EMIN master's thesis

Global LNG Supply and Demand Outlook (2017 - 2020)

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Challenge the future

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Erasmus Mundus Joint Master in Economics and Management of Network Industries (EMIN)

Master's Thesis

GLOBAL LNG SUPPLY AND DEMAND OUTLOOK (2017 - 2020)

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Menglin Xia
Madrid, June 2017

Executive Summary

1. Motivation:

   Liquefied natural gas (LNG), the liquid form of natural gas at minus 160 , enables natural gas to become a global commodity because of its ease of storage and transportation worldwide. LNG production and consumption have increased substantially in the last decade, accounting for 10% of the global total natural gas consumption in 2016. The LNG industry is in the middle of a huge change with a very significant increase of liquefaction capacity, equivalent to 22% of the current total capacity. Market agent's decision making is highly related with their expectations of future market situations. Thus, information on the future LNG supply and demand situation is of upmost importance to market agents in this business.

2. Research questions:

   The main research question is: *What will be the global LNG monthly supply and demand situation during the period from 2017 to 2020?*

   The sub-research questions are:

   - How much LNG will worldwide producers supply and importers consume monthly from 2017 to 2020?
   - What will be the LNG monthly supply and demand situation in different basins during the period from 2017 to 2020?
   - What are the factors that will have a big influence on the demand in Asian markets and how will they influence the market?
   - How can the global LNG market find its balance? Is Europe able to balance the expected market mismatch by itself?

3. Methodology:

   LNG supply and demand forecasting have been considered and carried out separately.

   The worldwide monthly LNG supply forecast is based on the information of physical liquefaction infrastructures, both currently existing and forthcoming liquefaction plants. Future LNG supply is calculated as the sum of current liquefaction plants' LNG production and forthcoming liquefaction plants' LNG production. In order to assess their production, a framework considering the utilization rate and ramping up process of new plants has been developed and applied.

   Forecasting future LNG demand is not that straightforward, as it is affected by numerous factors. At first, statistical time series models (mainly exponential smoothing models and ARIMA) have been used to build the base case scenario. The inputs of these statistical time series models were the historical monthly LNG import data of each country. Then, a fundamental industry analysis of the most important Asian countries was performed in order to compensate the limitation of statistical models and create different LNG demand scenarios.

4. Results and Conclusion:

   - The global total annual LNG supply in 2020 is expected to be 48% higher than that of 2016, reaching 387 MT from 263 MT in 2016. LNG supply is expected to increase substantially in the Asia Pacific and Atlantic basins, especially in the Atlantic basin, whose annual supply is expected to grow by 144% during the study period, reaching 129 MT in 2020. On the demand side, a 23% of global annual LNG demand increase is expected in the base case scenario, achieving 325 MT in 2020.

- Worldwide LNG exporters are expected to produce significantly more LNG than the global market will need during 2017 to 2020. In the base case scenario, the expected annual percentage surplus (annual surplus volume to demand of the year) will rise from 5.3% (14.9 MT) in 2017 to 19.4% (63.1 MT) in 2020.
- In the base case scenario, LNG supply is expected to surpass the expected demand in all months except for January 2017, December 2017 and January 2018. The LNG oversupply situation will be evident all the year round starting from 2018. The LNG surplus will be slightly higher in May and June months, and less in December and January months.
- Asia Pacific is the only region with an expected LNG deficit throughout the whole period. Middle East and Atlantic basins will produce more LNG than their own LNG demands. The LNG shortage in Asia Pacific will be much more severe during winter months, and LNG will be imported from Middle East and the Atlantic basin.
- Fundamental analysis identified that regulation of gas industry in China, coal-to-gas switching in South Korea, restart of nuclear power in Japan and infrastructure development in India are the most significant influencing factors of LNG demand in these most important Asian countries. Four scenarios on demand were developed on top on these factors.
- China is expected to have very significant LNG demand increase if strong policies and regulatory measures in favor of gas consumption are adopted. The mismatch of global monthly LNG supply and demand is expected to be very small in this scenario. Quicker than expected nuclear restart in Japan will further add 21 MT LNG surplus in 2020. The effects of higher demand scenario in India and South Korea on the global LNG supply and demand situation are relatively small.
- The surplus LNG is expected to reach Europe given Europe is the last resort market in global LNG business. This LNG will have to compete for demand with pipeline imported gas from Russia. LNG is expected to be in a tough situation due to Russian gas's strong position in Europe. As the result, Europe will not be able to balance the global LNG market by itself alone.
- Some of the other balancing mechanisms could be the reduction of the US liquefaction plants' LNG production or an increase of LNG demand in emerging countries.

Contents

List of Acronyms

bcm,	Billion Cubic Meters
MT[1],	Million Tons
MTPA,	Million Ton per Annum
MTOE,	Million Tonnes of Oil Equivalent
LNG,	Liquefied Natural Gas
C2G,	Coal to Gas
BAU,	Business as Usual
ARIMA,	Autoregressive Integrated Moving Average
ets,	Exponential Smoothing

[1] 1 MT LNG = 1.3 bcm natural gas at atmospheric pressure

1

Introduction

1.1. Background and motivation

Energy transition towards a sustainable and emission free future is a prevailing societal and research topic nowadays. Renewable energy production has experienced a very significant growth in the last decade and this trend should continue in the future. However, renewable energy currently needs the support of other conventional energy sources in order to cover the energy demand. Natural gas is the cleanest amongst existing fossil fuels and, being one of the most important primary energy sources, it will most likely perform a very important role in this energy transition.

Natural gas reserves are not always located close to consumption sites and the transportation of natural gas from one place to another becomes unavoidable. Pipeline transportation is the traditional and most common way. But it is not always possible or economical due to geographical constraints or the distance to be covered.

Natural gas can be converted into its liquid form at atmospheric pressure at minus 160ºC, commonly known as liquefied natural gas or LNG. LNG can be stored and provides the possibility to deliver natural gas oversea using LNG vessels. LNG, which has been liquefied, transported and regasified, emits around 40% less greenhouse gas emissions than coal when burnt to generate electricity.

The two main reasons why some gas importing countries may consider LNG as an interesting alternative to pipe gas import projects are the following:

- `Economic reasons`: LNG is generally able to compete with pipeline gas regarding cost at least over long distance deliveries (generally greater than 2000 kilometers) and even shorter distances where there are major obstacles to pipeline construction.

- `Security and supply source diversification`: Pipelines often have to cross several international boundaries, which may involve different governments, increasing the complexity of the project development. While LNG is generally transported across international waters, usually not affected by third countries legislation. Besides, LNG helps to diversify energy supply portfolios, either to diversify away from other energy sources or to reduce reliance on specific gas suppliers.

In 2016, 30% of the gas consumed worldwide was transported across borders, two thirds through pipelines and one third as LNG. In other words, LNG accounted for around 10% of the world's gas consumption in 2016.

The global LNG supply and demand have experienced significant changes in recent years and there expected more changes to come. On the supply side, substantial LNG liquefaction capacity will come into operation in Australia and United States. The capacity addition is big enough so that either of them might overtake Qatar as the world's largest LNG supplier in the near future. United States used to be a very significant LNG importer in the market. With the discovery and fast growing production of shale gas, US started to convert its LNG import terminals to LNG liquefaction plants in order to export its shale gas. On the demand side, Japan and Korea, the biggest LNG importers in the market, are witnessed to reduce their consumption, although this reduction should be more than compensated by the increase of demand of other countries such as China or India. Global LNG demand and supply will continue growing in the near future.

LNG purchase and sale transactions often take place up to several years before real consumption. Market agent's decision making is highly related with their expectations of future market situations. Thus, the information on future LNG demand and supply is of upmost importance to market agents in this business. Few academic papers have discussed this topic. Kumar et al. (2011) reviewed the current status of LNG trading and projected long-term LNG demand into 2035 with an emphasis on import potential in US, which can not represent the current situation anymore. Shell (2017) published its first LNG outlook and stated that demand in emerging countries and new markets will keep increasing in the future. However, no previous work has investigated the monthly LNG supply and demand projection in medium term.

The motivation of this thesis is to perform a bottom-up forecast of the global LNG supply and demand on a monthly basis from 2017 to 2020.

1.2. Objective and contribution

This thesis analyzes future monthly LNG demand and supply of the different countries worldwide. It aims to foresee possible global LNG supply and demand situations in each month from 2017 to 2020, with a especial focus on how it will influence the European LNG market. Different scenarios will be analyzed to recognize the influence on the supply and demand balance of major fundamental changes in the most influencing markets.

1.3. Objective and contribution

1.3.1. Main research question

The main research question to be addressed in this thesis is:

What will be the global LNG monthly supply and demand situation during the period from 2017 to 2020?

1.3.2. Sub-research questions

By decomposing the main research question, several sub-research questions are raised, respectively:

- How much LNG will worldwide producers supply and importers consume monthly from 2017 to 2020?
- What will be the LNG monthly supply and demand situation in different basins during the period from 2017 to 2020?
- What are the factors that will have big influence on the demand in Asian market and how will they influence the market?
- How can the global LNG market find its balance? Is Europe able to balance the market mismatch by itself?

1.3.3. Contribution

This thesis provides monthly forecasts of LNG demand and supply, using a tailor-made model. This paper simulated the possible outcome in the business as usual scenario, when historical trend will repeat in the future, and different scenarios based on the potential big changes in the most important markets. This type of information is critical for short term energy management teams.

No previous work of forecasting monthly LNG supply and demand in medium term can be found in the past literature.

1.4. Research scope

This study analyzes and forecasts monthly LNG supply and demand in every country that has exporting or importing facilities from January 2017 to December 2020. This analysis has included the different countries in three regions or basins (Figure 1.1), namely Asia Pacific, Atlantic and Middle East, in order to better perceive long distance inter-basin LNG movements.

Although price will certainly be a critical driver affecting the global LNG balance, this study will focus on the fundamental analysis of LNG demand and supply.

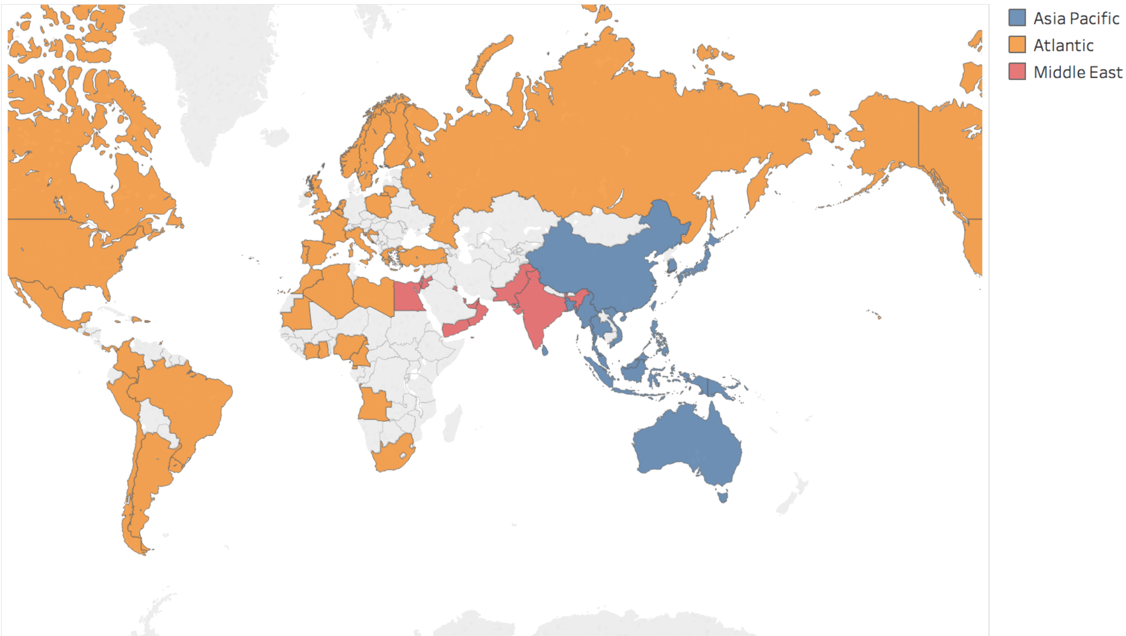


Figure 1.1: Three basins division

1.5. Structure of this report

The remainder of this thesis is organized as follows: chapter 2 provides an overview of the global LNG market with an especial emphasis on some key regional markets. Chapter 3 introduces the methodology used to perform the analysis and forecasts. Chapter 4 includes the forecast of global LNG supply. In chapter 5, monthly LNG demand is forecasted. Chapter 6 discusses global LNG supply and demand situation of business as usual case based scenario on results from chapter 4 and chapter 5. In chapter 7, several scenarios are explored based on possible variations of LNG demand in the most significant markets as well as their influence in the global LNG market. Chapter 8 analyzes the influence to Europe of global LNG supply and demand situation under different scenarios and whether Europe is able to balance the global market itself. Chapter 9 summarizes the results and concludes.

2

Overview of global LNG market

2.1. LNG supply chain

The LNG supply chain includes four main processes: production, liquefaction, transportation and regasification. Each process requires specific facilities. Liquefaction plants, cooling gas to liquid form, and regasification plants, converting LNG back to gas, are essential facilities to produce and receive LNG respectively. Liquefaction and regasification capacities become physical limits on volume of LNG that a country is able to export or import. LNG is transported oversea in LNG vessels, with a specific design in order to be able to transport gas at minus 160ºC.

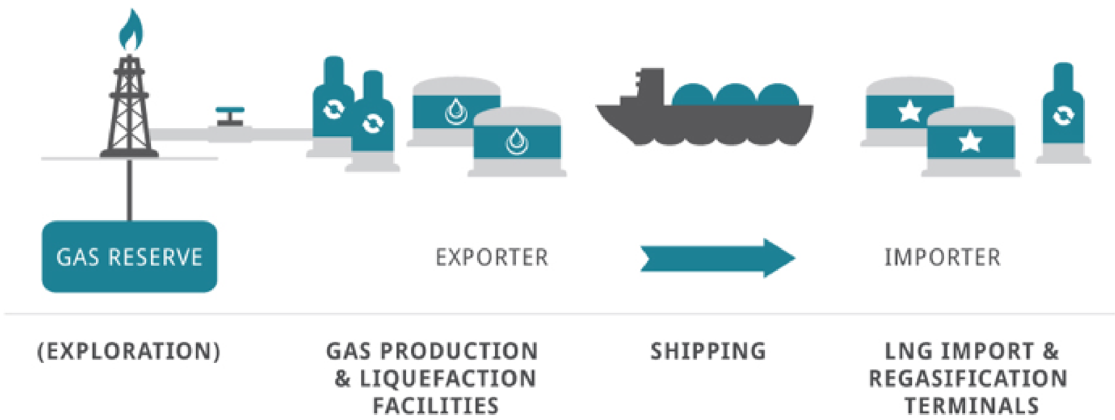


Figure 2.1: LNG supply chain

2.2. Characteristics of LNG market: from traditional model to new trends

The traditional way of organizing the LNG industry has long been described as a floating pipeline (Tusiani and Shearer, 2007). In this floating pipeline model, gas is transported continuously from one end of the pipeline, the liquefaction facility, to the other end, the import regasification terminal, by a dedicated shipping fleet.

The main features of the LNG business traditional model are: limited number of players, long-term commercial relationships and limited flexibility:

- Limited number of players: The number of international companies that could participate in the LNG business is limited because of the high entry costs and the need for government approvals

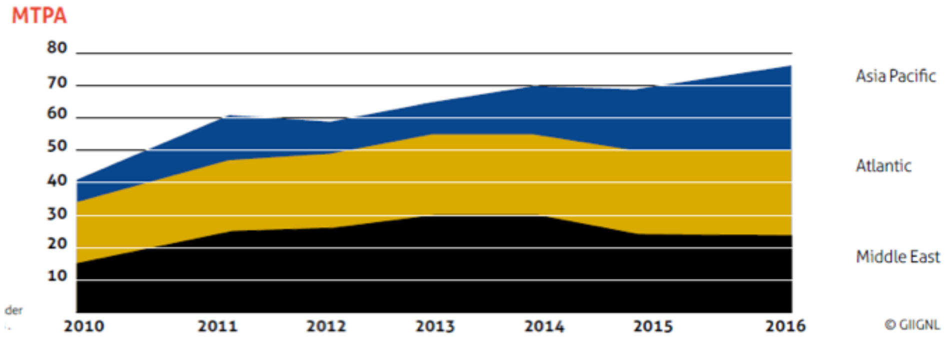


Figure 2.2: Share of spot and short-term LNG flows by exporting regions

on the buyer and seller sides. These participants usually are state-owned national oil companies and utilities and energy super majors.

- Long-term commercial relationships: Multi-year Sale and Purchase Agreements (SPAs), typically for 20 years, were prevailing LNG contracts in the traditional model. On the one hand, financial institutions backing a proposed liquefaction project required buyers to commit into long-term contracts before financing the projects. On the other hand, it minimizes project investor's risks by guaranteeing the project's ability to repay its borrowings while giving the project shareholders a reasonable return on their investments.

- Limited flexibility: Historically, contract terms were inflexible and did not accommodate changes in contract volumes that arose from shifts in market demand. Virtually all long-term SPAs contain what are called take-or-pay provisions. If the buyer fails to take the contracted gas volumes, it would have to pay for the LNG anyway. There was generally limited off-take flexibility and no destination flexibility. This meant that contracted volumes had to be delivered to the specified import terminals. Prices were largely set with reference to crude oil or petroleum products. And there was limited opportunity to review and reopen these pricing provisions.

However, this traditional model is experiencing major changes in the last decade. New patterns have appeared in the LNG market mainly due to the following reasons:

First of all, the share of spot and short-term LNG trading is constantly increasing compared to traditional long term contracts, along with the improved liquidity of the LNG market. And the duration of newly closed long-term contracts has decreased. Figure 2.2 indicates that short term LNG trading volumes have reached record high levels in 2016, accounting for 28% of the total trade. At present, most buyers are unwilling to go into a traditional 20 years long term contract.

Secondly, contracts include more flexible terms, such as off-take volumes, alternative delivery points and timing. Make up and carry forward quantities have been increased in new contracts, allowing more flexibility on quantities to off-takers. FOB (free on board) contracts with free destination deliveries have gained acceptance.

Another disruptive change in the market is the new "tolling" business model of forthcoming liquefaction plants in the US. The traditional way to structure LNG liquefaction plants respond to an integrated project model, in which one or more investors own rights to natural gas reserves and participate in the LNG production. The long term contracts underlying these projects are direct contracts for certain volumes of LNG with take or pay clauses. Off-takers in integrated project models are committed to pay the full price of the LNG. The amount of LNG contracted is going to be produced anyway given off-takers have paid for it. However, under a tolling model, the company owning the LNG liquefaction facility (Toll Co.) does not take title to the natural gas that is processed. Instead, Toll Co. receives a fee (the Tolling Fee) to provide the service of liquefying the natural gas owned and delivered to the liquefaction plant by a producer or a purchaser of LNG. The long-term contracts underlying these projects commit to future liquefaction capacity. Capacity off-takers only pay a reservation charge to ensure that the LNG plant has the necessary capacity to liquefy the offtaker's natural gas on a regular basis and is payable whether or not any natural gas is actually liquefied. Thus, capacity buyers might choose not to produce LNG under certain market situations in the future, meaning that liquefaction plants in the US might act in a different way compared to traditional projects.

2.3. Asia has the strongest demand in the global LNG business

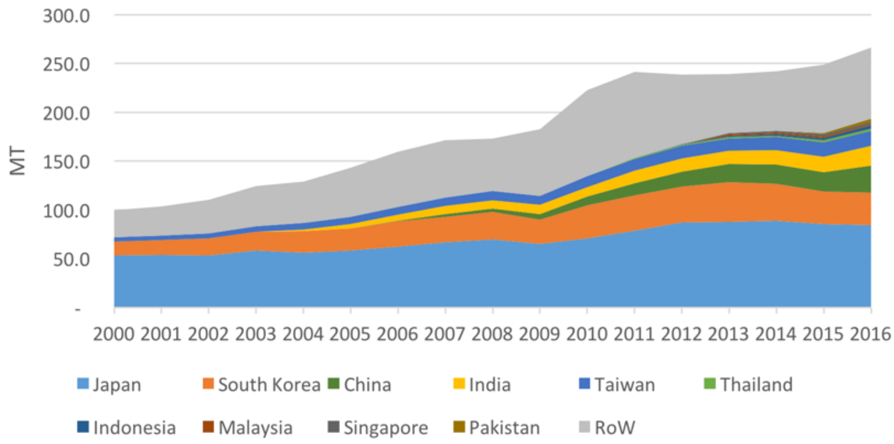


Figure 2.3: Asia's LNG import out of global total import

Asia is the world most important LNG import region. In 2016, LNG demand from Asia accounted for approximately 74% of the world total annual demand. Japan, South Korea, China, India and Taiwan are the largest five LNG importers worldwide.

Japan, South Korea and Taiwan are viewed as mature Asian LNG importers. They commenced LNG imports in 1969, 1986 and 1990 respectively. As a group they have represented more than 60% of global LNG imports from 1980 to 2006. Several reasons contributed to this huge amount of LNG consumption in these three markets. Firstly, these countries have very little domestic gas production and no international pipeline connections, so they are almost fully dependent on LNG for their gas demand. Secondly, these three countries are highly developed economies, enjoying economic growth based on export-oriented manufacturing and technology goods production. As a result, gas demand in these three countries is generally high. However, future LNG demand in Japan, South Korea and Taiwan is exposed to uncertainty. The economic growth in these countries has slowed down. More importantly, the future of gas in the power generation mix is uncertain, competing with renewable, nuclear and coal.

For China and India, LNG is an already established channel of gas supply. They started to import LNG in 2006 and 2004 respectively, growing swiftly to become the world's third and fourth LNG importers. Their future LNG demand potential growth is of key importance to global LNG market. Other emerging markets such as Pakistan and Thailand have recently started importing LNG. Although less predictive, future LNG demand in these markets is promising.

Given Asia's predominant role in the global LNG import market, any changes in this region should have an important influence on the global market. Therefore, investigating potential changes on future LNG demand in these countries is essential and critical when forecasting LNG global demand.

2.4. Europe's role as the last resort market in global LNG business

Europe, with extensive gas pipelines infrastructure, fulfills its gas demand mainly by pipeline import, covering 68% of its gas demand in 2015. Major suppliers of pipeline gas to Europe are Russia, Norway and Algeria. Russia has a leading position in Europe's gas supply, covering 33% of total European gas consumption. Indigenous gas production is the second largest source of Europe's gas supply, accounting for 22% of total gas consumption in 2015.

LNG is a complementary sources of gas supply for most of EU countries and its share in Europe's gas supply is only around 10%. Although European countries altogether only import 12% in global LNG

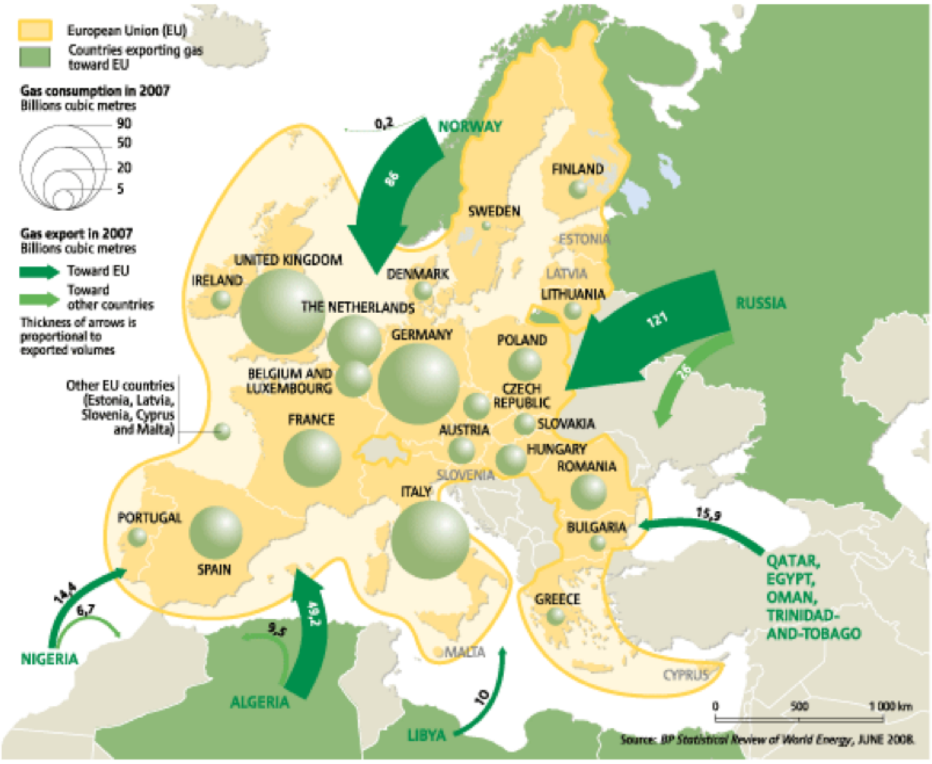


Figure 2.4: Europe’s gas supply map

market, Europe has a distinctive and significant role in the market – the global LNG balancing market. In other words, Europe is considered as the last resort market in the global LNG business, where the remaining LNG after satisfying demand in other regions will probably be sent to. The following unique features of the European gas market are the determinants for this role:

Firstly, Europe has sufficient import capacity to receive LNG and extensive pipeline network to distribute gas. The total regasification capacity in Europe is 151.6 MTPA, while utilization rate of these facilities was only about 25% in 2016, so Europe has adequate spare capacity that makes it possible to receive more LNG.

Secondly, European established and liquid gas markets provide access to monetize LNG for exporters. Most EU countries have liberalized their gas sector, providing third parties access to their regasification capacity and other gas infrastructure. National Balancing Point (NBP) in the UK and Title Transfer Facility (TTF) in the Netherlands are virtual trading hubs in Europe. Both of them are among the most liquid gas reference prices worldwide.

Thirdly, Europe can reduce its pipeline gas imports. The majority of Europe’s gas consumption is covered by pipeline imports. This amount is very big compared to LNG imports. Europe can import more LNG to replace part of the flexible pipeline gas imports. Therefore, if there is an LNG oversupply in the future, Europe is expected to be the market that can absorb this LNG surplus.

3
Methodology

According to Hyndman (2015), the predictability of an event or a quantity depends on several factors including:

1. how well we understand the factors that contribute to it;
2. how much data are available;
3. whether the forecasts can affect the thing we are trying to forecast.

3.1. Methodology for LNG supply projection

LNG supply is forecastable based on the criteria above. Firstly, LNG is produced from LNG liquefaction plants. The LNG supply volume is capped by the total liquefaction capacity available and dependent on how much capacity is utilized. Secondly, nominal capacity data of both existing and forthcoming liquefaction plants are available, along with historical utilization rates of existing plants and startup dates of new plants. Thirdly, the forecasts probably do not influence the real LNG supply in the future. Therefore, the predictability of LNG supply is high.

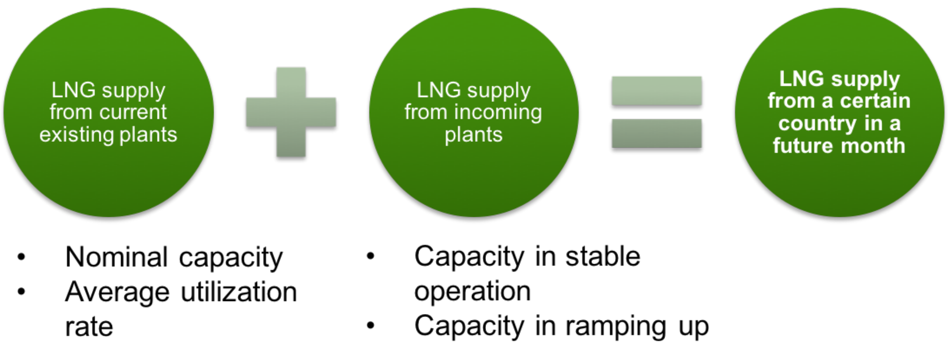


Figure 3.1: Mechanism to forecast future LNG supply

Figure 3.1 shows the process and mechanism that this study applied to forecast future monthly LNG supply. LNG supply from a certain country in a future month will come from both current existing liquefaction plants and new liquefaction plants that will be commissioned before that month. Regarding the current existing plants of each specific country, a country-level average utilization rate is calculated based on their historical performance. The LNG supply from current existing plants is the product of total current liquefaction capacity in the country and its average utilization rate. New plants expected to start up from January 2017 to the month of forecasting might have two possible statuses in that time. The sum of supply from these two cases makes up total LNG supply from forthcoming liquefaction plants. First, some plants that have already finished ramp-up are in stable operation. The same method used for existing plants is applied to forecast the supply. Second, some plants might still in capacity ramping up process at the month of forecasting. A simulated ramping up process is constructed to help to estimate the LNG supply from these plants.

3.2. Methodology for LNG demand projection

LNG demand forecasting is less intuitive and more complicated to address, which can also be explained by the aforementioned Hyndman's criteria.

First of all, there are a lot of factors such as GDP level, infrastructure, natural gas prices, meteorological features like temperature and rainfall, industry policy, and unexpected incidents that have great influence on the natural gas demand of a country (Sánchez-Úbeda and Berzosa, 2007; Krichene, 2002; Li et al., 2011). This demand is generally covered by indigenous gas production or pipeline imports which may be affected by the same regional factors. LNG is considered a complementary gas source in many countries. However, LNG itself is influenced by a great number of factors that may not just be driven by regional factors themselves. Secondly, data availability is rare since future values of many influencing factors, such as temperature and policy, are not foreseeable at present. Thirdly, in general, future demand will not be affected by the current forecasts. Therefore, it is challenging to forecast future LNG demand.

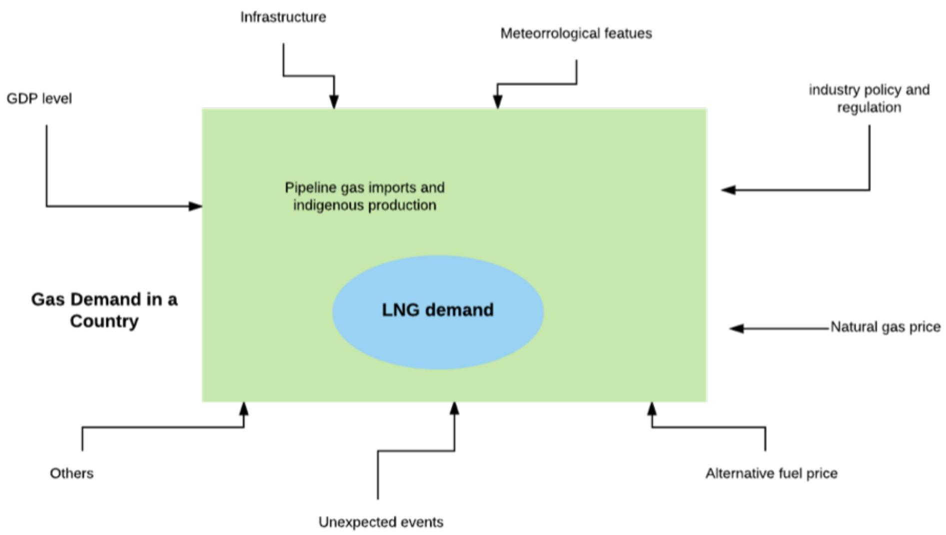


Figure 3.2: Influencing factors to LNG demand in a country

The task of this study is to forecast monthly LNG demand in each importing country over the next four years. Foreseeing some of the influencing factors with this precision is not always possible. It is necessary to take some assumptions in order to simplify the model and enhance the predictability. The historical LNG import evolvements are the results of overall influence from all kinds of factors. In a business as usual case, we consider the historical trends of these factors will continue in the future, especially for those that are not currently foreseeable. Thereafter, the effects of the potential disruptive changes on the most influencing factors can be discussed separately.

Almost all researches in the past were addressing natural gas demand forecasting while research on LNG demand forecasting is rare. Neural networks, system dynamics and metric models are the methods used by researchers to forecast natural gas demand. In the case of LNG demand forecasting, most of these methods would present significant limitations. Neural network is an advanced model that requires a lot of data in order to train an accurate model, while even countries like Japan only have 20 years history of LNG importing with only 240 data points. It is too short for such models and most other countries have even shorter data series. System dynamics is suitable for long term strategic planning with easy inclusion of many different factors. But for a monthly forecasting model, too many assumptions would be needed, sacrificing the objectivity.

Time series modelling in metric models is considered a suitable option for this study to obtain the forecast of global LNG demand under the base case scenario. A time series is defined as a sequence of numerical data points in successive order. Historical LNG import data series in each country can be considered a time series. And the final result we want is also a monthly time series from January 2017 to December 2020. We consider that time series modelling is a suitable method for LNG demand forecasting. Firstly, it is able to model the effect of influencing factors as a whole with the assumption that their historical trends will repeat in the future. Secondly, the requirement for data is lower, only historical import data are required to build a base case scenario. Thirdly, it is able to identify monthly demand's properties from historical time series and reproduce them into the future. The time series models chosen for this study and their underlying theory are discussed later in this chapter.

A significant shortcoming of time series models is that they cannot foresee any disruptive changes on influencing factors. This issue will be handled with a fundamental approach. Since the most influencing factors affecting LNG demand are different for every country, the effect of disruptive changes on these factors for the most significant countries will be discussed separately by looking into the gas supply and demand structure in these countries and analyzing how vulnerable they are to potential changes. Following this fundamental analysis, different demand scenarios will be developed and their influence in the global LNG demand and supply balance will be analyzed.

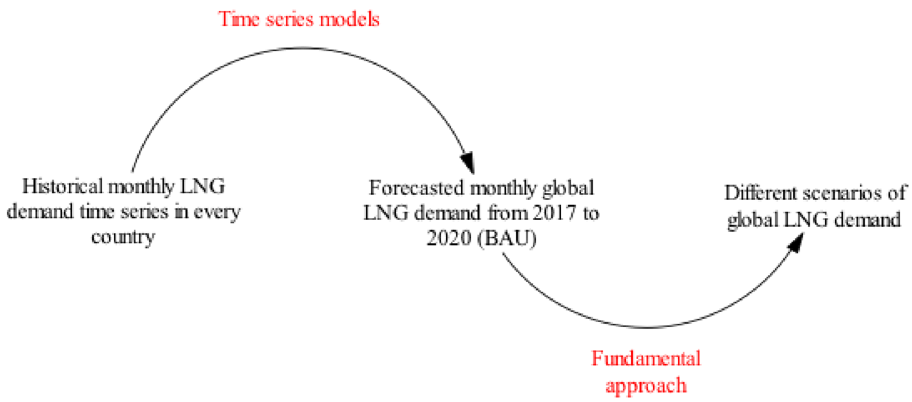


Figure 3.3: Mechanism to forecast future LNG demand

3.2.1. Time series models and the underlying principles

One of the main challenges for time series forecasting is the significant correlation between adjacent data, which severely limit the applicability of many conventional statistical methods with the assumption that these neighboring observations are independent and identically distributed (Shumway and Stoffer, 2013). Several statistical forecasting models are able to capture this time correlation. Among them, the two most widely-used models are exponential smoothing and ARIMA models (Hyndman and Athanasopoulos, 2015), which will be applied in this study.

Exponential smoothing

Exponential smoothing was proposed in the late 1950s and has motivated some of the most successful forecasting methods. Forecasts produced using exponential smoothing methods are calculated using weighted averages where the weights decrease exponentially as observations come from further in the past. In other words, the higher weight is given to more recent observation. This framework generates reliable forecasts quickly for a wide spectrum of time series, which is a great advantage for applications in industry.

1. `simple exponential smoothing`

   There are several kinds of exponential smoothing methods for forecasting time series with various characteristics. The simplest is called "simple exponential smoothing" (SES). This method is suitable for forecasting data with no trend or seasonal pattern.It is based on the following formula:

$$\hat{y}_{T+1|T} = \alpha y_T + \alpha(1-\alpha)y_{T-1} + \alpha(1-\alpha)^2 y_{T-2} + \cdots,$$

where $0 \leq \alpha \leq 1$ is the smoothing parameter. The one-step-ahead forecast for time $T+1$ is a weighted average of all the observations in the series $y_1,\ldots,y_T$. The rate at which the weights decrease is controlled by the parameter α.

2. `Holt's linear trend method`

   Holt (1957) extended simple exponential smoothing to allow forecasting of data with a trend. This method involves a forecast equation and two smoothing equations (one for the level and one for the trend):

$$\begin{aligned} \text{Forecast equation} \quad & \hat{y}_{t+h|t} = \ell_t + hb_t \\ \text{Level equation} \quad & \ell_t = \alpha y_t + (1-\alpha)(\ell_{t-1} + b_{t-1}) \\ \text{Trend equation} \quad & b_t = \beta^*(\ell_t - \ell_{t-1}) + (1-\beta^*)b_{t-1} \end{aligned}$$

   where l_t denotes an estimate of the level of the series at time t, b_t denotes an estimate of the trend (slope) of the series at time t, α is the smoothing parameter for the level, and β^* is the smoothing parameter for the trend, $0 \leq \beta \leq 1$.

3. `Holt-Winters seasonal method`

   Holt (1957) and Winters (1960) extended Holt's method to capture seasonality. The Holt-Winters seasonal method comprises the forecast equation and three smoothing equations - one for the level l_t, one for trend b_t, and one for the seasonal component denoted by s_t.

   There are two variations to this method that differ in the nature of the seasonal component. The additive method is preferred when the seasonal variations are roughly constant through the series, while the multiplicative method is preferred when the seasonal variations are changing proportional to the level of the series.

   The component form for the additive method is:

$$\begin{aligned} \hat{y}_{t+h|t} &= (\ell_t + hb_t)s_{t-m+h_m^+}. \\ \ell_t &= \alpha \frac{y_t}{s_{t-m}} + (1-\alpha)(\ell_{t-1} + b_{t-1}) \\ b_t &= \beta^*(\ell_t - \ell_{t-1}) + (1-\beta^*)b_{t-1} \\ s_t &= \gamma \frac{y_t}{(\ell_{t-1} + b_{t-1})} + (1-\gamma)s_{t-m} \end{aligned}$$

   m denotes the period of the seasonality, i.e., the number of seasons in a year. For example, for quarterly data m=4, and for monthly data m=12.

   The component form for the multiplicative method is:

$$\begin{aligned} \hat{y}_{t+h|t} &= \ell_t + hb_t + s_{t-m+h_m^+} \\ \ell_t &= \alpha(y_t - s_{t-m}) + (1-\alpha)(\ell_{t-1} + b_{t-1}) \\ b_t &= \beta^*(\ell_t - \ell_{t-1}) + (1-\beta^*)b_{t-1} \\ s_t &= \gamma(y_t - \ell_{t-1} - b_{t-1}) + (1-\gamma)s_{t-m}, \end{aligned}$$

4. `Exponential models in adjusted forms`

   The exponential smoothing methods methods introduced above are all in standard forms. There are some adjusted forms of exponential smoothing methods that are considered to possibly further improve accuracy. The following two methods are applied in this study.

- `"stlm" method:`
  This method first removes the seasonality from the time series. Then a non-seasonal exponential smoothing model with just error and trend terms is fitted. Finally, the forecast is re-seasonalised.
- `"thetaf" method:`
  a) Seasonal adjustment via decomposition (classical multiplicative seasonal decomposition);
  b) exponential smoothing with just an additive model (no trend or seasonality);
  c) estimate trend/drift by an adjusted form of linear regression of the seasonally adjusted variable against time.
  One way of looking at the difference of these methods is that standard method uses exponential smoothing for error, trend and seasonal; stlm for just error and trend; and thetaf for just error.

ARIMA Models

ARIMA models provide another approach to time series forecasting. While exponential smoothing models are based on a description of trend and seasonality in the data, ARIMA models aim to describe the autocorrelations in the data.

An ARIMA is an acronym for autoregressive integrated moving average. A full ARIMA model includes three parts. "AR" represents an autoregression model. "I" represents differencing. "MA" denotes a moving average model.

1. `Autoregression model`

   An autoregression model is similar to a multiple regression model. But instead of forecasting dependent variable using a linear combination of predictors, we forecast the variable of interest using a linear combination of past values of the variable. The term autoregression indicates that it is a regression of the variable against itself. Thus an autoregressive model of order p can be written as:

   $$y_t = c + \phi_1 y_{t-1} + \phi_2 y_{t-2} + \cdots + \phi_p y_{t-p} + e_t,$$

   where c is a constant and e_t is white noise. This is like a multiple regression but with lagged values of y_t as predictors. We refer to this as an AR(p) model.

2. `Differencing`

   A stationary time series is one whose properties do not depend on the time at which the series is observed. So time series with trends, or with seasonality, are not stationary. The trend and seasonality will affect the value of the time series at different times. One way to make a time series stationary is applying differencing, which compute the differences between consecutive observations. Differencing can help stabilize the mean of a time series by removing changes in the level of a time series, and so eliminating trend and seasonality.

   The differenced series is the change between consecutive observations in the original series, and can be written as:

   $$y'_t = y_t - y_{t-1}.$$

   Occasionally the differenced data will not appear stationary and it may be necessary to difference the data a second time to obtain a stationary series:

   $$\begin{aligned} y''_t &= y'_t - y'_{t-1} \\ &= (y_t - y_{t-1}) - (y_{t-1} - y_{t-2}) \\ &= y_t - 2y_{t-1} + y_{t-2}. \end{aligned}$$

3. `Moving average model`

   The another part of ARIMA is a moving average model. Rather than use past values of the forecast variable in a regression, a moving average model uses past forecast errors in a regression-like model.

$$y_t = c + e_t + \theta_1 e_{t-1} + \theta_2 e_{t-2} + \cdots + \theta_q e_{t-q},$$

   We refer to this as an MA(q) model. Of course, we do not observe the values of et, so it is not really regression in the usual sense.

4. `Non-seasonal ARIMA model`

   Combining these three parts, a full non-seasonal ARIMA model can be written as:

$$y'_t = c + \phi_1 y'_{t-1} + \cdots + \phi_p y'_{t-p} + \theta_1 e_{t-1} + \cdots + \theta_q e_{t-q} + e_t,$$

   where y'_t is the differenced series (it may have been differenced more than once). The 'predictors' on the right hand side include both lagged values of and lagged errors. We call this an ARIMA(p,d,q) model, where

   p=order of the autoregressive part;

   d=degree of first differencing involved;

   q=order of the moving average part.

5. `Seasonal ARIMA model`

   ARIMA models are also capable of modelling a wide range of seasonal data. A seasonal ARIMA model is formed by including additional seasonal terms in the non-seasonal ARIMA models. It is written as follows:

$$\text{ARIMA} \; \underbrace{(p,d,q)}_{\uparrow \atop \left(\text{Non-seasonal part} \atop \text{of the model}\right)} \; \underbrace{(P,D,Q)_m}_{\uparrow \atop \left(\text{Seasonal part} \atop \text{of the model}\right)}$$

   where m= number of periods per season.

   The seasonal part of the model consists of terms that are very similar to the non-seasonal components of the model, but they involve backshifts of the seasonal period. For example, an $ARIMA(1,1,1)(1,1,1)_4$ model (without a constant) is for quarterly data (m=4) and can be written as:

$$\underbrace{(1-\phi_1 B)}_{\left(\text{Non-seasonal} \atop \text{AR}(1)\right)} \; \underbrace{(1-\Phi_1 B^4)}_{\left(\text{Seasonal} \atop \text{AR}(1)\right)} \; \underbrace{(1-B)}_{\left(\text{Non-seasonal} \atop \text{difference}\right)} \; \underbrace{(1-B^4)}_{\left(\text{Seasonal} \atop \text{difference}\right)} y_t = \underbrace{(1+\theta_1 B)}_{\left(\text{Non-seasonal} \atop \text{MA}(1)\right)} \; \underbrace{(1+\Theta_1 B^4)}_{\left(\text{Seasonal} \atop \text{MA}(1)\right)} e_t.$$

Time series models selection criterion

Forecast accuracy is the key performance indicator for selecting the best model. The following measurements are frequently used to assess forecast accuracy. Let denote the t th observation in a time series and denote its forecast, where $t = 1, \cdots, n$

(1) Mean absolute error (MAE)

$$MAE = n^{-1} \sum_{t=1}^{n} |y_t - f_t|$$

(2) Mean square error (MSE)

$$MASE = n^{-1} \sum_{t=1}^{n} (y_t - f_t)^2$$

(3) Root mean square error (RMSE)

$$RMSE = \sqrt{n^{-1} \sum_{t=1}^{n} (y_t - f_t)^2}$$

(4) Mean absolute percentage error (MAPE)

$$MAPE = 100n^{-1} \sum_{t=1}^{n} \frac{|y_t - f_t|}{|y_t|}$$

One common significant defect of MAE, MSE and RMSE is they are all scale dependent. MAPE is scale independent but is only sensible if $y_t \gg 0$ for all i, and y has a natural zero. These conditions are satisfied by most of time series of LNG demand. Therefore, MAPE is chosen to measure forecast accuracy and select the best model. For exceptional time series that cannot meet the conditions, calculation of MAPE is adjusted.

$$MAPE = 100n^{-1} \frac{\sum_{t=1}^{n} |y_t - f_t|}{\sum_{t=1}^{n} |y_t|}$$

4

Global LNG Supply Projection

Gas and LNG sales and purchase agreement are usually made a long time, even a couple of years, before real consumption taking place. Thus, it is of great significance to forecast future supply for every agent in the market, such as liquefaction owners, trading houses and customers. LNG sellers need to assess how much LNG they need to sell at a specific time point of future. For trading companies, future supply outlook will have direct influence on the market balance situation. For big buyers like utility companies, they need to secure LNG supply for their future production in advance. Therefore, forecasting future LNG supply in the market is a key issue for different players.

There have been quite some articles discussing about future LNG supply (Rogers, 2017; BP, 2017). But readers can scarcely find the methodologies and steps they are applying to get these forecasts. And their results are usually an overall number for the global market, lacking of insights for each region. This chapter is going to focus on these gaps and take a bottom-up approach to investigate LNG supply in each region from the present to the end of 2020 on a monthly time step.

As already discussed above, LNG is a product requires certain physical infrastructure, which is liquefaction plant. The amount of LNG can be produced is limited by the total capacity of LNG liquefaction plants worldwide. Liquefaction plants are complex engineering projects require billions of investment and a very long construction time. As mentioned in chapter 2, current and incoming liquefaction plants except the ones in US are developed under the integrated project model. These plants have already secured buyers' commitment to pay for LNG they produce. That is to say, buyers have already paid for LNG going to be produced in these liquefaction plants with take or pay clause in their contracts. So liquefaction plants will produce at least their contracted volume anyway, which should be very close to their full capacity. Moreover, liquefaction plants have intention to produce as much as possible to monetize their gas resources.

The key issue for forecasting future LNG supply now becomes to foresee how much new liquefaction capacity is going to be online during the time of our study. LNG liquefaction plants usually take a long time (4-5 years) for construction. It is longer than the time period this paper is studying (4 years ahead). So for LNG supply before the end of 2020, only the projects that are currently under construction have to be taken into consideration since it is unlikely that projects in an earlier stage will go into operation.

The first step for supply projection is to collect the complete information for the liquefaction projects in operation and under construction. For incoming projects, the latest startup dates projections should be obtained. In order to be as accurate as possible, the next thing need to be taken into account is utilization rates of the operating plants and incoming projects. Finally, the ramping up process of new liquefaction projects also need to be handled properly. This chapter is going to explain these issues one by one.

4.1. Current LNG liquefaction plants

In 2016, 19 countries have LNG exporting capacity (Figure 4.1). Their total nominal capacity is 340 MTPA. Among all countries, Qatar has the biggest LNG export capacity in the world, with 77 MTPA liquefaction capacity, accounting for 32% of global total capacity. Australia, Indonesia, Malaysia and Algeria are following Qatar as the biggest exporters worldwide.

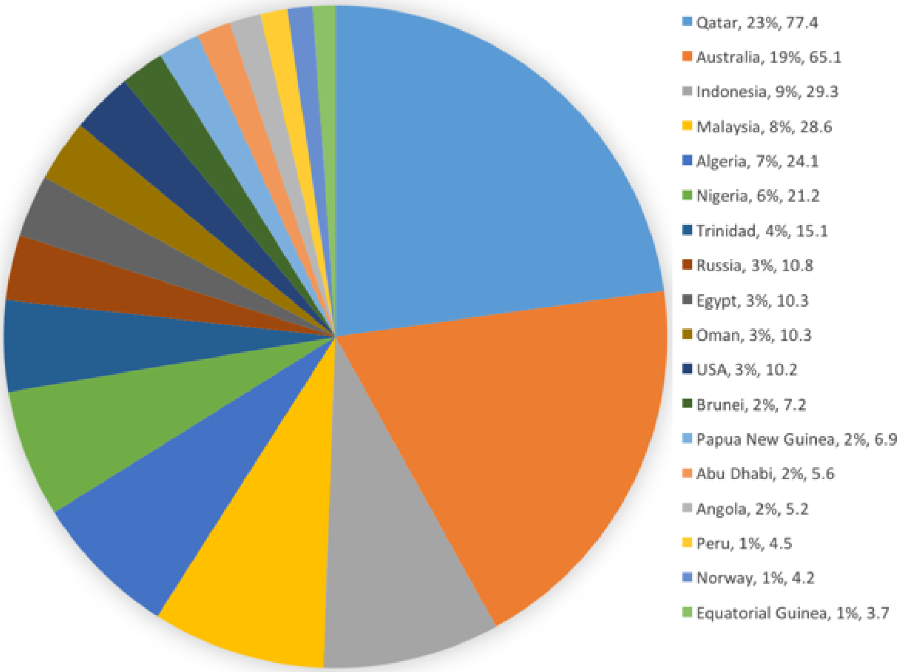


Figure 4.1: Liquefaction capacity in operation in 2016 by country

With two traditional big exporters in the region, Indonesia and Malaysia, and due to the fast growing Australian liquefaction capacity in recent years, Asia Pacific has become the largest LNG producer among the thre e basins. It is shown in Figure 4.2 that the capacity in Asia pacific reached 149.1 in 2016. Middle East is the second largest LNG producer mainly due to the contribution of Qatar. The LNG production capacity in Atlantic remains the lowest at present.

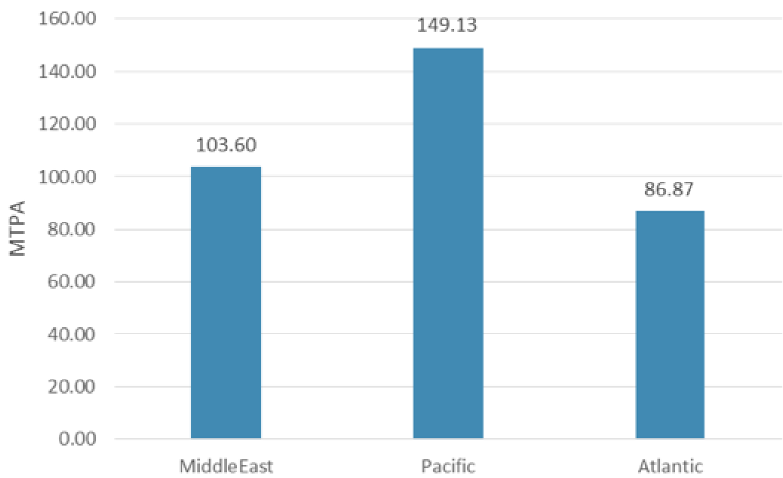


Figure 4.2: Liquefaction capacity in three regions

4.2. Incoming LNG liquefaction projects

LNG liquefaction capacity currently under construction is huge, namely 97 MTPA, accounting for 30% of current total liquefaction capacity.

Figure 4.3 exhibits the country of origin for the incoming LNG liquefaction capacity by 2020. Six

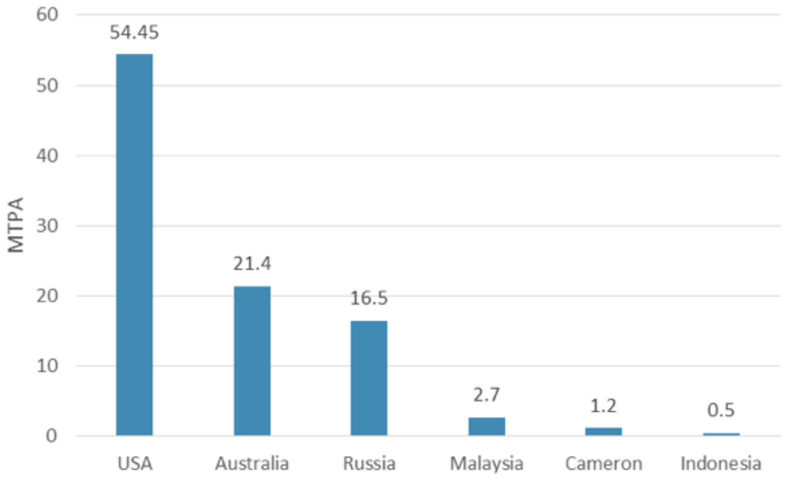


Figure 4.3: LNG liquefaction capacity under construction by country

countries have liquefaction projects in construction but capacity growth is mainly coming from three countries: USA, Australia and Russia. USA is the home to the greatest part of the new capacity with 54.5 MTPA. Australia, which already has 56.5 MTPA capacity in operation, is expected to overtake Qatar in order to become the number one LNG exporting country in the near future with additional 21.4 MTPA capacity under development. Russia, the global giant gas production country, is also expanding its liquefaction capacity by 16.5 MTPA. Figure 5 suggests 75% of the new capacity is in the Atlantic basin and the remaining 25% is in the Asia-Pacific basin. This means in the coming years liquefaction capacity in the Atlantic basin will surpass the Middle east liquefaction capacity.

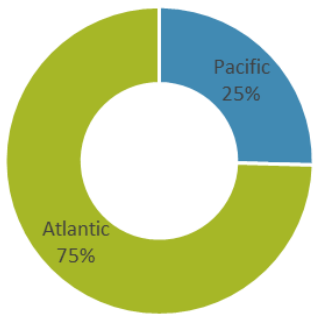


Figure 4.4: New liquefaction capacity by region

The complete list of liquefaction projects going to come online is shown in Table 4.1 with estimation of startup dates. Information in the table is the most up to date from industry reports, newspapers and project official websites. Seen from Figure 4.5, a large amount of capacity will come into operation in 2017, 2018 and 2019. Planned capacity increase in 2020 is much lower.

4.3. Liquefaction plants utilization rate

Liquefaction plants are designed to perform with the highest possible standards. However, most liquefaction plants don't always reach their nominal liquefaction capacity due to very diverse reasons. The utilization rate of liquefaction plants becomes a key parameter to be analyzed in order to forecast the real LNG supply available in the market.

Utilization rate is defined as the quotient of dividing the real annual production by the nominal liquefaction capacity. In reality, it is usually difficult for liquefaction plants to achieve a 100% utilization

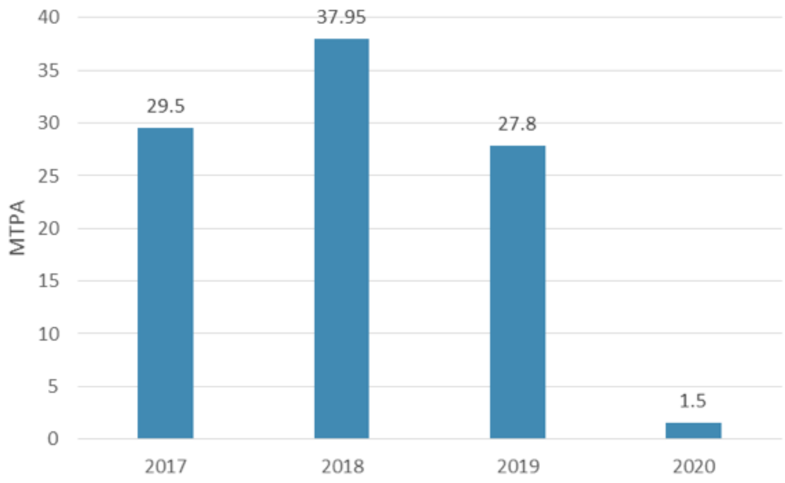


Figure 4.5: New capacity coming on line by year

Table 4.1: Liquefaction project in construction

Country	Project	Region	Capacity (MTPA)	StartYear	StartMonth
Australia	Wheatstone LNG T1	Pacific	4.45	2017	6
Australia	Prelude FLNG	Pacific	3.6	2017	12
Australia	Ichthys LNG T1	Pacific	4.45	2018	1
Australia	Wheatstone LNG T2	Pacific	4.45	2018	1
Australia	Ichthys LNG T2	Pacific	4.45	2018	4
Indonesia	Senkang LNG T1	Pacific	0.5	2017	2
Malaysia	PFLNG1	Pacific	1.2	2017	4
Malaysia	PFLNG2	Pacific	1.5	2020	1
Russia	Yamal LNG 1	Atlantic	5.5	2017	10
Russia	Yamal LNG 2	Atlantic	5.5	2018	6
Russia	Yamal LNG 3	Atlantic	5.5	2019	1
USA	Sabine Pass T3	Atlantic	4.5	2017	4
USA	Sabine Pass T4	Atlantic	4.5	2017	10
USA	Dominion Cove Point	Atlantic	5.25	2017	11
USA	Cameron LNG T3	Atlantic	4.5	2018	5
USA	Cameron LNG T1	Atlantic	4.5	2018	6
USA	Freeport LNG T1	Atlantic	4.4	2018	7
USA	Cameron LNG T2	Atlantic	4.5	2018	12
USA	Freeport LNG T2	Atlantic	4.4	2019	2
USA	Corpus Christi T1	Atlantic	4.5	2019	5
USA	Sabine Pass T5	Atlantic	4.5	2019	7
USA	Freeport LNG T3	Atlantic	4.4	2019	8
USA	Corpus Christi T2	Atlantic	4.5	2019	10
Cameron	Kribi FLNG	Atlantic	1.2	2018	5

rate due to various reasons like unexpected maintenance or potential issues related to their upstream gas supply. Utilization rate sometimes also can be higher than 100% because of better than designed performance.

Liquefaction capacity utilization rates differ by project and country, depending on its own specific conditions. In order to estimate future utilization rates, historical utilization values can be a valuable reference. Table 4.2 exhibits historical capacity utilization rates of each country in the past five years. These numbers are calculated from real historical annual production data divided by the nominal liquefaction capacity of each country.

Liquefaction plants in Papua New Guinea, Qatar and Equatorial Guinea have been operating with higher utilization rates than their nominal liquefaction capacities. However, the common utilization rate for liquefaction plants in full operation is around 90%. Countries with remarkably low utilization rates all have their own reasons behind.

Table 4.2: Historical capacity utilization rates by country

Capacity utilization by country	2012	2013	2014	2015	2016	Average
Abu Dhabi	99.6%	96.6%	105.0%	100.0%	101.1%	100.5%
Algeria	46.8%	45.2%	51.7%	48.7%	46.2%	47.7%
Angola		6.2%	6.3%	0.0%	15.8%	7.1%
Australia	85.0%	91.8%	71.5%	72.1%	67.0%	77.5%
Brunei	92.8%	92.9%	81.4%	88.9%	84.7%	88.1%
Egypt	40.8%	22.3%	2.7%	0.0%	4.0%	14.0%
Equatorial Guinea	96.8%	101.6%	96.0%	94.1%	101.6%	98.0%
Indonesia	102.8%	98.0%	94.2%	88.3%	92.1%	95.1%
Malaysia	89.8%	95.6%	95.0%	97.2%	92.1%	93.9%
Nigeria	94.4%	77.9%	86.4%	93.4%	80.9%	86.6%
Norway	82.1%	69.8%	92.1%	104.0%	112.4%	92.1%
Oman	79.3%	82.5%	73.8%	71.8%	78.4%	77.2%
Papua New Guinea				105.7%	112.8%	109.2%
Peru	89.0%	89.2%	95.1%	80.2%	84.3%	87.6%
Qatar	100.0%	99.8%	98.3%	100.5%	101.4%	100.0%
Russia	100.5%	96.9%	98.3%	99.1%	97.9%	98.5%
Trinidad	96.9%	91.1%	94.1%	81.9%	74.0%	87.6%
USA	18.5%	11.5%	22.3%	19.2%	34.2%	21.1%
Yemen	71.29%	100.23%	92.85%	21.20%	0.00%	57.1%

Some countries presented stable utilization rates over the last five years. For them, averages of utilization rates of the last five years data can be considered as a good way to approximate their future utilization rates. However, some countries are perceived to be exceptional. It is either because their utilization rates were varying very much in the past or situation regarding LNG production is going to experience major changes. These countries are Australia, Unite States, Trinidad, Egypt, Angola and Yemen.

- `Australia:`

  The average utilization rate for Australia plants is low. It is because new projects were constantly commissioned during the last 3 years and it took time for these new projects to reach their full nominal liquefaction capacity. There was no capacity addition in 2013 and the utilization rate there was 91.8%. It is reasonable to assume that the utilization rate in Australia will reach the 2013 level when plants finish ramping up and start stable operation.

- `the Unite States:`

  US has the same issue as Australia. Substantial projects will start up in the time period of this study (2017 to 2020). Sabine pass train 1 and train 2 just started up in May and September 2016 respectively, leading to the low utilization rate in 2016. Before 2016, the country only had one 1.2 MTPA LNG liquefaction plant (Kenai LNG) in Alaska. Kenai LNG started in 1969. Its operator ConocoPhillips announced in 2011 that it would be ceasing LNG exports from Kenai and preserving the plant for potential future use. It resumed exports in 2012 though in a very limited scale (ConocoPhillips, 2014). Therefore, historical data are not representative when it comes to decide the future utilization rate of incoming projects in mainland US. Another factor that makes US projects special is the tolling business model (LNGHub, 2015), which allows more flexibility in the usage of liquefaction facilities and possibly makes the utilization rate less predictable. Whereas, upstream producers have incentive to monetize their shale gas and want produce as much LNG as possible. For the business as usual case, a utilization rate similar to the one of Australia is assumed.

- Angola:

  The Angola LNG plant first started operations in mid-2013. It experienced a two-year shutdown from April 2014 to June 2016 to fix design flaws. The plant had been offline again for one month from December 2016 (Reuters, 2017). These are the reasons that generated its extremely low utilization rate. Future utilization is expected to grow rapidly from the current level, but taking into account its weak performance in the past, a utilization rate of 50% seems to be reasonable. It is assumed to reach similar level as Algeria.

- Egypt:

  Utilization rate of liquefaction plants in Egypt shrunk quickly from 2012 onwards and stopped completely in 2015 due to the gas shortage currently ongoing in Egypt (Adel, 2015). Although it started to rebound in 2016, Egypt is unlikely to become a significant LNG exporter again until the 30-Tcf Zohr discovered in the eastern Mediterranean starts commercial production. Egypt's utilization rate is going to increase depending on its upstream gas availability. Direct LNG export projection is more practical instead of utilization rate. Egyptian Natural Gas Holding Company estimates Egypt is set to begin exporting natural gas in the second half of 2019 (Farag, 2017). LNG export in 2017 and 2018 is expected to maintain the current volume. While it is expected that it will rise from 2019, reaching 6.5 bcm in 2020.

- Trinidad:
  The utilization rate is decreasing continuously year by year due to the lack of investment in upstream and a reduction of gas availability. The liquefaction plant in the country has suffered on average over 30% gas supply shortage (LNG World News, 2016). And there is no signal for significant improvement in the foreseeable future. So it is impossible for Trinidad to maintain the last five-year average utilization rate. Instead, the utilization rate will probably drop from the current 74%. Hence, 70% utilization is assumed for the next four years.

- Yemen:

  The liquefaction facility is not expected to restart in the foreseeable future due to civil war. So the utilization rate for the next four years is assumed to be 0 as it is at present.

Based on the above, projection of utilization rates is shown in Table 4.3. It is assumed that the existing liquefaction projects and incoming projects will operate with these utilization rates in the next four years.

Table 4.3: Utilization rates and production from current projects projection by country during 2017 to 2020

Capacity utilization by country	Utilization	Capacity	Production
Papua New Guinea	109.2%	6.90	7.54
Abu Dhabi	100.5%	5.60	5.63
Qatar	100.0%	77.40	77.40
Russia	98.5%	10.80	10.64
Equatorial Guinea	98.0%	3.72	3.65
Indonesia	95.1%	29.33	27.89
Malaysia	93.9%	28.60	26.87
Norway	92.1%	4.20	3.87
Australia	92.0%	65.10	59.89
USA	90.0%	10.20	9.18
Brunei	88.1%	7.20	6.35
Peru	87.6%	4.45	3.90
Nigeria	86.6%	21.15	18.32
Oman	77.2%	10.30	7.95
Trinidad	70.0%	15.10	10.57
Angola	50.0%	5.20	2.60
Algeria	47.7%	24.05	11.48
Yemen	0.0%	6.70	0.00

4.4. Capacity ramping up process of new projects

Newly commissioned liquefaction projects need to go through a ramp up process to reach stable full capacity operation. Since substantial capacity is going to come online in the next four years, it is very important to properly model the ramp up process in order to obtain reasonable results.

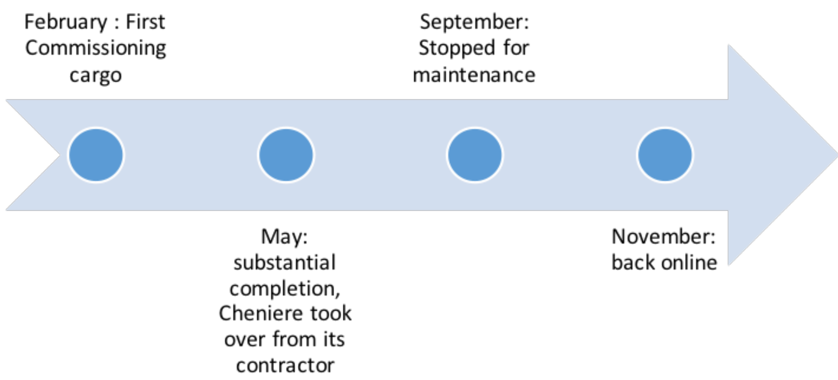


Figure 4.6: Sabine Pass train 1 ramp up process

In 2016, global liquefaction capacity increased by 36 MTPA. Sabine pass train 1 and train 2 are among the 2016 starting up projects. Sabine Pass train 1 is the first train that has started up in mainland Unite States. Its ramping up process is considered representative for the upcoming liquefaction projects, especially in the US. Figure 4.6 shows the capacity ramping up process of Sabine Pass train 1. The first commissioning cargo of train 1 was loaded on February 21(Cheniere, 2017). The LNG train reached substantial completion and Cheniere took control over the train from its contractor on May 27. In between, in total 8 commissioning cargos had been loaded. After 3 months' full capacity operation, the train shut down for maintenance in September. It came back online from the beginning of November. The amount of LNG train 1 produced in each month is exhibited in Table 4.4. The nameplate capacity for Sabine Pass train 1 is 4.5 MTPA or 5.85 bcm/y. So the monthly nameplate capacity is 0.488 bcm. It means the train almost reached its nameplate capacity in June, 2016. The production was lower in September and was totally suspended in October for maintenance. The train has resumed full capacity operation since November 2016.

Table 4.4: LNG produced in Sabine Pass train 1 during its ramping up

Month	Number of cargos	Volume (bcm)
Feb	1	0.056
Mar	3	0.269
Apr	3	0.283
May	3	0.279
Jun	6	0.465
Jul	5	0.445
Aug	7	0.534
Sep	3	0.276
Oct	0	0.000
Nov	6	0.465
Dec	7	0.591

Sabine Pass train 1's ramp-up process can be considered as a good example for other ramp-up processes, although its maintenance scheduling might be too specific for this project. In light of conciseness, a nine-month linear ramping up production is perceived to be a good assumption for other liquefaction plants. The simulated ramp-up process and the real ramp-up of Sabine Pass train 1 are compared in Figure 4.7. Although the maintenance period is not matched, the overall trend has been followed. Total LNG production from the real and the simulated process are 3.66 bcm and 3.41 bcm respectively. Thus, this simulated ramp-up process can be seen a good approximation.

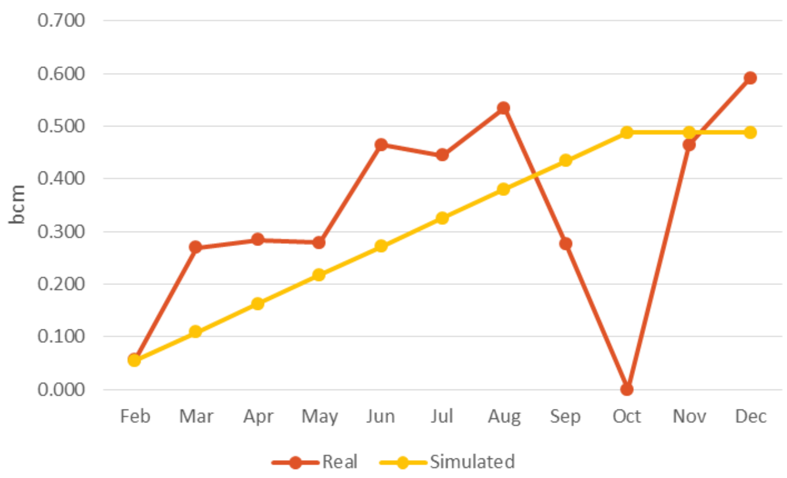


Figure 4.7: Sabine Pass train 1 LNG production in ramping up months

The estimated ramp-up process of new projects and their startup dates make it possible to forecast the monthly LNG production of each incoming project with the help of previously estimated utilization rates.

Figure 4.8 is an example of the LNG production expectation of US projects. 12 liquefaction trains are going to come online, from April 2017 with Sabine Pass T3 to Corpus Christi T2 in October 2019. Finally, these trains are going to produce 5.32 bcm LNG per month once they all reach stable operation.

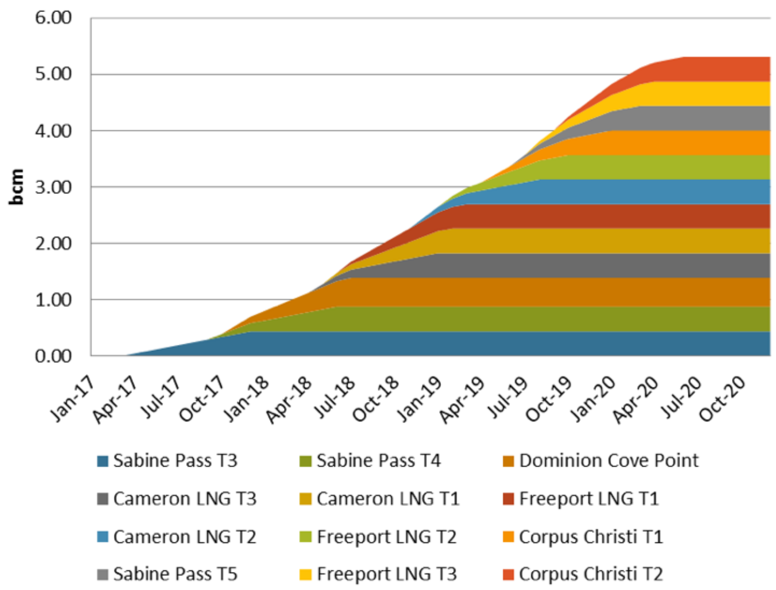
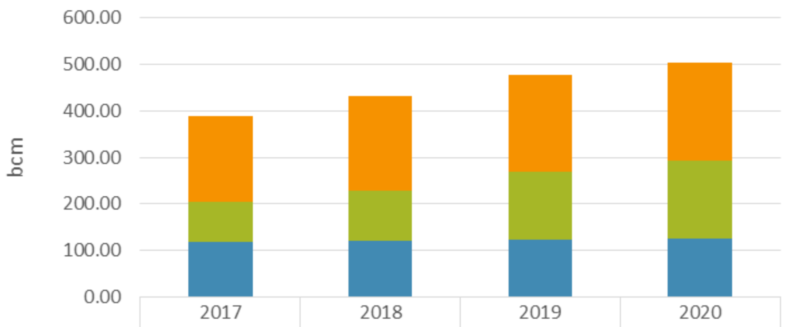


Figure 4.8: Incoming US LNG projects production projection

4.5. Conclusion on global LNG supply projection

In the previous sections, LNG production forecasts of current liquefaction projects and incoming projects have been worked out. The sum of these two should comprise the global LNG supply projection as a whole.



	2017	2018	2019	2020
Pacific	184.10	201.57	209.39	210.61
Atlantic	85.28	109.92	146.25	168.80
Middle East	119.05	119.57	122.17	124.77

Figure 4.9: Annual LNG production projection in three basins

Figure 4.9 displays annual LNG production forecast in three basins. Global total LNG production will increase from the current 340 bcm in 2016 to 388 bcm in 2017, reaching 504 bcm in 2020. Among three regions, Atlantic has the largest increase from 2017 to 2020 of about 83 bcm.

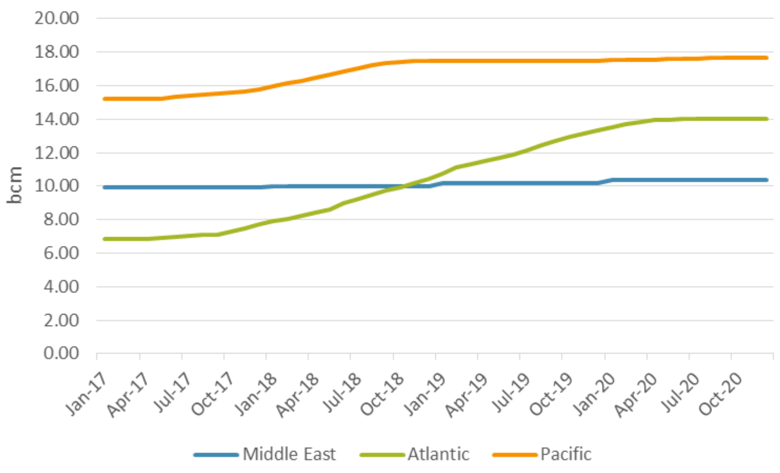


Figure 4.10: LNG production expectation over three regions

According to Figure 4.10, monthly production in Atlantic will grow most rapidly, especially during 2018 and 2019. Atlantic production is going to surpass Middle East in around November 2018.

5

Global LNG Demand Projection- the base case

This chapter is going to apply the aforesaid time series models to forecast LNG demand in each country under the business as usual case. It will be organized as follow. The first section will provide an overview of global LNG import. The second section presents exploratory analysis and time series forecasts of demand of different country in three basins. The final section interprets and summarizes the results obtained.

5.1. Global LNG import overview

In 2016, global LNG demand reached 263.6 MT, increasing by 18 MT from 2015 and stablishing a new record for global LNG demand (GIIGNL, 2017). LNG demand is expected to grow continuously in the coming years.

According to Figure 5.1, three traditional LNG import countries (or regions), namely Japan, South Korea and Taiwan, together imported more than 50% of global LNG in 2016. But their LNG demand is decreasing. The demand of other Asian countries, including China, India, Pakistan and southeastern Asian countries, is skyrocketing constantly in recent years. As a whole, Asia imports took up 73% of global LNG demand in 2016.

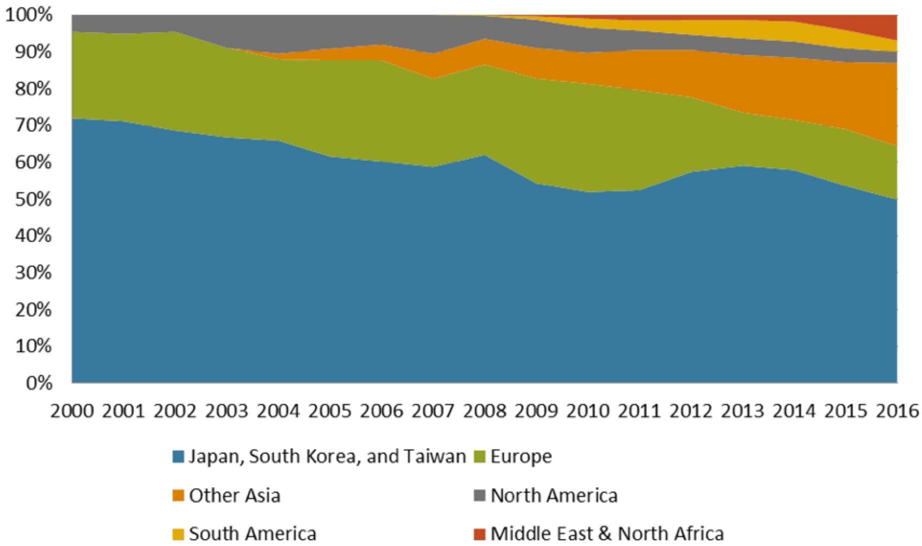


Figure 5.1: LNG import history by region

In the year 2000, 11 countries in northeastern Asia, Europe and North America imported LNG. Ever since, some more Asian, South American, Middle East and North African countries have invested in regasification infrastructures in order to be able to import LNG, increasing their share in the global LNG import market. The total number of LNG import countries increased to 39 in 2016 and the share of Europe's and North America's global LNG demand has decreased.

Japan, South Korea, China, India and Taiwan, these five Asian countries are the biggest five importers in the global LNG market at present. As the number 1 LNG import country outside Asia, Spain ranks 6th worldwide in the global LNG import market. Only countries with annual LNG import higher than 2.5 MT are included in Figure 5.2.

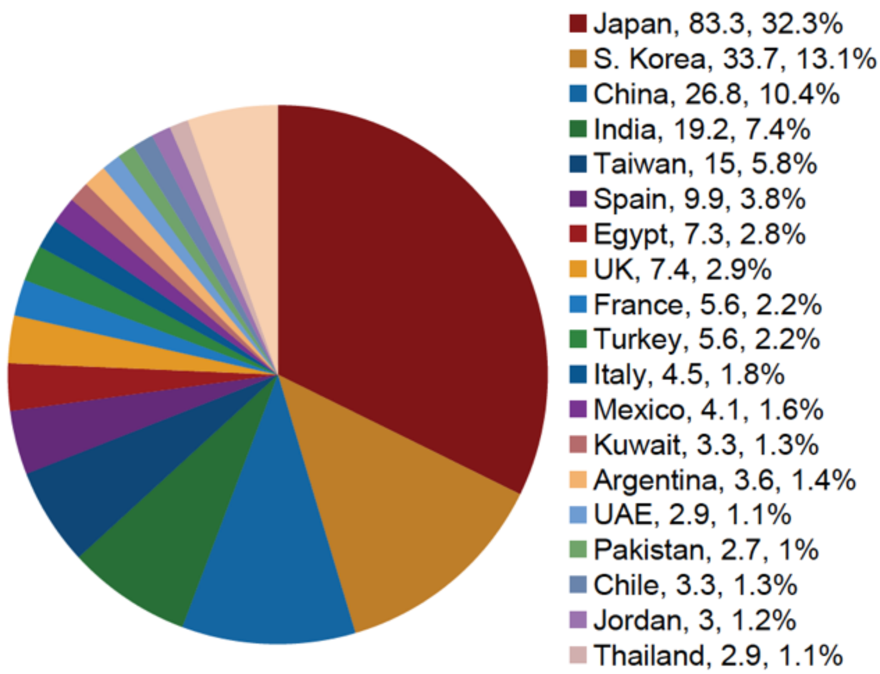


Figure 5.2: 2016 LNG Imports and Market Share by Country (in MTPA)

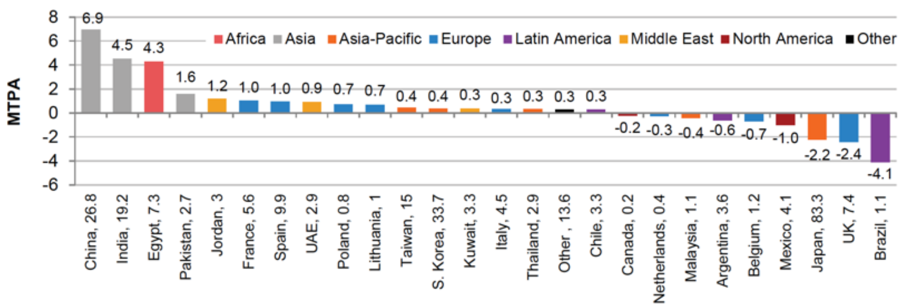


Figure 5.3: Incremental 2016 LNG Imports by Country & Incremental Change Relative to 2015 (in MTPA)

China and India led the LNG import increase in 2016, with a 6.9 MT and 4.5 MT growth respectively. Egypt, Pakistan and Jordan, although they just started importing LNG in 2015, have become the main contributors for global LNG import increase adding 7 MT in 2016 altogether. The largest demand drop was 4.1 MT in Brazil. The LNG demand decline was resulted from improved hydro-power availability in Brazil.

Figure 5.4 presents the intra-basin LNG trade in 2016. The largest global LNG trade flow route continues to be Intra-Pacific trade. It is expected to continue. Continuing growth in Chinese and Indian demand, along with Australian production, will strengthen this trade route's prominence. Almost no LNG left the Pacific basin given that the Pacific basin is the region with the greatest LNG demand.

Trade from the Middle East to the Pacific was the second-highest route by volume, because of Qatar's key role in supplying Japan and South Korea. Following an increase of LNG demand in Asian markets during the second half of 2016, much of Qatar's supply went to the Pacific, meaning Middle-East to Atlantic trade declined to just 7% of global trade in 2016. That explains UK's import decreased by 2.4 MT in the year.

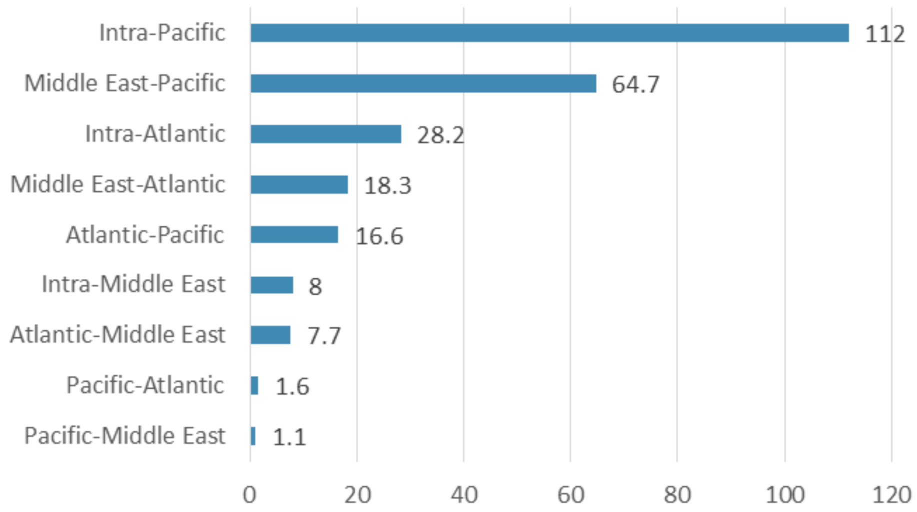


Figure 5.4: Intra-basin LNG trade in 2016

5.2. Demand forecasts in three basins by country

The raw data used for conducting this technical analysis are historical monthly LNG import data in chronological order in every LNG import country, namely a historical LNG import time series of each country since it started importing LNG to December 2016. The detailed step by step procedures for analyzing these time series are as follows.

(1) In the first place, a statistical exploratory analysis of the historical time series is conducted to understand and uncover potential intrinsic features of LNG import in the corresponding country.

(2) The second step is data preparation for time series models. The full time series data is divided into training set and validation set in order to better assess the accuracy that the time series model can achieve not only in fitting historical data but also in forecasting future. The length of validation set is 12 months.

(3) Third, the training set of the time series is fitted with standard exponential smoothing models, exponential smoothing models in adjusted forms and ARIMA models respectively. These fitted models are then used to forecast validation set.

(4) Accuracy measurements, namely MAPE, are calculated for all fitted model for both the training set and the validation set. The model with the overall highest accuracy is chosen as the final model to forecast the LNG demand to 2020.

(5) Then, seasonality of the LNG demand is extracted from the historical time series and the future forecast. These steps are realized in R, which is a widely used open source programming language and software environment for statistical computing. A generalized code template is attached in Appendix 1. However, the length of historical time series in some emerging LNG import countries is too short to conduct time series modelling analysis. For these countries, a fundamental approach based on assumptions is necessary.

5.2.1. Demand forecasts in Asia Pacific

Asia Pacific is the region with the greatest LNG demand. Excluding India and Pakistan, its import was still accounting for around 66% of LNG in global market in 2016. Four of the five biggest LNG import countries are located in East Asia. Besides, four southeastern Asia countries are increasing their LNG demand. Analysis of these countries is presented in Appendix 2.

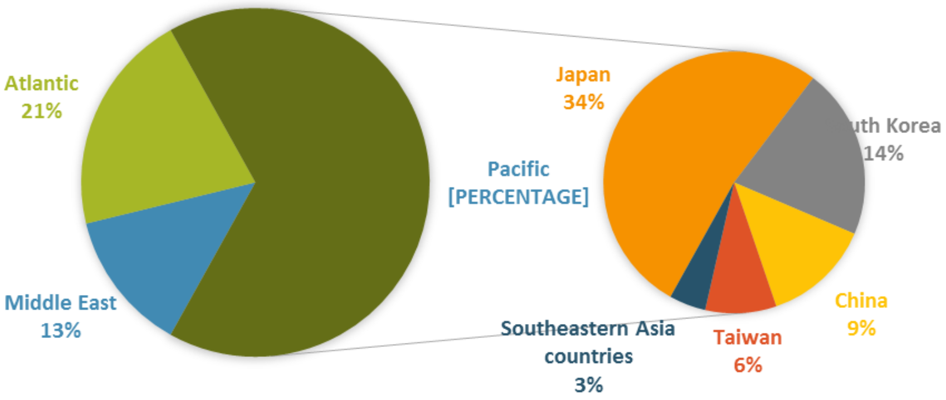


Figure 5.5: The proportion of Asia pacific countries in LNG import market

Japan

1. General situation

Japan has been the world largest LNG importer for a long time, accounting for 32% of world total LNG consumption in 2016. LNG imported to Japan was 53 MT in 2000, growing gradually every year and reaching the maximum of 88.7 MT in 2014. Thereafter, it went down slightly to 83.9 MT in 2016. The growth rate, although overall is positive, has experienced some oscillation. The highest growth rate was 11.84% in 2011. At that time Japan shut down all its nuclear power plants due to the Fukushima accident. The power gap was partly covered by gas-fired power plants, raising very significantly the demand for LNG. From 2013 onwards, the absolute growth rates became very close to zero, which implied the stabilization of LNG demand in Japan.

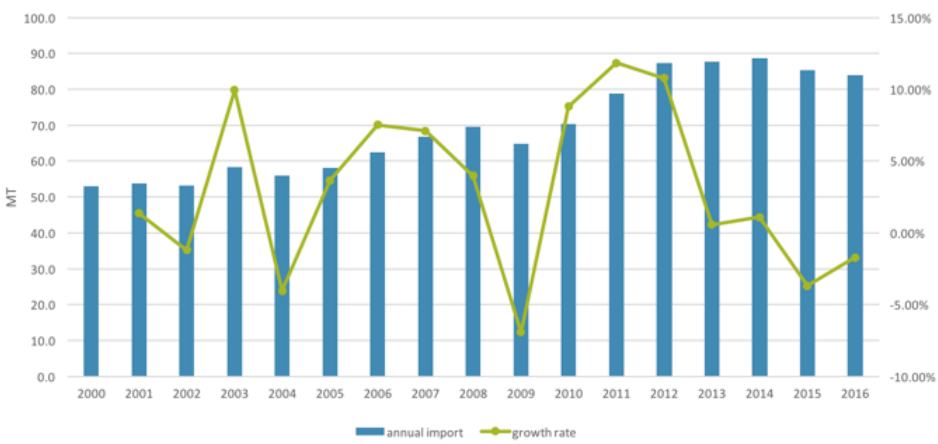


Figure 5.6: Japan yearly LNG import

A box plot of Japan's LNG imports over 12 months is presented below. LNG imports from December to March are the highest during the year in Japan, especially strong in January. It confirms graphically that winter is the peak LNG demand season in Japan.

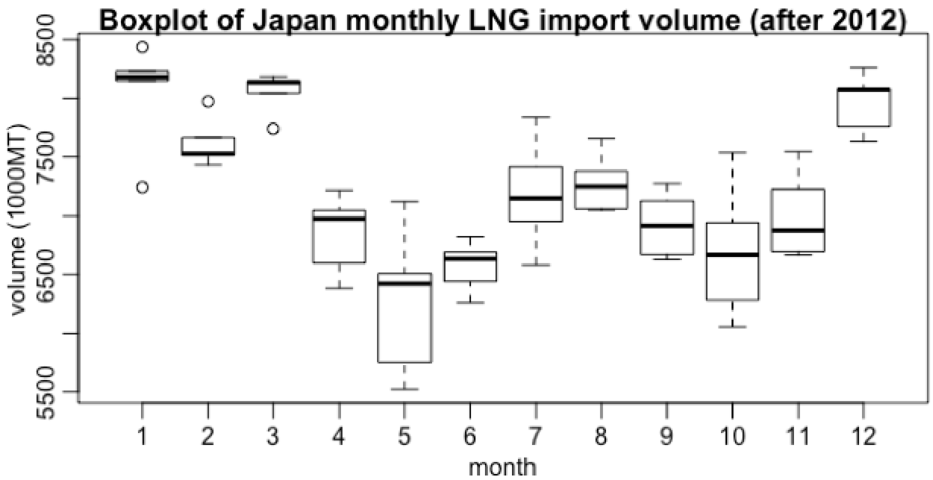


Figure 5.7: Boxplot of Japan's monthly LNG import

2. Time series decomposition

Seen from Figure 5.8, the historical monthly LNG import time series has been decomposed into three components: seasonal, trend and reminder. The grey bar on the right of each graph has the same absolute length so that it can be used to compare the scale of vertical axis of each component with that of the original time series. The smaller the grey bar is, the more influential the component is in the full time series. Thus, the trend is the most significant for LNG import in the whole time horizon. The level has increased a lot from 1995 to 2016. But the trend, even the seasonal part, becomes more stable in the last five years. The scale of the seasonal part is much bigger than the remainder part, which indicates the importance of seasonality.

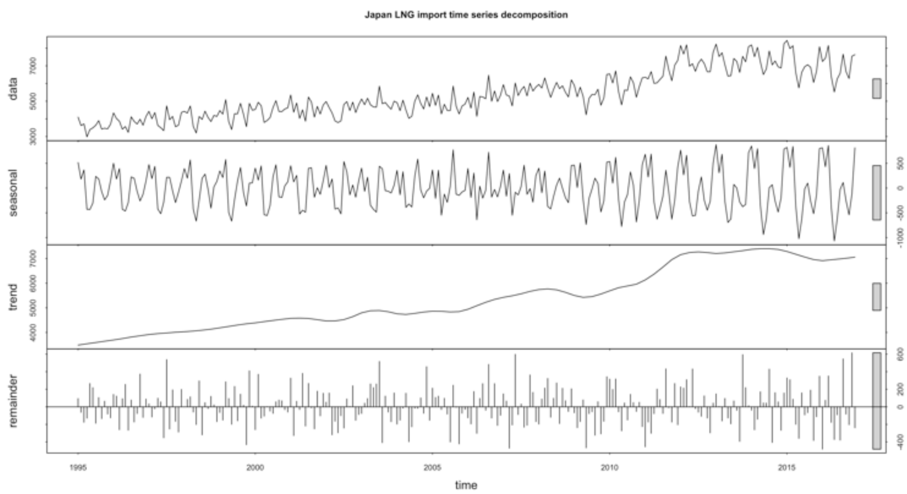


Figure 5.8: Japan's LNG import time series decomposition

3. Time series models comparison

'stlm' method has the lowest training set error and second lowest testing set error. So it is considered as the best. The prediction error for testing set is very low at 6%. Thus, time series modelling has a very good performance on forecasting Japan's LNG demand.

	training set	testing set
ets	5.62%	7.60%
stlm	4.10%	6.00%
thetaf	7.60%	6.40%
ARIMA	6.10%	5.50%

4. Forecast

The chosen model 'stlm' is applied to further forecast LNG demand in Japan for the next four years. The result indicates that Japan's annual demand will be flat overall during 2017 to 2020.

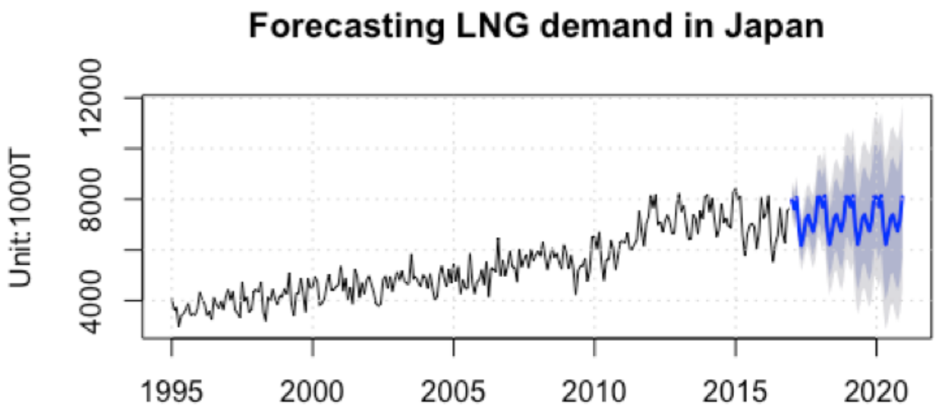


Figure 5.9: Forecasted Japan's LNG import

South Korea

1. General situation

The LNG import situation in South Korea is similar to Japan, increasing continuously from 2000 and currently tending to stabilize at 35 MT per year. The boxplot below reveals strong seasonality on LNG demand in Korea, with imports being significantly higher during winter months compared to those in summer.

Figure 5.10: South Korea's annual LNG import

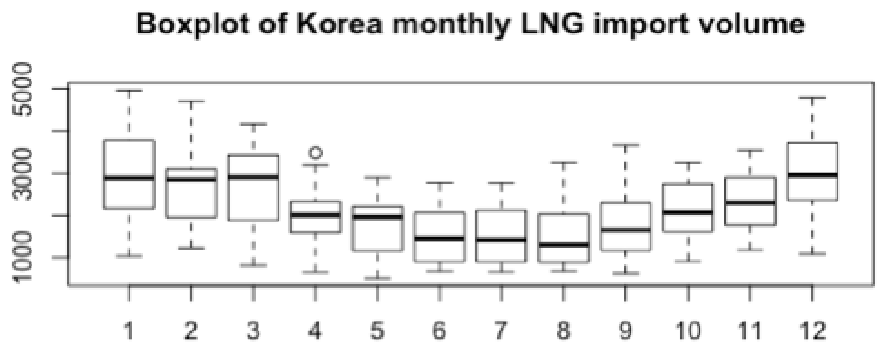


Figure 5.11: Boxplot of South Korea's monthly LNG import

2. Time series decomposition

   For South Korea, trend and seasonality have similar effect on LNG imports. The remainder part is very small usually with few exceptions.

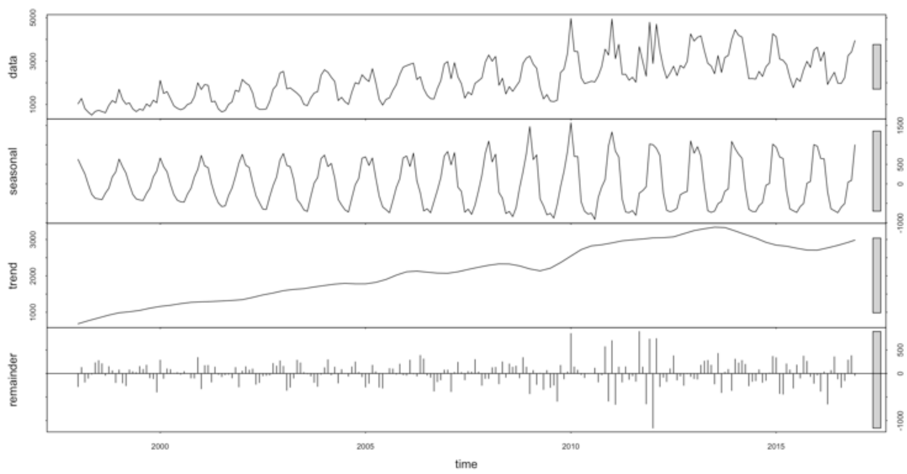


Figure 5.12: Korea's LNG import time series decomposition

3. Time series models comparison

   The "stlm" method presents the most accurate results. The accuracy is lower compared to Japan due to the effect of some very strong irregular spikes in the time series.

	training set	testing set
ets	13.48%	13.48%
stlm	10.79%	13.00%
thetaf	27.68%	12.38%
ARIMA	14.82%	13.87%

4. Forecast

   The forecasts for the next four years are very stable without trend. Annual LNG import is estimated to be sustained at around 35.5 MT.

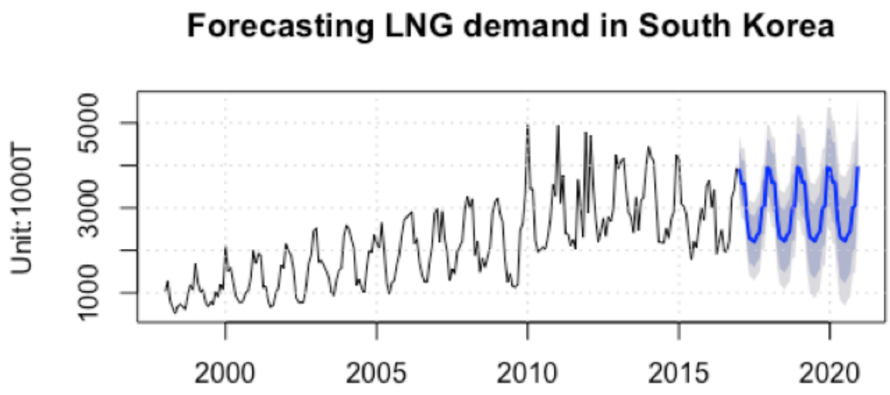


Figure 5.13: Forecasted South Korea's LNG import

China

1. General situation

China started to import LNG in 2006, much later than Japan or South Korea. One of the main differences between these countries is that China has its own indigenous gas production and imports gas through pipelines from other countries such as Turkmenistan, while Japan and South Korea rely completely on LNG for their gas consumption. China's LNG demand has grown very fast with an average annual growth rate of 30% since 2008 (extreme growth rate in 2007 excluded).

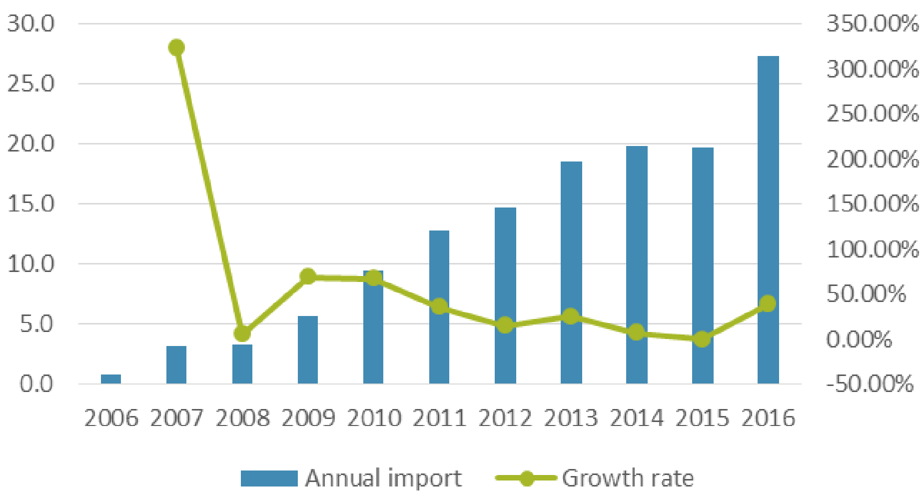


Figure 5.14: China's annual LNG import

The seasonality of LNG import in China is much subtle compared to Japan and South Korea, although imports in December and January are still slightly higher than other months. It is probably because China's territory is much bigger with different consumption features in its different regions. Seasonality features are counteracted in the total consumption figures.

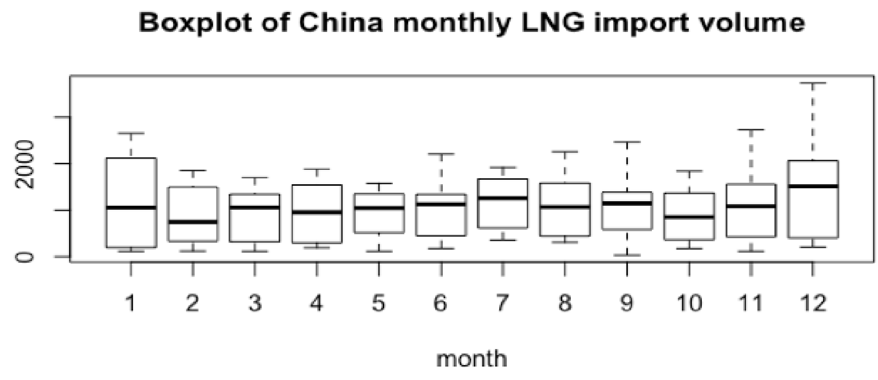


Figure 5.15: Boxplot of China's monthly LNG demand

2. Time series decomposition

   Time series decomposition also indicates that the seasonal part is as big as the error part, which is not significant in the original time series. However, demand spikes in winter has been increasingly obvious in recent years. It is because more capacity is utilized in China's northern regions for heating purpose, LNG imports are poised to become more seasonal, with demand spikes evident in the winter months (Lee, 2017).

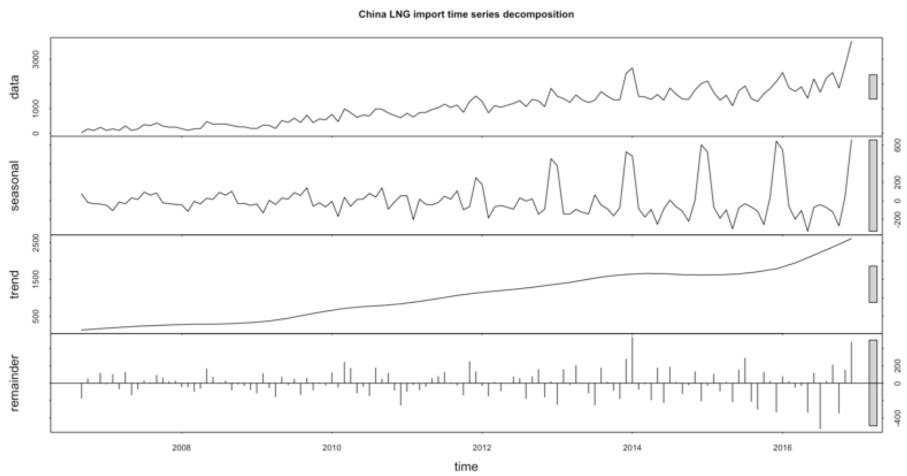


Figure 5.16: China's LNG import time series decomposition

3. Time series models comparison

   For countries where LNG covers only one flexible part of their gas demand, it becomes more difficult to forecast their LNG demand through univariate time series modelling approach. Other factors, such as governmental decisions or competitiveness of LNG prices over other alternatives, will affect the amount of LNG import.

	training set	**testing set**
ets	16.91%	18.18%
stlm	18.63%	18.69%
thetaf	21.03%	19.58%
ARIMA	21.80%	17.14%

4. Forecast

The forecast from the time series model for China's LNG demand will be rising rapidly. Annual demand will increase to 47 MT in 2020 from current 27.4 MT in 2016.

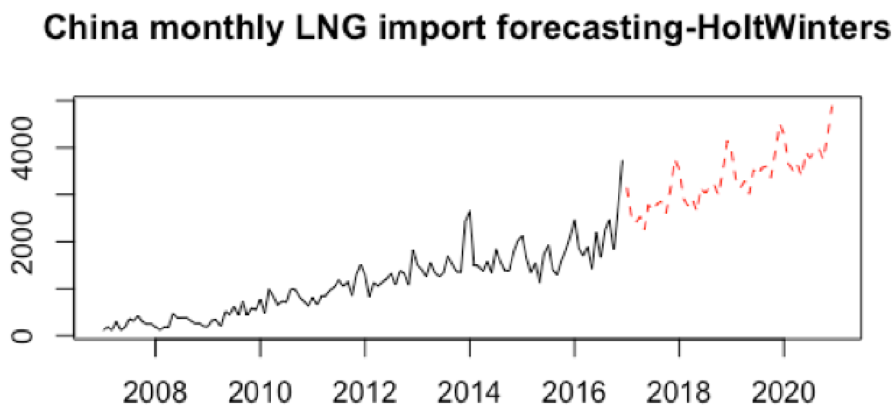


Figure 5.17: Forecasted China's LNG import

Taiwan

1. General situation

Taiwan is another traditional LNG importer with a similar situation to Japan and South Korea, lacking of other gas supplies except LNG. The current annual LNG import in 2016 was 15.3 MT. The growth rates since 2012 have slowed down to below 5%.

Figure 5.18: Taiwan's annual LNG import

Opposite to Japan and South Korea, Taiwan imports more LNG during summer. The climate is warmer as it is closer to the equator. Electricity consumption is higher in summer in Taiwan due to the need for cooling.

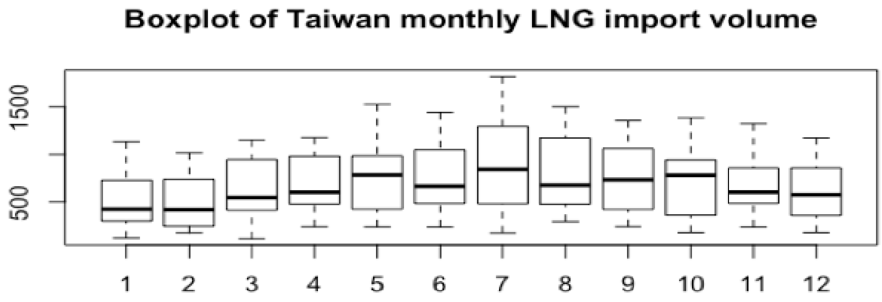


Figure 5.19: Boxplot of Taiwan's monthly LNG demand

2. Time series decomposition

Seasonality feature is very obvious with sharp spikes in summer while it is less significant compared to trend. The upward trend is very strong. It seems that future LNG imports will continue growing.

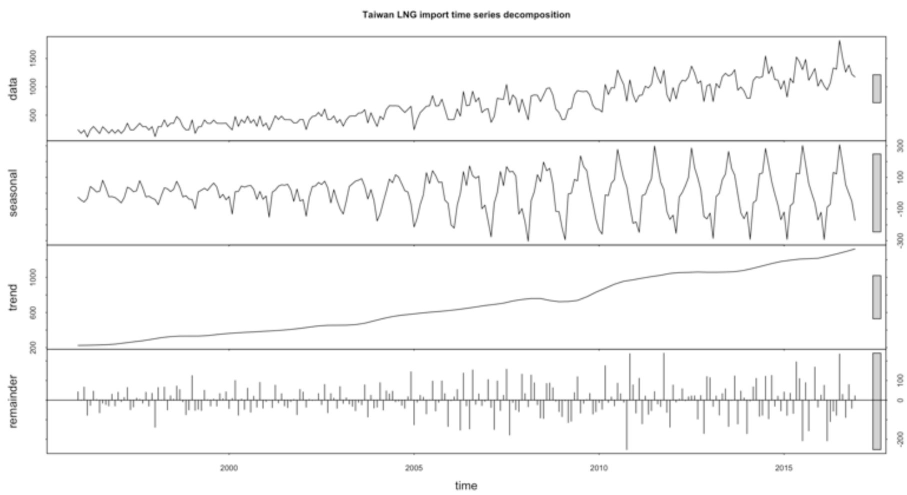


Figure 5.20: Taiwan's LNG import time series decomposition

3. Forecast

However, this growth will not be materialized considering the constraint of available regasification capacity. Taiwan has two regasification plants with a total capacity of 14.4 MTPA. The current 15.3 MT annual import has already exceeded the nominal capacity. Taiwan is currently expanding the capacity of one of its regasification plant, which will add 1.5 MTPA additional capacity and will be on line in 2019. Thus, the LNG import before 2019 will be the same as 2016, increasing to 16.8 MT in 2020. The new future projection is presented in Figure 5.21.

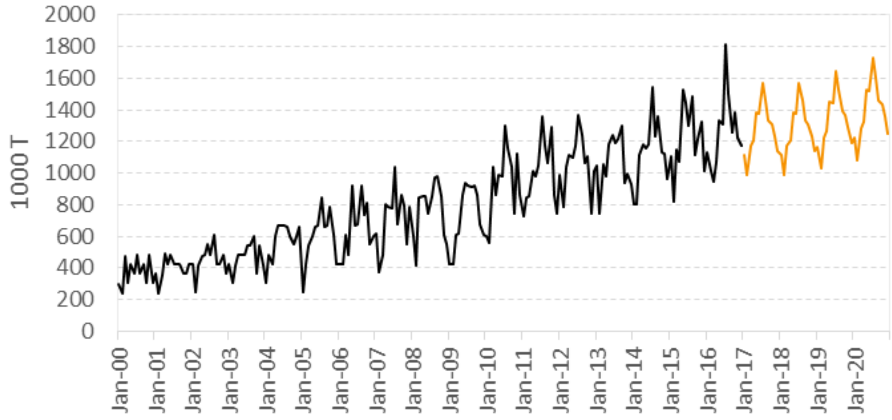


Figure 5.21: Time series model forecasted LNG demand in Taiwan

5.2.2. Demand forecasts in Middle East

Middle East is a region that traditionally plays a key role in LNG export market, hosting the world largest LNG exporter (Qatar). But recently, the emerging demand from this region has become an important driving force of global LNG demand increase. LNG import from Middle East constituted 13% of the global total imports in the last three years. Countries importing LNG in this region are India, Turkey, Egypt, Kuwait, UAE, Jordan, Pakistan and Israel. Although India and Pakistan are Asian countries, they are closer to Middle East geographically regarding LNG shipping. India imported 6.2% of global total LNG volumes, being the largest importer in this region. Turkey is following India as the second largest LNG import country, taking 2.1% of global LNG in 2016. The shares of the rest countries are all below 2%. The forecasts of these countries, except for Egypt and Pakistan, are presented in the Appendix 2 due to their relatively small influence on global total demand. The reasons to emphasize Egypt and Pakistan are:

- Egypt is going to experience major changes in its LNG import in the near future.
- Pakistan, although its share of global LNG demand is limited, it is considered as one of the key growing markets.

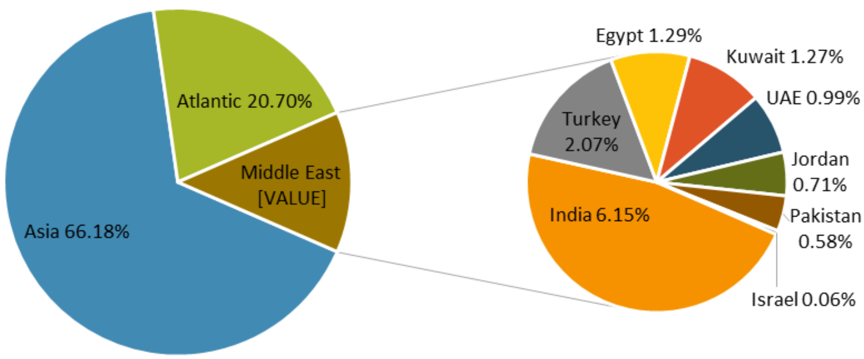


Figure 5.22: LNG Import Percentage of countries in Middle East

India

1. General situation

India is the fourth largest LNG importer worldwide. Similar to China, it has increased its LNG imports very significantly since 2004 with an average growth rate of 15.8% (excluding the extreme high value in 2005), reaching 20.4 MT in 2016. No monthly seasonality can be detected from the monthly LNG import. Time series decomposition confirms that the seasonal component is the smallest and unimportant in the whole time series.

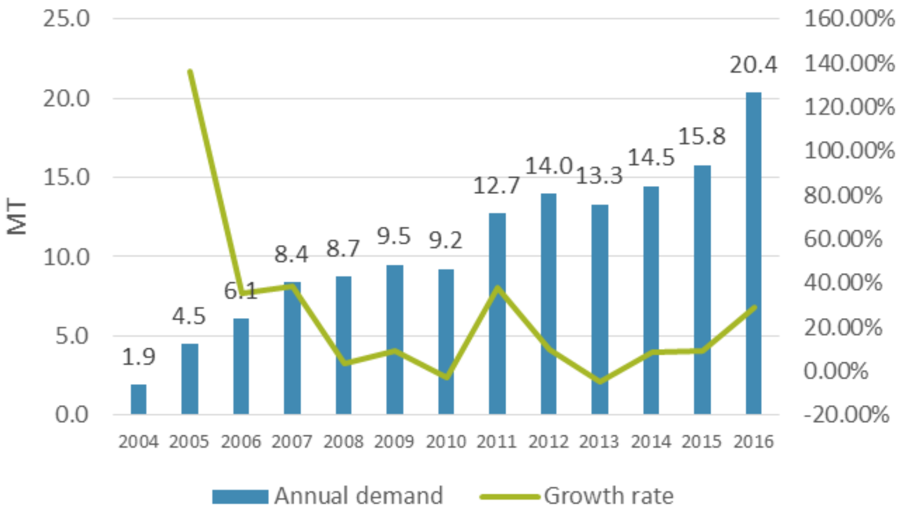


Figure 5.23: India's annual LNG import

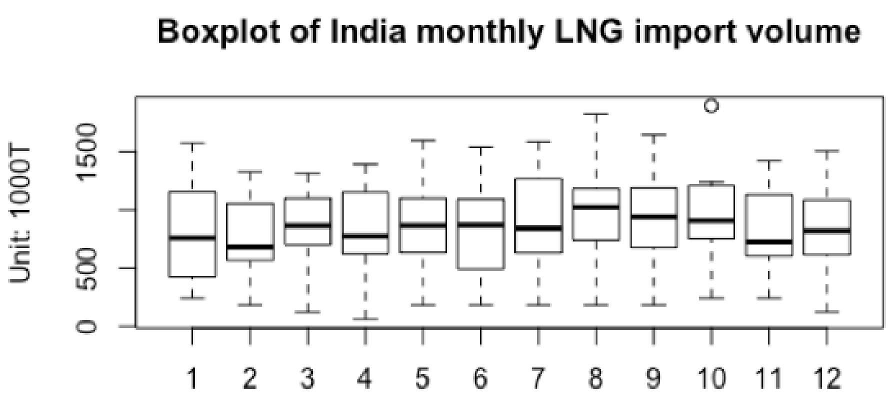


Figure 5.24: Boxplot of India's monthly LNG import

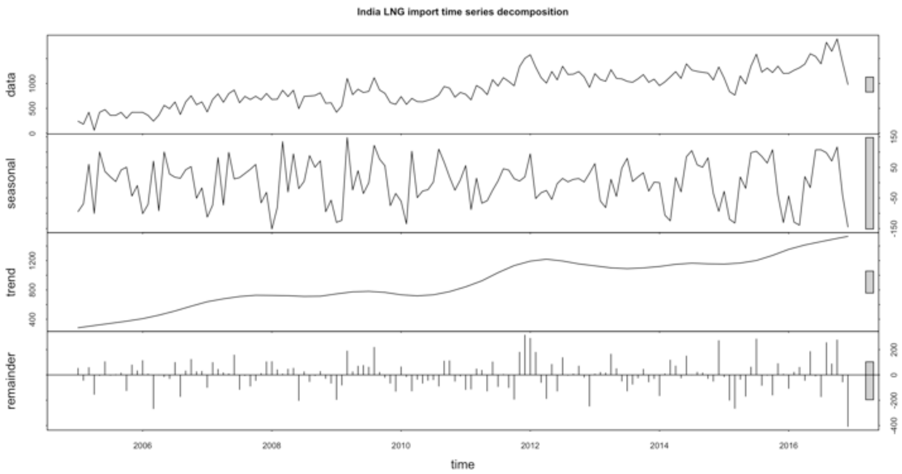


Figure 5.25: India's time series decomposition

2. Time series models comparison

ARIMA model is considered as a good fit in this case. Due to its weak seasonality, a non-seasonal ARIMA (1,1,1) model is proved suitable.

	training set	testing set
ARIMA	19.00%	14.30%
ets	18.90%	16.40%
stlm	15.80%	17.80%
thetaf	19.00%	14.20%

3. Forecast

Import in India is forecasted to grow linearly over 2017 to 2020, given its negligible seasonal effect.

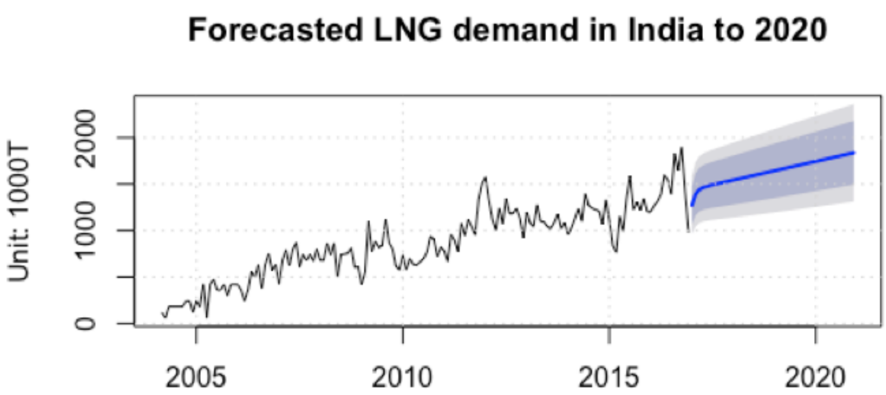


Figure 5.26: Forecasted India's LNG demand

Turkey

1. General situation

LNG import in Turkey fluctuated strongly over the past 17 years without a clear trend, which can be verified in the time series decomposition as the trend is the smallest component. Annual demand in the recent three years has stabilized at around 5.5 MT.

A strong monthly pattern with significant higher demand in months from November to March can be seen in Figure 5.28. Demand spikes have become more apparent in the last three years (see Figure 5.29).

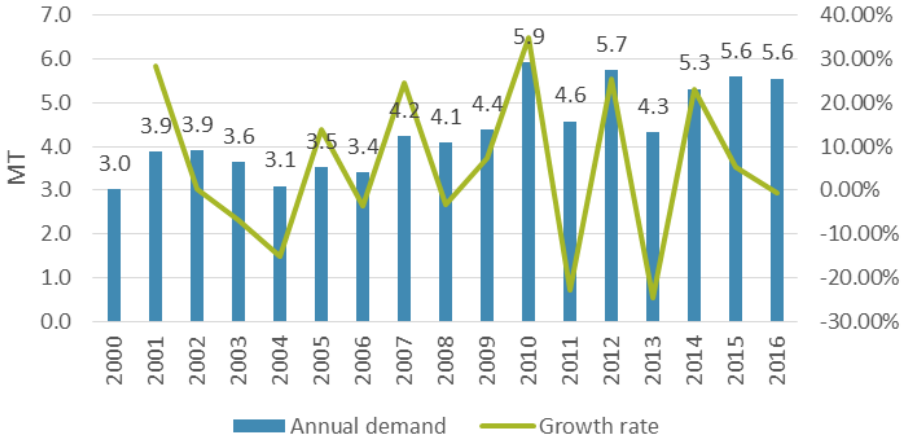


Figure 5.27: Turkey's annual LNG import

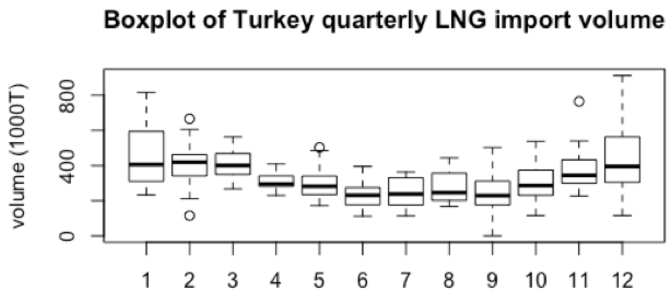


Figure 5.28: Boxplot of Turkey's monthly LNG import

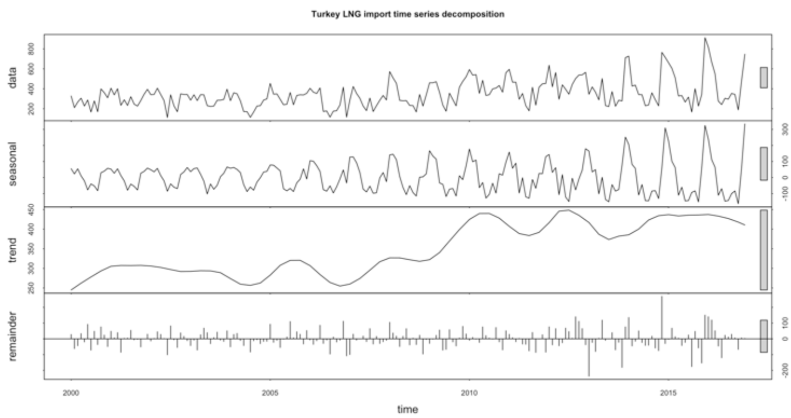


Figure 5.29: Turkey's time series decomposition

2. Time series decomposition

	training set	testing set
ARIMA	23.12%	19.76%
ets	22.60%	27.30%
stlm	17.49%	20.49%
thetaf	30.32%	28.56%

ARIMA model, which has the lowest testing set error and modest training set error, is chosen as the model to forecast Turkey's future LNG demand.

3. Forecast

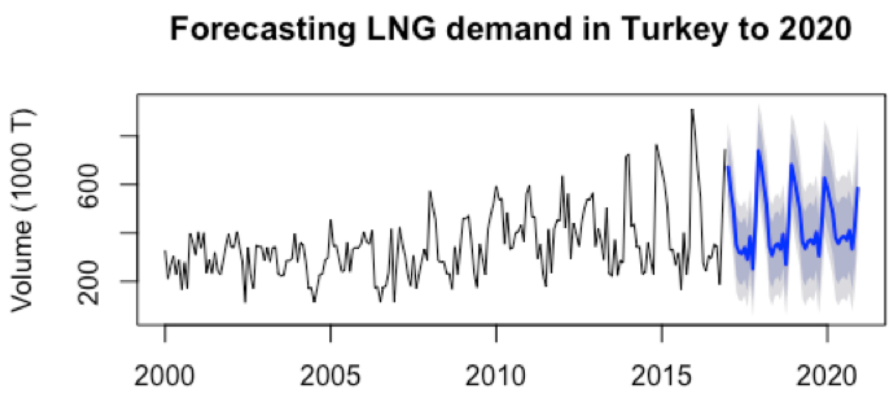


Figure 5.30: Forecasted Turkey's LNG demand

The ARIMA model forecasting output suggests that demand in Turkey is going to repeat the current monthly patterns with stable annual demand.

Egypt

1. General situation

Egypt used to be a LNG exporting country. Due to issues in its upstream gas supply and an increase of its own demand, liquefaction plants in Egypt have been shut down and the country began to import LNG to satisfy its own gas demand from 2015. In this case, the monthly import time series is quite short, which makes time series modelling approach unfeasible. Instead, a basic fundamental method is used to forecast future LNG demand. According to the monthly import patterns in 2016, it seems that demand in summer is higher than during the rest of the year. This pattern is in accordance with other countries in this region like UAE and Kuwait. So the monthly seasonality is assumed to be similar in the future.

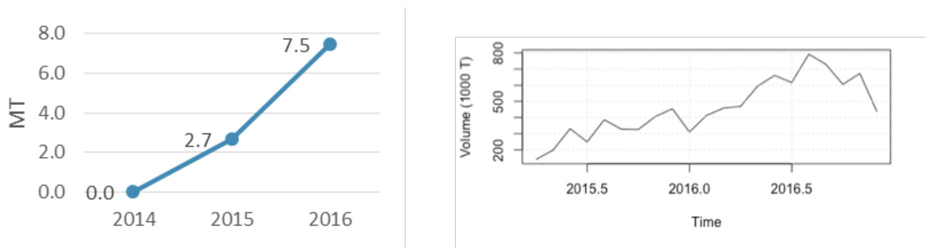


Figure 5.31: Egypt's annual and monthly LNG import

2. Forecast

LNG import in Egypt is expected to decrease as new gas fields will enter their production phase in the near future. Production from the East Mediterranean's giant Zohr gas field is expected to begin during Q4 2017. Zohr gas production will ramp up over 2019-2020. Egypt's indigenous gas production will allow the country to reduce its LNG imports. Egypt has concluded deals to import more than 100 cargoes or about 6.5 MT in 2017. LNG imports will gradually decrease from 6.5 MT in 2017 over the next four years.

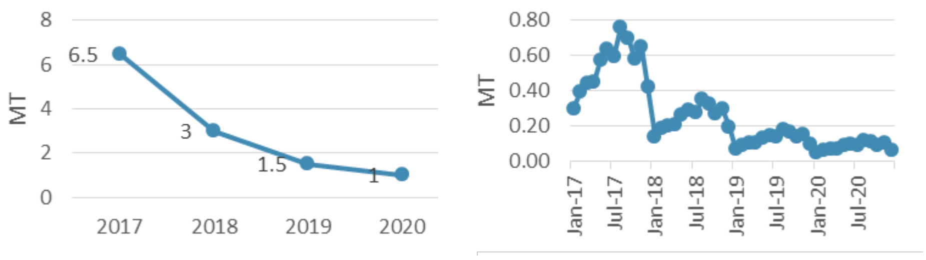


Figure 5.32: Forecasted Egypt's LNG demand

Pakistan

1. General situation

The same as Egypt, Pakistan started to import LNG in 2015. Pakistan's LNG import in 2016 was 3.3 MT through its only FSRU. Pakistan's LNG demand is expected to see substantial growth once the new Floating Storage Regasification Units with a total regasification capacity of 14.3mtpa enter operations in 2017 and 2018. Seasonality is unimportant for Pakistan, the same as for India.

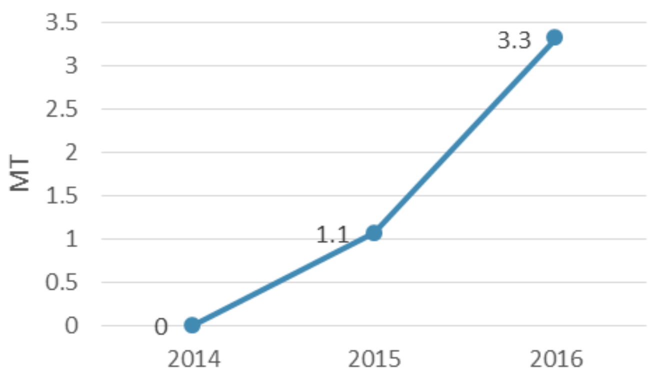


Figure 5.33: Pakistan's annual LNG demand

2. Forecast

Pakistan could become a LNG import market for 10 to 13.5 MTPA by 2018 (POTEN & PARTNERS, 2016). The assumption for LNG import in the next four years is shown as follows. The monthly pattern will be flat as lacking of seasonality.

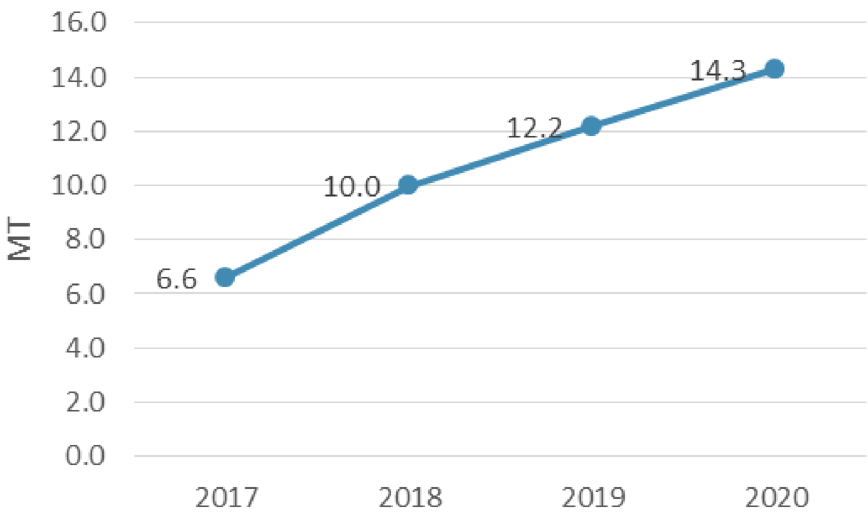


Figure 5.34: Forecasted Pakistan LNG demand

5.2.3. Demand forecasts in Atlantic basin

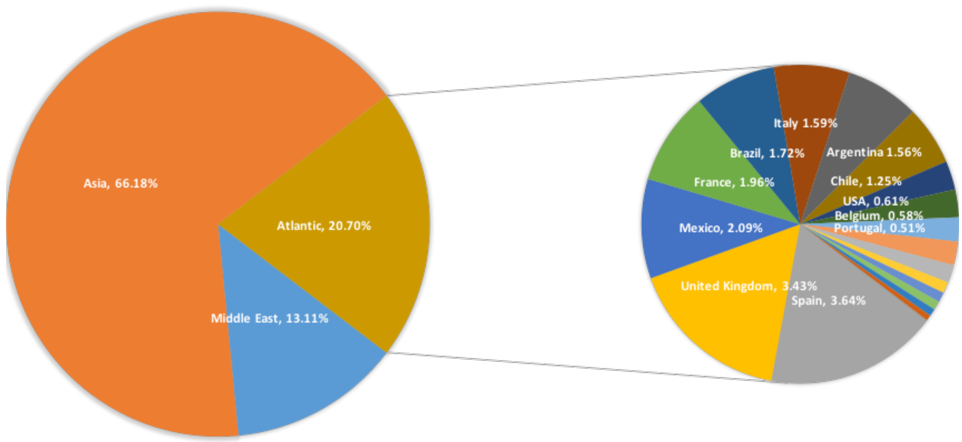


Figure 5.35: The proportion of Atlantic countries in LNG import market

The Atlantic basin, which takes up 20.7% of global total LNG import, has the largest number of LNG importing countries. In total 19 countries, mainly in Europe and Latin America, have imported LNG in 2016. The share each country has in global LNG market is very small. Only three countries, namely Spain, United Kingdom and Brazil, have a share greater than 2%. These three countries will be analyzed in detail. The analysis for the remaining countries is in the Appendix 2.

Spain

1. General situation

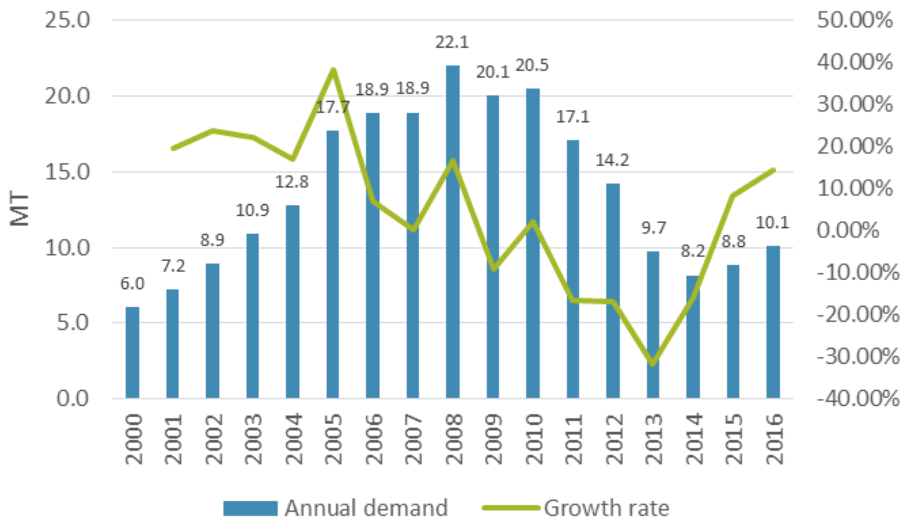


Figure 5.36: Spain's annual LNG demand

The LNG import in Spain has experienced strong growth from 2000 to 2008, sharp decline from 2009 to 2014 and a rebound since 2015. The demand in 2016 was 10.1 MT while the historically highest demand was 22.1 MT in 2008. Modest seasonality can be observed with slightly higher LNG demand in November, December and January compared to other months.

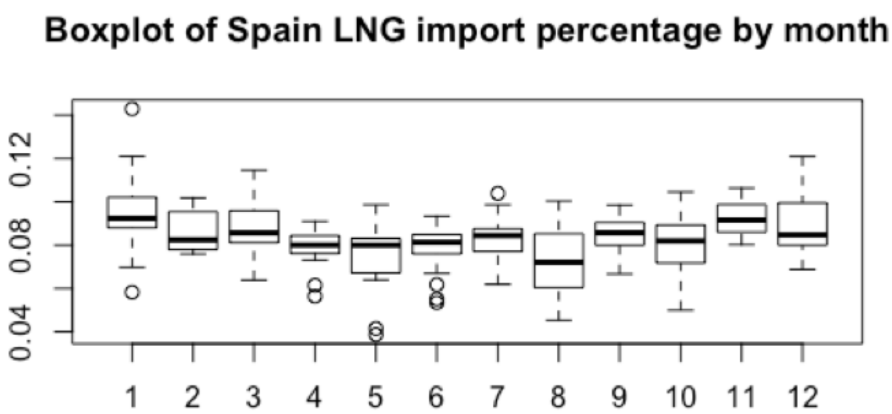


Figure 5.37: Boxplot of Spain's monthly LNG import

2. Time series decomposition

Time series decomposition confirms that seasonality is minor for Spain's LNG import. Instead trend is and will be playing a significant role to foresee LNG import.

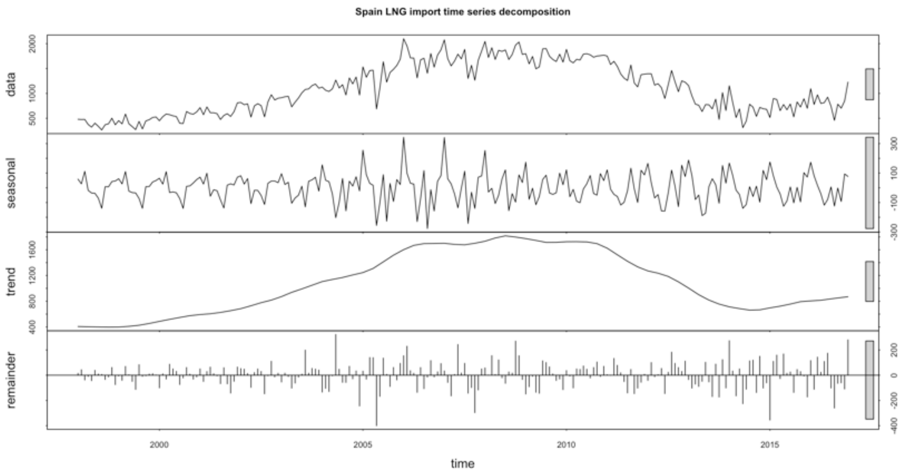


Figure 5.38: Spain's time series decomposition

3. Time series models comparison

The errors using thetaf method are lower compared to other methods. And the performance in training and testing set is stable and consistent. So thetaf method will be applied to forecast the future demand in Spain.

	training set	testing set
ARIMA	13.70%	17.60%
ets	12.80%	16.50%
stlm	10.00%	23.50%
thetaf	14.20%	15.90%

4. Forecast

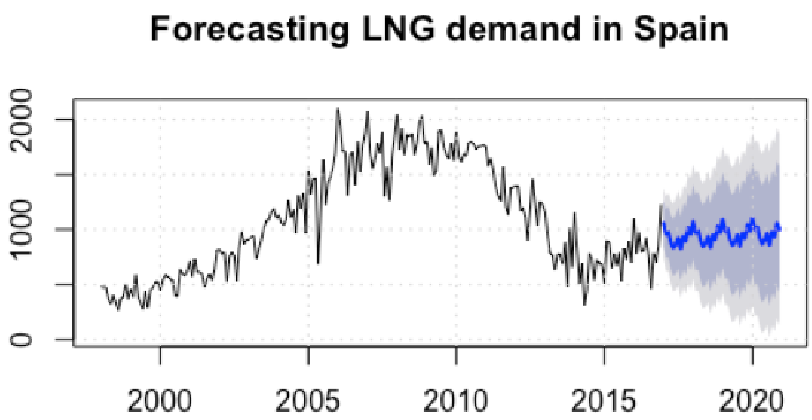


Figure 5.39: Forecasted Spain's LNG demand

According to this model, the demand in Spain is going to rise, but in a very conservative manner. The demand in 2020 is expected to be 12.5 MT.

United Kingdom

1. General situation

One apparent characteristic of UK demand is that the annual LNG import can change very quickly, as the massive increase from 2008 to 2009. The reason is gas market in UK is quite liquid. NBP is a virtual trading location for the sale and purchase of natural gas in UK, which has been an international gas price benchmark. UK is acting as the balancing market in Europe. Any excess LNG is able to be sent to UK, competing in the gas market there. For this reason, LNG import in each month is more affected by market situation in the whole region rather than UK's physical gas consumption. As a result, no seasonality can be seen for monthly LNG imports. Trend for the future is not possible to foresee.

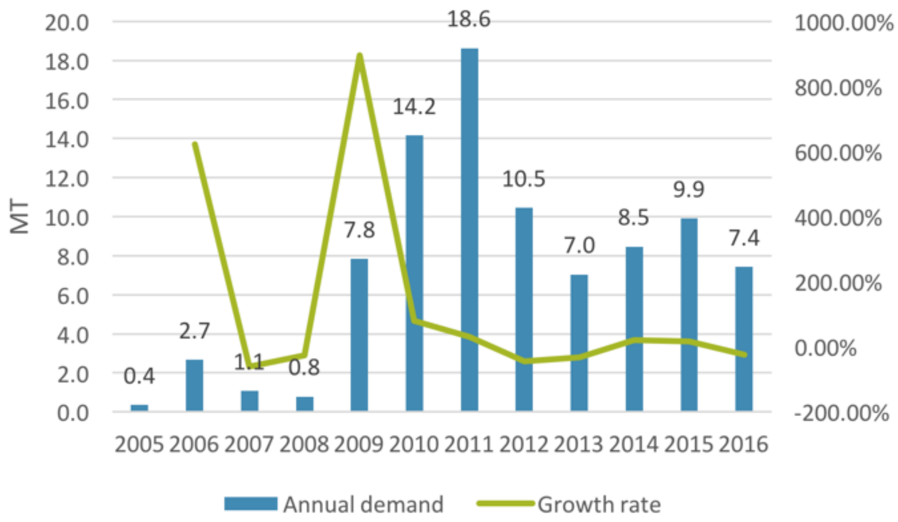


Figure 5.40: UK's annual LNG demand

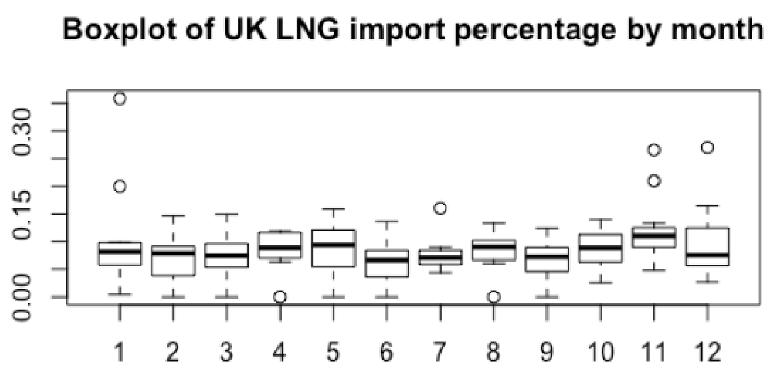


Figure 5.41: Boxplot of UK's monthly LNG import

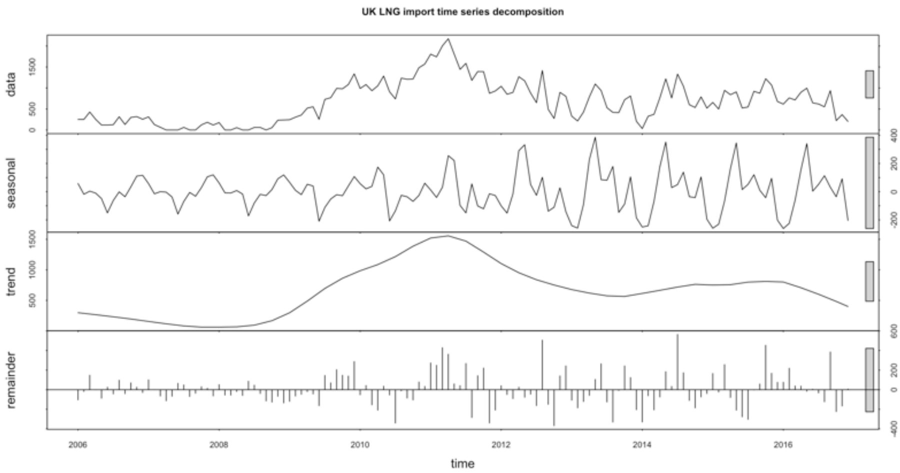


Figure 5.42: UK's time series decomposition

2. Forecast

The assumption for the base case scenario is that monthly LNG delivered to UK in the future will be the same as the present and stable.

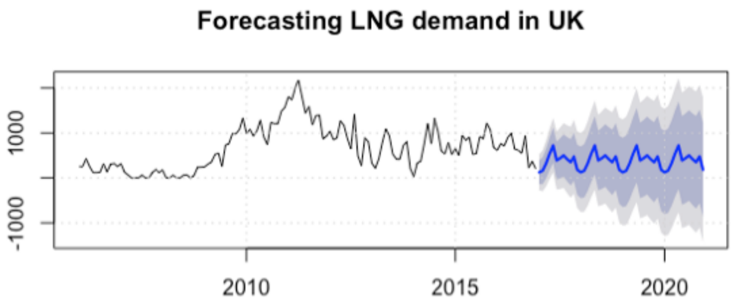


Figure 5.43: Forecasted UK's LNG demand

Mexico

1. General situation

Mexico LNG demand experienced a smooth growth till 2014 and started to decline. The current trend is expected to continue in the future because of increasing pipeline connection with US. US is going to increase gas export to Mexico. Given this information, only historical time series from 2013 onwards can represent this feature and hence only this part is utilized to fit time series models. The boxplot of monthly import implies that average import in summer is slightly higher. This effect is weak according to time series decomposition.

Figure 5.44: Mexico's annual LNG demand

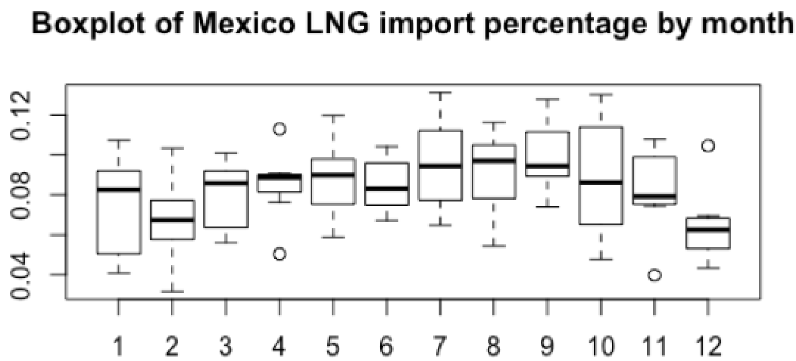


Figure 5.45: Boxplot of Mexico's monthly LNG import

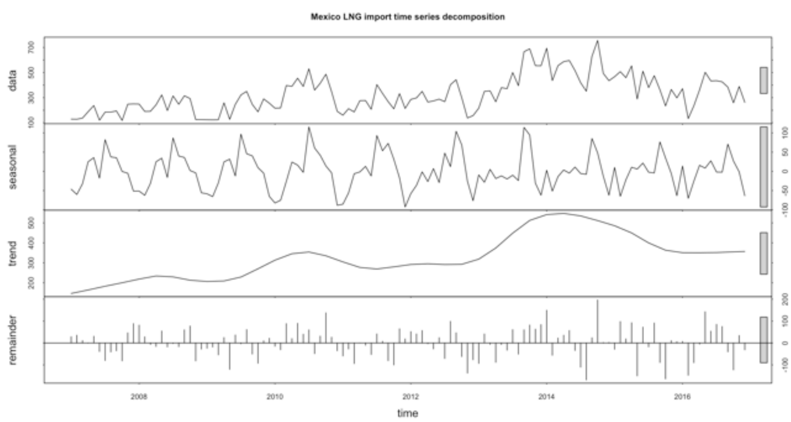


Figure 5.46: Mexico's time series decomposition

2. Forecast

	training set	testing set
ARIMA	23.48%	44.62%
ets	26.00%	28.80%
stlm	20.80%	33.10%
thetaf	22.07%	33.01%

Exponential smoothing has the best performance in forecasting LNG demand in Mexico. The annual LNG demand in Mexico decrease continuously to 2.7 MT in 2020.

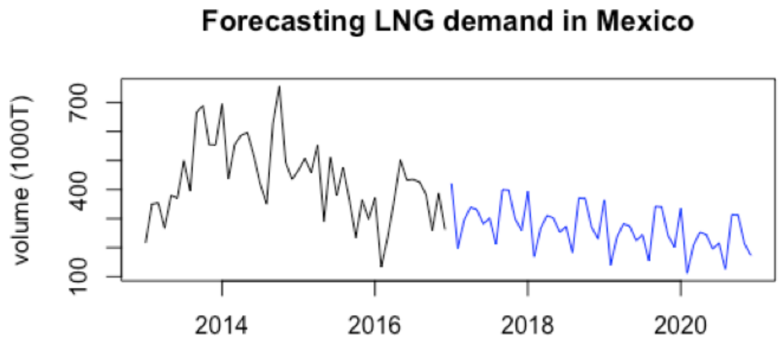


Figure 5.47: Forecasted Mexico's LNG demand

5.3. Summary on technical analysis of future LNG demand

1. Pacific basin:

   LNG demand in Asia Pacific is expected to grow with an expected average growth rate of 6%, reaching 213.5 MT in 2020 from 169.4 MT in 2016. The LNG demand annual growth rate will be the highest in 2017 reaching 9.3%, with an increase of 15.7 MT.

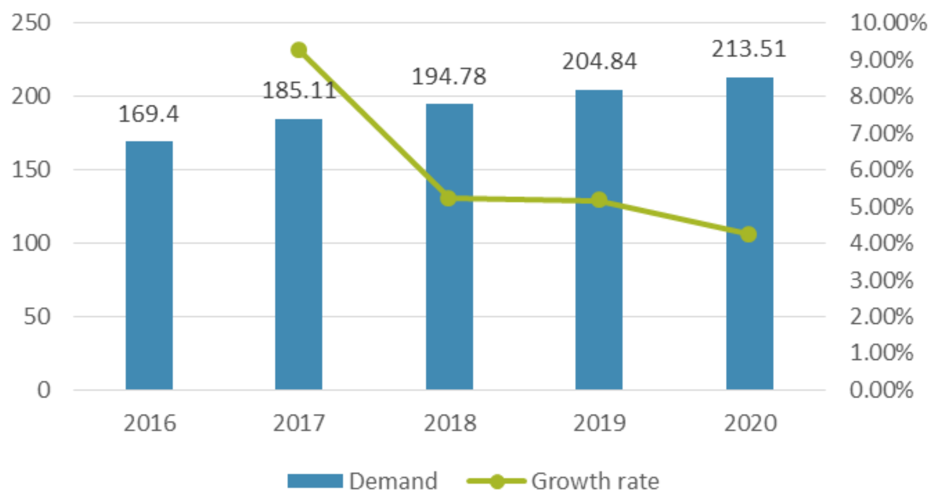


Figure 5.48: Forecasted Asia Pacific annual demand

The monthly LNG demand in Asia Pacific has a modest growing trend. As a whole, Asia Pacific countries have the highest LNG demand in December and January in a year and the lowest is in May. The difference between import of the highest and lowest month is around 5 MT as of 2016.

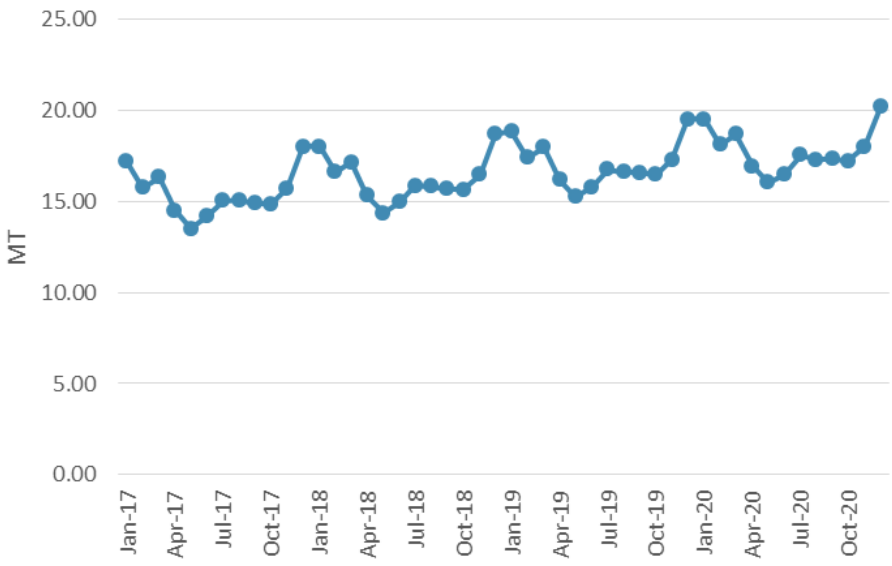


Figure 5.49: Forecasted monthly LNG demand in Asia Pacific

2. Middle East:

The annual demand in the Middle East is expected to increase by 12 MT from 47.7 MT in 2016 to 59.7 MT in 2020. These countries in total import 4 to 5 MT per month. The highest monthly demand throughout a year is in September while the lowest is in February.

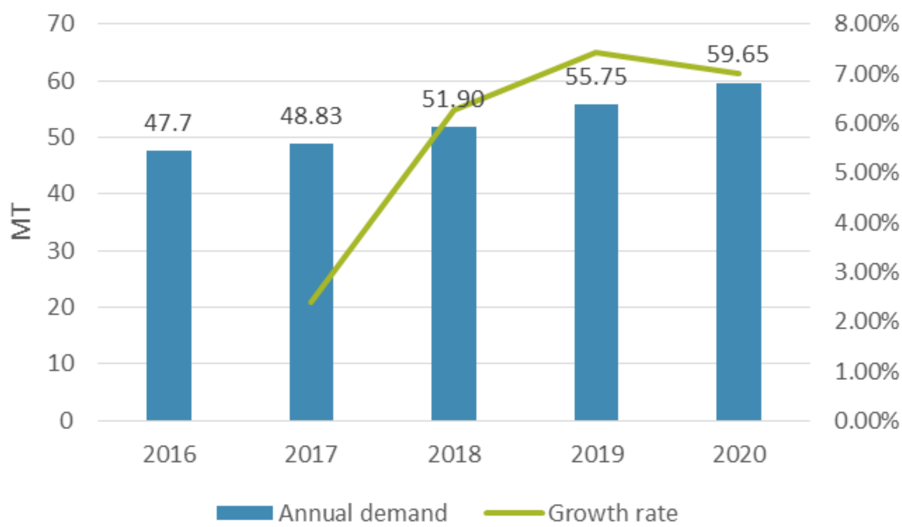


Figure 5.50: Forecasted Middle East annual LNG demand

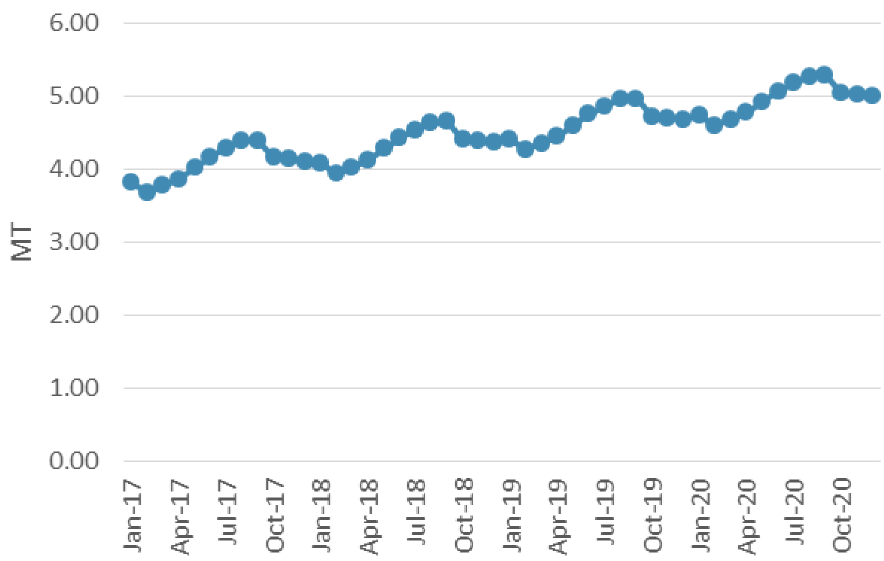


Figure 5.51: Forecasted monthly LNG demand in Middle East

3. Atlantic basin:

LNG demand in the Atlantic hardly sees any growth over the next four years. As a whole, LNG demand in May is the highest and in December is the lowest during a year. First, it is because South American countries import more in their winter (May) and less in their summer (December). Second, some European countries like UK, Belgium and the Netherlands act as balancing market for LNG, they also receive less volume in December.

Figure 5.52: Forecasted Atlantic annual LNG demand

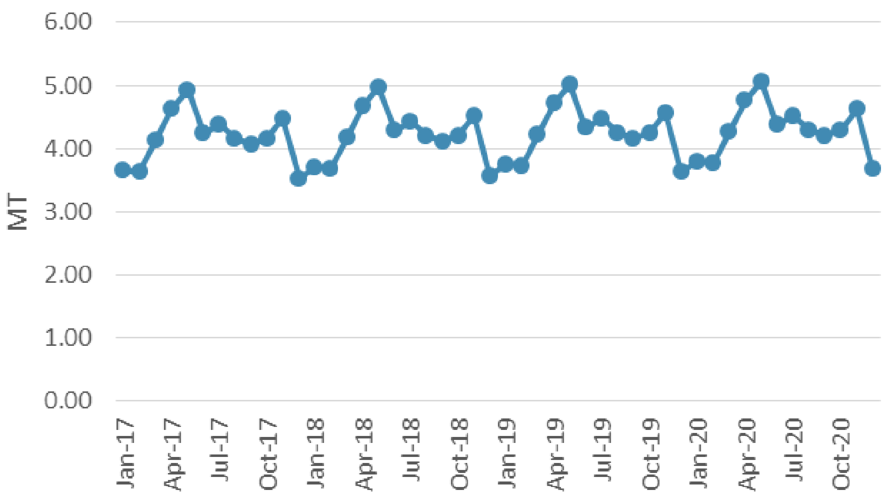


Figure 5.53: Forecasted Atlantic annual LNG demand

4. Global LNG demand:

Forecasted global LNG demand is shown in Figure 5.54 and Figure 5.55. Annual demand will rise to 324.8 MT in 2020, increasing by 61.8 MT from 263 MT in 2016. It is expected that annual demand in 2017 will witness a 20 MT growth from that of 2016, which is the highest annual increase over the next four years. Monthly seasonality becomes much milder when considering the three basins altogether. Demand in December and January is slightly higher than other months.

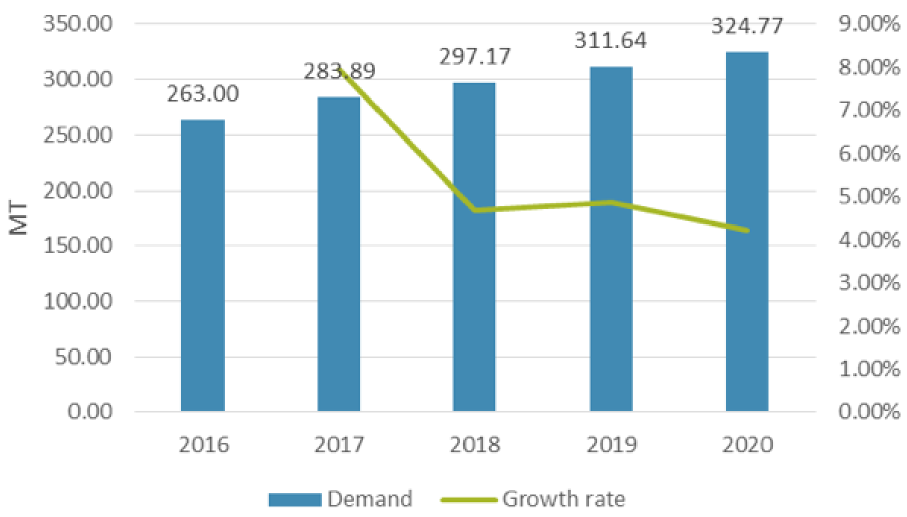


Figure 5.54: Forecasted global annual LNG demand

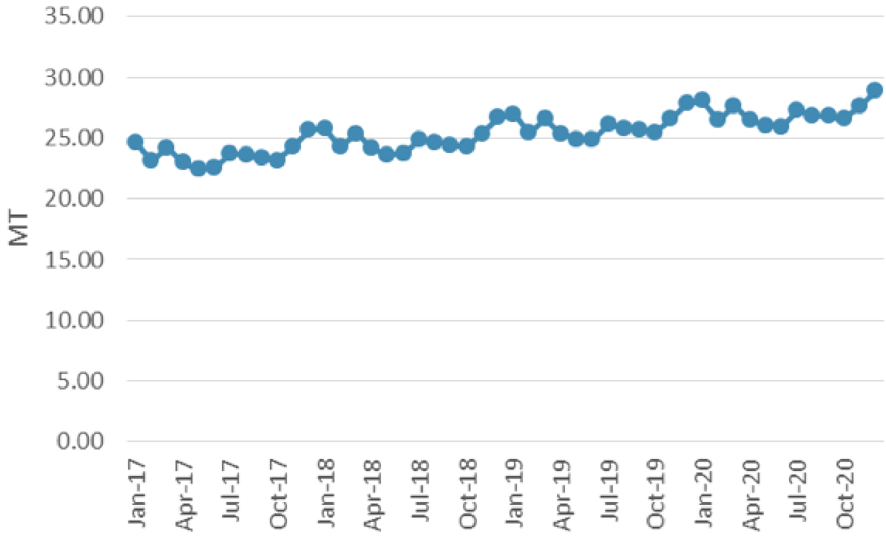


Figure 5.55: Forecasted global monthly LNG demand

6

LNG supply and demand forecasting results

1 LNG supply and demand forecasting results Global LNG supply forecasted in chapter 4 is compared with the projected LNG demand of the base case scenario in chapter 5. In the base case scenario, LNG supply will surpass the expected demand each year from 2017 to 2020 (Figure 6.1). The oversupply will grow from 14.9 MT in 2017 to 63 MT in 2020 (Figure 6.2). Therefore, liquefaction plants with uncommitted production will face fierce competition marketing their LNG. As discussed in Chapter 2, Europe, considered as a market of last resort will see a significant increase of its LNG imports.

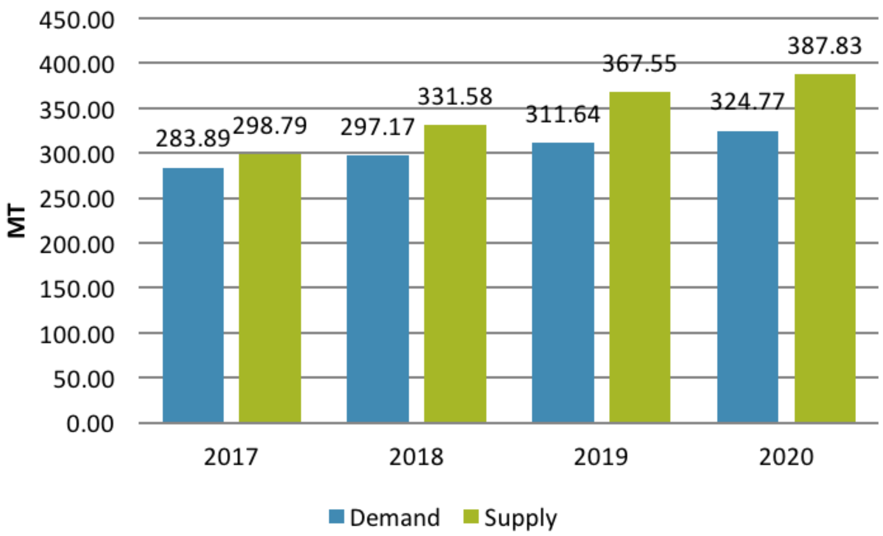


Figure 6.1: Forecasted worldwide supply and demand balance –base case scenario

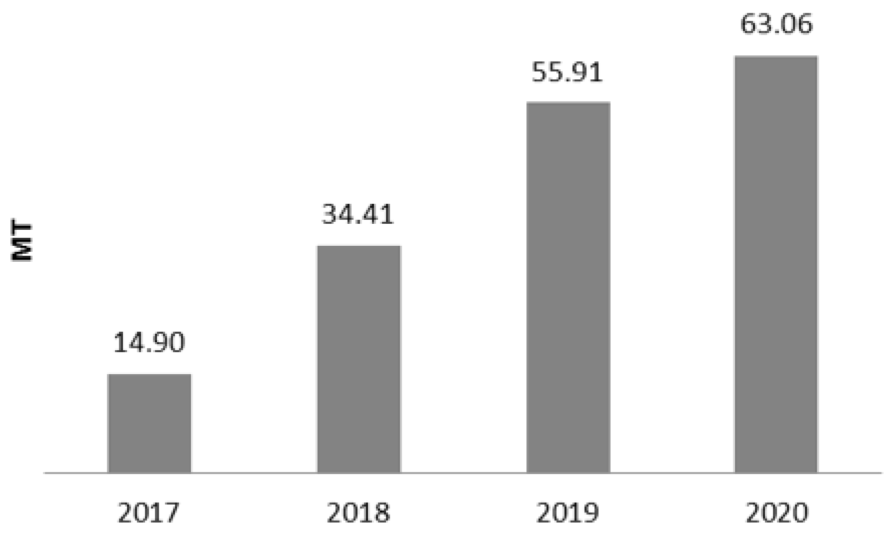


Figure 6.2: Forecasted LNG excess each year – base case scenario

Figure 6.3 shows the monthly forecasted demand and supply situation. LNG supply is expected to surpass the expected demand in all months except for January 2017, December 2017 and January 2018. The LNG surplus is slightly higher in May, June and October months and much lower in winter months (north hemisphere) such as December and January. The highest monthly LNG surplus is expected in June 2020, reaching 6.45 MT.

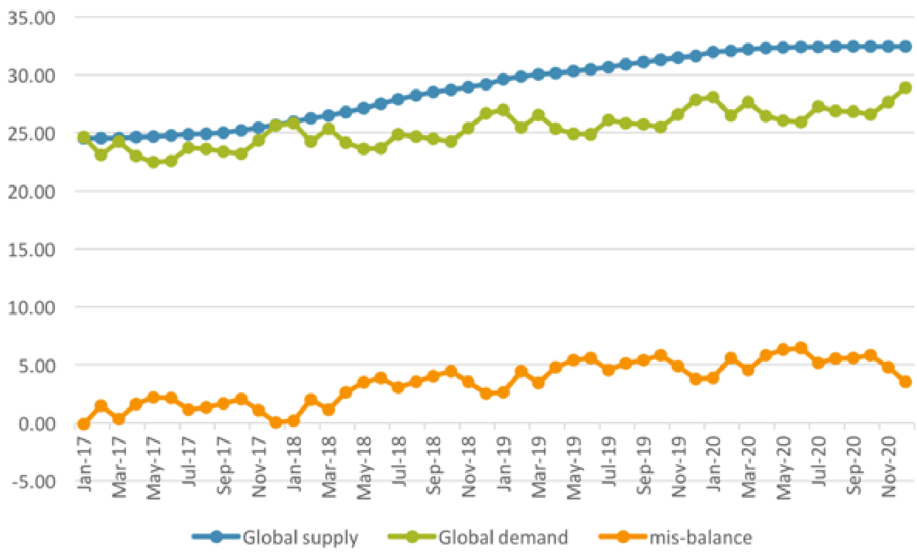


Figure 6.3: Forecasted global monthly supply and demand comparison - base case scenario

Figure 6.4 shows the forecasted annual LNG demand and supply situation in each basin. Asia Pacific is the only region where an LNG shortage is expected throughout the whole period under study, reaching 43.5 MT in 2017 to 51.5 MT in 2020. LNG surplus foreseen in Middle East will decrease slightly each year from 42.8 MT in 2017 to 36.3 MT in 2020 while the LNG surplus in the Atlantic basin will increase from 15.7 MT in 2017 to 76.24 MT in 2020. Since the LNG surplus in the Middle East and the Atlantic basin altogether is much larger than the LNG shortage in Asia Pacific and this gap is expected to grow rapidly each year, LNG supply from the Middle East and from the Atlantic will have to compete for the demand in Asia Pacific.

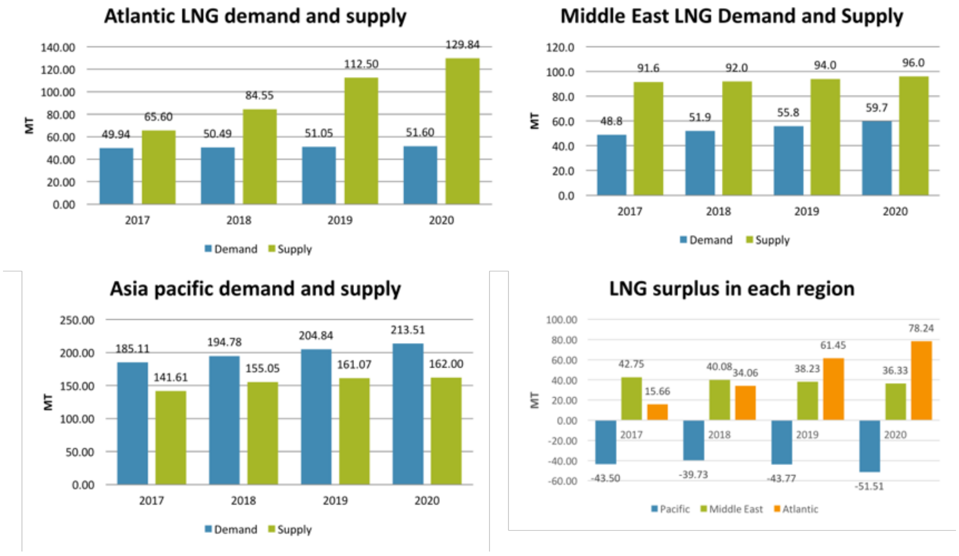


Figure 6.4: Forecasted annual LNG supply and demand comparison in each region

Middle East LNG producers are closer to Asia Pacific buyers than Atlantic producers geographically, which could give advantage to Middle East exporters to market their LNG. Annually speaking, it seems that Middle East will be able to supply Asian demand alone in 2017 and 2018. From 2019, there will be some room for Atlantic LNG.

However, the Asian Pacific LNG market has a much stronger shortage during winter months. LNG from Middle East will not be enough for Asia's demand in winter (Figure 6.4), when it needs to import LNG from both Middle East and Atlantic to meet its demand.

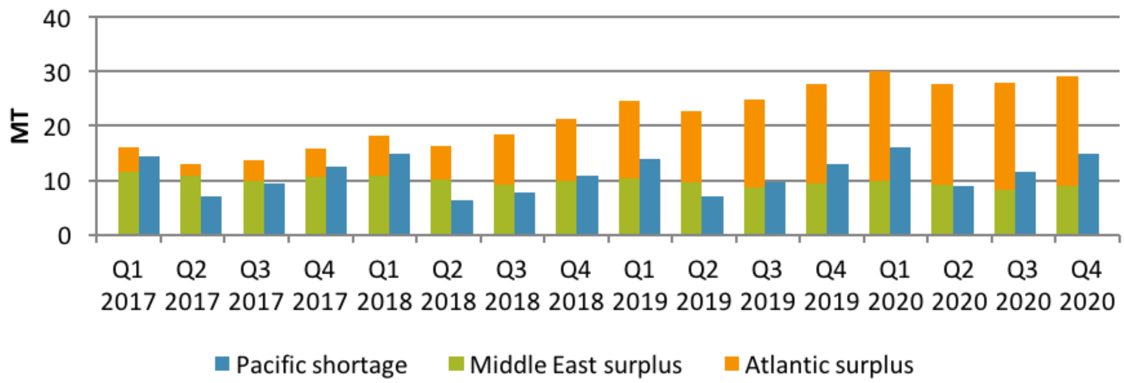


Figure 6.5: Asian quarterly LNG shortage in comparison with quarterly surplus in the other two basins

7

Fundamental analysis of LNG demand in key Asian markets

The time series analysis in chapter 5 has obtained monthly LNG demand forecasts from 2017 to 2020 in LNG importing countries worldwide in a base case scenario, assuming LNG demand will experience a similar trend to the past. However, such statistical method is unable to include the influence of underlying environment changes that might happen, such as changes in regulation, industry policies or infrastructure development.

This chapter will perform a fundamental analysis on gas and LNG markets in four of the most important LNG importing countries, namely China, Japan, South Korea and India, in order to identify potential changes that may affect their demand. Based on these potential changes, a plausible scenario of LNG demand in each of these countries will be considered, affecting the worldwide LNG supply and demand situation.

7.1. China

Among LNG importing countries, China deserves a special attention for the following reasons: Firstly, China is the third biggest LNG importer worldwide. Secondly, China has experienced the greatest LNG import growth in recent years. Thirdly, the time series analysis indicates China is expected to have the greatest import growth from 2017 to 2020. Therefore, it is important to have a holistic analysis of the Chinese LNG and gas market.

China's energy consumption structure

China has used coal as its main energy source for a long time, based on its rich coal resources and its lack of gas and oil reserves. As presented in , although consumption from other energy sources such as gas and renewables has been rising in recent years, coal still maintains its key position covering around 65% of China's primary energy consumption.

The role of natural gas is much less important. The share of natural gas in China's total primary energy mix rose from 2.3% in 2000 to 5.89% in 2015.

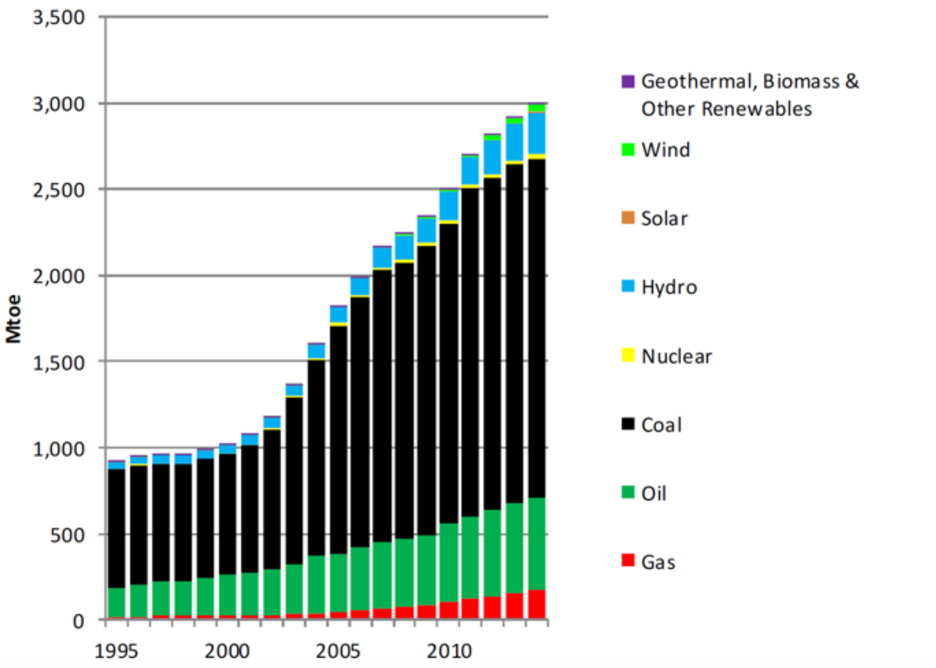


Figure 7.1: Primary energy consumption in China

China's natural gas supply and demand situation

Gas consumption in China grew rapidly from 25.3 bcm in 2000 to 198 bcm in 2015 (Figure 7.2). Indigenous production used to be sufficient to cover the domestic consumption until 2007. Ever since, China has to import natural gas to cover its demand. In 2015, domestic production constituted 70% of the gas consumption with the remaining 30% covered by imports.

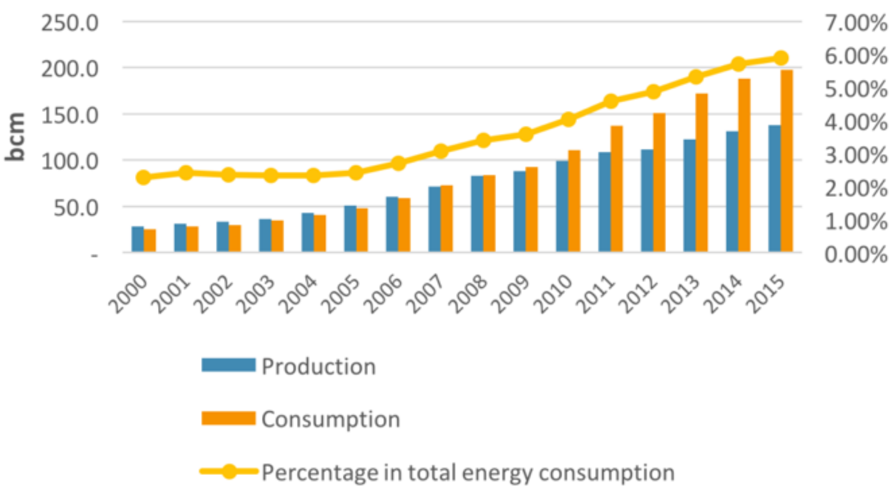


Figure 7.2: Chinese Natural Gas Production and Consumption

Figure 7.2 shows the gas supply structure from 2000 to 2015. In 2015, 57% of China's gas imports were pipeline gas imports, namely 33.6bcm. 83% of this pipeline gas was imported through the Turkmenistan pipeline in operation since 2010. The China-Myanmar pipeline started in 2015.

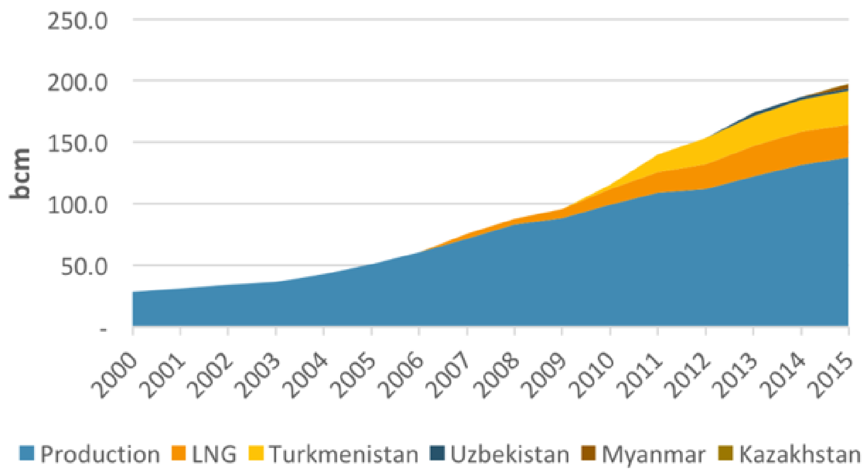


Figure 7.3: Chinese natural gas supply structure

In 2015, 43% of China's gas imports came from LNG imports (26.2 bcm). China started importing LNG in 2007 to compensate the deficit in domestic production. China's main LNG suppliers in 2015 were Australia, Qatar, Malaysia, Indonesia and New Guinea. These five countries currently have long term LNG supply contracts with China.

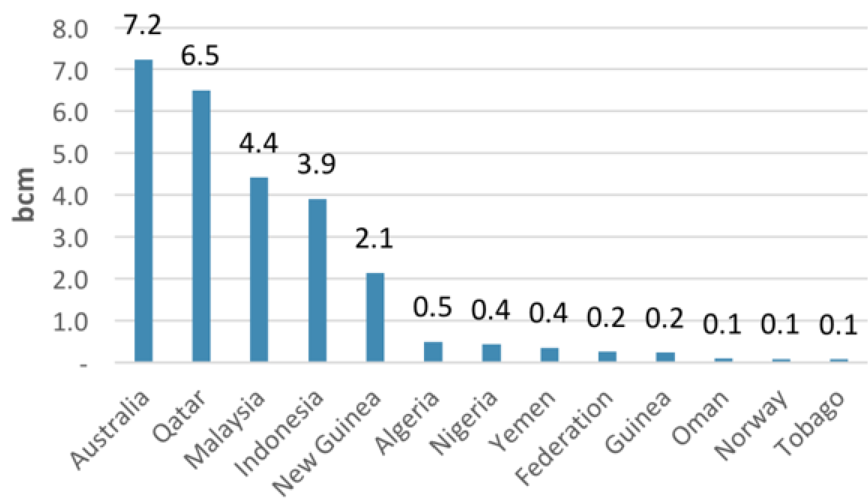


Figure 7.4: 2015 China LNG import sources

China's natural gas consumption

Figure 7.5 shows the gas consumption in China from 2000 to 2014 by sector. The Industrial sector including manufacturing and mining took up the largest share, which was more than 50% of the total consumption. Gas consumption for power production experienced the fastest increase with an average annual growth rate of 42.5% from 2005 to 2012.

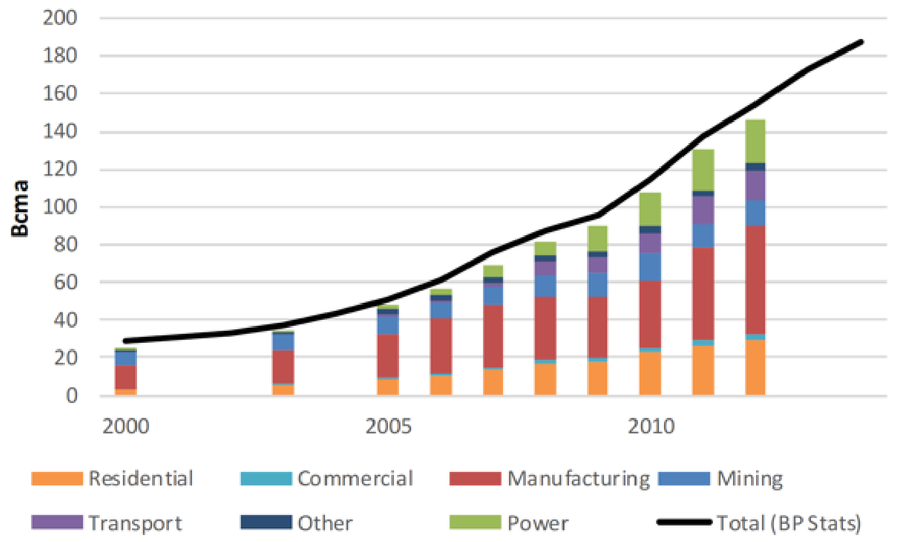


Figure 7.5: China Gas Consumption by Sector 2000 - 2014

Although gas consumption for power production has been rising consistently, the share of electricity production from gas-fired power plants is still very small. Figure 7.6 illustrates that Chinese electricity production is overwhelmingly dominated by coal.

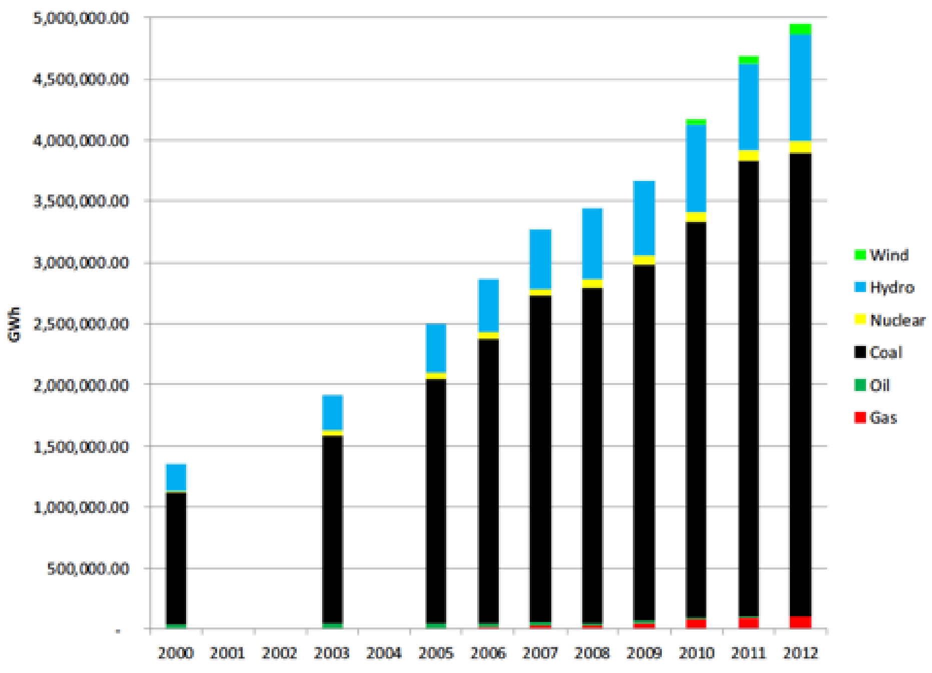


Figure 7.6: China Power Generation by Fuel/Technology 2000-2012

China's energy policy on gas

The use of coal as primary energy source has created severe environmental issues in China. Smog and air contamination has become an important problem for Chinese industrial cities. Besides, coal combustion is also a main emission source of CO_2. China has committed to reduce its CO_2 emission intensity of GDP by 60% by 2030. Hence, the government is facing both internal and external pressure to reduce the pollution and cut down carbon emissions, which requires China to switch coal consumption to other cleaner fuels. Gas is considered as the main alternative to coal. China's thirteenth five-year plan asserted that gas will cover 8.3% to 10% of the total primary energy consumption in 2020, while it covered 5.89% in 2016.

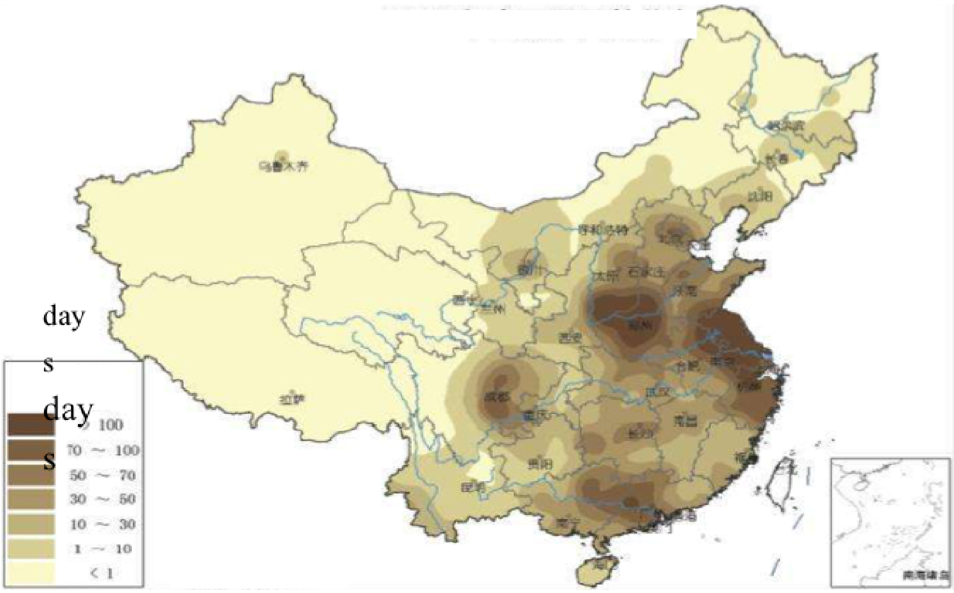


Figure 7.7: Number of haze days in 2013

Different measures are being implemented by the government in order to reform the gas industry with the aim to accelerate coal to gas switching:

- Pricing reform: Gas prices are regulated by the National Reform and Development Council (NRDC) and do not always reflect market prices. Final Chinese customers cannot take advantage of current low LNG spot market prices due to this disorder. The government intends to liberalize gas pricing for non-residential customers.
- Third Party Access to existing infrastructure: At present, three big national oil companies own almost all of the pipeline network and LNG import terminals without third party access. The government is pushing independent operation and third-party access to gas infrastructure so that more companies can develop gas business activities.

China's gas demand outlook

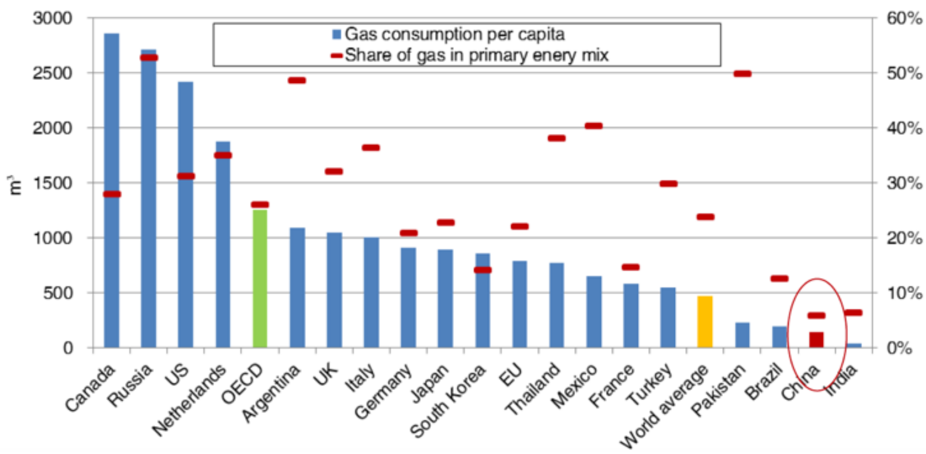


Figure 7.8: Natural gas per capita and share in primary energy consumption

China's natural gas consumption per capita was 144 m3 in 2015 and the share of natural gas in total primary energy consumption was only 5.89%, while the world averages were 472 m3 and 24%. China's gas market is still in a relatively early development stage and growing very fast. The potential gas consumption in China in the long term is huge.

Figure 7.9 presents different forecasts of China's natural gas demand into 2020. China National Petroleum Corporation (CNPC), China's biggest gas pipeline owner, expects that gas demand for China in 2020 will be 290 bcm in base case scenario (BAU). The Chinese Government's thirteenth five-year plan expects that the natural gas demand in 2020 will be between 306 bcm to 369 bcm.

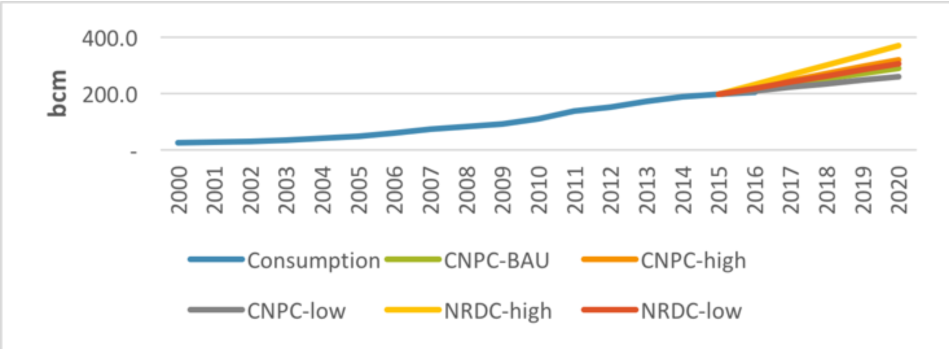


Figure 7.9: China's natural gas demand into 2020 in different scenarios

Figure 7.10 shows the historical annual gas demand growth rates and the expected average growth rate in each prediction scenario from 2017 to 2020. The average gas demand growth rate from the year 2000 to 2015 was 15% and it has declined to 8.45% over the past five years. The gas consumption growth rates in 2015 and 2016 were relatively low, because of the Chinese economy slow down. Looking into the future, CNPC's BAU and NRDC's expect similar growth rates to the growth seen during the last five years. NRDC expects much higher growth rates, reaching 13.34% annual growth rates.

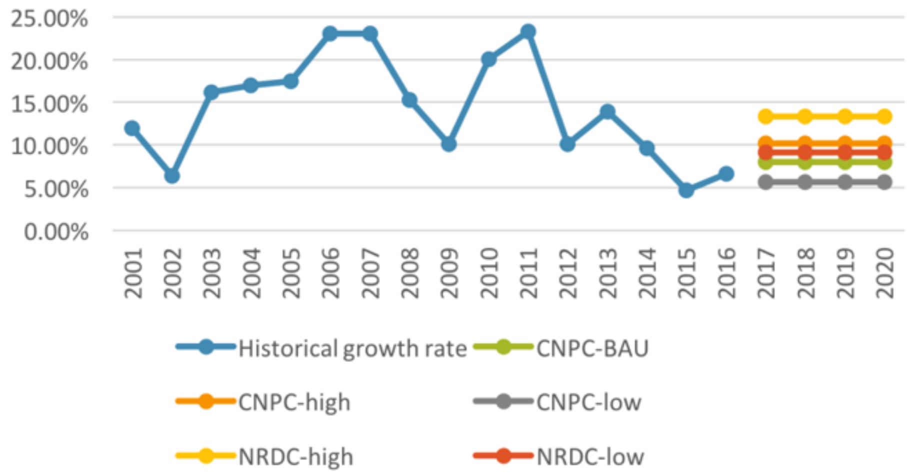


Figure 7.10: China's gas consumption growth rate

Table 7.1: Average growth rate from 2017 to 2020 for each forecast on China's gas demand

Scenarios	CNPC-BAU	CNPC-high	CNPC-low	NRDC-high	NRDC-low
Average growth rate	8.01%	10.15%	5.67%	13.34%	9.17%

China's LNG demand outlook

1. Gas production and pipeline gas import in the next years

- Gas production

  Chinese domestic gas production includes conventional gas, synthesized gas, coal-bed methane and shale gas production. provides CNPC's projection of each segment of gas production in China over the next 5 years. CNPC estimates that gas production will grow to 235 bcm in 2020 (CNPC, 2016). But it is widely believed that the objective for unconventional gas production is hard to realize since there has been not too much breakthrough yet. Hence, probably the production will be lower than CNPC expected. International Energy Agency forecasted that China's gas production in 2020 will be around 185 bcm (IEA, 2015), which is considered more plausible.

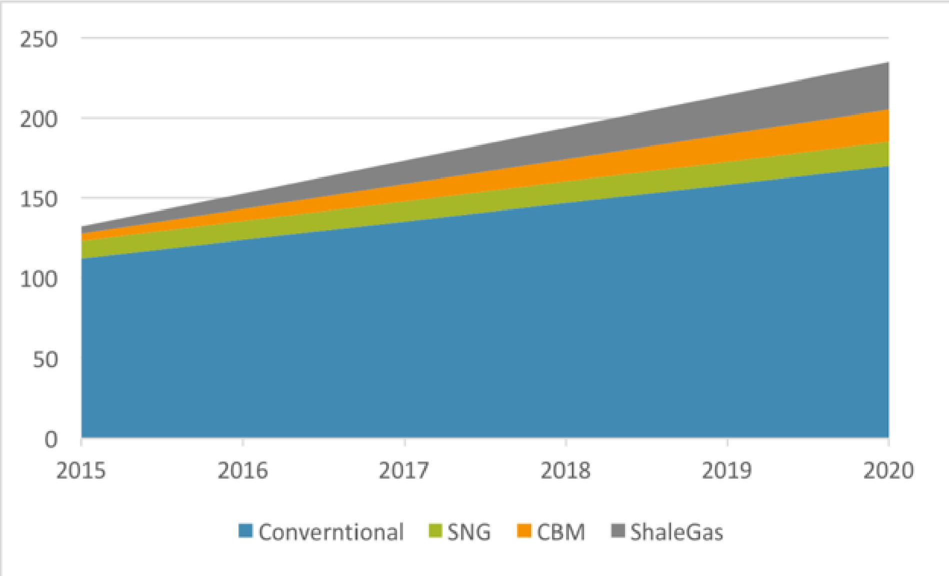


Figure 7.11: Gas production forecasts into 2020 by CNPC

- Pipeline imports

  Table 7.2 shows the pipe gas import projects in operation or under development in China. Currently, 3 pipelines from central Asia and 1 from Myanmar are in operation. The total working capacity is 67 bcm per year. Pipeline gas imports reached 33.6 bcm in 2015, mainly through central Asia pipeline A and B. Myanmar pipeline and central Asia pipeline C were completed recently and still in ramping up process.

Table 7.2: International natural gas pipelines to China

Unit: bcm	Status	Capacity	2015 imported volume	Startup
Central Asia pipeline A-B	Operating	30	28.3	2009, 2010
Central Asia pipeline C	Operating	25	1.3	2014
Central Asia pipeline D	Indefinitely suspended	30	0	2016
China-Myanmar pipeline	Operating	12	3.9	2013
China-Russia East pipeline	Under construction	38	0	2019
China-Russia West pipeline	Planning	30	0	

  The Chinese Government signed a huge contract with Russia in 2014 for 38 bcm/y of pipeline gas supply. The China-Russia east pipeline is under construction for this purpose. Two countries were planning to build another pipeline through the west border of China, but this project has been suspended and will take longer than expected. The construction of the east pipeline is also reported to be delayed and probably will not be in line before 2020.

  Therefore, the increase of pipe gas imports for China from2017 to 2020 will come from Myanmar pipeline and central Asia pipeline C. The full potential growth is 31.8 bcm.

2. LNG demand BAU case

Based on the assumptions taken above, the results presented in Table 7.3 can be attained. The amount of LNG needed during the next five years will grow in accordance with the rise of national gas consumption. This number will double from 27 bcm in 2015 to 55 bcm in 2020.

Table 7.3: China's gas demand and supply under base case

Unit: bcm	2015	2020
Demand	192	300
Domestic production	133	185
Pipeline-Myanmar	4	10
Pipeline-Central Asia	28	50
Pipeline – Russia	0	0
LNG import needed	27	55

Time series analysis suggested that LNG demand would be 58.8 bcm, which is very similar to the conclusion from this fundamental analysis.

3. LNG demand higher scenario

However, if the Chinese Government is determined to fulfill its gas consumption objective (covering 10% of primary energy consumption) under the pressure of the emissions reduction and pollution abatement, and if the low spot market LNG price can reach final customers, more gas demand will be activated. In this case, the 69 bcm additional gas demand is going to be met mainly by LNG. This brings China's LNG import projection in 2020 to 124 bcm. Whereas, it is a concern whether China has enough import capacity for such an increase. China's current total regasification capacity is 65 bcm/y, with 28 bcm/y capacity under construction. IHS (2017) expected that there will be 115 bcm/y import capacity in China. Therefore, 115 bcm should be the upper limit that China will be able to import in 2020.

Table 7.4: China's gas demand and supply on higher case assumption

Unit: bcm	2015	2020
Demand	192	369
Domestic production	133	185
Pipeline-Myanmar	4	10
Pipeline-Central Asia	28	50
Pipeline – Russia	0	0
LNG import needed	27	124
Import capacity limit	53	115

7.2. Japan

Japan's total energy consumption is stable overall since 1995, namely around 500 Mtoe. However, it started to decrease from 2008, reaching a record low level in 2014. Another significant feature in Japan's energy mix is the share of nuclear power that plummeted to almost 0 in 2011, resulting from the policy-induced shutdown of all Japan's nuclear generation plant after the Fukushima disaster. The energy provided by nuclear was compensated partly by gas, coal and oil-fired generation.

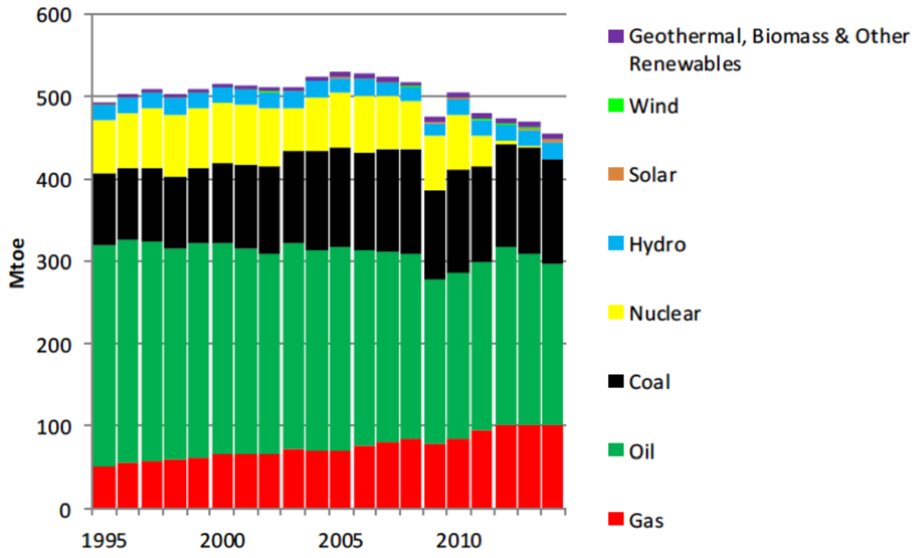


Figure 7.12: Japan's Energy Mix 1995-2014

Total gas consumption in 2015 was 113.4 bcm, accounting for 22.7% of total energy consumption. Japan, being an island, has no pipeline connection with other countries and its domestic gas production is negligible. Thus, the 113.4 bcm gas consumed is mostly LNG.

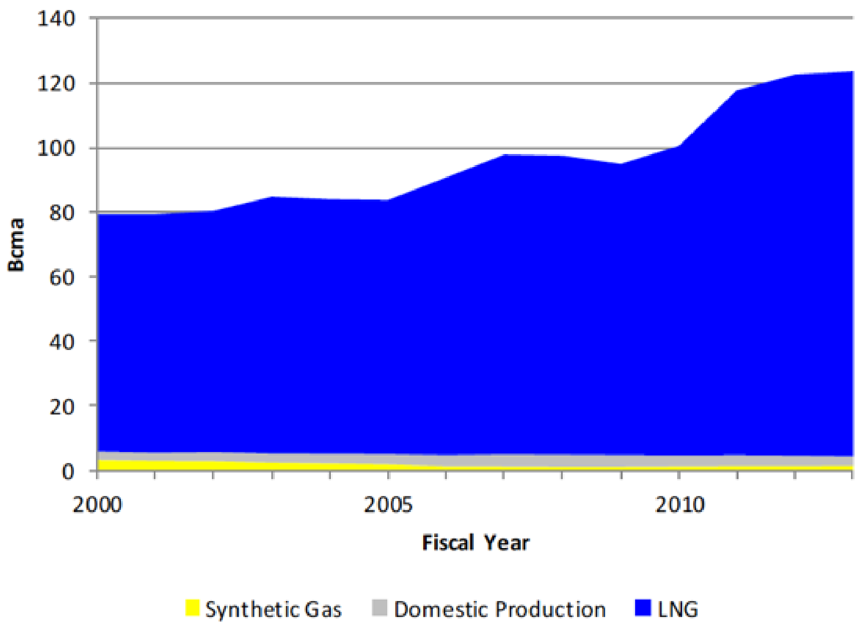


Figure 7.13: Japanese gas supply structure 2000-2014

In Japan, power generation consumes most of the gas. It increased drastically by approximately 20 bcm/y after the Fukushima disaster. City gas includes gas for industry, commercial and households. It rose slightly until 2008 and stabilized afterwards. Due to the low economy growth expectation and stabilized population, the amount of city gas required is expected to be stable.

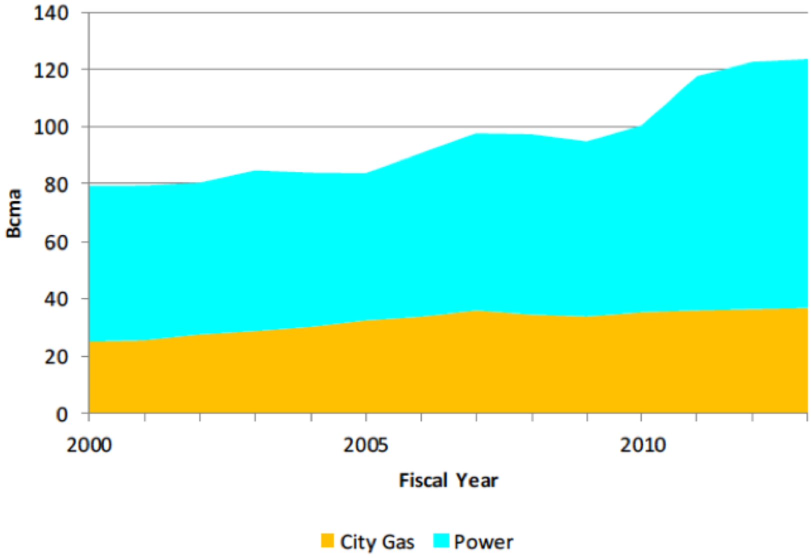


Figure 7.14: Japan gas consumption by power sector and non-power sector 2000-2014

The future gas demand in Japan will depend on the volume of gas required for power generation. In 2013, gas power covered more than 30% of total electricity production. While this share is expected to decline as nuclear power plants start up.

Before the Fukushima disaster, Japan's 50 main nuclear reactors provided 30% of the country's electricity (Figure 7.15). All of them were shut down for safety reasons after the accident in 2011. The process for restarting nuclear plant comprises a safety assessment by the nuclear regulation authority and the briefing of local governments by the operators. Currently 42 reactors are operable and potentially able to restart. 24 of these are in the process of achieving restart approvals. The first two rectors already restarted in August and October 2015. At the end of 2016, three nuclear reactors were in operation.

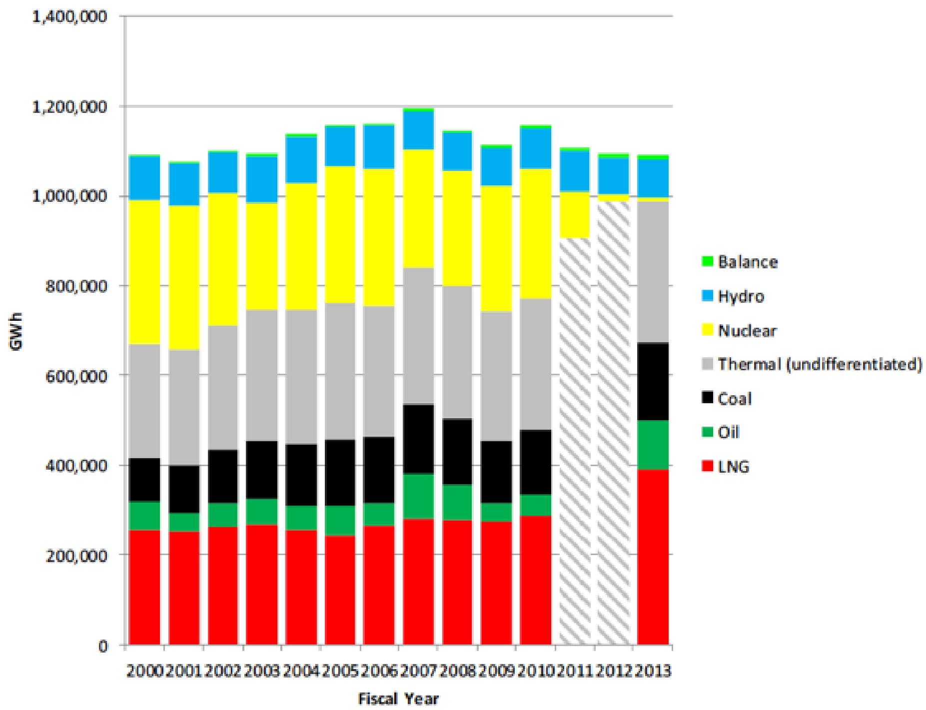


Figure 7.15: Japan electricity production by technology 2000-2014

The restart schedule of the remaining nuclear reactors is still uncertain. According to Howard (2016), Japan could achieve 35.45 GW of operational capacity by 2020 under a fast nuclear restart scenario. This would mean that the annual LNG demand would decline according to the following table:

Year	2017	2018	2019	2020
Import (MT)	83.31	79.15	68.92	66.15

7.3. South Korea

Overall, the total energy consumption in South Korea has experienced a steady growth, especially from 1999 to 2011. From 2011 onwards, total energy consumption has been essentially flat because of the slowdown of its economy. Natural gas covered 15.7% of the energy mix in 2014.

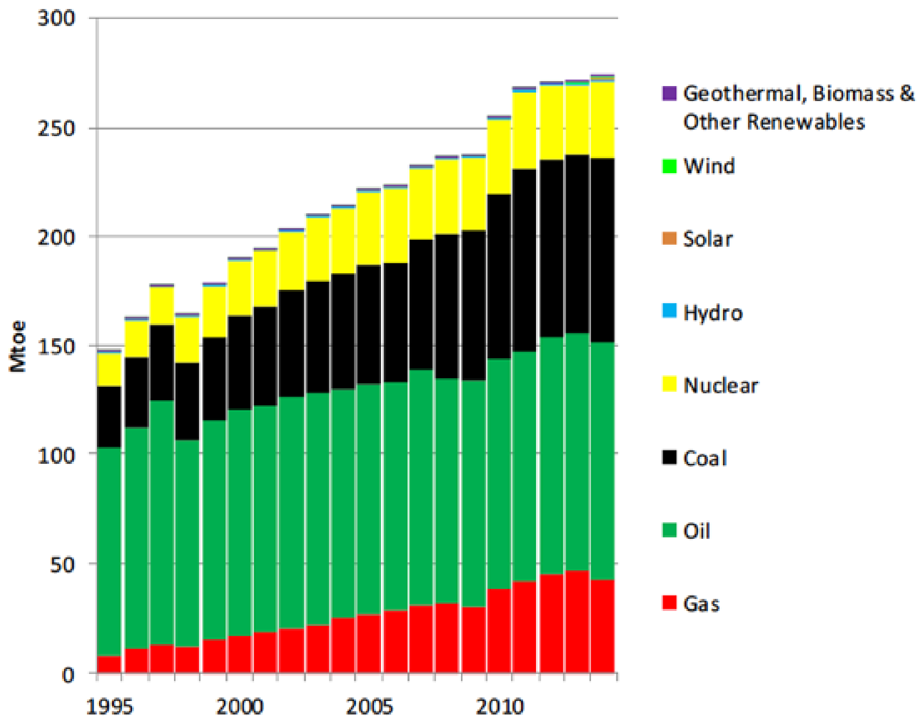


Figure 7.16: South Korea's Energy Mix 1995-2014

South Korea's gas supply is overwhelmingly covered by LNG imports. South Korea has no pipeline connections with third countries and its domestic production peaked at 0.5 MT in 2010 and has ever since declined.

South Korea's total gas consumption in 2014 was 36.6 MT, among which approximately 44% is used for power generation. City gas, including gas for industry, commercial, residential, district heating and transport, altogether constitutes 56% of total gas consumption.

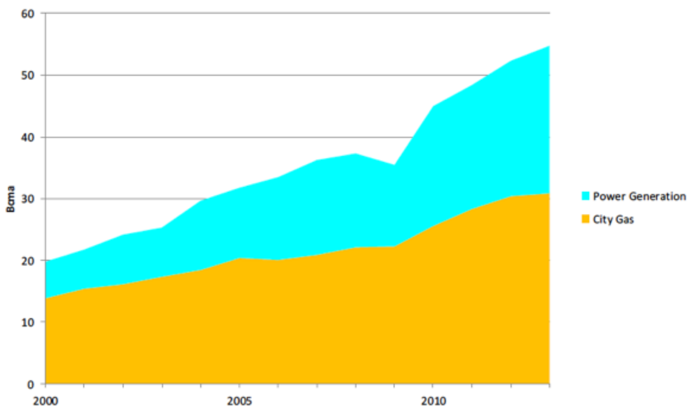


Figure 7.17: South Korea gas consumption by power sector and non-power sector 2000-2014

Among the different technologies for power generation, gas secures a 20% share in a sector dominated by coal and nuclear. Power production from coal has increased significantly from 2000 to 2014, putting the GHG (greenhouse gas) emission reduction target in pressure. The Korean Government committed to reduce the country's GHG emission by 37% in 2030.

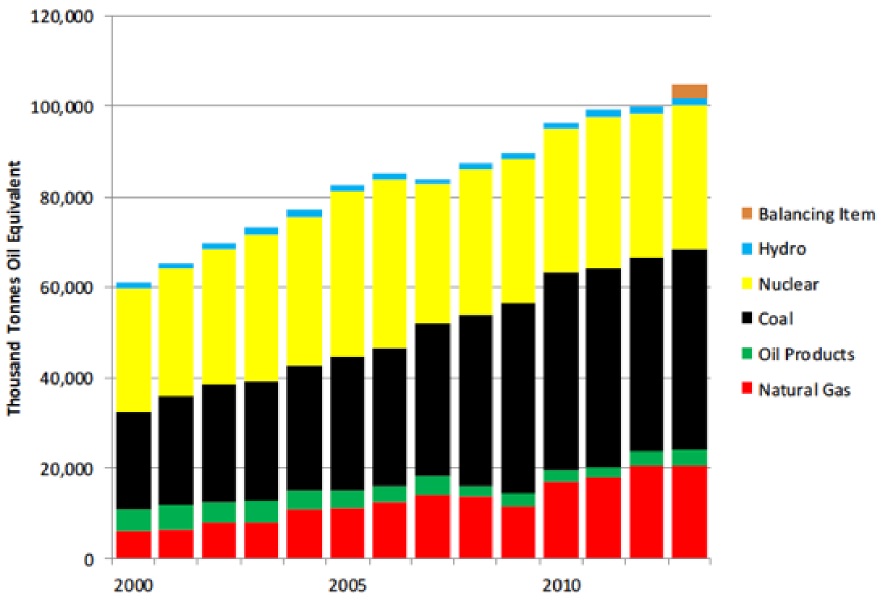


Figure 7.18: South Korea electricity production by technology 2000-2014

The future LNG demand for its power sector is determined by the need to reduce the role of coal and oil in its energy mix in order to reduce GHG emissions. As for the non-power sector, the country's LNG demand depends on its economic growth, its population growth and industry structure.

In the base case scenario, the time series result suggested that future LNG demand is expected to be stable. This result is reasonable given stagnant GDP growth and low or negative population growth. Whereas, the newly elected South Korean President Moon Jae-in announced to shift the country's power-generation mix away from coal to natural gas to alleviate pollution (Ft.com, 2017), providing the possibility of a higher LNG demand scenario by displacing coal with gas in the power sector.

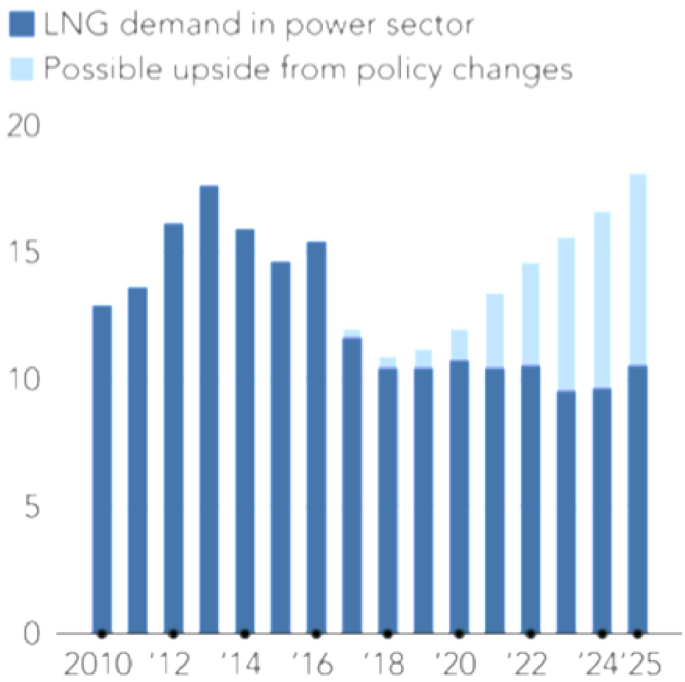


Figure 7.19: LNG demand potential due to C2G switch in South Korea

The influence of the replacement of coal with gas in the power sector is expected to be significant after 2020 (Nikkei Asian Review, 2017). Before 2020, the LNG increase is limited to 1 MTPA. The new LNG annual demand is shown in the table below, reaching 36.1 MT in 2020.

Year	2017	2018	2019	2020
Import (MT)	34.9	35.3	35.7	36.1

7.4. India

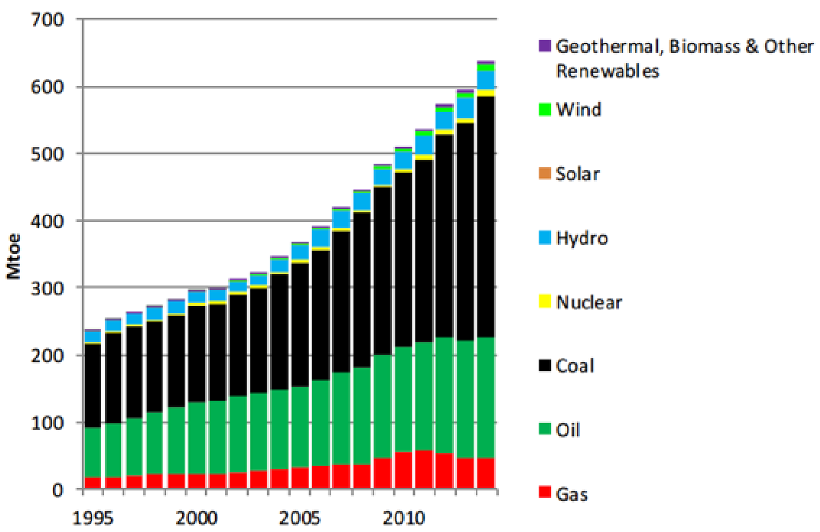


Figure 7.20: India's Energy Mix 1995-2014

India's total energy consumption, along with its GDP, is growing constantly since 1995. Total energy consumption tripled in 2014 compared to 1995. The energy mix was dominated by coal (56.5% in

2014) and oil (28.3% in 2014). Gas was the third energy source with a share of 7.1%.

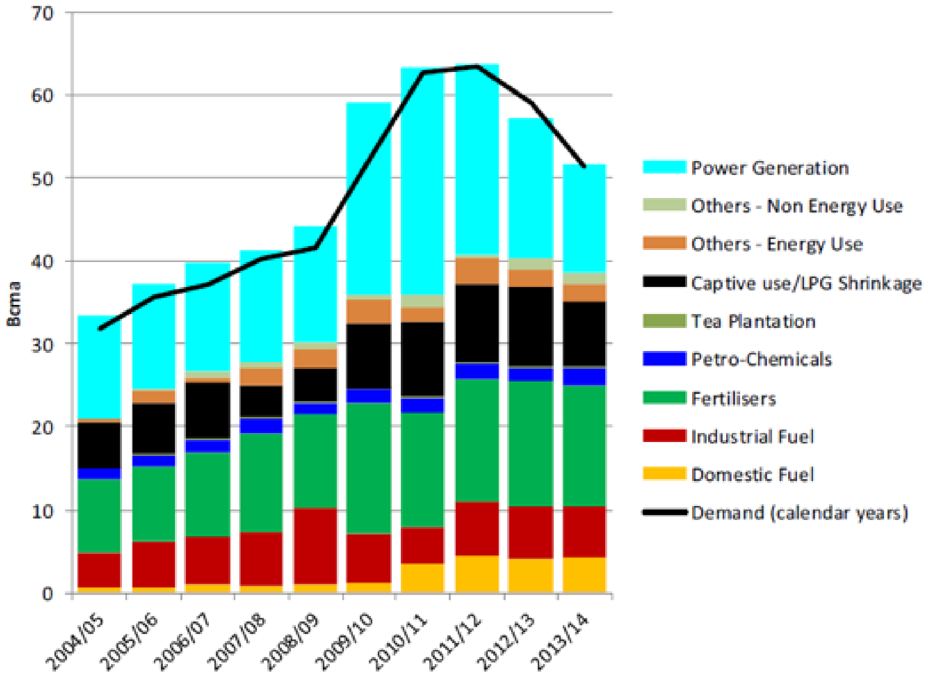


Figure 7.21: India gas consumption by sector 2000-2014

It is relevant to point out that the total gas consumption started to decline after 2011 (Figure 7.21), because domestic offshore gas production declined significantly from 2011 onwards and the growth of LNG imports was not enough to compensate this effect. The main sectors consuming gas in India are power generation and the fertilizer industry. The amount of gas for power generation experienced a swift increase till 2010 and started to decline thereafter. Gas for fertilizers had an overall growing trend but has stabilized after 2010. Gas for industry and households also remained flat from 2011 to 2013.

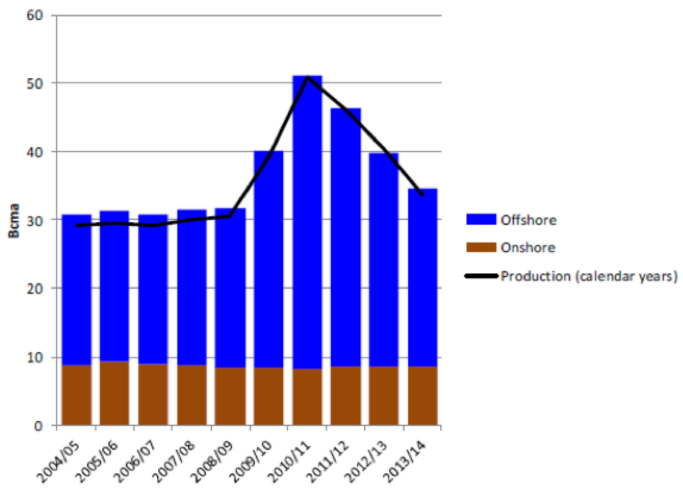


Figure 7.22: Gas production in India 2004-2014

The prospect towards future domestic gas production growth is not optimistic at this moment. The current and expected low LNG spot market price will hinder Indian gas producers to exploit more gas reserves. Thus, any future growth in gas demand will be met by LNG imports.

India could experience an important LNG demand growth in the future, but the country must overcome different barriers: Firstly, the fertilizer industry is subsidized by the government, although farmers only pay 50% of the real cost of the fertilizers. The expected population and economy growth should create additional gas demand for this industry, but the question is whether the government will be able to continue subsidizing this industry. Secondly, there is a lot of unused capacity to consume more gas for electricity production. Currently, the average load factor of gas power plants in India is only 10%. The growth of gas demand is however limited by the network distribution capacity and the price disadvantage over coal. Thirdly, city gas for domestic, commercial and transportation customers is expected to have potential for growth in the future. However, the lack of sufficient pipeline infrastructure becomes an issue.

Currently, no specific policy has been found to guide natural gas consumption in the country. Thus, estimating gas demand in India is hard and problematic at this juncture. One accessible benchmark is IEA 2015 New Policy Scenario (IEA, 2015), according to which LNG demand could reach 27.7 MT in 2020 when infrastructure and policy support materialize.

Year	2017	2018	2019	2020
Import (MT)	22.6	24.3	26	27.7

7.5. Impact of alternative demand scenarios of major Asian countries in the LNG market

1. Scenario 1: Higher LNG demand in China driven by favorable regulation and policy change

   If favorable regulation materializes in China, the potential LNG demand that can be activated is enormous. In this higher demand scenario, China will need 60 bcm additional LNG in 2020 compared to the base case scenario. LNG deficit in Asia will grow substantially due to this effect, reaching 93.5 MT in 2020.

   Global LNG surplus will be largely eased in this case, with surplus LNG volumes reaching a plateau of 25 MT in 2019 and decreasing to 21.1 MT in 2020. The mismatch of monthly LNG supply and demand is expected to be very small. LNG supply will even be short in winter months such as January during the whole period.

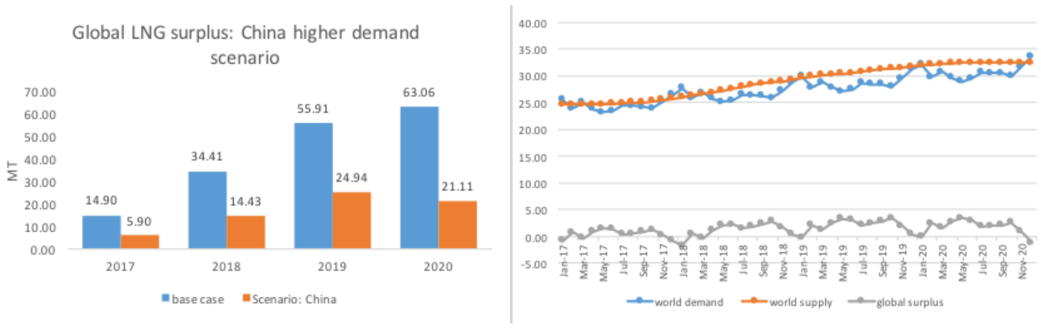


Figure 7.23: Forecasted global LNG supply and demand comparison - China higher demand

2. Scenario 2: Lower LNG demand in Japan due to quicker nuclear startup

   If Japan's nuclear restart process is quicker than expected, there will be a considerable LNG demand decrease in Japan. The country's demand will drop by about 21 MT in 2020. The global LNG surplus will appear from 2017, earlier than in the base case scenario.

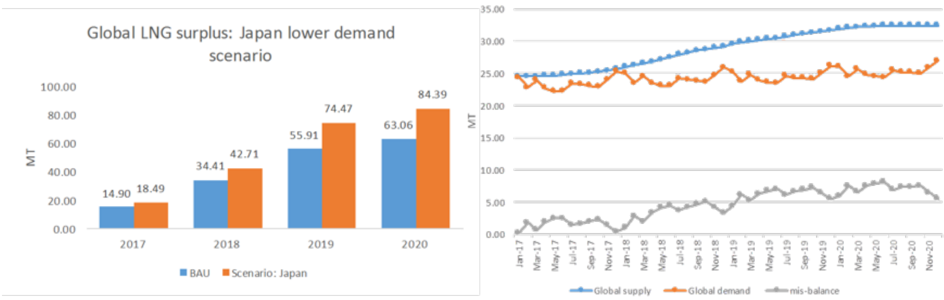


Figure 7.24: Forecasted global LNG supply and demand comparison - Japan quicker nuclear restart

3. `Scenario 3: Higher LNG demand in South Korea due to C2G switching in power generation`

   The new government in South Korea has released signals to promote coal to gas switching in its power sector in order to achieve its environmental objectives. As a result, LNG demand in South Korea is expected to increase. However, this effect is marginal during 2017 to 2020, with only 1 MT growth anticipated in 2020. Thus, this C2G switch in Korea will not have a significant impact on the global LNG market during 2017 to 2020, though it is important in a longer time horizon.

4. `Scenario 4: Higher LNG demand in India due to improved infrastructure`

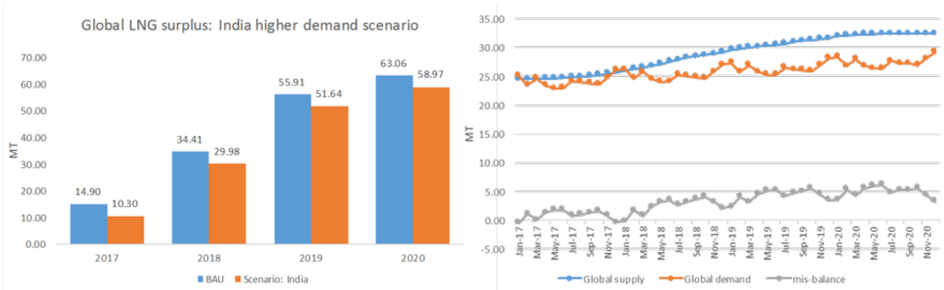


Figure 7.25: Forecasted global LNG supply and demand comparison - India infrastructure improves

India's LNG demand in 2020 will rise by 5 MT in this scenario, which slightly reduces the global LNG surplus. In this scenario, LNG supply will remain tight in winter 2017 and will significantly surpass the expected demand from 2018 onwards.

8

World LNG supply and demand situation's implications for Europe

As discussed in chapter 2, Europe is considered as the global LNG balancing market. Excess LNG will be probably sent to Europe and compete for demand there.

If this assumption holds true, the LNG volume that Europe is expected to receive in the next four years in different situation is shown in Figure 8.1 and Figure 8.2. Under base case scenario, the amount of LNG for Europe will rise from 47.3 MT in 2017 to 95.9 MT in 2020. This increase will be more aggressive if Japan has a quicker nuclear restart in the near future, reaching 117.3 MT in 2020. However, if China's gas industry regulation reform is successful in attracting more demand, LNG to Europe will be much less, first rising from 38.3 MT in 2017 to the plateau of 58.7 MT in 2019 and decreasing to 54 MT in 2020.

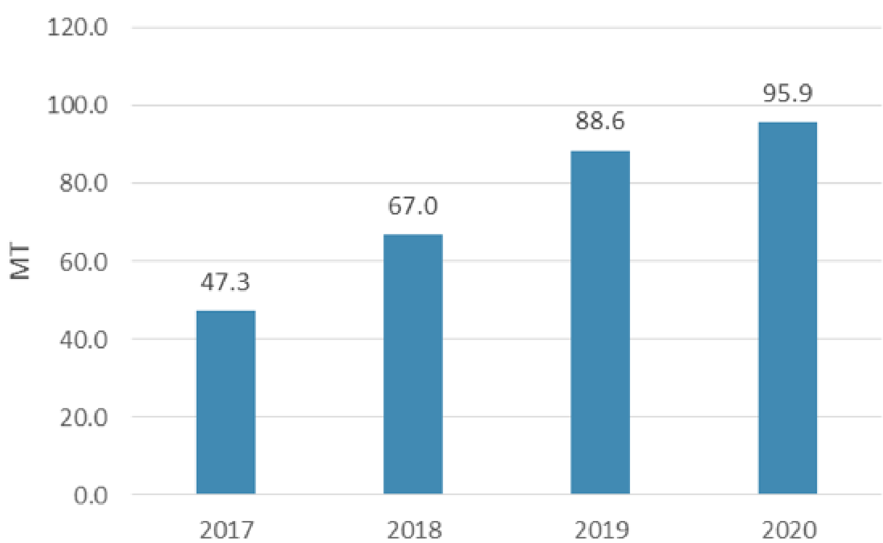


Figure 8.1: LNG expected to Europe over 2017 to 2020 –base case scenario

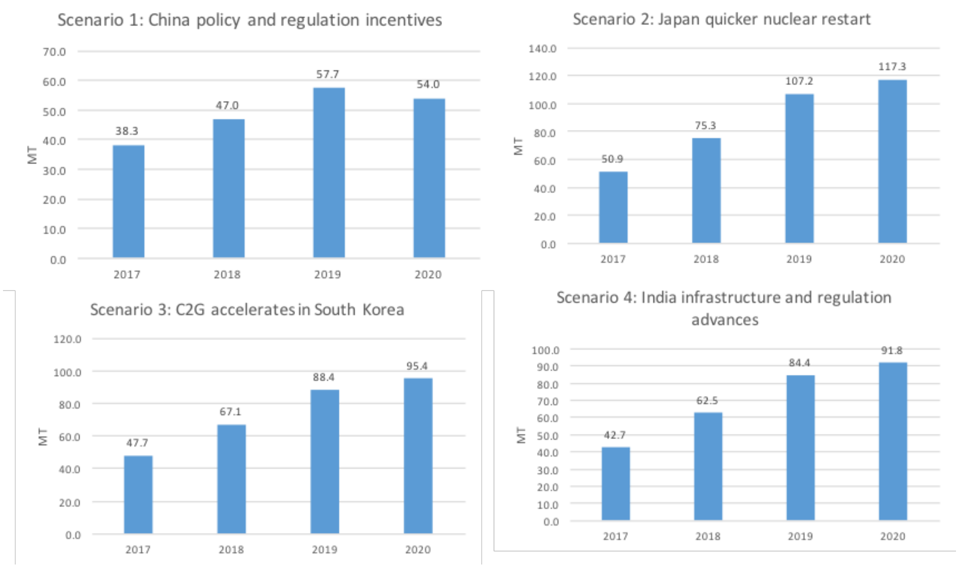


Figure 8.2: LNG expected to Europe over 2017 to 2020 in different scenarios

In all scenarios, Europe will receive more LNG than it used to receive in the past, at least from 2018 onwards. Because of this potential disruptive increase, it is crucial to look into what are this LNG wave's effects to Europe and whether Europe is able to balance global LNG market as it expected to. The following questions are proposed to structure the analysis.

- When will the excess LNG wave come to Europe? What is the monthly pattern?
- Does Europe have enough capacity to receive these amounts of LNG?
- How will this LNG wave change Europe's gas supply structure?
- Is Europe able to balance the market by itself?

1. `When the excess LNG wave will come to Europe, what is the monthly pattern?`

   Under the base case situation, as expected global LNG supply will surpass the expected demand by 14.9 MT in 2017, excess LNG will appear in European market right this year from February. According to Figure 105, the surplus in 2017 will be the highest from April to June while there will hardly be any excess in December and January. LNG oversupply will be evident from 2018 onwards with significant extra LNG during the entire year.

   This all the year round significant surplus will appear one year ahead to 2017 when Japan experiences a quicker nuclear restart. All other scenarios refer to a stronger demand in a single country, which will alleviate the excess situation in Europe. But the identified demand growth due to Korea's C2G switch and India's infrastructure advance is small compared to the volume of LNG excess expected. The excess situation from 2018 onward is staying unchanged. However, if demand in China receives proper incentives from policy and regulation, the demand growth will be impressive enough to change Europe's LNG supply and demand situation. There will be much less LNG excess in European market. Europe will even receive less LNG than the past during its winter due to the seasonality of Chinese demand.

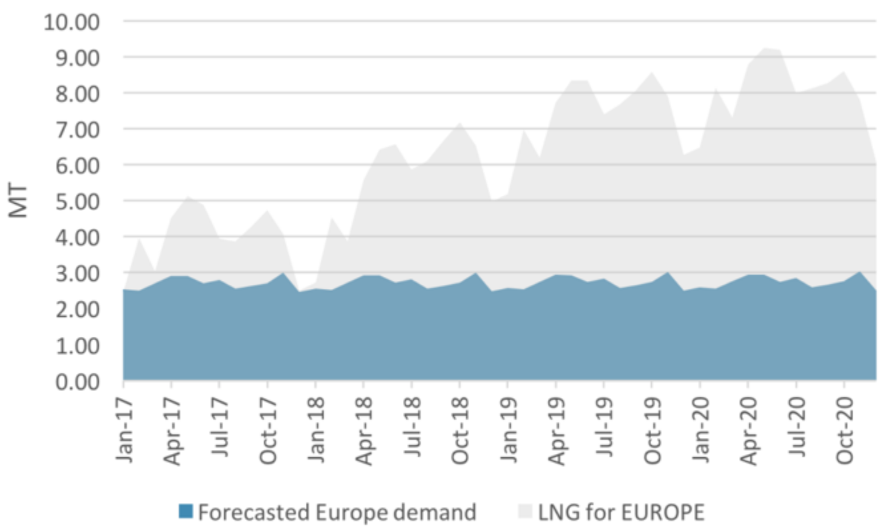


Figure 8.3: Forecasted monthly LNG to Europe – base case scenario

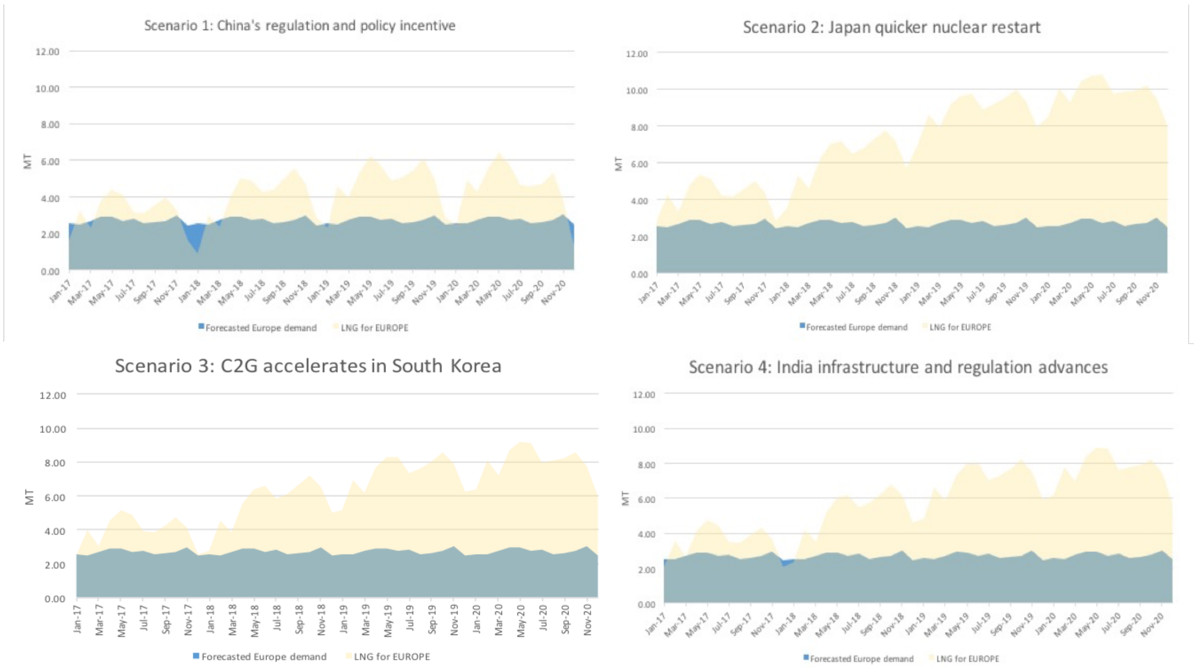


Figure 8.4: Forecasted monthly LNG to Europe – scenarios

2. `Does Europe have enough capacity to receive this amount of LNG?`

   The current total regasification capacity of all countries in Europe is 151.6 MTPA. It seems sufficient to accommodate the expected LNG excess volume in all situations we studied, which is 117 MT at most. Monthly speaking, the month with the greatest LNG volume to come among all scenarios is June 2020 when Japan nuclear plants restart faster, reaching 10.8 MT. It is still within the ability of European nominal monthly regasification capacity of 12.6 MT. Thus, Europe has sufficient regasification capacity to receive the global excess LNG over 2017 to 2020 in theory.

3. `What will be the influence of LNG wave on European gas supply structure?`

   As in 2015 Europe's gas supply structure (Table 9), 81% of gas imports needs were covered by pipeline gas. And 154 bcm out of 198 bcm (78%) pipeline gas import came from Russia. The role of LNG is less important as an alternative supply with only 36 MT imported in 2015.

Given the substantial amount of LNG expected to come to Europe from 2017 to 2020, LNG will face strong pressure to compete with pipeline gas imports due to the following situations. First, total gas demand in Europe is expected to grow very slowly from 2017 to 2020. Second, gas production in Europe is likely to stabilize with upstream investments, including Laggan-Tormore and Culzean in the UK and Aasta Hansteen in Norway, at least until 2020. These projects should offset the 10% cut to the Groningen quota and the decline at other mature fields. Thus, the only way for Europe to take more LNG is by replacing pipeline gas imports, mostly from Russia.

Table 8.1: European gas demand and supply structure

	Unit	2015
OECD Europe gas demand	bcm	**472**
Supply Sources		
Production in Europe ex Norway	bcm	106
Production in Norway	bcm	121
OECD Europe net import needs	bcm	**245**
Pipeline imports:		
-Russia	bcm	154
-Others	bcm	44
Total pipeline imports	bcm	**198**
as % of European net imort needs		81%
Total LNG imports need	bcm	**47**

At present, Russia is the marginal price setter in Europe's gas market. We expect LNG, mostly coming from US, will participate in the competition for demand in European gas market. If Russia still plans to keep the current role, then part of its supply will be substituted by LNG. Another possibility is that Russia decides to reduce price and defend its market share. It is easy for Russia since it is considered the lowest cost gas producer in the market. In this case, the additional LNG will be pushed out in European market and other balancing mechanisms for this LNG are required. Therefore, whether this LNG oversupply will be able to change European gas supply structure is dependent on Russia's strategy.

4. Can Europe balance the market by itself?

The base case scenario results indicate Europe's LNG demand will be stable in general. The excess LNG coming to Europe needs to compete with pipeline gas imports from Russia. The results will be dependent on Russia's strategic reaction. There is no space for additional LNG if Russia decides to maintain its market share by lowering price, given Russia's gas production and transport costs to Europe are the lowest compared to the rest of alternatives.

Russia has enough ability to defend its market share. It is able to supply more gas to Europe and hence to lower the price. First, it has plentiful spare capacity to export gas to Europe. The existing pipeline import capacity from Russia is 257 bcm and the utilization currently is only 69%. Second, Russian gas is the most competitive in cost. As seen from data provided by Goldman Sachs (2017), Russia has already increased its gas exports to Europe in 2017 (Goldman Saches) and it will probably take actions to defend its share in the future.

The gas price, at least LNG spot price, in Europe is expected to decline given the oversupply. One concern in the market is this low gas price might accelerate C2G switch in Europe. According to Goldman Sachs (2017), the full C2G potential will add 52.7 MT gas demand per year but the breakeven price of US LNG is not low enough to beat coal in cost in the current market environment. Even though this C2G switch can materialize in the next four years and all of the additional demand will be covered by LNG, the resulting LNG demand increase is still not enough to cancel the expected LNG surplus in all scenarios except for Chinese higher demand scenario. Overall, Europe is not able to digest all the expected excess LNG in the coming years. Other balancing mechanisms for LNG will be needed.

9

Conclusion and future work

9.1. Conclusion

Global annual LNG demand and supply has increased continuously from 99.7 MT in 2000 to 266.3 MT in 2016, achieving an annual average growth rate of 6.5%. The global LNG supply and demand are expected to increase further in the future, especially considering the 97 MTPA additional liquefaction capacity expected to start up in the coming years.

This study is aimed to explore the future global LNG supply and demand situation during the period from 2017 to 2020 on a monthly basis. Future LNG supply is calculated as the sum of current liquefaction plants' LNG production and forthcoming liquefaction plants' LNG production. In order to assess their production, a framework has been developed and applied. However, forecasting future LNG demand is not that straightforward, as it is affected by numerous factors. Firstly, time series models, which take historical LNG import data in each country as the input, are implemented to create the base case scenario of future LNG demand. Then, four scenarios are constructed in order to reflect possible fundamental changes that can affect LNG demand in the four most important Asian countries, namely China, Japan, South Korea and India.

According to the results we obtained in the base case scenario, worldwide LNG exporters tend to produce significantly more LNG than the global market will need in the study period. The expected annual LNG supply surplus will rise from 14.9 MT in 2017 to 63 MT in 2020. LNG supply is expected to surpass the expected demand in all months except for January 2017, December 2017 and January 2018. The LNG oversupply situation will be evident all the year round starting from 2018. The LNG surplus will be slightly higher in May and June months, and less in December and January months.

Asia Pacific is the only region with an expected LNG deficit each year, growing from 43.5 MT in 2017 to 51.5 MT in 2020. Both Middle East and the Atlantic basin will produce more LNG than their own demands. The anticipated LNG surplus in Middle East will decrease gradually from 42.8 MT in 2017 to 36.3 MT in 2020 while the LNG surplus in the Atlantic basin is expected to skyrocket from 15.6 MT in 2017 to 78.2 MT in 2020. However, the LNG shortage in Asia Pacific will be much more severe during winter months, and LNG will be imported from Middle East and the Atlantic basin.

Four alternative scenarios have been analyzed in this thesis:

- Higher LNG demand in China due to favorable regulation changes
- Lower LNG demand in Japan due to quicker nuclear restart
- Higher LNG demand in South Korea due to C2G switch
- Higher LNG demand in India due to improvement of the Infrastructure

Quicker than expected nuclear restart in Japan will further add 21 MT of LNG surplus in 2020. In this case, all the year round LNG excess is expected to appear one year ahead, namely in 2017, when compared with the base case scenario. All other scenarios will increase LNG demand in the corresponding country and hence reduce global LNG surplus. China is expected to have the greatest LNG demand increase if strong policies and regulatory measures in favor of gas consumption are adopted, increasing by 46 MT in 2020 compared to the base case scenario. In this case, the mismatch of global monthly LNG supply and demand is expected to be very small. LNG supply will even be short in winter months such as January. Under India's improved infrastructure scenario, the LNG demand in India is expected to increase by 5 MT in 2020. The significant oversupply situation will still be there from 2018 onwards. Demand growth from South Korea's potential C2G switching is expected to be very limited before 2020 and will not have a significant effect on the global LNG market.

Europe is considered to be the last resort market in the LNG business. It is likely that the LNG surplus will be sent to the European market. In this situation, the LNG heading to Europe is expected to grow from 47.3 MT in 2017 to 95.9 MT in 2020. Theoretically, Europe has 151.6 MTPA of regasification capacity, which should be enough to receive the entire LNG surplus produced in the base case and all other scenarios. But since the total gas demand in Europe is not expected to see a significant increase, the surplus LNG expected to reach Europe will have to compete for demand with pipeline imported gas, mainly from Russia. Pipe gas from Russia is considered the lowest cost gas in the market and pipelines connecting Russia and Europe have sufficient spare capacity. If Russia decides to increase its production and hence reduce price to defend its market share in Europe, the surplus LNG will not be able to gain market share from pipeline gas. Thus, whether this LNG oversupply can be absorbed by Europe is dependent on Russia's strategy. According to the updated market information from Goldman Saches (2017), there is evidence that Russia has already increased its export to Europe in 2017 to prevent potential competition from LNG. Therefore, it is likely that this surplus LNG will not find its home in Europe. Europe will not be able to balance the global LNG market by itself alone.

The market needs other mechanisms to balance the global LNG supply and demand. Unless no new demand is created in developing countries through the construction of new regasification plants, probably one of the only alternatives is to reduce the US liquefaction plants' production. Unlike the traditional integrated contracts, capacity off-takers of US projects using tolling business models can choose not to produce LNG. These off-takers will only be obligated to pay a reservation charge for their contracted capacity. Thus, production from US projects will probably be lower in the case of significant oversupply in the global LNG market.

9.2. Future work

This study explored worldwide future LNG supply and demand without taking into account the price of LNG, which limited the capability of the model to foresee the future supply and demand balance from a quantitative perspective. This approach will certainly enrich this research greatly.

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Appendices

A

Appendix 1: Time series code template in R

```
library(tframePlus)
library(xlsx)
library(astsa)
library(tseries)
library(forecast)
library(FinTS)
dev.off()
rm(list = ls())
cat("\014")
mydata=read.xlsx("/Users/xiamenglin/Documents/working directory for R/LNG_Forecast
/Importers_data.xlsx", 37, header=TRUE, colClasses=NA)
mydata[is.na(mydata)] <- 0
data<-ts(mydata[97:204,10], start=c(2006, 1), end=c(2014, 12), frequency=12)
data2<-ts(mydata[97:228,10], start=c(2006, 1), end=c(2016, 12), frequency=12)
test<-ts(mydata[205:228,10], start=c(2015, 1), end=c(2016, 12), frequency=12)
Year=as.annually(data2)
Quar=as.quarterly(data2)
ts.plot(data2,ylab="volume (1000T)",xlab="month",main= "X monthly LNG import")
ts.plot(Quar,ylab="volume (1000T)",xlab="quarter",main= "X quarterly LNG import")
ts.plot(Year,ylab="volume (1000T)",xlab="year",main= "X yearly LNG import")
#Yearly import bar chart
x = as.character(c(1998:2016))
y = round(t(Year)/1000, digits = 1)
xx = barplot(y,names.arg = x,xlab = "Year",ylab = "volume (MT)",col =
"deepskyblue", main = "X yearly LNG import")
text(x = xx, y = y, label = y, pos = 3,cex = 0.6)
ylim=c(0,30)
#Quarterly import bar charts
a=as.vector(Quar)
Quar=matrix(a,ncol = 4,byrow=TRUE)
colnames(Quar)=c("Qter1","Qter2","Qter3","Qter4")
rownames(Quar)=as.character(c(1998:2016))
Quar=t(Quar)
xx=barplot(Quar, main="X quarterly LNG import",
           xlab="",ylab="volume (1000MT)", col=c(1:4),
           beside=TRUE)
legend("topleft",
```

```
       legend = c("Qter1","Qter2","Qter3","Qter4"),
       fill = c(1:4),
       cex = 0.6)
text(x = xx, y = Quar, label = Quar, pos = 3, cex = 0.5)
#Decomposition
fit <- stl(data2,s.window = 7)
plot(data2, col="gray",
     main="X monthly LNG import",
     ylab="volume (1000MT)", xlab="")
lines(fit$time.series[,2],col="red",ylab="Trend")
plot(fit,main="X LNG import time series decomposition")
monthplot(fit$time.series[,"seasonal"], main="X monthly LNG import pattern",
ylab="Seasonal")
y=as.numeric(data2)
par(mfrow=c(1,2))
median(y)
mean(y)
#monthly import boxplot
boxplot(data2~cycle(data2),ylab="volume (1000MT)",xlab="month",
main= "Boxplot of X monthly LNG import volume")
#quarterly import boxplot
boxplot(Quar~cycle(Quar),ylab="volume (1000MT)",xlab="quarter",
main= "Boxplot of X quarterly LNG import volume")
#Exponential smoothing
h1=24
plot(forecast(stlm(data), h = h1)); grid()
lines(data2,col="red",lty=2)
legend("topleft",legend = c("actual","forecasted"),lty=c(2,1), col = c(2,4),
cex = 0.7 )
plot(forecast(ets(data), h = h1)); grid()
plot(forecast(thetaf(data), h = h1)); grid()
fc1 <- forecast(ets(data), h = h1)
fc2 <- forecast(stlm(data), h = h1)
fc3 <- thetaf(data, h = h1)
accuracy(fc1, test)
accuracy(fc2, test)
accuracy(fc3, test)
x= stlm(data)
ts.plot(data,fitted(x), col=1:2,lty=1:2,ylab='Volume (1000 mt)',
main = 'Comparison of actual and forecasted LNG demand in X')
legend("topleft",legend = c("actual","forecasted"),lty=1:2, col = c(1,2),
cex = 0.7 )
fc1 <- ets(data2)
fc2 <- stlm(data2)
fc3 <- thetaf(data2)
accuracy(fc1)
accuracy(fc2)
accuracy(fc3)
h2=48
fc = forecast(stlm(data2), h = h2)
plot(fc,main="Forecasting LNG demand in X"); grid()
aggregate(fc$mean)
R=fc$mean
Ftable = data.frame(as.numeric(R))
write.csv(Ftable, file = "/Users/xiamenglin/Documents/working directory for R
/LNG_Forecast/MiddleEast/Xforecast.csv")
```

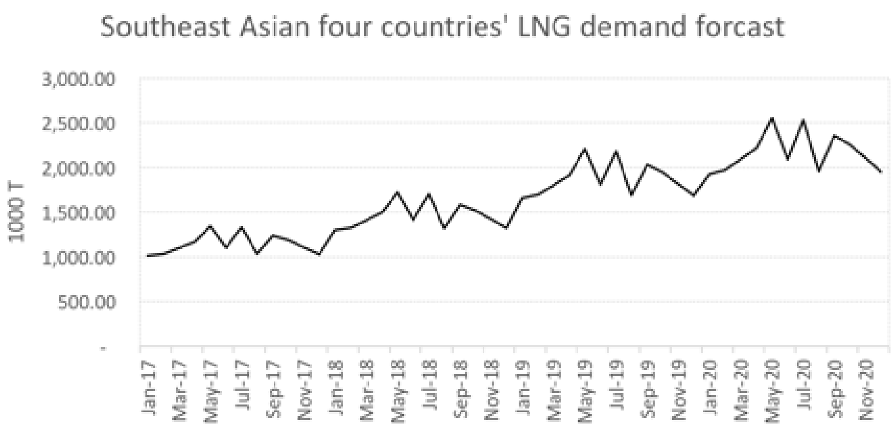
```
#ARIMA
mod = auto.arima(data)
arimaorder(mod)
summary(mod)
testset=forecast(mod,h=h1)
accuracy(testset,test)
plot(testset,col='red',ylab='Volume (1000 mt)',main = 'Forecasting LNG demand
in X(Testset)')
lines(data2,col='red')
legend("topleft",legend = c("actual","forecasted"), col = c("red","blue"),
lty = 1:2,cex = 0.7 )
mod2 = auto.arima(data2)
arimaorder(mod2)
summary(mod2)
plot(mod2$x, col='red',ylab='Volume (1000 T)',main = 'Comparison
of actual and forecasted LNG demand in X')
lines(fitted(mod2), col='blue')
legend("topleft",legend = c("actual","forecasted"), col = c("red","blue"),
lty = 1:2,cex = 1 )
Foredata= forecast(mod2, h=h2)
plot(Foredata,col='red',xlab='Time',ylab='Volume (1000 T)',main = 'Forecasting
quarterly LNG demand in X to 2020')
R=Foredata$mean
as.annually(R)
```

B

Appendix 2: Time series forecasts of the remaining countries

B.1. Asia Pacific

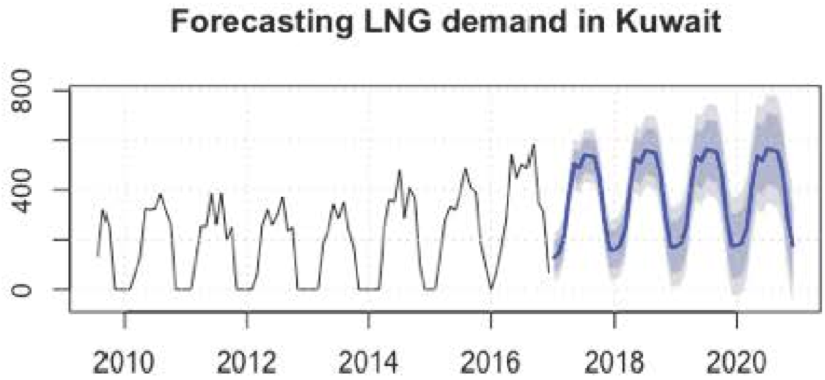
Southeastern countries' demand is expected to grow vey quickly.



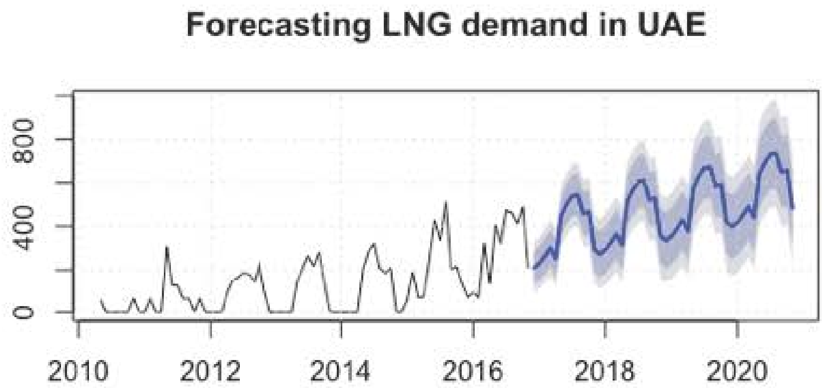
B.2. Middle East

The remaining Middle East countries' demand is expected to grow slightly but their volumes are relatively small.

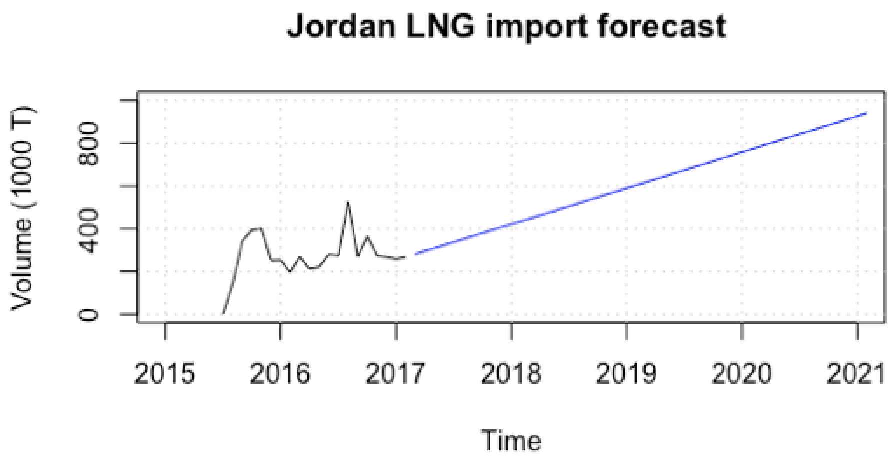
Kuwait


Forecasting LNG demand in Kuwait
0
400
800
2010
2012
2014
2016
2018
2020

UAE


Forecasting LNG demand in UAE
0
400
800
2010
2012
2014
2016
2018
2020

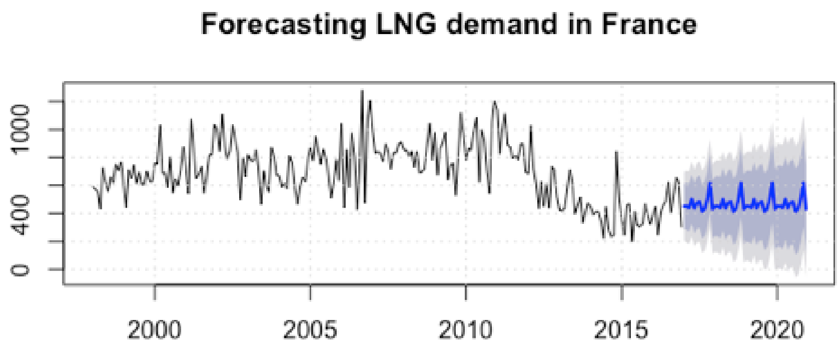
Jordan



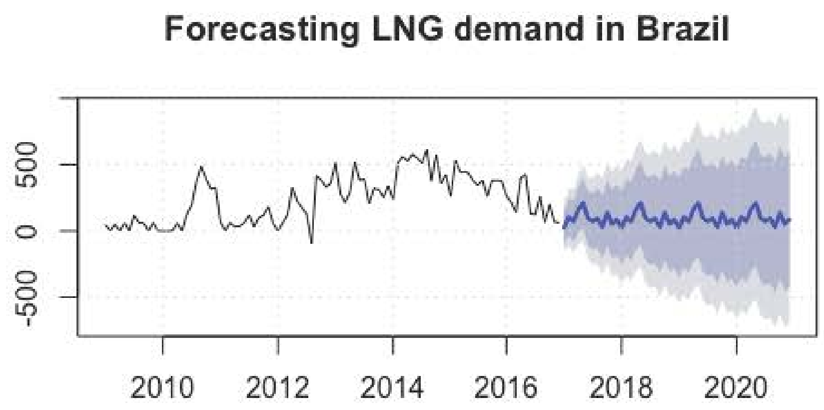
B.3. Atlantic

Atlantic basin has the largest number of countries. Future demand in these countries in Europe and South America.

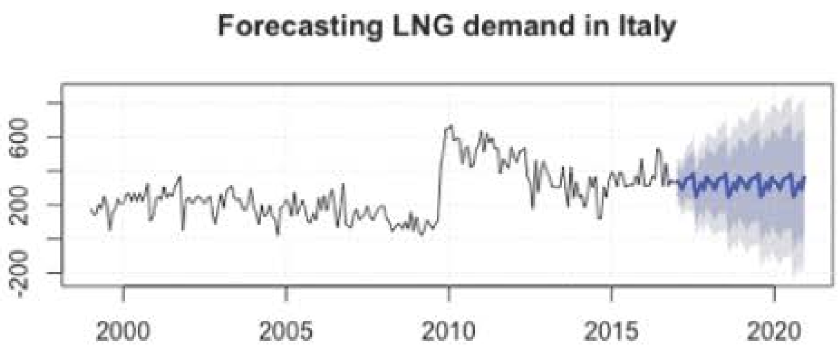
France



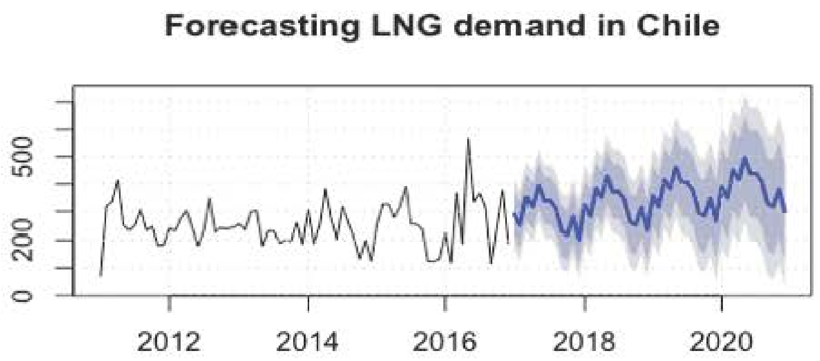
Brazil



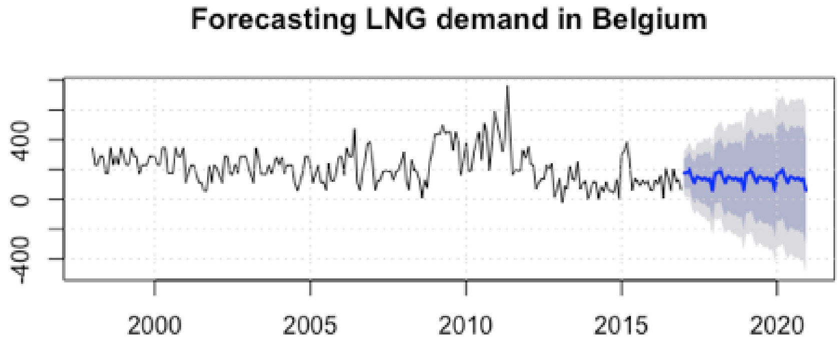
Italy



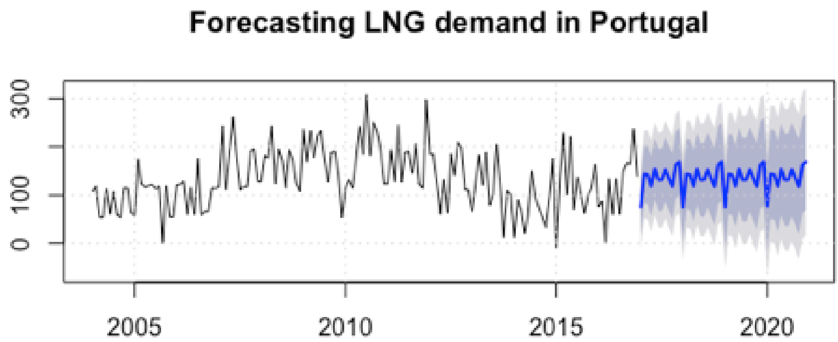
Chile



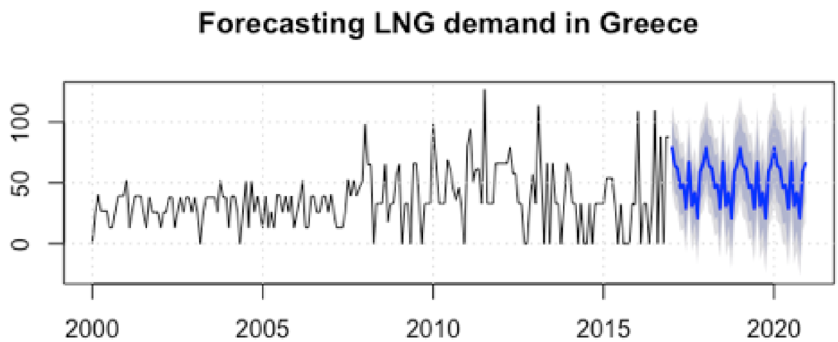
Belgium



Portugal



Greece



Netherlands