Clingendael International Energy Programme

Seasonal Flexibility in the Northwest European Gas Market

An Outlook for 2015 and 2020

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Nederlands Instituut voor Internationale Betrekkingen
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Clingendael

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Summary and conclusions

As a sequel to a discussion paper on the European Market for Seasonal Storage, published by the Clingendael International Energy Programme in 2006[1], a review of the future need for seasonal flexibility has been prepared. This new review focuses specifically on the operational aspect of security of supply for the Northwest European market and addresses the question:

“Will Northwest Europe have sufficient supply capacity to meet the cumulative demand over a severe winter in 2020?”

There are various reasons for addressing this question. In the first place we have seen a decline in flexible indigenous production: today, the Groningen field is the last field in Northwest Europe to offer more than standard production flexibility, and its flexibility is in decline. Secondly, Europe is increasingly dependent on imports of gas from remote locations; economics dictate that production and transportation from these sources should be carried out with low flexibility. Finally, in a competitive, liberalised market, market players will make provisions for flexibility on the basis of commercial criteria and not necessarily to ensure supply under all circumstances, unless of course there are contractual or legal requirements.

Apart from the recent EU regulation 994/2010 on security of gas supply[2], there are no common criteria or obligations for market players or TSOs to cater to security of supply under severe winter conditions. In a competitive market, supply provisions which are called upon only very occasionally are expensive and affect the cost-competitive positions of the players. It can therefore not be taken for granted that sufficient supplies will be available for all gas users under every conceivable demand condition. For our study we have chosen the criterion of a 1-in-20-years winter as the benchmark for assessing supply availability.

This study does not deal with the question of supply security in the case of supply interruptions, nor does it consider the outlook for the long-term availability of gas. It focuses on the availability of sufficient sources to supply the cumulative volumes of gas needed over a cold winter above the base load deliveries from indigenous and foreign producers. In doing so, it does not examine the adequacy of the “send-out” capacity of these sources to meet demand on any single day. This would require a more local and detailed study. Also, it assumes that the Northwest European market can be supplied from all identified sources without any limitations on the transportation of the gas.

In spite of this clear and narrow scope of the study, many other assumptions had to be made which affect the study’s outcome. Particularly the outlook for gas demand remains very uncertain. Therefore, two demand scenarios were used to describe the range of potential demand and its impact on security of supply: a Baseline Scenario, which represents a steady growth in gas demand and a New Policy Scenario, in which the role of gas is significantly reduced over the next decade.

Supply contributions to satisfy winter demand may come from storages but also from indigenous producing fields, supply contracts with producers abroad and from short-term supply sources, notably the international LNG market. To compare the potential contribution from all these sources with the demand for gas in any winter, we have developed a common standard of supply

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[1] Clingendael International Energy Programme (February 2006), “The European Market for Seasonal Storage”, *Discussion Paper*, <http://www.clingendael.nl/publications/2005/20050800_ciep_misc_gas_storage.pdf>.

[2] Regulation No 994/2010 of the European Parliament and of the Council of 20 October 2010 concerning measures to safeguard security of gas supply and repealing Council Directive 2004/67/EC, <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:295:FULL:EN:PDF>.

capacity. When referring to an underground storage facility we use the term “Working Volume” (WV) to mean its aggregate volumetric capacity to supply gas to meet winter demand. Similarly, we have expressed the capability of other supply sources to offer higher volumes in winter as if these also were provided from an imaginary underground storage facility. For this purpose we use the term “Working Volume Equivalent” (WVE). By also formulating the extra market demand in winter in terms of WVEs, we can compare the cumulative demand for gas over a 1-in-20 winter with the availability of aggregate supplies in such a winter.

The result of our analysis is that the current outlook for the supply of gas in Northwest Europe under serious winter conditions does not give rise to major concerns. This conclusion is supported by two developments which were not part of the 2006 study:

- The inclusion of caverns in this study reflecting the growing share of this type of storage in the market. Though they may not be the most economical option for seasonal supplies, they can be used for this purpose.

- A new aspect with regard to security of supply is the changing role of LNG. In the recent past, particularly in the Atlantic Basin, large volumes of new LNG have no longer been committed to single destinations and have been able to be directed to any local market of interest. The availability of excess regasification capacity in Northwest Europe therefore offers a plausible outlet for additional short-term sales of LNG into Northwest Europe, particularly during a cold winter

For the Baseline Scenario and similar demand scenarios, storage options in addition to those currently under construction will need to be developed, but LNG may also have to play a role as a potential source for seasonal supply. At least the additional contribution from the planned expansions and/or planned new storages will need to materialize.

A 1-in-20 winter is obviously not the coldest winter conceivable for Northwest Europe. The winter of 1963 offers a reminder of more severe conditions than those covered by the 1-in-20 supply options. Such a winter would call for significant additional measures.

Recent EU regulation 994/2010 for security of supply sets out (winter) supply criteria for 1-in-20 year conditions. Although the regulation addresses some aspects of winter volume requirements, the 1-in-20 winter volume conditions on which the analysis of this paper is based are the more demanding of the two.

While storage certainly continues to have an anchor role in catering for winter demand, new alternatives are being considered by market parties to provide gas for their customers, including winter supplies, like purchases on the spot market or LNG markets. It implies that they may decide to invest in extra pipeline, storage and/or regasification capacity to be able to arrange for cost-effective supplies from a portfolio of choice whenever the market calls. Each option carries its own cost and risk profile.

For market players, creating such options is an effective way to deal with the uncertainties and opportunities inherent to operating in a competitive gas market. The “by-product” can be more security in a cold winter.

Encouraging and facilitating such investments in supply options will not only help to create the business environment needed by industry to position itself competitively in the market but will also offer the best prospects for added security to consumers in a liberalised market.

1

Introduction

Objective

In 2006, the Clingendael International Energy Programme published a discussion paper on the European Market for Seasonal Storage[3]. The paper analyzed the means to balance seasonal differences between summer and winter demand and made projections for the future. It warned that investments in (seasonal) storage were lagging against the backdrop of a decline in European production flexibility.

Since then, the European business environment has developed further and new investments in storage have been made, particularly in caverns. LNG has become a more prominent supply source, with its own dynamics. Moreover, the economic recession has substantially changed the demand for gas. Today, the markets are oversupplied. Furthermore, uncertainties about new environmental measures loom above the EU energy market and hence the gas demand outlook.

These changing circumstances have given rise to a review of the future need to meet seasonal flexibility of gas demand. This new review focuses on the Northwest European market, including Germany, France, Denmark, the UK and Ireland, and the Benelux countries. These countries are well interconnected, not only through the transit pipeline systems but also institutionally, commercially and politically.

There are many uncertainties surrounding the question of how much gas storage will be needed in the future. Market players may decide to build and use storage for commercial and/or strategic reasons. In the current business environment, such storage facilities can play an important role in capturing and maximizing rents from the supply and trading opportunities. Indeed, some storage is constructed with the capacity to turn around their working volume several times per year. This paper does not enter this domain. It aims at addressing the following question:

“Will Northwest Europe have sufficient supply capacity to meet the cumulative demand over a severe winter in 2020?”

This evaluation is therefore strictly focused on the future ability of the gas industry in Northwest Europe to physically meet the demand for gas volumes in a serious winter under normal operating conditions in 2015 and 2020. It does not examine the adequacy of “send-out” capacity of the sources of gas supply to meet demand on any single day, nor does it deal with the requirements of operational flexibility and the liquidity of market players in a well-functioning competitive gas market, nor with the notional creation of “strategic” gas storages to mitigate the impact of a politically, economically or technically triggered interruption of supply.

Approach

Not surprisingly, the ability of the market in Northwest Europe to meet demand in a cold winter in 2015 and 2020 is primarily dependent on:

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[3] Clingendael International Energy Programme (February 2006), “The European Market for Seasonal Storage”, *Discussion Paper*, <http://www.clingendael.nl/publications/2005/20050800_ciep_misc_gas_storage.pdf>.

- the annual gas demand in 2015 and 2020,
- the impact of a cold winter on demand,
- the availability and flexibility of gas supply sources in 2015 and 2020, and particularly
- the available storage capacity in 2015 and 2020.

Gas demand projections for 2020 vary widely. For this study, we use two scenarios which form an envelope around the full range of demand projections currently available.

Based on a 6-month winter period, winter demand has been estimated for each market sector: residential, industry and power generation. Not surprisingly, the residential sector has the highest additional winter demand.

The study has addressed the outlook for indigenous Northwest European production and its ability to offer winter capacity, as well as the supply outlook from Norway and Russia. The data used for the study were collected from a variety of sources, all in the public domain. Reflections on future developments are based on our analysis, unless stated otherwise.

With regard to storage, the study also includes the working volume of caverns. Though not necessarily the most economical source of seasonal storage, caverns have a contribution to make in meeting winter demand.

The size of spot markets in Northwest Europe in 2020 will not play a role in this study. Spot markets offer a platform to balance supply and demand, but they do not generate additional supplies. To evaluate the potential of physical gas supply, we will examine the gas production in Northwest Europe and gas imports from external sources.

Supply contributions to satisfy winter demand may come from storages but also from indigenous producing fields, supply contracts with producers abroad and from short-term supply sources, notably the international LNG market. We took an approach under which we compared the cumulative demand for gas in a 1-in-20 winter with the total availability of supplies in such a winter, by expressing both amounts in terms of Working Volume Equivalent (WVE). The capacity of all the different sources to contribute gas volumes to winter demand has thus been converted to one standard measure, as if all this gas would have to be stored as working volume in an imaginary storage facility. For storage this term is straightforward. Similarly, winter flexibility of gas supplies by pipelines and LNG offers an alternative to supply from storage and can be expressed in WVE terms. For demand, WVE represents the cumulative additional volume of gas required in winter, as compared to 50% of annual demand; i.e., if all gas were consumed throughout the year without any (seasonal) flexibility.

A new element in this study is the role of LNG. The dynamics of LNG supply have changed considerably over the past five years, particularly in the Atlantic Basin. As a result, large volumes of new LNG are no longer committed to a single destination and can be directed to any market of interest. With the emergence of unconventional gas, the US market is likely to have less appetite for LNG than previously foreseen. The availability of excess regasification capacity in Northwest Europe will therefore offer a plausible outlet for additional short-term sales of LNG into Northwest Europe, particularly in a cold winter.

The specific focus of the approach to operational security of supply, i.e. the ability of the market to meet demand in a cold winter, did not preclude that a set of assumptions had to be made. To the extent that these affect the conclusions, their potential impact has been addressed in this paper.

2

Winter demand

2.1 Annual demand scenarios for 2015 and 2020

The starting point in establishing the flexibility requirements of the gas market lies in the outlook for future annual demand. However, gas demand projections for the European market in 2020 vary significantly. This is mainly caused by uncertainty about the growth of gas-fired power generation and the impact of environmental policy measures. The effect of the recession has also led to changes in the demand outlook.

For this study we have used the Primes New Energy Policy Scenario 2008 and the Primes Baseline Scenario 2007 as the basis for our analysis[4]. More recent scenarios show different projections of future demand, based on new assumptions of prices, economic growth and impact of policies. As shown in Figure 1, the two scenarios which we have chosen for this study span the wide range of uncertainty in future projections for 2015 and 2020.

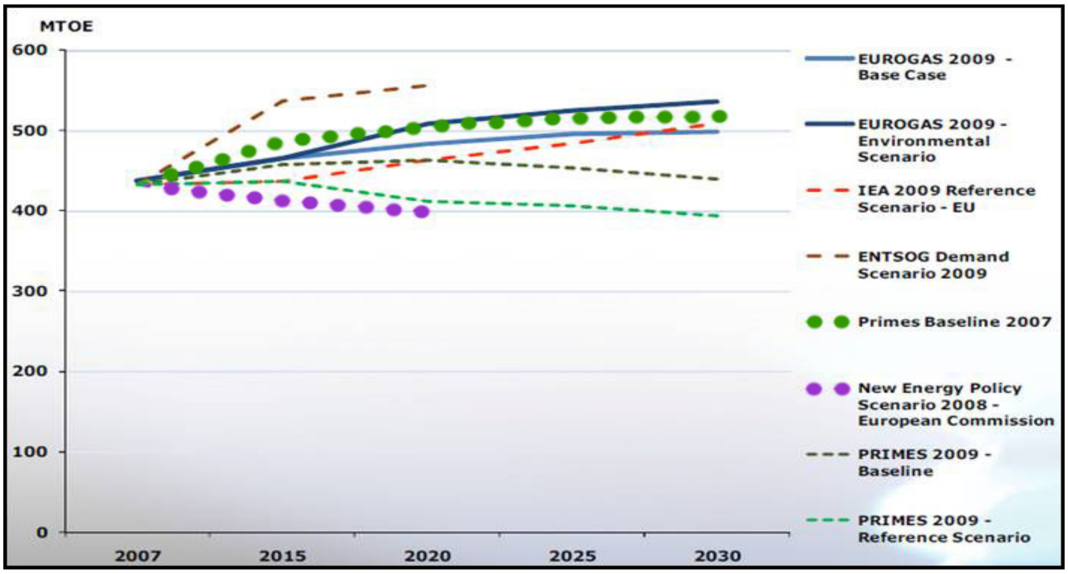

Figure 1. EU-27 Demand scenarios. Source: Eurogas (2010).

The Primes scenarios contain data per country and per sector and thus can be used for a regional and bottom-up analysis. As our study focuses on Northwest Europe, including Germany, France, the Benelux countries, Denmark and the UK and Ireland, annual demand ranges for the three sectors in Northwest Europe were derived for both scenarios as shown in Table 1. From here forward we shall refer to these scenarios as the “Baseline Scenario” and the “New Policy Scenario”.

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[4] See for further information: <http://ec.europa.eu/energy/strategies/2008/doc/2008_11_ser2/strategic_energy_review_wd_future_position2.pdf> Annex 1.

Annual Demand		**2015**		**2020**
In bcm(39MJ/Nm3 GCV) [5]	Baseline 2007	New Policy 2008	Baseline 2007	New Policy 2008
Residential Sector	149	126	150	112
Industrial Sector	66	63	63	55
Power Sector	101	69	111	60
Total	**316**	**259**	**324**	**227**

Table 1. Baseline and New Policy Scenario: annual demand per sector.

2.2 Winter flexibility required for 2015 and 2020

2.2.1 Introduction to WVE

During the winter, gas demand in Northwest Europe is higher than in summer. This requires additional gas supply to the market in the winter, which can be realised either by means of flexibility from indigenous production, pipeline and LNG imports or by the use of storage.

In order to express the need for higher winter flexibility in terms of volume, we first assume that all supplies are delivered at a flat rate and all additional winter volumes needed in the market will have to come from storage. On the basis of this we can express the required winter flexibility in terms of working volume from such a notional UGS (Underground Gas Storage) facility (working volume is defined as the amount of gas that can be held in and supplied from storage during normal operation[6]). This “working volume equivalent” (WVE) will be defined as:

$$\frac{winter\ demand\ -\ summer\ demand}{2}$$

For the purpose of this definition, “winter” represents the 6-month period from October to March, while “summer” covers the period from April to September. The flexibility needed can also be expressed as a WVE ratio: as a percentage of the annual demand. For example, in a market with an annual demand of 40 bcm, of which 10 bcm is required in summer and 30 bcm in winter, the WVE needed is (30-10)/2 = 10 bcm. The WVE ratio of this market is 10/40 x 100%= 25%. If the demand of this market rises to 50 bcm and the WVE ratio remains constant, the WVE requirement rises to 12.5 bcm. The WVE ratio characterises the flexibility needs of a market, or more specifically, of a particular market segment. The residential market has a very different WVE ratio from the industrial market or the power generation market.

In the following paragraphs, the required WVE will be calculated for both an average winter and a severe winter for the residential, industrial and power sectors. As far as sufficient data are available, these WVEs will be assessed for Germany, the UK, France and the Netherlands. These countries together represent a share of about 90% of the consumption in each of the three sectors in the Northwest European market[7].

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[5] In this paper, except where stated otherwise, all gas volumes are expressed in billion cubic metres with a gross calorific value of 39 megajoules per normal cubic metre (39MJ/Nm3 GCV). For example, Eurogas uses this standard in its publications. Since different information sources express cubic metres in different calorific values, we have converted these different cubic metres of gas to this standard. See for further information on the different calorific values of different supply sources: IEA (2005), ‘Energy Statistics Manual’, <http://www.iea.org/textbase/nppdf/free/2005/statistics_manual.pdf>

[6] See: CIEP (February 2006), “The European market for seasonal storage”, *Discussion Paper.*

[7] IEA (2009), Natural gas information.

To assess the WVE requirement for a severe winter, we define this as a winter that occurs statistically once every 20 years. The statistical probability of 1-in-20 years has become a norm which is often referred to in the public domain, including in EU documents, such as the new security of gas supply regulation 994/2010 repealing directive 2004/67/EC. Nevertheless, we have not found any prescription or criteria for its quantification. Neither the EU institutions nor the industry or individual countries have provided guidelines for the calculation of a 1-in-20 winter. We have therefore developed our own approach for defining such a severe winter.

2.2.2 Residential sector

Average winter

The residential sector has the largest seasonality requirement. This is a consequence of the fact that in most of Northwest Europe, houses are generally heated with natural gas. It is only in France that electric heating plays an important role, due to its nuclear power plants. We have employed 3 alternative methods to establish the WVE ratios for residential demand in the Netherlands. As is reported in Box 1, these methods resulted in WVE ratios between 24% and 28%.

Box 1: Methods used to determine the WVE for the Dutch residential sector in an average winter.

Method 1:
Based on the historical distribution of 'heating degree days' over the year.

Typically, the consumption of gas for space heating takes off below a threshold temperature of about 18°C. Furthermore, this gas consumption linearly follows the difference between actual temperature[8] and the threshold temperature. Thus, for example, a day with an average temperature of -2°C (20°C below 18°C) requires twice as much gas as a day with a temperature of 8°C (10°C below 18°C). *Heating degree days* are defined as the differences between actual average daily temperature and the threshold temperature. Under the above example, a day with an average actual temperature of -2°C has (18 minus -2=) 20 heating degree days. If the next day has an actual temperature of 8°C, it has (18 minus 8 =) 10 heating degree days. Together these two days represent (20+10=) 30 heating degree days. In this manner total winter heating degree days (the sum of heating degree days for 182 days, the "winter" period, as defined in this paper) and annual heating degree days (the sum of heating degree days over a full year) can be established.

Figure A illustrates the variation in total winter heating degree days in the Netherlands between October and March over the past 30 years. It shows that the cold winters of 1985/1986 and 1995/1996 have about 2600 heating degree days. The average over this period is 2247, represented by the blue dotted line.

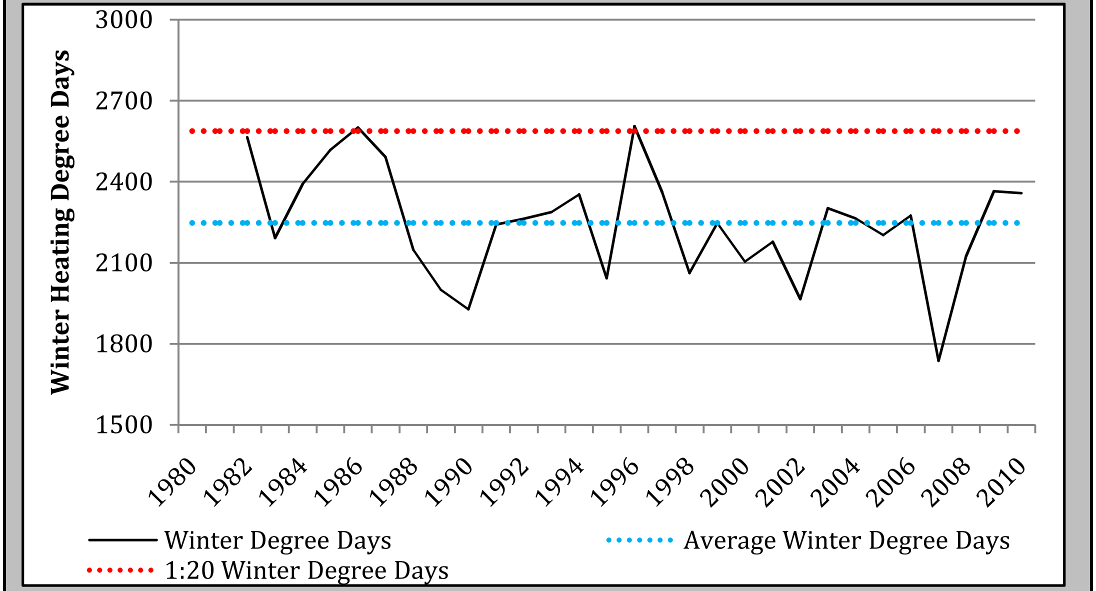

Figure A. Variation of winter heating degree days in the Netherlands.

The average number of annual heating degree days in the Netherlands over the same period is 2887. Thus, the average number of heating degree days per day is (2887/365=) 7.91. This average can be seen as the equivalent to base-load gas consumption. In winter, this 'base load' provides for 1440 (182x7.91) heating degree days. Given the winter average of 2247 heating degree days, this leaves an additional (2247-1440=) 807 degree days volume equivalent to be provided in an average winter. The WVE ratio for the residential sector for an average winter is therefore (807/2887=) 28% of the annual gas demand for space heating.

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[8] It should be noted that the temperatures used in this method are not corrected for wind chill.

Method 2:
By using a model that predicts residential gas demand based on temperature and the time of the year.

An alternative approach may be derived from a historically calibrated model for residential and commercial gas demand that predicts hourly demand based on the outside temperature and the time of day. The model was developed by 'Platform Versnelling Energieliberalisatie', a Dutch platform for enhancing competition in the energy markets, to enable allocation at the local distribution points in cases where there are several suppliers at such points. For this purpose, the model describes in detail the relationship between the effective temperature and individual consumption among specific classes of small consumers, both residential and commercial. The dependence of gas demand on effective temperature at an hourly level is estimated using a linear fit on data from the preceding three years[9]. The resulting model thus gives an estimated gas demand for any given set of effective temperatures. For this paper, a "normal year" was constructed using data of the past 30 years to deduce average winter demand. The model confirms a WVE ratio of 28% of annual gas demand for the residential sector, supporting the assumption that the WVE for the residential sector is by and large determined by the winter heating degree days used in Method 1.

Method 3:
By averaging the historical swing in demand.

A third approach uses monthly statistics for the Dutch gas demand. From these statistics the summer/winter consumption profile can be established for any year for which these statistics are kept and hence also the WVE requirement and the WVE ratio for that year. By averaging the WVE ratios (= ratio of WVE over annual demand) of all winters over the period 1995-2009, an average WVE has been calculated. As such, this method provides the most direct indication of the WVE ratio, as the ratio is determined by calculating the WVE ratio directly from the consumption data. The drawback of the method, as compared to the two methods described above, is that data is only available for the period 1995 to 2009. The resulting average WVE ratio is 24%, which is somewhat lower than the result of the two other methods. This may indicate that the first two methods produce conservative estimates. In fact, a very plausible explanation is that winters in the period 1995 to 2009 were mild and below average. This is confirmed by Figure A.

Due to a lack of data from other countries, we were not able to use Methods 1 and 2 described in Box 1 to calculate the WVE ratio for the residential sectors of the other Northwest European countries. Applying Method 3 to data about France over the period 1995-2009 and to the UK over the period 1998-2009, WVE ratios of respectively 27% and 23.5% were found[10].

No exact data are available for Germany, so none of the three methods could be used to establish a WVE ratio for an average winter in Germany. However, there is no reason to assume that a pattern of German residential demand would be very different from that of other Northwest European countries.

The WVE ratio of 28% for an average winter in the Netherlands, as calculated with Method 1 and Method 2, is higher than the WVE ratios estimated for the other Northwest European countries. A blanket WVE ratio of 28% of annual demand for an average winter in the residential sector,

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[9] The limitation to three years stems from what is perceived to be a manageable size of data sets as well as the desire to account for possible structural changes.

[10] For France, calculations are based on monthly data from "le service Statistique du ministère de l'Écologie, de l'Énergie, du Développement durable et de la Mer (SEEDM) and for the UK on quarterly data from the UK Department of Energy and Climate Change (DECC).

applied for all of Northwest Europe, would therefore represent a robust, albeit probably conservative assumption.

1-in-20 winter

The average winter volume requirements of the residential sector have been assessed empirically for the Netherlands, and a WVE ratio of 28% has been chosen. For a 1-in-20 winter the WVE ratio as a percentage of the residential annual demand has been estimated at 40% – this being 42% higher than the volume requirement for an average winter (see Box 2 below). The impact of a winter more severe than 1-in-20 winter will be discussed in Chapter 5.

Box 2: Establishing the 1-in-20 WVE demand from the distribution of heating degree days in a year with a 1-in-20 winter.

Here again, our starting point is Figure A above (see also Box 1), which illustrates the distribution of heating degree days in the Netherlands in the winter season for nearly the last 30 years. It was deduced that the average number of winter heating degree days is 2247.

A statistical approach to determine the impact of a 1-in-20 winter could be as follows. The amount of winter heating degree days varies with a standard deviation of 207. Assuming a normal distribution and a 5% chance of a 1-in-20 winter – equal to a standard deviation multiplier of 1.645 – the number of heating degree days in a 1-in-20 winter would be equal to 2247+1.645x207 = 2588. This is represented by the red dotted line in Figure A.

Actually, in the 30 years shown in Figure A, there were two severe winters with more heating degree days than the level of 2588: 1985/1986 (2600) and 1995/1996 (2605). In this regard, a rounded choice of 2600 winter degree days for a 1-in-20 winter seems appropriate. Given an average of annual heating degree days of 2887 (see also Method 1 in Box 1), and hence a winter ‘base load’ of 1440, the 1-in-20 winter demand of 2600 heating degree days leaves an additional (2600-1440=) 1160 degree days volume equivalent to be provided in a 1-in-20 winter. This equals a WVE requirement of around 40% (1160/2887x100%), i.e. the amount of supplies required for a 1-in-20 winter is about 40% of the annual demand for space heating. This is 42% higher than the extra requirement in a normal winter (28%).

Trend analysis: Factors affecting future seasonality of gas demand

The future need for seasonal flexibility may be influenced by a number of technological, environmental or political developments. In the residential sector, saving energy – notably through the insulation of dwellings and the switch to high-efficiency boilers – not only reduces annual demand but could also have an impact on the seasonal swing of that demand. In this respect, two counteracting effects have been identified. The first effect is that the ambient temperature at which heating starts to be required will be lower. This shortens the heating season and increases the relative WVE. The second effect is the reduction in temperature-dependent gas use. This effect is most significant in the heating season and therefore leads to a decrease in the relative WVE. The exact quantification of these effects would require more study. For this report we have assumed that these two effects cancel each other out.

Resulting WVE estimates for the residential sector in Northwest Europe

For the analysis of the WVE requirement in 2015 and 2020 (section 2.3), we assume that the situation in the Netherlands is characteristic for the average of winter demand in Northwest Europe (see paragraph 2.1.1). Consequently, to calculate the working volume requirements we will apply WVE ratios of 28% for an average winter and 40% for a 1-in-20 winter to the 2015 and 2020 annual demand projections for the residential sector in Northwest Europe.

2.2.3 Industrial sector

The seasonality of gas demand in the industrial sector is much lower than in the residential sector. A large portion of industrial demand is related to processes which are not dependent on variations in the outside temperature. Any seasonal pattern is a result of the heating of industrial buildings in winter, the shorter winter holiday period, and production processes which are related to a particular season, like sugar manufacturing.

Average winter

Analysis of the data on the basis of Method 3 has yielded significant differences in the WVE ratios between countries. For the Netherlands the ratio is equal to 3%, for the UK it is 10%[11], for France 8.5%[12] and for Germany it is estimated to be in the order of 10% as well. Analysis of these figures on a country-by-country basis is not available. In the absence of a detailed evaluation of the background to these figures, a WVE ratio of 10% will be used for all of Northwest Europe for an average winter. This represents the upper end for seasonal swing in this sector.

1-in-20 winter

The impact of a 1-in-20 winter is considered to be less strong for industry than for the residential sector, given the lower seasonal dependency of demand, but it still needs to be taken into account. In the absence of any further guidance from existing industry data, we assume that a 1-in-20 winter will result in additional demand of 25% relative to an average winter for all markets, leading to a WVE ratio of 12.5%.

2.2.4 Power sector

Average winter

As Figure 2 below shows, the WVE ratio for the power sector varies significantly between countries (i.e. Germany 9.5%, the Netherlands 4%, the UK 1% and France 8.5%). In part, this reflects the different roles of electricity in the energy systems of these countries. For example, France has the highest “swing” in power consumption, as electricity is used for residential heating more than in the other countries. It also reflects the difference in composition and size of the fuel mix in power production, the market structure of the sector, and last but not least the different gas and power pricing regimes of the UK and continental markets.

It is worth noting that in contrast to the continental countries, gas-fired power generation in the UK consistently shows a lower WVE ratio for gas, relative to the swing in total national power consumption. This is caused by the fact that lower gas prices in summer stimulate the use of gas, leading to a more balanced contribution of gas-fired power generation throughout the year.

Nevertheless, none of the historical analyses of the swing of this sector offer a sufficiently robust basis for projections for the future. Therefore, a conservative WVE demand ratio of 10% for the power sector across Northwest Europe will be used in this study.

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[11] The Dutch “Centraal Bureau voor de Statistiek” and UK DECC.

[12] This figure represents the WVE demand ratio for the industrial and power sector.

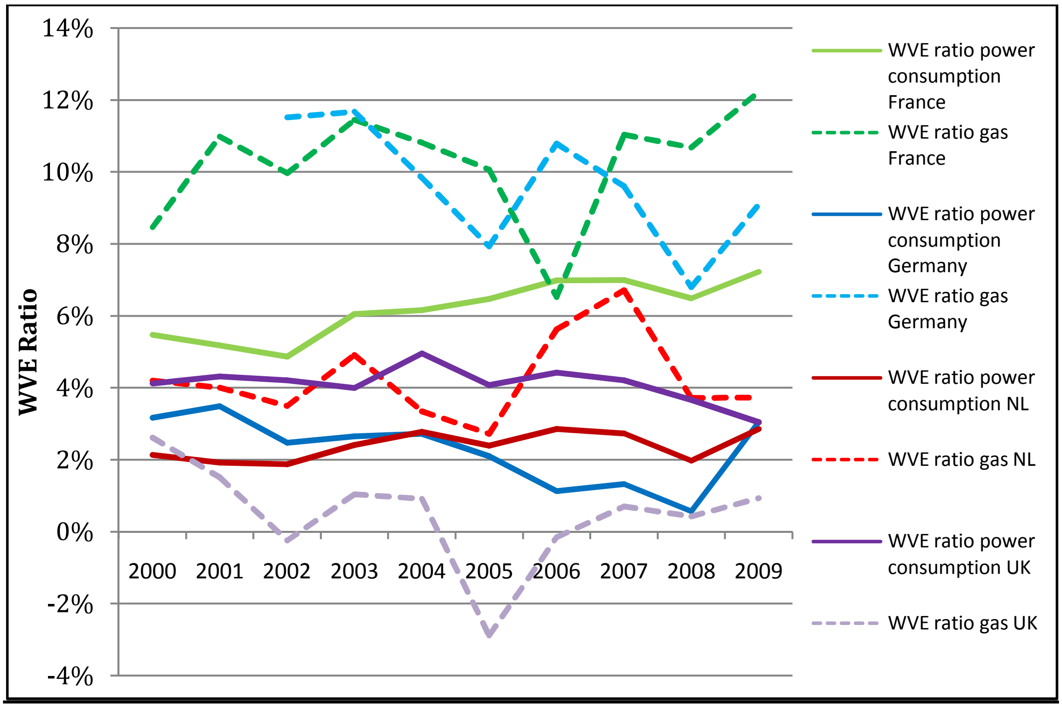

Figure 2. WVE ratios for gas consumption in the power sector compared to the WVE ratios for the power consumption. The WVE ratio for power consumption represents the difference in power consumption between winter and summer divided by 2 as a percentage of annual power consumption. Sources: IEA, UK DECC, CBS, Statistisches Bundesambt Deutschland, SEEDM.

1-in-20 winter

As for the industry sector, very little is known about the possible effect of a severe winter on its consumption. Arguably, as in the industry sector, demand in this sector is only partially affected by temperature. However, given the observation (see below) that the contribution from wind energy in a severe winter is lower than average, while the demand for fossil-based power will be higher, we foresee a higher incremental demand than for the industry sector. Therefore, we assume that a severe winter will result in additional 42% in gas demand relative to an average winter – similar to that in the residential market – resulting in a WVE ratio requirement of 14.2% for a 1-in-20 winter.

Trend analysis: Impact of wind power

The growing contribution of intermittent wind energy in power generation could have an impact on power sector gas demand for seasonal flexibility. Winds are *on average* stronger in winter than in summer. As wind energy becomes a larger part of the fuel mix, its contribution to winter demand will grow and lower contributions will be required from other sources, among which gas, to accommodate the sector's higher winter demand. So, theoretically, an increase in wind energy could partly offset winter gas demand. However, since it is highly uncertain as to how much wind capacity will be installed in the future and which fuels will be pushed out of the (local) merit order by wind in the winter, the WVE ratios of 10% of annual demand by the power sector for an average winter and 14.2% for a 1-in-20 winter have not been lowered in our base case analysis. With respect to the 1-in-20 winter, this approach is supported by the observation that a limited or even inverse correlation exists between a severe winter and the contribution of wind energy[13]. The effect of wind will be further discussed in Chapter 5 as sensitivity surrounding the base case.

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[13] National Grid (June 2009), "Operating the Electricity Transmission Networks in 2020".

2.2.5 WVE ratios of annual demand for 2015 and 2020

In sum, there are limited data and even fewer analyses available on the flexibility requirements of the three sectors in either an average or a 1-in-20 winter. Based on straightforward statistical analysis from the data, the future WVE ratios have been estimated for each sector for an average and for a 1-in-20 winter, as shown in the table below.

WVE ratios	Average winter	1-in-20 winter
Residential Sector	28%	40%
Industrial Sector	10%	12.5%
Power Sector	10%	14.2%

Table 2. WVE ratios per sector employed for this study.

2.3 WVE required for 2015 and 2020[14]

2.3.1 An average winter

Applying the WVE demand ratios for an average winter, as derived in section 2.2.5, to the annual demand of the Baseline and New Policy Scenarios of 2.1, the resulting WVE requirement for an average winter is shown per sector in Table 3 below. The total WVE requirement lies between 49-58 bcm in 2015 and 43-59 bcm in 2020, depending on the demand scenario.

WVE Requirement Average Winter		2015		2020
In bcm	Baseline	New Policy	Baseline	New Policy
Residential Sector	42	35	42	31
Industrial Sector	7	6	6	6
Power Sector	10	7	11	6
Total	**58**	**49**	**59**	**43**

Table 3. WVE required per sector for an average winter.

2.3.2 A 1-in-20 winter

Applying the WVE demand ratios for a 1-in-20 winter, as derived in section 2.2.5, to the annual demand volumes of the Baseline and New Policy Scenarios of section 2.1, the resulting WVE requirement for a 1-in-20 winter is shown per sector in Table 4 below. The total WVE lies between 68-82 bcm in 2015 and 60-83 bcm in 2020, depending on the scenario. Note that in a 1-in-20 winter the total gas demand for the 12-month period is higher than the volumes shown in Table 3 by 19-23 bcm in 2015 and by 17-24 bcm in 2020, depending on the scenario.

WVE requirement 1-in-20 Winter		2015		2020
In bcm	Baseline	New Policy	Baseline	New Policy
Residential Sector	59	50	60	44
Industrial Sector	8	8	8	7
Power Sector	14	10	16	8
Total	**82**	**68**	**83**	**60**

Table 4. WVE required per sector for a 1-in-20 winter.

In the following chapters we will examine the extent to which the combination of supply from production, imports and storage will be sufficient to cover the calculated additional volume requirement during an average and a 1-in-20 winter.

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[14] Figures may not add up due to rounding.

3

Winter supply capacity

3.1 Introduction

In the next steps of the analysis we will appraise the potential to meet the calculated additional winter volume requirements shown under the two demand scenarios in Chapter 2.

3.1.1 Annual gas supplies

Regarding annual supplies we have assumed the following supply hierarchy to make up the annual demand under the two demand scenarios:

- indigenous Northwest European production,
- pipeline imports from Norway and Russia,
- firm LNG import contracts.

As a result, the contribution of indigenous production under the two demand scenarios is identical. For pipeline gas we will assess the most likely capacities to supply volume levels, based in part on up-stream production capacities and also on the capacity of the pipeline infrastructure. For demand scenarios in which annual demand exceeds the sum of indigenous production and pipeline supplies, long-term base-load LNG contracts will be assumed to take precedence over pipeline supplies.

The reality may be more complex, however: LNG, both under term and spot contracts, can make more inroads into the European supply mix than suggested by these assumptions. Particularly in the near future, there will be a surplus of LNG in the global market. However, more LNG supplies will reduce estimated pipeline supplies in any demand scenario and thus increase the amount of unutilised pipeline capacity. Like unutilised LNG regasification capacity, underutilised pipeline capacity offers scope for additional winter supply (see also section 5.7.2). The impact of an overall larger role for LNG in Northwest Europe toward achieving the capacity needed to meet winter demand is therefore considered small.

3.1.2 Winter supply sources

The volumes needed by the Northwest European market to support the higher demand in winter may come from different sources. These can be grouped in three categories:

- production flexibility, i.e. a higher production during the winter season that can be directly attributed to the indigenous producing fields;
- flexibility in pipeline and LNG imports, where we distinguish between the long haul pipeline gas supplies under long-term contracts which offer contractual flexibility to acquire more gas in winter, and LNG supplies which may be acquired on a short term/spot basis to meet higher demands for gas; and
- flexibility provided by storage capacity in the Northwest European market.

For each supply source we examine the capacity to supply additional winter volumes.
The group of sources having a high level of supply certainty consists of:

- indigenous production,
- pipeline supplies under long term contracts from outside Northwest Europe, and

- long-term base-load LNG supplies (however, these are not considered to offeflexibility), and
- storage available in Northwest Europe.

We will also examine the less certain prospects for additional winter supplies from:

- investment plans for additional storage and
- the global LNG market.

Box 3: Determining a WVE ratio for supplies.

For supplies, the WVE ratio is determined as follows:

Under a long-term supply contract with 10% "swing", i.e. a flexibility of 10% around Annual Contracted Quantity (ACQ), the buyer is allowed to take 110% of average supplies in winter. For example, suppose a contract with an ACQ of 10 bcm. Without contractual flexibility the buyer will have to take 5 bcm in summer as well as in winter (assuming a winter period of 6 months). With 10% contractual swing the buyer can increase the winter off take by 10% to 5.5 bcm. This additional 0.5 bcm available for winter supplies is the Working Volume Equivalent (WVE) at the disposal of the market player and represents 5% of the total ACQ of 10 bcm. Thus, the equivalent of a contractual swing of 10% is a WVE ratio of 5%, illustrated by the following formulae:

$$WVE\ ratio = \frac{swing}{2} \qquad \text{and the corresponding WVE:} \qquad WVE = ACQ * \frac{swing}{2}$$

If there is no long-term contractual basis for flexibility (such as production from the Norwegian Ormen Lange Field), we can establish a WVE for a producing field or a number of fields by examining the production performance in the following manner:

$$WVE = \frac{winter\ production - \ summer\ production}{2}$$

The corresponding WVE ratio then becomes (WVE/ total annual production) x100%.

If there is no reason to assume a different summer/winter performance from this field or these fields, we calculate the future WVE contribution by applying this ratio to future production levels.

3.2 Outlook for indigenous production

The indigenous production of Northwest Europe has historically been an important source of seasonal flexibility. The majority of the production comes from the UK and the Netherlands. Germany and Denmark play only minor roles. Production from the UK, Germany, Denmark and the small fields in the Netherlands is in decline. Over the past 5 years seasonal production swing from all these sources has fallen to around 10% of annual production. This corresponds to a WVE ratio of 5% (see Box 3 for an explanation). Therefore, with the exception of the Groningen field, in this study we have assumed a WVE ratio of 5% for all Northwest European indigenous sources for 2015 and 2020.

Unlike other fields in Northwest Europe, the Groningen field still is a source of considerable flexibility, estimated at 12 bcm of WVE, corresponding to a WVE ratio of 30% of annual production in 2009. Yet the production swing from this field alone is also expected to decline (see Box 4). So for Groningen a different approach has been taken in the sense that we assume a linear reduction in the production WVE ratio to 5% by 2020. Tables 5 and 6 below show the expected total annual production, and the potential WVE contribution of the indigenous supplies.

In effect, the WVE from indigenous production will decline by 4.4 bcm by 2015 and a further 5.8 bcm by 2020, relative to the level of 2009[15].

Box 4 presents an evaluation of these figures for the largest WVE contributors, the UK and the Netherlands.

Annual production In bcm	2015	2020
Germany & Denmark	18	12
United Kingdom	41	30
The Netherlands	69	54
Total	**128**	**96**

Table 5. Indigenous supply: annual production.

WVE In bcm	2015	2020
Germany & Denmark	0.9	0.6
United Kingdom	2	1.5
The Netherlands	7.7	2.7
Total	**10.6**	**4.8**

Table 6. Indigenous supply: WVE.

Box 4: Determining the WVE contribution of the UK and the Netherlands.

The United Kingdom[16]

The UK's supply base is rapidly declining. In addition, the Southern North Sea fields, which historically have provided significant seasonal flexibility, are nearly exhausted. Consequently, the WVE as a percentage of annual production has declined from around 10% in the 1990s to 5% in the past 5 years. In 2009 the WVE was 2.7 bcm[17].

Expectations of UK annual production for 2015 run between 30 and 48 bcm and for 2020 between 14 and 39 bcm[18]. The National Grid, in its 2009 annual UKCS production forecast, applies production levels of 41 bcm in 2015 and 30 bcm in 2020 for its reference case. These projections will also be used in this study.

We assume a continuation of the current WVE contribution of 5% of annual demand, i.e. 2 bcm for 2015 and 1.5 bcm for 2020.

The Netherlands

Please note that except for Table C, the volumes below in this box are represented in Groningen Equivalents. This means that the gas has a calorific value of 35.17 megajoules per cubic metre. In Table C, these numbers are converted to the "standard" cubic metre used in this paper, i.e. 39 megajoules per cubic metre.

The Dutch supply base consists of the so-called "Small Fields" (non-Groningen) and the "Groningen System".

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[15] In 2009 the WVE contribution of indigenous production was 15 bcm (Germany and Denmark 1 bcm, The UK 2.7 bcm and The Netherlands 11.3 bcm).

[16] Note that the Figures in the original document represent 39.6MJ/Nm^3. The figures in this section about the UK are converted to 39MJ/Nm^3. See footnote 2 for further information.

[17] UK DECC, "Monthly gas production statistics".

[18] National Grid, "Ten Year Statement 2009".

The annual production of the Dutch Small Fields has declined from 41 bcm with a WVE ratio of 13% (5.2 bcm) in 2003 to respectively 36 bcm and 4% (1.2 bcm) in 2009[19]. Based on these data it is assumed that the Dutch Small Fields provide a flexibility (WVE) of 5 % for future annual production. Since it is projected that the annual production will decline to 29 bcm in 2015 and 15 bcm in 2020[20], the WVE capacity of the Dutch Small Fields is expected to be 1.4 bcm in 2015 and 0.7 bcm in 2020[21].

Most production flexibility comes from the Groningen System, consisting of the Groningen field supply capacity in combination with the storage facilities in Norg, Grijpskerk and Alkmaar. The three storage facilities, with a WVE of 5 bcm[22], operate on Groningen cushion gas. In the period 2003-2009, the production from the Groningen field resulted in a maximum realised WVE of 11.3 bcm[23]. On that basis we estimate a WVE of the Groningen field of at least 12 bcm and hence of 17 bcm for the total Groningen system (Groningen equivalent). Because the UGSes are reported separately in the GSE database, for the purpose of this study they are not included as production flexibility.

The Groningen field is projected to enter into decline. There are no data available on the expected annual decrease in flexibility of the field, important as it is in view of the significance of its current contribution. The field is operated as part of the Groningen System and both GasTerra[24] and NAM[25] have indicated that they are planning for investments in the Groningen system, through expansion of the storage facilities in Norg and Grijpskerk. We assume that these expansions[26] are technically feasible because of the significant pore volumes that these facilities hold, of which currently only a relatively small volume is used as working volume[27]. There is no information available on the timing and the volume of planned expansion. However, on the assumption that a ratio of working gas to cushion gas of 1:2 represents a rational use of the storage facilities[28], expansions to these levels would result in flexibility of the Groningen System at or above its current level, even if the flexibility from the Groningen field itself were to decline to the level achieved at other fields. However, the expected expansions are not certain. neither in timing nor in volume, and their realisation will depend on developing market conditions.

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[19] See: <www.nlog.nl>. To convert the Nm^3 of the small fields to $35.17 MJ/Nm^3$, a multiplier of on average 1.12 is used.

[20] TNO on behalf of The Dutch Ministry of Economic Affairs (2009), “Delfstoffen en aardwarmte in Nederland”, Jaarverslag (Annual Report).

[21] It should be noted that the Dutch government aims to maintain the annual production from the Dutch small fields at 30 bcm by 2030.

[22] NAM and Gasunie (April 2001), “Position paper ondergrondse bergingen”, <http://www-static.shell.com/static/nam-nl/downloads/gasstorageservices/position_paper.pdf>.

[23] 11.3 bcm is the highest Groningen field WVE in de period 2003-2009. See for further information: <www.nlogl.nl>.

[24] Gasterra, “Annual Report 2009”, <http://gasterraverslag.nl/ENG/Annual_Report_2009_files/index.html>.

[25] Dagblad van het Noorden (11 March 2009), “NAM stopt miljoenen in het Noorden”, <http://www.dvhn.nl/nieuws/economie/eco_noorden/article4467010.ece>.

[26] Gasterra, “Annual Report 2009”, ‘*….Large-scale investments are necessary to maintain the production capacity of the Groningen field. The existing underground storage facilities near Norg and Grijpskerk will be extended further for this purpose…*’. Shell (July 2010), “Shell Venster”, p. 24.

[27] G. Remmelts (TNO), paper presented at ‘Gasopslag 2010’, the Netherlands. NAM and Gasunie (April 2001), “Position paper ondergrondse bergingen”, <http://www-static.shell.com/static/nam-nl/downloads/gasstorageservices/position_paper.pdf>.

[28] G. Remmelts (TNO), paper presented at ‘Gasopslag 2010’, The Netherlands.

Therefore the following assumptions about WVE contributions have been made[29]:

- By 2020 flexibility from the Groningen field will be similar to other fields. Its contribution in terms of WVE will be 5% of production, expected to be 45 bcm in 2020[30], resulting in a WVE of 2.3 bcm.
- The current storages of the Groningen system make a firm contribution to WVE of 5 bcm through 2020.
- Expansions of the Groningen system storages are included in the category "planned expansions" with an additional WVE of up to 9.7 bcm by 2020.
- For 2015, assumptions for decline of flexibility and additional planned storage will be achieved by means of interpolation between current and 2020 data

Summarizing, for the indigenous Dutch production the following data will be used:

Dutch supply In bcm		**2015**		**2020**
(35,17MJ/Nm3 GCV)	Small Fields	Groningen Field	Small Fields	Groningen Field
Annual production	29	47.5	15	45
WVE	1.4	7.1	0.7	2.3

Table A. Dutch WVE contribution from production in Groningen Equivalents.

Dutch supply In bcm (39 MJ/Nm3 GCV)	**2015**	**2020**
Annual production	69	54
WVE	7.7	2.7

Table B. Dutch WVE contribution from production in "normal" bcm.

3.3 Outlook for pipeline imports

3.3.1 Introduction

The import of pipeline gas for Northwest Europe essentially concerns Russian and Norwegian gas. The prospects of future annual supplies from each of these sources will be briefly reviewed.

Regarding seasonal flexibility, pipeline suppliers from outside the EU traditionally have provided a certain degree of flexibility in their contracts. However, this flexibility is limited. The huge investments for production facilities and transport lines, accompanied by low variable costs of operation, create an economic incentive for any producer and pipeline operator to maximise the utilization rate. The larger the distance, the stronger the incentive becomes.

For this analysis we assume a continuation of the current contractual contribution to seasonal flexibility of around 10%, or a WVE ratio of 5%, of annual contractual quantities (see also Box 3 in the previous section).

3.3.2 Norwegian supply

Norway has, for the time being, put the expansion of its gas export infrastructure on hold. The overall capacity of these pipelines currently stands at 131 bcm/y[31].

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[29] Note that these figures are based on the Groningen equivalent bcm.

[30] TNO on behalf of the Dutch Ministry of Economic Affairs (2009), "Delfstoffen en aardwarmte in Nederland", Jaarverslag (Annual Report).

[31] National Grid, "Ten Year Statement 2009". Converted from 39.6MJ/Nm^3 (GCV) to 39MJ/Nm^3 (GCV).

The total annual Norwegian gas production capacity is projected to increase to 117 bcm by 2015. Thereafter a decline to 106 bcm in 2020 is expected, which is equal to the production in 2009[32]. In 2009, a little over 90% of the production was exported by pipelines. Assuming a continued use of 13 bcm for domestic purposes and LNG export[33], while 13 bcm will remain committed to pipeline export to other European countries[34], we conclude that respectively 91 bcm and 80 bcm will be exported to Northwest Europe in 2015 and 2020.

From 2004 to 2009 the production from Norway provided an average seasonal flexibility of 10%, corresponding to a WVE ratio of 5%[35]. For our base case, we assume that Norwegian production will continue to offer the same WVE of 5% of annual supplies to Northwest Europe. Combining the ratio with the annual export outlook to Northwest Europe, Norwegian supplies will provide a WVE capacity of 4.6 bcm in 2015 and 4 bcm in 2020.

3.3.3 Russian supply

For Russian gas it is more difficult to project the level of future supplies and their flexibility. Current Russian supplies are based on long-term contracts which, like the Norwegian contracts, are assumed to have a seasonal flexibility of 10% (WVE ratio of 5%). Various contracts extend well beyond 2020. It is unlikely that this commercial basis will significantly change over this period.

Total Russian pipeline capacity to Northwest Europe is expected to reach 147 bcm by 2015. This includes the Nordstream project, a major pipeline project for which construction has already been put in motion and which will create 55 bcm of extra transport capacity. This capacity could be used to facilitate additional long-term contracts, of which currently an estimated 23.5 bcm have been concluded[36]. It may also provide uncommitted capacity to Gazprom. Gazprom may decide to use this capacity, either (wholly or partly) as a strategic back-up to guarantee its ability to supply EU consumers, or for short-term and spot sales, to the extent its gas production capacity permits. Altogether it is quite difficult at this stage to develop a robust view of the future level of Russian gas supply under long-term contracts to Northwest Europe.

For this reason we have used an average for long-term contractual supply from Russia to Northwest Europe at a level between:

- a “low end” case, based on current long-term contracts, annual supplies from Russia to Northwest Europe plus another 4.5 bcm for Gazprom’s subsidiary in the UK (bringing the lower end of the range of possible long term supplies to 87 bcm in 2015 and 2020), and

- a “high end” case, under which Gazprom’s long-term contractual sales may rise linearly to 111 bcm in 2020, if Gazprom employs the Nordstream pipelines to 80% of their capacity for long term contract sales.

Averaging these numbers, annual supply under long-term contracts in 2015 and 2020 would rise to respectively 89 and 99 bcm. Assuming a WVE ratio of 5%, WVE capacity will amount to 4.5 bcm in 2015 and 5 bcm in 2020.

As for Norway, the costs of production and transportation of Russian gas, as well as the potential arbitrage value of flexible supply contracts for the buyers, are such that it would be economically

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[32] Ibidem.

[33] These 13 bcm consist of 7 bcm domestic consumption (2008 IEA Natural Gas Information) and 6 bcm LNG from Snovit (IEA, Natural Gas Market Review 2009).

[34] These 13 bcm represent contractual supplies to Spain, Italy and Poland, which run beyond 2020.

[35] Norwegian Petroleum Directorate. CIEP analysis.

[36] World Gas Intelligence, 17 March 2010.

rational for Gazprom to aim for low flexibility in its contractual supply. Gazprom's acquisition of storage capacity in Europe seems to underscore this point. On the other hand, the assumed underutilisation of pipeline capacity suggests an additional potential for the provision of seasonal flexibility in terms of WVE; these issues will be addressed in Chapter 5.

3.3.4 Conclusion: WVE capacity contribution of Russia and Norway

Summarizing, the annual supply of pipeline gas and the corresponding contribution to winter supply capacity for our base case analysis can be projected as follows:

Estimate of pipeline imports (not restrained by demand):

Annual export In bcm	**2015**	**2020**
Norway	91	80
Russia	89	99
Total	**180**	**179**

Table 7. Total annual supply.

WVE In bcm	**2015**	**2020**
Norway	4.6	4
Russia	4.5	5
Total	**9.1**	**9**

Table 8. Corresponding WVE.

3.4 Outlook and role of LNG

3.4.1 The growing contribution of LNG for Northwest Europe

LNG is developing into a global commodity with high "destination flexibility", particularly in the Atlantic Basin.

LNG is expected to play an important role in Northwest Europe in the near future. The combination of the current glut (which could very well last until beyond 2015), the existing and the new LNG regasification capacity, and the destination flexibility of much of the LNG supplied to the market offers a variety of supply scenarios, in the short term as well as towards 2020.

In this section we examine the contribution that LNG would have to make in order to meet the annual demand of Northwest Europe under the two demand scenarios. This is based on the premise that LNG will complement indigenous supply and pipeline imports and that it will be purchased by parties in the Northwest European market under long-term base load contracts. The supply of LNG which may be acquired today and in future on a short-term or spot basis to replace pipeline supplies or to meet winter demand will be addressed in section 3.6.

3.4.2 LNG import capacity Northwest Europe

In 2010, 73 bcm/y of LNG regasification capacity was operational in Northwest Europe. Another 18 bcm is under construction, bringing the availability of firm name-plate capacity up to 91 bcm/y[37]. There are plans to construct more capacity, but these will not be included in the base case analysis.

3.4.3 The LNG annual supply outlook

To incorporate LNG as a source of flexibility, a distinction has been made between base load LNG and additional winter LNG from "flexible" supply sources:

1. In 2015 and 2020 LNG will provide base load supplies to cover residual Northwest European demand beyond indigenous production and pipeline supplies from Norway and Russia. It is assumed that this base load LNG is supplied under long-term contracts. Due to the nature of LNG supplies it is assumed that these contracts will not have seasonal flexibility. Nevertheless, there may be contractual arrangements allowing

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[37] Gas LNG Europe (June 2010),'GLE Map Dataset', <http://www.gie.eu.com/maps_data/lng.html>.

contract parties to redirect cargoes. Hence, these LNG supplies do not serve as a WVE source in our approach.

2. Remaining regasification capacity may be used to import LNG in winter. This amount will be quantified in section 3.6.

The current contracted base load LNG supplies will amount to 20 bcm in 2015, declining to 10 bcm by 2020[38]. It is assumed that these contracts will not offer any seasonal flexibility.

3.4.4 Review of supply assumptions against demand scenarios

The supply assumptions are reviewed against the demand scenarios in Table 9.With exception of the Baseline Demand Scenario in 2020, the other three scenarios assume levels of pipeline supply that exceed demand. Under these scenarios new base load LNG supply contracts will not be required. For these scenarios we assume a reduction in pipeline supplies to balance supply and demand and only use the 5% WVE contribution of the lower pipeline quantities. In reality, if this were to happen, it would offer a prospect of ample availability of winter supply and hence reduce any concern for shortages in severe winters.

Under the Baseline Demand Scenario in 2020, however, supplies from indigenous production and imported pipeline gas will not meet projected annual demand. It is assumed that the supply gap of 40 bcm will be filled by LNG supplied under long-term contracts. The supply demand balance thus becomes:

Annual supply demand balance	**2015**		**2020**	
In bcm	Baseline	New Policy	Baseline	New Policy
Demand	316	259	324	227
Indigenous supplies	127	128	95	96
Pipeline supplies	180	180	179	179
Base load LNG supplies	20	20	10	10
Total firm supplies	327	328	284	285
Balance	**11**	**70**	**-40**	**58**
Downward adjusted pipeline supplies	169	110	179	121
Consequential LNG supplies	20	20	50	10

Table 9. Reconciliation of supply and demand scenarios.

Under the base case assumptions, the additional long-term LNG supply contracts will not contribute to WVE capacity. The availability of WVE from indigenous supplies and long-term import contracts thus becomes:

WVE	**2015**		**2020**	
In bcm	Baseline	New Policy	Baseline	New Policy
Indigenous supplies	10.6	10.6	4.8	4.8
Pipeline supplies	8.4	5.5	9.0	6.0
LNG supplies	0	0	0	0
Total WVE	**19.0**	**16.1**	**13.8**	**10.8**

Table 10. WVE contribution from supply sources.

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[38] Cedigaz (2008).

3.5 Storage

3.5.1 The changing role of storage

Gas storage has always been the main instrument for wholesale trading companies to balance supply and demand and to provide for additional supply capacity in the winter. But Europe's gas market has changed significantly since the start of liberalisation. The opportunities for arbitrage between periods of low and high prices have led to investments in different types of storage, notably caverns. Their versatility, the shorter investment time and lower investment costs make them an ideal asset for portfolio management for market players. Unlike our previous study (CIEP 2006[39]), this new storage inventory will include caverns. They increasingly contribute to the storage portfolio of the industry and, while perhaps not the most economical option, they have the physical capacity to contribute to seasonal balancing.

In this study the total available working volume of pore storage (i.e. depleted gas fields and aquifers) and caverns will be combined. No distinction is made between strategic and other storages. In view of the possibility that not all storage capacity will be completely filled at the start of a winter period (e.g. because of other use for caverns), and based on historical analysis[40], 95% of total nominal capacity will be assumed to be available to deal with the normal and severe winters in Northwest Europe, irrespective of the main purpose of the use of the storage.

3.5.2 Future availability of storage capacity

An inventory has been made of the working volume of existing storages, those facilities under development and possible additions. Also included are those storages in Austria which are clearly earmarked for use in the Northwest European market.

The inventory, included in the annex , is built up from the following categories:

- Existing storage in Northwest Europe;
- Storage "under construction", which comprises all storage developments for which GSE has expressed in its database that FID (Final Investment Decision) has been taken[41]. Storages in the permitting phase are not included in this category, but in the section "planned expansions" or "other planned new storages";
- Storage under construction in Austria for the Northwest European market;
- Planned expansions. Given the expected low marginal costs of expansion, the probability is high that this will be realised as planned. This group includes expansion of the storage facilities Norg and Grijpskerk in the Netherlands, as discussed in section 3.2.3.[42]; and
- Other planned new storages. Plans in Northwest Europe for new storages are found in different stages of development and they vary in likelihood of realization. Although the additional volume contribution of WVE capacity from this category is far from certain, it should be taken into account when considering the future balance of WVE supply and demand.

Figure 3 below shows the aggregation of these categories for 2015 and 2020 in terms of WVE, taking into account that 95% of nominal working volumes have been used for the total WVE assessment.

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[39] CIEP (February 2006), "The European Market for Seasonal Storage", *Discussion Paper*.

[40] Historical analysis of the fullness of storage facilities in Northwest Europe on October 1st between 2007 and 2010 on the basis of GSE data.

[41] LNG peak shaving facilities that are currently in operation have not been taken into account. According to GSE, existing facilities in Northwest Europe have a working volume of 0.3 bcm and no other LNG peak shaving facilities are under construction or planned in Northwest Europe.

[42] It should be noted that the volume of 9.7 bcm for Norg and Grijpskerk expansions by 2020 represents the maximum assumed volume for expansion. This could well be less depending on market conditions.

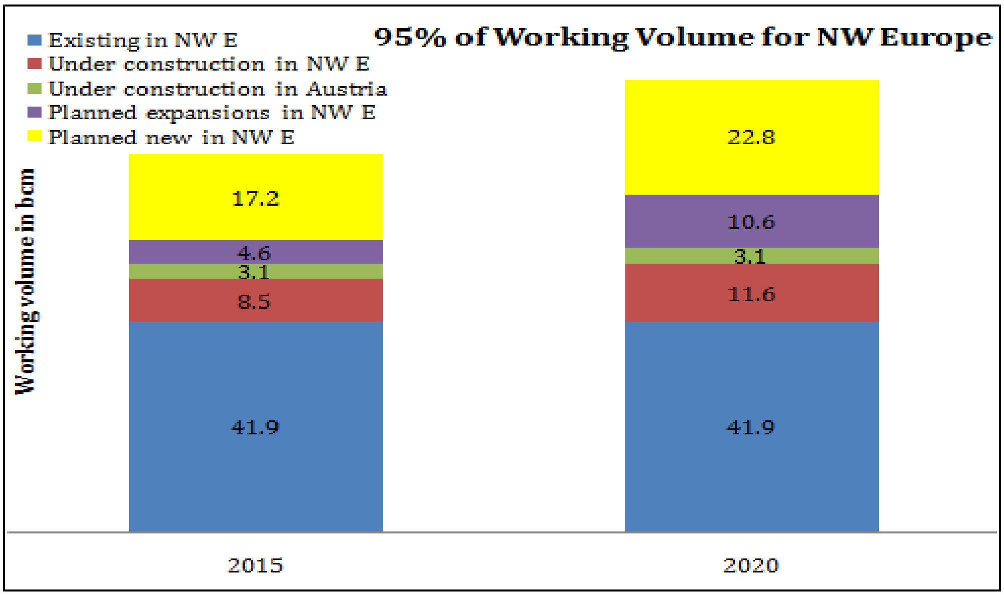

Figure 3. WVE contribution from storage. For further information see the annex in which 100% of working volumes are shown. Source: GSE data (January 2010), CIEP.

3.6 The contribution of "flexible" LNG

As mentioned in paragraph 3.4.1, large volumes of LNG have destination flexibility. According to the IEA World Energy Outlook 2009, the LNG industry has a total volume of around 1660 bcm of LNG available for sale from its existing production over the period 2009-2025.

In these circumstances, it is assumed that:

- By 2020 there will still be significant volumes of LNG with destination flexibility available in the global market, as well as sufficient shipping capacity, and

- Northwest Europe will be able to compete for this LNG if and when it needs to for its 1-in-20 winters, most likely at a premium, above-average market prices.

The LNG regasification capacity in Northwest Europe that remains after subtracting the base load supplies determined in paragraph 3.4.2 could be used to import extra volumes of LNG at any time of the year but particularly in the event of a very cold winter. Given the nature of the LNG business, we have assumed that the regasification capacity needed to accommodate base load LNG supply is 110% of base load volumes. As regards any remaining spare regasification capacity, in view of the irregular acquisition process of spot cargoes from different sources, we assume that 80% of this capacity will be potentially available for supplementary spot LNG trade.

LNG regasification terminals are not designed to stockpile gas for seasonality. In the event of a very cold (1-in-20) winter, the market players will attempt to acquire additional volumes of LNG at the time it occurs and not earlier. Therefore, the LNG capacity available for additional winter supplies is not calculated as the capacity for 6 months but only for the duration of the cold period. We assume that cold periods will last no longer than two months, and the WVE is calculated accordingly.

Given a nominal regasification capacity in Northwest Europe of 91 bcm/y from existing plants and those under construction, we can calculate the potential WVE contribution of these LNG supplies.

In 2015, with 20 bcm assumed as the annual base load (without WVE) under the Baseline Scenario, the remaining available winter regasification capacity will be 27.4 bcm. If we assume that the cold period will not last longer than two months, the effectively available LNG regasification capacity will be 9.1 bcm. If all this capacity would be successfully used to acquire LNG cargoes to deal with the cold, this would add a WVE of 9.1 bcm. However, it has to be stressed there is no certainty that the LNG will be actually available from the world market.

Similarly, we can calculate the maximum WVE of LNG capacity for 2020. Under the Baseline Scenario, we assume the annual base load volume (without WVE) required in 2020 to be 50 bcm, therefore leaving a remaining capacity of 4.7 bcm for 2 winter months. The WVE capacity for a 1-in-20 winter in the Baseline Scenario thus becomes:

LNG Import Capacity In bcm	**2015**	**2020**
Winter capacity for spot trade	27.4	14.2
WVE 1-in-20 winter	9.1	4.7

Table 11. Potential contribution to a 1-in-20 winter from "flexible" LNG.

Planned additional regasification capacity is not included in this assessment. These plans amount to over 100 bcm by 2020[43]. Converted to WVE capacity, this could add another 13.9 bcm to the 1-in-20 winter capacity. However, it is most uncertain how much of these plans will be realised.

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[43] GLE (June 2010), "GLE Map Dataset".

4

The WVE supply/demand balance

4.1 The WVE supply/demand balance under the Baseline Scenario

The Baseline Scenario has a higher demand for winter supplies than the New Policy Scenario. To examine how this demand can be met we have made two projections.

Figure 4 below shows the two WVE demand lines for an average winter and a 1-in-20 winter in 2015 and 2020, projected against the WVE availability from different types of long term supplies and categories of storage in these years. For reference purposes, for 2009 we have included the WVE capacity from annual supplies and existing storage as well as a notional "average" winter WVE demand, calculated on the basis of the same WVE ratios as for 2015 and 2020 and based on the annual consumption in 2009. Figure 4 shows that an average winter does not cause any problems in Northwest Europe in 2015 or in 2020. However, in a 1-in-20 winter the combination of capacity from supplies, existing storage and storage under construction will not suffice to meet the demand in either year. Even if the category of planned expansions are fully realised, the availability of winter capacity will be tight.

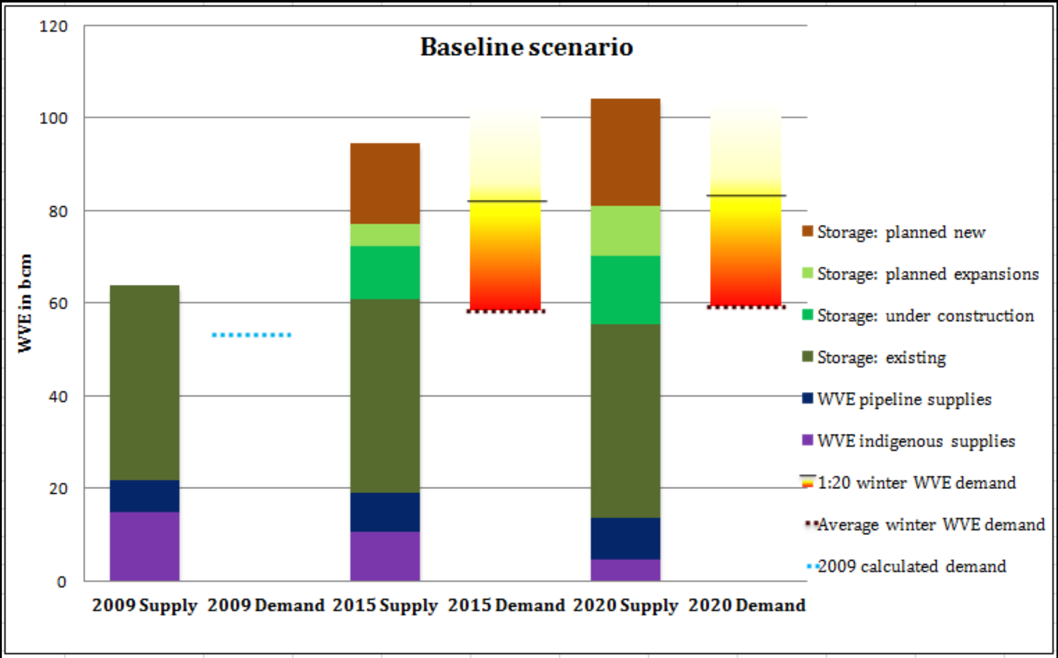

Figure 4. Baseline Scenario: winter demand vs contribution from term supply and storage.

However, Figure 4 does not take into account the potential for Northwest Europe to acquire winter supplies of flexible LNG. Figure 5 below shows the impact of this possibility. This figure shows the buildup of WVE availability from:

- long-term pipeline supplies;
- storage and existing, under construction and full planned expansions;
- "spare" LNG regasification capacity (net of firm LNG supplies), both firm and planned.

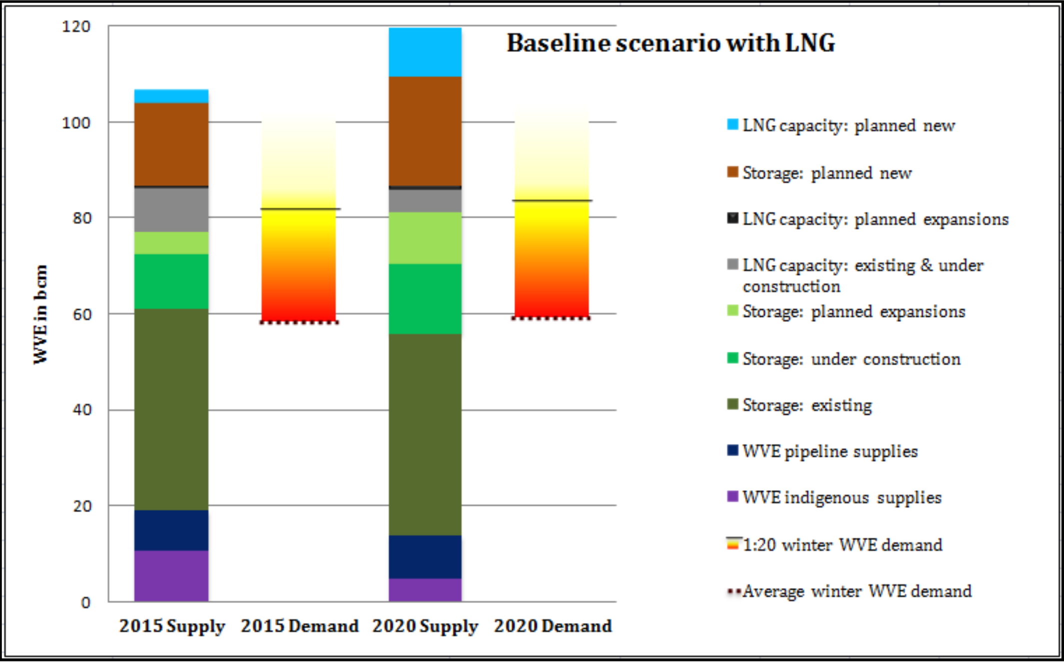

Figure 5. Baseline Scenario: potential additional contribution from flexible LNG.

This projection shows that the availability of winter supply capacity will be sufficient in the event of a 1-in-20 winter, if and when the planned storage expansions are realised, and if there is a sufficiently liquid market for spot LNG in the Atlantic Basin.

4.2 The WVE supply/demand balance under the New Policy Scenario

Figure 6 below shows the two WVE demand lines for an average winter and a 1-in-20 winter, projected against the WVE availability from supplies and from storage; the latter are categorised as in Figure 4 and 5.

It shows that under the New Policy Scenario, the Northwest European market is provided with sufficient supplies for both an average and a 1-in-20 winter, assuming that the planned storage expansions will have materialised by 2020, including the maximum volumes assumed for Norg and Grijpskerk.

As in the balance on the basis of the Baseline Scenario, we have added 2009 for reference purposes.

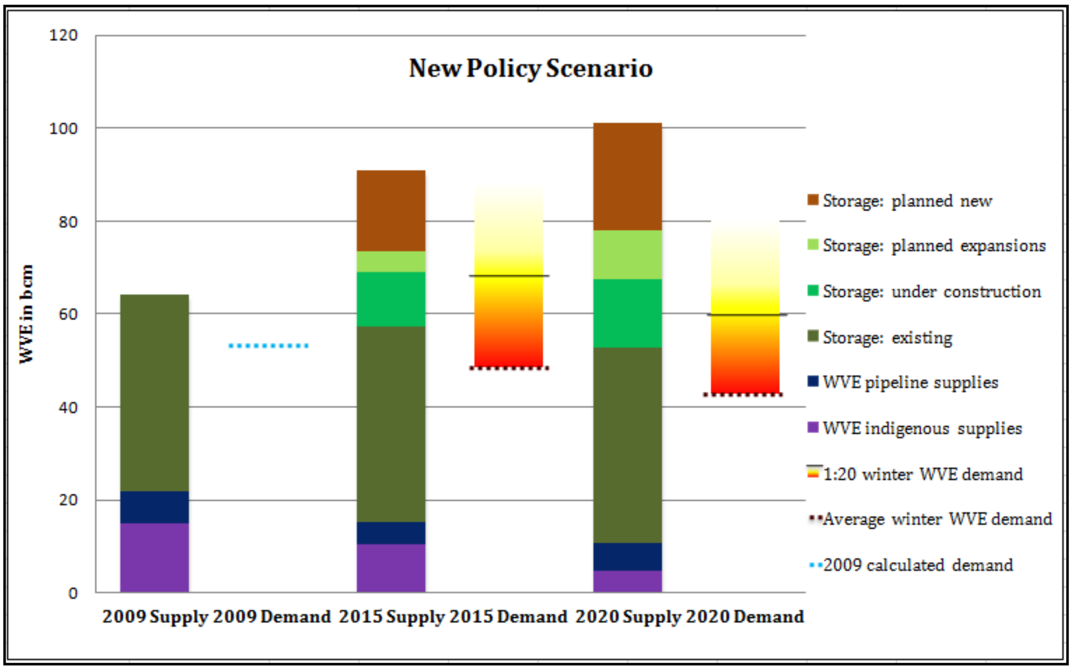

Figure 6. New Policy Scenario: winter demand vs. contribution from term supply and storage.

4.3 Summary

Summarizing, it can be concluded that for Northwest Europe:

- In both demand scenarios there will be sufficient capacity from indigenous supplies, pipeline imports and storage to accommodate an average winter in 2015 and 2020.
- To meet demand in an 1-in-20 winter, additional investments may be needed.
  - If the Baseline Demand Scenario materialises, representing rising demand for the years to come, a supply problem could emerge in the event of a 1-in-20 winter if planned expansions of existing storages in Northwest Europe are not realised.
  - Even if planned expansions of storage fully materialise under the assumed timing, there will be a remaining unsatisfied demand in a cold winter. LNG will have to play an essential role with additional (spot) supplies, using the spare capacity in LNG regasification terminals, unless the market decides to make additional investments in new storage capacity.
  - At the low end of demand projections, a 1-in-20 winter under the New Policy Demand Scenario will not create a real problem.

It should be noted that many assumptions underly these conclusions. Sensitivities around these results and further considerations surrounding the assumptions and their impact on the conclusions will be discussed in the next chapter

5

Discussion and sensitivities

5.1 Outlook for storage

Regarding the outlook for 2020, much depends on further investments in storage. Expansions of existing facilities seem most likely, as they offer an economic perspective at lower costs than new storages. Furthermore, new storage development plans are still on the drawing board with a total working volume of 24 bcm, as illustrated in the table in paragraph 3.5.2[44]. Nevertheless, these investments might not be made. The difference between summer and winter prices, which determines the value of seasonal storage, has dropped to historically low levels. These prices have a short time horizon. However, they may, together with uncertainties around regulatory measures, result in sentiments which could affect the likelihood that planned storage will be realised or that new plans will be made. This leaves the outlook for supply in a 1-in-20 winter exposed to underinvestment.

5.2 The scenarios

The two scenarios used in this study span by and large the range of projections of future gas demand made by a number of observers of the gas business. Consequently, the resulting winter demand figures represent the outer edges of what is presently seen as possible future demand. This implies that calculated Baseline winter demand lies on the high end and New Policy winter demand at the lower end of future demand projections.

To accommodate the low demand of the New Policy Scenario, Russian supplies were “shoehorned” down to a reduced annual volume. In fact, all Russian supply facilities are designed for much higher volumes. In the unlikely event of such a reduction of annual Russian gas volumes, the capacity of this supply line to accommodate high winter demand would be much greater than assumed under the strict terms of annual contractual supply.

5.3 Demand assumption sensitivity

The main impact on winter demand comes from the residential sector. Twenty-eight percent was used as the WVE ratio for an average winter in the residential sector. A reduction (or increase) by 1% in this ratio results in a reduction (or increase) of WVE requirement in the Baseline Scenario of 1.5 bcm in 2015 and 2020. For the industry or the power sector, a reduction (or increase) of the WVE ratio by 1% corresponds to a reduction (or increase) of WVE requirement in the Baseline Scenario of between 0.6 and 0.7 bcm in 2015 and 2020.

5.4 Strategic storage

We have assumed that if capacity in a UGS is marked as strategic storage by governments or industry, it will be used in the event of a 1-in-20 winter.

5.5 “Leakage” in and out of Northwest Europe

There is some other traffic of flexibility across the borders of Northwest Europe which has not been taken into account. A long-term contract from the Netherlands to Italy exports some flexibility which is therefore not available to Northwest Europe. However, this is estimated to

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[44] Please note that the figure depicted in this table (22.8 bcm) should be multiplied by (100/95) to come to 24 bcm. See the annex for further information.

have a relatively small impact on available WVE for Northwest Europe (probably less than 0.5 bcm by 2020). Gas will also flow across the borders of Northwest Europe under short-term business transactions. Finally, some of the Austrian storage included in the analysis, while earmarked for Germany in this study, may be used for Austria or Italy.

5.6 Northwest Europe is not a "Copper Plate"

Sufficient pipeline capacity and regulatory support to allow a free and unhindered flow of gas across Northwest Europe is assumed. However, in reality, storage capacity is not evenly spread across all markets in Northwest Europe, and constraints such as congestion on interconnection points and gas quality issues could affect the assumption of a fully integrated Northwest European market (see also CIEP paper[45]). Given current political and regulatory focus on this subject, we are more confident that during this decade additional investments in pipeline infrastructure will be made to reduce the risk of congestion.

5.7 Other considerations and sensitivities

There are various other observations and sensitivities which also place the results of this study in a proper perspective. Those which may give rise to more concern about adequate availability of winter supplies to meet the demands of a cold winter have been grouped accordingly on this basis (the downside considerations), others may improve the winter supply/demand balance (upside considerations).

5.7.1 Downside considerations

Possible downside risks and considerations which may have a negative effect on the supply of flexibility:

- The supply flexibility under the pipeline import contracts may be lower by 2020. In the extreme case of a 100% load factor, this would reduce the availability of supply flexibility by a WVE of 9 bcm in the Baseline Demand Scenario.

- The same 9 bcm of WVE in contracts with pipeline suppliers from outside the EU may also not be fully available if in future these suppliers meet part or all of their contractual obligations to supply flexibility from underground storage in Northwest Europe. Particularly, Gazprom possesses a significant working volume in storage in Northwest Europe that could be used for this purpose. Depending on the extent to which this option is employed by the Norwegian producers and Gazprom, it will reduce the combination of calculated supply flexibility and available storage capacity by a WVE volume of up to 9 bcm.

- Not all storage is meant for seasonal flexibility. Some storage, particularly caverns, may be (partially) depleted before a cold winter sets in. In the analysis we assume that 95% of storages are filled at the start of winter, but there have been years in which the storage levels were lower at start of winter.

- A 1-in-20 winter is not necessarily the coldest winter conceivable. The most severe winter in the last century is that of 1962/1963. The blue line in Figure 7 shows the number of heating degree days in Dutch winters since 1900.

  We don't want to speculate on the possible impact of climate changes (e.g. global warming). While this may raise average annual temperatures, there is no conclusive scientific indication that very cold winters will belong to the past, nor the frequencies thereof. Therefore, we

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[45] Aad Correljé, Dick de Jong and Jacques de Jong, (September 2009), "Crossing Borders in European Gas Networks: The Missing Links", *Energy Paper*, Clingendael International Energy Programme <http://www.clingendael.nl/publications/2009/20090900_ciep_paper_gas_networks.pdf>.

leave the impact of global warming on WVE for the reader to ponder. Instead, we have used the last 30 years for calculating in Boxes 1 and 2 of Chapter 2 the average (2247) and 1-in-20 (2588) winter heating degree days, illustrated by the dotted lines. As a rule of thumb, an increase (or decrease) of the amount of winter degree days by 100 in a very cold winter[46] would increase (or decrease) the required WVE in NorthwestE by 5 bcm in the Baseline Scenario for both 2015 and 2020.

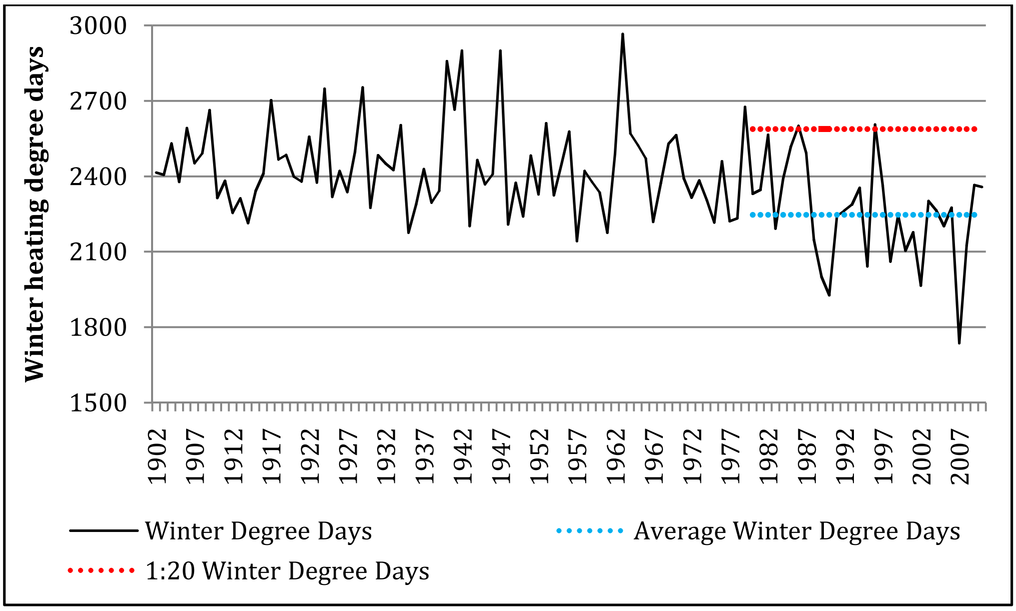

Figure 7. Winter heating degree days in the Netherlands.

5.7.2 Upside considerations

Upside considerations around this evaluation are:

- The evaluation of winter demand contains many assumptions. Whereas these are derived from ranges of uncertainty, we have aimed to err on the side of caution and a conservative figure has been used. The evaluation is thus probably statistically biased towards a higher than average call on seasonal flexibility.

- In this paper the total demand in a 1-in-20 winter is based on the assumption that such winter would occur equally across Northwest Europe. Indeed, there is a strong correlation between the severity of winters among Northwest European countries[47]. However, it is conceivable that only parts of Northwest Europe would suffer from a more severe winter than others in any given year. In such cases, the total demand of Northwest Europe would not reach the levels as calculated and supplies could flow from parts of Northwest Europe where the winter is mild to the areas of high demand. Indeed, in these circumstances relief may come from (inter-)national trade flows, and our paper indicates that this is now one of the options considered by market parties. This could help to meet the demand for gas in a severe winter.

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[46] Hence, 2588 +/- 100 heating degree days.

[47] See for monthly heating degree-days data per country within Northwest Europe: Eurostat, <http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_esdgr_m&lang=en>.Note that the definition of the heating threshold differs from the one used in this paper.

- However, this relief may be limited. Prudent market players are not likely to relinquish their own stocks for a cold winter to accommodate the needs of other markets as long as the potential for high demand still exists in their own markets. Equally, any legislation regarding security of supply, including the recent EU regulation 994/2010 (see 5.8 below) is aimed essentially at ensuring security for consumers in member states.

- We therefore expect that the effect of local rather than regional occurrence of a 1-in-20 winter will provide some upside potential when it occurs but does not materially impact the analysis of this study, neither in terms of the provisions to be made nor in terms of the expected conduct of market players when such a situation arises.

- No account has been taken of any form of demand management in a very cold winter. In reality, it can be assumed that supply to some (industrial) customers will be reduced when gas prices in a very cold winter with potential shortages become very high and this gas becomes available to households.

- The influence of wind was mentioned in section 2.2.4. On average, more wind energy is produced in winter than in summer. If 152 GW capacity is installed by 2020, representing the national policy goals of the countries in Northwest Europe in 2009, wind power could contribute between 5 and 10 bcm of WVE for the electricity sector in an average winter in 2020, depending on the impact of seasonality. However, statistical evidence suggests that there is less wind during a severe winter. Furthermore, at the end of 2009 only 40.7 GW was installed in Northwest Europe[48]. We have therefore not included the contribution of wind in the analysis.

- The import capacity of pipelines for Northwest Europe stands at 277 bcm/y. This exceeds the winter supply assumptions under the Baseline Scenario of this evaluation by some 40 bcm in 2020. Although there may not be a contractual obligation on the part of Russian and Norwegian suppliers, the available transportation capacity, in combination with high prices in a very cold winter, could bring more (spot) supplies to the market at times of a severe winter, provided the suppliers can allocate gas supply for this purpose.

5.8 New EU regulation on security of supply

Article 8 of EU regulation 994/2010 for security of gas supply stipulates that ‘a country should be able to cover gas demand in any period of at least 30 days of exceptionally high gas demand, occurring with a statistical probability of once in 20 years’. This is the condition in the regulation which implies both volume and capacity. Strictly with regard to storage *volume*, the condition of a 1-in-20 winter used in this paper is a stronger requirement – the WVE needed for a 1-in-20 winter exceeds the WVE required for a period of 30 days of exceptionally high demand with a 1-in-20-year probability. This paper has not looked at the capacity dimension of demand, which this regulation also implies. This would require a more local and detailed study.

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[48] EWEA (February 2010), ‘Wind in Power 2009 European Statistics’, <http://www.ewea.org/fileadmin/ewea_documents/documents/statistics/100401_General_Stats_2009.pdf

6

Conclusions

Seasonality is a crucial feature of the gas industry. For Northwest Europe, the difference between summer and winter demand is larger for gas than for any other commodity. The ability to meet demand under severely cold weather conditions has been a key success factor in the development of gas markets over the past 50 years.

The current outlook for the supply of gas in Northwest Europe under serious winter conditions does not give rise to major concerns. This conclusion is supported by two developments which were not part of the 2006 study:

- The inclusion of caverns in this study reflects the growing share of this type of storage in the market. Though they may not be the most economical option for seasonal supplies, they can be used for this purpose. The total cavern storage in Northwest Europe represents a significant volume and reports show that most volume is filled before the start of winter.

- The emergence of flexible LNG adds a new dimension to the operational aspect of security of supply. Flexible LNG represents a growing volume of potential supply, with its own price and market dynamics. The latter may well influence the market's appetite for investments in additional storage.

For the Baseline Scenario and similar demand scenarios, supply options in addition to those currently under construction will need to be developed, but LNG may also have to play a role as a potential source for seasonal supply. The outlook is not alarming, but at least the additional contribution from the planned expansions and/or planned new storages will need to materialise if the balance is to shift away from possible discomfort in a severe winter. It should be noted, however, that the small seasonal differences in current forward prices for gas do not contribute positively to the investment climate for new storage, even though these only reflect the short-term market conditions and not the longer-term demand.

Under low demand scenarios such as the New Policy Scenario, there appear to be adequate options for winter supplies in a 1-in-20 winter up to 2020, even if further investments beyond those which we have assumed to be committed do not materialise.

A 1-in-20 winter is obviously not the coldest winter conceivable for Northwest Europe. The winter of 1963 offers a reminder of more severe conditions than those covered by the 1-in-20 supply options. Such a winter would call for significant additional measures. It is unlikely that the market will make structural arrangements to accommodate such conditions, but the options described in Chapter 5 of this paper, including interruptible customers, may help to alleviate the impact.

Recent EU regulation 994/2010 for security of supply sets out (winter) supply criteria for 1-in-20 year conditions. Although the regulation addresses some aspects of winter volume requirements, the 1-in-20 winter volume conditions on which the analysis of this paper is based are the more demanding of the two.

Concluding observations: Options will play an essential role for security of supply.

In a liberalised market, market players' customer bases change over time, while cost-competitiveness is a critical condition for their profitability. In such an environment, they will not and cannot provide full security of supply for any cold winter to their current and potential customers at any time. Certainly over the medium and longer term, the suppliers cannot be sure what customers they will serve (obviously suppliers will make arrangements for their customers to the extent that there is a legal or contractual obligation). This medium- to longer-term outlook is important because investments in the required gas infrastructure have lead times of 3-7 years and project lives of 20-30 years.

There is no common legislation across Northwest Europe that requires firms to secure sufficient supplies for all gas consumers through a severe winter in the medium/long term future, as is the focus of this report. It would be difficult to introduce such legislation in a way that would ensure that the required level of security be provided in a cost-efficient manner.

While storage certainly continues to have an anchor role in catering for winter demand, new alternatives are being considered by market parties to provide gas for their customers, including winter supplies, like purchases on the spot market or LNG markets. It implies that they may decide to invest in extra pipeline, storage and/or regasification capacity to be able to arrange for cost-effective supplies from a portfolio of choice whenever the market calls. Each option carries its own cost and risk profile.

For market players, creating such options is an effective way to deal with the uncertainties and opportunities inherent to operating in a competitive gas market. The "by-product" can be more security in a cold winter.

This is illustrated by our study. For example, the LNG regasification terminal in the Netherlands and the smaller storages in caverns were not developed specifically because of concerns over supplies in a cold winter, but they may be able to make a critical contribution to this effect. The market players that have contracted capacity in this facility have acquired an option to buy LNG on the world market, be it under long-term contract or on the spot market. For consumers in Northwest Europe, this option adds security of supply at no additional costs**.**

Encouraging and facilitating such investments in supply options will not only help to create the business environment needed by industry to position itself competitively in the market but will also offer the best prospects for added security to consumers in a liberalised market.

Annex: Gas storages in Northwest Europe

Country	Company	Name of facility	Type of facility	Kind of investment	Status of investment	(Expected) WV(mcm)#	Expected date	Last Update	Source
Belgium	Fluxys	Loenhout	Aquifer	Existing	Existing	650	Existing	May-10	GSE
Belgium	Fluxys	Loenhout (remaining)	Aquifer	Expansion	U.C.	50	By 2015	Jan-10	GSE
Denmark	Energinet.dk Gaslager	Lille Torup	Salt Cavity	Existing	Existing	420	Existing	May-10	GSE
Denmark	DONG Storage	Stenlille	Aquifer	Existing	Existing	560	Existing	May-10	GSE
Denmark	DONG Storage	Stenlille	Aquifer	Expansion	U.C.	30	By 2015	Jan-10	GSE
France	Storengy	SERENE Nord		Existing	Existing	2110	Existing	May-10	GSE
		Germiny-s-Coulombs	Aquifer						
		Saint-Clair-sur-Epte	Aquifer						
		Cerville	Aquifer						
		Trois Fontaines	Depleted Field						
France	Storengy	SEDIANE Littoral, SERENE Sud		Existing	Existing	4475	Existing	May-10	GSE
		Chémery	Aquifer						
		Céré-la-Ronde	Aquifer						
		Soings-en-Sologne							
France	Storengy	SEDIANE		Existing	Existing	1185	Existing	May-10	GSE
		Beynes Profond	Aquifer						
		Beynes Supérieur	Aquifer						
		Saint-Illiers	Aquifer						

Country	Company	Name of facility	Type of facility	Kind of investment	Status of investment	(Expected) WV(mcm)#	Expected date	Last Update	Source
France	Storengy	SEDIANE B		Existing	Existing	1280	Existing	May-10	GSE
		Gournay-sur-Aronde	Aquifer						
France	Storengy	SALINE, SALINE Multi		Existing	Existing	754	Existing	May-10	GSE
		Etrez	Salt Cavity						
		Tersanne	Salt Cavity						
France	Geomethane	Manosque	Salt Cavity	Existing	Existing	274	Existing	May-10	GSE
France	TIGF	Izaute	Aquifer	Existing	Existing	1440	Existing	May-10	GSE
France	TIGF	Lussagnet	Aquifer	Existing	Existing	1127	Existing	May-10	GSE
France	Storengy	Céré La Ronde / Soings	Aquifer	Expansion	U.C.	60	By 2015	Jan-10	GSE
France	Storengy	Céré La Ronde	Aquifer	Expansion	Planned	200	Beyond 2015	Jan-10	GSE
France	Storengy	Etrez / Manosque	Salt cavity	Expansion	Planned	260	Beyond 2015	Jan-10	GSE
France	Storengy	Etrez / Manosque	Salt cavity	Expansion	U.C.	140	By 2015	Jan-10	GSE
France	Storengy	Hauterives	Salt cavity	New	U.C.	100	By 2015	Jan-10	GSE
France	Storengy	Serene Nord/Gournay	Aquifer	Expansion	U.C.	100	By 2015	Jan-10	GSE
France	Storengy	Alsace Sud	Salt cavity	New	Planned	200	Beyond 2015	Jan-10	GSE
France	Storengy	Trois Fontaines	Reservoir	New	U.C.	80	By 2015	Jan-10	GSE
France	TIGF	Izaute/Lussagnet	Aquifer	Expansion	U.C.	360	Beyond 2015	Jan-10	GSE
France	TIGF	Pécorade	Reservoir	New	Planned	750	By 2015	Jan-10	GSE
Germany	E.ON. Gas Storage	Krummhörn	Salt Cavity	Existing	Existing	39	Existing	May-10	GSE
Germany	E.ON. Gas Storage	Epe EGS H-Gas	Salt Cavity	Existing	Existing	1378	Existing	May-10	GSE

Country	Company	Name of facility	Type of facility	Kind of investment	Status of investment	(Expected) WV(mcm)#	Expected date	Last Update	Source
Germany	E.ON Gas Storage	Epe EGS L-Gas	Salt Cavity	Existing	Existing	492	Existing	May-10	GSE
Germany	Deutsche Essent	Epe EEG	Salt Cavity	Existing	Existing	265	Existing	May-10	GSE
Germany	RWE Gasspeicher GmbH	Epe RWE	Salt Cavity	Existing	Existing	478	Existing	May-10	GSE
Germany	E.ON. Gas Storage	Hähnlein	Aquifer	Existing	Existing	80	Existing	May-10	GSE
Germany	E.ON. Gas Storage	Stockstadt	Salt Cavity / Aquifer	Existing	Existing	135	Existing	May-10	GSE
Germany	E.ON. Gas Storage	Bierwang	Depleted Gas Field	Existing	Existing	1441	Existing	May-10	GSE
Germany	E.ON Gas Storage (share)	Etzel Erdgas Lager EGL	Salt Cavity	Existing	Existing	808	Existing	May-10	GSE
Germany	StatoilHydro Deutschland GmbH - NorskHydro -Total - ConocoPhillips (share)	Etzel Erdgas Lager EGL	Salt Cavity	Existing	Existing	284	Existing	May-10	GSE
Germany	E.ON Gas Storage (share)	Empelde	Salt Cavity	Existing	Existing	10	Existing	May-10	GSE
Germany	E.ON Gas Storage (share)	Eschenfelden	Aquifer	Existing	Existing	48	Existing	May-10	GSE
Germany	N-ERGIE (share)	Eschenfelden	Aquifer	Existing	Existing	24	Existing	May-10	GSE
Germany	E.ON. Gas Storage (share)	Sandhausen	Aquifer	Existing	Existing	15	Existing	May-10	GSE
Germany	GVS Gasversorgung Suedeutschland (share)	Sandhausen		Existing	Existing	15	Existing	May-10	GSE
Germany	BEB Speicher GmbH	Dötlingen	Depleted Gas Field	Existing	Existing	1065	Existing	May-10	GSE

Country	Company	Name of facility	Type of facility	Kind of investment	Status of investment	(Expected) WV(mcm)#	Expected date	Last Update	Source
Germany	BEB Speicher GmbH	Uelsen	Depleted Gas Field	Existing	Existing	750	Existing	May-10	GSE
Germany	BEB Speicher GmbH	Harsefeld	Salt Cavity	Existing	Existing	128	Existing	May-10	GSE
Germany	RWE Gasspeicher GmbH	Kalle	Aquifer	Existing	Existing	215	Existing	May-10	GSE
Germany	RWE Gasspeicher GmbH	Xanten	Salt Cavity	Existing	Existing	188	Existing	May-10	GSE
Germany	Kavernenspeicher Staßfurt GmbH	Stassfurt	Salt Cavity	Existing	Existing	200	Existing	May-10	GSE
Germany	VNG	Buchholz	Aquifer	Existing	Existing	175	Existing	May-10	GSE
Germany	VNG	Bernburg	Salt Cavity	Existing	Existing	1091	Existing	May-10	GSE
Germany	VNG	Bad Lauchstädt	Salt Cavity / Depleted Gas Field	Existing	Existing	1104	Existing	May-10	GSE
Germany	VNG	Kirchheiligen	Depleted Gas Field	Existing	Existing	190	Existing	May-10	GSE
Germany	RWE Dea for E.ON Gas Storage	Inzenham-West	Depleted Gas Field	Existing	Existing	500	Existing	May-10	GSE
Germany	RWE Dea	Wolfersberg	Depleted Gas Field	Existing	Existing	320	Existing	May-10	GSE
Germany	RWE Dea / ExxonMobil / for E.ON Gas Storage	Breitbrunn/Eggstätt	Depleted Gas Field	Existing	Existing	1080	Existing	May-10	GSE
Germany	Storengy Deutschland GmbH	Peckensen	Salt Cavity	Existing	Existing	60	Existing	May-10	GSE
Germany	Storengy Deutschland GmbH	Fronhofen-Trigonodus		Existing	Existing	36	Existing	May-10	GSE

Country	Company	Name of facility	Type of facility	Kind of investment	Status of investment	(Expected) WV(mcm)#	Expected date	Last Update	Source
Germany	Wingas	Rehden	Depleted Gas Field	Existing	Existing	4200	Existing	May-10	GSE
Germany	EWE	Huntorf - L	Salt Cavity	Existing	Existing	315	Existing	May-10	GSE
Germany	EWE	Neuenhuntorf	Salt Cavity	Existing	Existing	17	Existing	May-10	GSE
Germany	EWE	Nüttermoor - H	Salt Cavity	Existing	Existing	321	Existing	May-10	GSE
Germany	EWE	Nüttermoor - L	Salt Cavity	Existing	Existing	765	Existing	May-10	GSE
Germany	EWE for E.ON Gas Storage	Nüttermoor	Salt Cavity	Existing	Existing	110	Existing	May-10	GSE
Germany	EWE	Rüdersdorf	Salt Cavity	Existing	Existing	40	Existing	May-10	GSE
Germany	Stadtwerke München	Schmidhausen	Depleted Gas Field	Existing	Existing	150	Existing	May-10	GSE
Germany	Deilmann-Haniel	Lehrte	Oil Depleted Field	Existing	Existing	40	Existing	May-10	GSE
Germany	EON Hanse	Reitbrook	Oil Field with Gas Cap	Existing	Existing	380	Existing	May-10	GSE
Germany	ExxonMobil	Bremen-Lesum	Salt Cavity	Existing	Existing	204	Existing	May-10	GSE
Germany	Bremen Stadtwerke	Bremen-Lesum	Salt Cavity	Existing	Existing	78	Existing	May-10	GSE
Germany	Enovos - subsidiary of Creos	Frankenthal	Aquifer	Existing	Existing	63	Existing	May-10	GSE
Germany	Berliner Gaswerke	Berlin	Aquifer	Existing	Existing	780	Existing	May-10	GSE
Germany	Contigas	Allmenhausen	Depleted Gas Field	Existing	Existing	55	Existing	May-10	GSE
Germany	Kiel Stadtwerke	Kiel-Rönne	Salt Cavity	Existing	Existing	60	Existing	May-10	GSE
Germany	Hamburger Stadtwerke	Kraak	Salt Cavity	Existing	Existing	117	Existing	May-10	GSE
Germany	Gas-Union	Reckrod	Salt Cavity	Existing	Existing	82	Existing	May-10	GSE
Germany	EDF / EnBW	Etzel	Salt cavity	New	U.C.	360	By 2015	Jan-10	GSE

Country	Company	Name of facility	Type of facility	Kind of investment	Status of investment	(Expected) WV(mcm)#	Expected date	Last Update	Source
Germany	E.ON Gas Storage	Etzel EGS	Salt cavity	New	Permitting Phase	2500	Beyond 2015	Jan-10	GSE
Germany	E.ON Gas Storage	Etzel EGL (share EGS)	Salt cavity	Expansion	U.C.	154	By 2015	Jan-10	GSE
Germany	E.ON Gas Storage	Epe EGS H-Gas	Salt cavity	Expansion	U.C.	245	By 2015	Jan-10	GSE
Germany	E.ON Gas Storage	Jemgum	Salt cavity	New	U.C.	2000	Beyond 2015	Jan-10	GSE
Germany	E.ON Gas Storage	Krummhörn	Salt cavity	Expansion	U.C.	229	By 2015	Jan-10	GSE
Germany	E.ON Gas Storage	Bierwang	Reservoir	Expansion	U.C.	359	By 2015	Jan-10	GSE
Germany	E-ON Hanse	Kraak	Salt cavity	Expansion	U.C.	120	By 2015	Jan-10	GSE
Germany	Essent Energie Gasspeicher GmbH	Epe	Salt cavity	New	U.C.	200	By 2015	Jan-10	GSE
Germany	EWE	Nuentermoor	Salt cavity	Expansion	U.C.	210	By 2015	Jan-10	GSE
Germany	EWE	Ruedersdorf	Salt cavity	Expansion	U.C.	78	By 2015	Jan-10	GSE
Germany	EWE	Jemgum	Salt cavity	New	U.C.	220	By 2015	Jan-10	GSE
Germany	Gas Union	Reckrod	Salt cavity	New	Planned	30	By 2015	July-07	GSE
Germany	GHG	Empelde	Salt cavity	New	Planned	110	By 2015	July-07	GSE
Germany	Nuon	Epe	Salt cavity	Expansion	U.C.	80	By 2015	Jan-10	GSE
Germany	RWE Gasspeicher GmbH	Stassfurt	Salt cavity	Expansion	Permitting Phase	600	Beyond 2015	Jan-10	GSE
Germany	RWE Gasspeicher GmbH	Xanten	Salt cavity	Expansion	Planned	125	Beyond 2015	Jan-10	GSE
Germany	RWE Dea	Wolfersberg	Reservoir	Expansion	U.C.	45	By 2015		GSE
Germany	Creos	Frankenhal	Aquifer	Expansion	Planned	130	By 2015	July-07	GSE

Country	Company	Name of facility	Type of facility	Kind of investment	Status of investment	(Expected) WV(mcm)#	Expected date	Last Update	Source
Germany	SPC Rheinische Epe Gasspeicher GmbH&Co KG / Essent Energy Productie B.V.	Epe	Salt cavity	New	Planned	365	By 2015	June-08	GSE
Germany	Storengy Deutschland GmbH	Behringen	Reservoir	New	Planned	1000	By 2015	Jan-10	GSE
Germany	Storengy Deutschland GmbH	Peckensen (Phase I)	Salt cavity	New	U.C.	160	By 2015	Jan-10	GSE
Germany	Storengy Deutschland GmbH	Peckensen (Phase III)	Salt cavity	New	U.C.	180	By 2015	Jan-10	GSE
Germany	Storengy Deutschland GmbH	Ohrensen	Salt cavity	New	Planned	440	Beyond 2015	Jan-10	GSE
Germany	VNG	Bernburg	Salt cavity	Expansion	U.C.	71	By 2015	Jan-10	GSE
Germany	VNG	Bad Lauchstädt	Salt cavity	Expansion	U.C.	65	By 2015	Jan-10	GSE
Germany	VNG	Bad Lauchstädt	Salt cavity	Expansion	U.C.	195	Beyond 2015	Jan-10	GSE
Germany	Wingas	Jemgum	Salt cavity	Expansion	U.C.	280	Beyond 2015	Jan-10	GSE
Germany	Wingas	Jemgum	Salt cavity	New	U.C.	820	By 2015	Jan-10	GSE
Germany	Wintershall	Reckrod-Walf	Salt cavity	New	Planned	120	By 2015	July-07	GSE
Ireland	Kinsale Energy	Kinsale Southwest	Depleted Field	Existing	Existing	218	Existing	May-10	GSE
NL	TAQA Energy BV	Alkmaar	Depleted Gas Field	Existing	Existing	500	Existing	May-10	GSE
NL	NAM	Grijpskerk	Gas Field (not depleted)	Existing	Existing	1500	Existing	May-10	GSE

Country	Company	Name of facility	Type of facility	Kind of investment	Status of investment	(Expected) WV(mcm)#	Expected date	Last Update	Source
NL	NAM	Norg	Gas Field (not depleted)	Existing	Existing	3000	Existing	May-10	GSE
NL	NAM	Grijpskerk/Norg	Gas Field (not depleted)	Expansion	Planned	4396	By 2015	Dec-10	CIEP a.o.*
NL	NAM	Grijpskerk/Norg	Gas Field (not depleted)	Expansion	Planned	4396	Beyond 2015	Jan-11	CIEP a.o.*
NL	Gasunie Zuidwending BV	Zuidwending	Salt cavity	New	U.C.	300	By 2015	Jan-10	GSE
NL	TAQA	Bergermeer	Reservoir	New	Permitting Phase with FID	4100	By 2015	Jan-10	GSE/ CIEP*
NL	Zuidwending VOF	Zuidwending	Salt cavity	New	U.C.	180	By 2015	Jan-10	GSE
UK	Centrica Storage	Rough	Offshore Depleted Field	Existing	Existing	3300	Existing	May-10	GSE
UK	EDF Trading (EDFT)	Hole House Farm	Salt Cavity	Existing	Existing	55	Existing	May-10	GSE
UK	Scottish Power	Hatfield Moor	Depleted Gas Field	Existing	Existing	117	Existing	May-10	GSE
UK	SSE (Scottish & Southern)	Hornsea	Salt Cavity	Existing	Existing	325	Existing	May-10	GSE
UK	SSE / StatoilHydro	Aldbrough	Salt Cavity	Existing	Existing	115	Existing	May-10	GSE

Country	Company	Name of facility	Type of facility	Kind of investment	Status of investment	(Expected) WV(mcm)#	Expected date	Last Update	Source
UK	StarEnergy	Humbly Grove	Depleted Oil Field	Existing	Existing	279	Existing	May-10	GSE
UK	StarEnergy	Albury Phase 1	Reservoir	New	Planned	170	Beyond 2015	Jan-10	GSE
UK	StarEnergy	Albury Phase 2	Reservoir	Expansion	Planned	730	Beyond 2015	Jan-10	GSE
UK	SSE / Statoil	Aldbrough (Phase II)	Salt cavity	Expansion	Permitting Phase	330	By 2015	Jan-10	GSE
UK	Centrica / GDF Suez / First Oil	Bains (offshore)	Reservoir	New	Planned	570	By 2015	Jan-10	GSE
UK	Centrica/Perenco	Baird (offshore)	Reservoir	New	Planned	1700	By 2015	Jan-10	GSE
UK	StarEnergy	Bletchingley	Salt cavity	New	Planned	850	Beyond 2015	Jan-10	GSE
UK	EDF Energy / British Salt	British Salt	Salt cavity	New	Planned	100	Beyond 2015	Jan-10	GSE
UK	Centrica plc	Caythorpe	Reservoir	New	Permitting Phase	210	By 2015	Jan-10	GSE
UK	EnCore	Esmond / Gordon (offshore)	Reservoir	New	Planned	4100	By 2015	Jan-10	GSE
UK	Canatxx	Fleetwood	Salt cavity	New	Planned	1200	Beyond 2015	Jan-10	GSE
UK	Gateway Storage	Gateway	Salt cavity	New	Planned	1500	By 2015	Jan-10	GSE
UK	ENI / Perenco	Hewett (offshore)	Reservoir	New	Planned	5000	By 2015	Jan-10	GSE
UK	EDF Energy	Hole House (Phase III)	Salt cavity	New	U.C.	100	Beyond 2015	Jan-10	GSE

Country	Company	Name of facility	Type of facility	Kind of investment	Status of investment	(Expected) WV(mcm)#	Expected date	Last Update	Source
UK	E.ON. Gas Storage UK	Holford (formerly Byley)	Salt cavity	New	U.C.	165	By 2015	Jan-10	GSE
UK	Portland Gas	Isle of Portland	Salt cavity	New	Permitting Phase	1000	By 2015	Jan-10	GSE
UK	Portland Gas / NIEH	Larne Lough	Salt cavity	New	Planned	500	By 2015	Jan-10	GSE
UK	Storengy UK Ltd	Stublach	Salt cavity	New	U.C.	400	Beyond 2015	Jan-10	GSE
UK	StarEnergy	Welton / Scampton North	Reservoir	New	Planned	450	Beyond 2015	Jan-10	GSE
UK	E.ON. Gas Storage UK	Whitehill Farm	Salt cavity	New	Permitting Phase	420	By 2015	Jan-10	GSE
UK	Wingas / Gazprom Germania	Saltfleetby	Reservoir	New	Permitting Phase	715	By 2015	Jan-10	GSE
Austria	RAG	Aigelsbrunn	Reservoir	New facility	U.C.	85	By 2015	Jan-10	GSE
Austria	RAG/Wingas/Gazprom Export	Haidach	Reservoir	Expansion	U.C.	1460	By 2015	Jan-10	GSE
Austria	RAG / E.ON. Gas Storage	7 Fields	Reservoir	New facility	U.C.	1150	By 2015	Jan-10	GSE
Austria	RAG / E.ON. Gas Storage	7 Fields	Reservoir	Expansion	U.C.	600	By 2015	Jan-10	GSE

* as discussed in the paper

WV= Working Volume
Mcm= Million cubic metres
U.C. = Under Construction