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Analysis of Natural Gas Supply Chain and Optimisation of Small-Scale Liquefied Natural Gas Supply Chain in Spain

by

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Acknowledgements

I appreciate Dr. Zuidwijk for valuable feedback for my thesis.
Life is continuously unexpected and tough. However, I have managed it well so far with the support from my family. My mother always believes and supports me. Without my father, I would not be here since he introduced and helped me in the maritime industry.

Abstract

Spain has the most extensive infrastructure of small-scale LNG (SSLNG) in Europe. This leads to the complexity of the distribution of SSLNG to the domestic destinations. The purpose of the study is the optimisation of small-scale liquefied natural gas (SSLNG) supply chain by truckload transportation in Spanish territory in the Iberian Peninsula. Also, SSLNG in Spain cannot exist without large-scale LNG after trading the resource so, the whole markets are analysed.

Seasonality of LNG causes a problem for truck companies transporting LNG since the companies should manage the surplus from the gap between peak and off-peak season. Another problem is a limit of LNG output truckload capacity at LNG receiving terminals. This leads for SSLNG facility to be supplied SSLNG not always from the nearest terminal. The last issue is derived from El Musel terminal under not operation by Spanish government even though a tremendous amount of capital was invested for the terminal. So, it is essential to justify the operation of the terminal to the Spanish government not to waste the investment.

Mixed Integer Linear Programme (MILP) solves the network optimisation problems by using software “Excel Solver”. The scope of the study for simulations is from liquefied natural gas (LNG) import terminals to SSLNG facilities consisting of LNG fuel stations and satellite terminals. A regression model estimates a decision variable of SSLNG demand with seasonality for forecasting with using “Minitab” software. Three scenarios are applied to the model based on the degree of SSLNG demand with sub-scenario whether the operation of El Musel terminal or not.

The seasonality has effects on the supply chain by appearing or disappearing short-term transportation of LNG. This has been observable in high demand (scenario 1). When the high demand almost reaches the maximum LNG truckload capacity of LNG terminals, the geographical reliance from the destinations to the terminal is weak. On the other hand, the less demand (scenario 2) results in the high geographical reliance. The difference in total costs comparing operation and no operation of El Musel is not substantial. A lack of capacity in scenario 3 is not able to analysis since adjustments of the order of terminals lead to different results while the other conditions are the same.

Truck companies benefit from the number of trucks needed for LNG transportation calculated from the simulations since they can mitigate the adverse effects of the surplus of their asset in advance by setting appropriate strategy. There are three types of SSLNG facility depends on having a single or multiple LNG import terminals supplying SSLNG. The first and second types are not necessary to change the number of terminals since the numbers of terminal they needed remain same regardless of the scenario. On the other hand, the companies in the third type experiencing the change in the number of terminals between the two scenarios should consider making contracts to be supplied SSLNG. So, companies in the second type should be informed to meet the demands, otherwise satisfying the demand is impossible by losing the service terminals to other firms.

Table of Contents

List of tables

List of figures

List of Abbreviation

BOG: Boil-off gases
CNG: Compressed natural gas
Cbm: Cubic Metres
GHG: Greenhouse gas
GWh: Gigawatt hours
Km: Kilometre
LNG: Liquified natural gas
LTL: Less than truckload
MMBTU: One million British Thermal Units
R-sq: R-squared
SSLNG: small-scale liquified natural gas
TL: Truckload
US: United States

Chapter 1 Introduction

1.1 The topic

There is the growing interest in LNG ever since International Maritime Organization (IMO) has imposed the regulation against pollution derived from fuels of ships (Bittante, et al., 2017b). LNG is considered an eco-friendly resource and one of the best alternative fuels (Bittante, et al., 2017b). Also, LNG is necessary for the isolated area where the access of the pipeline for transportation of natural gas is not available (Bittante, et al., 2017a).

The concept of small-scale LNG is different from the one of large-scale LNG. Transport mode of large-scale LNG is a massive size of LNG ships and pipelines while the one of small-scale LNG is the small size of ships, trucks and trains (Jokinen, et al., 2015). The organisation of the mode for small-scale LNG is relatively more complicated than the one for large-scale LNG.

1.2. Problem Statement

This difference in the level of complication is derived from the lot size and the number of destinations. In the large-scale LNG, the LNG import terminal is the only destination for the relatively small number of ships carrying a considerable volume of LNG. However, In the small-scale LNG, many numbers of small-scale transportation modes are required to handle the capacity of LNG to various destinations.

Seasonality brings the problem of surplus derived from the gap between peak and off-peak demands (Prentice and Prokop, 2016). In SSLNG supply chain, truck companies have issues from the surplus. In order to tackle the problems, it is necessary to set a proper pricing strategy and allocation plan for trucks. So, the issue derived from the surplus of trucks in the off-peak season can be solved by understanding the seasonality of the LNG supply chain. However, the strategy of the truck companies to handle the surplus is out of scope in the study, so it is not discussed.

Also, understanding the seasonality is vital for LNG import terminals and SSLNG facilities to estimate demands.

Non-vertical integration of the supply chain tends to result in several issues such as delaying of sharing information, increasing transaction costs (Williamson, 1983). The obstacles are highly likely to discourage the optimisation of the supply chain.

It would be the best solution if there were no limit of LNG truckload transportation output capacity at LNG import terminal. In that ideal situation, SSLNG facilities could order SSLNG from the nearest LNG receiving terminals. However, there are limits to the output capacity at the terminal in reality. So, the limit capacity sometimes forces the SSLNG facilities to be provided LNG from the terminal where is not geographically closest. This issue is relevant for LNG import terminals and SSLNG facilities since they are decision makers to decide the distribution of the SSLNG.

EL Musel LNG import terminal was constructed entirely in 2013, but it has been mothballed after the construction due to the regulation of the Spanish government concerning the excessive capacity of natural gas with the expectation of less demand of the resource (Prontera, 2017). In other words, the government has an intention of avoiding the situation of the surplus of LNG by importing more LNG through El Musel terminal. Although the owner of the terminal has been negotiating to utilise the terminal in different ways such as gas storage, it would be the best way to operate the terminal as the original purpose to recoup a considerable investment (about 380 million euros) for the terminal (El Comercio, 2017).

1.3 Background and Justification

In order to meet the various demands, not only the large-scale also small-scale LNG supply chains need to be facilitated. However, the small-scale supply chain is underestimated, unlike the large-scale one which is traditionally well developed and optimised (Jokinen, et al., 2015). However, recently, several journals written by Bittante, et al. (2016) Bittante, et al. (2017a), Bittante, et al. (2017b) and Jokinen, et al. (2015) focus on SSLNG supply chain to research the area.

1.4 Deficiencies in the Evidence

Most case studies of prior researches such as Bittante, et al. (2017b) and Jokinen, et al. (2015) regarding small-scale LNG supply chain analysed the supply chain in Finland sometimes coupled with Sweden. So, in this paper, case studies in Spain is conducted to fill this gap in the lack of case studies in different areas. Another reason for opting for Spain is the size of the small-scale LNG infrastructure. According to Gas Infrastructure Europe (2018b, Spain is the largest country regarding the number of small-scale LNG facilities by accounting for 37% of Europe. The large numbers in Spain must cause more issues in the distribution of small-scale than the other countries. If the paper studied other countries' SSLNG supply chain with a few numbers of the small-scale facilities, the answer would be straightforward and obvious.

1.5 Audience

LNG import terminals, truck companies and small-scale LNG facilities are the audiences of the research. LNG import terminals is the origin of the SSLNG and distribute SSLNG by trucks companies to the destinations which are SSLNG facilities.

1.6 Research Objective

Overall objective is "To optimise SSLNG supply chain between LNG import terminals and SSLNG facility by means of truck transportation in Spain".

Four specific objectives are below.

1. To analysis the seasonality of NG and LNG at trade, LNG import terminals, gas storage, consumption.
2. To measure the degree of integration among LNG import terminals, natural gas pipeline, LNG fuel stations, LNG satellite stations.
3. To analysis the effect of the seasonality to the numbers of trucks and LNG import terminals needed for SSLNG facilities on a monthly basis.
4. To assess the role of El Musel terminal in the SSLNG supply chain comparing situations with and without operating the terminal.

1.7 Research Questions

There are four research questions for the objectives introduced.

1. What are the features of the seasonality of NG and LNG in import, distribution and consumption in Spain?
2. To what extent does the level of the vertical integration exist from LNG import terminals to SSLNG facilities in Spain?
3. To what extent do changes in SSLNG demand affect the allocation of small-scale LNG between LNG import terminals and SSLNG facilities in Spain.
4. To what extent does El Musel LNG import terminal play a key role in different SSLNG demands in small-scale LNG supply chain in Spain?

The first two questions are answered in Chapter 2. The research question 1 will be solved by a regression model with the relevant data. Searching for the ownership of the facilities in the supply chain solves the research question 2.
The answers for the two questions are essential to understanding the characteristics of SSLNG industry in Spain since they are linked in the massive scale of the supply chain. Answers for the other two are in Chapter 5. MILP model will solve the two research questions. The different input of the SSLNG demand in the scenario will solve the question 3. Furthermore, including or excluding El Musel terminal leads to the answer for question 4.

1.8 Methodology and Research Design

Figure 1 shows the overview of the methodology and research design. The principal methodology of this paper is Mixed Integer Linear Programme by Excel Solver in order to optimise the small-scale LNG supply chain between LNG import terminals and destinations which are LNG fuel stations and satellite terminals. Another model is the regression model to forecast future consumption of SSLNG and price of LNG. Also, the estimation of fuel costs is done by the Autoregressive model by Excel.
On the other hands, there are several inputs for the model. At first, SSLNG demand in the autonomous communities" scale is estimated by using the regression. After forecasting the future demand, the demand is allocated to the autonomous community covering the SSLNG facilities based on the population ratio in the related community. Another is the total transportation costs consisting of transportation costs and inventory holding costs. Transportation costs consider distance, fuel efficiency and fuel costs together to calculate the fuel costs of trucks per kilometres. Also, other transportation costs such as expenses for insurance, repair and maintenance are included in the costs. Pipeline holding costs are estimated by holding costs rate and price of LNG. The estimation of the rate and price are from other journals and running the regression model respectively.
The data of maximum SSLNG capacity for truck transportation at LNG import terminals is acquired from the terminal's website.
The full integration helps to improve the delay of information. Also, transaction costs are indeed avoided by the integration. In the study, the integration is assumed in the supply chain.
The research is designed in three scenarios having different demands of small-scale LNG demands. Before mentioning the scenarios, the research area is limited into Spanish Iberian Peninsula meaning that excluding Spanish Islands in order to focus on LNG truck transportation, not other LNG transportations. The demand of LNG almost reaching the maximum output capacity (full capacity) of LNG truckload transportation from LNG import terminals is verified in scenario 1. For the sub-scenarios for the main one is researching the effect of the existence (scenario 1.1.) and non-existence (scenario 1.2.) of El Musel LNG receiving terminals. Subsequently, scenario 2 (abundant capacity) simulates more margins of the output LNG truckload capacity to meet the demand. The scenario two also contains the two sub-scenarios depending on the operation of the El Musel terminal in the same way as scenario 1. Scenario 3 examines a case of a lack of output capacity from LNG import terminals not satisfying the demand.

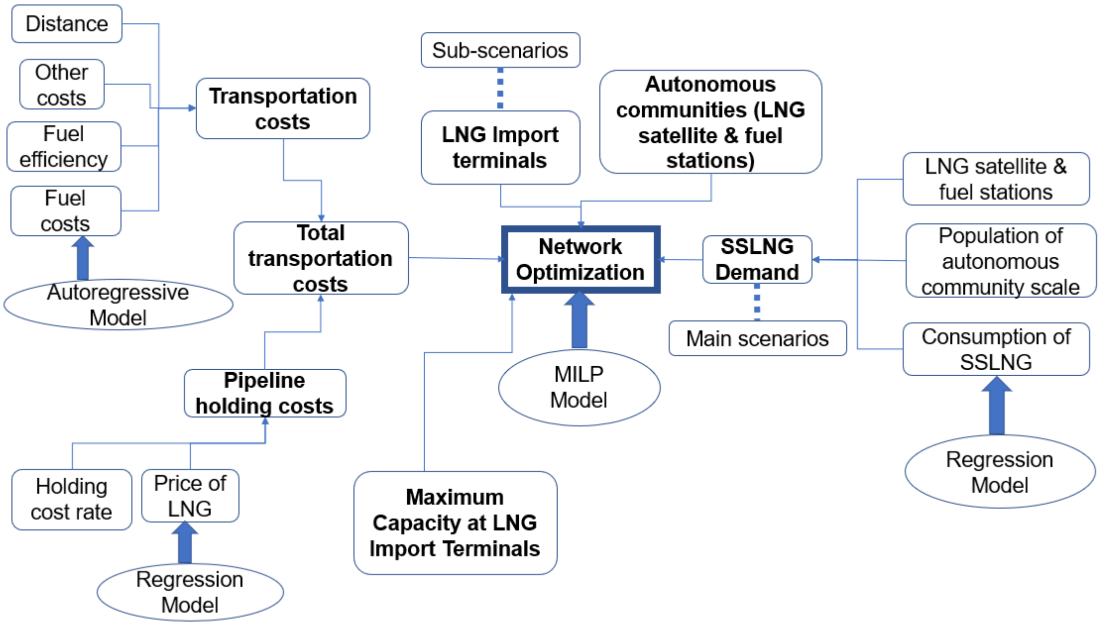

Figure 1 Flows of Methodology and Research Design

1.9 Thesis Structure

Figure 2 illustrates the overview of this paper. At first, introductions with research questions are stated. After that, other relevant papers about this thesis are discussed in the literature review. Subsequently, trade of the resources and LNG supply chain in Spain are explored. The next chapter explains methodology, and data collection for the study. After the simulations of the model, the results are analysed. Finally, the last chapter will conclude the study.

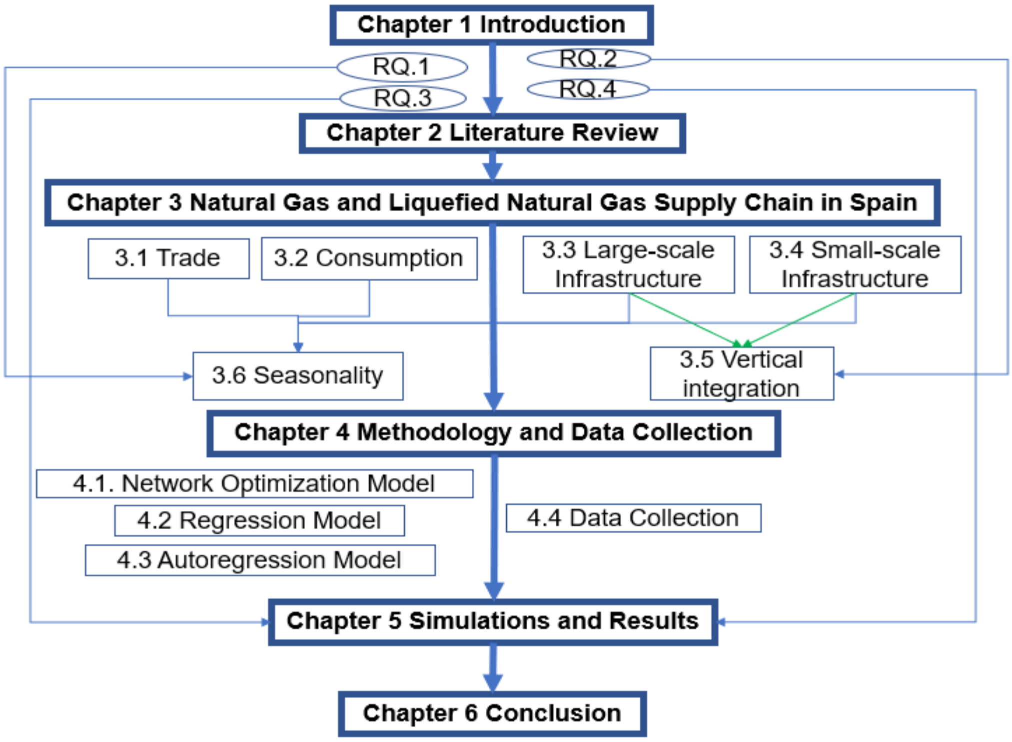

Figure 2 Structure of the thesis.

Chapter 2 Literature Review

Three topics which are seasonality, vertical integration and optimisation of SSLNG supply chain are discussed in the literature review. Chapter 2.1 discusses seasonality of LNG in other countries. The seasonality is the essential feature of the supply chain that it needs to understand before simulating the network optimisation model.

Designing a robust network is vital to deal with the seasonal changes. In other words, cooperating to design the robust network under seasonal changes is critical to optimise the supply chain. Regardless of the seasons, the well-prepared supply chain has a lot more efficient network available than the one does not consider the seasonality. The flexible network is not fully demanded toward winter nor summer. The dimension of the network, capacity, for example, is built with having quite an efficient operation that both winter and summer.

This discussion demonstrates that the seasonality of LNG in Spain is not the distinctive feature of Spain but occurs in other countries as well. Also, the reasons and effect of the seasonality are discussed in other countries, and these can be compared to the cases in Spain.

Vertical integration is discussed in Chapter 2.2. Vertical integration is necessary for the assumption of the optimisation model in the paper. If there is no vertical integration, it is difficult to handle the whole supply chain because every single SSLNG facility company makes different contracts with adverse effects of non-vertical integration. Less willingness to sacrifice for the common benefit of the entire supply chain and more transaction costs increasing the total costs are highly likely to be observed. So, in order to optimise the supply chain, it is assumed that the SSLNG supply chain is vertically integrated. At first, the theory of the vertical integration is discussed in detail. Subsequently, the theory applies to the natural gas industry to discuss the market with the vertical integration.

Chapter 3.3 shows SSLNG optimisation model in different papers. Apparently, the model is the major methodology so it is important to discuss. A matrix of the literature review is provided for a clear understanding of the trends of the SSLNG study. Types of models had been used in the majority of the papers are introduced first. The time period of the simulation, assumptions and target areas in the relevant papers are discussed in the order.

2.1 Seasonality

Seasonality of LNG demand in many countries is observed from various papers and they are discussed in this section. In the US, the seasonality coupled with long-term trend are the critical factors of domestic LNG demand (Zhu, 2008). Increases in economy and population lead to growing demands of LNG for resident and commerce sectors such as electric power, cooling and heating along with industry sectors in need of the gas and storage (Zhu, 2008). Also, some other reasons such as preventing environment by decreasing air pollutions, expending the size of houses lead to the growing demand (Zhu, 2008).

Seasonality of the consumption of natural gas is seen in the short-term by increasing the usage for heating purpose in cold days and cooling purpose at high-temperature days (Zhu, 2008). This seasonality affects the price of natural gas; In the winter season, there is relatively high price while the price is moderate in summer based on data from The International Energy Agency (Eliston, 2009). This consumption trend is easily seen in the residence and commercial sectors for the same purposes while industry and transportation sectors have stable demands (Zhu, 2008).

Storing natural gas during off-peak seasons are caused by the unbalance between the production of natural gas which is not seasonal and consumption of natural gas which is seasonal (Zhu, 2008). The inventory of the natural gas enables to meet the seasonality of the demand (Zhu, 2008). The term “peak shaving” explains the situation above which is buying natural gas at low cost in the off-peak season and liquified it as LNG to store (Zhu, 2008). Later, the LNG is regasified to be sold at a higher price in the peak seasons (Zhu, 2008). Also, some inventory of LNG without regasification are transported by trucks (Zhu, 2008).

Unlike Zhu (2008), Anne (2008) argued by using generated decorrelated time series that there were no clear relationships between the seasonality of the price of natural gas and demands in the US since power generations need natural gas in summer and winter.

However, Anne (2008) mentioned that Europe market had the strong relationships between the seasonality of price and demand for natural gas. Because most of the natural gas was for heating in winter seasons (Anne, 2008). Eliston (2009) supported this argument by showing the data on the LNG price seasonality in Europe from The International Energy Agency.

In Asian countries, a strong seasonal demand was observed in South Korea (Wood, 2007). This country met the seasonal demand by buying LNG in short-term contracts (Wood, 2007). So, it was critical for the Korean market to be affected by the fluctuation of the LNG price in spot markets (Wood, 2007). In order to overcome the vulnerability derived from the fluctuation, the capacity of the LNG storage tanks was expended, and the new LNG terminal was built in Korea (Wood, 2007).

Another country in Asia is Japan also having seasonality of natural gas consumption (Eliston, 2009). Unlike the increase in demand of natural gas for cooling purpose in the US mentioned by Zhu (2008) and Eliston (2009), there is seasonal demand for heating purpose in Japan which is observed by the higher price from August to December based on the data from The International Energy Agency (Eliston, 2009). This seasonality is similar to the one in Europe (Eliston, 2009).

2.2 Vertical Integration

Williamson (1985, p. 55) introduced the necessity of the vertical integration by mentioning “durable investments that are undertaken in support of particular transactions, the opportunity cost of which investments is much lower in best alternative uses or by alternative users should the original transaction be prematurely terminated”. Arfaa et al. (2011) stated that creating value and enhancing it are the advantages of the vertical integration enabling a single firm to run more than one company.

Based on the Williamson’s theory (1983, 1985), Neumann and Ruster (2006) suggest that there are three driving factors which are asset specificity, the frequency of transactions and uncertainty having influences on the high transaction costs in LNG supply chain. In order to reduce the transaction costs, it is highly likely to have a structure of the vertical integration (Neumann and Ruster, 2006).

Williamson (1983) mentioned the four types of the asset specificity: site specificity, physical asset specificity, human specificity and dedicated asset (Williamson, 1983). Site specificity means the proximity is required for the efficiency of processing and reducing costs (Williamson, 1983). Also, immobility of the asset resulting in costing a substantial capital in case of the relocation or new construction (Williamson, 1983). The second one is physical asset specificity meaning the usage or application for certain customers and products, not for others in general (Williamson, 1983). The third one is human asset specificity meaning that special knowledge acquired from tasks (Williamson, 1983). The last one is a dedicated asset about producing most of the products to meet a specific demand (Williamson, 1983).

The argument of Neumann and Ruster (2006) was agreed that the more asset is transaction-specific, the more possibility of gaining profit from opportunism (Klein, Crawford, and Alchian, 1978, cited in Doane and Spulber, 1994). In other words, the increase in contracting costs is more substantial than the one in vertical integration costs (Klein et al., 1978, cited in Doane and Spulber, 1994).
Apart from the theoretical approach of the vertical integration, Neumann and von Hirschhausen (2008) apply the vertical integration theory to large-scale LNG supply chain along with long-term contract, not the small-scale LNG supply chain.
Three entities try to exploit benefits from the vertical integration (Neumann and Ruster, 2006). At first, companies in upstream want additional profits generated from downstream business (Neumann and Ruster, 2006). Another entity is a transportation firm producing margins from arbitrage between the upstream and downstream (Neumann and Ruster, 2006). The last player is in downstream which is interested in not only producing profits but also securing the supply of LNG from upstream to satisfy the demand (Neumann and Ruster, 2006).

2.3 Optimisation of Small-Scale Supply Chain

A mixed integer linear programming (MILP) model was used to by a majority of authors regarding SSLNG supply chain. Table 1 shows the matrix of literature about SSLNG supply chain. Bittante, et al. (2018) research optimisation of the supply chain by sea-sea shipping with MILP model. However, the authors did not address land transports which are a part of small-scale LNG supply chain. Faaijf et al. (2017) used the MILP model with the transports modes of the road, rail and inland short sea shipping. Bittante, et al. (2016), Bittante, et al. (2017a), Bittante, et al. (2017b) and Jokinen, et al. (2015) focused on small-scale LNG supply chain with truck and ship transportation by using MILP model. Based on the trend of the using MILP models for the optimisation of SSLNG supply chain in the other papers, the MILP model is also used in this paper. The difference from the other journals is a selection of software which is Excel Solver to simulate the model.
Most of the paper use 30 days as the time period of their research. For instance, Jokinen, et al. (2015) set the time period in their paper as dividing a one year into twelve 30-day periods. Other studies conducted by Bittante, et al. (2016), Bittante, et al. (2017a) and Bittante, et al. (2018) also used a time horizon of 30 days. On the other hand, single (10 days) and multi-period (30 days) cases were presented by Bittante, et al. (2017b) which is different from the other papers. In the multi-period results, the three factors are addressed additionally: the amount of LNG transported by LNG by truck, the number of trucks and the related port-customers links (Bittante, et al., 2017b). Bittante, et al. (2017b) found that less overall cost in multi-period results which was more accurate. In a similar way of most of the journals, monthly (30 days) time period in a year is used for the simulation of this paper.
Regarding assumptions, enough storage capacity from customers are widely observed from the other journals (Bittante, et al., 2016, Bittante, et al., 2017a, Bittante, et al. 2017b and Jokinen, et al., 2015). This assumption is also applied in this paper. Several operational factors such as scheduling, supply availability linked to production rate or inventory, boil-off loss, time windows at the terminals are not considered (Bittante, et al., 2017b). This study also does not consider the operation factors like the same way of Bittante, et al. (2017b).
Most case studies of prior researches such as Bittante, et al. (2017b), Bittante, et al. (2016) regarding SSLNG supply chain analysed the supply chain in Finland coupled with Sweden. Study of a single area of Finland was done by Jokinen, et al. (2015). Also, Faaijf et al. (2017) focused Sweden for research area. Recently, the Caribbean

area was studied by Bittante, et al. (2018). On the other hand, there are still not sufficient academic journals about SSLNG supply chain in other areas. Even though SSLNG supply chain in Spain having a considerable amount of SSLNG facilities according to Gas Infrastructure Europe (2018b), there are no journals covering this country. So, this paper focuses on the supply chain in Spain to fill the gap of the other areas.

Author	Year	Transportation Modes	Time horizon	Relevant assumptions	Methodology	Research area
Bittante, et al.	2016	short-sea ships, trucks	30 days	-Enough storage capacity from destinations -no tank investment costs	MILP	Finland, Sweden
Bittante, et al.	2017a	short-sea ships, trucks	30 days	-Enough storage capacity from destinations -land transport is only available on weekdays - no tank investment costs	MILP	Finland, Sweden
Bittante, et al.	2017b	short-sea ships, trucks	10 days, 30 days	-Enough storage capacity from destinations -no investment costs - no consideration (scheduling, supply availability (production rate, inventory), boil-off gas, time windows at the terminals)	MILP	Finland, Sweden
Bittante, et al.	2018	short-sea ships	30 days	-Demand is smaller than storage Capacity -different LNG price	MILP	Caribbean region
Faaijf et al.	2017	short-sea ships, trucks, trains	-	-no boiled off gas - Price of LNG is assumed to be the current value	MILP	Sweden
Jokinen, et al.	2015	short-sea ships, trucks	30 days	-shipping strategy decides the routes - Enough storage capacity at destinations	MILP	Finland

Table 1 Literature Matrix of SSLNG optimisation.

Chapter 3 Natural Gas and Liquefied Natural Gas Supply Chain in Spain

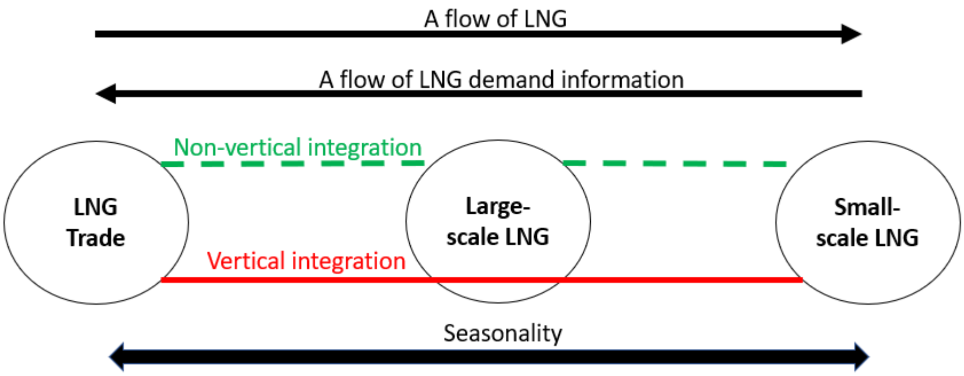

Figure 3 LNG supply chain in Spain.

Figure 3 illustrates the overview of Chapter 3. From chapter 3.1 to 3.3, seasonality of NG and LNG is observable after researching the data of the NG and LNG supply chain. Seasonality of LNG trade, large-scale LNG are shown in chapter 3.1 and 3.3 respectively. It is not available to access the direct data of flows of LNG in small-scale LNG facilities, however, using the data of the consumption of LNG in chapter 3.2 enables to seek the seasonality in the small-scale LNG. Those data of seasonality in the different stages in the supply chain are discussed altogether in chapter 3.6.
Chapter 3.1 and chapter 3.3 are necessary to discuss in advance of small-scale LNG since they are in the same supply chain. Regarding a flow of LNG, small scale-LNG in Spain would not exist unless there was the trade of LNG and large-scale LNG. Demands for SSLNG is estimated from downstream, and the information is delivered to upwards of the supply chain.
Vertical integration of the supply chain can reduce the obstacles derived from the other negative factors. In other words, the full integration encourages to improve the delay of information. In addition, transaction costs are indeed avoided by the integration. Chapter 3.5 seeks the degree of the vertical integration in the LNG and NG supply chain in Spain based on the information from chapter 3.3 and 3.4. So, in order to optimise SSLNG supply chain, it is required to understand not only SSLNG but also LNG trade and large-scale LNG since they are closely connected.

3.1 Trade of Natural Gas and Liquefied Natural Gas

The flow of the trade of NG and LNG is necessary to understand the SSLNG supply chain since the SSLNG supply chain is closely linked to the large-scale LNG supply derived from the trade.
The trade of the resources would not have played a key role in SSNLG if Spain domestically produced the sufficient NG and LNG. However, the independence of the exploits the resources is not observed in Spain. For instance, Spain merely produced 0.19% of NG out of total gas consumption in 2016 (Benito et al., 2017). In other words, Spain heavily relies on importing NG and LNG for the domestic consumption in Spain. The heavy reliance must affect SSLNG supply chain in Spain since the supplied LNG is originally from the trade of LNG.

For example, in case of the issues decreasing in the production of NG and LNG in some countries exporting the resources to Spain, players in SSLNG supply chain can expect the reduction and find the solutions.

3.1.1 Import of Natural Gas and Liquefied Natural Gas

Figures 4 shows the data about LNG and NG import in Spain. At the beginning of the given period, the amount of imported LNG approximately twice more than the one of imported NG. However, the amount of imported NG exceeded the one of imported LNG at most of the times since 2013. Also, the figure 4 illustrates that the seasonality of import NG and LNG to meet the change in the demand for natural gas consumption shown in figure 11 in chapter 2.6.

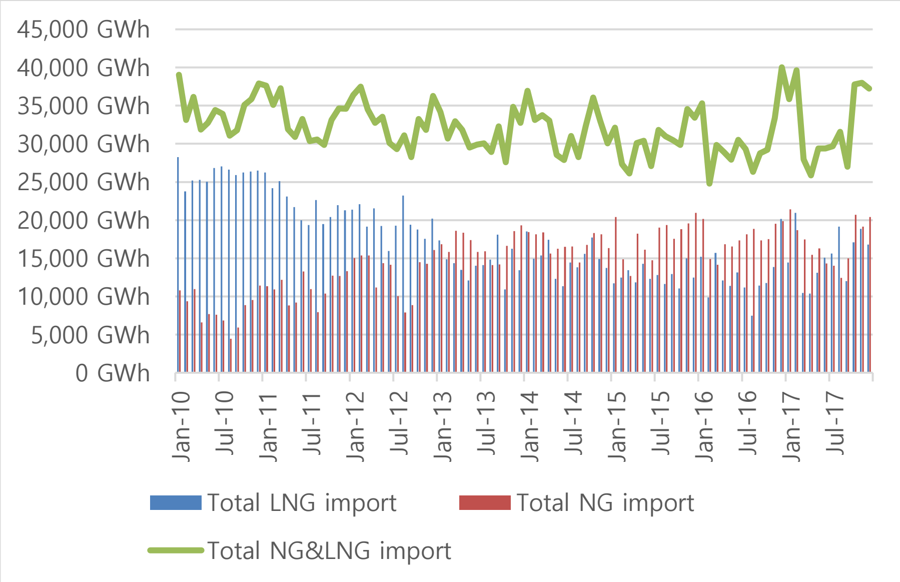

Figure 4 Total LNG and NG import in Spain. Source: Source: Corporacion de Reservas Estrategicas de Productos Petroliferos

Benito et al. (2017) mention that most of NG are imported to Spain through Medgaz and Maghreb pipelines (Benito et al., 2017) and figure 2 illustrates the amount of NG imported from other countries to Spain. Figure 2 shows that except for Alegria, the other relatively minor NG exporters to Spain are Norway, France and Portugal which are European countries.

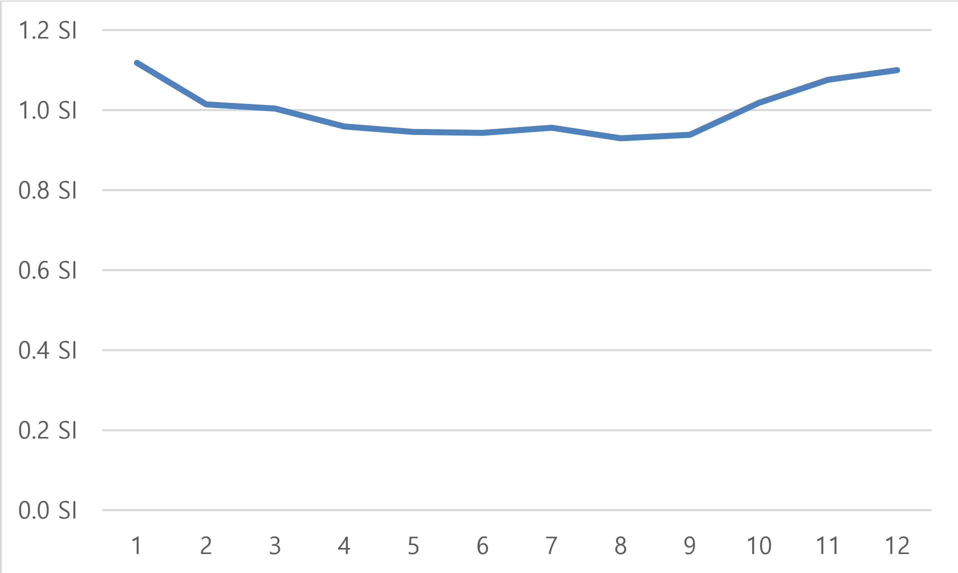

Figure 5 Seasonal Index of Import of NG and LNG. Source: Corporacion de Reservas Estrategicas de Productos Petroliferos

Figure 5 shows a seasonal index of import of the resources. The seasonal index is relatively high in winter season during low between April and September. In other words, Spain tends to import more NG and LNG in winter than the other seasons.

Figure 6 illustrates that the majority of NG is imported from Algeria to Spain while Norway is the second largest country for exporting NG to Spain.

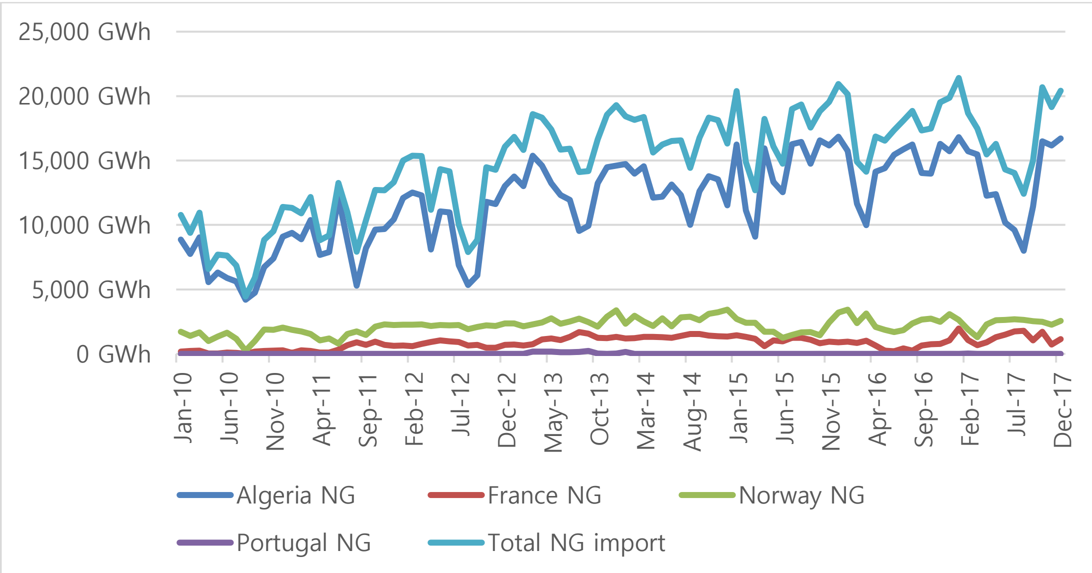

Figure 6 NG import from outside of Spain. Source: Source: Corporacion de Reservas Estrategicas de Productos Petroliferos

Figure 7 illustrates that even though there are both import and export of NG between the two countries, import NG from Portugal only occurred around in 2013. It implies that the pipelines are usually dedicated to distributing NG from Algeria to Portugal.

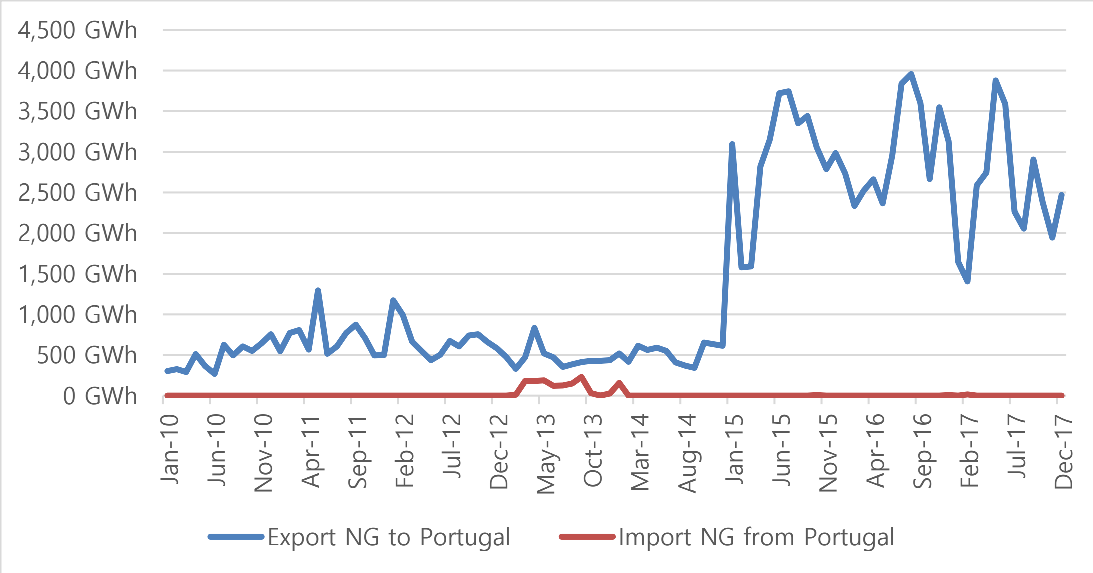

Figure 7 NG export and import between Portugal and Spain. Source: Source: Corporacion de Reservas Estrategicas de Productos Petroliferos

The allocations of the two pipelines are through Irun and Larrau for France's gas market (Enagas, 2016). In a similar way of the transport of NG between Spain and Portugal, however, figure 8 shows that Spain has been annually imported more NG than exported NG against France through these pipelines except for 2010.

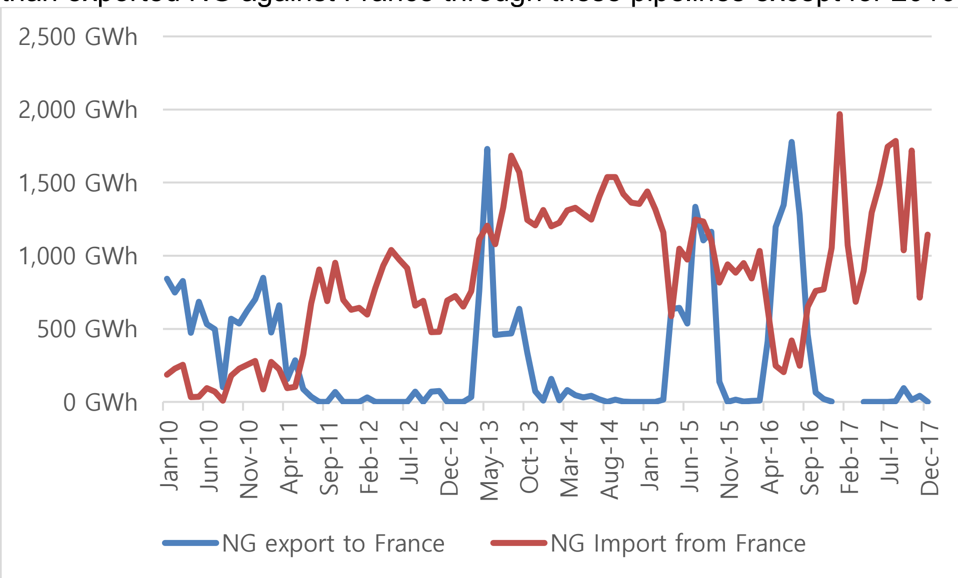

Figure 8 NG export and import between France and Spain. Source: Source: Corporacion de Reservas Estrategicas de Productos Petroliferos

A lack of clear explanation of NG from Norway to Spain can be explained by the pipeline connection between France and Norway. France is one of major NG import countries from Norway by pipeline so Norway must export NG to Spain through the pipeline in France in a similar way to Maghreb pipeline from Algeria to Spain through Morocco (Benito et al., 2017).

On the other hands, LNG is imported by LNG ships due to geographical restrictions of inaccessibility of gas pipeline such as from the Middle East, Africa and America or insufficient capacity of the gas pipeline such as Algeria. Within Europe, LNG from

Norway accounts for the most of LNG import (Corporacion de Reservas Estrategicas de Productos Petroliferos, 2018c). Figure 8 shows that Nigeria, Qatar and Algeria are the largest exporters of LNG to Spain. Figure 9 also illustrates that Norway is a significant LNG exporter country in Europe to Spain while Peru and Trinidad & Tobago play an essential role in importing LNG from America market.

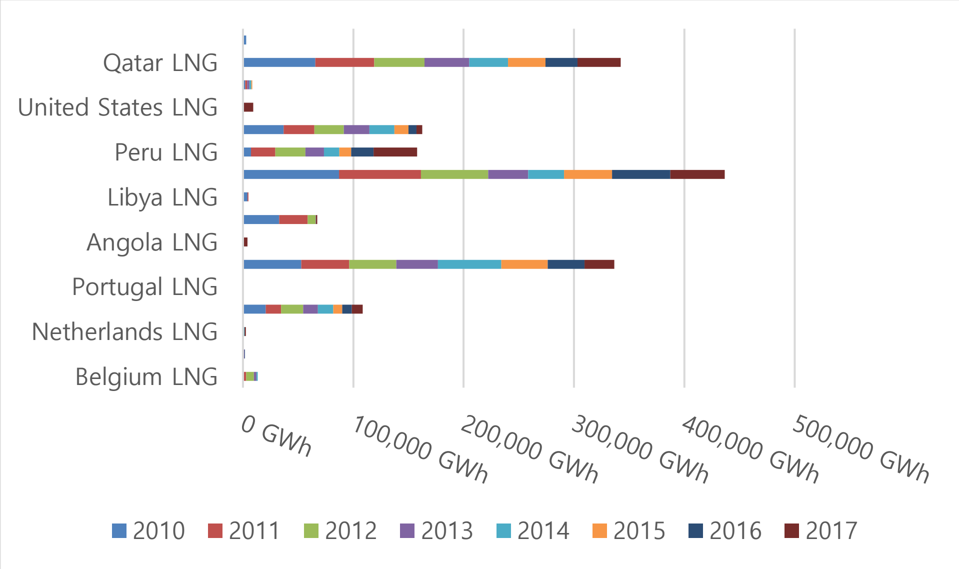

Figure 9 LNG import to Spain. Source: Corporacion de Reservas Estrategicas de Productos Petroliferos

3.1.2 Export of Natural Gas and Liquefied Natural Gas

Figure 10 shows that Spain solely transports NG to France and Portugal regarding the export of NG outside of Spain. It is noticeable that most of the distribution of the NG from Algeria through Spain is on Portugal. It is explained by a lack of geological access of Portugal than France. Portugal is more isolated from Europe since it is located in the Iberia Peninsula. On the other hand, France has connections from many countries in Europe.

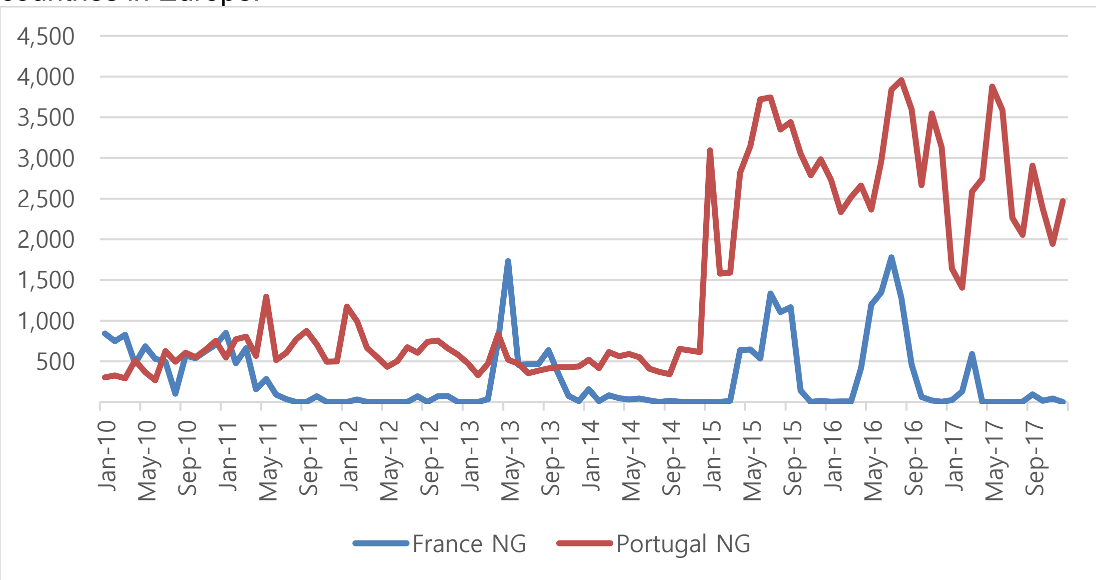

Figure 10 NG export from Spain to France and Portugal. Source. Source: Corporacion de Reservas Estrategicas de Productos Petroliferos

The fact that Spain has 0.19% of NG domestic production in 2016 would make no sense that Spain is the LNG and NG export country (Benito et al., 2017). However, Spain was one of the European countries generating substantial profits from LNG reloading (Timera Energy, 2013).

Reloading means the transaction of LNG from a storage tank receiving the cargo from LNG ships to other vessels by reloading of the cargo (Zhuravleva, 2009). It is considered as arbitrage since it is caused by price difference (Zhuravleva, 2009). In Spain, Huelva LNG import terminal exploited the LNG reloading to generate profits (Zhuravleva, 2009).

Even though Spain does not produce any LNG domestically, this country was the largest exporter of LNG in 2014 because of the LNG reloading. (Enriquez and Rojo, 2016b).

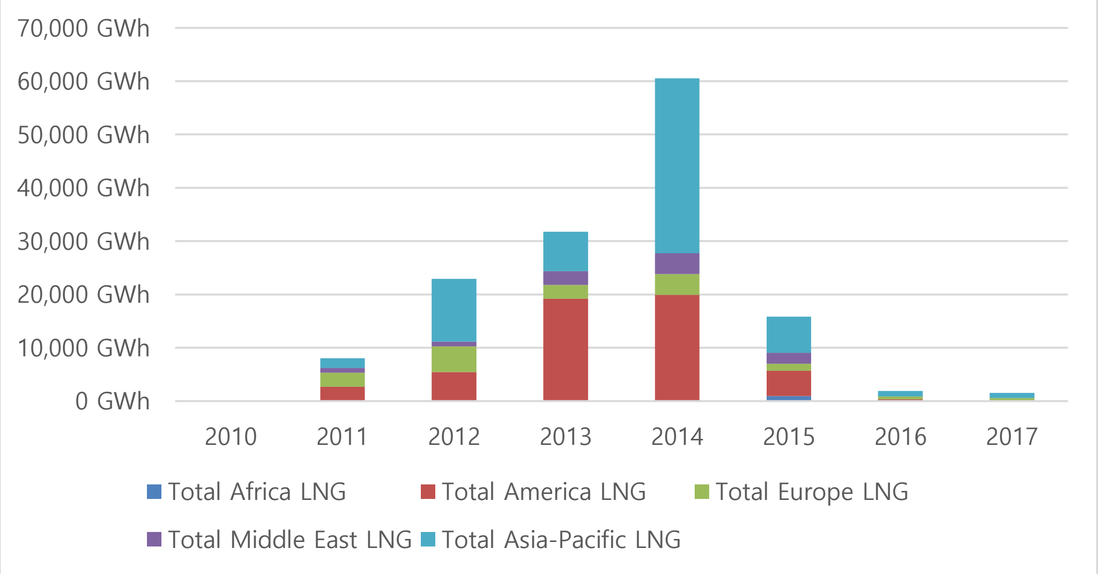

Figure 11 Worldwide LNG export from Spain. Source: Corporacion de Reservas Estrategicas de Productos Petroliferos

Figure 11 shows that the amount of reloading of LNG is the most significant in 2014 throughout the years. The major importers of Spanish reloading LNG are Asian countries and America countries. Between 2011 and 2015, the amount of Spanish reloading LNG roughly remains the same in Europe, while rapid increases of importing of LNG are observed in America from 2012 to 2013. Also, the amount of reloading to Asia substantially increase in the following year, so the amount is doubled from 2013 to 2014. After reaching the highest amount of the reloading in 2014, the amount substantially decreased to approximately 15,000 GWh in 2015. Following years, the amount of reloading barely exists.

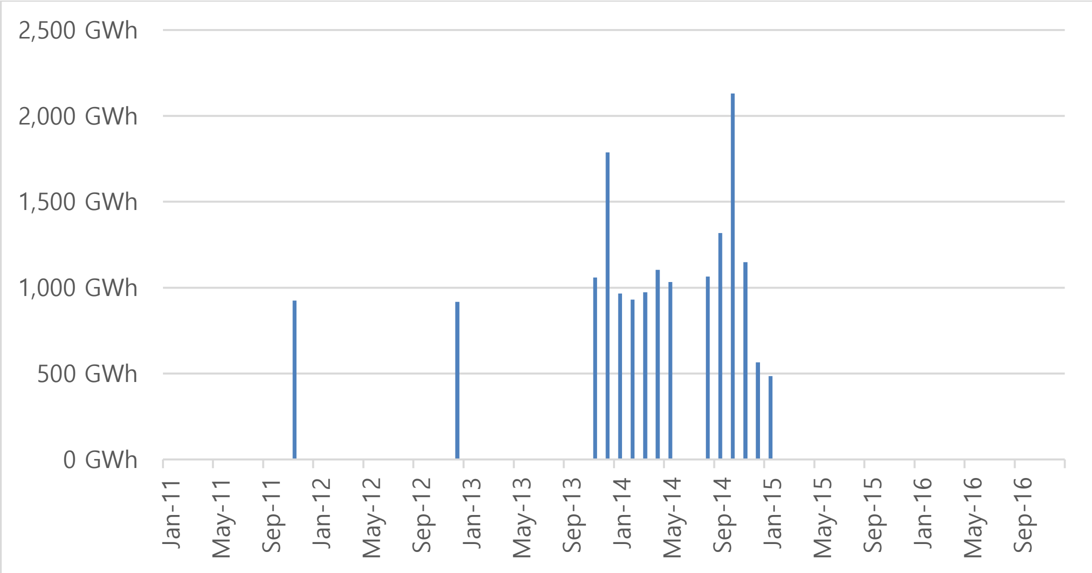

Figure 12 LNG export to South Korea. Source: Corporacion de Reservas Estrategicas de Productos Petroliferos

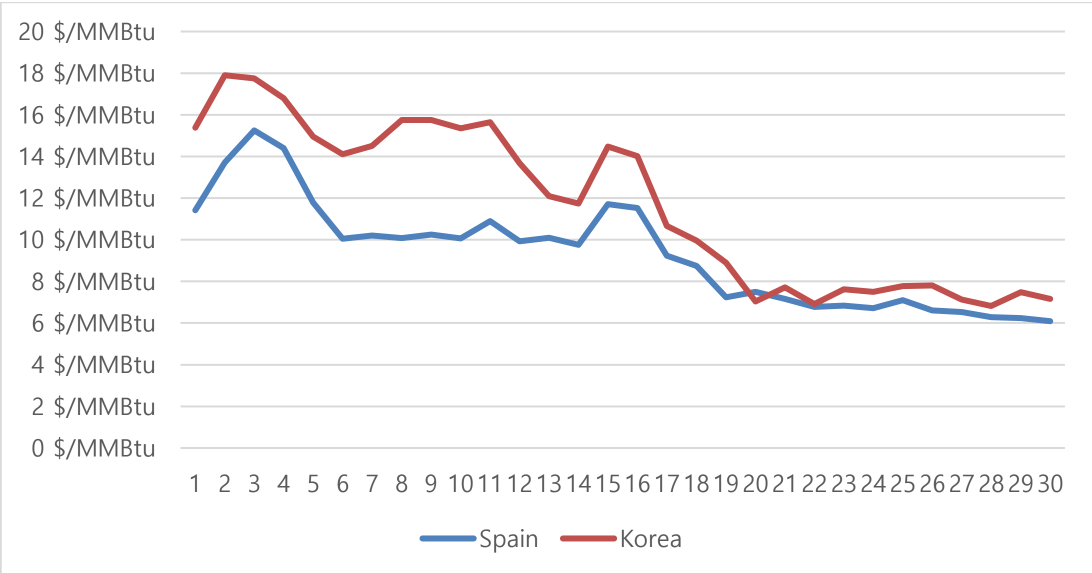

Figure 13 Landed LNG prices in Spain and South Korea from 2013 to 2015. Source: Waterborne Energy, Inc cited in Federal Energy Regulatory Commission

Figure 12 shows there was the high frequency of reloading of LNG from Spain to Korea between at the end of 2013 and at the beginning of 2015. The primary reason for the reloading is explained by a vast difference in landed LNG price between the two countries at the similar period. Figure 13 shows that there was a gap of at least 2 $/ one billion British thermal units (MMBtu) before the beginning of 2015. So, it was possible for the Spanish market to generate profits from the reloading. However, after January in 2015, the price difference between the two markets decrease to less than 2 $/MMBtu discouraging the reloading from Spain to Korea. In other words, the price elasticity is relatively high for the reloading market. The price gap which is around 2 $/MMBtu between the two markets is the threshold for the decision of reloading. This situation is also explained by Zhuravleva (2009) arguing that the price difference is the most critical factor in the reloading among other factors such as contractual

limitation, technical restrictions. The price gap should cover the expense of transaction and lead to favourable interest for aggregators (Zhuravleva, 2009).
The MMBtu is equivalent to a million of British thermal units (BTU), and BTU stands for "the amount of heat required to increase the temperature of a pint of water (which weighs exactly 16 ounces) by one degree Fahrenheit" (Energy Vortex, n.d., para 1.).

3.2 Domestic Consumption of Natural Gas and Liquefied Natural Gas

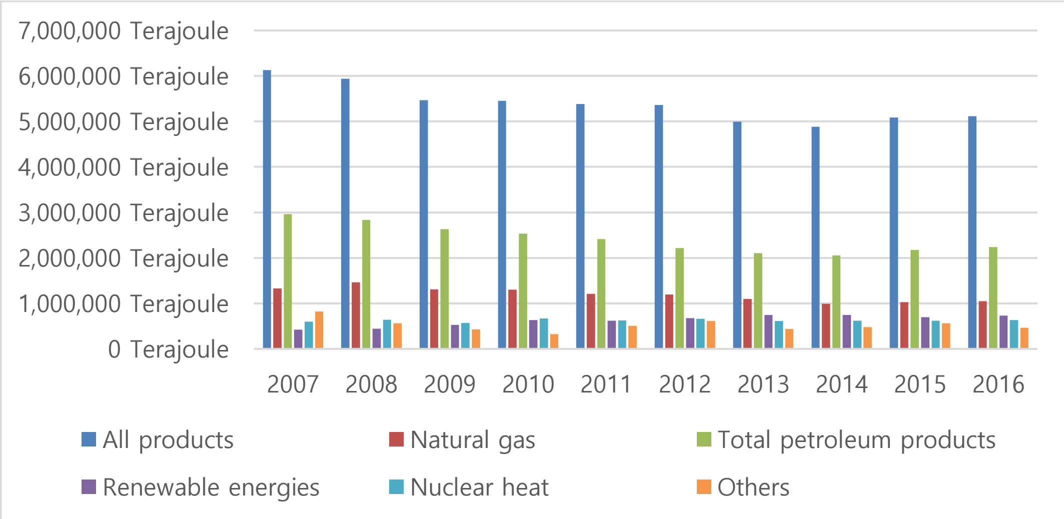

Figure 14 Gross inland consumption in Spain. Source: Eurostat

Figure 14 shows that natural gas is the second most abundant resource regarding the gross inland consumption in Spain between 2007 and 2016.

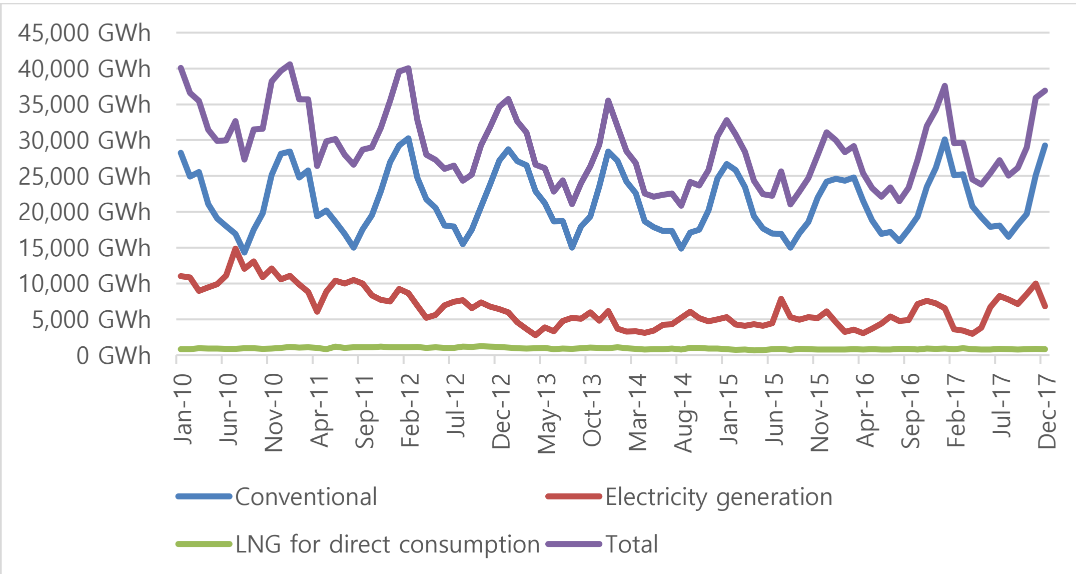

Figure 15 Natural gas consumption in Spain. Source: Corporacion de Reservas Estrategicas de Productos Petroliferos

Markets of NG and LNG consumptions are shown in figure 15. According to Corporacion de Reservas Estrategicas de Productos Petroliferos (2018), the domestic consumptions of natural gas in Spain consists of conventional, electricity generation and LNG for direct consumption. The conventional demand covers

Business, households and industries. Natural gas consumption for conventional usage accounts for the most of the consumption during an entire of the given period except for 2010. For instance, the usage of NG for conventional purpose accounted for more than 75% of total consumption of natural gas in 2017. Also, seasonality of the consumption of natural gas is also observable in figure 15. The demand for natural gas tends to increase in the winter season while the one decrease in the summer season. The change in demand depending on the seasons implied that the usage of the natural gas is for heating.

NG, LNG consumption		Heating degree days	Cooling degree days
Conventional (NG)	Pearson correlation	0.955679	-0.638376
	P-Value	=< 0.0001	=< 0.0001
Electricity Generator (NG)	Pearson correlation	-0.07028	0.196803
	P-Value	0.4698	0.0412
LNG direct use (LNG)	Pearson correlation	0.089981	-0.043696
	P-Value	0.3544	0.6534
Total consumption	Pearson correlation	0.741018	-0.396194
	P-Value	=< 0.0001	=< 0.0001

Table 2 Pearson correlations between NG, LNG consumption and heating, cooling degree days in Spain between 2009 and 2017. Source: Eurostat, Corporacion de Reservas Estrategicas de Productos Petroliferos

Chapter 3.1.3 explains Pearson correlations and p-value briefly. In order to check the relevance between the consumptions and heating purpose, heating and cooling degree days will be useful. Eurostat (n.d., para. 3) defines that “heating degree day is a weather-based technical index designed to describe the need for the heating energy requirements of buildings”. In addition, according to Eurostat (n.d., para. 3) “cooling degree day is a weather-based technical index designed to describe the need for the cooling (air-conditioning) requirements of buildings”.
Table 2 highlights the important correlation between heating days and conventional consumption of NG. Pearson correlation close to 1 and very low p-value (less than 0.001) implies that there is overwhelming evidence supporting the positive correlation between heating days and conventional consumption of NG (Keller, 2014). So, we can conclude that the principal purpose of conventional consumption of NG is for heating. Vice versa, for cooling days, the Pearson correlation is -0.64 which is relatively strong negative figures along with a very low p-value (less than 0.0001). This implies that the NG consumption for conventional purpose decreases during the summer season. Other two consumptions for the electricity generators and direct LNG use are not relevant for heating and cooling days judging from the Pearson correlations close to 0 meaning weak linear relationships and relatively high p-value meaningless evidence supporting the relationships (Keller, 2014).
On the other hands, since the NG consumption for conventional purpose accounts for large parts of the total consumption of the LNG and NG, it has a significant effect on the total consumption. This effect can be observed from a very low p-value (less than 0.001and high figures of Pearson correlations on the total consumption (Keller, 2014).

3.3 Large-Scale Infrastructure

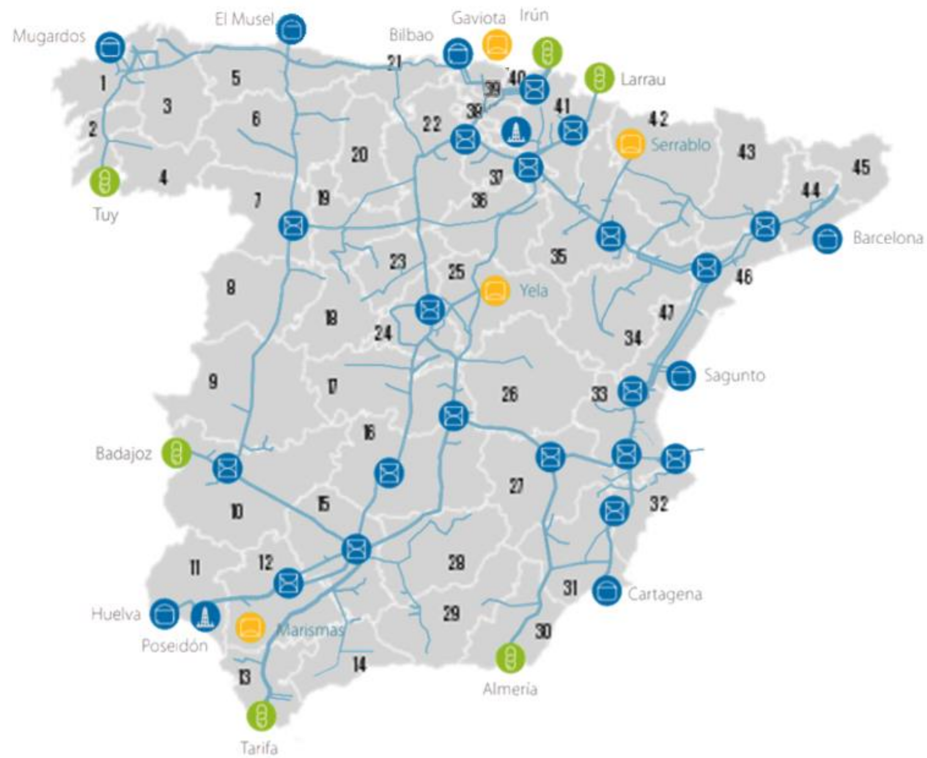

Figure 16 Network of large-scale LNG and NG supply chain in the Iberia Peninsula of Spanish territory. Source: Enagas

1	A Coruna	11	Huelva	21	Cantabria	31	Murcia	41	Navarra
2	Pontevedra	12	Sevilla	22	Burgos	32	Alicante	42	Huesca
3	Lugo	13	Cadiz	23	Segovia	33	Valencia	43	Lleida
4	Ourense	14	Malaga	24	Madrid	34	Teruel	44	Barcelona
5	Asturias	15	Cordoba	25	Guadalajara	35	Zaragoza	45	Girona
6	Leon	16	Ciudad Real	26	Cuenca	36	Soria	46	Tarragona
7	Zamora	17	Toledo	27	Albacete	37	La Rioja	47	Castellon
8	Salamanca	18	Avila	28	Jaen	38	Alava		
9	Caceres	19	Valladolid	29	Granada	39	Vizcaya (Biscay)		
10	Badajoz	20	Palencia	30	Almeria	40	Guipuzcoa (Basques)		

Table 3 List of provinces in Spain. Source: Tourism in Spain

The blue lines in figure 16 illustrate the distribution of the natural gas pipelines. The network of the pipeline set up on across the 47 provinces in Spain and the name of the provinces is seen in table 3. In addition, the 7 LNG import terminals including El Musel terminal is shown the figure 16. For the large-scale NG and LNG facilities, LNG import terminals, gas pipelines and natural gas underground storage tanks are discussed in the paper.

3.3.1 Liquefied Natural Gas Import Terminals

There are 7 Spanish LNG receiving terminals which are Barcelona, Cartagena, Huelva, El Musel and Bilbao LNG terminals (Enagas, 2016). The four main functions of the terminal are explained by the flow of LNG from arrival at LNG at the import terminal before being distributed as a natural gas according to Enagas (2015).

The first function of the LNG receiving terminals is a cargo operation to import and export LNG Enagas (2015). Unloading of LNG is operated by transporting of LNG from LNG vessels to the LNG terminal Enagas (2015). The flow of the loading operation of the LNG is from LNG terminals to the LNG ships Enagas (2015). According to Enagas (2015) owning most of the LNG terminals in Spain, the largest LNG carriers having LNG capacity of up to 266,000 m3 can enter and operate at the majority of their LNG terminals.
Another function is storage of LNG in special tanks for cryogenic conditions with inconsiderably more than atmospheric pressure (Enagas, 2015). Encyclopaedia Britannica (n.d., para 1.) defines the meaning of cryogenic as “cryogenic temperature range has been defined as from −150 °C (−238 °F) to absolute zero (−273 °C or −460 °F), the temperature at which molecular motion comes as close as theoretically possible to ceasing completely”.
Subsequently, LNG is regasified as natural gas by evaporators with the assistance of seawater making the temperature of LNG to above 0 º C (Enagas, 2015). Because of this function that LNG import terminals cover the regasification of LNG, the LNG import terminals are also called as LNG regasification facility.
Metering and odorisation is the last stage of the flow before distributed through the gas pipeline. These treatments are necessary for detecting natural gas in case of leakages of it (Enagas, 2015). Apart from transporting of natural gas by the gas pipeline, those 6 LNG receiving terminals also provide LNG truck loading service for other destinations such as satellite terminals and LNG fuel station (Gas Infrastructure Europe, 2018b).
Apart from El Musel, the other six terminals are under operation (Enagas, 2016). Even though El Musel terminal was built in 2012, the terminal is not under operation (Enagas, 2016). The underlying reason is to prevent the surplus of the LNG capacity in Spain judging from the decrease in Spanish gas consumption for electronic generator between 2008 and 2014 (Prontera, 2017). So Spanish government had an intention to prevent other new LNG import terminals by enforcing Royal Decree-Law 13/2012 (Prontera, 2017). This existence of the facility is not under operation will be simulated in the scenarios in the research.

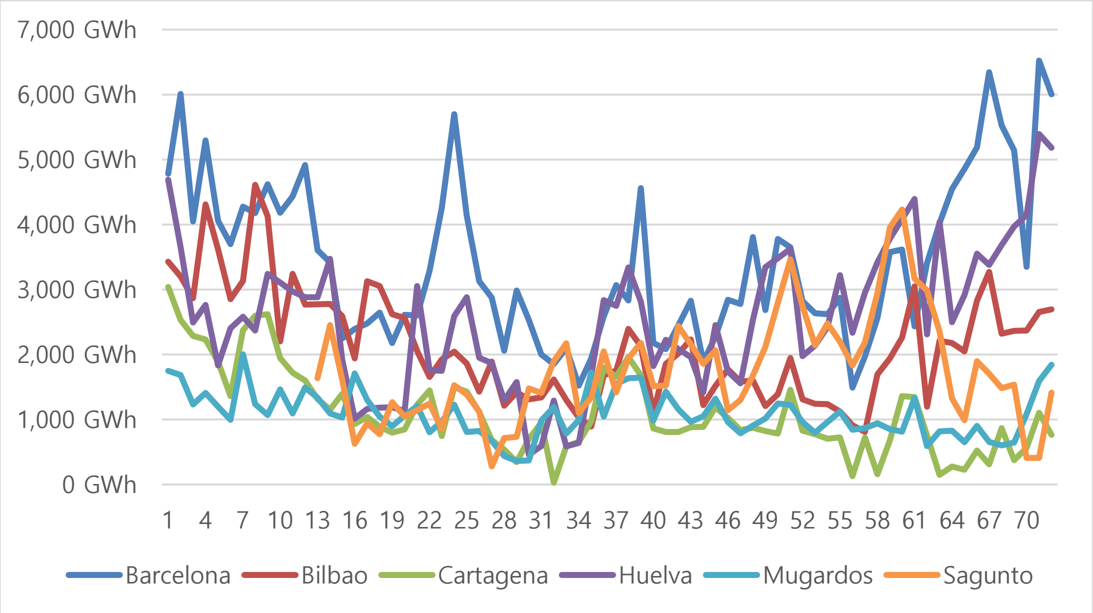

Figure 17 Monthly send out the level of regasified gas from the 6 LNG import terminal in Spain from 2012 to 2017 Source: Gas Infrastructure Europe

Also, the definition of send out of regasified natural gas from LNG terminals excludes the truckload loading service (Agency for the Cooperation of Energy Regulators, 2017). In addition, the data of sending out from Sagunto is available from 2013. Figure 17 shows that Barcelona LNG terminal tends to be the largest regarding the amount of send out among six terminals during the given period.

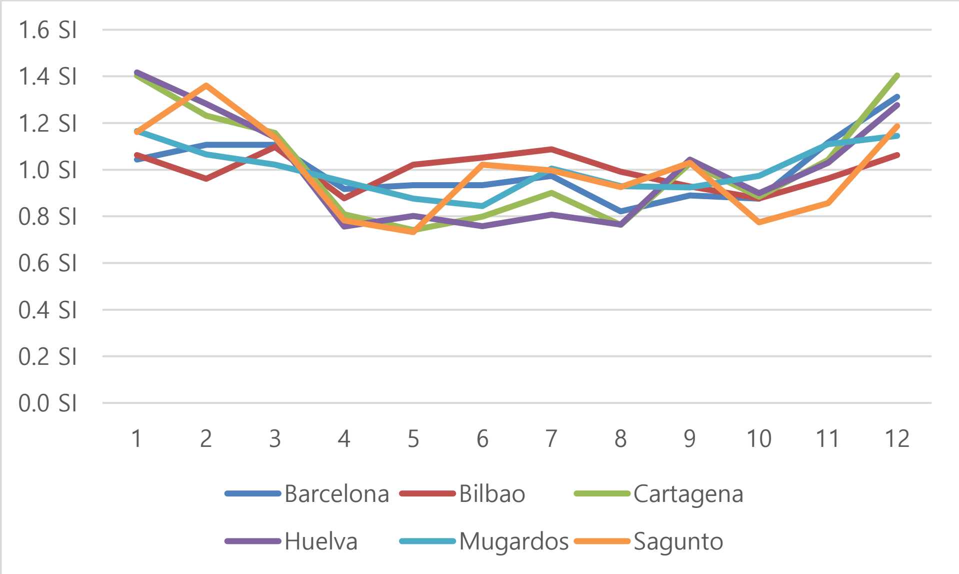

Figure 18 Seasonal Index (SI) of sending out of natural gas after regasification of LNG from 6 LNG import terminals in 12 months in Spain. Source: Gas Infrastructure Europe

The calculation of the seasonal index is explained in "chapter 4.2 Regression models with seasonality for forecasting". Figure 18 illustrates that the seasonal index of the send out of natural gas transformed from LNG by regasification at LNG terminals is highly likely to be low during the summer season. However, it tends to increase after October. Subsequently, the amount of send out of natural gas tend to be peak during winter seasons between November and February.

In terms of the owners of the terminals, there are four companies shown in table 4. The largest company is Enagas by owning four terminals: Barcelona, Cartagena, Huelva and El Musel LNG terminals (Gas Infrastructure Europe, 2018b). There are no major shareholders of Enagas since 95% of the total shares is a free float (Enagas, 2017a). Other two companies are Saggas which is an owner of Sagunto LNG terminal and Bahia Bizkaia Gas (BBG) owning Bilbao LNG terminal (Gas Infrastructure Europe, 2018b). However, Enagas is the major shareholder of BBG (50%) and Saggas (72.5%), so Enagas wholly owns four terminals and partially owns two terminals. In other words, Enagas engages in the ownership and operation of 6 out of 7 LNG terminal coupled with the regasification facility in Spain (Enagas, n.d.b). The last company is Reganosa owning Mugardos LNG terminal (Gas Infrastructure Europe, 2018b). According to Reganosa (n.d.), shareholders of the company are Reganosa Holdco, Sojitz Corporation and Sonatrach, 75%, 15% and 10% respectively.

Based on the findings, the structure of industry about LNG import terminals in Spain is close to monopoly by the horizontal integration of Enagas.

LNG import terminal	**Barcelona**	**Cartagena**	**Huelva**	**Gijon (El Musel)**	**Sagunto**	**Bilbao**	**Mugardos**
Owner	Enagas	Enagas	Enagas	Enagas	Saggas (72.5% Enagas)	BBG (50% Enagas)	Reganosa

Number of LNG tanks	6	5	5	2	4	3	2
Storage (m3)	760000	587000	619500	800000	600000	800000	300000

Table 4 The ownership, number of LNG tanks and storage capacity of terminals in Spain. Source: Enagas.

3.3.2 Natural Gas Pipelines

There is a favourable tendency that the supply chain of natural gas by pipeline is less greenhouse gas (GHG) and energy intensive than the one of LNG (Georgakaki et al., 2009). The gap reduces when comparing transportation of natural gas by pipeline to a remote area (Georgakaki et al., 2009). The leakage of the pipeline tends to occur more often for the long distances transportation to remote destinations (Georgakaki et al., 2009). Also, the less transport cost of natural gas through pipeline compared to LNG transportation is another advantage of the natural gas pipeline (Georgakaki et al., 2009).

Specially coated polyethene gas pipelines guarantee no corrosion of the steel pipeline because of the soil (Enagas, n.d.a). The typical minimum and maximum range of the pipelines on the ground are from 30 to 72 or 80 bar. On the other hand, pipelines which were set undersea such as Almeria international pipelines or a connection to Balearic Island are designed to have a pressure of 220 bar (Enagas, n.d.a).

In terms of international connections of the pipeline, there are six pipelines to transport NG between Spain and foreign countries (Benito et al., 2017). Two of them are Medgaz and Maghreb pipelines which are initially from Alegria; Medgaz pipeline is connected to Almeria in Spain, and Maghreb pipeline is connected to Tarifa in Spain through Morocco (Benito et al., 2017).

The other four pipelines are connected to France and Portugal to transport natural gas and all of them they are belong to Enagas (Enagas, 2012). Two of them are allocated to two cities which are Tuy and Badajoz for Portugal's gas market (Enagas, 2012). The other two for French gas market are connected to Irun and Larrau (Enagas, 2012).

When it comes to the owners or operators of the two pipelines dedicated to importing NG from Algeria (Maghreb and Medgaz pipelines), there are several Spanish shareholders. At Tarifa international connection on Maghreb pipeline, an owner is Enagas (2012). In the massive scale of the pipeline, Gas Natural Fenosa (Natrugy) accounts for 77.2% of a total share of Europe Maghreb Pipeline Limited (EMPL) and 76.68% of a total share of Metragaz which is operating and maintaining the pipeline for EMPL (Europe Maghreb Pipeline Limited, n.d.). Also, Gas Natural Fenosa (Natrugy) is also a significant shareholder of Medgaz by accounting for 15% of the total share while CEPSA which is a Spanish company has 42% shares of Medgaz (Medgaz, n.d.).

Gas pipeline	Coverage Province	length (km)	number of sections	Owner
Al Andalus	Cordoba, Sevilla, Cadiz, Malaga, Granada, Jaen	890.49	6	Enagas (6), Endesa (1, co-owner)
Algete-Haro	Burgos, Palencia, Valladolid, Zamora, La Rioja, Soria, Segovia, Madrid, Guadalajara	900.2	6	Enagas (6), T.R.G (1, co-owner)
Almeria-Chinchilla	Albacete, Murcia, Almeria	428.99	4	Enagas (3), *missing 1
Baleares	Valencia, Alicante, Ibiza, Mallorca	330.37	4	Enagas (3), *missing 1
Cordoba-Madrid	Madrid, Toledo, Cuenca, Ciudad Real, Cordoba, Jaen	1193.7	12	Enagas (12)
Eje Levante	Castellon, Valencia, Alicante, Tarragona, Murcia	912.36	9	Enagas (9), Natrugy (1, co-owner)
Eje transversal	Ciudad Real, Albacete, Valencia	264.2	4	Enagas (4), *missing 1
Extremadura	Badajoz, Cordoba	328.8	3	Enagas (3)

Huelva-Cordoba	Huelva, Sevilla, Cordoba	550.23	4	Enagas (4), Natrugy (1, co-owner)
Noroeste-Cantabrico	Pontevedra, A Coruna, Lugo, Asturias, Cantabria, Burgos	1005.55	6	Enagas (6), Reganosa (1, co-owner)
Pais Vasco	Alava, Guipuzcoa, Vizcaya, La Rioja	461.63	11	Enagas (5), ETN (6)
Ruta de la Plata	Asturias, Leon, Zamora, Salamanca, Caceres, Badajoz	756.44	6	Enagas (6), Gas Extremadura (1, co-owner)
Tivisa-Barcelona	Barcelona, Tarragona	531.28	8	Enagas (8), Natrugy (1, co-owner)
Valle del Ebro	La Rioja, Navarra, Zaragoza, Huesca, Teruel, Lleida, Tarragona	1309.37	11	Enagas (9), Natrugy (1, co-owner with Enagas), Endesa (2)

Table 5 Coverage areas, length, number of sections and owners of gas pipelines in Spain. Source: Enagas.

Missing 1* in table 5 means that there is no information of owner for 1 section on the website. Table 4 shows that Enagas is the largest company owning most of the gas pipelines within Spain. Regarding the connections of natural gas after being regasified from the LNG import terminals, not only Enagas but also Reganosa LNG receiving terminal owns its connection.

3.3.3 Underground Storage Tanks of Natural Gas

For the satisfaction of uncertainty and peak demands of natural gas derived from seasonal effect, sizeable natural gas storages are required (Enagas, n.d.c).
Underground storages of the natural gas are at “old deposits, or it is injected in deep water stratum or cavities generated in salt formations” (Enagas, n.d.c., para 2.).
The minimum pressure at the facilities is 45 bar while the maximum one is from 72 to 80 bars (Enagas, n.d.c).
Three underground storage tanks are under operation in Spain. Three of them which are Serrablo, Gaviota and Yela storage tanks are owned by Enagas (Enagas, 2018)

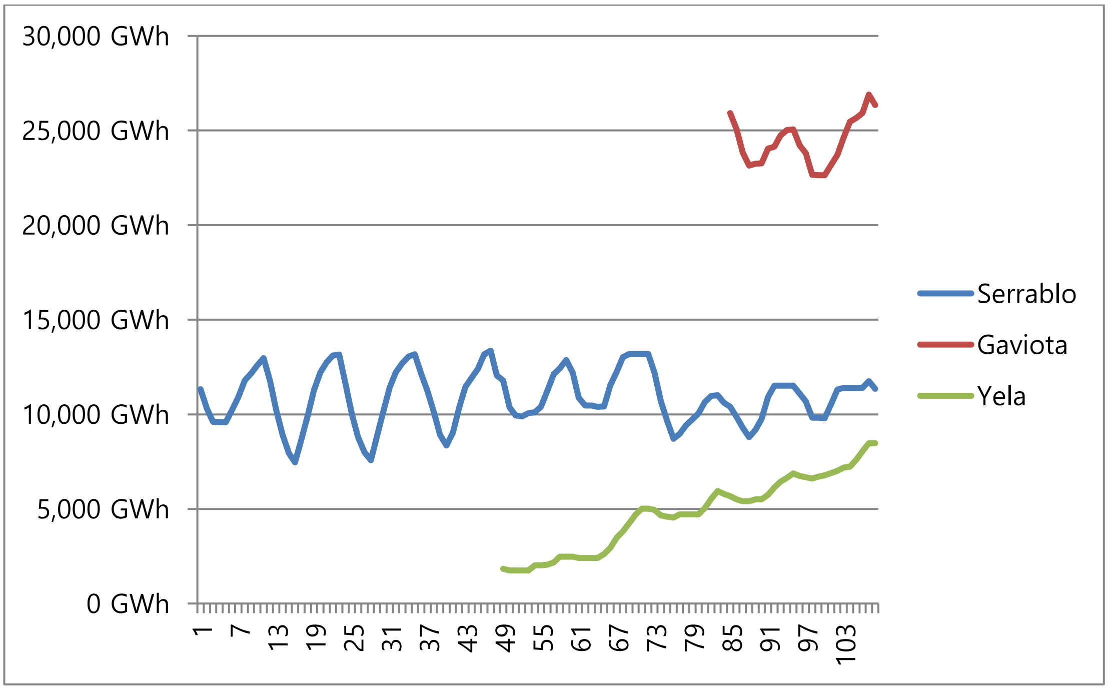

Figure 19 Monthly level of the three gas storage tanks in Spain from 2009 to 2017 Source: Enagas

The data of Yela storage tank and Gaviota are available to access from 2013 and 2016 respectively while the data of Serrableo from 2009 to 2017 is available from

Enagas (2018). Figure 19 shows illustrate that Gaviota and Yela tanks accumulate more gas inventory while the gas inventory level in Serrablo tends to remain the same throughout the period.

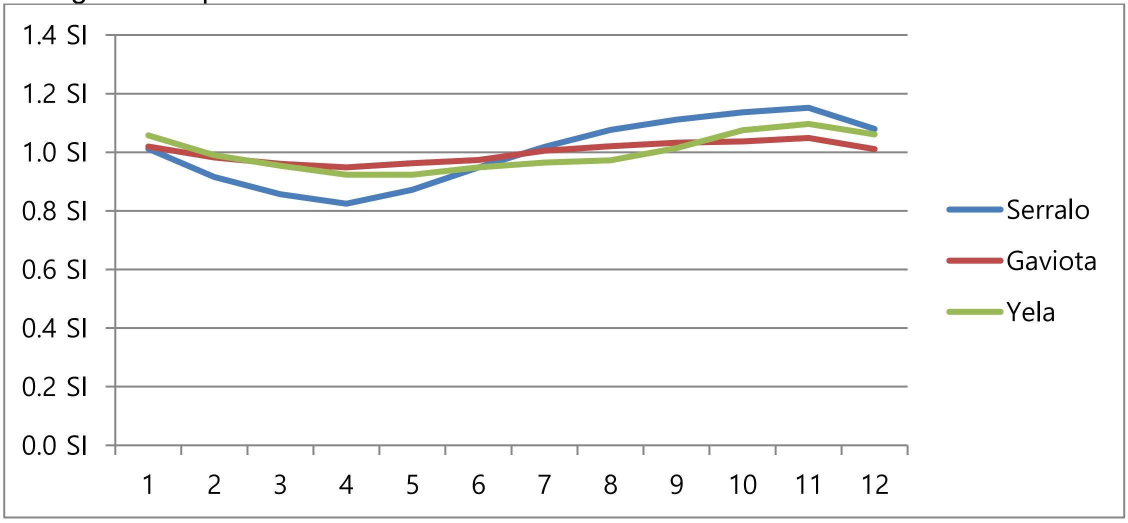

Figure 20 Seasonal Index (SI) of the level of inventory in three gas storages in 12 months in Spain. Source: Enagas

Figure 20 shows the general trend of the seasonal index that the storages tanks tend to be dedicated to the gas injection during the summer season and the gas withdraw winter season (Enagas, 2018). In particular, the storage level tends to decrease from November to April while there is a tendency that the level increase from April to November (Enagas, 2018).
In terms of the new facility of the gas storage tank, Pinasses storage tank owned by Gas Natural Fenosa (Natrugy) is planned to be constructed (Gas infrastructure Europe, 2015).

3.4 Small-Scale Infrastructure

3.4.1 Liquefied Natural Gas Satellite Terminal

The first satellite terminal was built in North East Spain in December of 1970 which means that Spain has a long experience of SSLNG (Enriquez and Rojo, 2016a).
LNG from LNG import terminal is transported by trucks or trains to satellite terminals (JFE engineering corporation, n.d.).
The LNG satellite terminals encompass several functions. The first one is storage and unloading of liquefied natural gas (Gu et al., 2010). Another one encompasses the process of regasification, calorie control, blending with water gas and coal gas, and send it to pipelines connecting to the city (Gu et al., 2010). The last one is using a distribution station for LNG loading and transporting to LNG fuel stations (Gu et al., 2010). Gu et al. (2010) excluded the last function for the satellite terminals but the first and second functions. In the same way, the function as the distribution of LNG at satellite terminals is not included in this study but the distribution centre of natural gas after regasification of LNG.
The satellite terminals enable for the remote areas in which the access of the gas pipeline is not possible to consume the gas (HAM, n.d.c). Because of the this, satellite terminal is regarded as a distribution centre for isolated areas.

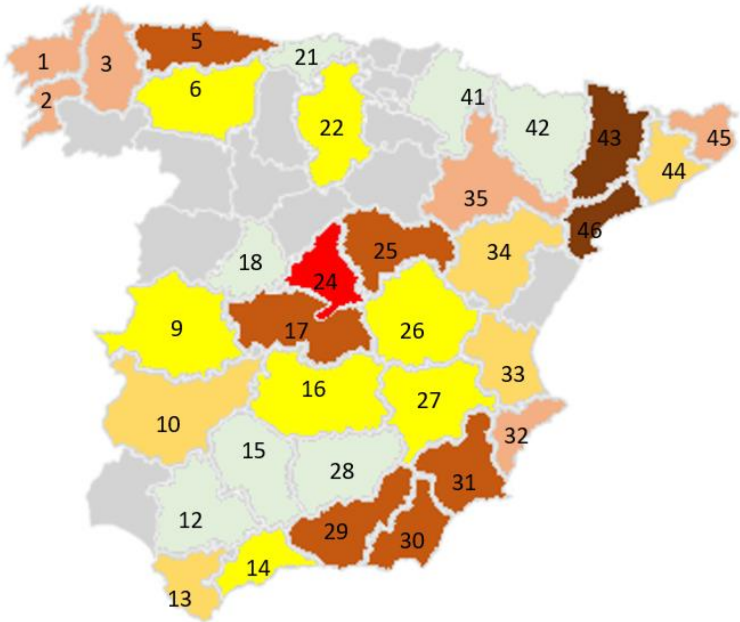

Figure 21 Location and distribution of LNG satellite stations in each Spanish province. Source: Gas Infrastructure Europe.

Number of LNG fuel stations in provinces	Number of provinces	Provinces
7	1	Madrid (24)
6	2	Lleida (43), Tarragona (46)
5	6	Asturias (5), Toledo (17), Guadalajara (25), Granada (29), Almeria (30), Murcia (31)
4	6	A Coruna (1), Pontevedra (2), Lugo (3), Alicante (32), Zaragoza (35), Girona (45)
3	5	Badajoz (10), Cadiz (13), Valencia (33), Teruel (34), Barcelona (44)
2	7	Leon (6), Caceres (9), Malaga (14), Ciudad Real (16), Burgos (22), Cuenca (26), Albacete (27)
1	7	Cordoba (15), Avila (18), Cantabria (21), Sevilla (12), Jaen (28), Navarra (41), Huesca (42)

Table 6 Location and distribution of LNG satellite stations in each Spanish province. Source: Gas Infrastructure Europe.

Figure 21 and Table 6 illustrate that the density of the location of LNG satellite stations is high in the centre, South and North-East of Spain. So, it is assumed that that area has less pipeline connection that the other region in the assumption that the distribution of natural gas is optimised and well facilitated.

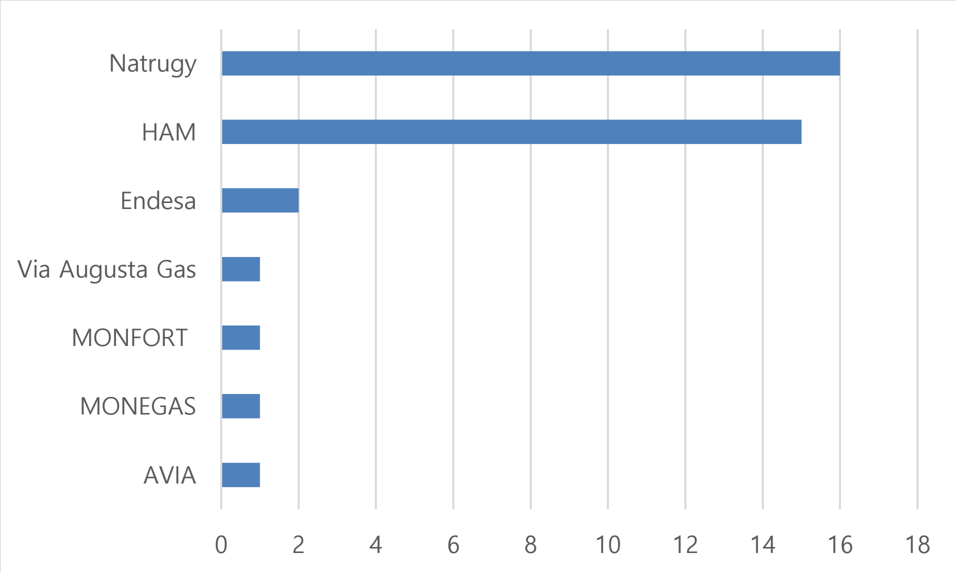

Figure 22 Owners/operators of LNG satellite terminals in Spain. Source: Gas Infrastructure Europe

On the other hand, in terms of local Spanish satellite terminals, there are six owners or operators from figure 22. There are three major players in the satellite terminal industry which are Natrugy, Redexis Gas and HAM. Since the title of the company "Gas Natural Fenosa" had been changed to Natrugy (La Vanguarida, 2018), this change is also applied in the research of the companies. Natrugy encompassing Gas natural Castilla y Leon, Cegas and Distribution is the largest company regarding the satellite terminals in Spain (Precio Gas, n.d.). Explore in more detail of the company, the major shareholders of the company Criteria Caixa Holding (35.3%) and Repsol Group (30.0%) (Precio Gas, n.d.).
Redexis Gas and HAM are the second largest companies owning 23 terminals each. Redexis Gas Aragon, Baleares, Distribution owing some satellite terminals are part of Redexis Gas, S.A. The major shareholders of the company are Arbejdsmarkedets Tillægspension (33.3%), Universities Superannuation Scheme couple with Guoxin Guotong Fund LLP (33.3%) and CNIC Corporation Limited (33.3%) (Redexis Gas, n.d.).
Ham group does not provide a clear explanation of the shareholder structure, but it mentions that family business is engaged in the business (HAM, n.d.a.) So, it is possible to assume that there are no shareholders outside of the company but a family business.
Judging from the data of the shareholder of the companies, these shareholders of the companies have no internal relationships with the owners or operators of the LNG import terminals. In other words, the owners or operators of the LNG import terminals do not identify with those of the LNG satellite terminals.
There is one satellite terminal planned to be constructed at Cobisa in the province of Toledo by Natrugy.
Apart from the satellite terminals, there are several types of SSLNG facilities which are about fuel loading road, fuel loading ship and bunker ship explained on the following sub-chapters.

3.4.2 Liquefied Natural Gas Fuel Loading Road Station

There are two different forms of natural gas used as a fuel for road vehicles: compressed natural gas (CNG) and liquefied natural gas (LNG) (Arteconi et al., 2010).

According to Gas Infrastructure Europe (2018b), some of the fuel stations provide service of fuelling of both CNG and LNG in Spain.
In terms of CNG fuel stations, there are two types of the stations. The first one is the time-fill station fuelling the vehicles from a compressor delivering CNG at low pressure to fuel tanks of the vehicles (International Energy Agency, 2017). Another one is fast-fill stations supplying CNG without the compressor from utility line at high pressure (about 300 bar) to the fuel tank of the vehicle in easy and quick ways (International Energy Agency, 2017).
On the other hand, the unique requirement of the equipment such as LNG storage tanks, safety gadget and cool down system preventing from an increase of LNG pressure in a storage tank at the dangerous level is necessary for the LNG fuel loading station (International Energy Agency, 2017).
Since the energy density of LNG is higher than the one of CNG, LNG is usually consumed for the heavy-duty road vehicles (Arteconi et al., 2010). Also, LNG as a fuel is proper for trucks in long-haul travel such as more than 100,000 km in a regular basis because of the evaporated LNG needed to be consumed while CNG is suitable for the small trucks less travelling and irregular operation (International Energy Agency, 2017).

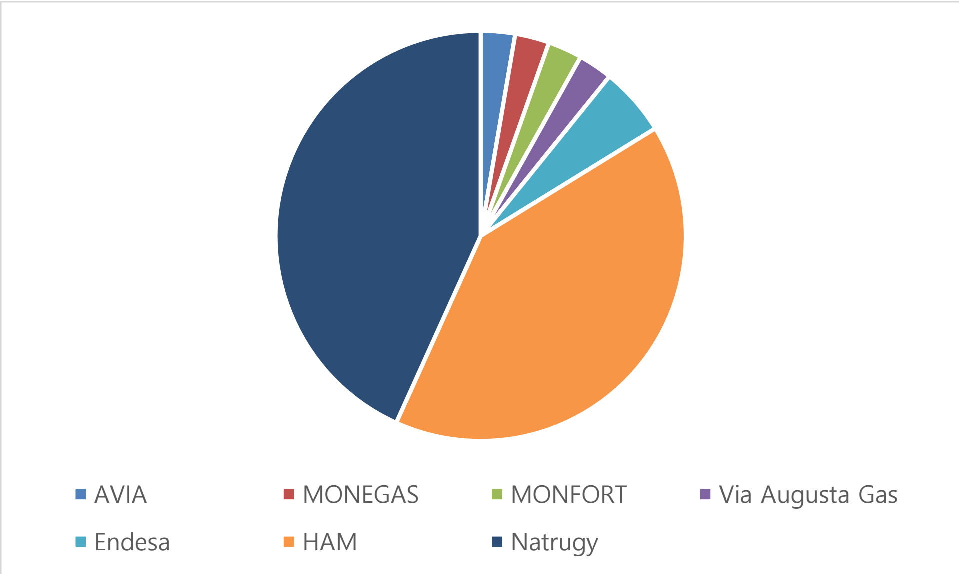

Figure 23 Owners/Operators of LNG fuel loading road stations in Spain. Source: Gas Infrastructure Europe

Before mentioning the structure of the LNG fuel road stations, there are two fuel stations are cooperated by Natrugy and Repsol, and one is cooperated by Endesa and Molgas (Gas Infrastructure Europe, 2018b). The former relation is assumed as sole ownership by Natrugy, and the latter one is by Endesa in the study.
Figure 23 illustrates 37 LNG fuel loading road stations under operation in Spain in 2018. Natrugy and HAM are considered as large LNG fuel station companies based on the number of the station they own. Each of the companies accounts for 40% of the LNG fuel station market in Spain in 2018.
Three LNG fuel stations are planned to be built. The two sites of the construction are in Madrid by HAM and Natrugy (Gas Infrastructure Europe, 2018b). The other one will be built in Cadiz by Repsol (Gas Infrastructure Europe, 2018b).

3.4.3 Liquefied Natural Gas Fuel Loading Ship Station

Fuel loading ship station	Owner/Operator
Port of Gibraltar	Port of Gibraltar
Cartagena fuel loading ship	Port Authority of Cartagena
Ferrol LNG loading ship (bunkering)	Reganosa
Bilbao	BBG

Table 7 Owners/operators of LNG fuel loading ship stations in Spain. Source: Gas Infrastructure Europe

Table 7 shows that the owners or operators of the fuel loading ships station are identical with the port authority or owner of the LNG import terminals. In addition, figure 24 coupled with table 8 illustrates the distribution of the SSLNG facilities in the province scale.

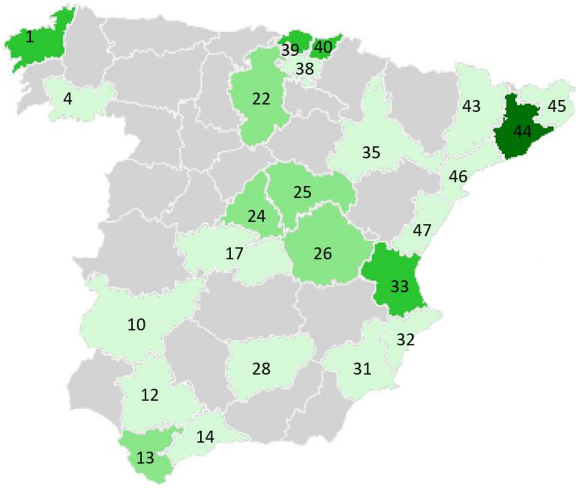

Figure 24 Locations and distribution of LNG fuel road and ship stations in each Spanish province. Source: Gas Infrastructure Europe

# of LNG fuel stations in provinces	# of provinces	Provinces
5	1	Barcelona (44)
3	4	A Coruna (1), Valencia (33), Vizcaya (39), Guipuzcoa (40)
2	5	Cadiz (13), Burgos (22), Madrid (24), Guadalajara (25), Cuenca (26)
1	14	Ourense (4), Badajoz (10), Sevilla (12), Malaga (14), Toledo (17), Jaen (28), Murcia (31), Alicante (32), Zaragoza (35), Alava (38), Lleida (43), Girona (45), Tarragona (46), Castellon (47)

Table 8 Location and distribution of LNG fuel road and ship stations in each Spanish province. Source: Gas Infrastructure Europe.

in terms of LNG fuel for ships, Valencia fuel loading ship station is under construction and LNG fuel station in Algeciras is planned to be built (Gas Infrastructure Europe, 2018b).

3.4.4 Liquefied Natural Gas Bunker Ships

There is one LNG bunker ship "Oizmendi" (former name was "Monte Arucas") in Bilbao in Spain (Gas Infrastructure Europe, 2018a) (LNG World News, 2018). According to LNG World News (2018), the first bunkering of LNG by ship-to-ship has been operated in the Port of Bilbao in Spain on February 3, 2018. The ship has two cryogenics tanks having a capacity of 300-cubic metres (cbm) to store LNG, and it was renovated as the bunker barge recently (LNG World News, 2018). Basque region project covers not only this bunker ship but also adaption of the BBG dock and regasification facility and building and design of tugs fuelled by tug (LNG World News, 2018).
Itsas Gas is the dominant player in the project. Basque Energy Agency (EVE) is the principal shareholder of the company by owning 49% of the shares (LNG World News, 2018). The rest of the shares (51%) are equally owned by Remolcadores Ibaizabal (25.5%) and Naviera Murueta (25.5%) (LNG World News, 2018).

3.4.5 Modes of Small-Scale Liquefied Natural Gas transportation

3.4.5.1 Trucks

The first transport mode is the truck equipping tanks designed for carrying LNG (Hansson, 2008). In terms of the short distance, truck transportation of LNG is the most suitable among other modes for minimising the total cost of the transportation (Hansson, 2008). Approximately 300 km is the traditionally maximum distance for LNG truckload (Eliot, cited in Hansson, 2008). However, further technical advances enable to extend the limits of the range (Lennerås, cited in Hansson, 2008). Another advantage is door-to-door service is available with no requirement of transfer from picking up and delivery of the cargoes (Chopra and Meindl, 2015). The disadvantage of the transport by trucks is not eco-friendly since most of them are powered by fossil fuels (Hansson, 2008). In Spain, table 8 shows a majority of road tractors which is capable of transporting LNG use diesel as fuel in Spain in 2016 (Eurostat, 2018). In other words, the most trucks are not eco-friendly, and this supports the argument of Hansson (2008). However, table 9 illustrates that there are a minimal number of trucks using LNG as a fuel (Eurostat, 2018).

	# of road tractors
Total	207889
Diesel	206305
Petroleum products	1219
Liquefied natural gas (LNG)	167
Compressed natural gas (CNG)	135
Liquefied petroleum gases (LPG)	35
Other	24
Electricity	4

Table 9 Road tractors by type of motor energy in Spain in 2016. source: Eurostat

Figure 24 shows that there are a growing number of LNG so if the growth rate is continuously increasing, road transportation of LNG is a more favourable option in the future by preserving the environment.

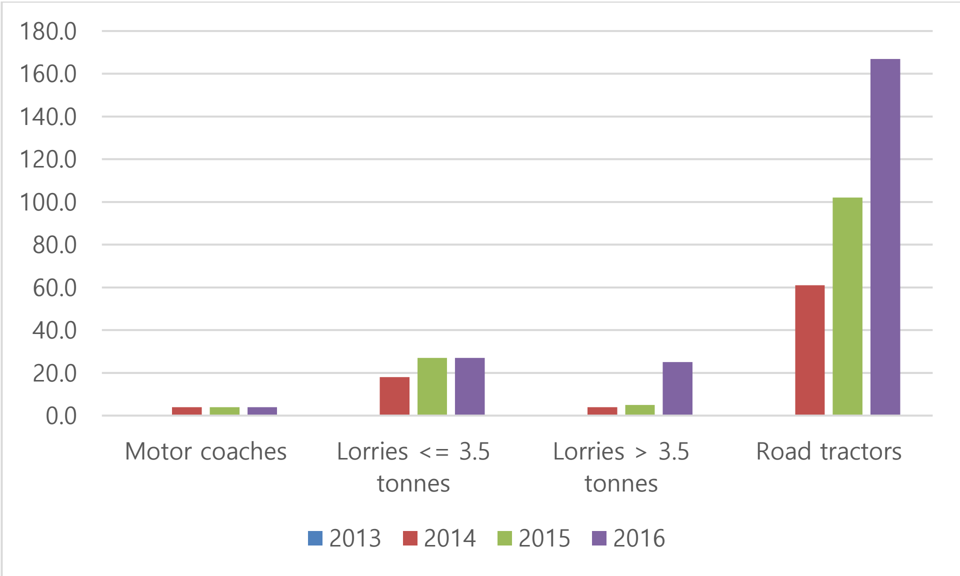

Figure 25 Numbers of vehicles fuelled by LNG in Spain from 2013 to 2016. Source: Eurostat.

According to Eurostat, small size of vehicles such as motorcycles and passenger cars are not equipped LNG fuelled motor engine while a large size of vehicles such as lorries and road tractors equipped one. Figure 25 shows the significant increases in the number of road tractors which are relatively more substantial than the other vehicles during the given period. Also, apart from motor coaches, there are increases in the other vehicles. So, we can conclude that there is a trend of the increase in the number of LNG fuelled vehicles.

There are seven facilities providing LNG truck loading service in Barcelona, Cartagena, Huelva, Bilbao, Mugardos, El Musel and Sagunto LNG terminals in Spain (King & Spalding LLP, 2018).

The market for truck loading accounts for approximately 4% of the entire annual conventional demand in 2015 (Natural Gas World, 2016)

3.4.5.2 Ships

The second mode is transportation by ships. However, since it is small-scale LNG transportation, it needs to be differentiated from large-scale LNG shipping (Hansson, 2008). An example of the small-scale LNG ships under operation in Norway is 1,100 m^3 while the large-scale LNG vessels are between 80,000 to 300,000 m^3 (Hansson, 2008).

3.4.5.3 Trains

The final one is the railroad transportation. The loading capacity of each railway wagon is approximately 40 tonnes (Näslund, cited in Hansson, 2008).

Fast transportation is one of the advantages of the railroad (Hansson, 2008). For instance, a single trip by railroad across an entire of Sweden within a day is highly likely available (Hansson, 2008). It is possible to apply in Spain since the territory of Sweden is more extensive than Spin. Another advantage is that trains are regarded as the eco-friendly modes if it is powered by electricity (Hansson, 2008).

On the other hand, there are some disadvantages of railroad transportation. At first, it is not suitable for short distance transportation since it costs more than the other alternatives (Hansson, 2008). Another issue occurs during the reloading operation. Mostly, the delivery of LNG by trains is not door to door system, evaporating of LNG

is inevitable during the operation (Hansson, 2008). The term evaporating of LNG is called as boiled off. Boiled off means the evaporation of LNG at a certain temperature higher than its boiling point (Dobrota et al., 2013). This is caused by entering of heat to LNG during cargo operation, transporting and storage occurs BOG (Dobrota et al., 2013). Subsequently, it increases pressure and decreases density. So, railroad transportation of train less favourable because of boiled off the gas (BOG) leading to the loss of the cargo (Vikersveen cited in Hansson, 2008)
In terms of the railroad for transporting LNG in Spain, no rail loading facilities are existing but they are planned to be constructed in Barcelona LNG terminal (Gas Infrastructure Europe, 2018b). Based on these data, the more significant numbers of fuel loading road facilities than those of ship facilities means the majority of transportation of SSLNG is done by trucks. This is supported by Enriquez and Rojo (2016a) mentioning that Spanish LNG truck loading to inside and outside of Spain accounts for 85% of hole LNG truck loading in the EU market in 2015.

3.5 Vertical Integration of Natural Gas and Liquefied Natural Gas Supply Chain in Spain

Large-scale facility		**Small-scale facility**			
Owner of LNG import terminal	**Numbers**	**Owner of Fuel loading station**	**Numbers**	**Owner of Satellite station**	**Numbers**
Enagas	6	Natrugy	16	Natrugy	53
Reganosa	1	HAM	15	HAM	23
Owner of underground storage tanks		Endesa	2	Redexis Gas	23
Enagas	3	AVIA	1	Nortegas	9
Owner of sections of the gas pipeline		MONEGAS	1	Distribución y Comercializacion de Gas Extremadura	3
Enagas	84	MONFORT	1	DISTRIBUIDORA REGIONAL GAS	1
ETN	6	Via Augusta Gas	1		
Endesa	2				

Table 10 Ownership of large- and small-scale LNG facility. Source: Enagas, Gas Infrastructure Europe

It is essential to know the degree of the vertical integration of the supply chain in the scope of the study since one of the assumptions is the supply chain is vertically integrated. There are co-ownership of facilities as mentioned above sub-chapters 3: some LNG import terminals, gas pipeline and fuel stations. The co-ownerships are supposed as a single owner who has a larger size than the other co-owner judging from the numbers of facility they have in table 10. It is possible to conclude that the vertical integration of the LNG supply chain between LNG receiving terminals and LNG fuel stations coupled with LNG satellite stations does not exist from table 10.
On the other hand, regarding the large-scale facility, Enagas is the dominant company by having six terminals out of 7 in Spain. When it comes to small-scale LNG infrastructure, Natrugy and Ham vastly run their business in both LNG fuel loading station and satellite station. Since the number of players of the industries is limited, the large-scale LNG industry including the LNG import terminals, underground storages and gas pipelines is close to Monopoly by Enagas while the small-scale LNG industry is considered an oligopoly.
The result of the scenarios in this paper would be more feasible if there was the vertical integration unlike this current situation between the LNG import terminals and the destinations. Other conditions such as individual contracts or relationships

between companies might discourage the freedom of contracts based on only total costs of transportation. So, without the vertical integration, the supply chain might not be able to be fully optimised regarding the viewpoints of the costs. The full vertical integration of the supply chain is assumed in the next chapter for simulation of the model.

3.6 Seasonality in the Natural Gas and Liquefied Natural Gas Supply Chain

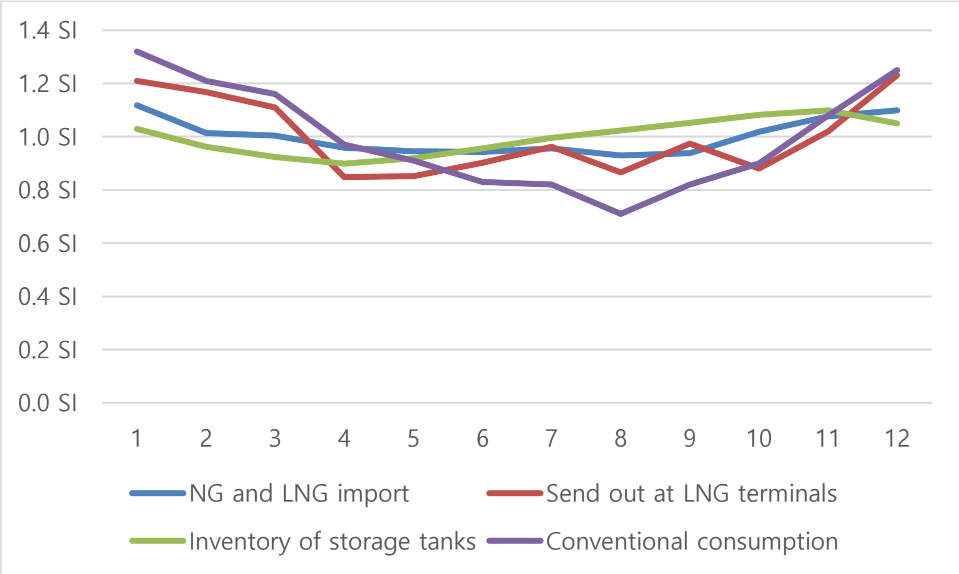

Figure 26 Seasonality in NG and LNG supply chain. Source: Gas Infrastructure Europe, Enagas and Corporacion de Reservas Estrategicas de Productos Petroliferos

Figure 26 illustrates the seasonality in NG and LNG supply chain in Spain. The value of the send out at LNG terminals and inventory of storage tanks are averaged among the related facilities introduced chapter above. Conventional consumption is chosen since it has strong seasonality and occupies the majority of parts among the other types of consumptions. It will represent the seasonality of SSLNG supply chain. The trends of the seasonality of NG and LNG import, send out at LNG terminals and conventional consumption are similar by having high value in winter while having less value in the other season.

Direct comparison with the seasonality of the inventory of storage tanks and the other seasonality is not available since the seasonality of the inventory storage has a different standard. However, interpretation of the data allows to analysis with the other values. An increase in the seasonal index at the inventory of storage means saving natural gas while a decrease means sending out natural gas for consumption. For example, after November, the storage tanks send out natural gas to consumers while saving natural gas after April.

To sum up, there is a seasonality in the entire NG and LNG supply chain in Spain by having the trend that high demand during winter and low demand apart from winter.

Chapter 4 Methodology and Data Collection

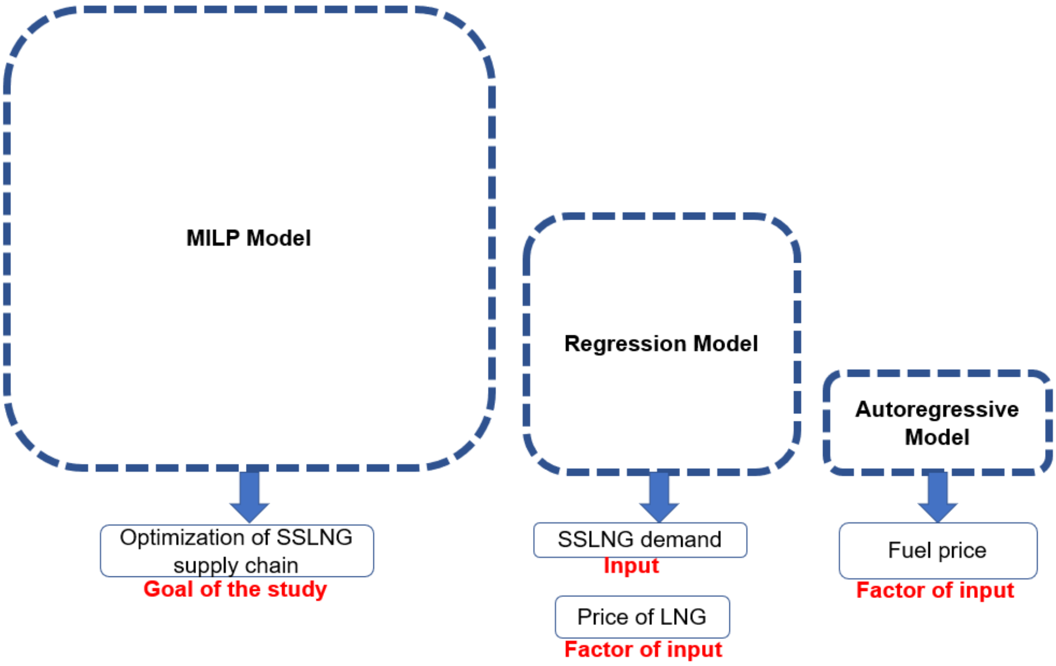

Figure 27 Models for the research.

Figures 27 introduce the three methodologies of the study. The different sizes of the boxes imply the importance in the study. The primary methodology of the study is the MILP model because it optimises the SSLNG supply chain which is the goal of the study. Another model which is the regression model is used for estimating of SSLNG future demand. The accurate forecasting of the demand plays a vital role in the paper since the demand is necessary for the model. Also, the model is applied for estimation of the price of LNG. So, instead of making a simple assumption from scratch, the regression model is used for more reliable data.
Moreover, the other analysis in chapter 4.2.1 and 4.2.2 support the feasibility of the demand. The last model is the autoregressive model for the estimation of the fuel price of trucks. This model plays the least important role among the other models since the fuel price is merely a factor of the input.

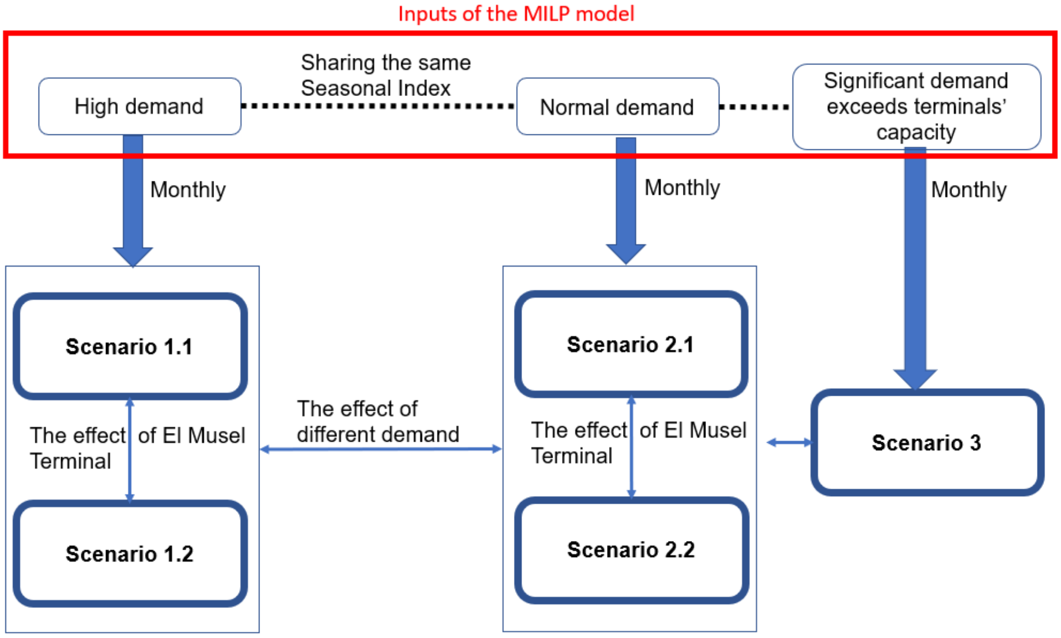

Figure 28 Relationships between MILP model and scenarios.

Regarding the relation between the scenarios and MILP model, figure 28 illustrates the how the scenarios are related to the model. The different inputs of demand sharing the same seasonal index differentiate the scenarios. This research enhances the flexibility and efficiency of the SSLNG supply chain regardless of the different demand. Furthermore, the supply chain becomes robust against seasonal effect which is the characteristic of the demand by monthly simulating with the scenarios.

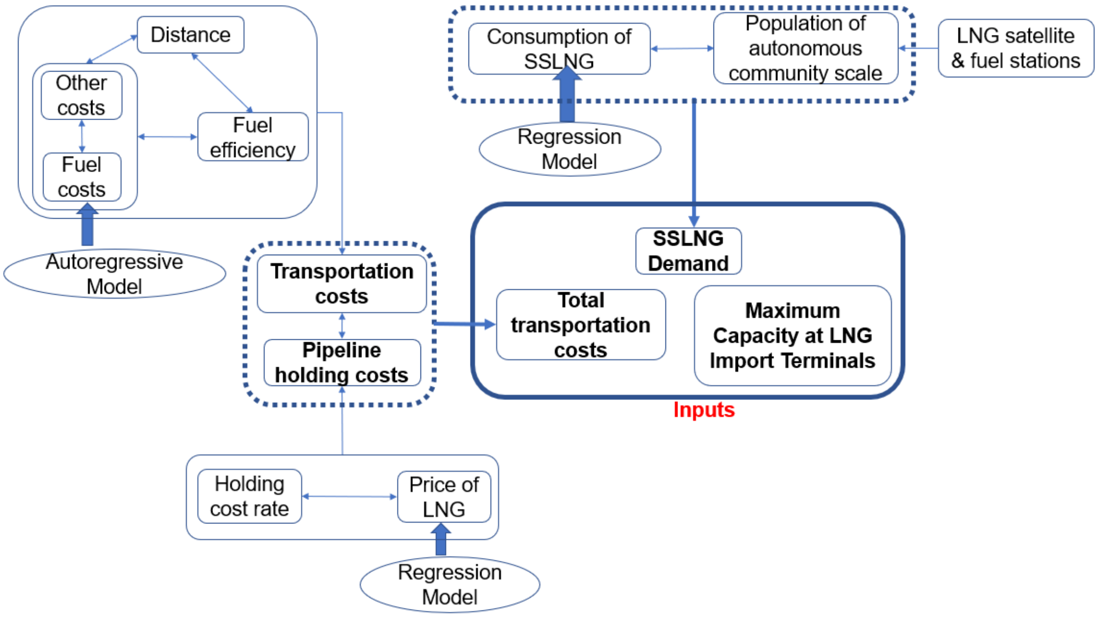

Figure 29 Data collections for inputs of the MILP model.

Figure 29 illustrates data collections for inputs of the MILP model. There are three inputs are required for the simulating MILP model: SSLNG demand, Total transportation costs and maximum capacity at LNG import terminals. Fixed costs of

the terminals are excluded according to the assumption of the study.
In order to acquire SSLNG demand, future consumption of SSLNG is needed by dividing the consumption in the autonomous community scale. The autonomous communities are selected when the locations of SSLNG facilities are covered by the community.
Other inputs are the total transportation costs consisting of transportation costs and pipeline holding costs. The transportation costs are calculated from the three factors: distance, fuel efficiency and fuel& other costs per kilometres. In particular, fuel costs are calculated by the autoregressive model. The calculation of the pipeline holding costs is done with holding costs rate assumed and price of LNG calculated from the regression model.
The last input is maximum capacity at LNG import terminals. This input is acquired on the terminal companies' website.
The detail process of the data collection is in chapter 4.4.

4.1 Network Optimisation Model

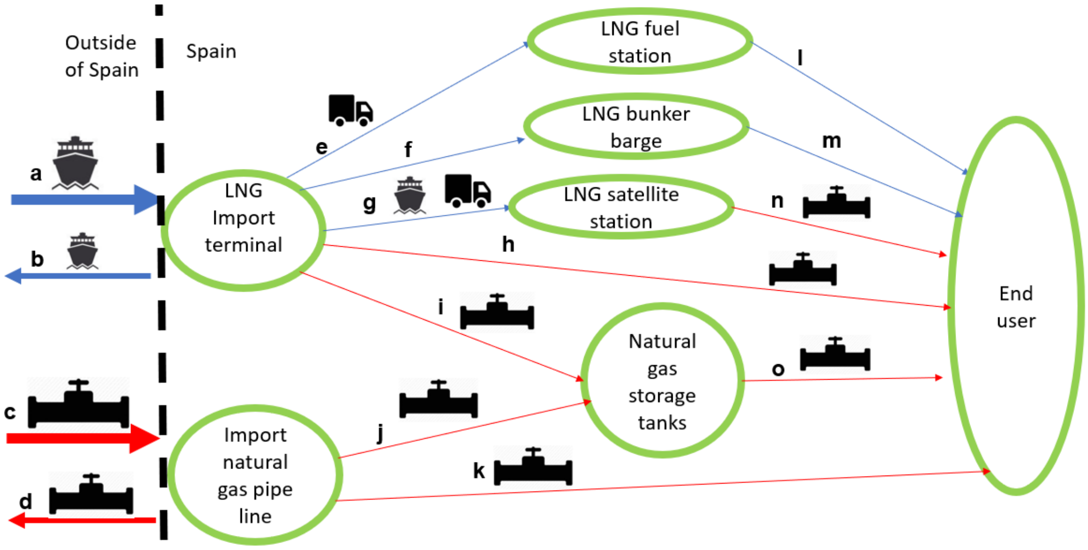

Figure 30 Flows of LNG and NG in Spain. Source: Enagas

Figure 30 shows the overview of the flows of LNG and NG. The flows of "e", "f", "g" by truck transportation in Spanish territory in the Iberian Peninsula are researched. The SSLNG transportation by ships on the flow "g" are excluded in this study. Also, the flow of "f" is included in the flow "e" since the LNG barge initially receives the LNG fuel from the LNG import terminals. In order to optimise the supply chain, the MILP model is applied since all the journals about the optimisation of the SSLNG supply chain discussed in the literature review used the model.

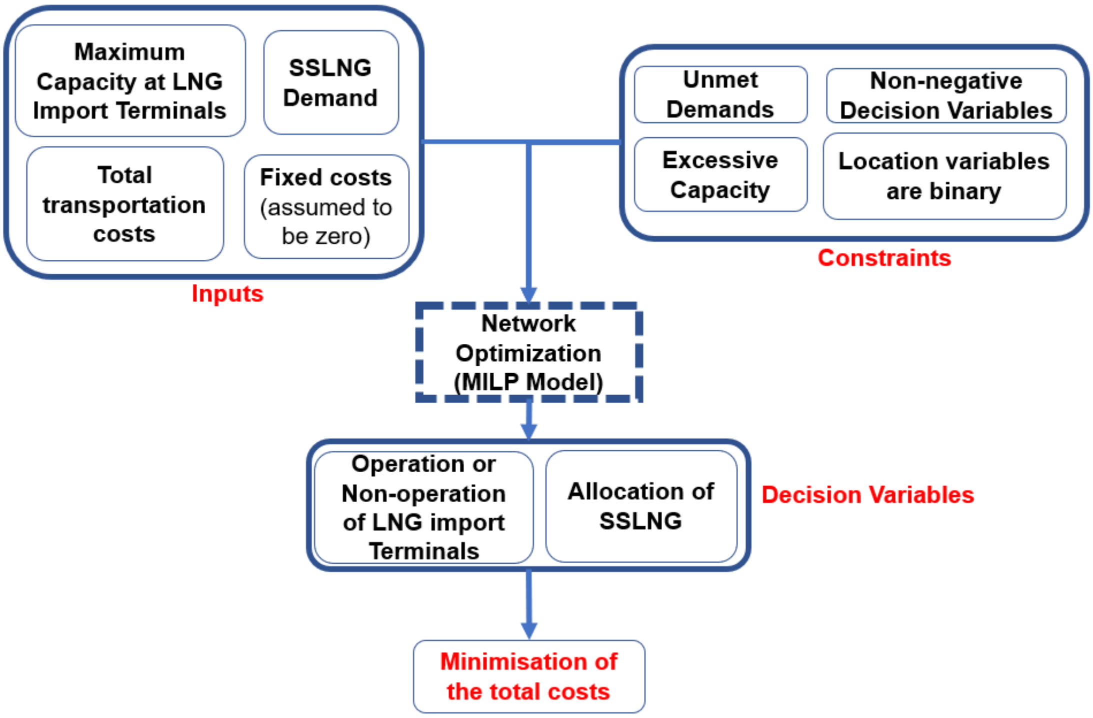

Figure 31 Descriptions of the MILP model.

Figure 31 illustrates the MILP model with inputs, constraints and decision variables for the minimisation of the total costs. The model description is discussed in detail in chapter 4.1.4, so this paragraph briefly shows the diagram of the simulation. There are four inputs, but fixed costs are set to zero according to the assumption of the study, so three inputs are actually applied. The decision variables are initially zero before simulating the model. After simulating the model with the inputs and constraints, the decision variables are calculated for the minimisation of the total costs in the SSLNG supply chain.

4.1.1 Players in the Model

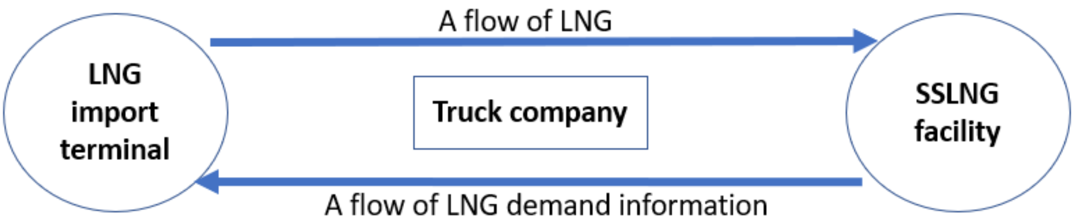

Figure 32 Players of the model.

Figure 32 illustrates three players in the research area: LNG import terminals, truck companies and small-scale LNG facilities. LNG import terminals supply LNG which does not exceed the maximum output capacity for SSLNG transportation by truck. Truck companies provide the truck transportation service from the origins to the destinations aligned with the demands. The small-scale LNG facilities demand the amount of the LNG they need and received the cargo. In the aspect of the allocation of the cargo, SSLNG facilities become a problem owner since they need to decide which LNG import terminals to receive the cargo.
On the other hand, decision maker for the amount of the SSLNG demand transported is SSLNG facility. The truck company is problem owner since they need to adjust the

number of trucks to meet the demand.
The owner of El Musel is the problem owner since the terminal is not under operation due to the Spanish government which is a decision maker in the context. So, the problem owner should convince the Spanish government to operate the terminal with the positive proofs.

4.1.2 Assumption of the Model

Most of the assumptions in the papers are same as the assumptions from other journals from “Chapter 2. Literature Review”.
At first, enough storage capacity from the destination is assumed. It means that there would be no issues of inventory management at the SSLNG facilities.
Another is the fixed costs such as investment costs of LNG import terminals, and SSLNG facilities are not considered. This assumption affects the MILP model by not inputting fixed costs in the model.
Also, boiled-off gas is not considered for simple calculation. In other words, there would be no loss of cargo during transport.
Schedule of the truck transportation is not taken into account.
Regarding the period of the research, in order to check the seasonality, monthly data of 12 months in a year are simulated by inputting monthly changeable factors such as different demands of SSLNG.
On the other hand, there are different assumptions from the other papers. There are no transaction costs and delays of sharing information by assuming that there is a vertical integration in the supply chain.
Other customers for SSLNG do not exist other than LNG satellite stations and fuel stations.
Lot size of the truck is 0.3 GWh and truckload (TL) is assumed by having only single origin and destination.

4.1.3 Scenario Description

There are three main scenarios with sub-scenarios. The main scenarios are set based on the assumption of the different SSLNG demands in order to test to what extent the supply chain does change in the different demands on a monthly basis in a year.
The scenarios simulate the supply chain in the different situations. The main scenarios are the optimisation of SSLNG supply chain in the “full capacity”, “abundant capacity” and “a lack of capacity”. The “full capacity” does not literally have full capacity but the LNG transportation by trucks is close to the limits of the amount of LNG transported from the LNG import terminals. Another one is “abundant capacity” has the relatively lower amount of LNG is transported than the amount of the “full capacity” scenario. The first and second scenario has two sub-scenarios to examine the effect of the operation or no operation of El Musel LNG import terminal. The last one is “a lack of capacity” that the demand of SSLNG exceeds the maximum output capacity of LNG truckload transportation from LNG receiving terminal. So, the difference of allocation of the LNG transportation between the origin and destination will be discussed in the results. Also, the sub-scenarios are about discussing the effect of additional LNG import terminal which is El Musel LNG terminal in Spain. Enagas (2016) mentioned that the LNG terminal had been built however it has not been operated. So how will the additional terminal affect the optimisation of the supply chain is studied if the terminal would be under operation.

4.1.4 Description of Optimisation Model

The SSLNG supply chain has 7 LNG import terminals (6 terminals in sub-scenario)

and 14 autonomous communities in Spain. The former is the origin of the SSLNG and the latter are the destination of the SSLNG.
The model optimises the supply chain by minimising the total costs in the supply chain.

Following inputs are required for the network optimisation model.

n = number of LNG import terminals locations
m = number of destinations for the demand (LNG fuel stations and LNG satellite terminals in autonomous community level)
D_j = monthly demand from LNG fuel station and LNG satellite terminals "j" in the autonomous community level
$K_i =$ Monthly maximum capacity of the LNG terminals "I"
$f_i =$ Monthly fixed costs of keeping plant "I" open
$c_{ij} =$ cost of transporting costs (fuel costs) from the LNG terminals "I" to the destinations (LNG fuel stations and LNG satellite terminals).

Decision variables are below.
y_i = 1 if the location of LNG receiving terminal is at i, otherwise it is 0
x_{ij} = 1 if LNG receiving terminal i supplies market j, otherwise it is 0

The formulation of the problem is below (Chopra and Meindl, 2015).

Minimise

$$\sum_{i=1}^{n} f_i y_i + \sum_{i=1}^{n}\sum_{j=1}^{m} c_{ij} x_{ij}$$

Subject to

- Equation 1.1.

$$\sum_{i=1}^{n} x_{ij} = D_j$$

for j = 1,…, m

- Equation 1.2.

$$\sum_{j=1}^{m} x_{ij} \leq K_i y_i$$

for i = 1, … , n

- Equation 1.3.

$$y_i \in \{0,1\}$$

For i= 1,…, n, $x_{ij} \geq 0$

Excel Solver is the software to run the model in this study. Inputs of the data of capacity of terminals, costs and demand are the first step (Chopra and Meindl, 2015). Annex A shows the excel sheet for the simulating model by Excel Solver. The number of origins of the SSLNG (n) is 7 or 6 (sub scenario without El Musel terminal). The number of the destination (m) is set 14. The fixed costs (yellow area) from cell P4 to P10 is set as zero according to the assumption of the model that there is no fixed cost (f_i). Capacity of the terminal (K_i) is input from Q4 to Q10 (Green area). The grey area (cell between B11 and O 11) illustrates SSLNG demands (D_j) from the autonomous communities in Spain. The total transportation costs (c_{ij}) are entered in the cells from B4 to O10 (Orange area).
When it comes to decision variables, cells from B17 to O 23 (Blue area) represent the allocation of SSLNG from origins to destinations (x_{ij}). Another decision variable (y_i) about operation or non-operation of the LNG import terminals is shown between P17 and P23 (Sky blue area). The two variables are initially set as zero before running the model (Chopra and Meindl, 2015).

Subsequently, it is necessary to set the Excel formula for the model. Excel formula "= B11-SUM(B17:B23)" is copied from B36 to O36 (Orange area) for unmet demand (Equation 1.1.). Equation 1.1 means that the total demand from an autonomous community minus divided demands transported from LNG import terminals.
Equation 1.2 (Excess Capacity) is applied to Excel as "=P17*Q4-SUM(B17:O17)" by being copied from B27 to B33 (Grey area). Equation 1.2 expresses the difference between the maximum output capacity at terminals and the sum of SSLNG transported from the terminals to the destinations.
The objective function is shown in the cell B39 with the formula below.
"SUMPRODUCT(B4:O10,B17:O23)+SUMPRODUCT(P4:P10,P17:P23)"
The total fixed costs (excluded from the study based on the assumption) and variable costs are measured in the objective function (Chopra and Meindl, 2015).

The minimisation of the total cost (Cell B39) is in needs of constraints below (Chopra and Meindl, 2015).

B17:P23 $\geq$ 0 {Decision variables are non-negative}

B27:B33 $\geq$ 0 {$K_i y_i - \sum_{j=1}^{m} x_{ij} \geq 0$ for i = 1,…,7 or 6 (without El Musel terminal)}
This formula defines that the sum of SSLNG transported from the LNG import terminals to the destination cannot exceed the maximum SSLNG output capacity at the terminals.

B36:O36 = 0 {$D_j - \sum_{i=1}^{n} x_{ij} = 0$ for j = 1,…,14}
This constraint is for unmet demand. It is an ideal situation that the unmet demand is zero meaning that all the demands are satisfied.

P17:P23 = binary {Location variable y_i is 0 or 1}

Finally, Simplex LP and minimization are selected in the Solver Parameters and the model is simulated.

4.2 Regression Model with Seasonality for Forecasting

Seasonal variations mean that cycles have a short calendar repetition within a year (Keller, 2014). It covers the patterns happens daily, weekly, monthly or even four seasons (Keller, 2014). In order to estimate the seasonal effect, seasonal indexes must be calculated (Keller, 2014). In addition, abundant time series are necessary for the calculation of the seasonal indexes (Keller, 2014). Keller (2014) mentions that a minimum of 4 years of time series data is needed to observe the proper seasonal index. Keller (2014) shows the procedures for the calculation of the seasonal indexes below.

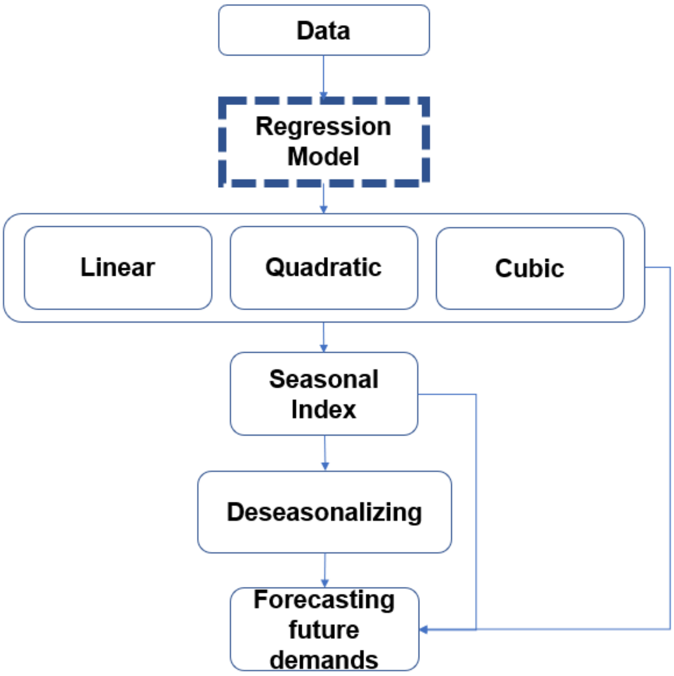

Figure 33 Process of forecasting future demand.

Figure 33 illustrates the process of the forecasting future demands by using the regression model. At first, data of SSLNG consumption is used for the regression model. The data is checked among the three model which are linear, quadratic and cubic. Based on analysis with p-value and r-squared, a suitable model for the demand data will be selected. After the seasonal index is calculated, the time series is deseasonalised. Finally, forecasting of the future demand is available with the regression model, seasonal index. The process in detail is in the below paragraphs.

1. Computing regression lines. These could be linear, quadratic or cubic regression line.

Linear:

$$\hat{y_t} = b_0 + b_1 t$$

Quadratic:

$$\hat{y_t} = b_0 + b_1 t + b_2 t^2$$

Cubic:

$$\hat{y_t} = b_0 + b_1 t + b_2 t^2 + b_3 t^3$$

2. Computing the ratio for each time period. Most of the trend variations are removed by this ration.

$$\frac{y_t}{\hat{y_t}}$$

3. Calculating the average of the ratios in step 2 for the months. The most of the random variations are eliminated, but the seasonality is left.

4. Adjusting the averages to make an entire of the average of the seasonality 1.

Subsequently, deseasonalising the time series are necessary to acquire the seasonally adjusted time series (Keller, 2014). The deseasonalising means that eliminating the seasonal variation by using the seasonal index (Keller, 2014).

The procedure of the deseasonalising is computed by the formula below (Keller, 2014).

$$\frac{Time\ Series}{Seasonal\ Index}$$

Easier comparisons of time series among months are available by deseasonalising since there are no seasonal effects anymore (Keller, 2014).

The final step is forecasting by using the seasonal indexes, and the formula are below. (Keller, 2014).

$$F_t = [b_0 + \ b_1 t] * SI_t$$

$$F_t = [b_0 + \ b_1 t + b_2 t^2] * SI_t$$

$$F_t = [b_0 + \ b_1 t + b_2 t^2 + b_3 t^3] * SI_t$$

where

$$F_t = Forecast\ for\ period\ t$$

$$b_0 + \ b_1 t = Regression\ equation\ (Linear)$$

$$b_0 + \ b_1 t + b_2 t^2 = Regression\ equation\ (Quadratic)$$

$$b_0 + \ b_1 t + b_2 t^2 + b_3 t^3 = (Cubic)$$

$$SL_t = Seasonal\ index\ for\ period\ t$$

In this paper, the monthly data of LNG direct consumption, NG consumption for conventional and NG consumption for electricity generators in Spain from 2009 to 2017 will be used for the calculation of the future consumption in Spain in 2018 (Corporacion de Reservas Estrategicas de Productos Petroliferos, 2018). In particular, one of the consumption sectors which is LNG direct consumption in 20018 will be used as a decision variable for the demand of LNG at the LNG fuel stations for trucks and ships. So, LNG direct consumption other than these destinations is excluded from this research. The calculation 1of the forecasting of the future consumption is done by Minitab. In addition, in order to run the model, periods are going to be used by setting period in ascending order such as period 1 (January 2009), period 2 (February 2009).

4.2.1 Analysis of the relationships of Pearson correlation and p-value

The value of the Pearson correlation is close to 1 meaning that it is close to a perfect positive relationship between the two variables (Keller, 2014). In addition, the p-value of this relation is less than 0.0001 which is very low.

4.2.2 Analysis of the regression models with P-value, R-squared

In order to interpret the regression models, it is necessary to use some figures representing a different aspect of the models.
Because of the limitation of the coefficient of correlation only having three figures which are -1, 0, 1, other proper measurements are required to interpret properly (Keller, 2014). The coefficient of determination fits for the purpose (Keller, 2014). The coefficient of determination of 0 (0%) means there are no relationships between independent and dependent variables compared while the one of 1 (100%) expresses that the independent variable fully explains the variation in the dependent variable (Keller, 2014). In addition, the figures other than 0 and 1, the degree of the figures whether close to 1 or 0 determine the relationships (Keller, 2014).

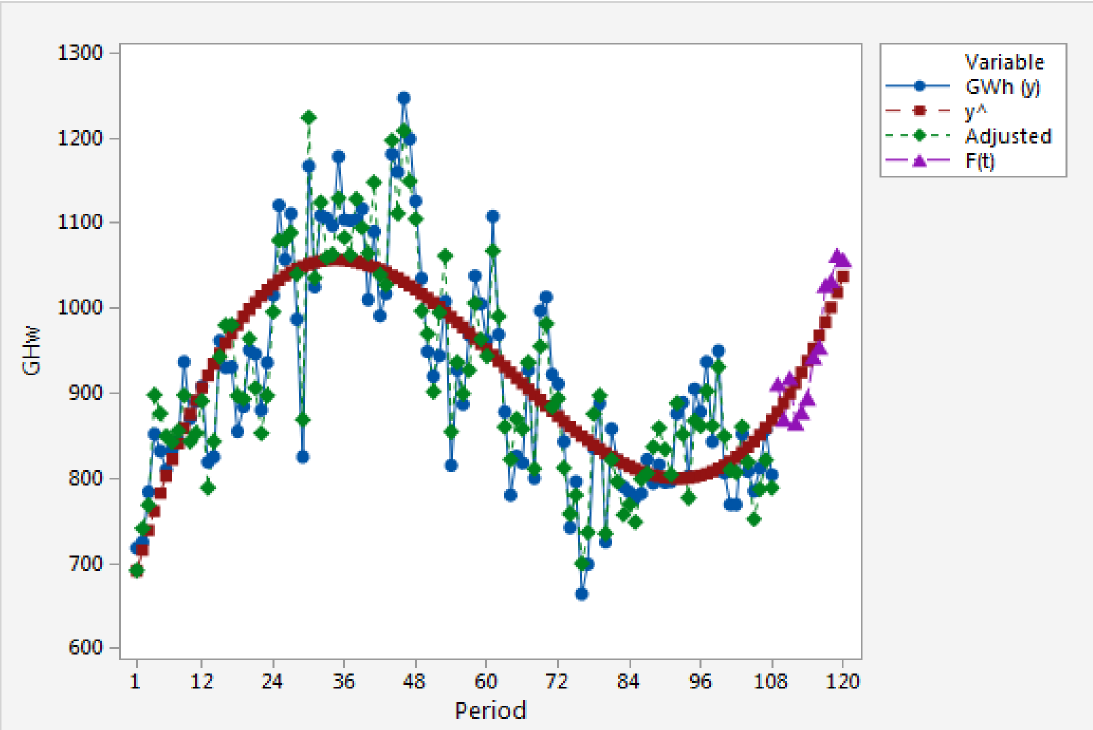

Figure 34 LNG direct consumption between 2009 and 2018 in Spain. source: Corporacion de Reservas Estrategicas de Productos Petroliferos

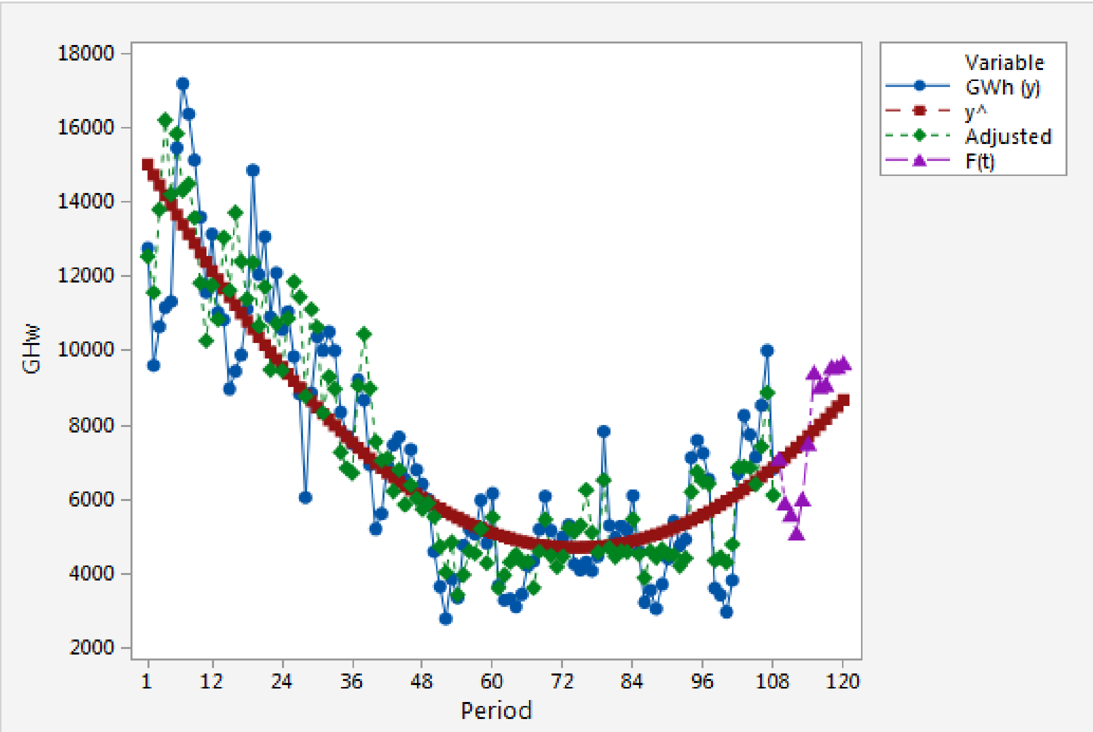

Figure 35 NG consumption for electricity generator between 2009 and 2018 in Spain. Source: Corporacion de Reservas Estrategicas de Productos Petroliferos

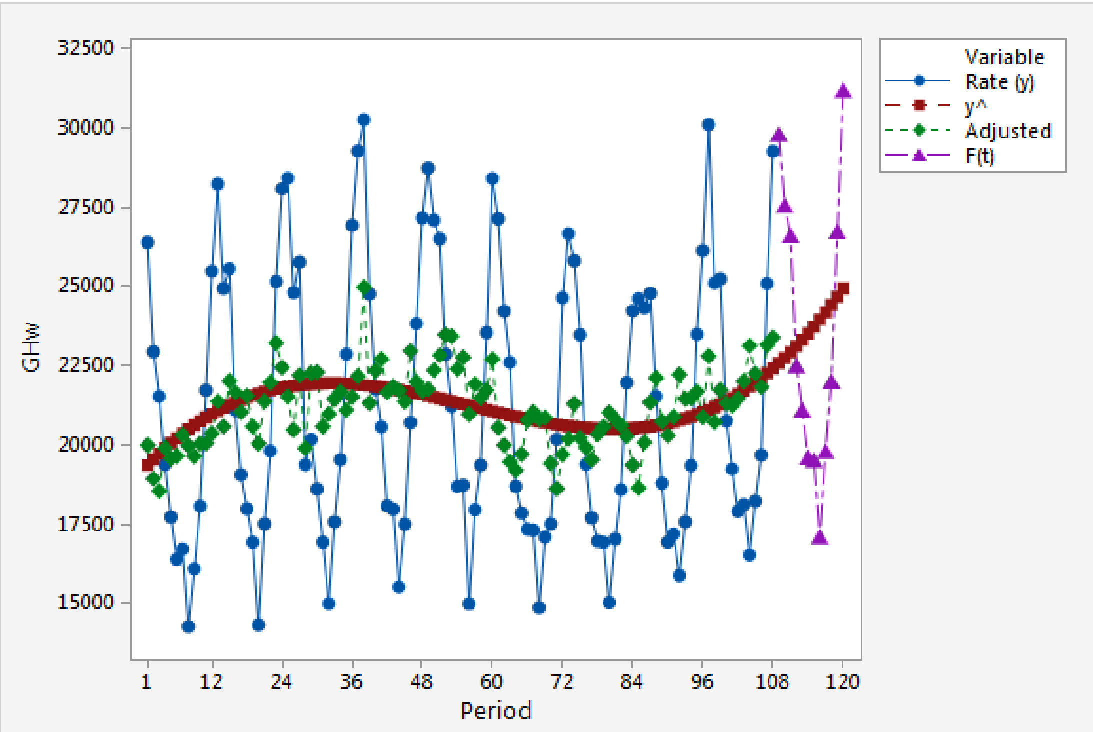

Figure 36 NG consumption for conventional between 2009 and 2018 in Spain. Source: Corporacion de Reservas Estrategicas de Productos Petroliferos

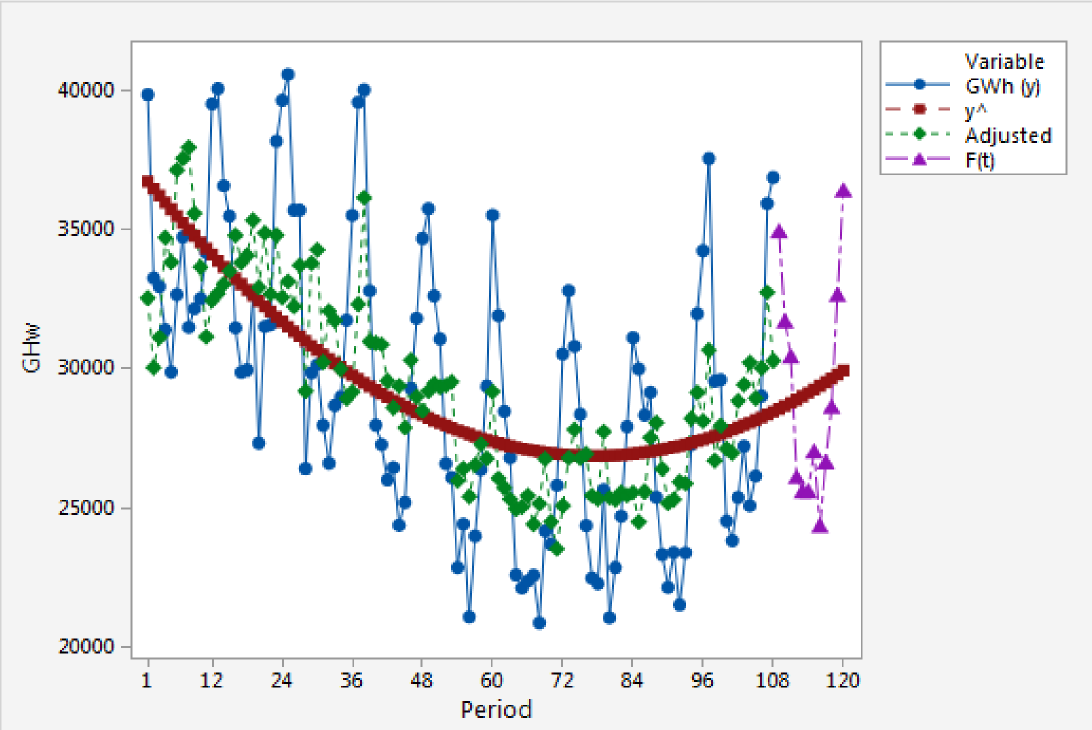

Figure 37 A total NG and LNG between 2009 and 2018 in Spain. Source: Corporacion de Reservas Estrategicas de Productos Petroliferos

Figure 34, 35 and 36 illustrate the three different consumption history data of NG and LNG from 2009 to 2017 coupled with the data in the year of 2018 acquired from the forecasting with seasonality in the regression model. Period 1 means January in 2009 and period 120 means December in 2018. The blue line is the data acquired from Corporacion de Reservas Estrategicas de Productos Petroliferos (2018a). from the three tables, the seasonality of the consumption is clearly observed. Deseasonality of the consumptions is seen from the green line. The red lines show the direct results of the regression models. The purple line is the result of multiplying of red lines in 2018 and seasonal indexes. In other words, the purple line is the consumption forecasted in 2018. The lines of figure 37 are similar to figure 36 since conventional consumption (figure 36) accounts for the large part of the total consumption (figure 37).

Conventional	GWh (y) = 19155 + 199.3 Period − 4.327 Period^2 + 0.02556 Period^3
Electricity generator	GWh (y) = 15294.4 − 284.77 Period + 1.9130 Period^2
LNG direct consumption	GWh (y) = 665.73 + 25.829 Period − 0.51289 Period^2 + 0.0026954 Period^3
Total consumption	GWh (y) = 36995 − 261.96 Period + 1.6922 Period^2

Table 11 Regression models for the consumptions by Minitab. Source: Corporacion de Reservas Estrategicas de Productos Petroliferos

Table 11 shows the regression models are used for the LNG and NG consumption data in Spain. There are three regression models available from the Minitab which are linear, quadratic and cubic regression models. There are two quadratic models, and two cubic models are chosen. The choice of the proper model is based on the p-value of the regression models and variables of the model along with R-squared (R-sq). The figures are shown in table 12 below.

	Conventional	Electricity generator	LNG direct consumption	Total
Regression Model	P-Value	P-Value	P-Value	P-Value
	0.5103	<0.0001	<0.0001	<0.0001
	R-sq	R-sq	R-sq	R-sq
	2.19%	74.59%	60.30%	30.56%
	P-Value	P-Value	P-Value	P-Value
Constant	<0.0001	<0.0001	<0.0001	<0.0001
Period	0.1386	<0.0001	<0.0001	<0.0001
Period^2	0.1306	<0.0001	<0.0001	0.0006
Period^3	0.1388		<0.0001	

Table 12 Interpretation of the regression models of the consumptions of LNG and NG in Spain by Minitab. Source: Corporacion de Reservas Estrategicas de Productos Petroliferos

Table 12 shows the general overview that except for the regression model of conventional, the others are considered as a suitable model for the data. For instance, a p-value of the regression models is less than 0.0001 in the data given except for conventional having a high p-value (0.5103). In a similar way, the p-value of the constant, period, Period^2 and Period^3 is less than 0.001 apart from the one of Period^3 in total consumption among the data apart from conventional on which p-value of the constant is less than 0.0001. However, the figure 0.0006 is also tiny, so it has a proper value for the p-value.

When it comes to the figures of R-squared, the data of consumption of natural gas at electricity generator is fit to its model at a high degree (74.59%) among the 4 data. The next one is the data on LNG direct consumption having a figure of R-squared (60.30%) while the data of conventional consumption is poorly fit its data. The effects of the high value of R-squared of the electronic generator and low value or R-squared of the conventional are represented by the value of the total consumption between them.

4.3 Autoregressive Model for Forecasting

An autoregressive model is useful for forecasting without discernible trend seasonality, and it is believed that a correlation exists among successive residuals (Keller, 2014). There is a formula for the autoregressive model for forecasting below.

$$y_t = B_0 y_{t-1} + B_1 y_{t-2} + \varepsilon$$

This model indicates the correlation of the successive values in the time series (Keller, 2014).

This model will be used for deciding the single diesel price for trucks transporting LNG in 2018 based on the monthly price data of diesel in Spain from 2011 to 2017. The price is calculated by Excel Regression on data analysis.

4.4 Data Collection

This chapter explains data collection for simulating the model along with relevant assumption for each data collection altogether.

4.4.1 Demand for Liquefied Natural Gas Direct Consumption

This data is one of the decision variables (x_{ij}) for the simulation of the study while the opening or closing of the LNG import terminals (y_i) is the other decision variables. Forecasting for the demand of the LNG direct consumption is done based on the data from Corporacion de Reservas Estrategicas de Productos Petroliferos (2018) coupled with the regression model with seasonality.

Before calculation of the demand, it is assumed that there would be no LNG loss such as boiled off gas during the truck transportation. So, the initial amount of LNG transported from LNG import terminals to the fuel stations coincides with the amount of LNG arrived at the destinations. The flowing paragraphs are related to inputs of the research.

According to table 3 in chapter 3.2.1., the sum of the capacity of LNG truck transportation in the 6 LNG terminals in Spain apart from El Musel which is not under operation (Enagas, 2016) is 2160. So, it is assumed that the estimated maximum capacity of LNG transportation by trucks to LNG satellite terminals by

$$Total\ LNG\ transportation\ capacity\ by\ trucks\ in\ LNG\ terminals \\ -\ LNG\ direct\ consumption\ in\ 2018$$

The next step is the calculation of estimated LNG demand from LNG satellite terminal without SI. This value is calculated from natural gas conventional consumption. The reason why using natural gas consumption for LNG satellite terminal is that the input of the satellite terminals is LNG while the output of the terminals is natural gas. In addition, it is assumed that the usage of natural gas from LNG satellite terminals is for the conventional purpose. So, the SI and the regression model for from conventional usage of NG are applied for this calculation. However, the results of the original regression model exceed the total maximum capacity of LNG truck transportation in LNG receiving terminals; there is an adjustment of the constant in order to limit the value below the maximum capacity. So, instead of using the model from the original regression model of conventional usage of natural gas

$$Rate\ (y)\ =\ 19155\ +\ 199.3\ Period\ -\ 4.327\ Period^2\ +\ 0.02556\ Period^3$$

, the new formula

$$Rate\ (y)\ =\ -500+\ 199.3\ Period\ -\ 4.327\ Period^2\ +\ 0.02556\ Period^3$$

is applied by only adjusting the constant from -19155 to -500. After applying it, the data from period 73 to 84 is used. Subsequently, SI from original data is multiplied to this figure. This new model is for the scenario 1 which is the “full capacity”. For the scenario 2, another model adjusted the constant to -1000 is used in the same way as the model in scenario 1. The last scenario adjusts the constant to 200.

The formula for the scenario 2

$$Rate\ (y)\ =\ -1000+\ 199.3\ Period\ -\ 4.327\ Period^2\ +\ 0.02556\ Period^3$$

The formula for the scenario 3

$$Rate\ (y)\ =\ 200+\ 199.3\ Period\ -\ 4.327\ Period^2\ +\ 0.02556\ Period^3$$

The result of the calculation is shown in table 12.

2018	SI of Conventional	LNG Direct (GWh)	Scenario 1. LNG demand from Satellite (GWh)	Scenario 2. LNG demand from Satellite (GWh)	Scenario 3. LNG demand from Satellite (GWh)	Available capacity for satellite terminals (GWh)
Jan	1.32	911.6	1232.9	572.3	2156.3	1248.4
Feb	1.21	869.4	1104	497.4	1949.4	1290.6
Mar	1.16	918.1	1034.8	453.9	1845.9	1241.9
Apr	0.97	865.1	851.3	363	1527	1294.9
May	0.91	877.9	779.2	327.9	1419.9	1282.1
Jun	0.83	894.4	708.7	290.1	1286.1	1265.6
Jul	0.82	942.8	692.7	280.4	1264.4	1217.2
Aug	0.71	954.5	598.7	239.9	1091.9	1205.5
Sep	0.82	1027	694	276.7	1260.7	1133
Oct	0.9	1032.4	757.9	306.7	1386.7	1127.6
Nov	1.08	1062.5	919	375.9	1671.9	1097.5
Dec	1.25	1057.3	1075.4	449.3	1949.3	1102.7

Table 13 Estimated demands from the destinations in Spain. Source: Enagas and Corporacion de Reservas Estrategicas de Productos Petroliferos

Also, table 13 shows the number of trucks for LNG transportation is calculated by dividing 0.3 GWh in each scenario.

	Scenario 1	Scenario 2	Scenario 3
Jan	7149	4947	10227
Feb	6578	4556	9396
Mar	6510	4574	9214
Apr	5722	4094	7974
May	5524	4020	7660
Jun	5344	3949	7269
Jul	5452	4078	7358
Aug	5178	3982	6822
Sep	5737	4346	7626
Oct	5968	4464	8064
Nov	6605	4795	9115
Dec	7109	5022	10022

Table 14 Number of trucks required for each scenario.

Since the figures in table 14 have the feature of the seasonality, the number of the trucks needed for LNG transportation to align with the trend. Winter season requires more trucks than the other season. In particular, the demand for trucks in January is the approximately 38% higher than the one in August. In the view point of the entire supply chain, it is necessary to deal with the surplus of the trucks in off-peak season. However, it is not in the scope of the study so it is not discussed in the paper.

4.4.2 Distribution of the Demand in the Autonomous Community Scale.

Autonomous Communities	Provinces with LNG satellite stations	Provinces with LNG fuel stations
Galicia	A Coruna, Lugo, Pontevedra	A Coruna, Ourense
Castile and Leon	Burgos, Avila, Leon	Burgos
Extremadura	Badajoz, Caceres	Badajoz
Andalusia	Almeria, Cadiz, Cordoba, Granada, Jaen, Malaga, Sevilla	Cadiz, Jaen, Malaga, Sevilla
Murcia	Murcia	Murcia
Castilla La Mancha	Albacete, Ciudad Real, Cuenca, Guadalajara, Toledo	Cuenca, Guadalajara, Toledo
Madrid	Madrid	Madrid
Valencia	Alicante, Valencia	Alicante, Castellon, Valencia
Catalonia	Barcelona, Girona, Lleida, Tarragona	Barcelona, Girona, Lleida Tarragona
Aragon	Huesca, Teruel, Zaragoza	Zaragoza
Navarre	Navarra	
Asturias	Asturias	
Cantabria	Cantabria	
Basque Countries		Alava, Bizkaia, Gipuzkoa

Table 15 Autonomous Communities having provinces with small-scale LNG facilities. Source: Gas Infrastructure Europe

At first, the population data is gained from Instituto Nacional de Estadistica (2018) and the data of the 1st of January 2018 is applied for this study. Table 15 shows that the monthly LNG direct and NG conventional consumptions are be divided for each autonomous community having the LNG fuel loading stations and LNG satellite terminals respectively. For the calculation, each LNG fuel station and satellite station are collected in a province-level at first. After that, the population in the province are summed in the autonomous community level. Subsequently, the ratios of the population of each autonomous community against the total population of the autonomous community collected are calculated. This ratio will be multiplied by the monthly estimated consumption of the LNG direct consumption and NG conventional consumption. The figure after the calculation represents the amount of LNG demand from the autonomous community through the truck transportation since the resource of NG convention consumption from satellite terminal was previously LNG. So, LNG demand from the LNG fuel stations and satellite terminals are summed up, so there is a total demand for LNG by truck transportation in the autonomous community level. The results are in Annex B.

4.4.3 Distance between Liquefied Natural Gas Import Terminals and Autonomous communities

In order to calculate the distance between LNG import terminals and autonomous community, it is necessary to collect distance data from the terminals to each LNG fuel stations and satellite stations. The locations of the 7 import terminals are provided by Global Energy Observatory (n.d.a) (n.d.b) (n.d.c) (n.d.d) (n.d.e) (n.d.f) (n.d.g). Also, the locations of the LNG fuel loading stations for road vehicles and ships and the satellite stations have been provided by Gas Infrastructure Europe (2018b) and Dieselo Gasolina (2018) for the more accurate position of the facilities. The location data which is not accessed by Gas Infrastructure Europe (2018b) has been searched on the relevant website. Subsequently, based on the collected information, the distance (kilometres) between the LNG import terminals and the destinations are calculated on Google Maps. The shortest distance by car is chosen among the

suggested distances from Google Maps. After collecting all the distance data between LNG receiving terminals and the destinations, the distance data is averaged in the autonomous level. So, there is a single distance from the LNG receiving terminals to the autonomous community.
Furthermore, only LNG fuel stations existing in Spanish territory in Iberia peninsula is considered for the research. So, three LNG satellite terminals which are Cala Millor, Can Picafort and Manacor are located in the Balearic Islands are excluded from the research.

4.4.4 Lot Size of the Trucks

LNG import terminal	Barcelona	Cartagena	Huelva	El Musel	Sagunto	Bilbao	Mugardos
LNG truck loading bay	3	3	3	2	2	1	2*
Numbers of LNG trucks per day	50	50	50	30	40	15	35*
Daily max. capacity of LNG truckload transportation (GWh)	15	15	15	9	12	4.5	10.5
Monthly max. capacity of LNG truckload transportation (GWh)	450	450	450	270	360	135	315

Table 16 LNG truckload capacity in LNG terminals in Spain. Source: Enagas

Before discussing the lot size of the trucks, there is no data of LNG truck loading bay in Mugardos, however, it can be assumed as 2* since El Musel terminals (the capacity of 30 trucks) and Sagunto terminals (the capacity of 40 trucks) have two loading bays. In addition, there is no data for the daily number of trucks available in Mugardos so 35* from the figure XX is calculated by $\frac{10.5\ GWh(Max.Capacity\ of\ LNG\ transported\ by\ trucks\ in\ Mugardos\ terminals)}{0.3\ GWh(lot\ size\ of\ trucks)}$).
Based on the data provided by the table 16, it is possible to it is possible to calculate the maximum capacity of LNG transported by single truck although Enagas (2012) did not mention the lot size of the trucks. After dividing from the maximum capacity of LNG transported by trucks per day by the maximum number of trucks transporting LNG per day, the figure of 0.3 Gigawatt hours (GWh) is calculated. So, 0.3 GWh is considered as the maximum amount of LNG transported by a truck, and this will be used for the research. Eurostat (2013, para 1.) explains the meaning of GWh as "GWh is a unit of energy representing one billion-watt hour and is equivalent to one million kilowatt hours" (Eurostat, 2013, para 1.). "Gigawatt hours are often used as a measure of the output of large electric power stations" (Eurostat, 2013, para 1.). "A kilowatt-hour is equivalent to a steady power of one kilowatt running for one hour and is equivalent to 3.6 million joules or 3.6 megajoules" (Eurostat, 2013, para 1.). In addition, the capacity of LNG in fuel station is assumed sufficient to be received the full amount of LNG from the lot size.

4.4.5 Capacity of LNG Transportation by Trucks in the LNG terminals

Figure 18 also shows the maximum capacity of the LNG transportation by trucks in the LNG terminals. Barcelona, Cartagena, Huelva have the largest capacities (450 GWh) while Bilbao terminal has the lowest capacity (135 GWh),

4.4.6 Transportation Costs

In this study, the total cost consists of transportation costs and inventory holding costs during transit time. Fixed costs derived from operating the LNG receiving terminals are excluded.

4.4.6.1 Fuel Price per Kilometre for the Trucks
Before deciding the fuel price for the research, it is vital to opt for the what type of the fuel is applied. According to the table 8 in chapter 3.3.4.1., around 99 % of the road tractor is fuelled by diesel so, all the trucks transporting LNG are considered as diesel-fuelled vehicles.
The price data of diesel is presented on the website of European Commission (2018). Based on the monthly data, the diesel price in Spain in 2018 will be calculated by using the autoregression in Minitab. Since this study is about the minimisation of the transportation costs, only one value of the fuel cost is applied in the entire of the year to clearly observe the changes in the transportation costs regardless of the fluctuation of the diesel price.
The Autoregressive formula of the diesel price in Spain is below.

y_t= 0.046517+ 1.1567y_{t-1} - 0.1957y_{t-2}

After calculation, 1.13 euros are acquired for the diesel price for January 2018. This value is considered as the fixed diesel price of a whole 2018.
In order to acquire the data of fuel consumption per kilometre, the data of the fuel efficiency is required. In this study, the information about the fuel efficiency of the truck transporting LNG is acquired from Dünnebeil et al. (2015). Dünnebeil et al. (2015) set the fuel efficiency of the semi-trailer truck as 34.5L (Litre-Diesel/100km). In the calculation, the fuel efficiency is divided by 100 to make it as litre-diesel / 1km. So, the result is 0.38985 Euros per kilometre.

4.4.6.2 The Rest of Transportation Costs
According to Hopper and Murray (2017), many factors are consisting of the transportation costs of the truck. Data for 2016 provided by Hopper and Murray (2017), is applied for the simulation in 2018 apart from the fuel costs already calculated in the sub-chapter above. The rests of transportation costs along with the calculated fuel price are shown in the table below. In addition, since Hopper and Murray (2017) provided the currency as dollars and the measurement of length as miles, those two are converted to Euro and kilometres respectively: 1 dollar to 0.9 Euros and 1 mile to 1.6 kilometres.

Rate based on trucks (Euro/km)	
Fuel Costs	0.38985
Payments for leasing or purchasing vehicles	0.143
Repair and Maintenance	0.093
Truck Insurance Premiums	0.042
Permits and Licenses	0.012
Tires	0.02
Tolls	0.014
Rate based on workers (Euro/km)	
Driver Wages	0.294
Driver Benefits	0.087
Total (Euro/km)	1.095

Table 17 Transportation costs in the scenario of the study. Source: American Transportation Research Institute, European Commission and Dünnebeil et al.

Table 17 indicates that 1.095 Euros per kilometre is the rate of the transportation costs in this study.

4.4.7 Design of Transportation Networks

Direct shipment from a single destination is applied for the research (Chopra and Meindl, 2015). In this assumption, the adverse effects such as complication of coordination and operation derived from multiple destinations are removed (Chopra and Meindl, 2015). In other words, a direct shipment with a milk run for LNG transportation is excluded from the research, but solely direct shipping is considered for LNG truckload transportation (Chopra and Meindl, 2015).

Transportation by means of less than truckload (LTL) has smaller lot sizes than truckload (TL) (Chopra and Meindl, 2015). In this study, it is assumed that the amount of shipment of LNG by the truckload is the full size of the LNG tank, so TL is applied for the simulation. In addition, hub-and-spoke networks which are likely used for LTL shipments are not relevant to this study (Chopra and Meindl, 2015). So, LTL is excluded but TL transporting from a single origin to a single destination is considered for the research.

Furthermore, it is supposed that sufficient LNG storage capacity in the LNG fuel stations and satellite stations to satisfy the amount of LNG receiving by trucks. Moreover, end customers directly from the LNG import terminals are excluded

4.4.8 Pipeline Holding costs

Inventory holding costs occur during the transportation of the products (Chopra and Meindl, 2015). According to Chopra and Meindl (2015), calculation of the annual holding costs in transit is below.

H: Annual holding costs
h: Holding cost rate
c: Price of the LNG (0.3 GWh) in the tank by truck transportation.

$$H = h * c$$

To calculate holding costs per days H_d, $\frac{Transit\ days}{365\ days}$ will be multiplied for holding costs. So, the formula for holding costs in transit days is below

$$H_d = \frac{Transit\ days}{365\ days} * h * c$$

So, there are three variables are required for the calculation of the holding costs: holding cost rate, transit time, and LNG price in truck transportation. They are explained below paragraphs.

At first, many kinds of literature mentioned the holding cost rate around annually 25% of the price of the good (Durlinger, 2012). The underlying reason for the figure is argued that “It will be assumed here that a charge of ten per cent on the stock is a fair one to cover both interest and depreciation. It is probable that double this would be fairer in many instances” (Hariss, cited in Durlinger, 2012, p. 2). Also, 25% is also derived from averaging of the holding costs rates in other industries between 5% and 45% (Durlinger, 2012). So, in this study, the fixed holding cost rate of 25% is used.

On the other hands, Yang (2014) stated that many holding costs are assumed to be constant per unit time even though the holding cost is variable for the same products depends on time for perishable products. In this study, the holding costs also will also vary but the different reason which is seasonality of LNG. As mentioned before, the seasonality of LNG price affects the price of holding costs.
Since the holding cost calculation is about annual cost, so it might not be possible that calculating monthly holding costs with seasonality from annual holding costs. In other words, the monthly seasonal price is only applied to a month, not a whole year. However, in order to explore the effect of seasonality and holding costs, the monthly holding cost is calculated from the annual holding cost.
In terms of transit time by the truck transportation, there are some factors to delay the transportation by trucks such as traffic congestions, working hours for drivers and road constructions (Reed TMS Logistics, n.d.). So, these factors are required to consider for calculation of the transit time by the truckload.
The transit time is assumed based on the data of the estimated transit time for TL by Reed TMS Logistics (n.d.). Reed TMS Logistics (n.d.) provided data of distance by miles, so it has been converted to kilometre by multiplying 1.6 from miles. The result is in table 18.

Distance (kilometres)	Transit time
0 ~ 639	Same day or next day
640 ~ 960	1 day
961 ~ 1920	2 days
1921 ~ 2880	3 days

Table 18 Transit time depends on distances. Source: Reed TMS Logistics

In this study, the distance range between 0 ~ 639 km is considered as same day service and the transit time is estimated as half of the days. So, holding cost per a half day is calculated by dividing half from holding cost per 1 day.
Finally, the price of the LNG in 2018 is calculated based on the data from Federal Energy Regulatory Commission (2018) by using the regression model with seasonality for forecasting. After that, the measurement of Dollar/MMBtu is converted to Euro/GWh. Since 1000 MMBtu is approximately equally to 0.29 GWh, it is assumed that 1000 MMBtu is 0.3 GWh to make the GWh to the same as lot size of LNG tank for the truck transportation (0.3 GWh) in the research. Subsequently, after converting dollar with Euro, table 21 shows the LNG price per 0.3 GWh along with monthly holding costs of LNG with 25% of the holding cost rate after calculations.

2018	$/MMBtu	€/0.3 GWh	Annual Holding Cost (€)	Holding Cost (€) per a half day	Holding Cost (€) per 1 day
Jan	9.33	8397	2099.25	2.88	5.75
Feb	8.96	8064	2016	2.76	5.52
Mar	8.23	7407	1851.75	2.54	5.07
Apr	8.34	7506	1876.5	2.57	5.14
May	8.94	8046	2011.5	2.76	5.51
June	9.68	8712	2178	2.99	5.97
July	10.03	9027	2256.75	3.09	6.18

Aug	10.83	9747	2436.75	3.34	6.68
Sept	11.99	1079 1	2697.75	3.7	7.39
Oct	13.66	1229 4	3073.5	4.21	8.42
Nov	14.68	1321 2	3303	4.53	9.05
Dec	15.75	1417 5	3543.75	4.86	9.71

Table 19 Forecasted Estimated Landed Price of LNG and Holding Costs in 2018. Source: Waterborne Energy, Inc cited in Federal Energy Regulatory Commission

Table 19 shows that the holding costs gradually go up from April 2018 and in December, the cost reaches its peak to 9.71 euros per day.

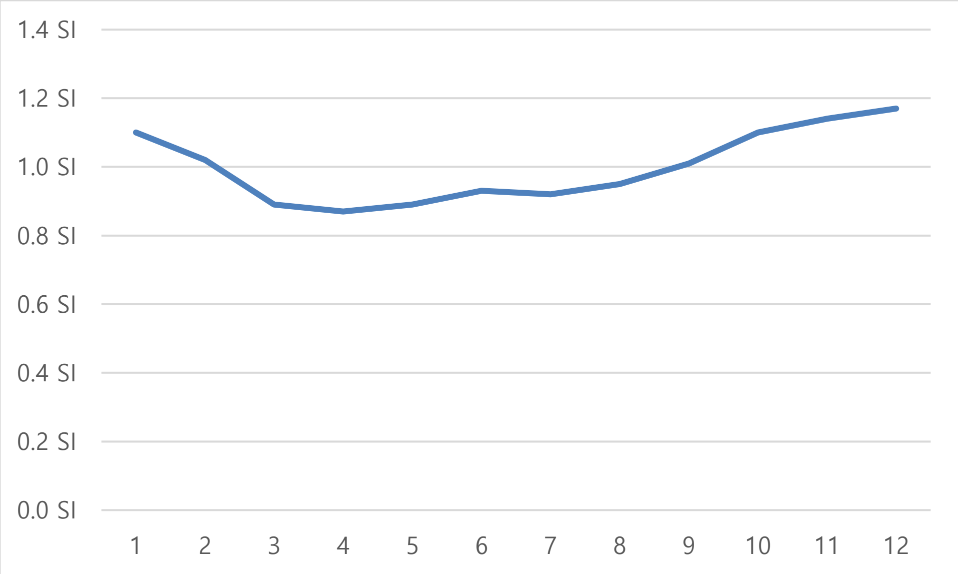

Figure 38 Seasonal Index (SI) of the estimated landed price of LNG in Spain in 12 months in Spain. Source: Waterborne Energy, Inc cited in Federal Energy Regulatory Commission

Figure 38 illustrates that the seasonal index of the estimated landed price of LNG in Spain acquired from on the data between 2015 and 2017 are high during winter season whereas relatively low from March to July. The figures also related to the seasonality of the demand for LNG and NG in Spain shown the chapters above. As the demand for the resources goes up, the price follows the upward trend. Oppositely, if the demand decrease, the price also decreases.

Chapter 5 Simulations and Results

The network optimisation model enables to test the scenarios. The significant difference between the scenarios is the different demand of SSLNG. So, adjusting the SSLNG demand aligning with the scenarios is done in the model by inputting different the figures of the demands. Also, it is merely including or excluding the related cells for El Musel LNG import terminal in the model in order to test the sub-scenarios.
Each scenario is monthly simulated to verify the monthly difference by putting the different demands, holding inventory costs. Three significant results are acquired from the model: Allocation of LNG, excess capacity and total costs. The three are essential to analyse the result of running the simulations.

5.1 Result of Scenario 1. Full Capacity

5.1.1 Allocation of LNG

There are two critical factors of the distribution. The first one is that distances between the origin and destination play a vital role in the distribution since the more distance, the more costs occur. The amount of the LNG demand with the seasonality also affects the allocation of LNG.

	Destination of LNG (Months)													
LNG Supply Terminal	Galicia	Asturias	Castilla and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
Barcelona	x	x	x	x	x	x	X	x	x	x	12	10	X	x
Cartagena	x	x	x	x	x	2	12	4	12	x	x	x	X	x
Huelva	X	x	x	x	12	12	X	x	x	x	x	x	X	x
El Musel	X	12	5	2	x	x	x	x	1	x	x	x	x	x
Sagunto	X	x	x	x	x	x	x	12	7	12	2	5	x	x
Bilbao	X	x	10	10	x	x	x	x	7	x	x	5	12	12
Mugardos	12	x	x	x	x	x	x	x	x	x	x	x	x	x
Transportation pattern		Appear during winter		Disappear during winter		An entire of year								

Table 20 Monthly allocations of LNG between LNG import terminals and destinations in Scenario 1.1.

Table 20 illustrates the results of simulation 1.1 about the monthly frequency of LNG distribution between the origins and destinations. Before analysis of the results, there are trends of the allocation between the origin and destination. Some allocations of relatively short months happen only during in winter season while other allocations with a relatively more extended period occur only during the other seasons. The amount LNG of these occurrences tend to account for the relatively low ratio against the total LNG demand in the autonomous community level and be smaller than one of occurring 12 months. For instance, the situation that the destinations where LNG transportation disappears during winter can be observed at Aragon and Catalonia supplied LNG from Barcelona terminal. Barcelona LNG import terminal is entirely dedicated to the LNG demand from Catalonia apart from January and December because the terminal also transports LNG to Aragon at that time.
Regarding the demand in Aragon, the amount of LNG which is supposed to transport this autonomous community during the winter season is taken over by Catalonia since the demand in Catalonia is higher with having lower total costs for the transportation than the other months. Oppositely, Andalucía is supplied additional LNG from Cartagena LNG terminal to meet the peak demand in winter. Because the capacity of

LNG supplied by Huelva LNG import terminal is not sufficient and there is no alternative for Cartagena terminal.
In the viewpoints of the terminals, Mugardos terminal is the only dedicated terminal supplying LNG to only Galicia while Bilbao terminal has six destinations which are the most significant number of the seven terminals. In other words, Mugardos LNG terminal and Galicia are the most isolated from the other terminals and autonomous community. Oppositely, Bilbao terminal has a relatively close connection of the other autonomous community than other terminals.
In the autonomous community's point of view, Madrid is supplied LNG from 4 LNG import terminals which are the largest among other autonomous community. The geographical feature located in the centre of Spain is the underlying reason for it. In other words, there are no LNG import terminals in the vicinity of the centre of Spain. Oppositely, Galicia, Basque Countries and Navarra are only supplied LNG by one terminal which is physically close to those autonomous communities.

	Destination of LNG (Months)													
LNG Supply Terminal	Galicia	Asturias	Castilla and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
Barcelona	x	X	x	x	x	x	X	X	x	x	12	10	x	x
Cartagena	x	X	x	x	x	2	12	5	12	x	x	x	x	x
Huelva	x	X	x	x	12	12	X	X	x	x	x	x	x	x
Sagunto	x	X	x	x	x	x	X	12	7	12	2	5	x	x
Bilbao	x	X	12	9	x	x	X	X	7	x	x	5	12	12
Mugardos	12	12	x	5	x	x	X	X	2	x	x	x	x	x
Transportation pattern		Appear during winter		Disappear during winter		An entire of year								

Table 21 Monthly allocations of LNG between LNG import terminals and destinations in Scenario 1.2.

The red coloured figures in table 21 are different from the result in scenario 1.1 in which El Musel is operated. The absence of the operation of the El Musel LNG terminal affects the other terminals mainly to Mugardos LNG import terminals. In the scenario 1.2, Mugardos is not only dedicated to supplying LNG to Gallica but to additional three autonomous communities which are Asturias, Cantabria and Madrid. In other words, some amount of LNG transported from El Musel terminal is allocated to Mugardos terminal. Asturias is fully supplied LNG from the terminal for a whole year while Mugardos terminal supplies LNG to Cantabria for five months during winter. Similar to the distribution to Cantabria, Madrid is supplied LNG for two months during winter time by the same terminal. Take a look at the distribution of LNG to Madrid in January in both scenario 1.1 and 1.2 from annex C, the amount of LNG should have been transported from El Musel terminal in scenario 1.1 distributed to El Musel. Also, the 42 GWh of LNG transportation from Cartagena terminal to Madrid is taken over to Mugardos from scenario 1.1 to 1.2. This is the notable result that El Musel terminal is relatively located far from Cartagena terminal unlike the Bilbao and Mugardos terminal. Other terminals affected the frequency of the monthly transportation by the absence of the operation of the El Musel terminal are Bilbao and Cartagena terminal. In Bilbao terminals, Castilla and Leon are supplied LNG during the entire year, and the frequency of the monthly transportation decreased by one month. Also, the Cartagena LNG import terminal supply LNG one more month in this scenario than the one in scenario 1.1.

5.1.2 Excess capacity

Supply Region	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Barcelona	0	0	0	28.2	41.7	53.9	45	64	23	6.7	0	0
Cartagena	0	0	0	129.9	155.1	177.6	160.2	195.5	116.7	85.8	0	0
Huelva	0	24.7	31.9	85.4	100	113.7	108.3	128.3	92.1	76	32.1	0
El Musel	88.3	224.8	235.9	246.9	248.8	250.7	251.2	253.7	251.1	249.4	206.2	96.7
Sagunto	0	0	0	0	0	0	0	0	0	0	0	0
Bilbao	0	0	0	0	0	0	0	0	0	0	0	0
Mugardos	197.1	207.1	209.3	223.2	227.2	231	229.9	235.3	226.1	221.8	210.3	200.6
Total	285.4	456.6	477.1	713.6	772.8	826.9	794.6	876.8	709	639.7	448.6	297.3

Table 22 Excess capacity with El Musel Terminal in Scenario 1.1. (GWh).

From table 22, El Musel LNG import terminal which is currently not under operation has the largest surplus capacity while Sagunto and Bilbao LNG receiving terminals has no excess capacity among the 7 LNG import terminals throughout the year. Since the demand for LNG has seasonality, the amount of the total excess capacity hare larger during summer seasons while the less excess capacity during winter seasons.

Supply Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Barcelona	0	0	0	28.2	41.7	53.9	45	64	23	6.7	0	0
Cartagena	0	0	0	129.9	155.1	177.6	160.2	195.5	116.7	85.8	0	0
Huelva	0	24.7	31.9	85.4	100	113.7	108.3	128.3	92.1	76	32.1	0
Sagunto	0	0	0	0	0	0	0	0	0	0	0	0
Bilbao	0	0	0	0	0	0	0	0	0	0	0	0
Mugardos	15.4	161.9	175.2	200.1	206	211.7	211.1	219	207.2	201.2	146.5	27.3
Total	15.4	186.6	207.1	443.6	502.8	556.9	524.6	606.8	439	369.7	178.6	27.3

Table 23 Excess capacity without El Musel Terminal in Scenario 1.2. (GWh).

Table 23 in scenario 1.2 shows that the absence of the El Musel LNG import terminal does not affect the amount of excess capacity at Barcelona, Cartagena and Huelva. The far distance between El Musel and three terminals is the underlying reason. The effect is on the Mugardos LNG import terminals since the terminal, and El Musel terminals are geographically closer than the other three terminals. On the other hand, Sagunto and Bilbao LNG receiving terminals are not affected by the close of El Musel terminal since they do not have excess capacity from the scenario 1.1.

5.1.3 Total costs

	With El Musel (€)	Without EL Musel (€)	The difference (€)	Ratio of the difference against the costs without El Musel (%)
Jan	421012.7	438982	17969	4.09
Feb	374939.6	379079	4139	1.09

Mar	369740.1	372728	2988	0.80
Apr	321065.4	322990	1924	0.60
May	309496.3	311262	1766	0.57
Jun	298968.4	300576	1608	0.53
July	305434	307000	1566	0.51
Aug	289302.9	290660.7	1358	0.47
Sept	323328.9	324903.2	1574	0.48
Oct	338150.3	339868.4	1718	0.51
Nov	380686	387001	6315	1.63
Dec	420806.8	437956.8	17150	3.92

Table 24 Total costs in Scenario 1.1 and 1.2.

The difference between the scenario 1.1 with El Musel terminal and scenario 1.2. are significant during the winter season, and it becomes narrow during the winter season. It is an obvious result since the more transportation of LNG to the destination to meet the demand with the seasonality. Explore more in detail of ratio of the difference against the total costs without El Musel in table 24, the ratio does not account for substantial parts which are mostly below 1% apart from the one from November to February. So, there is not an outstanding advantage of operating El Musel terminal. If the fixed costs of operating the LNG import terminal which is excluded from the study are considered, it would be a worse choice to run the LNG import terminal. The positive of the operation of the terminal tend to appear if there is unmet LNG demand or the increase in transportation costs and inventory holding costs.

5.2 Result of Scenario 2. Abundant Capacity

5.2.1 Allocation of LNG

	Destination of LNG (Months)													
LNG Supply Terminal	Galicia	Asturias	Castilla and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
Barcelona	x	x	x	x	x	X	x	X	x	x	12	12	x	X
Cartagena	x	x	x	x	x	X	12	X	12	x	X	x	x	X
Huelva	x	x	x	x	12	12	x	X	x	x	X	x	x	X
El Musel	x	12	x	x	x	X	x	X	1	x	X	x	x	X
Sagunto	x	x	x	x	x	X	x	12	12	12	X	x	x	X
Bilbao	x	x	12	12	x	X	x	X	12	x	X	x	12	12
Mugardos	12	x	x	x	x	X	x	X	x	x	X	x	x	X
Transportation pattern		Appear during winter		Disappear during winter		An entire of year								

Table 25 Monthly allocations of LNG between LNG import terminals and destinations in Scenario 2.1.

Table 25 shows that the decrease in LNG demand in scenario 2.1 has effects on the

distribution of LNG. At first, the seasonal distributions appearing and disappearing during the winter season does not seem necessary anymore apart from LNG transportation from El Musel to Madrid. The red figures represent that the difference against the scenario 1.1. Another effect of the decrease in LNG demand is that the autonomous communities tend to be supplied LNG from a single terminal. As a result, some of the autonomous communities have the more frequency of receiving LNG than the one from scenario 1.1. For instance, Castilla and Leon and Cantabria are solely transported LNG from Bilbao terminal by decreasing in the frequency of receiving LNG from EL Musel terminal to zero month.
On the other hand, Madrid still has 4 LNG import terminals to receive LNG compared to the scenario 1.1. Again, the central location of Madrid substantially affects this arrangement that having the many connections from the LNG terminals. The only change of the distribution to this autonomous community is that the frequency of LNG transportation increases from 7 months to 12 months from Sagunto and Bilbao terminals.

	Destination of LNG (Months)													
LNG Supply Terminal	Galicia	Asturias	Castilla and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
Barcelona	x	x	x	x	x	x	x	X	x	x	12	12	x	x
Cartagena	x	x	X	x	x	x	12	X	12	x	x	x	x	x
Huelva	x	x	x	x	12	12	x	x	x	x	x	x	x	x
Sagunto	x	x	x	x	x	x	x	12	12	12	x	x	x	x
Bilbao	x	x	12	12	x	x	x	x	12	x	x	x	12	12
Mugardos	12	12	X	x	x	x	x	x	x	x	x	x	x	x
Transportation pattern		Appear during winter		Disappear during winter		An entire of year								

Table 26 Monthly allocations of LNG between LNG import terminals and destinations in Scenario 2.2.

Table 26 illustrates that the change in the frequency in scenario 2.2 compared to scenario 2.1 nearly does not exists even though El Musel LNG import terminal is not under operation. This is quite a different result from the comparison of the distribution between scenario 1.1 and 1.2 experiencing the several changes. The only change in the frequency is that Mugardos terminal becomes a supplier of LNG to Asturias for 12 months. This is taken from El Musel terminal and this result is the same as the one between scenario 1.1 and 1.2.

5.2.2 Excess capacity

Supply Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Barcelona	81.1	109.5	107.1	141.9	146.7	151.2	141.1	147.4	120.1	111.7	87.8	72.1
Cartagena	228.9	283.3	277.7	344.6	353.7	361.9	341.5	353.3	300.1	284.4	238.5	208.9
Huelva	142.7	168.4	169.5	201.1	206.9	212.8	206	213.3	191	182.9	160.8	144.3
El Musel	254.5	256.5	257.7	260.1	261.1	262.1	262.4	263.5	262.5	261.7	259.8	257.8
Sagunto	0	0	0	0	0	0	0	0	0	0	0	0

Bilbao	0	0	0	0	0	0	0	0	0	0	0	0
Mugardos	238.9	245.5	246.1	254.1	255.8	257.5	256	258	252.5	250.4	244.7	240.3
Total	946.1	1063.2	1058.1	1201.8	1224.2	1245.5	1207	1235.5	1126.2	1091.1	991.6	923.4

Table 27 Excess capacity with El Musel Terminal in Scenario 2.1. (GWh).

From table 27, the less LNG demand leads to the more surplus capacity of the LNG transportation by trucks. There is no excess capacity in Sagunto and Bilbao LNG import terminal which is the same as the scenario 1. However, apart from the two terminals, the other terminals have the excess capacity the entire of the year.

Supply Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Barcelona	81.1	109.5	107.1	141.9	146.7	151.2	141.1	147.4	120.1	111.7	87.8	72.1
Cartagena	228.9	283.3	277.7	344.6	353.7	361.9	341.5	353.3	300.1	284.4	238.5	208.9
Huelva	142.7	168.4	169.5	201.1	206.9	212.8	206	213.3	191	182.9	160.8	144.3
Sagunto	0	0	0	0	0	0	0	0	0	0	0	0
Bilbao	0	0	0	0	0	0	0	0	0	0	0	0
Mugardos	223.4	232	233.8	244.2	246.9	249.6	248.4	251.5	245	242.1	234.5	228.1
Total	676.1	793.2	788.1	931.8	954.2	975.5	937	965.5	856.2	821.1	721.6	653.4

Table 28 Excess capacity without El Musel Terminal in Scenario 2.2 (GWh).

In the same way of the scenario 1.2., Mugardos terminal absorbs the LNG demand by trucks transportation while the other terminals are not affected by the absence of the operation of the El Musel terminal from table 28.

5.2.3 Total costs

	With El Musel (€)	Without EL Musel (€)	Difference (€)	Ratio of the difference against the costs without El Musel (%)
Jan	275428.6	276720	1291	0.47
Feb	251385.8	252510	1125	0.45
Mar	251932.2	252957	1025	0.41
Apr	223396.7	224221	825	0.37
May	219124.3	219866	741	0.34
Jun	215042	215700.1	658	0.31
July	222715.9	223349	633	0.28
Aug	217271.8	217813.3	541	0.25
Sept	239377.6	240002.4	625	0.26
Oct	247091	247783.2	692	0.28
Nov	267579.2	268428.9	850	0.32
Dec	281844.1	282860.3	1016	0.36

Table 29 Total costs in Scenario 2.1. and 2.2.

Table 29 shows that compared to the scenario 1, the ratio in the scenario 2 is less than the one in the scenario 1. In other words, operating El Musel terminal become less critical in the viewpoints of the total costs. So, it is apparent that it is a better strategy not to run the additional terminal if the LNG demand is lower like in the scenario 2.

5.3 Result of Scenario 3. A lack of Capacity

In this scenario, excessive LNG demand above the available capacity from the LNG import terminals. Since the constraint which LNG demand should be less than the available capacity is violated in this scenario, the supply chain is not able to be optimised with a massive amount of the total costs. In other words, Excel Solver is not able to acquire a feasible solution. In order to verify the possibility of analysis, there are some adjustments in the model. When the orders of the terminals have been changed, the results including the distributions of the LNG, excessive capacity and the objective costs are different from the original model.

	Supply Region	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque countries	Navarre
Original Model	Barcelona	0	0	0	0	0	0	0	0	125.8	324.2	0	0	0	0
	Cartagena	0	0	0	0	0	0	0	26.3	423.7	0	0	0	0	0
	Huelva	0	0	0	0	0	210.7	123.8	115.5	0	0	0	0	0	0
	El Musel	0	0	0	0	0	270	0	0	0	0	0	0	0	0
	Sagunto	34.7	53.0	62.1	30	77.0	103.2	0	0	0	0	0	0	0	0
	Bilbao	135.0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Mugardos	0	0	0	0	0	0	0	0	0	61.4	628.2	98.8	70.2	33.2
Adjusted Model	Supply Region	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque countries	Navarre
	Barcelona	0	0	0	0	0	0	0	0	0	196.4	628.2	98.8	70.2	33.2
	Cartagena	0	0	0	0	0	0	0	0	260.8	189.2	0	0	0	0
	Huelva	0	0	0	0	0	30.7	123.8	6.8	288.7	0	0	0	0	0
	El Musel	0	0	0	0	0	270	0	0	0	0	0	0	0	0
	Mugardos	0	0	0	0	31.8	283.2	0	0	0	0	0	0	0	0
	Sagunto	169.7	53.0	62.1	30	45.2	0	0	0	0	0	0	0	0	0
	Bilbao	0	0	0	0	0	0	0	135.0	0	0	0	0	0	0

Table 30 Result of the distribution of LNG in December in Scenario 3

Supply Region	Original Model	Supply Region	Adjusted Model
Barcelona	0	Barcelona	-576.8

Cartagena	0	Cartagena	0
Huelva	0	Huelva	0
El Musel	0	El Musel	0
Sagunto	0	Mugardos	0
Bilbao	0	Sagunto	0
Mugardos	-576.8	Bilbao	0
Cost (€)	1802590.8	Cost (€)	1338180.7

Table 31 Results of excess capacity and the total costs in December in Scenario 3.

For instance, when the order of Mugardos terminal is located to the 5th from the 7th line in December, the result is different from the original one. Table 30 and 31 show the results in the adjusted model that Barcelona should have more capacity to transport LNG to the destinations while the original results indicate that Mugardos should have done it. So, it does not make sense to analyse the results if there is a lack of capacity of terminals to handle the peak demand of LNG. In addition, there is no need to compare the two situations that with and without the operation of the El Musel LNG import terminal because the model cannot run the model in case of the lack of capacity.

Chapter 6 Conclusion

6.1 Summary of the problem and methods

There are the several issues of the SSLNG supply chain in Spain. The first one is derived from seasonality. Seasonality affects the SSLNG facilities' choices of the LNG import terminals to meet the demand. In addition, truck companies transporting SSLNG are required to set out an effective strategy to handle the surplus derived from the gap between peak and off-peak season. However, the subject is not covered by the study so it is not studied in the paper.

Another is that not fully integrated supply chain leads to detrimental factors such the high transaction costs and delays of the sharing information.

The third is that the limits of the SSLNG output capacity at LNG terminals deter for SSLNG facilities to be supplied SSLNG from the nearest LNG import terminals.

In order to recoup the investment of the El Musel LNG import terminal which is in mothballed, the owner of the terminal should know in what circumstance does the terminal is required to operate.

MILP model by Excel Solver is used to optimise the SSLNG supply chain related to the issues of the limit capacity and El Musel terminals. The regression model by Minitab forecasts the input of MILP model which is the future demands with seasonality. In addition, the regression model is used for estimated of the price of LNG which is a factor of holding costs. The estimation of the fuel price of the trucks are done by autoregressive model.

6.2 Key findings

With the regression model and data of the flows of the NG and LNG gas, the seasonality of natural gas is verified. In the winter season, there is an increase in consumption of NG and LNG for heating purpose. However, the consumption decreases during the summer season since the primary reason for consuming the resource is heating.

Vertical integration of small-scale LNG supply chain from LNG receiving terminals to the destinations of the cargo which are LNG fuel stations and satellite terminal is not observed. On the other hand, it is notable that Enagas is considered as a monopoly player in LNG import station while oligopoly is observed in the small-scale LNG facilities by several large companies such as Natrugy and HAM.

In the research, the network optimisation model with the three scenarios is simulated. Throughout the entire results of the simulation, the two key factors deciding the distribution of the small-scale is observed. The first one is that distance. Majority of the distributions tend to occur if the origin and destinations are closer than alternatives. Another is that the amount of LNG demand with seasonality. The demand is a root cause for the appearance and disappearance of the frequency of the transportation during winter time. Take a closer look at the results of each scenario. Scenario 1 is simulated in the assumption of the full capacity. The sub-scenario 1.1 would show the role of the El Musel LNG import terminal if the terminal was operated. Asturias is fully supplied LNG from the terminal while the terminal provides the service of the short-term seasonal LNG transportation for the three autonomous community: Castilla and Leon, Cantabria and Madrid. The absence of the operation of El Musel terminal has mostly effects on the terminals in the vicinity of the El Musel terminal. For instance, El Musel terminal takes over the most amount of LNG transportation to Bilbao and Mugardos terminal. However, Cartagena terminal is also affected by the no operation of the El Musel terminal by being taken over 42 GWh of LNG which is supposed to be transported to Madrid in January in the scenario 1.1. to Mugardos terminal.

The sufficient capacity is applied to scenario 2. Due to the less LNG demand, the short-term seasonal transportations disappear. So, regarding the frequency of the LNG transportation in scenario 2.1 compared to 2.2, the increase in the frequency from the terminal where has relatively long-term frequency is observed by reducing the relatively small seasonal frequency. The notable change from scenario 2.1 to 2.2 is that Mugardos terminal is taken the entire of the LNG transportation to Asturias by the El Musel terminal.
It is impossible to optimise the model in the case of a lack of capacity in scenario 3. Merely adjusting the order of LNG import terminals in the model with having all other same conditions generates the different results.
The results of the simulation would be helpful to decide the distribution of LNG by trucks depending on the number of LNG demands from the destinations and the open of El Musel terminal.
In the scenario 1 and 2, the costs difference between operation and no operation of El Musel LNG terminal is relatively small, and the ratio of the difference against the total cost is also not substantial.

6.3 Implication

The three players (truck companies, SSLNG facilities, LNG import terminals) benefit from the study. In the SSLNG supply chain, the seasonality is essential to reduce the loss derived from surplus between peak and off-peak season. By estimating the gap of utilising their trucks from the seasonality, truck companies well establish strategy such as price differentiation. For instance, a higher price should be charged during peak season which is winter to maximise total profits while lower price needs to be charged during the off-peak season which is summer season to attract more customers (Prentice and Prokop, 2016). Also, truck companies should consider different types of cargo transportation other than LNG during the summer season for more utilisation of their assets to generate profits. However, the research of the strategies for truck companies is out of scope in the paper so it is not discussed.

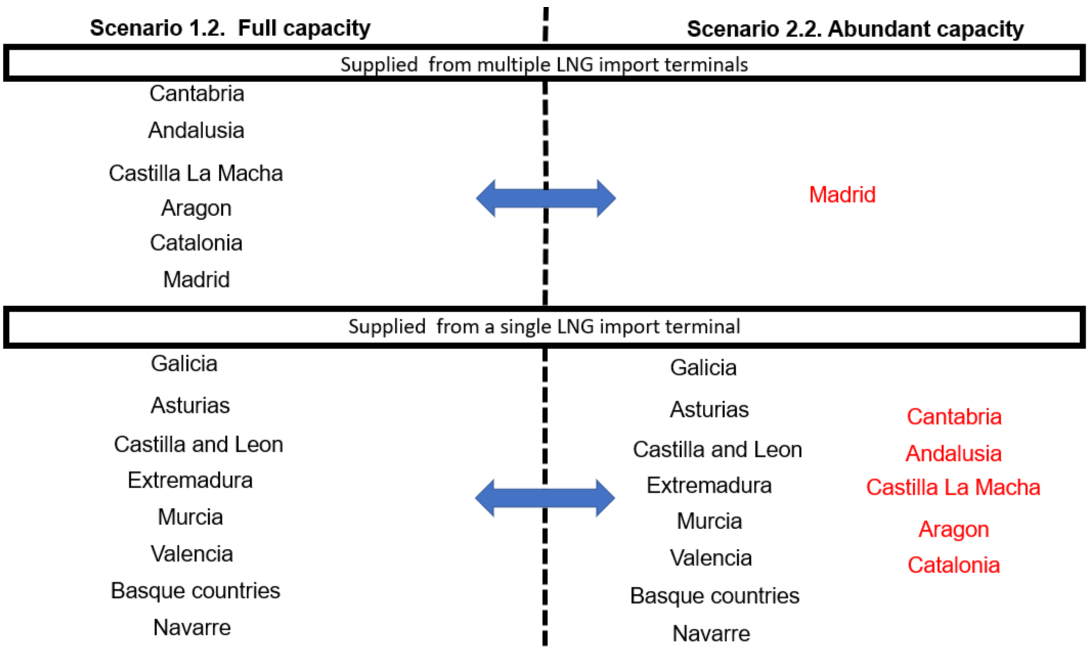

Figure 39 Single or Multiple LNG import terminals to supply LNG to Autonomous Communities in Spain.

Depends on the different amount of SSLNG demand, SSLNG facility should decide what terminals they need to contract to be supplied SSLNG. Figure 39 shows that there are three types of SSLNG facilities can be discussed comparing scenario 1.2 and 2.2 which are no operation of El Musel LNG terminal. This comparison is more feasible than the one of scenario 1.1 and 2.1 since El Musel terminal is not under operation in reality. The first type is SSLNG facilities covering several possible LNG import terminals supplying SSLNG in scenario 1.2 while coverage area becomes a single terminal in scenario 2.2. SSLNG facilities in Cantabria, Andalusia, Castilla La Macha, Catalonia and Aragon are the first type. So, SSLNG companies in the area should set the plan to be supplied SSLNG depends on the amount of SSLNG demand. If the demand is high, the should seek the other terminals to be supplied SSLNG to meet the demand. If there is low demand, they can make a contract with the nearest LNG import terminals.

The second type is the coverage of LNG import terminals are multiple regardless of the amounts of SSLNG in scenario 1.2 and 2.2 Only Madrid belongs to the type because of the geographical feature of Madrid. In other words, the location of Madrid which is the centre of Spain result in the second type. So, SSLNG facilities located in the autonomous community should consider that a single terminal cannot satisfy the demand so always make contracts with several LNG import terminals.

The last type is SSLNG facilities having a single LNG import terminal in the vicinity of their autonomous community regardless of the scenarios. So, it is not necessary for the companies owning the facilities to consider what terminals they needed to be supplied SSLNG other than one. SSLNG facilities in Galicia, Asturias, Castilla and Leon, Extremadura, Murcia, Valencia, Basque countries, Navarre are only supplied from only one nearest LNG import terminal.

The simulation of sub-scenarios for El Musel terminal is valuable for the owner of the terminal. This result implies that it is a better option not to run El Musel terminal as long as there is not higher LNG demand than the current capacity of the six terminals. So, the owner of the terminal should claim for the necessity of operating the terminal to the Spanish government only if there are the high NG and LNG consumption are estimated in the future.

6.4 Limitation of the research and Suggestion of the Further Research

One of the limitations of the research is that the fixed costs of the LNG terminal are not considered in this paper. In order to acquire a more precise result, it would be better to consider the fixed cost of operating LNG import terminals in the future study. Also, a limit of Excel solver which is not able to run the model with more than 200 variables discourages to simulate the scenario with the distances from the LNG terminals to the exact location of each LNG fuel station and satellite terminals. Using other software handling more variables would be suggested to acquire more accurate data and more detailed analysis.

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Annex A

1. MILP model in Excel Solver.

Inputs - Costs, Capacities, Demands (SSLNG)

Jan. 2018 — Transportation and Holding costs

	Galicia	Asturias	Castile and	Cantabria	Extremadura	Andalusia	Murcia	Castiila La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque countreis	Navarre	**Fixed Cost**	**Capacity**
Barcelona	927.3	379.9	482.2	284.2	712.3	911.8	468.1	521.5	488.4	377.4	98.3	233.7	611.5	202.7	-	450
Cartagena	887.1	397.9	524.4	348.7	504.8	442.6	26.1	369.0	346.1	218.2	595.9	443.7	911.6	346.5	-	450
Huelva	810.7	384.6	613.4	414.4	215.4	270.7	498.6	592.0	475.0	694.0	1052.1	716.0	1013.6	429.3	-	450
El Musel	252.1	24.4	234.4	102.8	464.8	859.4	697.6	542.5	375.6	795.7	793.2	434.3	351.8	174.1	-	270
Sagunto	821.9	345.3	405.0	286.8	476.3	593.7	230.6	279.1	298.4	109.8	312.2	223.0	624.7	219.3	-	360
Bilbao	487.5	126.9	164.2	27.1	522.7	867.2	642.4	442.4	332.1	643.8	551.2	255.4	79.0	67.8	-	135
Mugardos	95.1	107.7	374.6	205.2	551.1	961.3	798.9	664.5	472.6	929.5	1007.9	613.8	618.3	279.5	-	315
Demand	117.9	33.5	42	19	53.7	410	89.3	98.2	396.2	280.6	453	69.6	60.6	21		

Decision Variables

Supply Region	Galicia	Asturias	Castile and	Cantabria	Extremadura	Andalusia	Murcia	Castiila La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque countreis	Navarre	Plant (1=open)
Barcelona	0	0	0	0	0	0	0	0	0	0	450	0	0	0	1
Cartagena	0	0	0	0	0	14	89	38	309	0	0	0	0	0	1
Huelva	0	0	0	0	54	396	0	0	0	0	0	0	0	0	1
El Musel	0	34	42	19	0	0	0	0	87	0	0	0	0	0	1
Sagunto	0	0	0	0	0	0	0	60	0	281	3	16	0	0	1
Bilbao	0	0	0	0	0	0	0	0	0	0	0	53	61	21	1
Mugardos	118	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Constraints

Supply Region	*Excess Capacity*
Barcelona	0
Cartagena	0
Huelva	0
El Musel	88
Sagunto	0
Bilbao	0
Mugardos	197

	Galicia	Asturias	Castile and	Cantabria	Extremadura	Andalusia	Murcia	Castiila La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque countreis	Navarre
Unmet Demand	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Objective Function

Cost =	€ 421,012.75

Jan | Feb | Mar | Apr | May | Jun | July | Aug | Sept | Oct | Nov | Dec

Annex B

1.Estimated LNG demands in the autonomous community level in scenario 1.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Galicia	117.9	107.9	105.7	91.8	87.8	84	85.1	79.7	88.9	93.2	104.7	114.4
Asturias	33.5	30	28.1	23.1	21.2	19.3	18.8	16.3	18.9	20.6	25	29.2
Castile and Leon	42	38.1	36.9	31.5	29.8	28.2	28.3	25.9	29.2	30.9	35.4	39.5
Cantabria	19	17	15.9	13.1	12	10.9	10.6	9.2	10.7	11.6	14.1	16.5
Extremadura	53.7	49.2	48.3	42	40.2	38.5	39.1	36.7	40.9	42.8	48	52.3
Andalusia	410	376.1	369.8	322.6	309.8	297.8	302.6	285	317	331.2	369.9	401.6
Murcia	89.3	82.3	81.8	72.3	70	68	69.6	66.5	73.4	76.2	83.8	89.7
Castilla La Mancha	98.2	89.8	87.8	76	72.6	69.4	70.2	65.6	73.3	76.9	86.6	94.8
Madrid	396.2	365.4	363.2	320.8	310.9	302	308.9	295	326	338.2	372.1	398.1
Valencia	280.6	259.3	258.7	229.4	223	217.4	222.8	213.7	235.7	243.9	267.1	284.5
Catalonia	453	417.8	415.2	366.8	355.4	345.2	353.2	337.2	372.7	386.6	425.4	455.2
Aragon	69.6	63.9	62.9	55	52.9	50.9	51.8	48.8	54.3	56.7	63.1	68.4
Basque countries	60.6	57.8	61	57.5	58.3	59.4	62.6	63.4	68.2	68.6	70.6	70.2
Navarre	21	18.8	17.6	14.5	13.3	12.1	11.8	10.2	11.8	12.9	15.6	18.3
Total	2144.5	1973.4	1952.9	1716.4	1657.1	1603.1	1635.5	1553.2	1721	1790.3	1981.5	2132.7

2.Estimated LNG demands in the autonomous community level in scenario 2

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Galicia	117.9	107.9	105.7	91.8	87.8	84	85.1	79.7	88.9	93.2	104.7	114.4
Asturias	33.5	30	28.1	23.1	21.2	19.3	18.8	16.3	18.9	20.6	25	29.2
Castile and Leon	42	38.1	36.9	31.5	29.8	28.2	28.3	25.9	29.2	30.9	35.4	39.5
Cantabria	19	17	15.9	13.1	12	10.9	10.6	9.2	10.7	11.6	14.1	16.5
Extremadura	53.7	49.2	48.3	42	40.2	38.5	39.1	36.7	40.9	42.8	48	52.3
Andalusia	410	376.1	369.8	322.6	309.8	297.8	302.6	285	317	331.2	369.9	401.6
Murcia	89.3	82.3	81.8	72.3	70	68	69.6	66.5	73.4	76.2	83.8	89.7
Castilla La Mancha	98.2	89.8	87.8	76	72.6	69.4	70.2	65.6	73.3	76.9	86.6	94.8
Madrid	396.2	365.4	363.2	320.8	310.9	302	308.9	295	326	338.2	372.1	398.1
Valencia	280.6	259.3	258.7	229.4	223	217.4	222.8	213.7	235.7	243.9	267.1	284.5
Catalonia	453	417.8	415.2	366.8	355.4	345.2	353.2	337.2	372.7	386.6	425.4	455.2
Aragon	69.6	63.9	62.9	55	52.9	50.9	51.8	48.8	54.3	56.7	63.1	68.4
Basque countries	60.6	57.8	61	57.5	58.3	59.4	62.6	63.4	68.2	68.6	70.6	70.2
Navarre	21	18.8	17.6	14.5	13.3	12.1	11.8	10.2	11.8	12.9	15.6	18.3
Total	2144.5	1973.4	1952.9	1716.4	1657.1	1603.1	1635.5	1553.2	1721	1790.3	1981.5	2132.7

3.Estimated LNG demands in the autonomous community level in scenario 3.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Galicia	176.4	161.4	157	134.5	128.3	120.6	121.3	110.9	124.8	133	152.3	169.7

Asturias	58.6	53	50.2	41.5	38.6	34.9	34.4	29.7	34.3	37.7	45.4	53
Castile and Leon	65.9	60.1	57.9	49.1	46.4	43.1	43.1	38.8	43.9	47.3	55	62.1
Cantabria	33.1	30	28.4	23.5	21.8	19.8	19.4	16.8	19.4	21.3	25.7	30
Extremadura	79.9	73.1	71.2	61.1	58.3	54.9	55.3	50.6	56.9	60.6	69.3	77
Andalusia	602.6	552.4	538.9	463.5	443.4	418.2	421.8	387.8	435.2	462.4	526.9	583.9
Murcia	125.3	115.3	113.5	98.6	95	90.6	91.9	85.7	95.6	100.7	113.2	123.8
Castilla La Mancha	147.8	135.2	131.4	112.4	107.1	100.4	101	92.1	103.7	110.7	127.1	141.8
Madrid	556.1	511.8	503.7	437.8	421.8	402	407.9	380.4	424.2	447.1	502.5	549.5
Valencia	387.5	357.1	352.5	307.6	297.2	284.2	289	270.8	301.3	316.7	354.3	385.6
Catalonia	635.8	585.1	575.8	500.5	482.3	459.6	466.4	434.9	484.9	511.1	574.5	628.2
Aragon	101.7	93.2	91.1	78.4	75.1	70.9	71.6	66	74	78.5	89.3	98.8
Basque countries	60.6	57.8	61	57.5	58.3	59.4	62.6	63.4	68.2	68.6	70.6	70.2
Navarre	36.7	33.2	31.4	26	24.2	21.9	21.5	18.6	21.5	23.6	28.5	33.2
Total	1483.9	1366.8	1372	1228.1	1205.8	1184.5	1223.2	1194.4	1303.7	1339.1	1438.4	1506.6

Annex C

1.Distribution of LNG demand in Scenario 1.1. (GWh)

Month	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
Jan-18	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	450.0	0.0	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	13.7	89.3	38.0	309.0	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	53.7	396.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	33.5	42.0	19.0	0.0	0.0	0.0	0.0	87.2	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.2	0.0	280.6	3.0	16.2	0.0	0.0
	Bilbao	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	53.4	60.6	21.0
	Mugardos	117.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	417.8	32.2	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	82.3	2.3	365.4	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	49.2	376.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	30.0	15.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	87.5	0.0	259.3	0.0	13.2	0.0	0.0
	Bilbao	0.0	0.0	22.9	17.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.5	57.8	18.8
	Mugardos	107.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mar-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	415.2	34.8	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	81.8	5.0	363.2	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	48.3	369.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	28.1	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	82.8	0.0	258.7	0.0	18.5	0.0	0.0
	Bilbao	0.0	0.0	30.9	15.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.6	61.0	17.6
	Mugardos	105.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Apr-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	366.8	55.0	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	72.3	0.0	247.8	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	42.0	322.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	23.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	76.0	54.6	229.4	0.0	0.0	0.0	0.0

	Bilbao	0.0	0.0	31.5	13.1	0.0	0.0	0.0	0.0	18.4	0.0	0.0	0.0	57.5	14.5
	Mugardos	91.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
May-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	355.4	52.9	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	70.0	0.0	224.9	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	40.2	309.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	21.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	72.6	64.4	223.0	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	29.8	12.0	0.0	0.0	0.0	0.0	21.6	0.0	0.0	0.0	58.3	13.3
	Mugardos	87.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jun-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	345.2	50.9	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	68.0	0.0	204.4	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	38.5	297.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	19.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	69.4	73.2	217.4	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	28.2	10.9	0.0	0.0	0.0	0.0	24.4	0.0	0.0	0.0	59.4	12.1
	Mugardos	84.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jul-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	353.2	51.8	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	69.6	0.0	220.2	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	39.1	302.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	18.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.2	67.0	222.8	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	28.3	10.6	0.0	0.0	0.0	0.0	21.7	0.0	0.0	0.0	62.6	11.8
	Mugardos	85.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aug-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	337.2	48.8	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	66.5	0.0	188.0	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	36.7	285.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	16.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.6	80.7	213.7	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	25.9	9.2	0.0	0.0	0.0	0.0	26.3	0.0	0.0	0.0	63.4	10.2

	Mugardos	79.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sep-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	372.7	54.3	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	73.4	0.0	259.9	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	40.9	317.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	18.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	73.3	51.0	235.7	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	29.2	10.7	0.0	0.0	0.0	0.0	15.1	0.0	0.0	0.0	68.2	11.8
	Mugardos	88.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	386.6	56.7	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	76.2	0.0	288.0	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	42.8	331.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	20.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	76.9	39.2	243.9	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	30.9	11.6	0.0	0.0	0.0	0.0	11.0	0.0	0.0	0.0	68.6	12.9
	Mugardos	93.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nov-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	425.4	24.6	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	83.8	0.0	366.2	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	48.0	369.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	25.0	32.9	0.0	0.0	0.0	0.0	0.0	5.9	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	86.6	0.0	267.1	0.0	6.3	0.0	0.0
	Bilbao	0.0	0.0	2.5	14.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.2	70.6	15.6
	Mugardos	104.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	450.0	0.0	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	3.9	89.7	46.4	310.0	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	52.3	397.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	29.2	39.5	16.5	0.0	0.0	0.0	0.0	88.1	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.4	0.0	284.5	5.2	21.9	0.0	0.0
	Bilbao	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.5	70.2	18.3

	Mugardos	114.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

2. Distribution of LNG demand in Scenario 1.2. (GWh)

	Supply Region	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
Jan-18	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	450.0	0.0	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	13.7	89.3	80.0	267.0	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	53.7	396.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.2	0.0	280.6	3.0	58.2	0.0	0.0
	Bilbao	0.0	0.0	42.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.4	60.6	21.0
	Mugardos	117.9	33.5	0.0	19.0	0.0	0.0	0.0	0.0	129.2	0.0	0.0	0.0	0.0	0.0
Feb-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	417.8	32.2	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	82.3	2.3	365.4	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	49.2	376.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	87.5	0.0	259.3	0.0	13.2	0.0	0.0
	Bilbao	0.0	0.0	38.1	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.5	57.8	18.8
	Mugardos	107.9	30.0	0.0	15.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mar-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	415.2	34.8	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	81.8	5.0	363.2	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	48.3	369.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	82.8	0.0	258.7	0.0	18.5	0.0	0.0
	Bilbao	0.0	0.0	36.9	9.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.6	61.0	17.6
	Mugardos	105.7	28.1	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Apr-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	366.8	55.0	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	72.3	0.0	247.8	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	42.0	322.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	76.0	54.6	229.4	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	31.5	13.1	0.0	0.0	0.0	0.0	18.4	0.0	0.0	0.0	57.5	14.5
	Mugardos	91.8	23.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Month	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
May-18	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	355.4	52.9	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	70.0	0.0	224.9	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	40.2	309.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	72.6	64.4	223.0	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	29.8	12.0	0.0	0.0	0.0	0.0	21.6	0.0	0.0	0.0	58.3	13.3
	Mugardos	87.8	21.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jun-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	345.2	50.9	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	68.0	0.0	204.4	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	38.5	297.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	69.4	73.2	217.4	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	28.2	10.9	0.0	0.0	0.0	0.0	24.4	0.0	0.0	0.0	59.4	12.1
	Mugardos	84.0	19.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jul-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	353.2	51.8	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	69.6	0.0	220.2	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	39.1	302.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.2	67.0	222.8	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	28.3	10.6	0.0	0.0	0.0	0.0	21.7	0.0	0.0	0.0	62.6	11.8
	Mugardos	85.1	18.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aug-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	337.2	48.8	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	66.5	0.0	188.0	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	36.7	285.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.6	80.7	213.7	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	25.9	9.2	0.0	0.0	0.0	0.0	26.3	0.0	0.0	0.0	63.4	10.2
	Mugardos	79.7	16.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sep-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	372.7	54.3	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	73.4	0.0	259.9	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	40.9	317.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	Supply Region	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	73.3	51.0	235.7	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	29.2	10.7	0.0	0.0	0.0	0.0	15.1	0.0	0.0	0.0	68.2	11.8
	Mugardos	88.9	18.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	386.6	56.7	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	76.2	0.0	288.0	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	42.8	331.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	76.9	39.2	243.9	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	30.9	11.6	0.0	0.0	0.0	0.0	11.0	0.0	0.0	0.0	68.6	12.9
	Mugardos	93.2	20.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nov-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	425.4	24.6	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	83.8	18.8	347.4	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	48.0	369.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	67.8	0.0	267.1	0.0	25.1	0.0	0.0
	Bilbao	0.0	0.0	35.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.4	70.6	15.6
	Mugardos	104.7	25.0	0.0	14.1	0.0	0.0	0.0	0.0	24.7	0.0	0.0	0.0	0.0	0.0
Dec-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	450.0	0.0	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	3.9	89.7	85.9	270.5	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	52.3	397.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.9	0.0	284.5	5.2	61.4	0.0	0.0
	Bilbao	0.0	0.0	39.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	70.2	18.3
	Mugardos	114.4	29.2	0.0	16.5	0.0	0.0	0.0	0.0	127.6	0.0	0.0	0.0	0.0	0.0

3. Distribution of LNG demand in Scenario 2.1. (GWh)

	Supply Region	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
Jan-18	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	322.2	46.7	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	63.5	0.0	157.6	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	35.0	272.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62.7	93.1	204.2	0.0	0.0	0.0	0.0

	Bilbao	0.0	0.0	24.8	8.8	0.0	0.0	0.0	0.0	31.1	0.0	0.0	0.0	60.6	9.7
	Mugardos	76.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	297.7	42.8	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	58.7	0.0	108.0	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	32.0	249.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57.2	113.7	189.1	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	22.4	7.6	0.0	0.0	0.0	0.0	38.7	0.0	0.0	0.0	57.8	8.5
	Mugardos	69.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mar-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	300.2	42.7	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	59.2	0.0	113.1	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	31.8	248.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	12.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	56.5	112.0	191.5	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	21.8	7.0	0.0	0.0	0.0	0.0	37.5	0.0	0.0	0.0	61.0	7.7
	Mugardos	68.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Apr-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	270.1	38.0	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	53.2	0.0	52.2	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	28.1	220.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	9.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	49.8	137.3	172.9	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	18.9	5.6	0.0	0.0	0.0	0.0	46.8	0.0	0.0	0.0	57.5	6.2
	Mugardos	60.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
May-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	266.1	37.2	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	52.4	0.0	43.9	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	27.4	215.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.4	140.8	170.8	0.0	0.0	0.0	0.0

	Bilbao	0.0	0.0	18.1	5.0	0.0	0.0	0.0	0.0	48.0	0.0	0.0	0.0	58.3	5.6
	Mugardos	59.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jun-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	262.4	36.4	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	51.7	0.0	36.4	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	26.7	210.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	7.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.9	144.2	168.9	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	17.3	4.5	0.0	0.0	0.0	0.0	48.9	0.0	0.0	0.0	59.4	4.9
	Mugardos	57.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jul-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	271.5	37.4	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	53.5	0.0	55.0	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	27.4	216.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	7.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.1	136.8	175.1	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	17.6	4.3	0.0	0.0	0.0	0.0	45.7	0.0	0.0	0.0	62.6	4.8
	Mugardos	59.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aug-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	266.2	36.4	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	52.5	0.0	44.2	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	26.5	210.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.3	141.5	172.2	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	16.6	3.7	0.0	0.0	0.0	0.0	47.2	0.0	0.0	0.0	63.4	4.1
	Mugardos	57.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sep-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	290.1	39.8	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	57.2	0.0	92.7	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	29.0	230.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.8	121.7	187.5	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	18.4	4.3	0.0	0.0	0.0	0.0	39.4	0.0	0.0	0.0	68.2	4.7

	Mugardos	62.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	297.3	41.0	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	58.6	0.0	107.0	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	30.0	237.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.6	115.7	191.7	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	19.2	4.7	0.0	0.0	0.0	0.0	37.3	0.0	0.0	0.0	68.6	5.2
	Mugardos	64.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nov-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	317.9	44.3	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	62.6	0.0	148.9	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	32.6	256.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	10.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57.4	98.3	204.3	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	21.3	5.8	0.0	0.0	0.0	0.0	30.9	0.0	0.0	0.0	70.6	6.4
	Mugardos	70.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	331.2	46.7	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	65.3	0.0	175.8	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	34.6	271.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	El Musel	0.0	12.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	61.2	86.8	212.0	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	23.2	6.9	0.0	0.0	0.0	0.0	27.1	0.0	0.0	0.0	70.2	7.6
	Mugardos	74.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

4.Distribution of LNG demand in Scenario 2.2. (GWh)

	Supply Region	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
Jan-18	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	322.2	46.7	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	63.5	0.0	157.6	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	35.0	272.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62.7	93.1	204.2	0.0	0.0	0.0	0.0

	Bilbao	0.0	0.0	24.8	8.8	0.0	0.0	0.0	0.0	31.1	0.0	0.0	0.0	60.6	9.7
	Mugardos	76.1	15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	297.7	42.8	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	58.7	0.0	108.0	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	32.0	249.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57.2	113.7	189.1	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	22.4	7.6	0.0	0.0	0.0	0.0	38.7	0.0	0.0	0.0	57.8	8.5
	Mugardos	69.5	13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mar-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	300.2	42.7	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	59.2	0.0	113.1	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	31.8	248.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	56.5	112.0	191.5	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	21.8	7.0	0.0	0.0	0.0	0.0	37.5	0.0	0.0	0.0	61.0	7.7
	Mugardos	68.9	12.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Apr-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	270.1	38.0	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	53.2	0.0	52.2	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	28.1	220.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	49.8	137.3	172.9	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	18.9	5.6	0.0	0.0	0.0	0.0	46.8	0.0	0.0	0.0	57.5	6.2
	Mugardos	60.9	9.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
May-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	266.1	37.2	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	52.4	0.0	43.9	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	27.4	215.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.4	140.8	170.8	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	18.1	5.0	0.0	0.0	0.0	0.0	48.0	0.0	0.0	0.0	58.3	5.6
	Mugardos	59.2	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jun-	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre

18	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	262.4	36.4	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	51.7	0.0	36.4	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	26.7	210.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.9	144.2	168.9	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	17.3	4.5	0.0	0.0	0.0	0.0	48.9	0.0	0.0	0.0	59.4	4.9
	Mugardos	57.5	7.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jul-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	271.5	37.4	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	53.5	0.0	55.0	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	27.4	216.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.1	136.8	175.1	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	17.6	4.3	0.0	0.0	0.0	0.0	45.7	0.0	0.0	0.0	62.6	4.8
	Mugardos	59.0	7.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aug-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	266.2	36.4	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	52.5	0.0	44.2	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	26.5	210.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.3	141.5	172.2	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	16.6	3.7	0.0	0.0	0.0	0.0	47.2	0.0	0.0	0.0	63.4	4.1
	Mugardos	57.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sep-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	290.1	39.8	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	57.2	0.0	92.7	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	29.0	230.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.8	121.7	187.5	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	18.4	4.3	0.0	0.0	0.0	0.0	39.4	0.0	0.0	0.0	68.2	4.7
	Mugardos	62.5	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	297.3	41.0	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	58.6	0.0	107.0	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	30.0	237.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.6	115.7	191.7	0.0	0.0	0.0	0.0

	Bilbao	0.0	0.0	19.2	4.7	0.0	0.0	0.0	0.0	37.3	0.0	0.0	0.0	68.6	5.2
	Mugardos	64.6	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nov-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	317.9	44.3	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	62.6	0.0	148.9	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	32.6	256.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57.4	98.3	204.3	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	21.3	5.8	0.0	0.0	0.0	0.0	30.9	0.0	0.0	0.0	70.6	6.4
	Mugardos	70.3	10.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec-18	*Supply Region*	Galicia	Asturias	Castile and Leon	Cantabria	Extremadura	Andalusia	Murcia	Castilla La Mancha	Madrid	Valencia	Catalonia	Aragon	Basque Countries	Navarre
	Barcelona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	331.2	46.7	0.0	0.0
	Cartagena	0.0	0.0	0.0	0.0	0.0	0.0	65.3	0.0	175.8	0.0	0.0	0.0	0.0	0.0
	Huelva	0.0	0.0	0.0	0.0	34.6	271.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sagunto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	61.2	86.8	212.0	0.0	0.0	0.0	0.0
	Bilbao	0.0	0.0	23.2	6.9	0.0	0.0	0.0	0.0	27.1	0.0	0.0	0.0	70.2	7.6
	Mugardos	74.7	12.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0