG exports. For example, the price of natural gas, is estimated by assuming that price formation in the OECD-Europe countries and the EU countries is based on the volume-weighted average prices. The shares of pipeline gas and LNG in the EU natural gas market over period 2014 and 2030 is assumed as 90% and 10%, respectively. Correction factor to convert forecasted natural gas demand of OECD-Europe countries to the demand of the EU countries is taken as 0.91.

Existence of many uncertainties, such as volatile natural gas prices and instable growth in the EU countries, affects reliability of the models. Hence, the outcomes of security supply and economic impact analyses should be used as supplementary determinants.

Although abovementioned uncertainties decrease the reliability of the analyses, the results of the analyses give good indication for US LNG exports to the EU countries. For this reason, the outcomes found in this study could help LNG investors, politicians and the regulators in both the US and the EU countries. Both the US and the EU countries should seek the other opportunities before implementing US LNG exports. While the US analyzes the other options like exporting LNG to markets in Asia-Pacific or South America, the EU countries should investigate other natural gas suppliers and resources, such as shale gas production.

## Abbreviations

| | |
|---|---|
| \$/bbl | US Dollar per barrel |
| \$/MBtu | US Dollar per million British Thermal Unit |
| \$/Tpa | US Dollar per tonnes per annum |
| €/Mwh | Euro per megawatt-hour |
| AEO | Annual Energy Outlook |
| Bcf | Billion cubic feet |
| Bcf/d | Billion cubic feet per day |
| Bcm | Billion cubic meters |
| Bcm/d | Billion cubic meters per day |
| Bcm/y | Billion cubic meters per year |
| BP | British Petroleum |
| BREE | Australian Government Bureau of Resources and Energy Economics |
| CAAGR | Compounded Average Annual Growth Rate |
| CEGH | Central European Gas Hub |
| $CH_4$ | Methane |
| DOE | The US Department of Energy |
| E&P | Exploration and Production |
| EC | European Commission |
| EIA | The US Energy Information Administration |
| ENI | Ente Nazionale Idrocarburi |
| EU | The European Union |
| FERC | The Federal Energy Regulatory Commission |
| FPSU | Floating Production and Storage Unit |

| | |
|---|---|
| FPU | Floating Production Unit |
| FTA | Free Trade Agreement |
| GDP | Gross Domestic Product |
| GHG | Greenhouse Gas |
| GIIGNL | International Group of Liquefied Natural Gas Importers |
| HH | The Henry Hub |
| HHI | Herfindahl-Hirschman Index |
| IEA | International Energy Agency |
| IGU | International Gas Union |
| JCC | Japan Crude Cocktail |
| LNG | Liquefied Natural Gas |
| $m^3$ | Cubic meter |
| MBtu | Million British Thermal Unit |
| Mcm/day | Million cubic meters per day |
| MENA | The Middle East and North Africa |
| Mt/y | Million tonnes per year |
| Mtoe | Million tonnes of oil equivalent |
| Mtpa | Million tonnes per annum |
| NBP | The National Balancing Point |
| NCG | Net Connect Germany |
| Non-FTA | Non Free Trade Agreement |
| OECD | The Organization for Economic Co-operation and Development |
| PEGS | Points d'Echange Nord |
| PSV | Punto Di Scambio Virtuale |
| STSM | The Structural Time Series Model |

| | |
|---|---|
| SWI | Shannon-Wiener Index |
| Tcf | Trillion cubic feet |
| TIGF | Points d'Echange Sud |
| TTF | Tile Transfer Facility |
| UEDT | The Underlying Energy Demand Trend |
| UK | The United Kingdom |
| US | The United States of America |
| WIPO | The World Intellectual Property Organization |
| ZEE | Zeebrugge |
| $/bbl | US Dollar per barrel |

## Nomenclature

| | |
|---|---|
| $(P_{av})_t$ | Average price of imported natural gas at year t, \$/MBtu |
| $(P_{Henry\ Hub})_t$ | Average price of natural gas at Henry Hub at year t, \$/MBtu |
| $(P_{Liquefaction})_t$ | Average cost of liquefaction process at year t, \$/MBtu |
| $(PLNG)_t$ | Average price of imported LNG at year t, \$/MBtu |
| $(P_{pipeline\ gas})_t$ | Average price of imported pipeline natural gas at year t, \$/MBtu |
| $(P_{Regasification})_t$ | Average cost of regasification process at year t, \$/MBtu |
| $(P_{Shipping})_t$ | Average shipping cost from the US to the EU countries at year t, \$/MBtu |
| $b_i$ | Index of political stability of country i, ranging from 0 to 1 |
| $D_t$ | Total natural gas demand at year t, Billion $m^3$ (Bcm) |
| $g_i$ | The share of indigenous production in the total consumption |
| $g_t$ | The natural logarithm of natural gas demand at year t |
| $G_t$ | Natural gas demand at year t, Billion $m^3$ (Bcm) |
| $I_t$ | Amount of imported natural gas purchased under long term contract at year t, Billion $m^3$ (Bcm) |
| $LNG_t$ | Projected LNG demand at year t, Billion $m^3$ (Bcm) |
| $p_t$ | The natural logarithm of natural gas price index at year t (2005=100) |
| $P_t$ | Natural gas price index at year t (2005=100) |
| $Q_t$ | Indigenous natural gas production at year t, Billion $m^3$ (Bcm) |
| $S_n$ | The market share of the firm |
| $UEDT_t$ | Underlying Energy Demand Trend for natural gas at year t |
| $x_i$ | The fraction share of the imports from supplier i |
| $X_t$ | The share of pipeline gas in the total natural gas import at year t |

| | |
|---|---|
| $y_t$ | The natural logarithm of Gross Domestic Product (GDP) at year t (US Dollar 2005= 100 PPP) |
| $Y_t$ | Gross Domestic Product (GDP) at year t (US Dollar 2005= 100 PPP) |

**Greek alphabets**

| | |
|---|---|
| $\varepsilon_t$ | A random error term |
| $\beta_t$ | The slope of the UEDT |
| $\mu_t$ | Level of the UEDT at year t |

**Subscripts and superscripts**

| | |
|---|---|
| t | Year |
| av | Average |

# References


Alaska Support Industry Alliance. (2013, December ). LNG 101: Spot Market Pricing and Economics. *Alaska Journal of Commerce*(2). Retrieved January 28, 2015, from http://www.alaskajournal.com/Alaska-Journal-of-Commerce/December-Issue-2-2013/LNG-101-Spot-Market-Pricing-Economics/

America's Oil and Natural Gas Industry. (2014). *Liquified Natural Gas Exports- Amerca's Opportunity and Advantage.* American Petroleum Institute. Retrieved January 20, 2015, from http://www.api.org/~/media/files/policy/lng-exports/lng-primer/liquefied-natural-gas-exports-highres.pdf

Australian Government Bureau of Resources and Energy Economics. (2014). *Gas Market Report.* Canberra. Retrieved January 15, 2015, from http://www.bree.gov.au/files/files/publications/gas-market/gasmarketreport-201411.docx

Badea, A. C. (2010, May 19-21). Energy Security Indicators. Belgrade. Retrieved October 17, 2014, from http://www.drustvo-termicara.com/resources/files/7fa5460.pdf

Bobbish , D. (2014, June). US Takes Steps to Advance LNG Exports-DOE, Export License, Applications. *Project Finance NewsWire*. Retrieved February 10, 2015, from http://www.chadbourne.com/us_advance_lng_exports_june2014_projectfinance/

Boersma, T., Mitrova, T., Greving, G., & Galkina, A. (October 2014). *Business As Usual: European Gas Market Functioning in Times of Turmoil and Increasing Import Dependence.* The Brookings Energy Security Initiative. Retrieved January 20, 2015, from http://www.brookings.edu/~/media/Research/Files/Papers/2014/10/european%20gas%20market%20import%20dependence/business_as_usual_final_3.pdf

Bonhomme, D., Burignat, D., Miquel, P., Engoian, A., & Aubry, C. (2013). Competition: Pipeline Gas and LNG in Europe. Retrieved February 15, 2015, from http://www.gastechnology.org/Training/Documents/LNG17-proceedings/6-3-Denis_Bonhomme.pdf.

BP. (2014). *BP Statistical Review of World Energy 2014*. Retrieved January 21, 2014, from http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB4QFjAA&url=http%3A%2F%2Fwww.bp.com%2Fcontent%2Fdam%2Fbp%2Fexcel%2FEnergy-Economics%2Fstatistical-review-2014%2FBP-Statistical_Review_of_world_energy_2014_workbook.xlsx&ei

Brown, J. (2014, September 30). NEPA and Environmental Impacts of LNG Exports. Texas, USA. Retrieved February 10, 2015, from http://www.utexas.edu/law/centers/energy/blog/2014/09/nepa-and-environmental-impacts-of-lng-exports/

Canadian Association of Petroleum Producers. (January 2014). *An Overview of the World LNG Market and Canada's Potential for Exports of LNG.* Retrieved January 19, 2015, from http://www.capp.ca/getdoc.aspx?DocId=237161&DT=NTV

Černoch, F., Dancak, B., Kodouskova, H., Ocelik, P., & Vrbkova, I. (2010, March). The LNG Option: Re-thinking the EU's Gas Supplies? *International Issues & Slovak Foreign Policy Affairs, Vol. 19*(1), 61-78.

Collins, G. (2015, January 16). The "LNG Permitting Certainty and Transparency Act"—A Positive Step Toward Expediting U.S. LNG Export Projects. North America Shale Blog. Retrieved February 03, 2015, from http://www.northamericashaleblog.com/2015/01/16/the-lng-permitting-certainty-and-transparency-act-a-positive-step-toward-expediting-u-s-lng-export-projects/?utm_source=Mondaq&utm_medium=syndication&utm_campaign=View-Original

Cornell University, INSEAD, and the World Intellectual Property Organization (WIPO). (2014). *The Global Innovation Index 2014: The Human Factor in Innovation.* Geneva. Retrieved February 20, 2015, from https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB4QFjAA&url=https%3A%2F%2Fwww.globalinnovationindex.org%2Fuserfiles%2Ffile%2Freportpdf%2Fgii-2014-v5.pdf&ei=NZELVePaLciaNrvFg_gN&usg=AFQjCNHhzMdsup99piz-PlzrOUS9whMV0A&bv

Cornot-Gandolphe, S., Appert, O., Dickel, R., Chabrelie, M., & Rojey, A. (2003). The Challenges of Further Cost Reductions for New Supply Options (Pipeline, LNG, GTL). *22nd World Gas Conference*, (pp. 1-17). Tokyo. Retrieved January 22, 2015, from http://www2.hmc.edu/~evans/PipelinesTokyo.pdf

Cunningham, N. (2013, March). The Geopolitical Implications of US Natural Gas Exports. Washington DC. Retrieved January 20, 2015, from https://www.americansecurityproject.org/ASP%20Reports/Ref%200116%20-%20The%20Geopolitical%20Implications%20of%20U.S.%20Natural%20Gas%20Exports.pdf

De Micco, P. (2014). *A Cold Winter to Come? The EU Seeks Alternatives to Russian Gas.* Directorate-General for External Policies, Policy Department. Brussels: European Union. Retrieved December 20, 2014, from http://www.europarl.europa.eu/RegData/etudes/STUD/2014/536413/EXPO_STU(2014)536413_EN.pdf

Dickel, R., Hassanzadeh, E., Henderson, J., Honore, A., El-Katiri, L., Pirani, S., . . . Yajimava, K. (2014). *Reducing European Dependence on Russian Gas: Distinguishing Gas Security From Geopolitics.* Oxford: Oxford University for Energy Studies. Retrieved February 15, 2015, from http://www.oxfordenergy.org/wpcms/wp-content/uploads/2014/10/NG-92.pdf

Dilaver, O., Dilaver, Z., & Hunt, L. (2014). What Drives Natural Gas Consumption in Europe? Analysis and Projections. *Journal of Natural Gas Science and Engineering*(19), 125-136.

Dresden University of Technology (TUD). (2008, January 1). A Quanification of the Diversification of the European Coal Supplies. Retrieved February 27, 2015, from http://www.feem-project.net/secure/plastore/Deliverables/SECURE%20_Deliverable_5.3.3.pdf

Du, Y., & Paltsev, S. (November 2014). *International Trade in Natural Gas: Golden Age of LNG (.* MIT Joint Program on the Science and Policy of Global Change. Cambridge: Massachusetts Institute of Technology (MIT). Retrieved January 21, 2015, from http://globalchange.mit.edu/files/document/MITJPSPGC_Rpt271.pdf

Duncan, C. (2015, February 4). *Forbes.* Retrieved February 10, 2015, from LNG Exports Offer A Path Away From OPEC Domination Of Energy Markets: http://www.forbes.com/sites/danielfisher/2015/02/04/lng-exports-offer-a-path-away-from-opec-domination-of-energy-markets/

Duval, V. (2011). World LNG Market: Cuurent Developments and Prospects. Retrieved February 20, 2015, from http://www.gep-aftp.com/_upload/ressources/textes_conferences/23_11_2011/2011-11-23_gep-aftp-gs_lng_market_perspectives_vf.pdf

Economides, M. (2007, October 18). Compressed Natural Gas: Monetizing Stranded Gas. *Energy Tribune*. Retrieved January 27, 2015, from http://www.energytribune.com/941/compressed-natural-gas-monetizing-stranded-gas#sthash.UxBuGV7G.10VtsHoz.dpbs

Eurogas. (2011). *Natural Gas Demand and Supply: Long Term Outlook to 2030.* Retrieved February 15, 2015, from http://www.dma.dk/themes/LNGinfrastructureproject/Documents/Market%20analysis/Eurogas%20long%20term%20outlook%20to%202030%20-%20final.pdf

European Commission (EC). (2014). *In-depth Study of European Energy Security.* Commission Staff Working Document, Brussels. Retrieved February 15, 2015, from http://ec.europa.eu/energy/sites/ener/files/documents/20140528_energy_security_study_0.pdf

European Commission. (2013). *Quarterly Report on European Gas Markets First Quarter 2013.* Brussels. Retrieved January 05, 2015, from http://ec.europa.eu/energy/sites/ener/files/documents/20130611_q1_quarterly_report_on_european_gas_markets.pdf

European Commission, J. R. (2009, June 7). Liquefied Natural Gas: Advantages And Drawbacks. *ScienceDaily*. Retrieved January 25, 2015, from www.sciencedaily.com/releases/2009/07/090707094816.htm

European Union (EU). (2014, May 25). *Communication from the Commision to the European Parliament and the Council European Energy Security Strategy (COM/2014/0330)*. Retrieved February 18, 2015, from http://eur-lex.europa.eu/legal-content/EN-ES/TXT/?uri=CELEX:52014DC0330&fromTab=ALL&from=EN

ExxonMobil. (2015). *The Outlook for Energy: A View to 2040.* ExxonMobil. Retrieved January 23, 2015, from http://cdn.exxonmobil.com/~/media/Reports/Outlook%20For%20Energy/2015/2015-Outlook-for-Energy_print-resolution.pdf

Global Energy Info. (2015, January). *World's LNG Liquefaction Plants and Regasification Terminals.* Retrieved February 02, 2015, from Global energy Info Website: http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB4QFjAA&url=http%3A%2F%2Fwww.globallnginfo.com%2Fworld%2520lng%2520plants%2520%26%2520terminals.pdf&ei=LyTUVMCNNselNqvHgeAE&usg=AFQjCNELORNMXf6sIEDvymk61h0brthfRw

Goldthau, A. (2013). *The Geopolitics of Natural Gas Development in the European Union.* Harvard University's Belfer Center & Rice University's Baker Center Institute for Energy Studies. Retrieved January 20, 2015, from http://belfercenter.ksg.harvard.edu/files/MO-CES-pub-GeoGasEU-102513.pdf

Goncalves, C. (2014, November 18). Breaking Rules and Changing the Game: Will Shale Gas Rock the World? *Energy Law Journal, 35*(2), 225-262. Retrieved January 27, 2015, from http://www.felj.org/sites/default/files/docs/elj352/13-225-262-Goncalves-final-11.1.pdf

Hellenic Shipping News Worldwide. (2015, January 21). *Spain's LNG Reloads Face a Though Market in 2015.* Retrieved February 3, 2015, from http://www.hellenicshippingnews.com/spains-lng-reloads-face-a-tough-market-in-2015/

Henderson, J. (2012). *The Potential Impact of North American LNG Export.* Oxford Institue for Energy Studies. Retrieved March 2, 2015, from http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB4QFjAA&url=http%3A%2F%2Fwww.oxfordenergy.org%2Fwpcms%2Fwp-content%2Fuploads%2F2012%2F10%2FNG-68.pdf&ei=doX2VI20L4jlgwSChYDYAQ&usg=AFQjCNH5qEvtIIvtMvrJkgaLH0WHJTDXJA&bvm=b

Holleaux, D. (2006). *Value of Transatlantic Arbitrage.* Paris: Gaz De France. Retrieved February 3, 2015, from http://www.cne.es/cgi-bin/BRSCGI.exe?CMD=VEROBJ&MLKOB=311672242525

Hufbauer, G., Bagnall, A., & Muir, J. (2013, February). *Liquified Natural Gas Exports: An Opportunity for America.* Washington DC: Peterson Institute for International

Economics. Retrieved February 11, 2015, from http://www.piie.com/publications/pb/pb13-6.pdf

Hunt, L., & Ninomiya, Y. (2003). *Modelling Underlying Energy Demand Trends and Stochastic Seasonality: An Econometric Analysis of Transport Oil Demand in the UK and Japan.* University of Surrey , Department of Economics. The Surrey Energy Economics Centre (SEEC). Retrieved March 3, 2015, from http://www.seec.surrey.ac.uk/Research/SEEDS/SEEDS107.pdf

Institute of Energy for South-East Europe (IENE). (July 2014). *The Outlook for a Natural Gas Trading Hub in SE Europe.* Athens. Retrieved January 20, 2015, from http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=43&cad=rja&uact=8&ved=0CCwQFjACOCg&url=http%3A%2F%2Fwww.depa.gr%2Fuploads%2FOutlook_for_a_natural_gas_trading_hub_in_SE_Europe_FINAL%2520DRAFT%2520%25282%2529.pdf&ei=BuC-VOHKAczjsAS_voLoDg&usg=A

International Energy Agency (IEA). (2015). What is Energy Security? Retrieved February 26, 2015, from http://www.iea.org/topics/energysecurity/subtopics/whatisenergysecurity/

International Gas Union (IGU). (2014). *World LNG Report-2014 Edition.* Retrieved January 21, 2015, from http://www.igu.org/sites/default/files/node-page-field_file/IGU%20-%20World%20LNG%20Report%20-%202014%20Edition.pdf

International Group of Liquefied Natural Gas Importers (GIIGNL). (2009). *Information Paper No.2 - LNG Process Chain.* Retrieved February 04, 2015, from http://www.giignl.org/sites/default/files/PUBLIC_AREA/About_LNG/4_LNG_Basics/090801publique_lngbasics_lng_2_-_lng_supply_chain_7.3.09-aacomments.pdf

International Group of Liquefied Natural Gas Importers (GIIGNL). (2014). *The LNG Industry in 2013.* Retrieved January 20, 2015, from http://www.giignl.org/sites/default/files/PUBLIC_AREA/Publications/giignl_the_lng_industry_fv.pdf

Jacobs, D. (2011). The Global Market for Liquefied Natural Gas. *RBA Bulletin*, 17-28. Retrieved January 22, 2015, from http://www.rba.gov.au/publications/bulletin/2011/sep/pdf/bu-0911-3.pdf

Jansen, J., Van Arkel, W., & Boots, M. (2004). *Designing Indicators of Long-Term Energy Supply Security.* Energy Research Center of the Netherlands. Retrieved February 26, 2015, from http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB4QFjAA&url=http%3A%2F%2Fwww.ecn.nl%2Fdocs%2Flibrary%2Freport%2F2004%2Fc04007.pdf&ei=IyfxVPWGBrb-sATC44LIDg&usg=AFQjCNFUbRm1IMIwABnmQziveetNp0pWSg

Jensen, J. (2011). Asian Natural Gas Markets: Supply Infrastructure and Pricing Issues. *2011 Pacific Energy Summit.* Jakarta. Retrieved February 3, 2015, from http://www.nbr.org/downloads/pdfs/eta/PES_2011_Jensen.pdf

Kato, T. (2014, May 2). *Nikkei Asian Review.* Retrieved February 1, 2015, from China, Japan, South Korea gulp down 62% of global LNG production: http://asia.nikkei.com/Markets/Commodities/China-Japan-South-Korea-gulp-down-62-of-global-LNG-production

King & Spalding. (2006). *LNG in Europe: An Overview of European Import Terminals.* Retrieved December 20, 2014, from http://www.kslaw.com/library/pdf/LNg_in_Europe.pdf

Lajtai, R., Czinkos, A., & Dinh, T. (2009). Nabucco vs. South Stream: The Effects and Feasibility in the Central abd Eastern European Region. *Proceedings of the 24th World Gas Conference 2009 (WGC 2009). 5*, pp. 4112-4145. Buenos Aires: Curran Associates. Retrieved February 26, 2015, from http://www.kgu.or.kr/download.php?tb=bbs_017&fn=wgcFinal00780.pdf&rn=wgcFinal00780.pdf

Market Realist. (2014, October 21). *Must-know: Cheniere Energy prospects in a nutshell.* (B. K., Ed.) Retrieved January 30, 2015, from http://marketrealist.com/2014/10/must-know-cheniere-energy-prospects-nutshell/

Mitrova, T. (2014). Russian Energy Sector: Entering New Era. Washington. Retrieved February 20, 2015, from http://csis.org/files/attachments/141014_Mitrova.pdf

Montgomery, W., & Tuladhar, S. (2013, April 23). *Nera Economic Consulting.* Retrieved January 20, 2015, from Macroeconomic Impacts of LNG Exports from the United States: http://www.nera.com/content/dam/nera/publications/archive2/PUB_Macroeconomic_Impacts_LNG_Exports_0413.pdf

Morosuk, T. , & Tsatsaronis , G. (2012). *LNG – Based Cogeneration Systems: Evaluation Using Exergy-Based Analyses, Natural Gas - Extraction to End Use.* Retrieved from http://www.intechopen.com/download/pdf/40567

PFC Energy. (2013). *Global LNG Supply and Demand Study.* Retrieved January 28, 2015, from https://docs.neb-one.gc.ca/ll-eng/llisapi.dll/963808/A3I5K7_-_Appendix_C_-_Global_LNG_Supply_and_Demand_Study_-_PFC_Energy.pdf?func=doc.Fetch&nodeid=963808

Poten & Partners. (2013, January). Regional Gas Prices: What Role Has LNG to mitigate these? Vienna. Retrieved January 20, 2015, from European Gas Conference: http://www.europeangas-conference.com/sites/default/files/Poten%20-%20European%20Gas%20Conference%202013%20Vienna.pdf

Poten & Partners. (2013, November). Role of LNG in the Current and Future Energy Mix. Retrieved January 26, 2015, from http://idee.stcr.nl/@api/deki/files/944/=1.Poten_-_Role_of_LNG_in_the_Current_and_Future_Energy_Mix_(3).pdf

Poten & Partners. (October 2010). *2015-2035 LNG Market Assessment Outlook for the Kitimat LNG Terminal.* Retrieved January 15, 2015, from http://www.arcticgas.gov/sites/default/files/documents/km-lng-10-10-poten-partners-lng-mkt-assess.pdf

Renier, P. (2013, September 25). European LNG Terminal Developments. London. Retrieved February 15, 2015, from http://www.gie.eu/index.php/publications/doc_download/21154-gle-presentation-at-lnggc-2013-london-european-lng-terminal-developments

Rogers, H. (2010). *LNG Trade-flows in the Atlantic Basin: Trends and Discontinuities.* Oxford Institute for Energy Studies. Retrieved January 28, 2015, from http://www.oxfordenergy.org/wpcms/wp-content/uploads/2010/11/NG41-LNGTradeFlowsInTheAtlanticBasinTrendsandDiscontinuities-HowardRogers-2010.pdf

Sakmar, S. (2013). *Energy for the 21st Century: Opportunities and Challenges for Liquefied Natural Gas (LNG).* Northhampton: Edward Elgar Publishing, Inc.

Songhurst, B. (February 2014). *LNG Plant Cost Escalation.* Oxford: Oxford Institute for Energy Studies. Retrieved February 04, 2015, from http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB4QFjAA&url=http%3A%2F%2Fwww.oxfordenergy.org%2Fwpcms%2Fwp-content%2Fuploads%2F2014%2F02%2FNG-83.pdf&ei=GLLSVMDDJMiWgwSI9YLgBw&usg=AFQjCNEXPbldhvmS-KG6Vw83hLiI5W6S8w&bvm=b

Teekay LNG Partners L.P. (2015, February 05). *LNG Shipping 101*. Retrieved from http://www.teekaylng.com/about-the-lng-market/lng-shipping-101/default.aspx

U.S. Energy Information Administration (EIA). (2012). *Effect of Increased Natural Gas Exports on Domestic Energy Markets.* Independent Statistics and Analysis, Washington DC. Retrieved February 12, 2015, from http://www.eia.gov/analysis/requests/fe/pdf/fe_lng.pdf

U.S. Energy Information Administration (EIA). (August 2014). *Global Natural Gas Markets Overview: A Report Prepared by Leidos, Inc., Under Contract to EIA.* Washington D.C. Retrieved January 20, 2015, from http://www.eia.gov/workingpapers/pdf/global_gas.pdf

U.S. Energy Information Administration (EIA). (May 2014). *Annual Energy Outlook 2014.* Washington D.C. Retrieved February 9, 2015, from http://www.eia.gov/forecasts/aeo/pdf/0383(2014).pdf

Von Hirschausen, C., Haftendorn, C., Herold, J., Holz, F., Neumann, A., & Ruster, S. (2010, November). Europe's Coal Supply Security: Obstacles to Carbon Capture, Transport and Storage. *CEPS Policy Brief*(223). Retrieved February 27, 2015, from http://aei.pitt.edu/15196/1/Policy_Brief_223_Hirschhausen_Secure.pdf

Weems, P., & Hwang, M. (2015, February). *King & Spalding*. Retrieved February 11, 2015, from The Top 10 Questions Facing the LNG Industry in 2015: http://www.kslaw.com/library/newsletters/EnergyNewsletter/2015/February/article2.html

Wood Mackenzie. (2014, August 15). Panama Canal: Will Expansion be Enough for US LNG? Retrieved February 10, 2015, from http://www.woodmac.com/public/views/12287878

Zelenovskaya, E. (2012). *Impact of Shale Gas Production on the Market Fundamentals and Energy Security of Certain Countries.* International Center for Climate Governance (ICCG). Retrieved January 15, 2015, from http://www.iccgov.org/FilePagineStatiche/Files/Publications/Reflections/06_reflection_april_2012.pdf

Zhuravleva, P. (2009). *The Nature of LNG Arbitrage: an Analysis of the Main Barriers to the Growth of the Global LNG Arbitrage Model.* Oxford Institute for Energy Studies. Retrieved February 3, 2015, from http://www.oxfordenergy.org/wpcms/wp-content/uploads/2010/11/NG31-TheNatureofLNGArbitrageAndAnAnalysisoftheMainBarriersfortheGrowthofGlobalLNGArbitrageMarket-PolinaZhuravleva-2009.pdf