Developments on the northwest European market for seasonal gas storage

Historical analysis and future projections

J. de Joode

Ö. Özdemir

ECN-E--09-065 September 2009

Acknowledgement/Preface

This report was prepared for GasTerra. The contact person for this project at GasTerra is Gerard Martinus (Gerard.Martinus@gasterra.nl). In preparing this report we have benefited from a number of discussions on the addressed topic and preliminary drafts of this report at the Clingendael International Energy Programme (CIEP). We like to thank Johan Boerema, Leendert Florusse, Rutger van Hoogstraten, Dick de Jong, Hans van der Meer, Bert Steenbergen, and Steven van Vliet for their contributions in this respect. Furthermore, we thank Herman Snoep for his feed-back throughout the research process and for reviewing this report. Finally we thank Linda Pronk for editing work on the report.

The responsibility for the contents of this report lies with ECN. However, no responsibility for decisions made on the basis of the report is taken.

This report is based on research performed under ECN project number 5.0245. For more information on this project please contact Jeroen de Joode (dejoode@ecn.nl / +31 224 568250).

Abstract

This study focuses on the demand and supply of seasonal swing in the northwest European gas market and the role of gas storage facilities therein. We apply a statistical analysis to analyse historic developments and a model-based analysis to analyse possible future developments with respect to northwest European swing demand and supply. The latter analysis provides projections for swing demand and gas storage developments until the year 2030. We analyse various scenarios with respect to future gas demand and seasonal flexibility characteristics of different gas supply options. Within the framework and assumptions used in our model-based analysis we find that northwest Europe needs to increase its gas storage capacity within a business-as-usual scenario as well as in alternative lower demand scenario. In order to realise the needed seasonal gas storage capacity, a substantial amount of projects currently planned need to go ahead.

Contents

List of tables

List of figures

Executive summary

E.1 Scope of the study

This study addresses the role of seasonal gas storage in providing the flexibility required to accommodate seasonal variability in demand. The focus is on northwest Europe, which consists of Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, and the United Kingdom. This study is an update and extension of the study into the future demand for seasonal gas storage in Europe undertaken by CIEP in 2006 (CIEP 2006). The focus is on seasonal flexibility, which is also referred to as seasonal swing, and not on hourly, weekly or monthly flexibility.

In this study we analyse historic developments in gas demand variability (for the Netherlands and the United Kingdom) and the provision of seasonal flexibility (for northwest Europe as a whole) and the role of gas storage therein. In addition, we provide estimates for the future need for seasonal gas storage by applying a market-model based analysis.

The main questions addressed in this study are:

1) How has the demand for seasonal swing in gas supply been developing in the period from 1990-2008?
2) What was the role of gas storage in providing this seasonal swing?
3) What was the role of other potential sources of seasonal swing?
4) What do different gas demand scenarios imply for the demand for seasonal swing, and how do these affect gas storage requirements?
5) How sensitive are the different projections on the role of gas storage in seasonal swing provision for changes in assumptions on the 'seasonal swing capability' of other supply options such as seasonal swing in indigenous production and seasonal swing in gas imports?

E.2 Continuing demand for seasonal gas deliveries

The basic need for gas markets to provide instruments that are able to deliver seasonal flexibility in gas supply follows from a seasonal pattern in gas demand. The seasonality in demand varies from sector to sector. Seasonality is the highest in the residential and services sector, and quite low in the industrial sector. Seasonality in gas demand in the electricity sector falls in-between the former two sector but is still relatively low. The need for instruments to accommodate seasonal variability varies across northwest European countries, because the larger the share of the residential and services sector in national gas demand, the relatively higher are flexibility requirements.

An analysis of seasonality in UK and Dutch gas demand in various sectors confirms the above statements. Gas demand in industry has been relatively stable whereas gas consumption in the electricity sector has been increasing in all countries, with the UK showing the largest increase in the last two decades. Gas demand in the residential sector has been slowly decreasing in the Netherlands in recent years due to market saturation in combination with savings in gas consumption, whereas residential gas demand in the other countries has been increasing at low to moderate levels. The potential increase in residential gas consumption in these countries could be subject to further study, especially as it may have an impact on the demand for flexibility in gas delivery. After all, the residential sector has the highest flexibility requirements when gas consumption is concerned. For the time period considered we have not found any evidence that the relative level of seasonality in the gas demand in the different sectors is changing over time: in fact it has been rather constant throughout the last two decades.

Projections for future gas demand vary from increasing gas demand in reference scenarios to decreasing gas demand in scenarios related to the reaching of the EC's 2020 sustainability targets. Model-based analysis shows that demand for seasonal supply of gas to end-consumers will remain substantial, varying from about 92 billion m^3 in a reference scenario assuming business as usual conditions to 104 and 62 billion m^3 in respectively a high demand and a low demand scenario. The conclusions drawn in this study with respect to gas demand and the demand for seasonality in gas deliveries are conform the conclusions drawn in a previous study on seasonal storage by CIEP (2006): there is a continuing demand for instruments that can provide seasonal flexibility. However, the growth rate in demand for seasonal flexibility as estimated in this study falls within lower range of estimates of the CIEP study. This is mainly due to downward revisions in total gas demand developments for so-called reference outlooks as published by the IEA and the EC.

E.3 Increasing role of storage in providing seasonal flexibility

A thorough assessment of IEA gas balance data leads us to conclude that the role of gas storage in providing seasonal flexibility to the northwest European market is becoming increasingly important. The main reason for this development is the decreasing capability of indigenous northwest European gas production to deliver seasonal flexibility. When gas fields reach depletion, which is the case for the UK on the short term and the Netherlands in the medium term, they also lose the capability to vary production from summer to winter.

The assessment of gas balance data over the last two decades shows indeed that the amount of seasonal flexibility delivered by gas production is declining, both in absolute and relative sense. Whereas seasonal variation in indigenous gas production covered over 60% of the total need for seasonal flexibility in the beginning of the 1990s, its share is now reduced to below 40%. At the same time, historical data analysis shows that gas imports via pipelines from Norway and Russia or via LNG tankers from Algeria and Egypt is not able to compensate for the decline in seasonal flexibility provided by indigenous production.[1] Economic considerations (e.g. capital intensity of gas transport) give rise to an almost base load infrastructure usage. However, due to its proximity to the northwest European gas market Norway seems to be able to deliver more seasonal flexibility in its exports than Russian and LNG exports to northwest Europe. LNG imports into northwest Europe are still a relatively small share of total gas supply but based on historical data on LNG flows we conclude that LNG is not structurally contributing to the provision of seasonal flexibility in northwest Europe.

We conclude that the decline in seasonal flexibility provided by indigenous gas production in the last two decades has been largely compensated for by (seasonal) gas storage. Total gas storage capacity in northwest Europe has hardly expanded in the last 5 years, the level of gas storage withdrawals during wintertime has been increasing for some time now, despite the fact that the last few winters were relatively mild to northwest European standards. The average use of available gas storage capacity has increased from about 40% in the early 1990s to about 60 to 70% in the last 5 years. The former study on seasonal gas storage by CIEP already signalled a significant increase in existing gas storage use, but whereas CIEP projected an increase in gas storage ratios for the last 5 years, the actual gas storage ratio has been more or less constant at about 65%. This can be explained by the relative mild winters over this same period.

E.4 Future developments in seasonal gas storage

A gas market model covering the whole European gas market was used to estimate the physical future need for seasonal gas storage. Using real cost data the market model determines the opti-

[1] Technically speaking pipeline imports could provide high levels of seasonal flexibility but it is considered to be not economic, and in fact has not been observed in the past.

mal mix of different alternatives for the provision of seasonal flexibility. Within a reference scenario based on business as usual conditions the model estimates a total need for additional gas storage capacity of about 17 billion m^3 in 2015. This can be observed in Figure E.1. The main driver for the increase in required gas storage capacity is the decline in seasonal swing provided by indigenous production (i.e. the Netherlands and UK). The share of production in the overall provision of seasonal swing supply further decreases from the current 30-40% to about 5% in 2030. Imports provide only a very limited compensation for the decline in the share provided by indigenous production.

Confronting the estimated needs for gas storage capacity in the next 20 years with existing gas storage capacity, gas storage capacity under construction and planned gas storage investments we find that a substantial share of planned gas storage investments need to be realised for future gas storage requirements be met. In fact, it seems that at least 46% of planned investments need to come on stream in the next two decades. When gas demand and associated demand for seasonal flexibility in gas deliveries is much lower, for example as low as in a scenario where the EC´s 2020 sustainability targets are reached, we find that still current capacity combined with capacity under construction is not sufficient in meeting required gas storage capacity in the next two decades. On the other hand, realising all currently known gas storage investment plans would give rise to substantial more capacity than needed according to our model calculations, even in a high demand scenario that takes into account a 10% increase in total gas demand compared with the reference outlook.

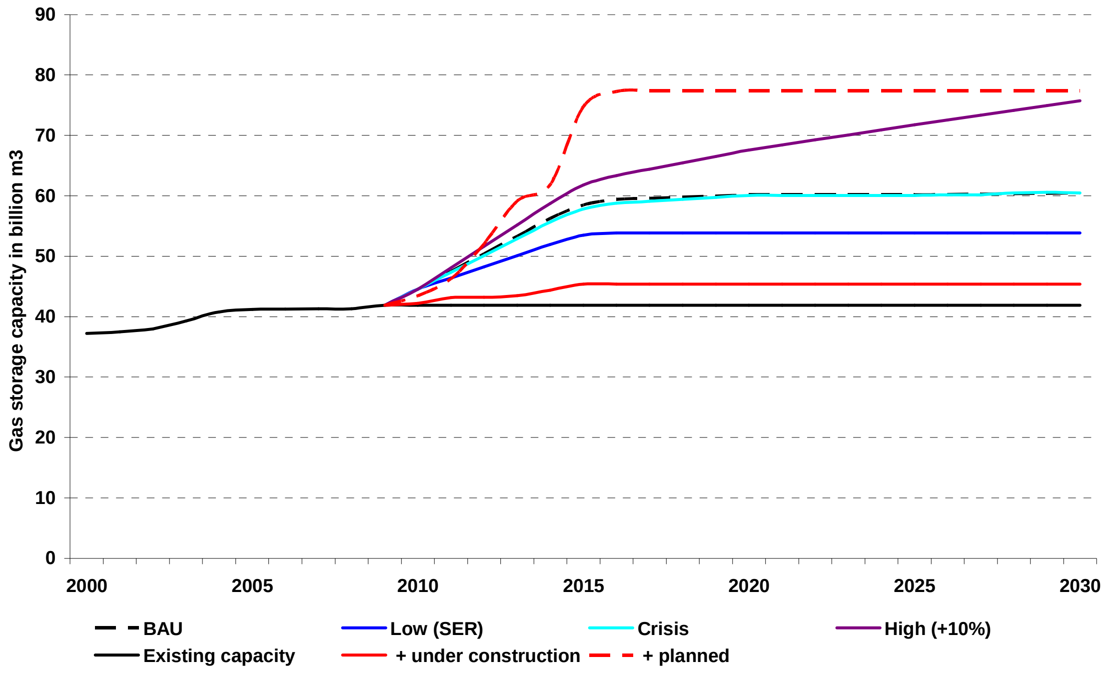


Figure E.1 *Total gas storage capacity in northwest Europe: confrontations based on model-based scenarios and existing gas storage investment database*

Source: GSE, IGU.

The above conclusions are robust for changes in modelling assumptions with respect to the availability of alternative sources of seasonal flexibility. Either an extension in the capability of indigenous production in providing seasonal flexibility over time or an increase in seasonal flexibility of LNG supplies to northwest Europe has relatively little impact on total gas storage requirements. The same holds for changes in the assumption with respect to gas infrastructure availability. More efficient usage of the existing pipeline infrastructure reduces the need for additional gas storage investments. More in general, improved market integration in northwest Europe, without a persistent transport bottlenecks, and efficient infrastructure operation reduces the need for seasonal gas storage as existing storage capacity across Europe would be then used in a more efficient manner.

Future gas storage requirements were also estimated in CIEP (2006) but these are difficult to compare with estimates in this study since the geographical scope is somewhat different: OECD-Europe in the CIEP study versus northwest Europe in this study. However, we can state that future physical gas storage requirements estimated in this study are comparable to the lower end of the range of estimates provided in the CIEP study. This is explained by a downward revision of gas demand projections for the future.

E.5 Points for further discussion and research

A number of aspects are important to raise with respect to the outcomes of this study. This at the same time provides some interesting directions for future research efforts in the area of seasonal gas storage.

First of all, the need for future seasonal flexibility provision could decrease if average temperature decrease over the long-term, making average winter conditions milder. The number of heating degree-days in winter in the last 18 years in northwest Europe has been decreasing. However, the considered time span does not warrant firm conclusions on the very long-term trend in average temperatures in northwest Europe. This would require substantial study that falls outside the scope of this study.

A second issue is the potential role of LNG as a source for seasonal flexibility in northwest Europe in the future. Although historical data does not provide proof of a structural role for LNG in supplying seasonal flexibility, there are two possible reasons why this could be different in the future. Firstly, the current overcapacity in re-gasification of LNG worldwide might induce different dynamics in LNG supply. From an investment perspective it would be difficult to see a profitable re-gasification project come off the ground based only on seasonal gas deliveries (e.g. partial load instead of near-base load), if that usage would imply such seasonality in the entire LNG chain. This fact could be somewhat obscured by the current overcapacity in re-gasification. Alternatively it has been argued that perhaps a structural overcapacity in re-gasification could facilitate a structural seasonal flexibility contribution by LNG, in view of a world-wide gas market. The argument then goes that there is a sink somewhere in the world for summer LNG, for example because there is a demand centre with relatively cheap gas storage operations in summertime (e.g. the United States) and as compared to the relatively expensive gas storage operations in Europe. This would be economically sound if the storage and transport differential together would be able to cover the investment costs due to overcapacity in re-gasification. As a matter of fact, some argue that this option is currently already played out, as a result of the oversupply of gas in the world. Both these issues could be addressed in a further study.

Third of all, given the nature of the tool used in this study it has proven too difficult to in-depth explore the issue of gas storage required to accommodate ‘1-in-20 years winter demand’. As reference point in this study we have been able to calculate the optimal level of gas storage capacity for average winter demand conditions, corrected for a constant additional reserve margin of total storage capacity to accommodate more extreme winter demand conditions. The assumed reserve margin is based on historic gas storage capacity usage in northwest Europe and is as such a correct point for departure in this study, but in future research we need to consider the option that the implied reserve margin covering more extreme winter demand might be decreasing over time due to increased market integration and more efficient use of existing infrastructure capacity.

1. Introduction

1.1 Context of this study

The current EU natural gas market is faced with a number of important developments that have implications for the dynamics of specifically the market for the storage of gas. The most important developments are:

- The decline in EU gas production;
- The transition to a more sustainable energy system;
- Increasing fears for insufficient responsive capacity for supply interruptions.

Traditional large EU-internal gas suppliers like the Netherlands and the United Kingdom experience a decline in gas reserves and will increasingly need to import larger shares of their gas demand from EU-external gas suppliers further away. On the demand side, gas consumers varying from the residential to the industrial and electricity sector show a specific demand profile throughout the year that requires a constant matching of available gas supply with total gas demand. With the decline in indigenous production the capability to match total gas supply to (seasonal) fluctuations will decline as well. In other words, the market needs to shift to other sources of flexible gas supply than indigenous production. Since long-distance imports generally exhibit low levels of flexibility due to economic considerations, the most attractive alternative is provided by gas storage facilities. In short: the decrease in flexible indigenous production potentially increases the need for substantial new gas storage investment. This holds for the case where current gas demand stays constant until 2020, but even more so when gas demand increases further over time.

EU energy policy consists of a number of ambitious targets regarding the transition from the current energy system to a more sustainable energy system in the future. Here we refer to the so-called 20-20-20 targets set at EU level. This means that the EU vows to reduce greenhouse gasses with 20% (30% if international agreement is reached), reduce energy consumption with 20% through increased energy efficiency, and increase the share of renewable energy in total energy supply to 20% by the year 2020. As an important part of the EU energy mix, the gas sector will naturally be impacted by the measures implemented in different sectors to realise these EU wide targets. More specifically it impacts the level of gas demand and consequentially the need for flexible gas supply and gas storage as well.

Recent disturbances in the gas supply from Russia through Ukraine to the EU have fuelled fears among policy-makers that the current EU gas market might be insufficiently prepared for ‘low probability, high impact’ events. This has caused inter alia increasing pleas for specific security of supply measures, such as building strategic gas stocks similar to the already existent strategic petroleum stocks. An increase in the amount of commercial gas storage facilities also contributes to an increased level of security of supply.

1.2 Goal of this study and research question

In 2006 GasTerra commissioned a report on gas storage developments in (OECD) Europe (CIEP 2006). Three years on, the gas market has changed and a more extensive update is needed. Total gas demand scenarios prepared by different international institutions have been revised downwards, possibly implying a decrease in the demand for (seasonal) flexibility in gas supply. However, there is still uncertainty on the role of gas in power generation across north-west Europe: it could increase its share in the electricity generation mix. More importantly, the main source of seasonal flexibility provision, indigenous gas production, is running out. A scenario-based analysis is needed to get insight into the impact of (1) different gas demand scenarios and (2) different assumptions with respect to the development in (seasonal) flexibility provision from other sources in the period until 2030.

This study provides an update of the CIEP (2006) study in two respects. Firstly, we update the analysis of historical developments on the gas demand side for seasonal flexibility in the last couple of years as well as the developments with respect to gas storage capacity and usage. Secondly, we provide a more extensive update on the possible future developments on the market for gas storage. The following types of questions are addressed in this study:

1) How has the demand for seasonal swing in gas supply been developing in the period from 1990-2008?
2) What was the role of gas storage in providing this seasonal swing?
3) What was the role of other potential sources of seasonal swing?
4) What do different gas demand scenarios imply for the demand for seasonal swing, and how do these affect gas storage requirements?
5) How sensitive are the different projections on the role of gas storage in seasonal swing provision for changes in assumptions on the 'seasonal swing capability' of other supply options such as seasonal swing in indigenous production and seasonal swing in gas imports?

1.3 Reading guide

The remainder of the report is as follows. First we provide a brief overview of the main concepts and definitions used in this study and a discussion on the methodology adopted in our study (Section 2). Thereafter we turn to the actual analysis. An analysis on the historical trends and current status quo with respect to the provision of seasonal swing in the northwest European gas market, and the role of gas storage therein is provided first (Section 3). Then we turn to an analysis on future developments in the provision of seasonal swing using our gas market model (Section 4). Finally we turn to the main conclusions (Section 5).

2. Concepts, definitions and methodology

2.1 Concepts and definitions

Geography

With northwest Europe we refer to the countries of Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands and the United Kingdom. In analysing the demand for seasonal flexibility and the supply of seasonal gas storage, both in recent years, currently and in the near future, we focus on these seven countries. When relevant we will discuss developments in third countries as well. This for example concerns the supply of production flexibility by Norway and the supply of seasonal gas storage by Poland. This geographical focus is somewhat different than was taken in CIEP (2006). This is exemplary for the more in-depth analysis of those particular countries directly neighbouring the Netherlands that together form the northwest European gas market.

Flexibility

As the CIEP 2006 study extensively explains there are different dimensions to flexibility in the gas market (see Table 2.1). In the current study the focus is on the demand and supply of seasonal flexibility only. Hence, we focus on the flexibility provided by production at short distance (indigenous production), production at large distance (imports via LNG and pipelines) and gas storage facilities. Although interruptible contracts can technically provide some seasonal flexibility as well, we will not include this option in the analysis in this study for two reasons. Firstly, the contribution of interruptible contracts to the provision of seasonal flexibility is limited. Secondly, within the chosen methodologies it would be very difficult to include this instrument in our analysis. Trying to assess the seasonal responsiveness of large gas consumers requires a sufficiently detailed level of gas demand data over time, which is not something that is readily available and hence deployable in this study.

Table 2.1 *Overview of flexibility segmentation*

Flexibility instruments	Time dimension				
	Annual	Seasonal	Weekly	Daily	Hourly
Long-distance production flexibility	Yes	Yes	Yes	No	No
Short-distance production flexibility	Yes	Yes	Yes	Yes	No
Underground storage (fields & aquifers)	No	Yes	Yes	Yes	No
Underground storage (caverns)	No	No	Yes	Yes	Yes
Interruptible contracts	No	No	Yes	Yes	Yes
LNG storage (peak shaving)	No	No	No	Yes	Yes
Small-scale local compressed gas	No	No	No	Yes	Yes
Line pack	No	No	No	No	Yes

Source: CIEP 2006.

At this point we especially stress that we look at the issue of seasonal flexibility from a physical perspective, not from a contractual or primarily economic one. We assess (historic data) and project (model-based) developments with respect to seasonal flexibility in terms of gas flows, and we do not assess or hypothesize on the reflection of these physical developments in the flexibility clauses in gas delivery contracts. For example, the actual observed physical demand for seasonal swing is likely to be different from the contracted seasonal swing.

Strategic storage

The focus of this study is on commercial storage and not on strategic storage. In our view strategic storage involves a permanent holding of gas in storage required for low probability high impact events where decision-making on the timing and amount of withdrawals lies with government authorities. In this sense strategic gas storage is interpreted in the same vein as the OECD's strategic oil stocks. In literature on the subject of gas storage the term strategic gas storage is often misinterpreted and includes storage of gas following public service obligations (PSOs) with respect to cold winter spells. In our view the latter type of storages is part of the commercial market and should not be labelled as strategic gas storage. Off course all types of (commercial) storage facilities contribute to an overall level of security of supply.

2.2 Statistical analysis

This study adopts two different methodologies to gain insight into the posed research questions. First, when dealing with historical trends regarding gas demand, gas production and gas storage use we perform basic statistical analysis. Second, when turning to an analysis of future projections on gas storage developments we undertake a model-based analysis. Below we elaborate on the two methodologies.

2.2.1 Indicators for flexibility

In evaluating the demand and supply for seasonal swing we use three different indicators:
- The flexibility ratio.
- The swing volume.
- The swing ratio.

The flexibility ratio indicator is mainly used in the historic analysis of gas demand data for the Netherlands and UK, while the swing volume and swing ratio are used in both the historic analysis and the model-based analysis.

In analysing the demand and supply of flexibility on a *monthly basis* we will be using the concept of flexibility ratio. The flexibility ratio in demand (supply) is defined as being the maximum demand (supply) in a certain time period (month, quarter) divided by the average demand (supply) over the monthly or quarterly demand (supply) volume. Below we provide the mathematical expression for this definition.

$$\textit{Maximum flexibility ratio} = \frac{Max[q_1,...,q_n]}{\left(\frac{\sum[q_1,...,q_n]}{n}\right)} \qquad (1)$$

$$\textit{Minimum flexibility ratio} = \frac{Min[q_1,...,q_n]}{\left(\frac{\sum[q_1,...,q_n]}{n}\right)} \qquad (2)$$

With:

$n = 12$	for ratios based on monthly data
$n = 4$	for ratios based on quarterly data
q_t	representing production in period *t*

The same formula applies for swing ratios of demand, where q_t is replaced by d_t, where:

d_t	represents demand in period *t*.

In order to analyse seasonal swing, i.e. flexibility on a *seasonal basis* we use the other two indicators: swing volume and swing ratio. In defining them we follow Höffler and Kübler (2007). We define the total swing volume of gas to be the difference between total gas supplies in winter (October to March) minus total gas supplies in summer (April to September). The swing ratio is defined to be the aforementioned difference divided by total gas supply (sum of summer and winter supply. For example, a swing ratio of 0.25 means that the total supply differential between summer and winter is equal to 25% of total consumption in that gas year.[2] A swing volume of 0 would give rise to a swing ratio of 0%, which implies that there is no difference in summer and winter gas supply. A swing ratio of 100% means that there is in fact no gas supply in summer.

In the same way, the swing volume and swing ratio of gas imports and gas production figures can be derived.

2.2.2 Datasets

Based on publicly available, historical country-based data we assess trend developments for the gas market in northwest Europe. Here we focus on the following gas market indicators. Firstly we use gas demand on a country, and where available, sectoral basis to assess the demand for swing, i.e. the flexible delivery of gas. The lower the aggregation level, the more accurate actual flexibility required can be computed. The sectoral assessment is based on demand from three main gas consuming sectors, namely: industry, residential and services, and power generation. Secondly, we look at the way the required flexibility is met by the different possible sources. It can be provided by indigenous gas production, gas imports and gas storage facilities. For all three sources we assess the absolute and relative flexibility provided currently and in recent history. Thirdly, we assess the current status quo with respect to the capacity and investment plans of gas storage facilities in northwest Europe. Below we give a description of the data used in this part of the analysis.

Table 2.2 *Overview of data used in the historic analysis*

Description	Period	Aggregation	Countries[3]	Source
National gas consumption	1990-2008	Monthly	BE, DK, FR, GE, IE, LUX, NL, UK	IEA gas balance data
National gas production	1990-2008	Monthly	BE, DK, FR, GE, IE, LUX, NL, UK	IEA gas balance data
National gas storage change	1990-2008	Monthly	BE, DK, FR, GE, IE, LUX, NL, UK	IEA gas balance data
National gas imports	1990-2008	Monthly	BE, DK, FR, GE, IE, LUX, NL, UK	IEA gas balance data
National gas exports	1990-2008	Monthly	BE, DK, FR, GE, IE, LUX, NL, UK	IEA gas balance data
National gas consumption in industry	1991-2006	Yearly	BE, DK, FR, GE, IE, LUX, NL, UK	IEA natural gas information
National gas consumption in transformation sector	1991-2006	Yearly	BE, DK, FR, GE, IE, LUX, NL, UK	IEA natural gas information
National gas consumption in residential sector	1991-2006	Yearly	BE, DK, FR, GE, IE, LUX, NL, UK	IEA natural gas information
Dutch gas consumption via national gas transmission network	1995-2008	Monthly	NL	CBS Statline[4]
Dutch gas consumption in power generation sector	1995-2008	Monthly	NL	CBS Statline[1]
Dutch gas consumption via national gas transmission network (excl. power generation sector)	1995-2008	Monthly	NL	CBS Statline[1]

[2] The gas year runs from October 1st in year *t* to September 30th.in year *t+1*.
[3] BE = Belgium, DK = Denmark, FR = France, GE = Germany, IE = Ireland, LUX = Luxembourg, NL = Netherlands, UK = United Kingdom.
[4] http://statline.cbs.nl

Description	Period	Aggregation	Countries[3]	Source
Dutch gas consumption via regional gas distribution networks	1995-2008	Monthly	NL	CBS Statline[1]
UK consumption in electricity generation	2005-2008	Quarterly	UK	BERR[5]
UK final consumption in iron and steel industry	2005-2008	Quarterly	UK	BERR[2]
UK final consumption in other industries	2005-2008	Quarterly	UK	BERR[2]
UK final consumption in the domestic sector	2005-2008	Quarterly	UK	BERR[2]

2.2.3 Correcting for variations in temperature

A substantial part of demand for gas is related to the demand for heat. In turn, the demand for heat is related to the temperature. Considering the purpose of this study we below expand on basic indicators for heat demand and the methodology that is applied in correcting specific gas related variables for temperature. Temperature-corrected gas demand data are useful as they allow for improved interpretation of gas demand trends on a more accurate basis. Throughout the report no correction is applied when it is not explicitly stated. When a correction is made, the following approach is taken.

An indicator that can be used to analyse the impact of outside temperature on gas market developments is the amount of so-called heating degree-days. For the definition of a heating degree-day we adopt the Eurostat definition (Eurostat, 2007), since this is the definition underlying the only publicly available database on degree-days with coverage of all countries analysed in this study.

$$\textit{Heating degree-days} = \begin{cases} d\,(18°C - T_M) & \textit{when} \quad T_M \leq 15°C \\ 0 & \textit{when} \quad T_M > 15°C \end{cases} \qquad (3)$$

Where:

$15°C$ is the heating threshold

T_M is the mean outdoor temperature over a period of d days

In this study we have used monthly Eurostat statistics for the actual heating degree-days per month over the period 1990-2008. For each country the average amount of heating degree-days was used (which in turn is based on a weighted average of local heating degree-days per country). For the actual correction of gas demand values the relative heating degree-days have been used. These are defined to be the ratio of the actual heating degree-days and the mean heating-degree-days. The mean monthly heating degree-days per country are provided by Eurostat and reflect the mean for the 1980 to 2004 period. Throughout this study we will either use this dataset to technically correct specific gas market variables or use insights from this database (for example with respect to the impact of a particular harsh winter) to explain certain observations.

In the section where gas storage withdrawals have been analysed (Section 3.2) we have also corrected the total amount of withdrawals in winter. There we have used the same data on degree-days (on a monthly basis) from Eurostat but have compiled a new data series on a country level depicting the relative heating degree-days in the winter period only (October to March). We assume that gas storage withdrawals are fully used for heat-demand driven demand. We have directly corrected original withdrawals data by dividing by the relative heating degree-day ratio

[5] http://www.berr.gov.uk/energy/statistics/source/gas/page18525.html.

(i.e. the actual amount of heating degree-days in a particular winter divided by the average amount of heating degree-days per winter) in the period 1990-2008.

In general heating-degree corrections are expected to smooth time-series data for gas demand, gas storage withdrawals and the like. However, it should be noted that the resulting corrected time-series might still contain some 'irregular patterns'. This could be explained by various indirect effects.

2.3 Scenario-based analysis

2.3.1 General model characteristics

In the model-based analysis we have applied ECN's gas market model GASTALE. GASTALE is a market simulation model that is capable of calculating gas market demand and supply and gas prices for the entire EU market while taking into account the available gas infra-structure. Earlier applications of the GASTALE model have been described in Boots et al. (2004), Lise et al.(2005), Van Oostvoorn and Lise (2007), Lise and Hobbs (2008), and Lise et al.(2008). Below we sketch some main characteristics of the model, before turning to the modelling characteristics of specific elements in the gas market value chain.

Firstly, the model distinguishes different seasons. It specifies prices, production, transport, and storage volumes for three periods; namely summer (April-September), winter (December and January) and autumn & spring (February, March, October, and November).

Secondly, the model has a dynamic version, meaning that the model computes output for a series of consecutive 5 year periods thereby endogenously determining new investments in the transport infrastructure, LNG facilities and also gas storage facilities. In other words: given input data and a specific demand projection, the model endogenously calculates the amount of new storage capacity required. Since output is specified on a seasonal basis (also reflecting seasonal demand profiles) the model thus explicitly calculates required gas storage capacity in the future. Note that given the fact that new investment in pipelines, LNG and storage are considered in the model, the relation between the three modes for delivering seasonal flexibility are also implicitly addressed.

Thirdly, the model abstracts from natural gas quality issues. For the whole of EU one gas quality is assumed. In other words, we assume that different gas qualities across the EU can be converted into other gas quality at no additional cost.

Fourthly, it should be kept in mind that the model is based on economics and that calculated market prices are fully gas market-reflective: only gas market fundamentals determine natural gas prices. Since the world oil market is not included in the model, there is no oil price linkage in natural gas prices.

Gas demand

Gas demand in the model is specified at the country and sectoral level. The gas demand sectors distinguished are the industrial sector, the residential and services sector and the power generation sector. For each demand sector in each country a seasonal variation factor is identified that reflects the gas demand profile for each gas demand sector across different seasons. The values for the seasonal variation factors for the countries in northwest Europe are included in Appendix A. The factors have been estimated based on the country specific data underlying the analysis in Section 3. For each demand sector a different price elasticity of demand is assumed. Demand elasticity is not country-specific but uniform across countries. The values for price elasticity of demand have been based on literature analysis in this field and are common in gas market modelling analyses. We have assumed a price elasticity of -0.40, -0.25 and -0.75 for respectively the industrial and services, residential and power generation sector. For example, this means that it is assumed that a 1% increase in the gas price gives rise to a 0.4% decrease in gas demand in industry.

Investment

The model is able to take into account different types of investment decision-making when it comes to investment in different gas infrastructure assets. Here we refer to investment in gas pipelines, LNG liquefaction and re-gasification terminals, and gas storage facilities. Investment decision-making in new gas production facilities (i.e. production from new fields) or investment in expansion of existing gas production facilities is not explicitly modelled. Under the header on *gas production* we explain how future gas production is taken into account.

Investment decision-making in pipelines, LNG terminals and gas storage facilities is endogenous, i.e. determined within the model. The investment decision is modelled through a practical rule of thumb containing a specific hurdle rate for investment. In every 5 year period, the model assesses whether the expected market environment in the next 5 years is sufficiently attractive to warrant investment. More concrete: whenever the additional expected income for the investor (i.e. the network operator, LNG terminal operator, gas storage operator) from the new investments is sufficient to cover X% on top of the unit cost of investment, the investment goes ahead. The X% on top op investment cost is the so called 'hurdle rate'. The endogenous nature of investment decision-making by for example the TSO implies that no large transmission bottlenecks are emerging across the EU. That is, investment is always undertaken and leads to new capacity coming on-stream 5 years later if the financial conditions are sound. This does not mean that no congestion in the network can take place: for network connections with only a relatively small amount of congestion during part of the year it might turn out that expansion is not a financially viable option.

Although the basic investment decision rule is identical for the different types of infrastructure investments, the specific cost and investment parameters are not. The investment cost per unit (among others dependent on the lifetime of the asset), the discount rate and hurdle rate for investment differ. The table below describes the value of these parameters. Parameter values have been based in earlier Gastale studies and have been discussed with GasTerra. Differing parameter values have been chosen for investment decision-making concerning the different type of assets due to their relative risk of investment. Actual investment decision-making parameter values as applied by gas companies across Europe actually depend on local economic and regulatory conditions.

Table 2.3 *Parameter values for investment decision-making in gas infrastructure assets*

Type of asset	Economic lifetime [years]	Hurdle rate [%]	Interest rate [%]
Gas pipeline	20	20	8
LNG terminal	30	20	10
Gas storage facility	30	10	10

Gas production

Both the cost and capacity for gas production now and in the future is determined exogenously. Hence, no investment decision-making is modelled for gas production. This means that an assumed gas production curve is put into the model as an external restriction for the whole time period (2005-2030). Figure 2.1 and Figure 2.2 indicate the assumed production capacity and marginal production cost curves for the different gas producing countries respectively identified in the model. These 'capacity curves' are based on discussion with the ´Observatoire Mediterraneen de l´energie' (OME), a research partner in earlier Gastale studies and have been updated for this study.

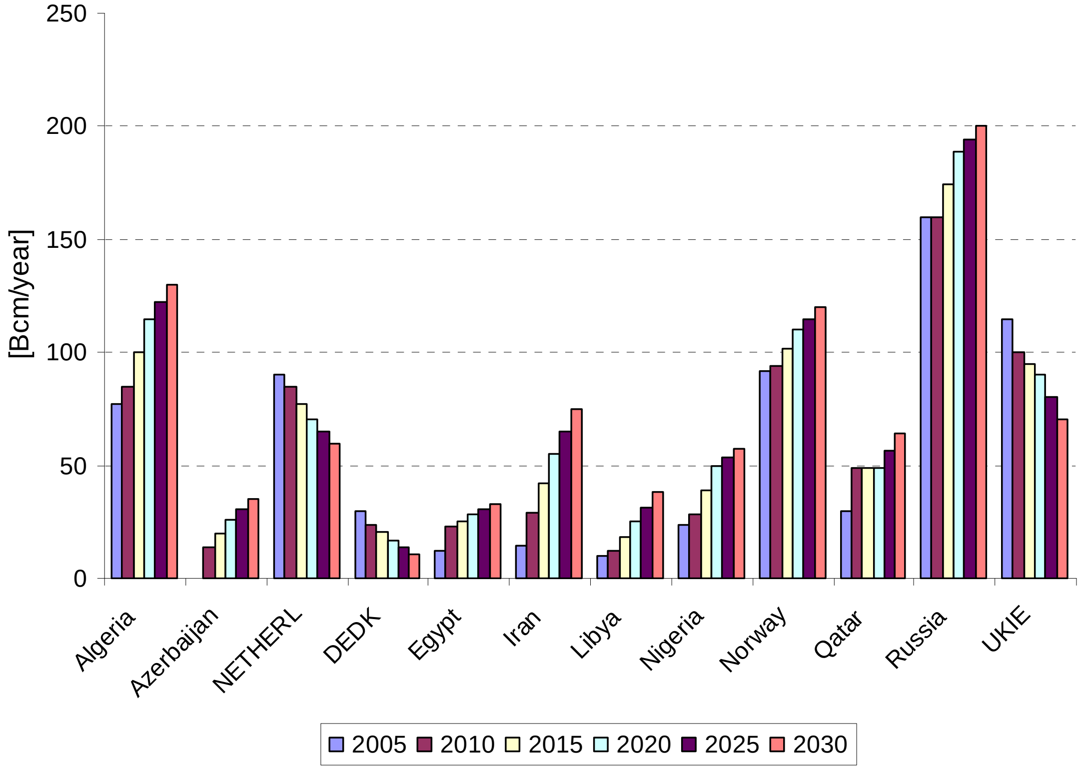


Figure 2.1 *Production capacities of each producer in GASTALE*

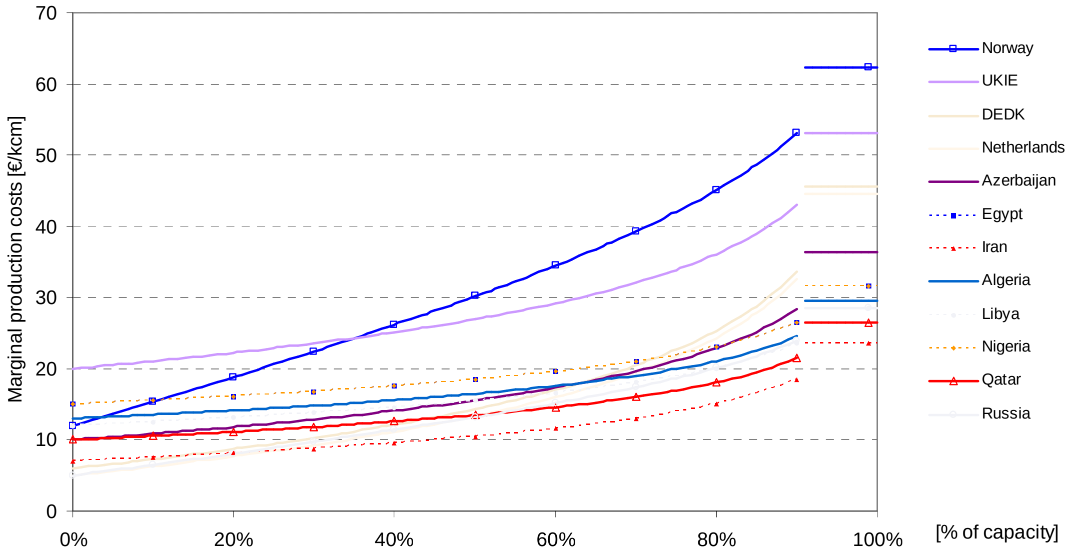


Figure 2.2 *Marginal cost curve of gas producing regions in GASTALE*

As for flexibility, each individual gas field has its own limits with respect to the capability to vary the production level throughout the year. Several ways have been considered to incorporate the flexibility in production. We have opted to make the decision of a gas producer in determining the actual level of gas production dependent on the gas demand situation, the technical capabilities of the field and the marginal costs of producing gas. This basic decision-making environment has been reflected in the model as follows. For any given year, the gas producer is faced with a maximum total production level given in Figure 2.1. This means that the sum of actual production in summer, winter and the intermediate season needs to be equal or lower than this maximum. For all individual seasons within a year, the same production curve containing the marginal cost of gas production is valid. Total production across all seasons for a certain year can obviously be lower than the set maximum yearly production for that year, since marginal cost properties might be putting him at a disadvantage vis-à-vis his competitors. Obviously, gas producers selling their gas need to adhere to limitations in the transport network (i.e. pipeline and LNG capacity). The gas producer is now faced with an explicit trade-off in setting gas production levels across seasons. This results in a swing in gas production. In calibrating the model the actual observed swing ratios in recent years (based on IEA data) have been used as a comparative indicator.

Gas storage
The model incorporates all existing gas storage facilities that are currently in operation. Its operation over the seasons is modelled as follows. Injection in gas storage facilities takes place in the summer while withdrawals take place in mid-season and the winter period. The role of gas storage in the model is primarily aimed at seasonal storage. This means that the role of storage facilities in for example daily arbitrage and as strategic means to overcome unexpected interruptions in supply are not included in the analysis. Daily arbitrage can not be modelled since the lowest level of output data of the deployed model is on a seasonal basis. Gas storage capacity requirements in the future, as calculated by the model, are based on average supply and demand conditions. Storage capacity build-up for extraordinary and above-average winter demand periods could be simulated using stochastic demand modelling (instead of current deterministic gas demand modelling). Therefore we had to correct model input data on gas storage capacity. We have corrected for the difference in the role of gas storage in the model (where there are only 'average winter conditions') and the role of gas storage in reality (providing a buffer for extreme winter conditions) by using a capacity reserve margin of 40%. This figure is based on discussion in CIEP (2006) and on estimates on gas storage use in the last 18 years. For the 2006 situation regarding gas storage CIEP (2006) estimated that from the total of 70 billion m^3 of installed working gas capacity in OECD Europe about 30 billion m^3 is used as a buffer for more extreme winter conditions. This implies that only about 57% of total working gas capacity is used under average winter demand conditions, and that there is implied reserve margin of about 43%. These estimates were based on discussions with gas market experts and are not referenced. For this study we assume that a similar level of reserve margin is kept with respect to gas storage working gas capacity. We have rounded off the earlier figure to a 60% ratio. This seems appropriate given the utilization rates found in the historic analysis in Section 3.2. For our model output this assumption is implemented as follows. Under the basic modelling framework the model calculates the optimal level of storage for average winter demand conditions, implying usage ratios approaching 100% of total gas storage capacity. We adapted this approach by exogenously increasing the calculated optimal gas storage capacity level with a factor of 100/60. This at the same time implies that capacity usage ratios in our model can not exceed 60%.

Calibration based on current market conditions: strategic behaviour
From earlier analyses with the GASTALE model we have learned that the parameter reflecting the degree of market power that can be exhibited by the gas producers and traders is an important parameter especially for wholesale market price levels and levels of production. Previous studies with GASTALE model have been undertaken under partial strategic behaviour assumption in which Russia is assumed to exercise market power on 25% of their export potential to EU while all other producers exercise market power on 75% of their production capacity in EU or export potential to EU. It has been observed by previous studies that this assumption gives more realistic outcomes in terms of gas price and supply developments. For example, the seasonal gas production of the producers in 2005 match with the real observations better under the assumption of market power. Another interpretation of the calibration based on 'strategic behaviour settings' is that this is a way in which to simulate the impact of the gas-to-oil price linkage on the European gas market. In the presentation of the results derived in the model-based analysis we focus on the runs based on strategic behaviour and we test sensitivity of results when the model would be calibrated to conditions resembling perfect competition.

2.3.2 Scenario analysis and parameters

When assessing possible future developments that are subject to large uncertainties with respect to key drivers it is common to adopt a scenario-based approach where different futures are assessed based on varying the particular value of a limited number of variables. We have identified the following variables to be of particular interest in the context of future developments with respect to gas storage developments:

- Level of gas demand:
- Flexibility of alternative sources of flexibility (e.g. production flexibility and LNG supply flexibility):
- Netting of counter flows within EU gas markets.

In our reference scenario, the gas demand levels are based on the gas demand projections published in the Primes 2007 update (EC 2008a). The level of overall gas demand can influence the need for new seasonal storage facilities. Especially sectoral gas demand developments are important in this respect since for example the residential sector requires substantially more swing in gas supply than the industrial sector. Hence besides the gas demand level in the reference scenario, we simulate three other demand scenarios which will show the impact of high versus low gas demand growth on the supply of gas storage.

A second important aspect for this study is the competition in the provision of flexibility between production, LNG imports and storage. The flexibility in production can vary largely across gas producing fields and is difficult to project for the future. High assumed production flexibility in indigenous production will generally discourage the development of gas storage. The flexibility of LNG supplies to the market competes with gas storage development in a similar manner as production flexibility. In order to explicitly study the impact of production flexibility and flexibility of LNG supplies on the demand for gas storage, we identified two separate scenarios that are different from the reference scenario assumptions when it comes to flexibility. On the one hand we assume an alternative scenario where production flexibility in the Netherlands remains constant over time, as opposed to the decreasing production flexibility in the reference scenario. On the other hand we also we assume a scenario where the flexibility of LNG supplies to the EU countries is at a higher level then assumed in the reference scenario.

Thirdly, a basic assumption needs to be made with respect to the availability of pipeline capacity and more in particular the availability of back-haul (also called counter-flow) capacity. While some pipelines in the European gas transmission network are bi-directional, others are only built to physically transport gas in only one direction. In practice however, TSOs may offer gas shippers the option to offer virtual capacity in the other direction. This is called back-haul or counter-flow capacity. The maximum level of back-haul capacity at any time is equal to the actual physical flow of gas at the time. The term ‘netting’ may be used to describe the case of virtual counter flow gas transport cancelling out physical gas transport. The model is capable of simulating gas network operation including or excluding ‘netting’. Currently, most TSOs in northwest Europe seem to offer back-haul capacity services at interruptible basis. However, the EC signals that in practice (gas and electricity) TSOs throughout Europe might still refrain from offering full counter-flow transmission capacity: *“By not providing such counter flow capacity, TSOs would be obstructing the possibility for suppliers to enter neighbouring markets and therefore limit competition and market integration which in the end leads also to higher costs of providing energy to European consumers.”* (EC 2009).[6]

[6] This memo accompanied the new infringement proceedings that the EC launched on June 25th 2009 against 25 Member States (MS) for not complying with the EU legislation on the internal market for electricity and gas, notably the Electricity Regulation (1228/2003), the Gas Regulation (1775/2005), the Electricity Directive (2003/54/EC) and the Gas Directive (2003/55/EC). The somewhat older DG TREN energy sector inquiry released in 2007 (EC 2007) does not include an analysis on the provision of back-haul capacity but does have a large focus on the availability of gas transmission capacity. One of the observations on this issue is that access to both primary and secondary capacity can be problematic for new market entrants due to market power and contractual congestion.

Based on the above described main variables we have constructed a number of different model runs to be analyzed. Table 2.4 presents an overview of the performed model runs. When a cell is marked red this indicates the difference of this run compared to the reference run (#1). The results of these scenario runs are reported in Section 5.

It should be noted that the identified number of runs do not cover runs related to political interference. For example, market developments resulting from a gas supply interruption from Russia through Ukraine are not simulated. Such scenarios have been analyzed using the model in earlier projects but these do not address the core of the issue analyzed in this study: the development of seasonal gas storage.

Above we have explained the focus in scenario variables - the level of gas demand and the flexibility of other sources. Below we discuss how these are actually transferred into input for the Gastale model.

Gas demand
The gas market model Gastale needs to be given exogenous input with respect to future demand levels. We identified and analysed a total of four different demand scenarios in order to get sufficient insight into the impact of overall gas demand on gas storage developments. In constructing the scenarios we have linked-up with existing scenario projections that are publicly available. More precisely, we use the gas demand projections published in the Primes 2007 update (EC 2008a) and the Strategic Energy Review (SER) (EC 2008b). Linking to existing scenarios has an advantage when it comes to the presentation and communication of the results of this study to the outside world. A particular goal of this study was to gain insight into the possible impact on the developments in the gas storage market under substantially different scenario settings with respect to gas demand. The existing two scenarios differ sufficiently to enable us to do exactly this. We will take the Primes 2007 update projection as a starting point for reference scenario, whereas the SER high oil price scenario will be the point of departure for a low gas demand scenario. In addition, we have constructed a so-called crisis-variant for the Primes scenario: we take a pragmatic stand by assuming that this scenario is identical to gas demand developments in the reference scenario, but with a 5-year delay, and realignment with the reference scenario from 2025 onwards. This means that we assume the currently ongoing crisis to cause a stagnation in the growth in overall gas demand for a period of 5-year. From 2025 onwards we assume that the crisis hit economy (and gas market) are back on the ‘original path’ of the reference scenario of Primes 2007. Finally, we have constructed a higher gas demand scenario that equals the reference Primes 2007 scenario plus an additional 10% of gas demand for all sectors.

Figure 2.3 contains the four scenarios concerning the total gas demand in the northwest European countries. The actual model input is based on the underlying individual country and sectoral based projections. Also depicted in the figure for referencing purposes is the latest IEA World Energy Outlook scenario (IEA 2008b). This scenario is comparable with the Primes 2007 scenario except for a larger ‘dip’ in total gas demand in 2010. One of the reasons for choosing the Primes scenario over the IEA scenario in this analysis is the data availability on country and sectoral level. The reference scenario of the IEA World Energy Outlook gives neither country nor sectoral based projection data.

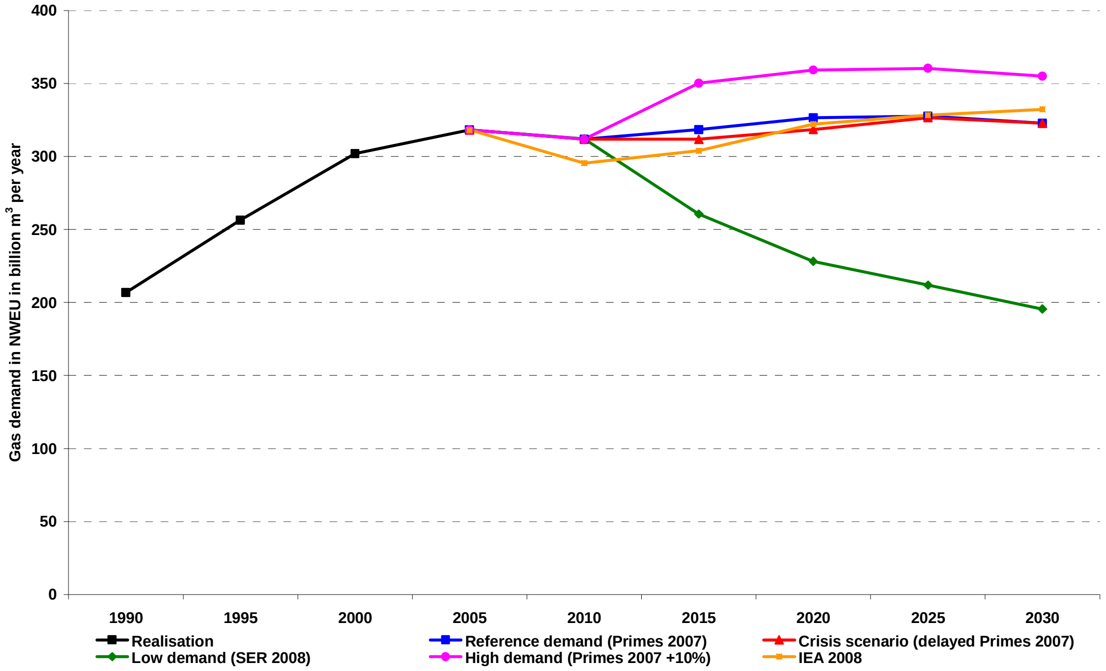


Figure 2.3 *Total gas demand in northwest Europe in three scenarios*
Source: EC 2008a, EC 2008b, IEA 2008b[7].

Flexibility in production, LNG supply and pipelines
Currently the production flexibility of the Netherlands is higher than production flexibility in other gas supply countries such as UK, Denmark and Norway. One of the reasons of Netherlands being a more flexible supplier is its capability to vary its production level throughout the year.

In the reference scenario run, the production flexibility of Netherlands and UK are both assumed to be decreasing. The production flexibility in UK is decreasing since its gas reserves are substantially decreasing. Gas production in the Netherlands is assumed to decrease as well. In addition, it is assumed that the capability of gas fields in the Netherlands to vary its production level throughout the year, and hence its capability to provide seasonal flexibility, is decreasing. It is assumed that the flexibility ratio[8] of Dutch gas production is equal to 1.50 in 2005 is linearly decreasing to 1.00 until 2030. In an alternative production flexibility run, this ratio equal to 1.50 in 2005 is assumed to be maintained throughout the period 2005-2030. This might be an overestimation of the potential capacity to deliver seasonal flexibility but it can also be interpreted as follows. For the purpose of optimising production from the Dutch Groningen field, two gas storage facilities in the Netherlands (Norg and Grijpskerk) are in fact from regulatory point of view considered to be so-called additional production facilities. Assuming a continuation of the seasonal swing capability of Dutch gas production can be interpreted as a future expansion of these additional production facilities to the Groningen system.

We have also varied the flexibility of LNG supply from re-gasification terminals in Europe. In the reference scenario run, we assume that LNG terminals are base load suppliers and the difference of their gas supply between summer and winter may vary with a maximum of 10%. This is achieved by assuming that the utilization of the capacity of an LNG re-gasification terminal is at

[7] Gas demand projections by IEA (2008) are on a EU27 basis. Original EU27 data have been translated into projected developments for northwest Europe based on gas market shares of different countries and sectors in the total market as projected by Primes.
[8] The flexibility ratio of production is the ratio of maximum available production capacity in a day (or month, or quarter) and the average production capacity per day (or month, or quarter).

least 90% during the summer. As a result, LNG becomes a base load gas supplier. In an alternative scenario run, we have decreased the minimum utilization of LNG capacity in summer to 80% which implies increase in flexibility of LNG supplies; that is the maximum difference of total LNG gas supply between summer and winter is increased from 10% to 20%.

Thirdly, regarding the availability of counter-flow capacity we assume that no ‘netting’ of gas flows by TSO takes place in the reference scenario. When no counter-flow capacity is offered, gas trading across borders may be limited and have a negative impact on the level of competition in the market. In addition, it might have an impact on the amount of flexibility that can be provided / transported across pipeline networks. Hence, we simulate in an alternative scenario the impact of including full availability of counter-flow capacity (still limited by the actual physical flow off course).

Table 2.4 *Overview of studied scenarios*[9]

Variable		Scenario (S1)	(S2)	(S3)	(S4)	(S5)	(S6)	(S7)
Gas demand		BAU	*Low*	*Crisis*	*High*	BAU	BAU	BAU
Availability of flexibility alternatives	Production flexibility	Low decreasing	Low decreasing	Low decreasing	Low decreasing	*High constant*	Low decreasing	Low decreasing
	LNG flexibility	Low	Low	Low	Low	Low	*High*	Low
	Netting of counter flows	No	No	No	No	No	No	*Yes*

9 The text in italic red indicates the change in scenario setting compared to the reference scenario (S1).

3. Historical analysis of demand and supply of seasonal swing

3.1 Demand for seasonal flexibility

3.1.1 The Netherlands

For the Netherlands we have analysed monthly gas consumption data for the period January 1995 - December 2008 from the CBS 'aardgasbalans', publicly available at Statline (http://statline.cbs.nl). The gas consumption categories that are of main interest for our purposes are:

- Total consumption via the national transmission network
  - Consumption in power generation
  - Consumption of other users
- Total consumption via the regional networks

This categorisation differs from the one adopted by the IEA (IEA, 2008a). This is important to note since we will be using IEA data in other analyses in this chapter. The Natural Gas Information 2008 (IEA, 2008a) provides data on gas consumption across different sectors in the Netherlands for the year 2006[10]. Table 3.1 provides a comparison of the two data sources. We find that total gas consumption differs in the two databases. Furthermore, we observe that total gas consumption in transformation (IEA) is substantially higher than power generation connected to the national transmission network. This may be explained by the fact that part of gas consumption used in transformation in the CBS database is reported under gas consumption via regional distribution networks. The latter is somewhat higher than gas consumption in the commercial and public sector, the residential and the agricultural sectors taken together.

Table 3.1 *Comparison of gas consumption data in the Netherlands according to IEA and CBS (data are in million m^3 per year)*

IEA Natural Gas Information 2008 (2006 data)		CBS Aardgasbalans (2006 data)	
Oil and gas extraction	0,8	Gas consumption at extraction	0,6
Total transformation, industry, energy sector	27	Gas consumption via national transmission network	23,1
Transformation	*15,3*	*Power generation*	*8,32*
Industry	*10,6*	*Other consumption*	*14,8*
Other energy sector	*1,1*		
Total commerce & public, residential and agriculture	19,8	Gas consumption via regional distribution networks	21,6
Commerce & public	*5,8*		
Residential	*10,3*		
Agriculture	*3,7*		
Total consumption	47,9		45,3

Figure 3.1 presents the observed delivered flexibility ratio in demand for the three main gas consuming sectors in the period 1995-2008. It confirms the relative large flexibility required in gas deliveries to the residential and services sector compared with the power generation and industry sectors. Power generation shows a somewhat larger flexibility requirement than the industry sector. The seasonal cycle in residential and services demand is apparent, but no strong

[10] Data for more recent years are not yet available. This data from Natural Gas Information 2008 can not be used for the purpose of analysing seasonal flexibility since data are provided on yearly basis only.

underlying long-term trend is observed in this figure. This observation is confirmed in Figure 3.2 where the maximum required swing in each individual year for each of the three sectors is depicted. Based on this figure we can not draw any conclusions regarding a structural increase or decrease in the flexibility required in delivering gas to final consumers in the Netherlands. Indeed, the patterns appear to be constant over time, leading to the assumption of a fixed seasonality on the sector level.

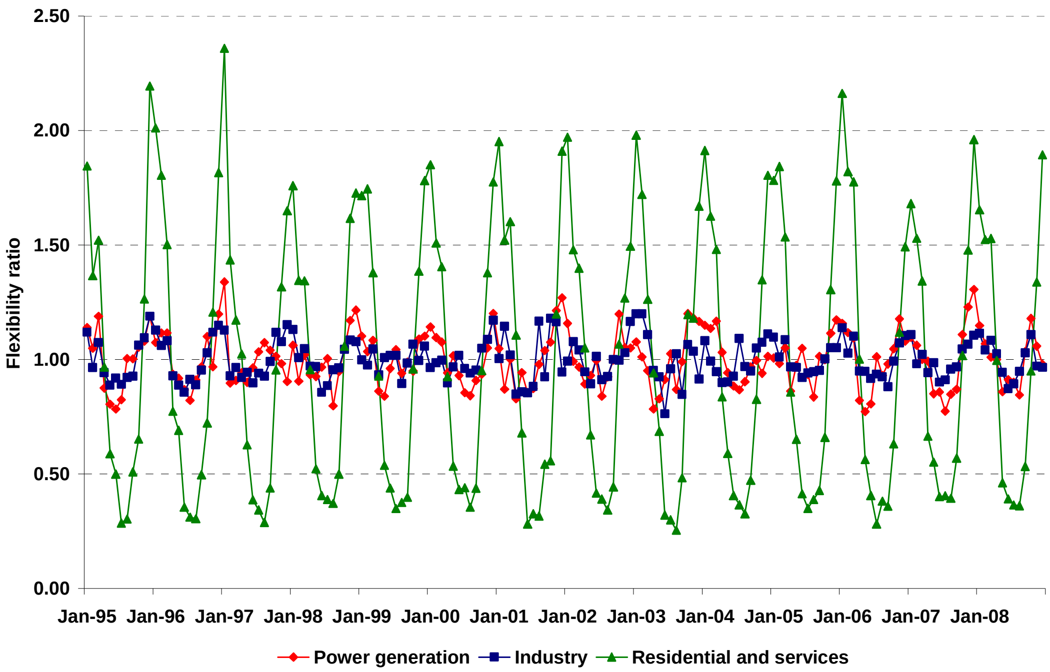


Figure 3.1 *Flexibility in gas demand in the Netherlands 1995-2008 based on monthly data*
Source: CBS[11].

As was illustrated, the level of detail in which data is available varies across databases. For example, for the Netherlands we have acquired and analysed monthly data while for the UK we have acquired quarterly data. In general we expect the level of flexibility in demand to diminish when higher aggregation levels over time are used. An aggregation in quarters will to some degree smooth out the monthly peaks. To get insight in the relative magnitude of this effect we have aggregated the monthly data for the case of the Netherlands into quarterly data and performed identical calculations with respect to the observed flexibility. We indeed found the expected decrease in flexibility in demand. The observed maximum and minimum flexibility levels for each year in the period 1995-2008 using quarterly data were on average 10% lower and 7% higher respectively compared to monthly data. This means that the spread in observed flexibility values was lower. This is captured by the variance indicator. The variance of the flexibility ratio for the residential and services sector on a monthly basis is about 0.331, while the variance of the same ratio for the quarterly data series was about 0.265: this implies a lower level of spread of about 20%.

Other useful indicators that can be used in analysing the demand for seasonal flexibility are the swing volume and swing ratio. Figure 3.3 and Figure 3.4 show the development of these indicators over the last 14 years. Both indicators are presented since they provide different pieces of information with respect to the seasonal flexibility issue. The swing volume per sector provides information on the absolute amount of swing volume required for each sector, whereas the swing ratio provides insight into the relative flexibility required per sector.

[11] Note that the data underlying this figure have not been corrected for temperature.

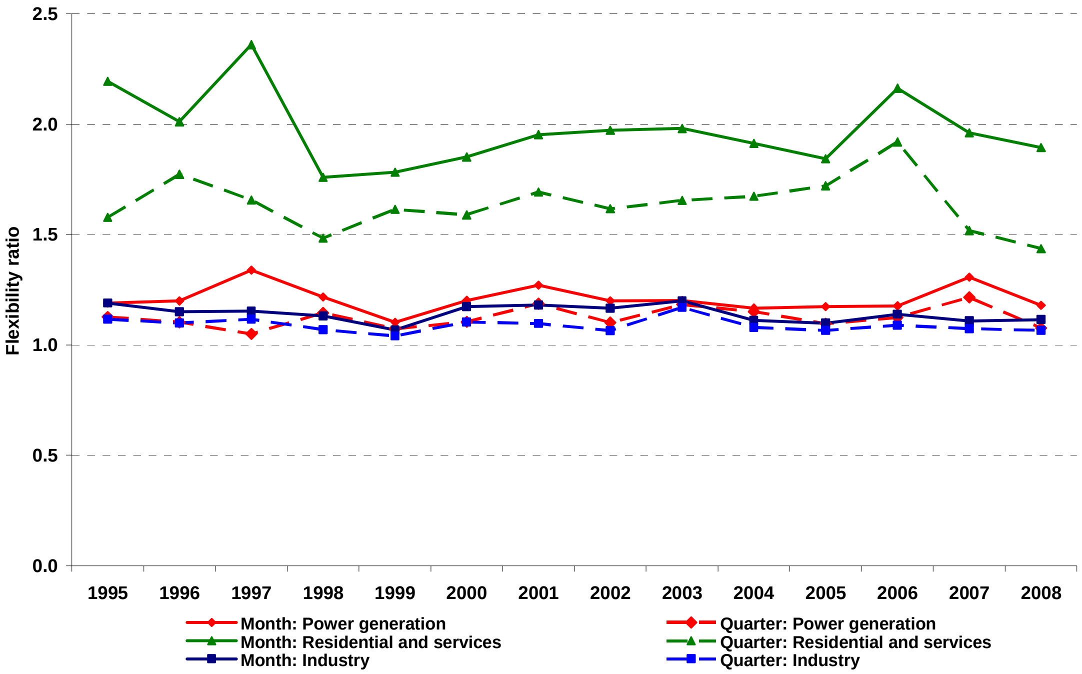


Figure 3.2 *Maximum required flexibility ratio in gas demand in the Netherlands 1995-2008 based on monthly and quarterly calculations*

Source: CBS[12].

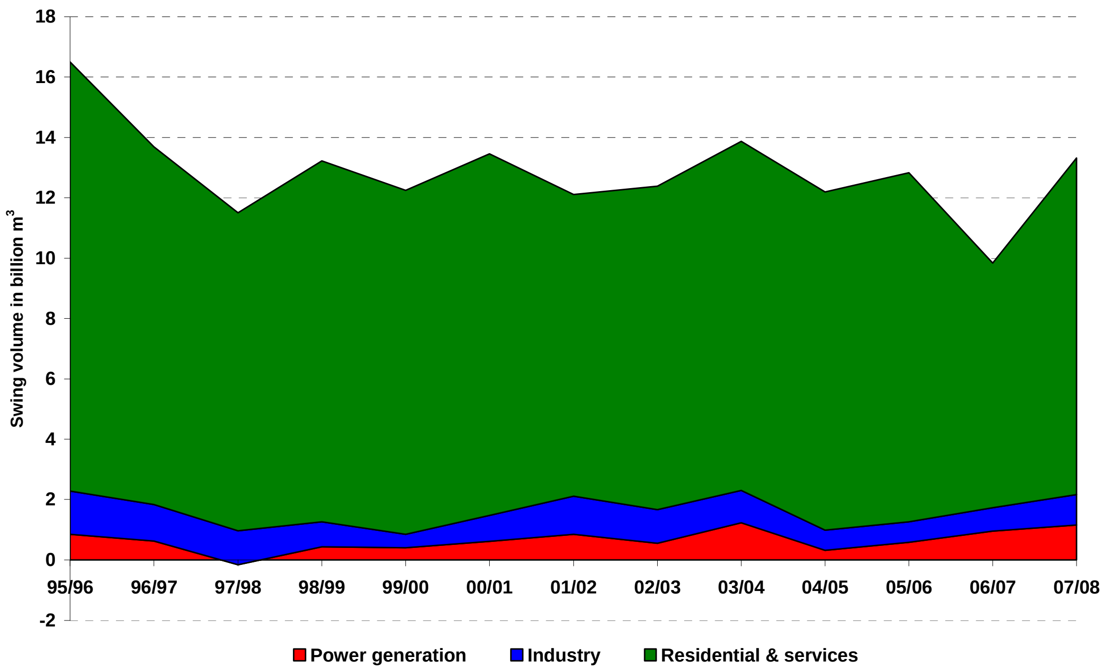


Figure 3.3 *Swing volume of Dutch gas demand per sector in the period 1995-2008*

Source: CBS.

Figure 3.3 shows that about 85 to 95% of total seasonal swing volume comes from the residential sector, whereas the industry and power generation sector make up for the remainder. There does not seem to be a long-run trend in this figure. The total swing volume keeps fluctuating be-

[12] Note that the data underlying this figure have not been corrected for temperature.

tween 12 and 13 billion m^3 per year. The swing ratio for Dutch gas demand (in Figure 3.4) has been at a constant level of about 0.28. This means that the difference between total summer and total winter demand is equal to about 28% of total gas demand. Unsurprisingly, the ratio for the residential sector is the highest of the three assessed sector. For the residential sector the ratio is about 0.48 on average, with a minimum value of 0.43 and a maximum value of 0.53 in the assessed period. The swing ratio of the other two sectors varies between 0 and 0.10.

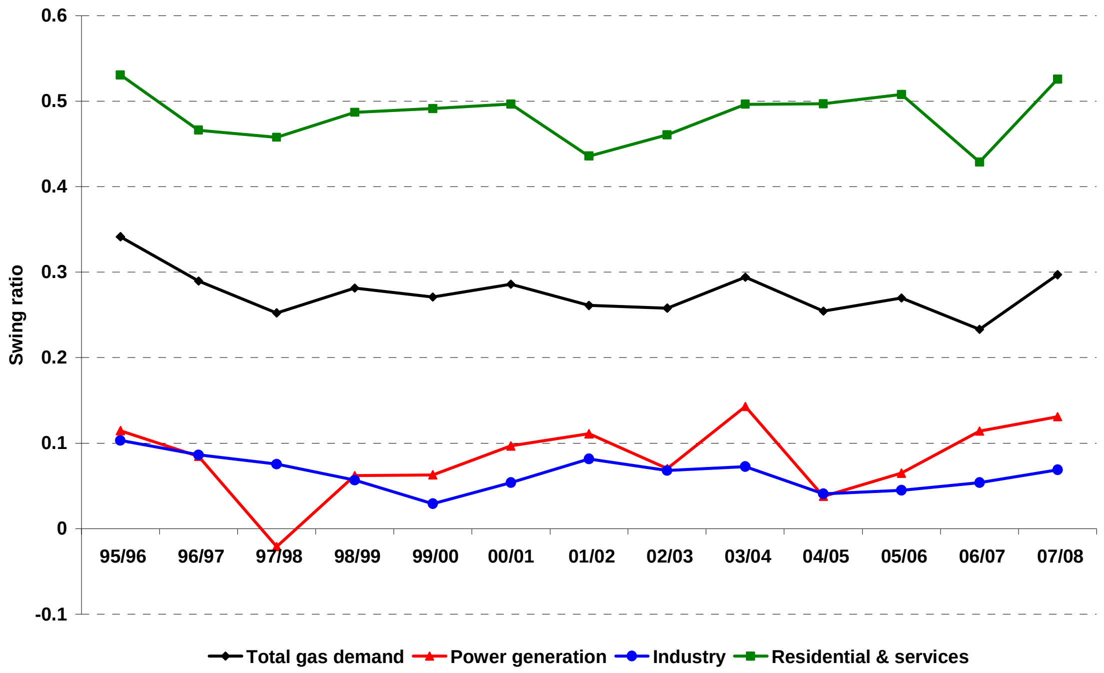


Figure 3.4 *Swing ratio for Dutch gas demand per sector in the period 1995-2008*
Source: CBS, own calculations.

3.1.2 United Kingdom

For the United Kingdom we assessed quarterly data on gas demand for the period Q1-2005 until Q4-2008.[13] Data are provided for different gas consumer categories. For our analysis we have looked at the following categories:

1) Consumption in electricity generation.
2) Final consumption in iron and steel industry.
3) Final consumption in other industries.
4) Final consumption in the domestic sector.
5) Final consumption by other final users (other than consumption under (2) - (4)).

We interpret the first category as total gas consumption in the power generation sector. Categories (2) and (3) together comprise consumption in the industrial sector. Finally, categories (4) and (5) together make up consumption in the residential and services sector. Here it should be noted that the UK consumption classification differs from the classification used in the dataset for the Netherlands. For example, final consumption in other industries might include some small industries that fit the Dutch consumption category of gas consumption at regional network level. Since there is no access to underlying UK data we are not able to make any kind of corrections. This should be kept in mind when comparing results based on the UK and Dutch datasets.

[13] Data is provided by the Department for Business, Enterprise and Regulatory Reform (BERR) at http://www.berr.gov.uk/energy/statistics/source/gas/page18525.html.

Figure 3.5 presents the observed degree of flexibility required in UK gas deliveries to the three distinct gas consumer categories. First, it should be noted that the data depicted in this figure are not immediately comparable to the data earlier presented for the case of the Netherlands when it comes to the absolute levels for the swing ratio. After all, Dutch swing ratios are based on monthly data, whereas UK swing ratios here are based on quarterly data. In general, the more detailed the aggregation level of data, the higher the calculated swing ratio. The residential and services sector is the consumption category with the highest required flexibility in gas delivery. In addition, there is substantial seasonal variation in the demand for gas in the industry sector. The required level of flexibility in this sector is apparently higher than the power generation sector. Comparing the Dutch and UK flexibility ratio for power generation we find that the Dutch power generation sector requires relatively more flexibility. Looking at the data in Figure 3.5 it seems that in the quarters between 2000 and 2005 the required flexibility in the power generation sector was substantially lower than before 2000 and after 2005. This could have something to do with the relative price of gas compared to other energy carriers. No real structural long-term developments are observed for any of the distinguished sectors. This is supported by Figure 3.6, where the development of the maximum levels in the swing ratio is depicted. Comparing the Dutch and UK flexibility ratio for power generation we find that the Dutch power generation sector requires relatively more flexibility.

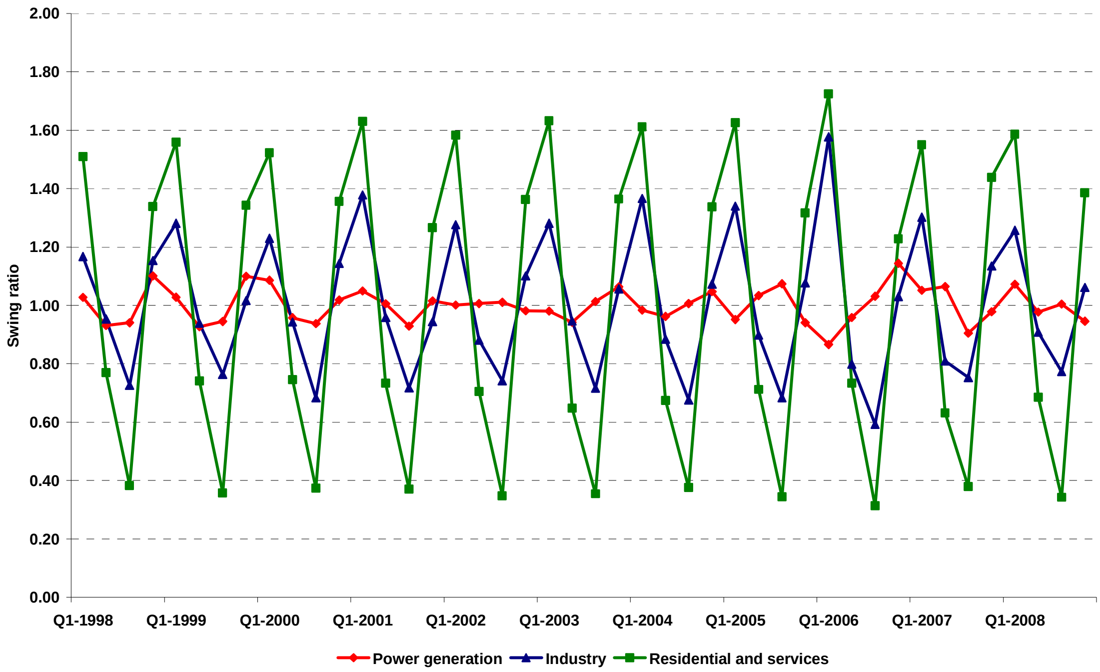


Figure 3.5 *Flexibility in gas demand in the United Kingdom 1998-2008*
Source: BERR.

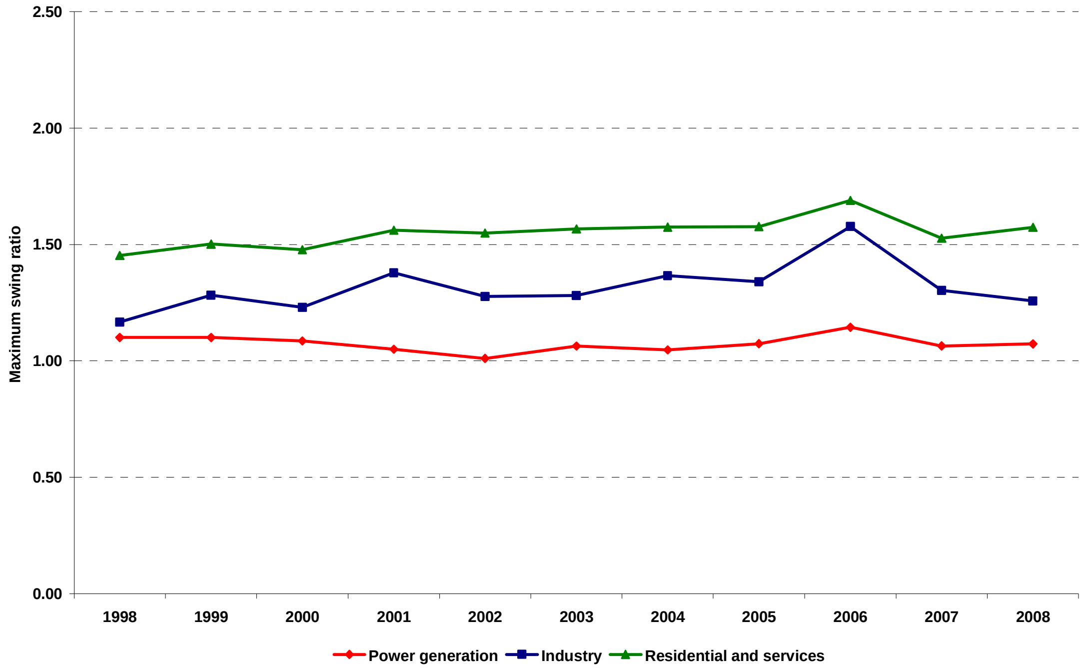


Figure 3.6 *Maximum required flexibility in gas demand in the United Kingdom 1998-2008*
Source: BERR

Like has been done for the Netherlands, we have calculated the value of the other two remaining seasonal swing indicators as well.

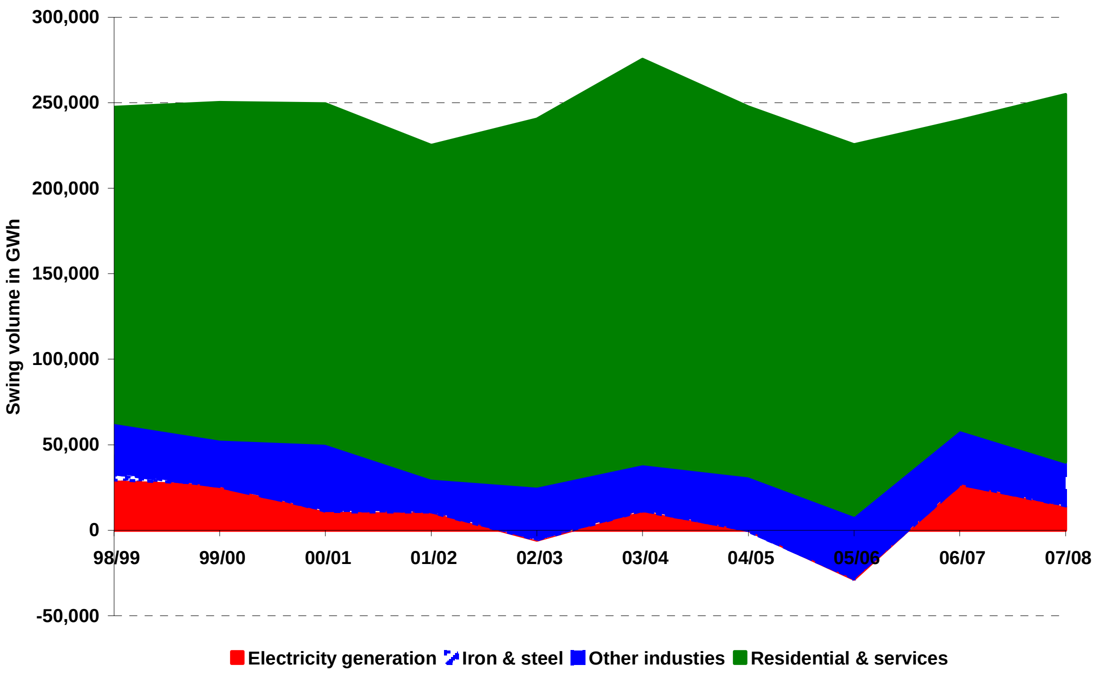


Figure 3.7 *Swing volume of UK gas demand per sector in the period 1998-2008*
Source: BERR.

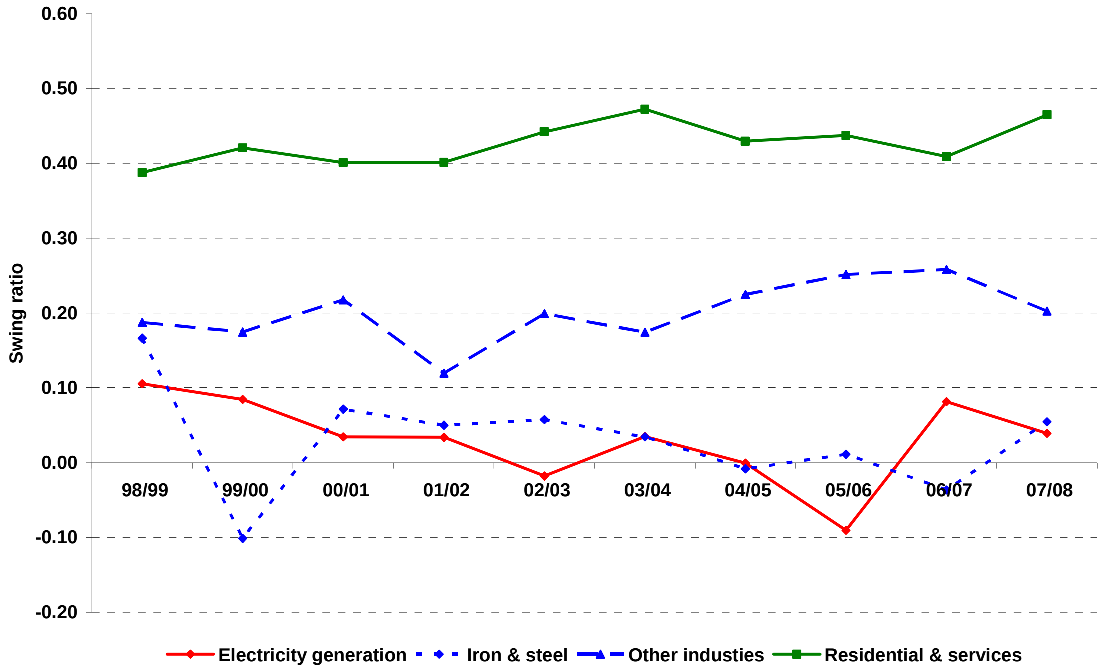


Figure 3.8 *Swing ratio for UK gas demand per sector in the period 1998-2008*
Source: BERR.

3.1.3 northwest Europe

For the other countries in northwest Europe no data with sufficient detail with respect to either the level of aggregation in consumption categories or in time was found available. For other countries than the UK and the Netherlands the IEA gas balance data was the best dataset available. This data contains monthly data for total gas consumption with no separation in different gas consumption categories. We have assessed data for the period January 2000 until December 2008. Below we turn to an analysis of this data for the countries in northwest Europe.[14] Figure 3.9 gives insight into the amount of swing volume in winter for the selection of northwest European countries.

[14] For a full comparison of countries, we include the IEA data for the Netherlands and the United Kingdom as well.

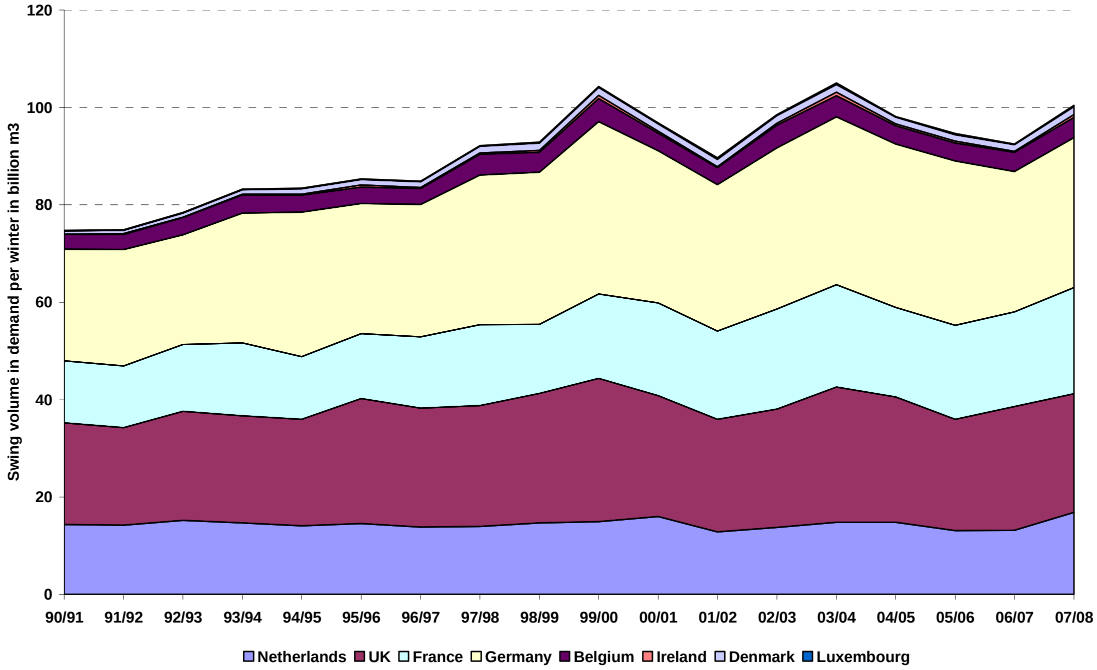


Figure 3.9 *Heating degree-days corrected swing volume of gas for selection of northwest European countries for the period 1990 to 2008*

Source: IEA.

The figure shows that the total amount of gas to be supplied in winter in addition to the yearly average supply has been increasing throughout the whole period, except for a dip in the gas year 2001/2002. Over the period 1990 to 2007, the total swing volume in northwest Europe has increased with an annual percentage of about 1.7%. This is lower than the average growth of total gas demand over the same period, which is about 2.8% per year. The difference is explained by the fact that not all additional gas demand occurs in winter. Additional demand in the power generation sector or the industry sector is likely to be spread more evenly throughout the year, thereby not significantly influencing swing volume of gas in winter. The growth in gas demand in the residential and services sector was on average about 2% per year, which compares to the 1.7% increase in swing volume. It is evident that the larger gas consuming countries have a consequential large share in the need for swing volume in winter. The average share of France, Germany, Netherlands, and UK in total swing volume in northwest Europe over the considered timeframe is 18%, 34%, 16% and 27%. From these largest gas consuming countries, France and Germany have seen the largest growth in swing volume. Swing volume in France and Germany increased on average with 2.7% and 1.5% respectively, while that rate is about -0.5% and 1.2% for the respective countries of the Netherlands and the United Kingdom.

Figure 3.10 gives insight into the relative swing volume compared to total gas supply for each individual country. The link with Figure 3.9 is the following: multiplication of total gas supply in summer and winter (total gas supply for a gas year) with the swing ratio results in the swing volume.

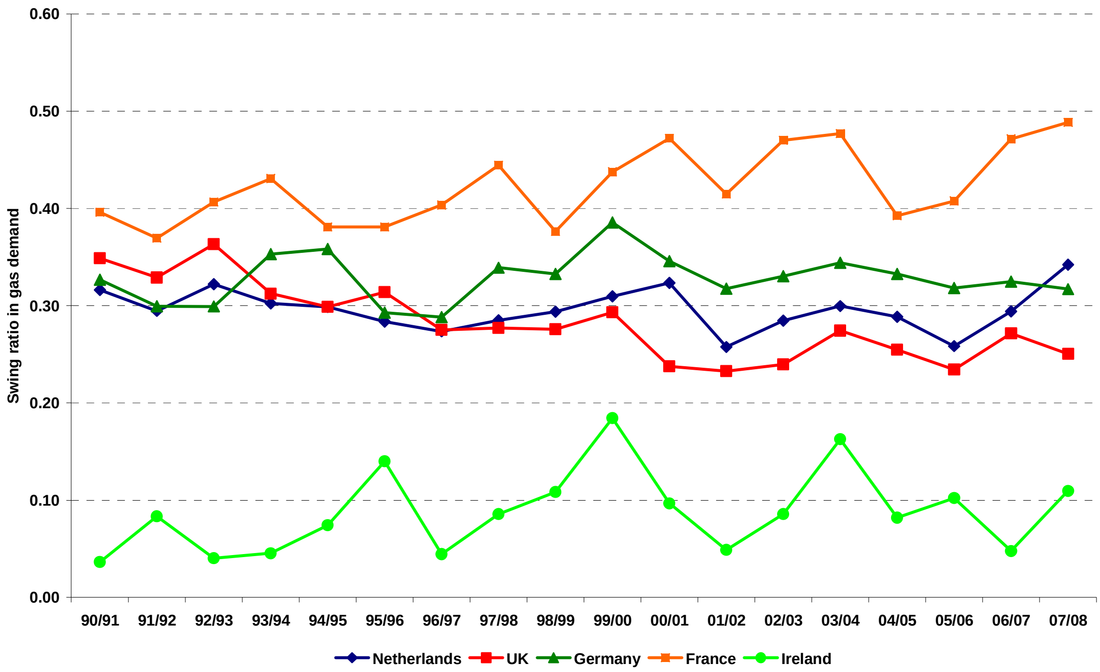


Figure 3.10 *Heating degree-days corrected swing ratio of gas demand for selection of northwest European countries for the period 1990-2008*

Source: IEA.

Based on Figure 3.10 we conclude that the required level of flexibility in gas delivery to consumers varies largely across individual countries. Whereas the required flexibility in Irish gas deliveries is relatively very small, French gas consumers require relatively the highest level of flexibility. As we know from our analysis of Dutch and UK data for different consumer categories the residential and services sector requires the highest level of flexibility in gas delivery, followed by the power generation sector and the industry sector. Ireland has a relatively low share of gas consumption in the residential and services sector compared to other countries. France on the other hand has the relatively largest share of gas consumption from the residential and services sector. The swing ratio of France has been slowly increasing the last years, which is mainly to a gradual increase in gas consumption in the residential and services sector. Residential demand in France has been growing with 71% from 1998 to 2006. The swing ratio in the UK has been declining until about 1999 and has been rather flat since. This can be explained by the continuous growth in gas consumption in the electricity sector in the years 1991-1999 and the stagnation afterwards. The flexibility required in gas supplies to the power generation sector are relatively lower than flexibility required in the large UK residential and services sector, and also lower than the average flexibility in overall UK gas consumption. Although German gas demand in the residential and services sector has been increasing 21 billion m^3 in 1991 to 36 billion m^3 in 2006, the swing ratio has not shown a significant structural increase. The swing ratio in the Netherlands shows a small decrease, which may be caused by a combination of effects: (1) an increase in power generation demand (which increases total gas consumption), and (2) a small decrease in demand from the residential and services sector.

A large part of the above discussed results may be summarised in one picture depicting a relationship between the share of demand from the residential and services sector in total demand, and the swing ratio. This relationship is depicted in Figure 3.11.

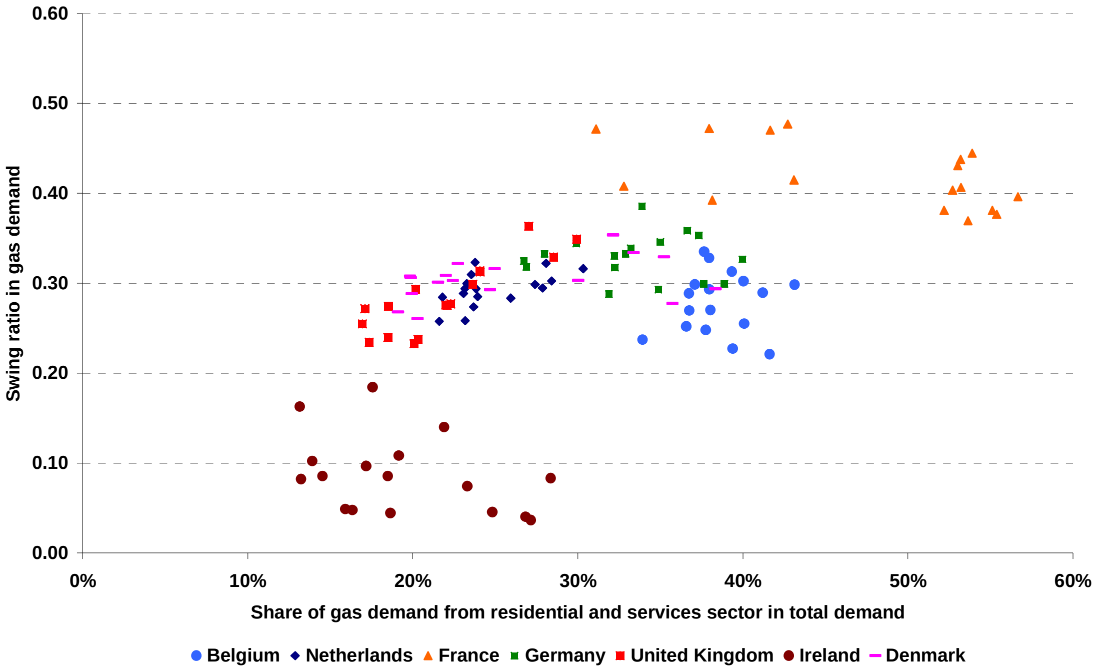


Figure 3.11 *Relationship between the share of demand from the residential and services sector in total demand, and the swing ratio for selection of northwest European countries*

Source: IEA, Eurostat.

Based on the depicted relationship one can conclude that there is a positive relationship between the relative size of the residential and services sector in total gas demand and the need for swing volume in winter. This was to be expected since this sector showed to have the highest flexibility requirements. However, as can be seen from the clustering of individual countries and the position of individual clusters versus others there are also other country-specific factors affecting the swing ratio. For example, the UK data show a much 'flatter' relationship than the other countries, whereas Denmark data seems to indicate a much steeper relationship. A more econometric-based analysis could be undertaken to gather more insight into more technical relationships regarding the demand for swing volume (i.e. flexibility). Such an investigation is outside the scope of this study however.

As was indicated before the outside-temperature has a substantial impact on the demand for gas in northwest Europe. In relatively milder winters the total demand for gas will be lower. Figure 3.12 depicts the actual amount of heating degree-days in northwest Europe in the period 1990 to 2008. Based on this figure we observe a trend towards milder winters over the last decade, spurred by increasing average temperature in winter in this same period.

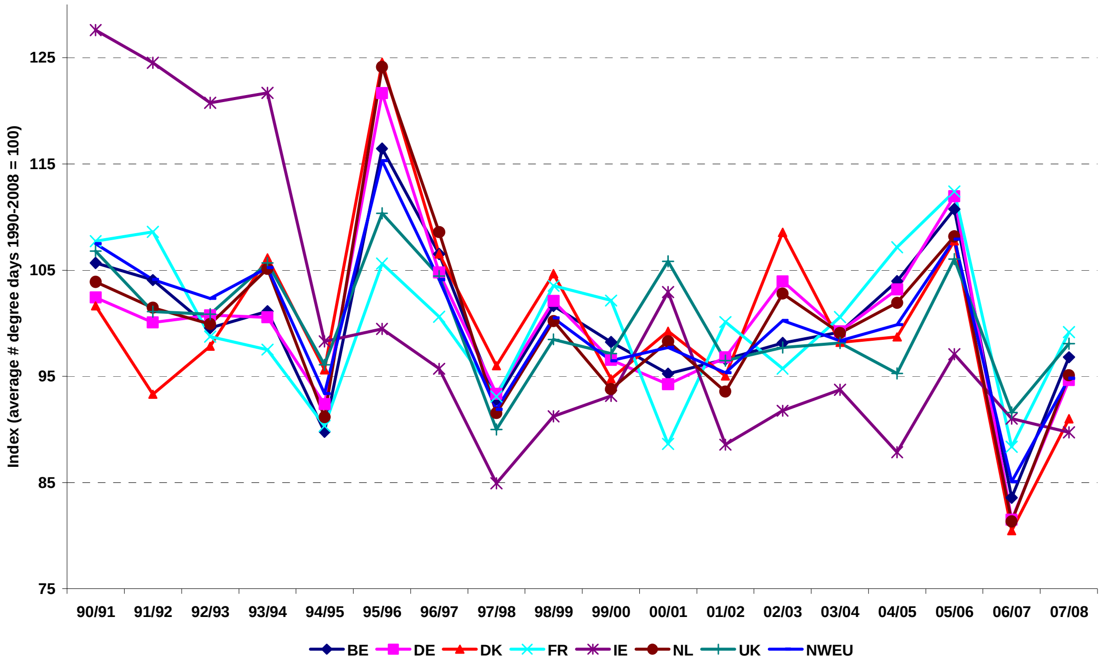


Figure 3.12 *Amount of heating degree-days in winter (November to March) in the period 1990-2008*

Source: Eurostat.

3.1.4 Gas storage in northwest Europe

According to IEA (2008a) total working gas capacity of natural gas storage facilities in northwest Europe[15] at the end of 2007 totalled little over 38 billion m^3. The database on existing gas storage facilities in the EU maintained by Gas Storage Europe (GSE)[16] provides a total gas storage working capacity at the beginning of 2009 in northwest Europe of about 41 billion m^3. A database from the International Gas Union (IGU) estimates total storage capacity in northwest Europe to be 40.5 billion m^3. An assessment of the detailed databases of both GSE and IGU by GasTerra gives rise to a fourth estimate for total gas storage working capacity which is somewhere in-between but closer to the GSE estimate.

Table 3.2 *Overview of total working volume of gas storage facilities in northwest Europe in million m^3*

Country	IEA (2008a) [mln m^3]	GSE (April 2009) [mln m^3]	IGU (2006) [mln m^3]	GasTerra [mln m^3]
Belgium	655	659	550	655
Denmark	760	1,001	820	765
France	10,800	11,860	11,643	11,090
Germany	19,138	18,452	19,314	19,713
Ireland	198	0	0	0
Luxembourg	0	0	0	0
Netherlands	2,478	5,078	5,000	5,072
United Kingdom	4,364	4,001	3,192	3,617
Total	38,393	41,051	40,519	40,912

Source: IEA (2008a), GSE website, IGU 2006.

15 northwest Europe is defined as Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, and the United Kingdom.

16 Gas storage data on existing capacity and planned investments are available at http://www.gie.eu.com/index.html.

GSE also provides a database on the different gas storage expansion plans within the EU. Based on this database we have constructed a database with all currently known investment plans. The status of the included gas storage projects vary from being under construction, to committed or planned. This separation is sensible since not all currently planned gas storage investments will necessarily go ahead in the future. According to our calculations, the total working volume of gas storage facilities that are currently under construction, committed or planned in northwest Europe is about 36 billion m^3, which equals about 87% of existing gas storage capacity. However, of this total only 3.8 billion m^3 is actually reported to be under construction (which is about 9% of current installed storage capacity).

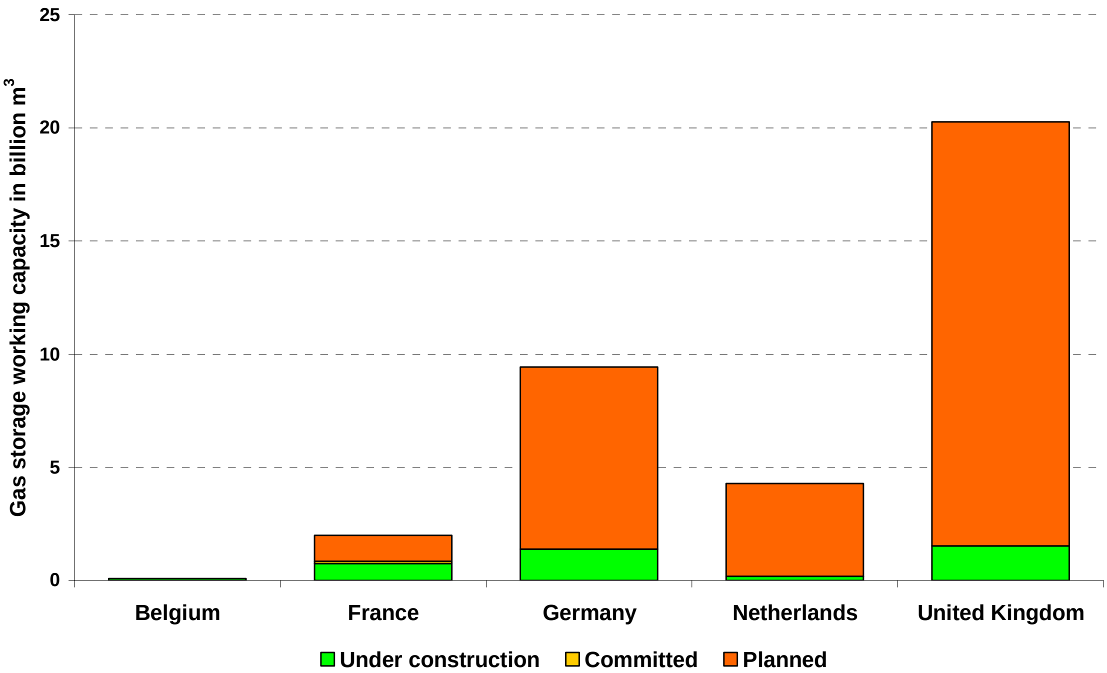


Figure 3.13 *Total working volume capacity (in million m^3) of gas storage investment plans in northwest Europe*

Source: GSE.

The above reported figures include both small and large-scale gas storage facilities. Large-scale gas storage facilities are typically filled to maximum capacity at the beginning of the winter season. Small gas storage facilities are pre-dominantly used to arbitrage between low and high gas prices on a daily or weekly basis. These facilities could be used for the provision of seasonal swing when they are fully filled at the beginning of the summer season.

Figure 3.14 sets out the existing gas storage capacity and the currently known gas storage investment projects based on current status. It shows the large amount of planned or projected gas storage investments and the relatively little number of projects under construction at this moment.

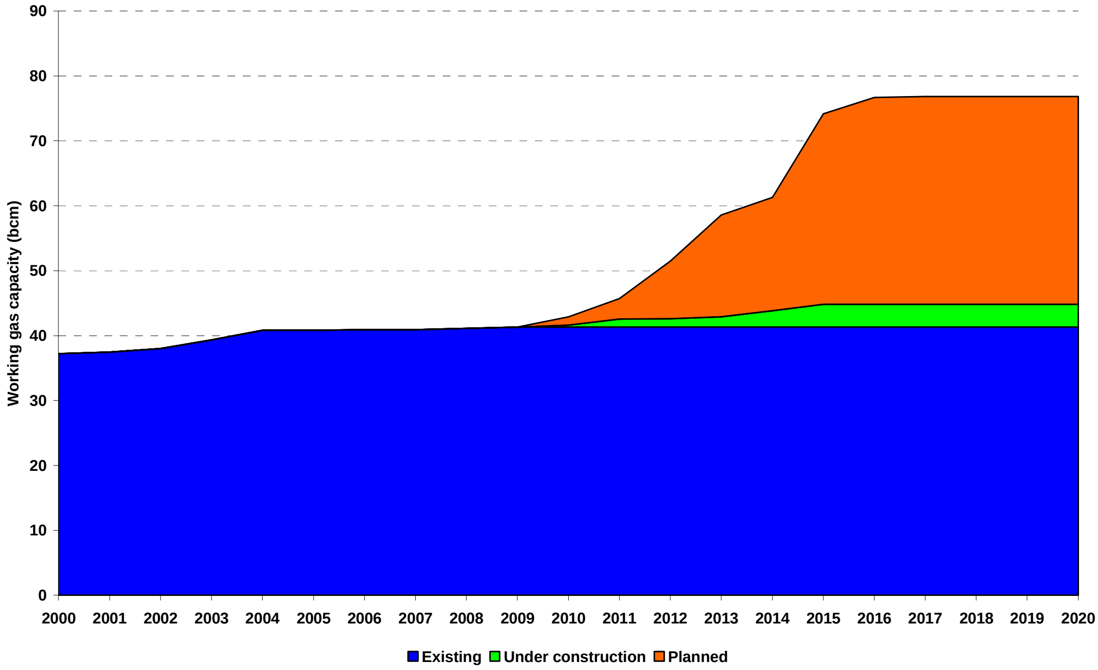


Figure 3.14 *Existing gas storage capacity and projected development of working gas capacity in northwest Europe according to project status*

Source: GSE 2009, IGU 2006.

In the previous gas storage study prepared by CIEP (2006) a list of projects in a number of OECD-European countries was presented that were considered to come on stream in 2010. This involved a total of about 5 billion m^3 working capacity. Based on the most recent GSE database update, it seems that only 1.1 billion m^3 of this capacity will be actually there in 2010. Some projects however are still underway and have experienced delays, while yet others are scrapped or are still in the planning phase. Based on the 1.1 billion m^3 we could say that the success rate of the listed projects is about 20%.

3.2 Seasonal swing provision from gas storage facilities

From the data available in the gas balance database of the IEA we have derived the total withdrawal of gas from storage facilities over the winter months in the last 18 years. By summing the monthly withdrawals for the months October to March we get the total seasonal storage withdrawal for a certain winter. We have corrected for the influence of temperature by dividing the actual observed storage withdrawals with the ratio of actual heating degree days (October to March) and mean heating degree days (October to December).[17] Figure 3.15 presents the total amount of gas withdrawn from gas storage facilities on a country level for the countries in northwest Europe.

[17] The mean heating degree-days in the period October to March is based on the period 1980-2004.

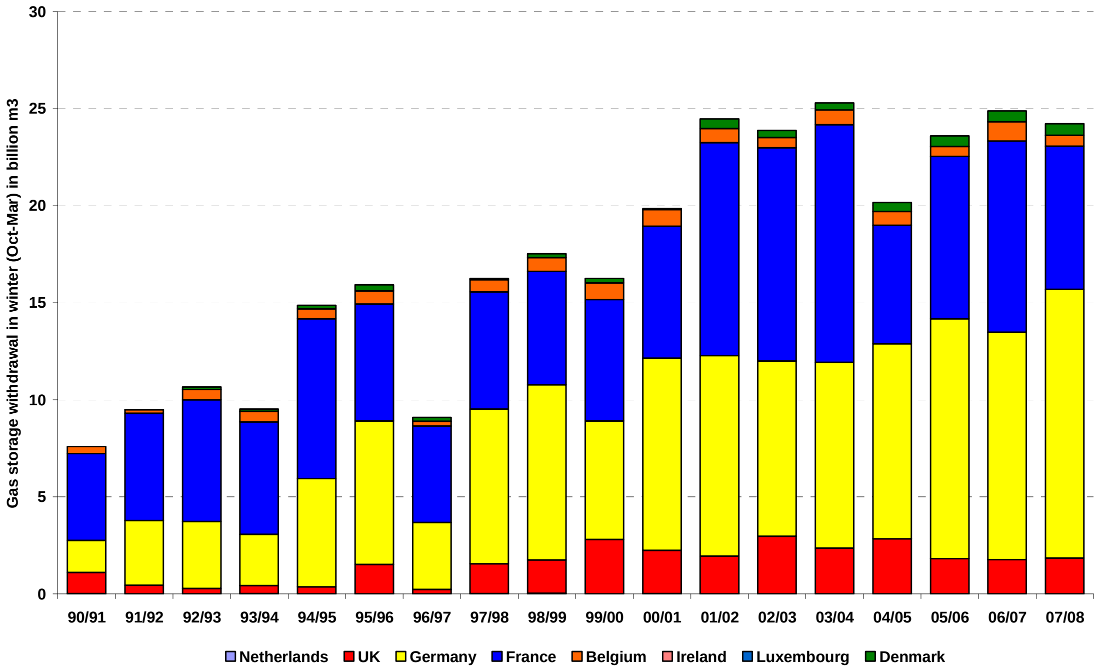


Figure 3.15 *Heating degree-days corrected seasonal gas storage withdrawals in northwest Europe in the period 1990-2008*

Source: IEA[18].

From the above figure we infer that total winter storage withdrawals especially have been increasing in France and Germany. France and Germany are also the countries that have shown the largest increase in required swing volume (see Figure 3.9) in comparison with the other northwest European countries. In this period total working gas capacity in Germany has been expanded enormously, while total French working gas capacity has remained almost unchanged. The Netherlands and the UK on the other hand do not show any substantial increase. This can be explained by the fact that in both countries a larger part of swing is provided by production facilities instead of storage facilities. The development in total gas storage withdrawals shows in northwest Europe until the gas year 2003/2004 is similar to the development in total gas storage withdrawals in OECD-Europe as reported in CIEP (2006). However, total gas storage withdrawals seem to have been staying at a more or less constant level since that winter, indicating a possible flattening of the trend curve. This can be explained by the relatively mild winters in the last four years.

Relating the actual gas storage withdrawals to the available gas storage capacity gives insight in the usage rate of the latter. Therefore we have related the gas withdrawals depicted in Figure 3.15 to two sets of gas storage data. As already explained the available data sets (IEA, GSE 2009, IGU 2006) show quite some diverging figures for some countries (notably for France, Germany and the Netherlands). Figure 3.16 presents total gas storage withdrawals and the implied capacity usage based on different gas storage capacity figures. When looking at the usage of gas storage according to the GSE/IGU database, gas storage capacity usage in the last 8 years has been varying from 46 to 56%. When using the gas storage database of the IEA capacity usage amounts about 55 to 70%. Concerning the relative development of capacity usage we observe that capacity usage in the period 1990-2000 was at a significant lower level than the years

[18] In CIEP (2006) the figure representing gas storage withdrawals contains *net* withdrawals and not the absolute level of withdrawals over a winter season (October to March). Therefore our figures slightly differ from those presented in CIEP (2006). This is caused by the fact that in very mild winters, there is actual injection taking place instead of withdrawal.

thereafter. The difference in average capacity usage between the two periods is about 15%-points.

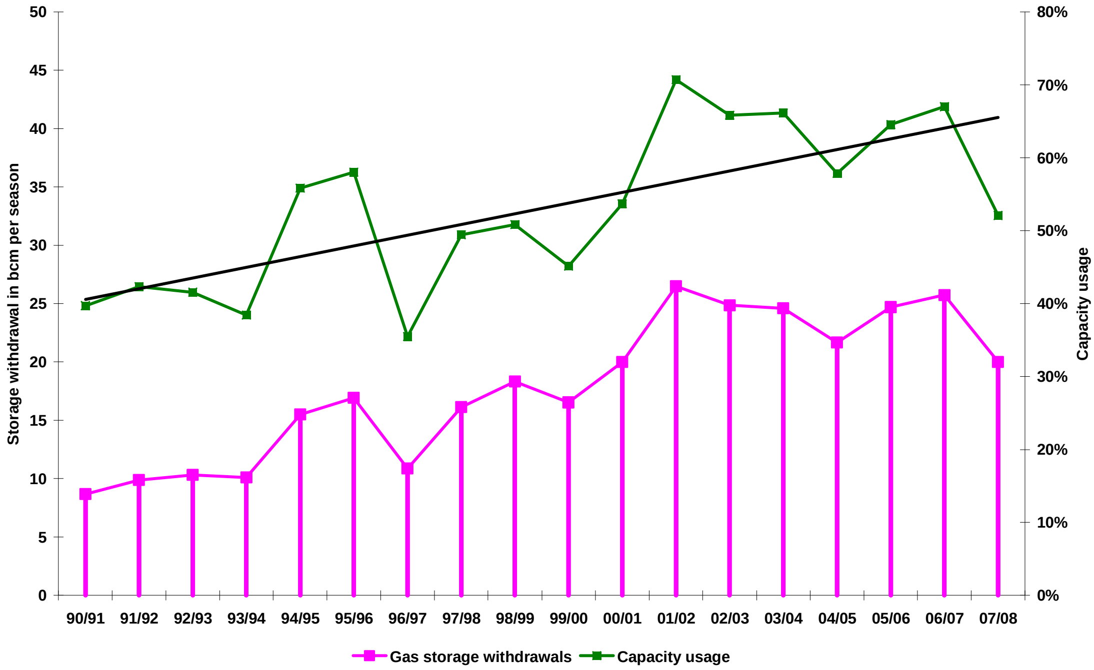


Figure 3.16 *Gas storage withdrawals in northwest Europe and implied capacity usage*
Source: IEA.

The above figure is an update of a figure depicted in CIEP (2006). In the CIEP (2006) figure a trend line in gas storage use was added indicating a flat line at about 43% until 1995/1996, and from there a continuous increase to 68% in 2003/2004. The updated figure indicates gas storage capacity usage has been hovering around the same average for the last 6 years. The extended dataset seems to suggest a more balanced and evenly spread growth in capacity usage over the whole assessed time period of 18 years.

3.3 Seasonal swing provision from other sources

One of the important instruments to deliver flexibility in gas consumption is production flexibility. Obviously, not all countries in northwest Europe have direct access to this option. Others rely more on flexibility delivered via gas imports. In northwest Europe production flexibility is mainly delivered by the Dutch and United Kingdom gas fields. In this section we assess the amount of seasonal flexibility provided by gas production, gas pipeline imports and LNG imports.

3.3.1 Seasonal swing by gas production

In Figure 3.17 the monthly gas production levels for the northwest European countries are depicted. We observe that substantial variability at high volumes of gas production is provided by both the Netherlands and the United Kingdom. Much less variability, at much lower volume levels, is provided by Germany and Denmark. The only obvious trend that can be derived from this figure is the initial increase in levels of UK gas production until 2000, while maintaining the degree of swing, and the decrease in the years afterwards, which is a consequence of nearing depletion of UK gas reserves. Thus, while overall production now is at similar levels as in the 1990’s, the flexibility delivered is considerably less.

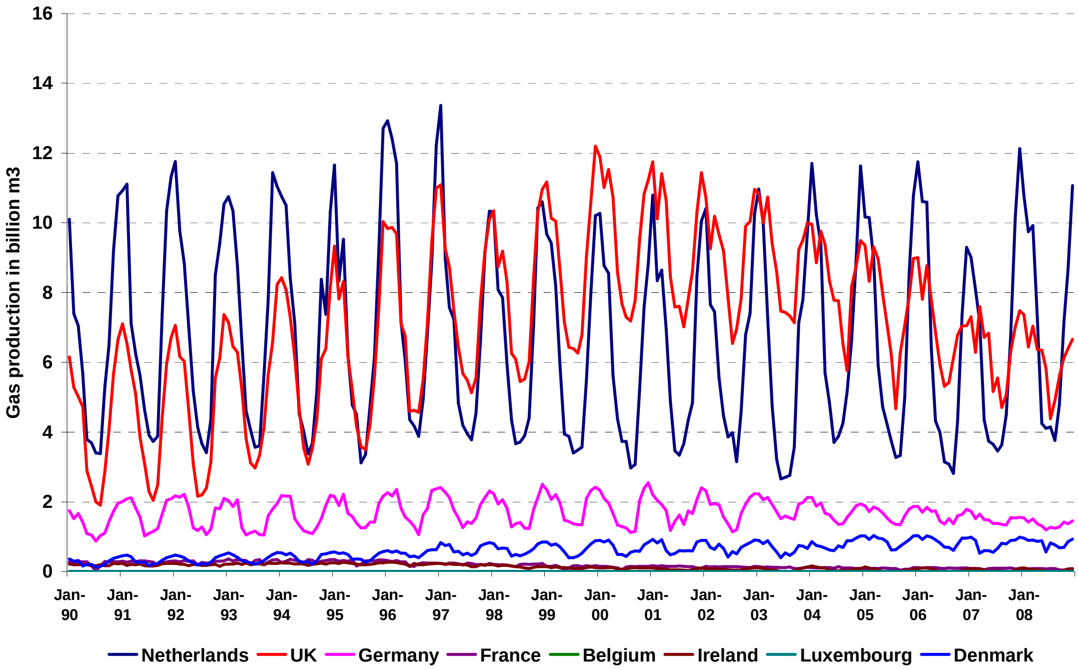


Figure 3.17 *Gas production in selected northwest European countries in the period January 1990 - December 2008*

Source: IEA.

Figure 3.18 shows the minimum and maximum flexibility ratios for a selection of gas producing regions. This confirms our earlier observation that the flexibility of UK gas production has been in decline for some years. UK flexibility in gas production has reached levels comparable to the rest of northwest Europe (the Netherlands excluded). We note that that the Netherlands shows the largest production flexibility: there is no gas producing region with lower minimum flexibility ratios or higher maximum flexibility ratios. Secondly, the flexible capacity of the United Kingdom has been steadily declining from 1990 to 2008. Previously, gas production from the United Kingdom showed similar flexibility figures as the Netherlands, but currently is only at the same level of the remainder of northwest European countries. Figure 3.19 presents the amount of swing provided by indigenous gas production in northwest Europe.

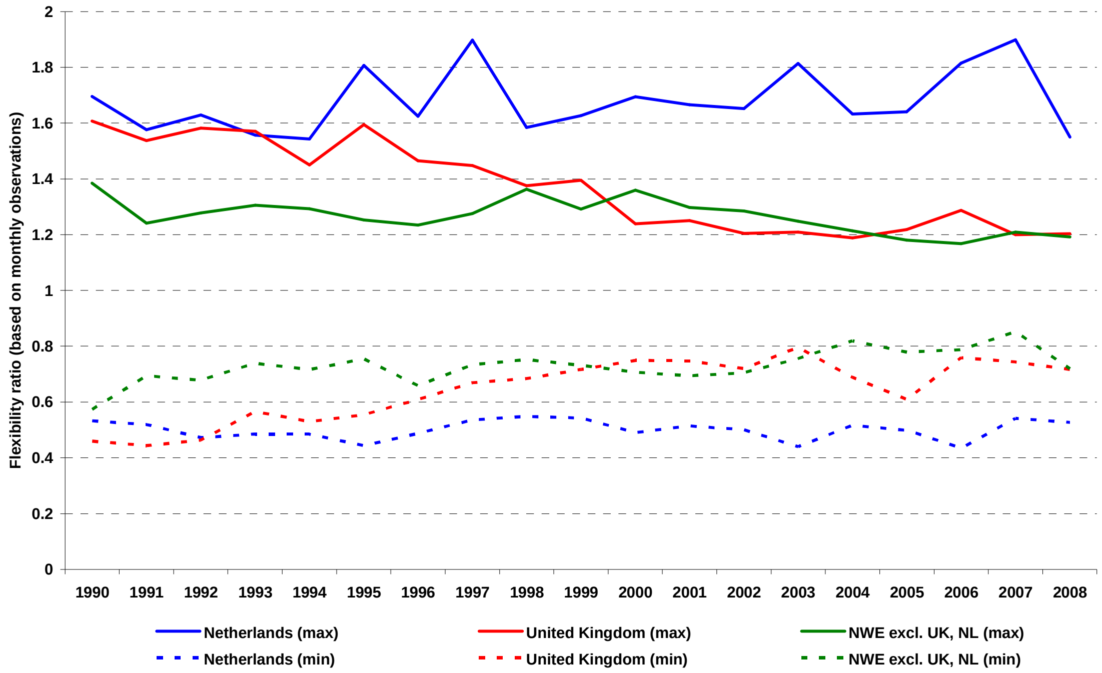


Figure 3.18 *Minimum and maximum flexibility ratio for selection of gas producing regions*
Source: IEA.

The amount of swing volume provided by the Netherlands has remained more or less constant throughout the assessed period. Since the swing volume provided by mainly the UK has been decreasing the share of the Netherlands in the total swing volume of northwest European gas production has been increasing from about 50% in the 1990s to over 70% in recent years. The total amount of swing volume provided by indigenous gas production has been declining. The decline in swing volume provided by the UK has not been compensated for by other countries (i.e. the Netherlands).

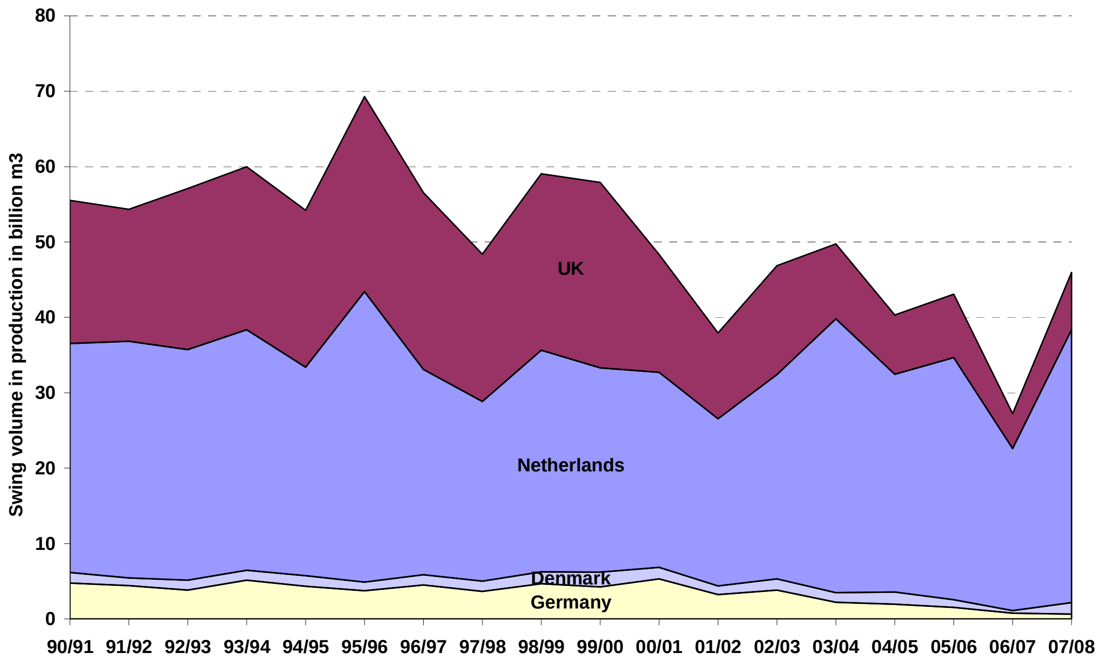


Figure 3.19 *Swing volume in northwest Europe delivered by indigenous production*
Source: IEA.

Figure 3.20 presents the swing ratio of indigenous gas producing regions. This relates the total swing volume presented in the previous figure to total gas production throughout the gas year. On the basis of this figure the same observations can be made as before. Seasonal swing in Dutch gas production has been the highest of all northwest European countries and has been more or less constant in the last 18 (gas) years. The swing ratio for northwest Europe as a whole has been decreasing due to a decrease in UK swing volumes. The current swing ratio of UK gas production is at about the same level as the swing ratio of northwest European gas production excluding the UK and the Netherlands.

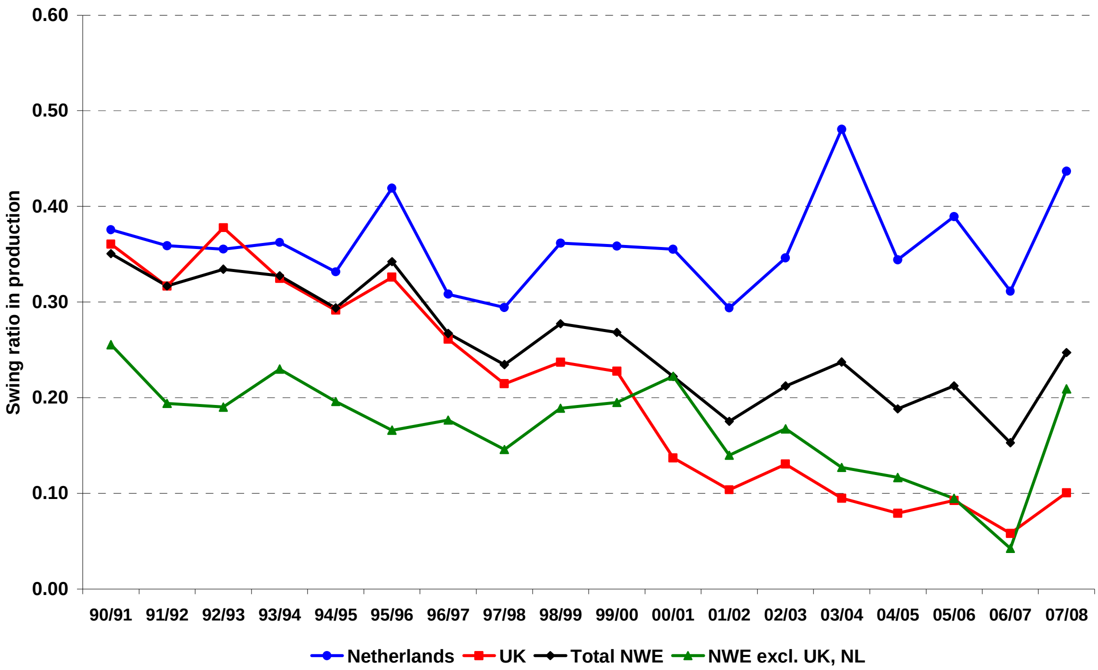


Figure 3.20 *Swing ratio of gas production in selection of gas producing regions in northwest Europe*

Source: IEA.

3.3.2 Seasonal swing by pipeline imports

Gas production outside the northwest European territory could theoretically also provide seasonal swing via pipeline or LNG imports. We look at these two types of gas imports separately.

Figure 3.21 shows the gas exports of Norway and the Former Soviet Union to northwest Europe. When comparing this figure with the figure containing the monthly gas production levels for northwest European countries (see Figure 3.17) it is apparent that gas imports from Norway and the Former Soviet Union show considerably less seasonal fluctuation. The seasonal spread in Norwegian gas exports to northwest Europe in absolute sense have increased over time. This could be the result of an increasing linkage of Norwegian gas production fields with continental Europe over time. Based on this figure we could suspect that Norwegian gas production has to some degree compensated for the decline in seasonal swing provided by the UK. Gas exports to northwest Europe from the FSU shows less of a seasonal pattern and have been at about the same level since 1994.

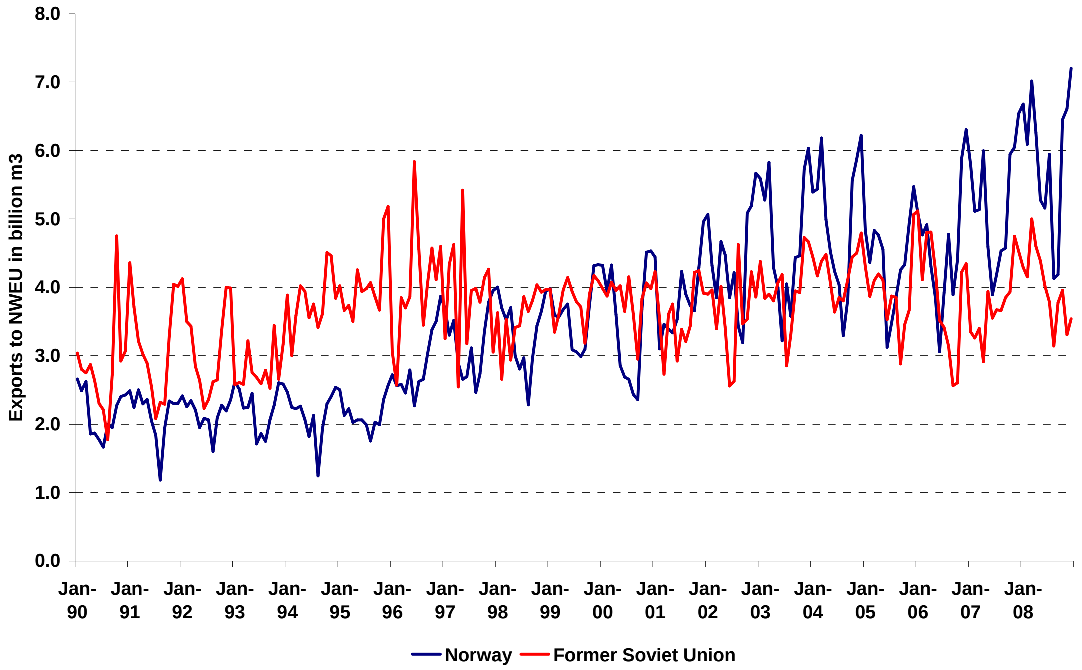


Figure 3.21 *Total gas exports from Norway and Russia to selected northwest European countries in the period January 1990 - December 2008*

Source: IEA.

Figure 3.22 compares the observed maximum and minimum flexibility ratios of the main gas suppliers to the northwest European market. Actually the depicted figures represent production flexibility for the Netherlands and the UK, but flexibility of *gas exports* to northwest Europe for Norway and Russia. The export flexibility ratio of Russia and Norway seem to be at comparable levels. The last 10 years flexibility for respectively Russia and Norway, according to our analysis, was about 120/76 and 126/72. This means that for example maximum and minimum production in Russia was respectively 20% above and 24% below average production.

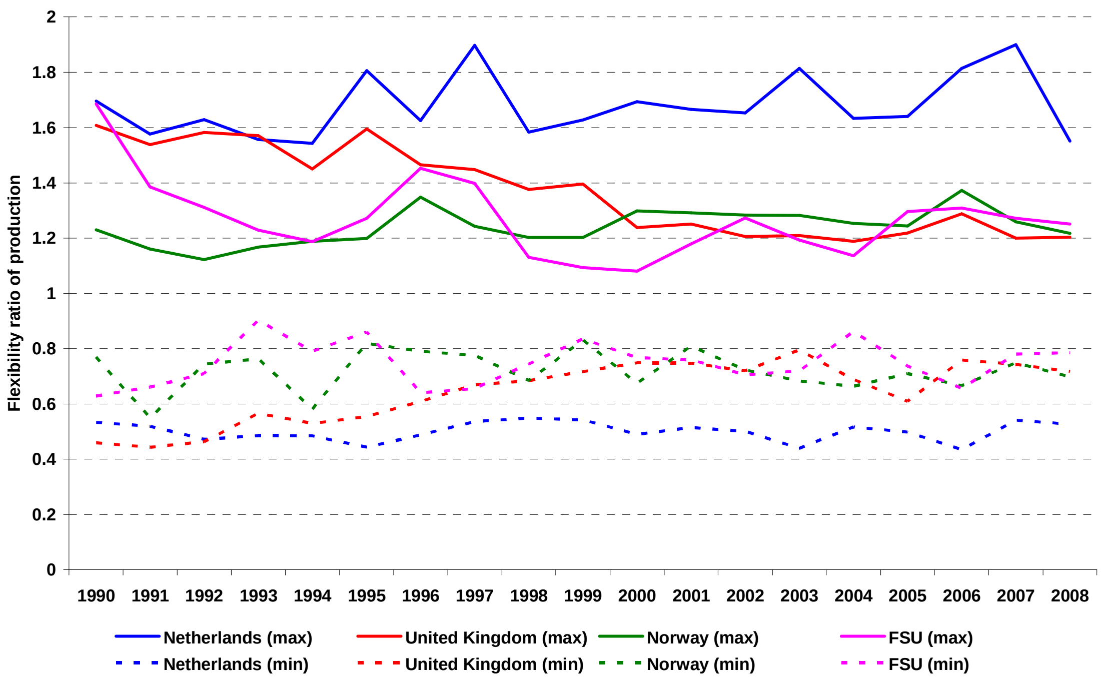


Figure 3.22 *Flexibility ratio of selected gas producing regions in the period January 1990 - December 2008*

Source: IEA.

The swing volume and swing ratio indicators can give additional information on the degree in which seasonal swing is provided by Russian and Norwegian imports. Figure 3.23 shows that the swing volume of Dutch exports (the difference between total Dutch exports in winter and total Dutch exports in summer) is the largest compared to other large suppliers such as Norway, the UK and the Former Soviet Union. The swing volume in Norwegian exports have been increasing from about 3 billion m^3 in gas year 1995/1996 to about 10.5 billion m^3 in gas year 2007/2008. Earlier we noted that the maximum and minimum flexibility ratios of exports from Norway and the Former Soviet Union were comparable, but based on the figure below we conclude that both exporting countries largely differ when it comes to the amount of gas that is additionally supplied in winter. The swing volume of Norwegian exports has been consistently larger than the swing volume in FSU exports. Although the UK has large seasonal flexibility in indigenous gas production it is definitely not a large exporter of seasonal swing.

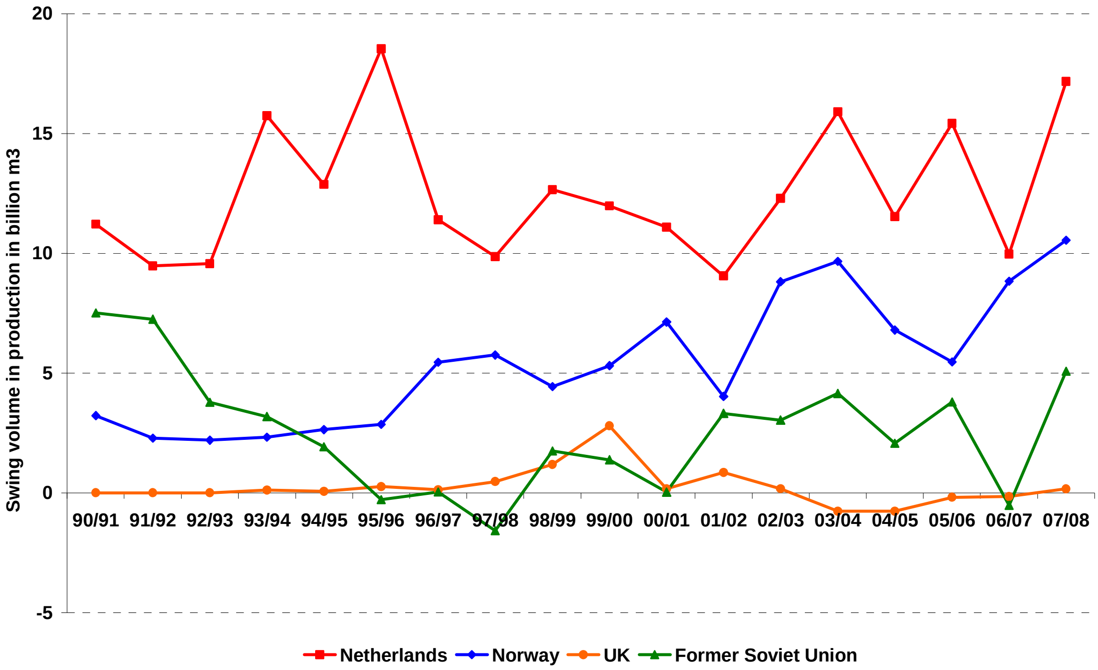


Figure 3.23 *Comparison of the wing volume in gas exports (Norway and FSU) and gas production (Netherlands and UK)*

Source: IEA.

In Figure 3.24 the total swing volume in exports is related to total exports for each the gas year. Based on this data the UK might have had a high swing ratio at certain moment in time but it is associated with a very limited amount of gas export. More meaningful are the indicators for the Netherlands, Norway and the FSU. The Norwegian swing ratio has been rather constant at about 0.10 to 0.15. The swing ratio of the Netherlands has varied over a larger bandwidth of 0.26 to 0.48. The FSU swing ratio in exports to northwest Europe was declining from 1990 to 1996, and has then increased somewhat to stay at a level of 0.08. In the last 8 years, the difference between total FSU exports in winter and in summer was about 8% of the total yearly exports.

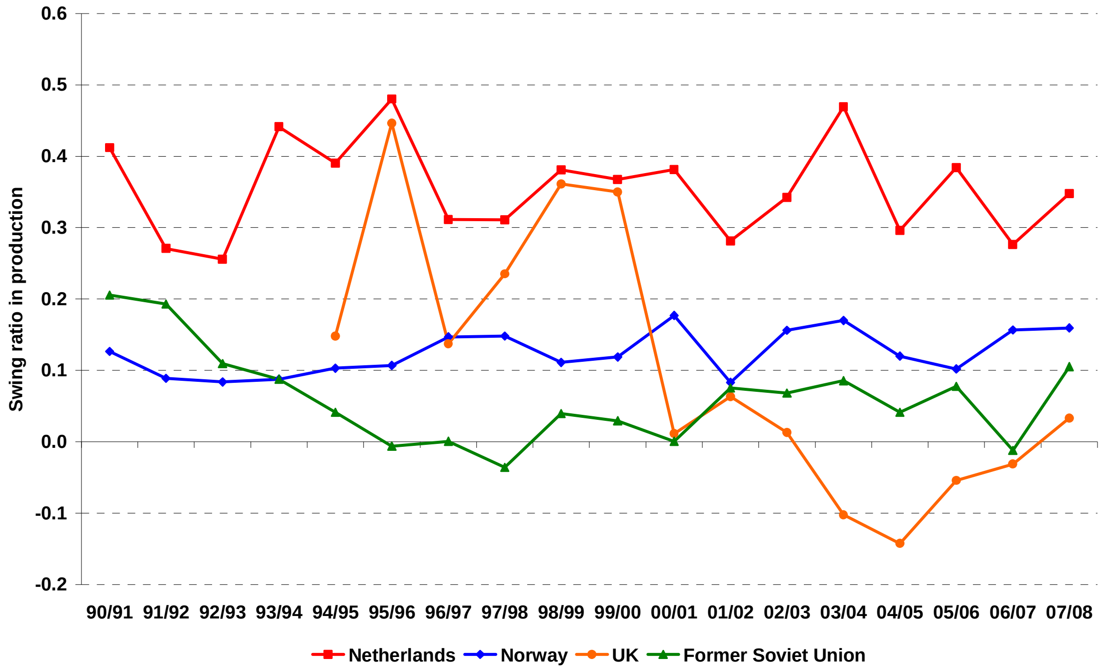


Figure 3.24 *Swing ratio in gas exports of large gas supplying countries to northwest Europe*
Source: IEA.

3.3.3 Flexibility in LNG supplies

The supply of gas via LNG cargoes can theoretically provide seasonal flexibility as well. The transport of gas via LNG tankers does not necessarily need to occur at full capacity during the whole year. Given that the current gas market has relatively more re-gasification than liquefaction terminals this cannot simply be the case on a global scale (though locally it might still be the case). When seasonal price differences indeed influence operational decision-making with respect to the diversion of LNG shipments to certain demand areas, seasonal flexibility provision can be realised.

Available data for monthly gas exports from LNG exporting countries to northwest Europe could give an indication of the degree of seasonality in LNG deliveries. For this purpose we have looked at the following IEA data:

- Exports from Algeria to Belgium, France, and the United Kingdom.
- Exports from Egypt to France and the United Kingdom.
- Exports from Nigeria to France.

Figure 3.25 presents the amount of LNG exports from Algeria, Egypt and Nigeria to Belgium, France and the United Kingdom. From this figure we learn that the export flows are quite irregular from month to month and year to year, with no immediate seasonal pattern observable.

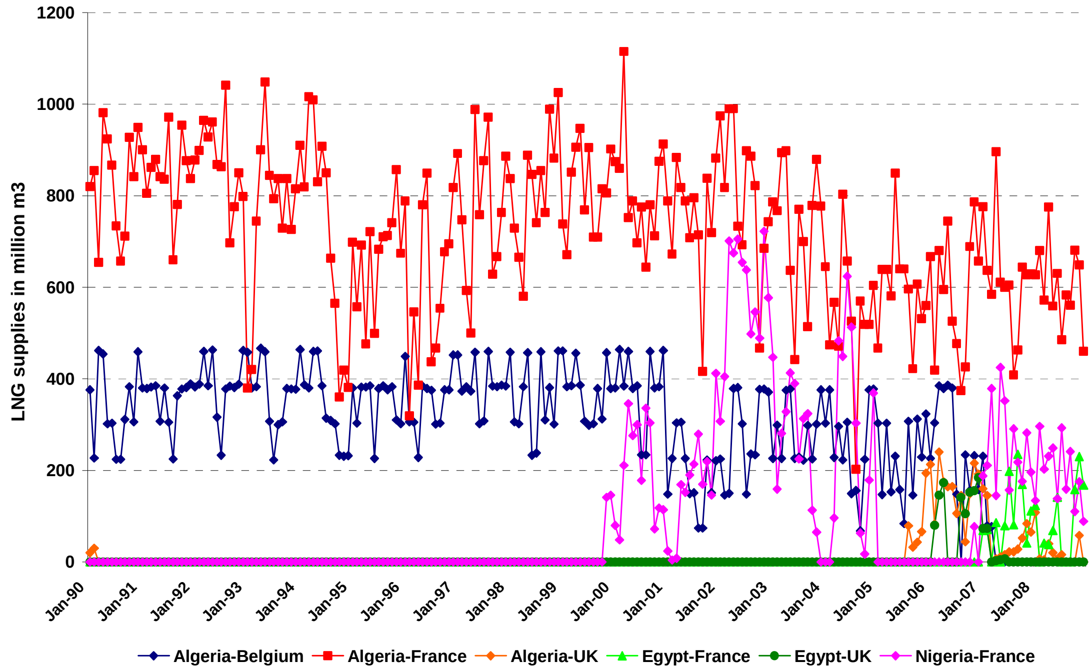


Figure 3.25 *LNG export flows to Belgium, France and the United Kingdom from January 1990 to December 2008*

Source: IEA and own calculations.

In order to judge whether LNG can actually provide seasonal swing volume we have calculated the seasonal swing volume of these LNG flows. Figure 3.26 shows the swing ratios of LNG flows. LNG flows in this figure are aggregated for both countries of origin and destinations in order to see if patterns emerge.

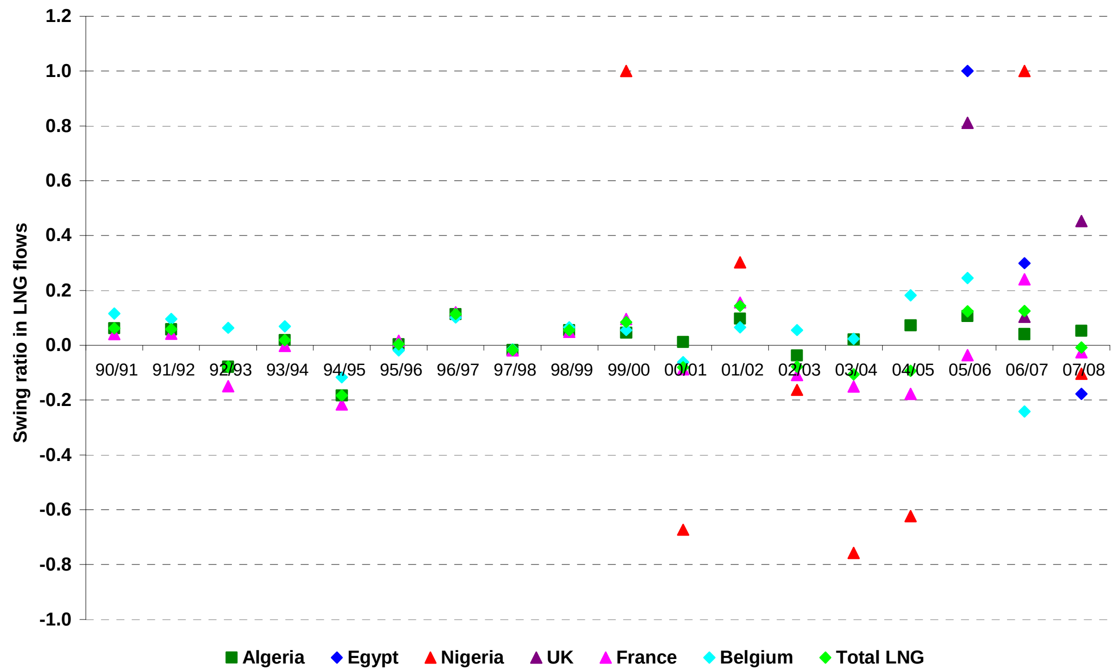


Figure 3.26 *Development of swing ratio for LNG to northwest Europe based on both country of origin and destination*

Source: IEA, own calculations.

In Figure 3.26 we observe that the swing ratio for LNG imports to northwest Europe is negative in a substantial number of cases. This implies that total LNG exports from the particular gas producing country, or the imports to a particular northwest European country are higher in summer than in winter. For those cases we conclude that LNG does not provide seasonal swing. The swing ratio of total LNG flows to northwest Europe varies between -0.18 and +0.14. This implies that the total LNG flow in winter does not always exceed the total LNG flow in summer and that even when it does its size is limited to about 14% of total yearly LNG flows. This observation is supported by looking in particular at the LNG flows from Algeria to respectively France and Belgium. The swing ratio of LNG flows for the Algeria-Belgium and Algeria-France LNG flows -0.22 and +0.18. The figure also suggests that LNG flows to the UK are indeed very seasonally oriented since the swing ratio of LNG flows to this destination by far exceeds the average swing ratio for total LNG flows. However, since the number of observations for this particular LNG importing country is very small no firm conclusions can be based on this observation.

3.3.4 Overall seasonal swing provision

What has been the role of storage in accommodating the seasonal variation in total gas demand in northwest Europe? Answering this question basically requires an integration of earlier presented results on the possible sources of flexibility. Figure 3.27 and Figure 3.28 shows respectively the total amount of seasonal swing supply in northwest Europe and the relative shares of each source of swing supply. This data are calculated by taking the difference between total winter and total summer supply per source.

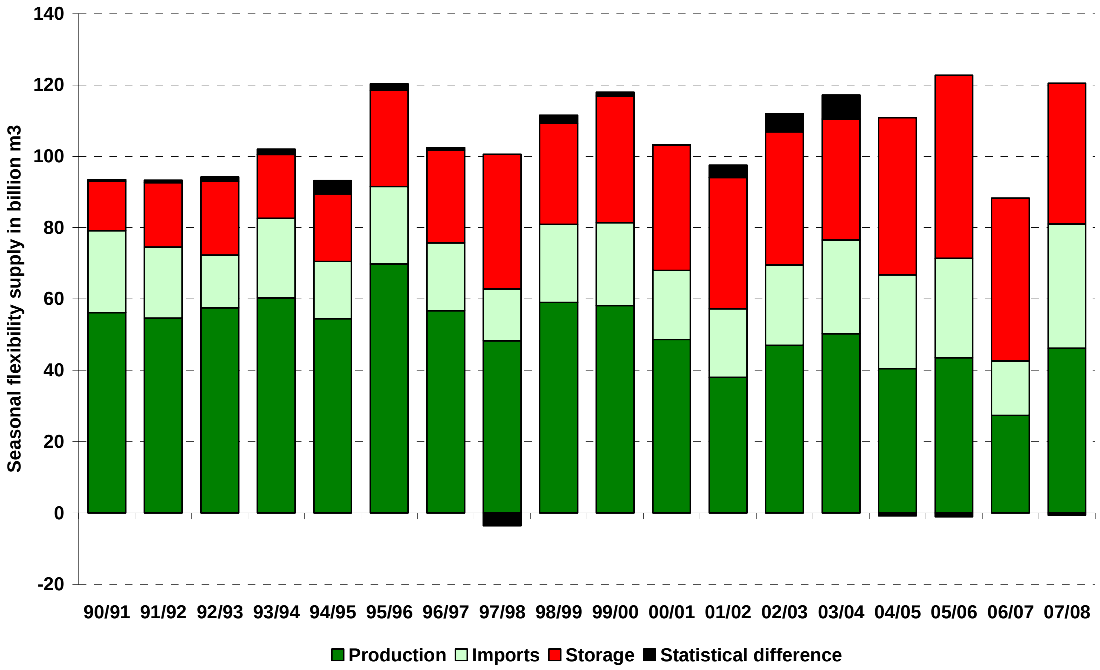


Figure 3.27 *Total amount of swing supply in northwest Europe in the period 1990-2008*
Source: IEA[19]

In the above figure we find that the total amount of swing supply has been varying between 95 and 120 billion m^3. Figure 3.28 depicting the development of the relative shares of the different options gives a clearer picture on possible long-term developments in the supply of seasonal swing. There we observe a significant decline in the share of indigenous production in the sup-

[19] Note that statistical differences are identified by the IEA in the respective country gas balances and are not the result of our calculations.

ply of seasonal swing. Whereas the average share in meeting the total seasonal swing in demand was at 60% in the early 1990s, its share has been at or below 40% since the winter of 2001/2002. The share of imports has remained at a constant level of about 20% of total swing supply. The share of gas storage largely compensated for the decline in swing supply from

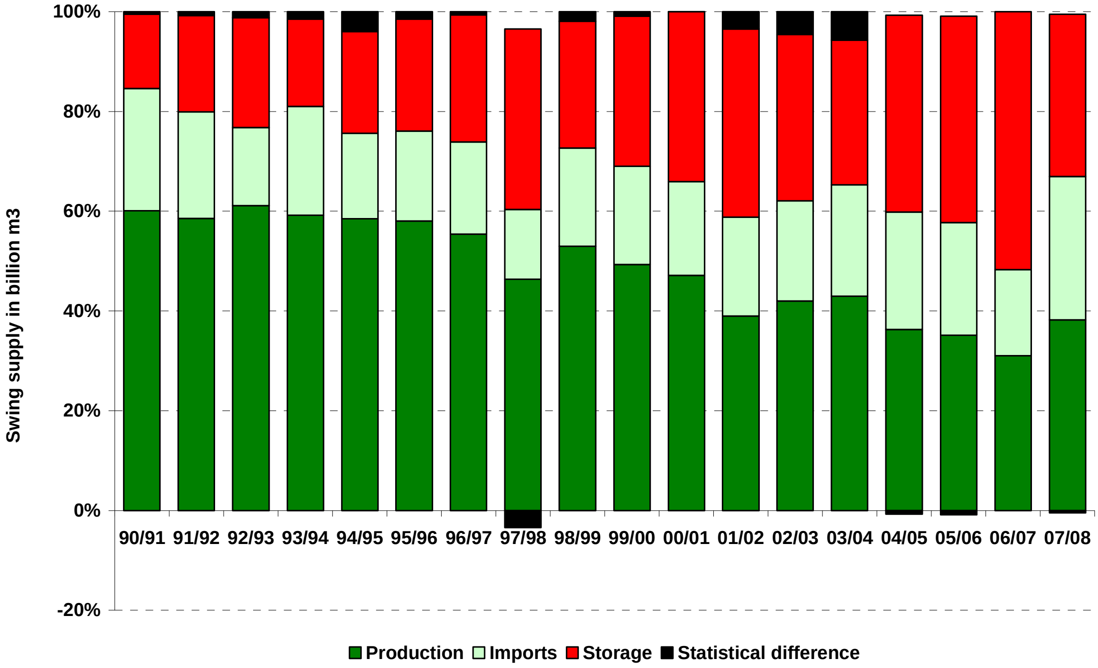


Figure 3.28 *Relative shares of the different sources of swing supply in northwest Europe in the period 1990-2008*

Source: IEA.

3.4 Summary

Gas demand

A detailed assessment of monthly and quarterly gas demand data at sectoral level was undertaken. The notion of different flexibility requirements when it comes to supplying gas to the industrial, residential and power generation sector was illustrated for the case of the Netherlands and the UK. The residential sector requires the highest level of flexibility, whereas flexibility requirements in both the industrial and power generation sector are much lower. There is no long term trend found in the swing ratio of sectoral gas consumption over the time period considered. However, we did find some differences in the sectoral demand development across countries in northwest Europe. Total gas demand in industry has been relatively stable in all assessed countries over the considered time span. Gas consumption in the electricity sector however has increased in all countries, with the UK showing the largest increase. Gas demand in the residential sector has been slowly decreasing in the Netherlands in recent years due to market saturation in combination with savings in gas consumption, whereas residential gas demand in the other countries has increased somewhat. The potential increase in residential gas consumption in these countries could be subject to further study, especially as it may have an impact on the demand for flexibility in gas delivery. After all, the residential sector has the highest flexibility requirements when gas consumption is concerned.

In the next Section we present our model-based projections for future demand for flexible gas supply. There we take existing gas demand scenarios published by international institutions as a point of departure. This obviously takes into account future developments in overall gas demand in different sectors, but an in-depth analysis of a larger variety of uncertainties and the impact on gas demand in particular the residential and services sector is outside the scope of this study. We did include an overview on the development in the number of heating degree-days in the last 18 years as documented by Eurostat. We observe a decline in the amount of heating degree-days in winters in the last 18 years, which is related to on average increasing outside temperatures in winter. However, the considered time span does not warrant firm conclusions on the very long-term trend in average temperatures in northwest Europe. This, again, would require substantial study that falls outside the scope of this study.

Gas storage
The current total amount of working capacity of existing gas storage facilities in northwest Europe is about 41 billion m^3. Given that total gas consumption in this region in 2008 was about 406 billion m^3, current working volume represents about 10% of gas demand in this region. This is quite low when compared to the specific markets in this region, in particular such as Germany and France (both at about 20%). This can be explained by the fact that these two countries did not have the luxury of large sources of flexibility in indigenous gas production. An inventory of existing gas storage investment plans shows that a large number of new gas storage facilities are currently planned. However, only very few are actually under construction. A constructed database combining GSE and IGU data on gas storage investment projects shows total new gas storage projects of about 12.3 billion m^3. From this total projected gas storage capacity, only 9% is actually under construction.

Over the last 10 years, the total amount of gas that is withdrawn from gas storage facilities in northwest Europe has increased from about 10-12 billion m^3 to about 25 billion m^3. This is indicative for the increasing role storage has been playing in the provision of seasonal swing. In the last 18 years, the share of gas storage in bridging the gap between summer and winter demand has been increasing steadily from less than 20% to more than 35%.

Flexibility in production
Assessment of flexibility in production shows that the UK is experiencing a substantial decrease in its capability to provide flexible gas supply. This is related to the increasing depletion of domestic gas reserves. The Netherlands is by far the largest supplier of flexibility in northwest Europe and has so far not showed any sign of decreasing seasonal flexibility capacity. Over the whole region, the contribution of seasonal flexibility provided by indigenous production has decreased from about 60% in the beginning of the 1990s to about 40% in recent years.

Flexibility in imports
Gas imports from outside northwest Europe show considerably less seasonal flexibility than indigenous gas production. Norway though has recently (about the last 7 years) increased total yearly export to northwest Europe and at the same time managed to increase the seasonal flexibility of these export volumes. However, its flexibility is not sufficient in compensating the decline in flexibility in indigenous production. The increase in seasonal swing in Norwegian exports to northwest Europe is made possible by an increasing capacity in direct pipeline links to Germany and the UK. Russian exports to northwest Europe exhibit less seasonal flexibility than both Norwegian exports and indigenous production. This can be explained by the longer distance between Russian gas fields and the gas demand centres in northwest Europe and the capital intensity of the costs of transporting gas to northwest Europe, which induces more or less base load exports. Imports to northwest European re-gasification terminals have been steady in recent years but small compared to pipeline imports. Based on historic data we cannot conclude on specific seasonal flexibility in LNG supplies.

Reflection on CIEP (2006) findings
The CIEP (2006) study assumed an increase in total gas demand in the whole of (OECD) Europe of about 2 to 3% per year in the period 2005 to 2020. These figures were based on projections in Tönjes (2005). In reality, gas demand in northwest Europe has actually decreased from 321 billion m^3 in 2005 to 315 billion m^3 in 2008.

The analysis of historic gas storage withdrawals and gas storage usage ratios in CIEP (2006) led to expectations that both would follow a continuous upward trend from the 2003/2004 winter onwards. With hindsight we can now say that this upward trend was not continued in the last 4 years. Looking at the updated analysis on gas storage withdrawals and gas storage use we find that absolute withdrawal levels and capacity usage ratios have been more or less constant over the last 4 years. This can be largely explained by the relative mild winters in northwest Europe in this period. Harsher winter conditions would most probably have led to an increasing trend in gas storage withdrawals and gas storage capacity usage.

4. Future demand and supply of seasonal swing

In this Section we focus on possible future developments on the northwest European gas market with respect to the demand and supply of seasonal swing, and in particular the role of seasonal storage therein. Here we discuss the results of the performed model-based analysis.

Section 4.1 presents the model results for the reference scenario. Here we describe the projected developments with respect to the future demand for seasonal swing, investment in gas storage capacity, the use of gas storage capacity and the overall provision of flexibility from other sources than gas storage. In Section 4.2 we turn to an analysis on the impact of different gas demand growth assumptions on the above-mentioned developments. This corresponds to the presentation of model results for scenarios S1 to S4. Thereafter, in Section 4.3 we analyse the impact of different assumptions with respect to flexibility provision on above listed developments, this corresponds to an analysis of scenarios S1 and S5 to S7. Section 4.4 confronts the model-based projections with current gas storage investment plans (as were presented in Section 3.1.4). Finally Section 4.5 presents some conclusions.

4.1 Developments in the reference scenario

In this section we present and analyze the results acquired in the reference scenario. When presenting the results we focus on developments in northwest Europe instead of country-specific results. This also means that projected gas storage capacity additions and gas storage withdrawals are presented at the northwest European level. Figure 4.1 gives an overview of developments in the demand and supply of swing in northwest Europe in the reference scenario.

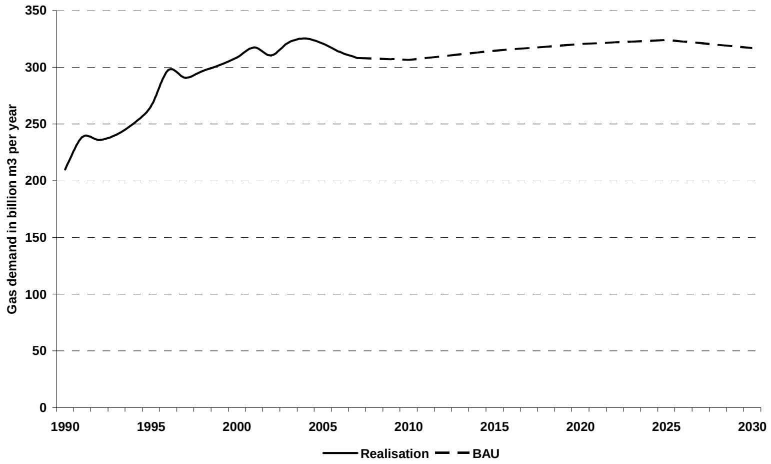
The demand for swing is expected to slowly increase from now to 2030 (Figure 4.1, part (b)). This increase is linked to the increase in total gas demand, but the growth rates differ. Since the increase in total gas demand per sector varies, as well as the amount of swing volume required in each sector the growth in total swing volume is actually less that the growth rate in total gas demand (see part (a)). Total gas demand increases with 8.8 billion m^3 to 317 billion m^3 in 2030, while total swing volume increases with 9.3 billion to 93 billion in 2030. Finally, with respect to the allocation of demand over the different seasons it is important to note that the observed swing ratio for each separate sector is comparable with the observed historical swing ratios. The swing ratio was earlier defined as being the difference in demand in winter (October to March) and summer (April to October) divided by total demand. Historical analysis for total gas consumption in northwest Europe indicated a swing ratio of 0.26, whereas the model results show a swing ratio of about 0.26 in 2010, increasing to about 0.28 in 2025 and 0.29 in 2030. This can be explained by differential developments in gas demand in different sectors across the northwest European countries.

Based on the demand developments projections are constructed for the development of gas storage capacity in northwest Europe until 2030 (Figure 4.1 part (c)). This projection takes into account the fact that the installed gas storage capacity needs to provide enough swing capacity in very cold winters.[20] In the model results we observe a substantial increase in storage capacity in the period until 2015. There is a total need for additional gas storage capacity of 17 billion m^3 in 2015. This is explained as follows. The model, and more particularly the economic optimisation-based mechanism within the model, in fact suggests that the current amount of gas storage capacity in reality is too low compared to the economic optimum. The required growth is on av-

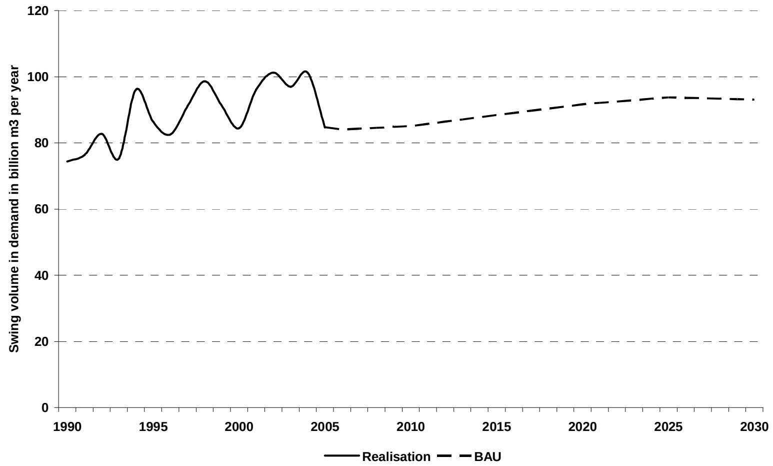
20 As explained in the model description we have assumed a maximum usage ratio of 60% of actual storage capacity. This means that 60% of total installed storage capacity needs to cover average winter demand. The remainder 40% is 'reserved' for above-average winters and strategic storage purposes.

erage 1.9% per year over the period 2009-2030. This projected growth rate in gas storage capacity falls within the range of projections provided in CIEP (2006). The additional gas storage capacity to be installed in northwest Europe is mainly realized in the UK (about 8 billion m^3 working gas capacity in 2015), and to a smaller degree in the Netherlands and Belgium. The fact that the model chooses to invest in gas storage capacity in the UK instead of the Netherlands is caused by a large decrease in production flexibility in the UK and the tendency of the model to build as close to the market as possible. This makes sense based on economic considerations. However, we think that this particular allocation of storage investment is also caused by the rather basic representation of gas storage investment decision-making in the model. For example, the model does contain operational and investment cost for storage that differ between countries but it does not include a total database of gas storage potential. In reality, a potential gas storage supply curve exists with the most attractive potential storage sites being developed first and with investment and operation cost of storage increasing when more and more potential is realized. Including such a mechanism would probably lead to a re-allocation of new storage capacity compared to the current model results. On the other hand we expect the level of total new storage investment for the northwest European region as a whole to be robust. In short: the model is capable of simulating the additional required storage investment on a regional, but might be less accurate in precisely determining the location within the regions. Outside the northwest European region the model projects a doubling of gas storage capacity in Poland from current 1.6 to 3.2 billion m^3 in 2030. Another region where substantial gas storage capacity is developed is the Balkan / Turkey region. Until 2030 a total of about 13 billion m^3 is added to existing capacity in this region.

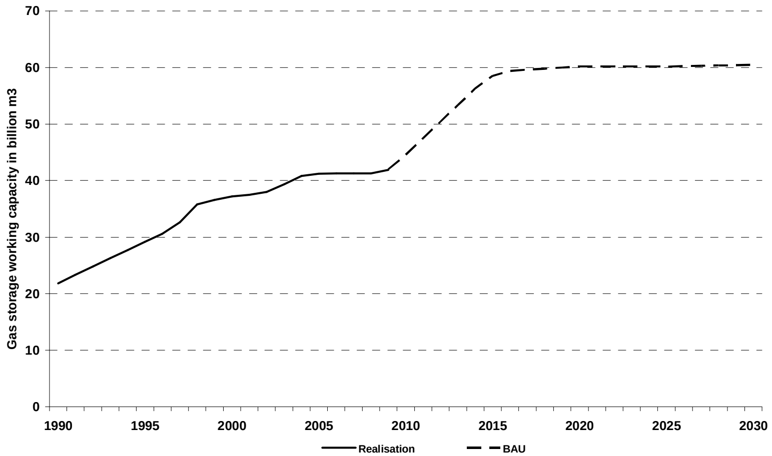
On average, gas storage withdrawals in winter in the reference scenario increase with about 1.3% per year until 2030 (Figure 4.1 part (d)). This projected increase in the reference scenario is substantial and its growth rate clearly exceeds the growth in swing demand that was depicted in part (a). The total amount of storage withdrawals in winter is projected to increase with about 34% in 2030. This equals more than 8 billion m^3. The relatively large increase in storage withdrawals compared to the increase in gas demand and the swing volume in gas demand is explained by the fact that storage capacity is actually compensating for the declining capacity of indigenous gas production to provide seasonal swing.



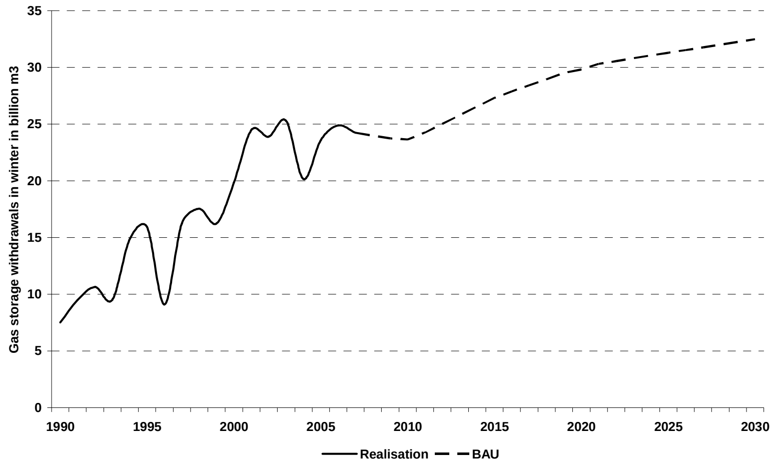
(a) Total demand for gas



(b) Swing demand for gas



(c) Gas storage capacity



(d) Gas storage withdrawals

Figure 4.1 *Projected developments in the demand and supply of flexibility in northwest Europe until 2030 in the reference scenario*

Finally, Figure 4.2 gives the full picture concerning the share of storage in the overall supply of seasonal swing in northwest Europe until 2030.

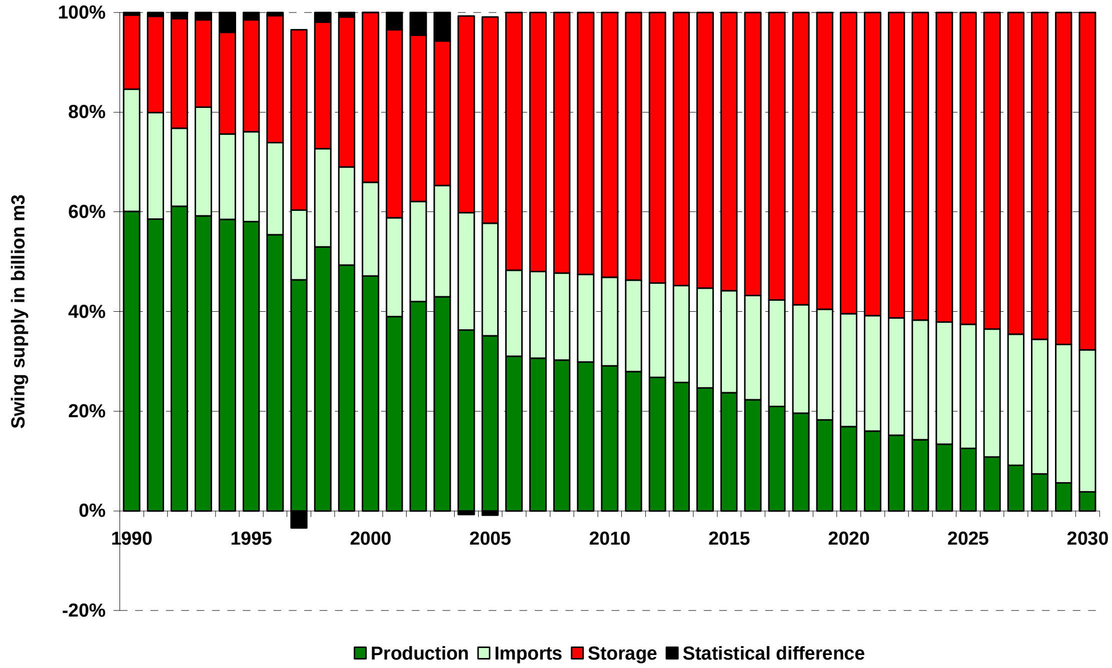


Figure 4.2 *Historic data and model-based projection of the relative shares of different swing supply options in total swing supply in northwest Europe until 2030*[21]

Model projections for the reference scenario show a continuously decreasing role for production in the provision of seasonal swing. The share of production in this scenario decreases from little over 30% to about 20% in 2020 and 5% in 2030. Furthermore the model projects an increase in the amount of flexible gas supply through imports. This is mainly based on gas imports from Norway. The decline in flexibility from indigenous production is for the largest part compensated for by gas storage. Until 2030 gas storage is projected to play an increasingly important part in the provision of swing in northwest Europe. The share of seasonal storage is projected to increase from abut 53% in 2010 to about 61% in 2020, and 68% in 2030.

In the next two subsections we analyze the impact of different gas demand assumptions and different assumptions with respect to alternative sources of seasonal swing on the need for seasonal swing and the role of storage in providing seasonal swing.

4.2 Impact of changes in gas demand

In this section we compare the results from the model runs listed in Table 4.1.

[21] Historic data is presented until 2007 (which is actually gas year 2007/2007). Afterwards model-based projections are presented.

Table 4.1 *Overview of model runs assessed in Section 4.2*

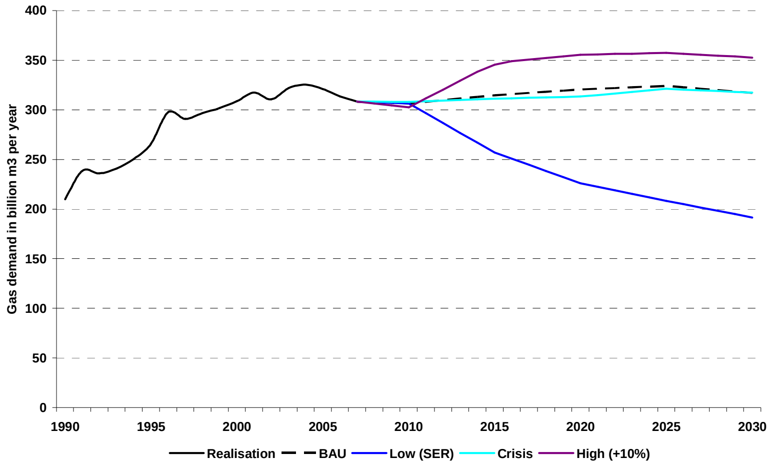
Model run	Name	Description
S1	Reference scenario (BAU)	Reference scenario based on the Primes 2007 update. This run was analyzed in Section 4.1.
S2	Low demand (SER)	Scenario related to achieving the EUs 2020 goals with respect to sustainability, leading to a strong decrease in gas demand.
S3	Crisis (delay BAU)	Scenario constructed to investigate the impact of the current financial and economic crisis. This scenario is based on the reference scenario but has a delay in gas demand of about 5 years. Realigns with reference scenario projection from 2025 onwards.
S4	High (BAU +10%)	High gas demand scenario assuming a 10% increase in gas demand in every sector compared to the reference scenario.

Figure 4.3 presents the main output data required for the analysis of the impact of different demand scenarios on the need for seasonal swing and the role of gas storage in the provision thereof.

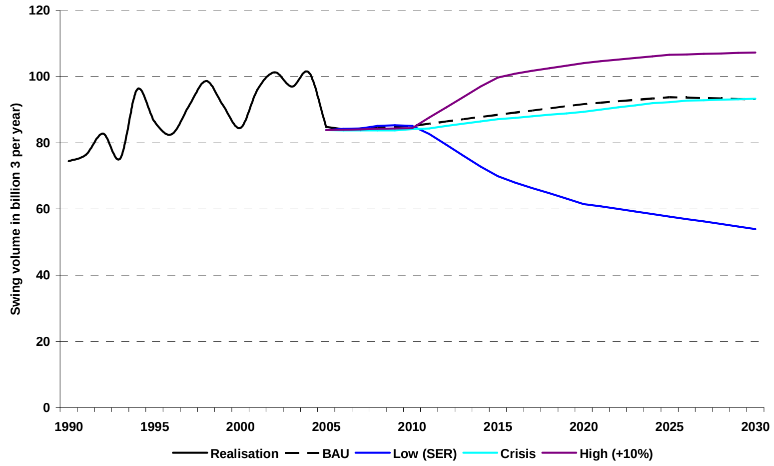
The gas demand projections for northwest Europe reflect the gas demand input for the model that was depicted in Figure 2.3. The change in the total demand of swing volume that is related tot total demand projections closely resembles the total demand for gas but is not identical due to differential growth rates for each gas consuming sector. The low gas demand scenario that was based on the 2020 sustainability targets-based SER study has a lower swing demand in 2030 of about 39 billion m^3 compared to the reference scenario. We also observe a noticeable impact of the crisis scenario on total swing demand. Compared to the reference scenario, the crisis scenario has a decrease in the amount of swing demand of about 1.2 to 2.3 billion m^3 per year in the 2010-2025 time period; which equals about 1.5% - 2.5% of swing demand in the reference scenario. Finally the high demand scenario, which was based on a 10% increase in total demand in the reference scenario, shows an increase of swing demand of more than 10% compared to the reference scenario. This is due to the fact that the additional demand is not equally spread over summer and winter time.

In all considered demand scenarios substantial new investments are undertaken in the years until 2015 (+13 to +21 billion m^3 working gas capacity).[22] After 2015 additional gas storage investments of about 14 billion m^3 are needed in the high demand scenario when the 2015 and 2030 gas storage capacity levels are compared. Total installed working volume of storage facilities stays constant after 2015 in the low demand and crisis scenarios, with total need for gas storage capacity in the latter scenario being about 7 billion m^3 lower. The difference in total storage capacity developments between the reference and crisis scenarios seems negligible. The impact of different demand developments on storage capacity developments outside the northwest European region varies. When gas demand decreases until 2030 (low demand scenario) the total need for new investment in gas storage capacity decreases in northwest Europe with about 30%, whereas the decrease is about 43% in the Balkan/Turkey area and even over 90% in Poland. In the high demand scenario, investments in gas storage working capacity increase with 31% in the Balkan/Turkey region and about 63% in northwest Europe and Poland.

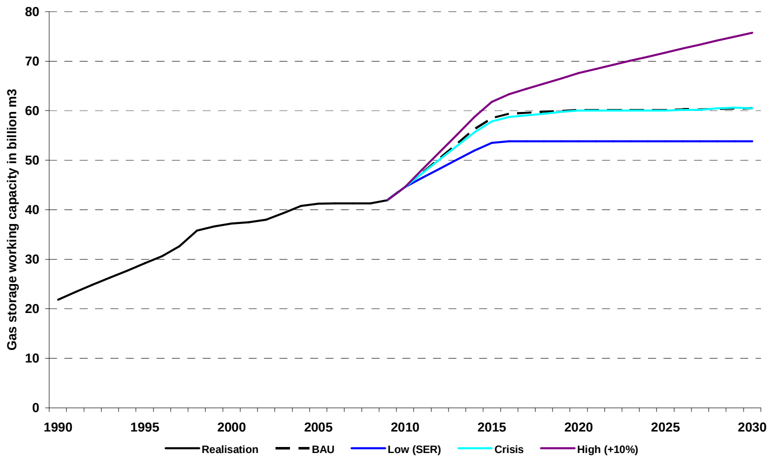
[22] When assessing this projection we need to keep in mind our discussion on differences in estimates for existing gas storage capacity in Section 3.



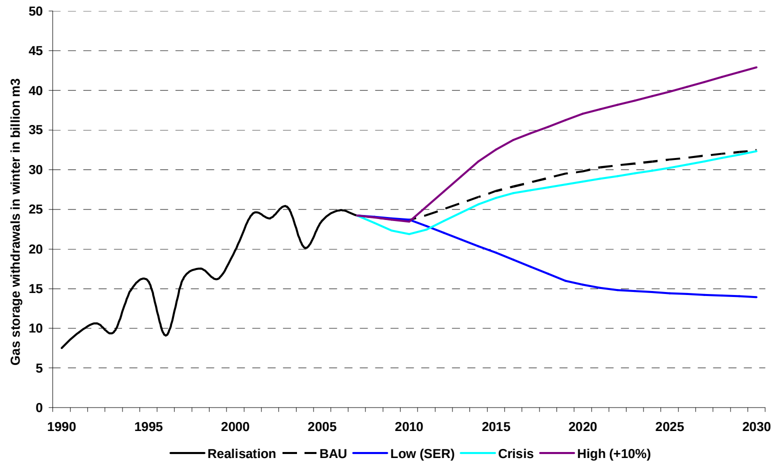
(a) Total demand for gas



(b) Swing demand for gas



(c) Gas storage capacity



(d) Gas storage withdrawals

Figure 4.3 *Projected developments in the demand and supply of flexibility in northwest Europe until 2030 in the reference scenario and three other demand scenarios*

The impact of a low gas demand has large implications for the total volume of gas storage withdrawals. Whereas gas storage withdrawals increase over time in all other scenarios, including the crisis scenario, total gas storage withdrawals in the low demand scenario are 50% to 57% lower in respectively the years 2020 and 2030. Gas storage use in the crisis scenario is just a little below the gas storage use in the reference scenario; about 4% to 5% in the years 2020 and 2025. Finally the high demand scenario representing a 10% increase in total gas demand gives rise to an increase in total gas storage withdrawals compared to the reference scenario of about 7 billion m^3 (+23%) per year in 2020 and about 10 billion m^3 (+32%) per year in 2030.

Figure 4.4 presents the shares of the different alternatives for seasonal swing provision for the different demand scenarios. Compared to the reference scenario, that was already discussed in Section 4.1, the role of storage in providing seasonal swing in northwest Europe is much smaller in the low demand scenario when compared to the reference scenario. This is explained by the lower production levels within northwest Europe and the extension of the capability to produce seasonal swing over time. Whereas the share of gas storage in seasonal swing in 2030 is about 67% in the reference scenario, it only amounts to about 45% in the low demand scenario. When the reference scenario is compared with the crisis scenario we find only little differences in overall development of shares, except for the observation that developments in the crisis scenario are lagging behind the developments in the reference scenario for five years. As expected, the role of storage in providing seasonal swing is especially large in the high demand scenario. This demand scenario projects a quicker and earlier depletion of indigenous gas production. Combined with the fact that swing supply in imports is limited storage has to provide an even larger share of total seasonal swing in each year compared to the reference scenario. The difference between the shares of gas storage in the reference scenario and the high demand scenario amounts to about 12 %-points (67% versus 79%).

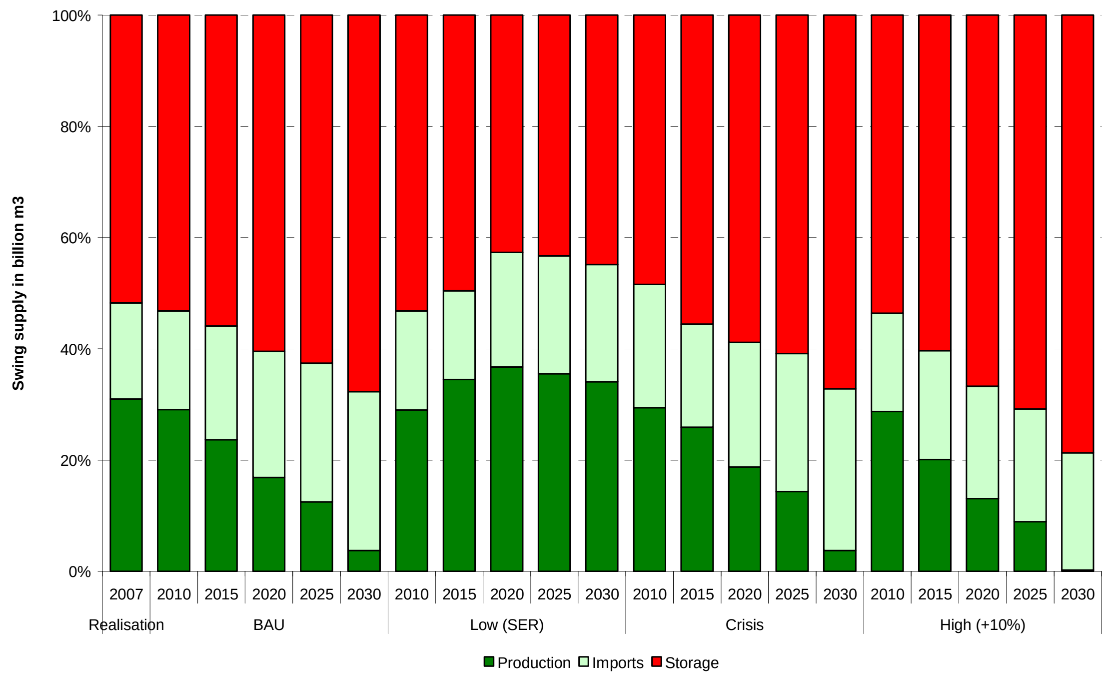


Figure 4.4 *Model-based projection of the relative shares of different swing supply options in total swing supply in northwest Europe until 2030 for different demand scenarios*

In the next subsection we turn to an analysis of the impacts of different assumptions with respect to flexibility on the role of storage in the overall provision of seasonal gas supplies.

4.3 Impact of changes in flexibility assumptions

In this section we compare the results from the model runs listed in Table 4.2.

Table 4.2 *Overview of model runs assessed in Section 4.3*

Scenario	Name	Description
S1	Reference scenario (BAU)	Reference scenario based on the Primes 2007 update. This run was analyzed in Section 4.1.
S5	High production flexibility	Compared to the reference scenario production function parameters have been adapted to simulate a higher flexibility in gas production in the Netherlands.
S6	High LNG availability	Compared to the reference scenario production function parameters have been adapted to simulate a higher flexibility of LNG gas supplies.
S7	Netting of gas flows	Compared to the reference scenario this model run assumes netting of gas flows (e.g. full availability of counter-flow capacity (back-haul capacity) up to the technical maximum given by the forward flow.

The different parts of Figure 4.5 show the impact of changing the assumptions with respect to the provision of other possible swing supply alternatives.

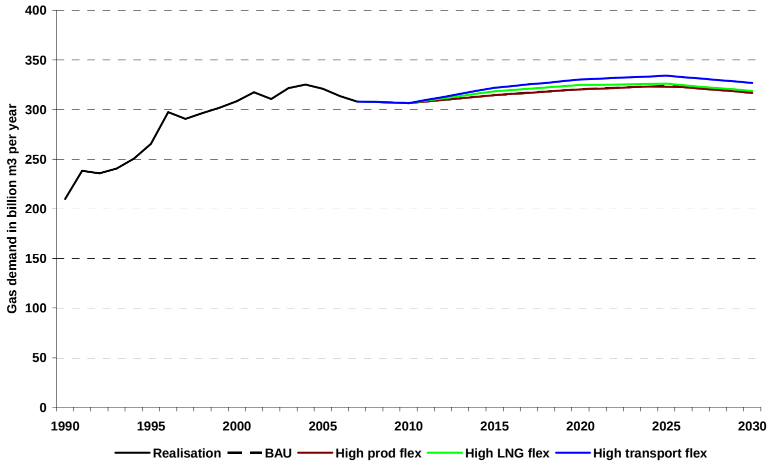
Since the scenarios assessed in this section mainly differ with respect to the level of flexibility provided on the supply side, we do not expect total demand for gas or the seasonal swing in demand to be affected to a very large degree. Possibly, there is a small demand-increasing effect the changes give rise to somewhat lower or higher gas prices. Figure 4.5 (a) and Figure 4.5 (b) show the model-based projections for total gas demand and the amount of swing volume (i.e. the difference between winter and summer gas consumption) until the year 2030. Varying the assumptions with respect to the provision of production flexibility, the flexibility of LNG supplies and the efficiency in which transport capacity can be used has a small but in some cases noticeable small impact on gas storage developments. Changing the minimum usage rate of LNG import capacity to 80% instead of 90%, gives rise to an increase the demand for gas. This gives rise to a somewhat larger demand for additional gas supplies in winter as well (see part (b) in Figure 4.5). Also a change in the availability of back-haul capacity affects the total level of demand. An increasing availability of transport capacity enables a higher level of arbitrage between markets and ultimately gives rise to a decrease in gas prices. The decrease in gas prices in turn leads to an increased demand for gas. Since part of the increase in gas demand concerns temperature related demand, the demand for swing volume in winter also increases. The latter effect is indeed observed in part (b) of Figure 4.5, where the total amount of swing volume is about 2 billion m^3 (about 2%) higher than in the reference scenario over the 2010 to 2030 time span.

We have observed that the absolute level of demand for seasonal swing has not been affected that much, as was to be expected, but the differences in scenario parameters should have quite a differential effect on the use of different seasonal swing provision options, for example gas storage. Part (c) and (d) in Figure 4.5 present the model-based projections for the amount of gas storage working capacity and the amount of gas storage withdrawals under average winter demand conditions.

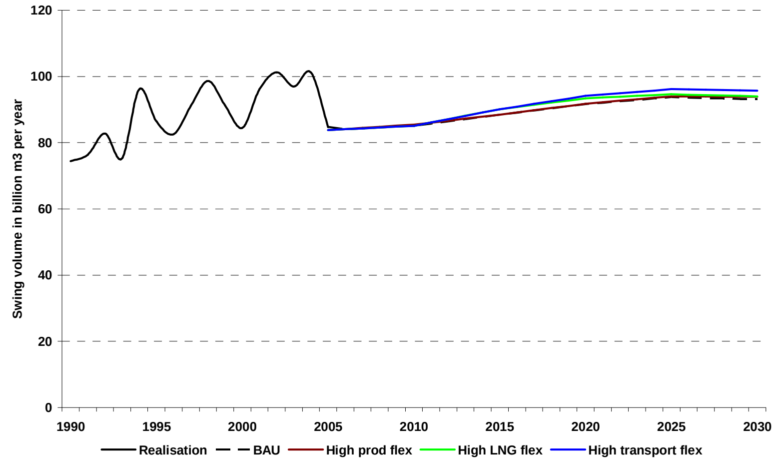
Changes in the scenario environment (i.e. higher flexibility in production, higher flexibility in LNG supplies, and more efficient use of transport capacity) give rise to a decrease in the amount of storage investments. An increase in the assumed flexibility of indigenous gas production leads to a decrease in total needed storage capacity in northwest Europe in 2030 of about 3 billion m^3. In this case, storage investment requirements are about 12% less than storage investment requirements in the reference scenario. The increase in the flexibility of LNG supplies gives rise to a decrease in the need for investment in storage capacity in northwest Europe of about 1 billion m^3 (4%) when compared to investment need in the reference scenario. When full availability of back-haul capacity is introduced it raises the potential for arbitrage between markets. This results in partial cancelling out of gas flows on some routes. Overall this leads to more efficient use of available transport capacity, also in winter periods. This finally results in less need for additional gas storage capacity. The impact amounts to about 1 billion m^3 or 4% less need for investment in additional gas storage capacity when compared to the base case. Also gas storage investments elsewhere in Europe are affected by changes in flexibility assumptions. Higher production flexibility of gas production in northwest Europe decreases storage investments with over 30% (0.8 billion m^3 of working capacity) in Poland, but only 1% (0.2 billion m^3 of working capacity) in the Balkan/Turkey area. This is explained by the proximity of the Polish storage to the northwest European gas demand centres. The impact of higher flexibility in LNG supplies decreases total need for gas storage investment over the whole period by about 14% in Poland while need for gas storage investment in the Balkan/Turkey region remains unaffected. More efficient use of existing pipeline capacity via full availability of back-haul capacity (up to the physical forward flow) gives rise to a decrease in Polish storage investments of about 23%, which is a substantially larger decrease than we observed for the northwest European market (-4%).

Part (d) of Figure 4.5 presenting the actual use of gas storage in winter the above observations. When production flexibility is assumed to be higher, there is less need for additional supplies in winter from storage facilities. The total reduction in average winter gas storage withdrawals is about 8% (2.7 billion m^3) in the year 2030. An increase in the flexibility of LNG supplies to northwest Europe also reduces total gas storage withdrawals in winter, but to a lesser extent: about 2.6% throughout the whole time period (0.85 billion m^3). The availability of back-haul capacity however gives rise to an increase in the amount of gas storage withdrawals. This can be explained as follows. The increasing use of available transport capacity gives more opportunities for shippers and traders to efficiently use available storage capacity.[23] As we saw earlier, total gas storage capacity in northwest Europe increases as a result of higher capacity availability, but the usage rate of total storage capacity increases by even more. Total gas storage withdrawals in an average winter can therefore be about 3.4 billion m^3 higher (+11%).

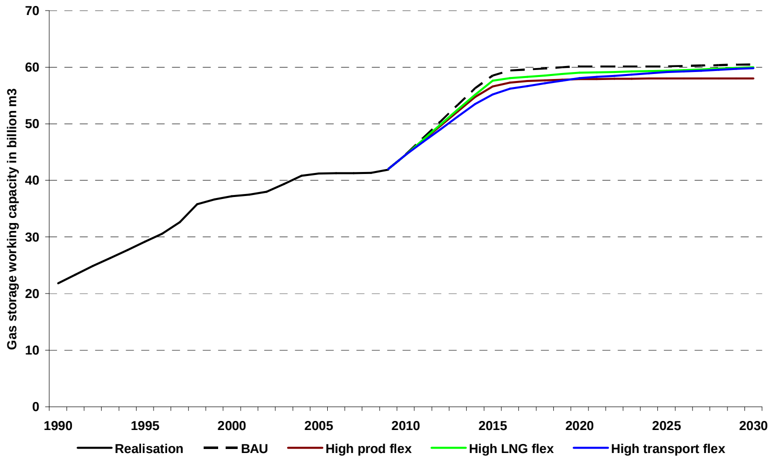
[23] Note that this also presumes that all available transport capacity is indeed offered to the market. I.e. there is no ca pacity hoarding.



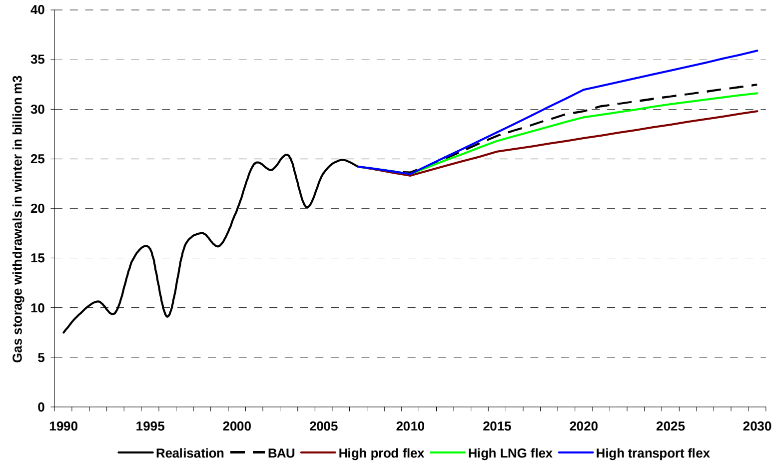
(a) Total demand for gas



(b) Swing demand for gas



(c) Gas storage capacity



(d) Gas storage withdrawals

Figure 4.5 *Projected developments in the demand and supply of flexibility in northwest Europe until 2030 in the reference scenario and three other scenarios*

Figure 4.6 presents the development of the shares of the different flexibility options in the total provision of swing supply.

In the high production flexibility scenario we have assumed that the Netherlands is able to maintain its level of flexibility in gas production as compared to a decline of this capacity in the reference scenario. The result is a much larger share of production in the provision of seasonal swing by 2030; 20% in the high production flexibility scenario versus 4% in the reference scenario. Also the share of imports is relatively larger in this scenario. The share of storage decreases with about 7%-points in every year until 2030. An increase in the minimum usage rate of LNG import terminals only marginally increases the total swing provision of total imports: 3%-points in 2030. Finally, a more efficient use of available transport capacity gives rise to a lesser need for gas storage since available seasonal swing capacity of both imports and indigenous gas production can be used more efficiently. The impact of terms of shares in total provision however is small.

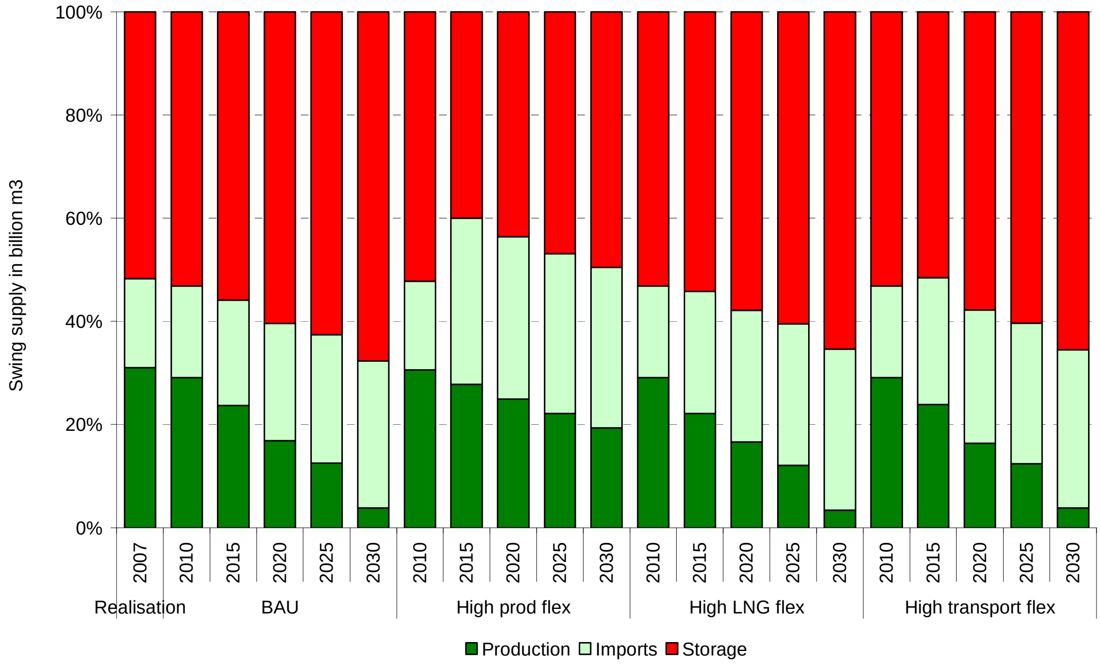


Figure 4.6 *Model-based projection of the relative shares of different swing supply options in total swing supply in northwest Europe until 2030 for different flexibility assumptions scenarios*

4.4 Confrontation of existing storage investment and projections

Figure 4.7 presents a confrontation of the expected development in gas storage capacity based on currently known investment plans on the one hand (see section 3.1.4), and the model-based projections on the other (sections 4.1-4.3).

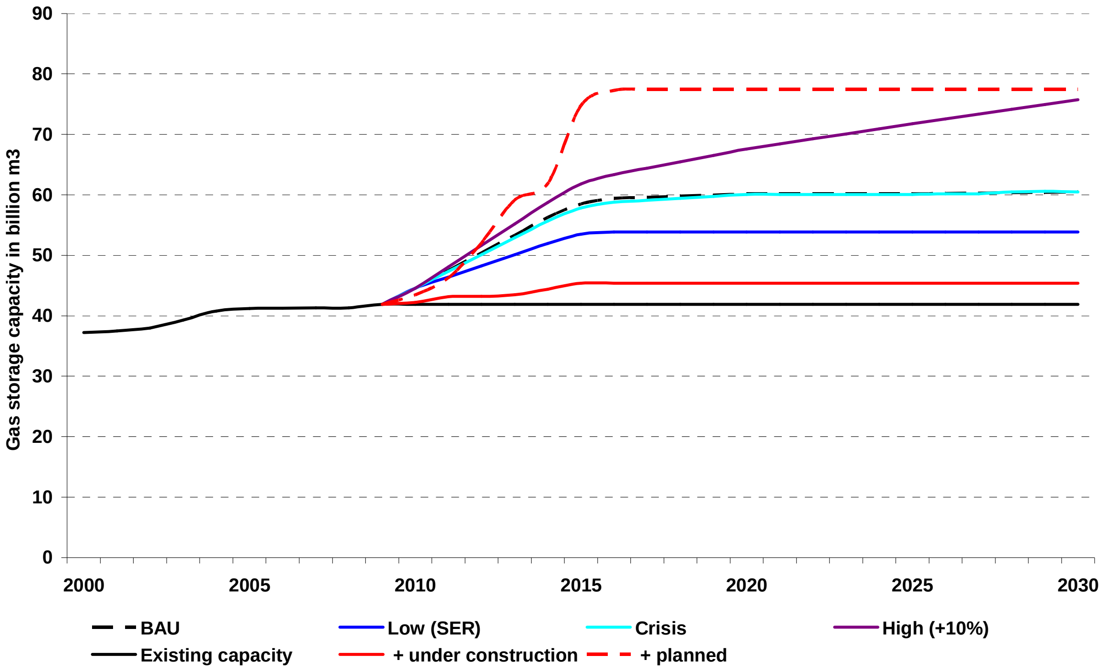


Figure 4.7 *Total gas storage capacity in northwest Europe: confrontations based on model-based scenarios and existing gas storage investment database*

Source: GSE, IGU.

From the confrontation we learn that the total amount of planned gas storage investments largely exceeds the required gas storage capacity as calculated in our model. Planned investments even exceed the total gas storage capacity needed to accommodate a total gas demand that is 10% higher than projected in the Primes 2007 reference scenario. In short, if all planned investments in gas storage go ahead it is likely that northwest Europe as a whole will have substantial gas storage overcapacity. Based on the current amount of existing gas storage capacity, plus capacity under construction we observe that there would be a lack of storage capacity of about 14 billion m^3 in 2015. Even in the low gas demand scenario the existing capacity plus capacity under construction falls short of the needed gas storage capacity in 2015, by about 8 billion m^3. In order to achieve the level of gas storage capacity in 2015 as calculated by the model, at least 46% of currently planned gas storage investment needs to be realised in 2015.

4.5 Summary

Reference scenario outlook

A gas market model covering the whole European gas market is used to estimate future developments in the northwest European market with respect to gas demand, the need for seasonal flexibility in accommodating gas demand, required gas storage capacity and gas storage withdrawals. Using real cost data the market model determines the optimal mix of different alternatives for the provision of seasonal flexibility. Within a reference scenario based on business as usual conditions the model estimates a total need for additional gas storage capacity of about 17 and 21 billion m^3 for respectively the years 2020 and 2030. The amount of total gas storage withdrawals is estimated to increase with about 50% to 32.5 billion m^3 in 2030. One of the main drivers of the increase in required gas storage capacity is the assumed seasonal swing provided by indigenous production (i.e. the Netherlands and UK). The share of production in the overall provision of seasonal swing supply decreases from 30% in 2010 to about 5% in 2030. Imports provide only a very limited compensation for this decline.

Impact of different demand scenarios on gas storage

Three alternative demand scenarios have been assessed on their impact on gas storage and the provision of seasonal flexibility: (1) a crisis scenario reflecting the current economic and financial crisis, (2) a low demand scenario reflecting demand developments related to reaching the EC 2020 sustainability targets, and (3) a high demand scenario that provides a reference maximum in expected gas storage developments. The crisis scenario reduces the amount of gas storage withdrawals somewhat but leads only to a negligible decrease in total gas storage requirements when compared to the reference scenario. A low demand scenario still gives rise to additional need for gas storage investment, but significantly below the reference scenario level (-5 to -7 billion m^3 in 2015 and 2030 respectively). A high gas demand scenario (+10% compared to the reference scenario) poses large additional requirements for total gas storage development. It would increase required gas storage capacity with 4 billion m^3 in 2015, and with 14 billion m^3 by the year 2030.

Impact of different flexibility assumptions

We have assessed the impact of alternative assumptions with respect to the future provision of seasonal flexibility via other sources than gas storage: (1) seasonal flexibility provided by indigenous production, (2) seasonal flexibility provided by LNG supplies, and (3) seasonal flexibility from pipeline imports in a situation where available pipeline capacity is optimally used. Our results indicate that especially production flexibility and transport capacity assumptions have a significant impact on the required amount of gas storage investments in the future. Higher production flexibility of indigenous production can reduce the need for gas storage investments with 3 billion m^3 (4%) in 2030. In addition, more efficient use of available transport capacity induces more arbitraging between regions and markets and gives rise to more efficient use of existing gas storage capacity. This decreases the need for gas storage investment with about 1 billion m^3 (1%) in 2030. Increasing the flexibility of LNG supplies to northwest Europe by decreasing the minimum supply level from 90 to 80% decreases the need for additional gas storage also with about 1 billion m^3 (1%) in 2030.

Confronting future estimates with existing investment plans

When the projected gas storage capacity requirements are confronted with currently known gas storage investment plans we find that the current amount of installed capacity plus additional capacity under construction is not even sufficient in accommodating gas storage requirements as estimated for the low gas demand scenario, let alone for the other scenarios. The gas storage capacity requirements as simulated in the reference scenario run still require additional commitments of about 14 billion m^3 in 2015. On the other hand we observe that including all planned and projected gas storage projects to the total capacity currently in the market combined with capacity under construction would give rise to some degree of over capacity in the period to 2030, even when the high gas demand scenario is taken as point of departure. In order for real-life gas storage capacity to match the model-based estimate for required gas storage capacity in 2020, about 46% of currently planned gas storage investment projects for 2015 need to be realised.

Reflections on model approach and assumptions

Two important considerations need to be kept in mind when it comes to interpreting the estimated projections that originate from the gas market model. These are related to the distinction between ‘average winter conditions’ modelling versus ‘peak winter conditions’ modelling, and to the supposed seasonal flexibility provided by LNG supplies.

As to the first issue, the model in its current version is only capable of simulating average winter demand conditions, implying that initial gas storage investment requirements calculated by the model are only sufficient to cover seasonality in gas demand experienced in average winters. In reality the provision of seasonal flexibility via gas storage needs to be dimensioned on much harsher winter conditions (e.g. 1-in-20 years winters). We have corrected for this fact by exogenously assuming that in average winters gas storage capacity is only used at 60% of maximum capacity. Hence, a cold winter reserve margin of 40% is applied. This figure is based on data on historic use of gas storage capacity in northwest Europe. However, this implied reserve margin might have a different value in the future. If European gas market integration will be improved, sufficient new investment in gas transport capacity will be undertaken and total capacity will be fully available. Thus, it could induce a more efficient use of existing gas storage capacity resulting in lower required gas storage capacity reserve margins. If this is indeed the case, the future required gas storage capacity requirements should be interpreted as an upper bound. On the other hand, as uncertainty of import flows may be higher than that of indigenous production, there might be a tendency towards higher reserve capacities.

Regarding the flexibility in LNG imports, in the model-based analysis we have assumed that LNG is mainly acting as a base load gas supplier, with a minimum level of gas supply at 90% of full export capacity in the reference scenario and 80% of full export capacity in an alternative scenario. Reasons for this approach were the following. Firstly, our model does not represent a world gas market where LNG shipments can go to the different international markets (the US, Asia and Europe). Secondly, investment in LNG facilities across the full LNG chain for only seasonal deliveries is not deemed to be financially viable, i.e. there should be some sort of sink for summer LNG. Thirdly, historic data on LNG supplies to northwest Europe does not show any seasonal pattern. When we would assume higher (seasonal) flexibility in LNG supplies to northwest Europe, this would improve the competitive position of LNG versus that of gas storage in providing seasonal swing and could lead to less investment in gas storage capacity in the future.

5. Conclusions

5.1 Continuing demand for seasonal gas deliveries

The basic need for gas markets to provide instruments that are able to deliver seasonal flexibility in gas supply follows from a seasonal pattern in gas demand. The seasonality in demand varies from sector to sector. Seasonality is the highest in the residential and services sector, and quite low in the industrial sector. Seasonality in gas demand in the electricity sector falls in-between the former two sector but is still relatively low. The need for instruments to accommodate seasonal variability varies across northwest European countries, because the larger the share of the residential and services sector in national gas demand, the relatively higher are flexibility requirements.

An analysis of seasonality in UK and Dutch gas demand in various sectors confirms the above statements. Gas demand in industry has been relatively stable whereas gas consumption in the electricity sector has been increasing in all countries, with the UK showing the largest increase in the last two decades. Gas demand in the residential sector has been slowly decreasing in the Netherlands in recent years due to market saturation in combination with savings in gas consumption, whereas residential gas demand in the other countries has been increasing at low to moderate levels. The potential increase in residential gas consumption in these countries could be subject to further study, especially as it may have an impact on the demand for flexibility in gas delivery. After all, the residential sector has the highest flexibility requirements when gas consumption is concerned. For the time period considered we have not found any evidence that the relative level of seasonality in the gas demand in the different sectors is changing over time: in fact it has been rather constant throughout the last two decades.

Projections for future gas demand vary from increasing gas demand in reference scenarios to decreasing gas demand in scenarios related to reaching of the EC's 2020 sustainability targets. Model-based analysis shows that demand for seasonal supply of gas to end-consumers will remain a high level, varying from about 92 billion m^3 in a reference scenario assuming business as usual conditions to 104 and 62 billion m^3 in respectively a high demand and a low demand scenario. The conclusions drawn in this study with respect to gas demand and the demand for seasonal gas deliveries are in line with the conclusions drawn in a previous study on seasonal storage by CIEP (2006): there is a continuing demand for instruments that can provide seasonal flexibility. However, the growth rate in demand for seasonal flexibility as estimated in this study falls within the lower range of estimates of the CIEP study. This is mainly due to downward revisions in total gas demand developments for so-called reference outlooks as published by the IEA and the EC.

5.2 Increasing role of storage in providing seasonal flexibility

A thorough assessment of IEA gas balance data leads us to conclude that the role of gas storage in providing seasonal flexibility to the northwest European market is becoming increasingly important. The main reason for this development is the decreasing capability of indigenous northwest European gas production to deliver seasonal flexibility. When gas fields reach depletion, which is the case for the UK on the short term and the Netherlands in the medium term, they also lose the capability to vary production from summer to winter.

The assessment of gas balance data over the last two decades shows indeed that the amount of seasonal flexibility delivered by gas production is declining, both in absolute and relative sense. Whereas seasonal variation in indigenous gas production covered over 60% of the total need for seasonal flexibility in the beginning of the 1990s, its share is now reduced to below 40%. At the same time, historical data analysis shows that gas imports via pipelines from Norway and Russia or via LNG tankers from Algeria and Egypt is not able to compensate for the decline in seasonal flexibility provided by indigenous production.[24] Economic considerations (e.g. capital intensity of gas transport) give rise to an almost base load infrastructure usage. However, due to its proximity to the northwest European gas market Norway seems to be able to deliver more seasonal flexibility in its exports than Russian and LNG exports to northwest Europe. LNG imports into northwest Europe are still a relatively small share of total gas supply but based on historical data on LNG flows we conclude that LNG is not structurally contributing to the provision of seasonal flexibility in northwest Europe.

We conclude that the decline in seasonal flexibility provided by indigenous gas production in the last two decades has been largely compensated for by (seasonal) gas storage. Total gas storage capacity in northwest Europe has hardly expanded in the last 5 years, the level of gas storage withdrawals during wintertime has been increasing for some time now, despite the fact that the last few winters were relatively mild to northwest European standards. The average use of available gas storage capacity has increased from about 40% in the early 1990s to about 60 to 70% in the last 5 years. The former study on seasonal gas storage by CIEP already signalled a significant increase in existing gas storage use, but whereas CIEP projected an increase in gas storage ratios for the last 5 years, the actual gas storage ratio has been more or less constant at about 65%. This can be explained by the relative mild winters over this same period.

5.3 Future developments in seasonal gas storage

A gas market model covering the whole European gas market was used to estimate the physical future need for seasonal gas storage. Using real cost data the market model determines the optimal mix of different alternatives for the provision of seasonal flexibility. Within a reference scenario based on business as usual conditions the model estimates a total need for additional gas storage capacity of about 17 billion m^3 in 2015. The main driver for the increase in required gas storage capacity is the decline in seasonal swing provided by indigenous production (i.e. the Netherlands and UK). The share of production in the overall provision of seasonal swing supply further decreases from the current 30-40% to about 5% in 2030. Imports provide only a very limited compensation for the decline in the share provided by indigenous production.

Confronting the estimated needs for gas storage capacity in the next 20 years with existing gas storage capacity, gas storage capacity under construction and planned gas storage investments we find that a substantial share of planned gas storage investments need to be realised for future gas storage requirements be met. In fact, it seems that at least 46% of planned investments need to come on stream in the next two decades. When gas demand and associated demand for seasonal flexibility in gas deliveries is much lower, for example as low as in a scenario where the EC´s 2020 sustainability targets are reached, we find that still current capacity combined with capacity under construction is not sufficient in meeting required gas storage capacity in the next two decades. On the other hand, realising all currently known gas storage investment plans would give rise to substantial more capacity than needed according to our model calculations, even in a high demand scenario that takes into account a 10% increase in total gas demand compared with the reference outlook.

[24] Technically speaking pipeline imports could provide high levels of seasonal flexibility but it is considered to be not economic, and in fact has not been observed in the past.

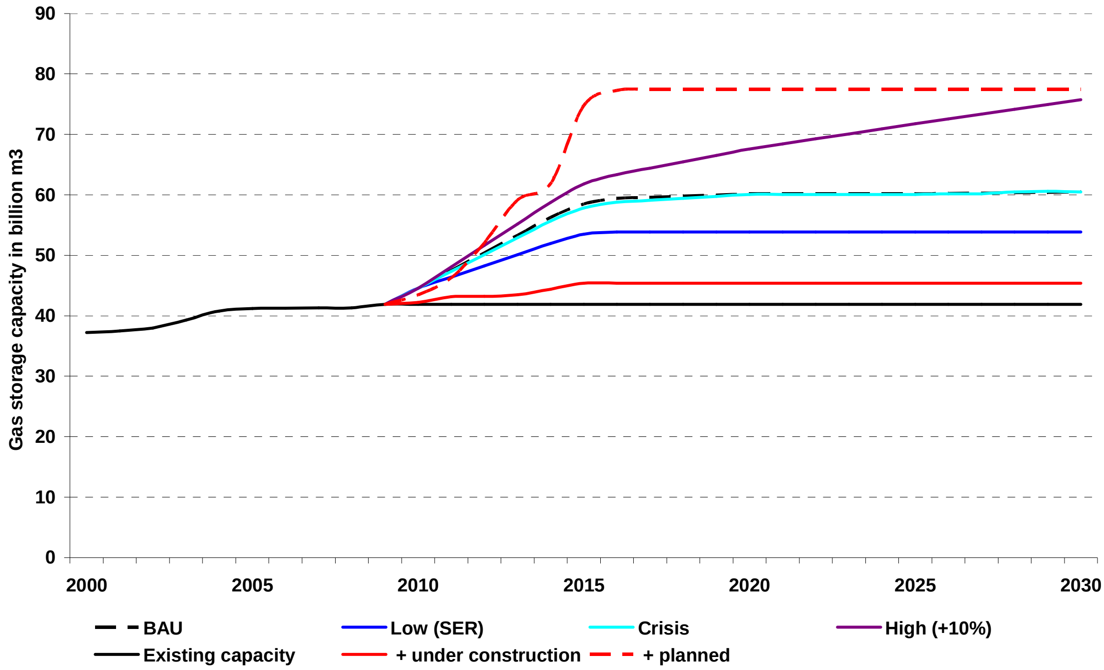


Figure 5.1 *Total gas storage capacity in northwest Europe: confrontations based on model-based scenarios and existing gas storage investment database*

Source: GSE, IGU.

The above conclusions are robust for variations in modelling assumptions with respect to the availability of alternative sources of seasonal flexibility. Either an extension in the ability of indigenous production to serve as a supply for seasonal flexibility over time or an increase in seasonal flexibility of LNG supplies to northwest Europe has relatively small impact on total gas storage requirements. The same holds for changes in the assumption with respect to gas infrastructure availability, although a more efficient and transparent use of existing gas pipelines does have a noticeable impact on gas storage requirements. Improved usage of the existing pipeline infrastructure reduces the need for additional gas storage facilities. More in general, improved market integration across Europe without persistent transport bottlenecks, and transparent and efficient infrastructure operation reduces the need for seasonal gas storage as existing storage capacity across Europe would be then used in a more efficient manner.

Future gas storage requirements were also estimated in CIEP (2006) but these are difficult to compare with estimates in this study since the geographical scope is somewhat different: OECD-Europe in the CIEP study versus northwest Europe in this study. However, we can state that future physical gas storage requirements estimated in this study are comparable to the lower end of the range of estimates provided in the CIEP study. This is explained by a downward revision of gas demand projections for the future.

5.4 Points for further discussion and research

A number of aspects are important to raise with respect to the outcomes of this study. This at the same time provides some interesting directions for future research efforts in the area of seasonal gas storage.

First of all, the future demand for seasonal flexibility could decrease if average temperature decrease over the long-term, making average winter conditions milder. The number of heating degree-days in winter in the last 18 years in northwest Europe has been decreasing. However, the considered time span does not warrant firm conclusions on the very long-term trend in average temperatures in northwest Europe. This would require substantial study that falls outside the scope of this study.

A second issue is the potential role of LNG as a source for seasonal flexibility in northwest Europe in the future. Although historical data does not provide proof of a structural role for LNG in supplying seasonal flexibility, there are two possible reasons why this could be different in the future. Firstly, the current overcapacity in re-gasification of LNG worldwide might induce different dynamics in LNG supply. From an investment perspective it would be difficult to see a profitable re-gasification project come off the ground based only on seasonal gas deliveries (e.g. partial load instead of near-base load), if that usage would imply such seasonality in the entire LNG chain. This fact could be somewhat obscured by the current overcapacity in re-gasification. Alternatively it has been argued that perhaps a structural overcapacity in re-gasification could facilitate a structural seasonal flexibility contribution by LNG, in view of a world-wide gas market. The argument then goes that there is a sink somewhere in the world for summer LNG, for example because there is a demand centre with relatively cheap gas storage operations in summertime (e.g. the United States) and as compared to the relatively expensive gas storage operations in Europe. This would be economically sound if the storage and transport differential together would be able to cover the investment costs due to overcapacity in re-gasification. As a matter of fact, some argue that this option is currently already played out, as a result of the oversupply of gas in the world. Both these issues could be addressed in a further study.

A third observation is that, given the nature of the tool used in this study, it has proven too difficult to in-depth explore the issue of gas storage required to accommodate ‘1-in-20 years winter demand’. As reference point in this study we have been able to calculate the optimal level of gas storage capacity for average winter demand conditions, corrected for a constant additional reserve margin of total storage capacity to accommodate more extreme winter demand conditions. The assumed reserve margin is based on historic gas storage capacity usage in northwest Europe and is as such a correct point for departure in this study, but in future research we need to consider the option that the implied reserve margin covering more extreme winter demand might be decreasing over time due to increased market integration and more efficient use of existing infrastructure capacity.

References

Boots, M.G., B.F. Hobbs, F.A.M. Rijkers (2004): *Trading in the downstream European gas market: a successive oligopoly approach*. The Energy Journal, 25(3):73-102.

CIEP (2006): *The European market for seasonal storage*. Clingendael International Energy Programme (CIEP) discussion paper, February 2006.

Codognet, M.K., and J.M. Glachant (2008): *Weak investment incentives in new gas storage in the United Kingdom?* Working paper available at: http://www.grjm.net/documents/M-K-Codognet/CodognetGlachantUKstorage.pdf.

European Commission (EC) (2007): *DG Competition report on energy sector inquiry*, Brussels, SEC(2006) 1724, 10 January 2007.

European Commission (EC) (2008a): *European energy and transport: Trends to 2030 - Update 2007*. Directorate-General for Energy and Transport. April 2008, Brussels.

European Commission (EC) (2008b): *Commission staff working document accompanying the communication from the commission to the European parliament, the council, the European economic and social committee of the regions on the Second Strategic Energy Review: An EU energy security and solidarity action plan. Europe's current and future energy position.* SEC(2008) 2871, November 2008, Brussels.

European Commission (EC) (2009): *Q&A: the infringement exercise concerning cross-border energy network access and regulated prices*, MEMO/09/297.

Eurostat (2007): *Panorama of energy: Energy statistics to support EU policies and solutions, 2007 edition*, ISBN 92-79-03894-X.

Höffler, F. and M. Kübler (2007): *Demand for storage of natural gas in northwest Europe: Trends 2005-2030*. Energy Policy 35, pp. 5206-5219.

IEA (2008a): *International Gas Information 2008*, IEA: Paris.

IEA (2008b): *World Energy Outlook 2008*, IEA: Paris.

IGU (2006): *Gas storage data*, World Gas Conference 2006.

Joode, J. de and F. Touber (2008): *Verkenning naar de voorzienings- en leveringszekerheid van de Nederlandse gasvoorziening in de periode tot 2020*. ECN report, ECN-E--08-049.

Lise, W. and B.F. Hobbs (2008): *Future evolution of the liberalised European gas market: Simulation results with a dynamic model*. Energy 33, pp. 989-1004.

Lise, W., B.F. Hobbs, F. van Oostvoorn (2008): *Natural gas corridors between the EU and its main suppliers: Simulation results with the dynamic GASTALE model*. Energy Policy 36: 1890-1906.

Lise, W., J. de Joode, and M. Boots (2005): *Druk in de gasleiding*, Second edition, ECN report, ECN-C--05-098 (in Dutch).

Oostvoorn, F. van, and W. Lise (2007): *Analysis and assessment of the optimal gas corridors and infrastructure to secure supply. A model based analysis*. ECN report: ECN-E-07-024.

Rambol (2008): *Study on natural gas storage in the EU*. Final report. Prepared for DG-Tren. October 2008.

Tönjes, C. (2005): *Gas to power in Europe*. IGU/EDI/CIEP Discussion paper. April 2005.

Appendix A Model parameters

A.1 Gas demand parameters

Table A.1 *Flexibility in gas demand per sector and season for a selection of northwest European countries*

Sector	Season	Country				
		Belgium	Germany	France	Netherlands	UK
Industry	low	0.95	0.95	1	0.95	0.95
	medium	1	1	1	1	1
	high	1.1	1.1	1	1.1	1.1
Power generation	low	0.93	0.93	1	0.93	0.93
	medium	1.04	1.04	1	1.04	1.04
	high	1.14	1.14	1	1.14	1.14
Residential	low	0.36	0.31	0.28	0.39	0.34
	medium	1.45	1.47	1.52	1.41	1.42
	high	2.04	2.13	2.12	2.02	2.13

A.2 Cost data

Table A.2 *Overview of long run gas storage cost data used in Gastale*

Gastale region	Typical storage costs [€ / m^3]
Balkan region	0.035
Baltic states	0.035
Belgium	0.034
Central Europe	0.035
Germany & Denmark	0.032
France	0.034
Iberian peninsula	0.044
Italy and Alpine region	0.040
Netherlands	0.030
Poland	0.035
Turkey	0.035
UK & Ireland	0.034

Table A.2 gives the aggregated cost of bring LNG from the producer region to the consuming region. This total cost includes liquefaction, transport and re-gasification but excludes the cost of producing at the gas field.

Table A.3 *Overview of total LNG long run operational cost data used in Gastale [in € per m^3]*

Consuming region	Producing region						
	Algeria	Egypt	Libya	Nigeria	Norway	Qatar	Russia
Balkan region	0.057	0.056	0.056	0.066	0.077	0.064	0.079
Belgium	0.059	0.068	0.062	0.068	0.062	0.076	0.065
France	0.057	0.066	0.060	0.066	0.064	0.074	0.066
Iberian peninsula	0.053	0.062	0.056	0.062	0.068	0.070	0.071
Italy and Alpine region	0.054	0.060	0.056	0.063	0.074	0.068	0.076
Turkey	0.059	0.055	0.056	0.068	0.079	0.063	0.081
UK & Ireland	0.058	0.067	0.062	0.068	0.063	0.076	0.065