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**Working Paper**

## Demand for storage of natural gas in Northwestern Europe: a simulation based forecast 2006-2030

Preprints of the Max Planck Institute for Research on Collective Goods, No. 2006,9

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Max Planck Institute for Research on Collective Goods

*Suggested Citation:* Höfler, Felix; Kübler, Madjid (2006) : Demand for storage of natural gas in Northwestern Europe: a simulation based forecast 2006-2030, Preprints of the Max Planck Institute for Research on Collective Goods, No. 2006,9, Max Planck Institute for Research on Collective Goods, Bonn

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A simulation based  
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March 2006

# Demand for storage of natural gas in northwestern Europe. A simulation based forecast 2006-2030<sup>‡</sup>

Felix Höffler<sup>\*</sup>

Madjid Kübler<sup>#</sup>

March 24, 2006

## Abstract

The seasonal demand for natural gas requires supply flexibility. This “swing” is now largely provided in northwestern Europe by indigenous production. Declining reserves will increase the dependency on imports from far-off sources, which are less flexible. Hence, flexibility must be provided by additional storage. We estimate that in 2030 (depending on the desired level of security of supply) between 11 and 37 billion cubic meter of working gas volume will be required, in addition to the existing 37 billion cubic meters. This estimation is based on production and consumption forecasts for natural gas and observations of the relationship between the supply and demand of gas and the supply and demand of flexibility in the period 1995-2004. Scenarios and Monte Carlo simulations are provided to check for the robustness of our results. We also briefly discuss policy implications for the regulation of third party access to storage facilities.

**Keywords:** Natural gas, storage, swing, third-party access

**JEL-Classification:** L98, L51, Q41

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<sup>‡</sup> We would like to thank Felix Bierbrauer, Christoph Engel and Martin Hellwig for helpful discussion. The usual disclaimer applies.

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# 1. Introduction

Natural gas is the strongest growing primary energy source in western Europe. According to the US Energy Intelligence Agency (EIA, 2005, 94), the consumption of natural gas increased on average by 3.4 per cent per annum between 1990 and 2002. Total primary energy consumption grew only at 1 per cent in the same period. While growth is projected to slow down, natural gas is projected to remain the strongest growing primary energy source in the future (with a compound annual growth [CAGR] of 1.8 per cent compared to 0.5 per cent CAGR for the total primary energy consumption for 2002-2025).<sup>1</sup>

Since natural gas is largely used for heating, consumption is subject to a significant seasonal swing. In northwestern Europe<sup>2</sup> (NWE) approximately two-thirds of the gas is consumed during the winter (October till March). For local gas providers, it is not uncommon to have daily peaks in gas delivery in the winter amounting to ten times the delivery on a summer day. This strong seasonal consumption profile requires flexibility on the supply side. In NWE there are two main sources of flexibility: production and storage. The significant indigenous production in the region (in particular of the highly flexible Dutch Groningen gas field) provides considerable “swing”. Imports from more remote sources (like Russia) show a far flatter profile due to the high capital cost of the pipelines, which call for a constant high utilization.

However, since the flexible indigenous production will decrease and has to be replaced by less flexible imports, more flexibility has to come from the second source, namely gas storage facilities. Our research question is: How much (new) storage is required to deal with the foreseeable change in the supply structure of NWE?

To answer this, we propose a simple top-down analysis. We start from the IEA’s forecast for the overall gas consumption in NWE in 2030. Based on historical ratios of gas consumption and the seasonal swing in the 1995-2004 period, we forecast the demand for seasonal swing in the year 2030. Employing a similar approach, we take an existing prediction for the supply structure of natural gas for NWE in 2030 from EUGAS, a forecast model of the German EWI (Institute for Energy Economics, see Bothe and Seeliger 2005). Again, based on historical observations of the ability to supply swing from production for each country of origin, we approximate the possible swing supply from production and imports in 2030.

Comparing these figures to the storage facilities which exist in 2005 or are already planned, we find a gap of at least 7.2 to 11.4 billion cubic meters (BCM) of the required working gas volume. This is in the order of one-quarter to one-third of the facilities operational in 2005. Taking additional security of supply considerations into account, this gap can be expected to be even higher, i.e. between 33.6 to 36.9 BCM.

Thus, our main finding is that the projected growth in gas consumption is inconsistent with the current level of gas storage facilities in NWE. Since the triggering event for this gap – the depletion of indigenous

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1 The International Energy Agency (IEA 2005, I.17) also projects that the gas consumption in the European Union will grow at 1.8 per cent per year until 2030.

2 Northwestern Europe, in the definition of the paper, comprises Belgium, Denmark, France, Germany, the Netherlands, Switzerland, and the UK. Western Europe in the EIA definition includes also Austria, Finland, Greece, Iceland, Ireland, Italy, Luxembourg, Norway, Portugal, Spain, and Sweden.

gas fields – is largely undisputed, this implies that either gas demand cannot grow (without new storages, it would have to decrease) or new storage facilities have to be built. Alternatively, price signals might adjust the structure of gas supply and gas demand such that demand exhibits less swing and supply – even from more distant fields – becomes more flexible (as far as this is technically feasible).

Our findings of a significant long-term shortage of underground gas storage have strong policy implications. Liberalization of the European gas markets requires third-party access to essential facilities of the network infrastructure. Although there is no consensus on whether or not storage is part of the network infrastructure, European energy regulators have agreed on guidelines for third-party access to storage facilities (REGEG 2004). However, regulation of assets tends to reduce the incentive to invest. Therefore, European legislation allows for exemptions from regulation for new investments. Our analysis tends to support the view that such exemptions are indeed sensible.

Our forecast is heavily dependent on strong assumptions about the underlying parameters, and it leaves out a couple of additional important factors which are hard to quantify. Therefore, we provide a Monte Carlo analysis of our basic model with plausible, though ad hoc, distributions for the underlying parameters. Furthermore, we discuss additional influences, like the impact of regulation or policy decisions such as those in most countries calling for the compulsory holding of strategic stock similar to the oil reserves.

There exists a literature, mainly applied, on gas storages. In a recent book, Grewe (2005) studies the German market for gas storage in detail. In a report to the Dutch regulator DTe, the consulting firm Frontier Economics (2005) analyzed the market structure in the Dutch market for flexibility. In an older study, Cornot-Gandolphe (1995) examines the European market for flexibility. That new storage facilities will be required due to increases in the gas demand has also been noted by the UN/ECE (2000) in a forecast up to 2010. In its energy outlook, the IEA (2005, I.18) stresses the change in the supply structure that is to be expected, but it does not elaborate on the consequences for the market for flexibility. In a large study on the security of supply (IEA 2004), the IEA provides a valuable overview of how OECD countries currently use storages as strategic stock. We want to contribute to this literature by (i) using a transparent forecasting method, (ii) relying on a precise import split for gas with respect to the country of origin, (iii) checking for the robustness of the results using scenarios and Monte-Carlo simulation, and (iv) by using up-to-date, publicly available data.

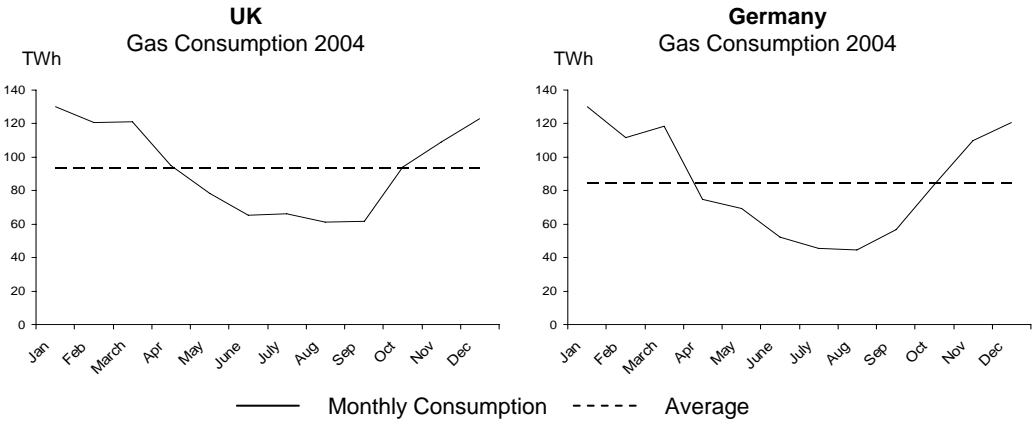
The remainder of the paper is organized as follows. Section two describes technical details and the status quo in the provision of flexibility in NWE. Section three explains how we derive our forecasts. Section four presents the results and analyses them with the help of different scenarios and Monte Carlo techniques. Section 5 discusses additional factors not covered in the quantitative analysis. Section 6 concludes and proposes policy implications.

## 2. Status quo of flexibility provision in NWE

The focus of our analysis is NWE, which accounted for almost three-quarters of the gas consumption in Western Europe in the period mentioned (see footnote 1 for the regional definitions). The countries of this region share important characteristics. First, and most importantly, all these countries use large amounts of natural gas from the North Sea. It is precisely the depletion of North Sea gas fields which is triggering the change in the supply structure we want to examine. Second, and related, the major gas flows, and, therefore the infrastructure, connect these countries in North-South flows from the North Sea. Third, most countries have significant indigenous production. The flexibility from their own production has made gas storage less important.<sup>3</sup>

The gas demand of these mature gas markets is heavily driven by the residential heat market. Thus, the consumption profile reflects the strong usage for heating purposes in winter compared to the summer consumption, which, for its part, is mainly due to industrial customers and power plants. Although there is additional, more short-term, variability in the demand structure (between night and day, working day versus the weekend), we will base our analysis on the seasonal swing. Figure 1 provides data of the annual consumption profile of the UK and Germany, the two largest gas consuming countries in Western Europe. Both countries use approximately two-thirds of their gas in the winter months (October to March).

**Figure 1: Load profile 2004 of UK and Germany**



Source: International Energy Agency 'Natural Gas Balance'

For the purposes of the paper, we want to define “swing” simply as the difference between the sum of the winter values and the sum of the summer values of a variable, i.e. “swing demand” equals the sum of the winter consumption (defined as the months October to March) minus the sum of the summer consumption. The “swing ratio” is the ratio of the swing divided by the total consumption. For the UK and Germany, this figure was 0.25 and 0.33, respectively, implying

<sup>3</sup> Norway produces a large amount of gas from the North Sea, but has virtually no gas consumption of its own. Eastern and southeastern European countries (including Austria) always used to be heavily dependent on Russian gas and had to provide flexibility through storage. Thus, there is no major change to be expected. Italy – the only major Western European gas consumer not covered in our analysis – and Spain get the majority of their gas supply from Africa.

that the “above-average” demand in winter was 25 and 33 per cent of the annual demand, respectively.

We take the swing demand as given, which essentially means to assume a price inelastic demand, which is also inflexible with regard to timing. Note that peak load pricing, which tries to shift demand from “peak” times to “off-peak”, is unlikely to shift gas demand. The reason for the seasonal swing is the heating demand in winter. Obviously, households cannot substitute heating in the winter by heating in the summer (like they can do by, e.g., substituting telephone calls in peak hours by off-peak calls). Also industrial demand is unlikely to exhibit the flexibility to substitute production in the winter by production in the summer.

There are essentially three ways to meet the seasonal swing demand: first, by flexible production, i.e. by producing less in the summer than in the winter; second, by flexibility in import contracts; third, by storing gas in the summer and releasing it in the winter.<sup>4</sup>

Each alternative is costly. Production of natural gas exhibits strong economies of scale. The fixed and sunk costs of exploration and the installation of production facilities are huge, while the variable costs of production are small. Thus, using production facilities up to the maximum capacity all the time is the most cost-effective method of energy production. Also it has to be differentiated into pure gas production and associated gas production; in the latter, the production schedule is driven by the oil production. In addition, many fields have technical limitations to the variation in output.

A similar logic applies to transportation. Long pipelines, e.g. from Russia to France, require large investments and thus cause high capital costs. Thus, leaving capacity idle is costly, and these costs increase with the distance of transportation.

Large underground storage facilities are suitable to provide enough volume (known as “working gas volume”, WGV) to balance seasonal swing and also require significant investments.

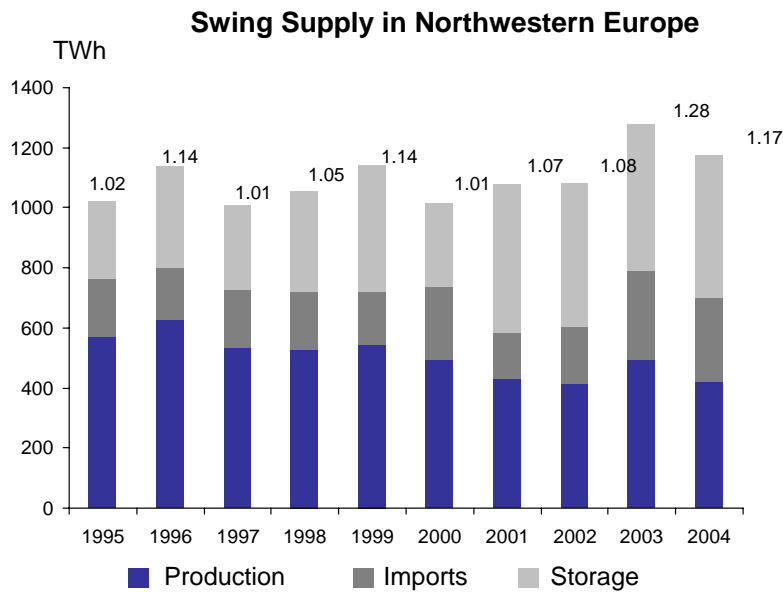
Figure 2 shows how, in the 1995-2004 period, the seasonal swing was met by the three different forms of supply flexibility in NWE. NWE is treated as an aggregate such that exports and imports within the region cancel out. Storage and swing from production are the main suppliers of flexibility.

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4 To a limited extent, “line pack” can also be used, i.e. storage in the pipeline system, and liquefied natural gas (LNG). However, this as well as surface storage is much smaller and best suited for short-term peak shaving.



**Figure 2: Swing Supply in NWE 1995-2004**



Source: International Energy Agency 'Natural Gas Balance'

The data show a clear trend: as a swing supplier, storage became increasingly more important than in indigenous production. While (for a three year average) in the beginning of the period, production accounted for 55 per cent of the swing supply, its contribution declined to 38 per cent at the end. Since the share of import swing remained stable at about 20 per cent, the contribution of storage rose from below 30 per cent to more than 40 per cent.

The largest part of swing from indigenous production stems from the Netherlands (in 2003: approximately 63 per cent), in particular from one large gas field in Groningen, which is very well suited to provide flexibility (in 2003 Groningen accounted for 48 per cent of all production swing in NWE).<sup>5</sup>

While production swing is concentrated in the Netherlands, most storage facilities are located in Germany. In 2004 the overall WGV in NWE was 37 BCM, with 19 BCM located in Germany. Storage capacities were increased in Germany by 81 per cent between 1994 and 2004. This increase implies that the maximum storage WGV in NWE is now well above the level of storage currently used.<sup>6</sup> For example, in 2004 only 55 per cent of the storage capacities were actually used. This is, however, not necessarily a sign of excess capacities, since gas companies hold reserves (buffer) for extremely cold winters.

A series of additional storage facilities are planned within NWE. The total amount of planned storage is approximately 18 BCM WGV, equivalent to a little less than 50 per cent of existing

5 This figure is calculated using the Dutch regulator's Data, cited by Frontier Economics (2005, 28) and the IEA Data "Natural Gas Balance" for 2003.

6 Since we have defined swing as the difference between summer and winter consumption, one unit of storage can provide two units of swing: one is filled in the summer, which is then released in the winter; thus we have  $1 - (-1) = 2$  as the swing supply from one unit of storage.

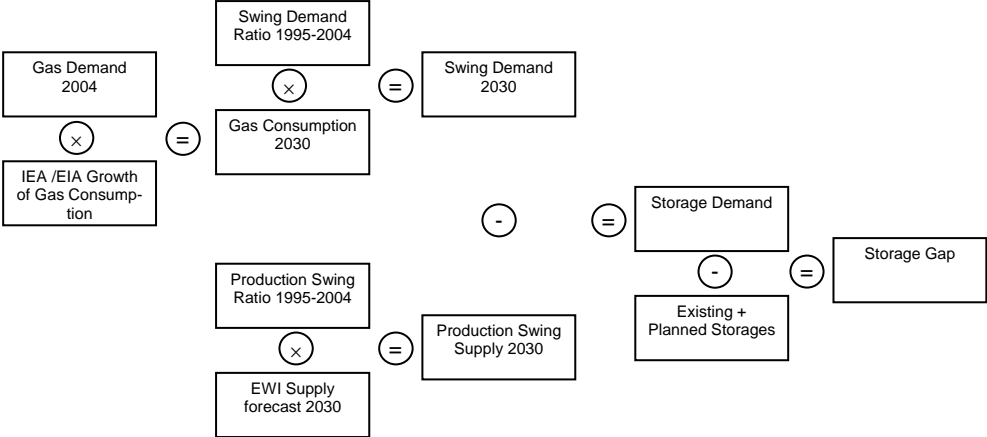
volume. It is not certain whether all of these projects will be finalized and will reach the planned size. Usually it is not clear in the beginning how much WGV a specific site will actually store. It is not uncommon for storage operators, to apply for the absolute maximum storage size in the planning period in order to avoid having to apply for additional authorization in case a site turns out to be more promising than expected.

Furthermore, storage projects are long-term and can take up to ten years to complete. Thus, some of the existing “excess capacities” might be provisions for the expected additional need for flexible storage in the future. In the next section we propose a model to approximate whether the operational and planned storage facilities are sufficient for this purpose.

### 3. Model

We use a simple top-down approach to forecast the demand for flexibility in the year 2030. We take gas demand and gas supply as exogenously given and derive the resulting swing demand and swing supply from production and imports by extrapolation from the current structure. The details of the assumptions and results can be found in the appendix. The results of the model are not equilibrium results, since we do not look at prices. The gas market outcome would be a market equilibrium only if one assumes a perfectly competitive supply of gas and fully price inelastic demand. Figure 3 provides a schematic overview of our approach.

**Figure 3: Approach for extrapolation**



We rely on the demand forecast by the IEA and the EIA for Western Europe and the European Union. Both forecast an annual growth rate of 1.8 per cent. Although the regional coverage of both forecasts includes more countries than NWE, we believe that this is still a valid proxy given that NWE accounts for the vast majority of consumption in Western Europe and the European Union.

To derive the swing that results from this gas demand, we apply the maximum “swing ratio” observed over the period 1995-2004. This provides us – assuming no structural changes in the demand – with a lower bound for the demand for flexibility that has to be met. It is a *lower*

bound since suppliers probably want to be able to meet the peaks, which – in particular in very hard winters – might well exceed the ratios observed from 1995-2004.

Restricting attention to observations from 1995-2004 makes sense since the gas industry is relatively young and has been growing very fast in the last twenty to thirty years. Thus, only the structures in the last 10 years might be sufficiently mature to serve as a basis for extrapolation. Furthermore, this period also includes the winter of 1995/1996, which was a rather cold winter in NWE (i.e. in Germany and Netherlands it was the coldest winter in the last 30 years).

**Figure 4: Temperature Data for NEW (Average winter temperature, C°)**

	Winter 1995/96	Coldest Winter in .... years				
		10	20	30	50	100
Belgium	3.9	3.9	3.6	3.5	1.9	1.9
Denmark	0.9	0.9	0.8	0.8	-0.2	-1.5
France	6.6	6.1	5.3	5.3	3.9	3.9
Germany	1.5	1.5	1.5	1.5	-0.2	-0.2
Netherlands	3.3	3.3	3.3	3.3	1.8	1.8
Switzerland	0.6	0.6	-0.3	-0.5	-2.1	-2.1
UK	5.3	04.8	4.2	4.2	3.7	3.7

Source: Tim Mitchell, Tyndall Centre for Climate Change Research, Data Set TYN CY 1.1, downloadable <http://www.cru.uea.ac.uk/~timm/cty/obs/>

In the past, gas suppliers held significant buffers on top of that. Often they attempted to be prepared for the hardest winter in the last fifty years. At least under current legislation, they are often obliged to do so, e.g. in France and Belgium.<sup>7</sup> Instead of using average temperatures, the industry refers to the concept of “degree days”, which tries to provide a better proxy for the influence of the weather on the heating behavior. Definitions, however, differ between countries, thus, as a short cut, we use the maximum value of the last ten years and will discuss different scenarios in Section 5.

On the supply side, we borrow estimations from Bothe and Seeliger (2005).<sup>8</sup> They use the EUGAS model, which assumes a least cost provision of gas. They also take the IEA consumption forecast as a given exogenous parameter, and calculate how this demand – until 2030 – can be met for each European country by the lowest cost producer (taking into account some policy and diversification motives of importing countries). This essentially means to assume a competitive supply of natural gas and a price inelastic demand for natural gas.

This provides us with a regional split in the country of origin for the natural gas supply in 2030. This is important since different countries exhibit different abilities to supply swing from their production. Again, we take the swing ratios from the observations in 1995-2004, use the average

7 IEA (2004) Security of Gas Supply in Open Markets, p. 345-346. Other countries, like Denmark, the Netherlands, Spain, and UK, have similar obligations.  
 8 We are particularly grateful to them for providing us with a regional split from their model for our NWE definition for the country of origin of the natural gas supply in 2030.

and just multiply the result with the supply figures from Bothe and Seeliger. This provides an upper bound for the supply of swing, from production and imports. True swing supply will probably be lower since (i) the depleting fields in NWE will be less able to supply swing, and (ii) imports, in particular from Russia, will come from more distant fields, also reducing the swing capability.

We finally compare the lower bound of swing demand to the upper bound of swing supply from production and consumption to derive the minimum demand for storage; we compare this to the sum of all operating and all planned storage facilities to derive the minimum additional need for storage.

The calculations rest on a series of very strong assumptions. In particular, we assume that, in the year 2030, supply and demand will have the same characteristics with respect to seasonal swing as observed in 1995-2004. We will discuss these assumptions in Section 5, where we will argue that plausible assumptions about structural changes will not qualitatively alter, but rather strengthen, our results.

## **4. Results**

We present four kinds of results. We start by providing the extrapolation (point prediction) for the minimum additional storage required in NWE that results from the model just described, which we will refer to as the “base line scenario”. Second, as an additional scenario to this base case, we add security of supply considerations. Third, we propose some adjustments to the underlying parameters, which, in our view, make the predictions more realistic. We will refer to this as the “realistic scenario”. Forth, we present results from a Monte Carlo simulation to get a sense of the robustness of the predictions.

### **Extrapolation**

Assuming an annual growth rate of 1.8 per cent per year, the gas demand will amount to 5.421 TWh in 2030. Using swing ratios from the period 1995-2004, this translates into a swing demand of 1.965 TWh (see Table 1).

**Table 1: Swing Demand in 2030**

	Average consumption 2004	CAGR	Gas demand 2030	Max. swing ratio 1995- 2004	Swing demand 2030
	(1)	(2)	(3)	(4)	(5) = (3) x (4)
unit	TWh	CAGR (%)	TWh	Ratio	TWh
<b>NWE</b>	<b>3.349</b>	<b>1,8%</b>	<b>5.421</b>		<b>1965,0</b>
Belgium	171	1,8%	276	0,29	79,2
Denmark	60	1,8%	97	0,36	35,4
France	506	1,8%	819	0,47	384,2
Germany	1.003	1,8%	1.624	0,36	582,4
Netherlands	460	1,8%	744	0,34	253,0
Switzerland	34	1,8%	55	0,47	25,7
UK	1.115	1,8%	1.805	0,34	605,0

In accord with the values from Bothe and Seeliger (2005), by the year 2030, it will only be possible to meet approximately 19 per cent of the gas demand by indigenous production (while in 2005 it was 56 per cent). The majority now comes from more distant sources, mainly from Russia and other former GUS: In 2030, 35 per cent will come from there (19 per cent in 2005), 17 per cent will come from Africa and the Caribbean (8 per cent in 2005), and 5 per cent from the Middle East (0 per cent in 2005). The change in the country of origin translates into a much smaller swing supply from production. In Table 2, we use the average swing ratio of production from 1995-2004 to derive the (maximum) swing supply from production in 2030.

**Table 2: Swing Supply from Production 2030**

	Gas Supply 2030	Average Swing Ratio 1995-2004	Swing Supply
	(1)	(2)	(3) = (1) x (2)
	TWh	Ratio	TWh
NWE	1.023	0,28	281
Norway	1.253	0,12	146
Russia and ex-GUS	1.894	0,03	61
Middle East	313	0,03	10
Africa	938	0,04	37
<b>Total</b>	<b>5.421</b>		<b>535</b>

Source: Gas Supply 2030 based on IEA / EIA forecast and supply split by Bothe and Seeliger 2005.

Comparing the values of Table 2 and Table 1 shows that at least 1.430 TWh of swing will have to be provided by storage in 2030. Even if all currently planned storage is tapped, only 1.265 TWh of the swing supply from storage will be available, leaving a gap of 165 TWh.<sup>9</sup> This is equivalent to a gap in storage of 7.2 BCM of the working gas volume in storage which would be required to supply sufficient flexibility. Since, in 2005, only 37.2 BCM of WGV was opera-

<sup>9</sup> We calculate at 1 BCM = 11.5 TWh. This makes the additional assumption that all storage that is currently run as L-gas (low caloric gas) is transformed to H-gas (high caloric gas) storage. Storage data for NWE are from the IEA, Natural gas information, 2005 edition.

tional, an additional 20 per cent increase in storage will be required. Figure 5 shows that, in this base line scenario, a “storage gap” arises only at the very end of the forecast horizon (bold dotted line).

## **Security of Supply**

We have not yet calculated an additional buffer for the security of supply into our calculations. This means that, with the levels of flexibility calculated so far, it has not been possible to take account of very hard weather conditions or supply interruption for longer time periods.

As already mentioned, it is common to ensure that suppliers are able to meet the demand in weather conditions of the coldest winter in the last 50 years. Although Figure 4 showed that the winter of 1995/96 was rather cold, it was still considerably warmer than the coldest winter in the last 50 years in each country. Thus, an additional buffer for cold winters needs to be taken into account.

It is difficult to estimate the buffer necessary for provision during extreme weather, in particular, since changes in the market structure could alter the attitude of gas companies with respect to this parameter. More competitive pressure might reduce the level of supply security. In Germany, the largest storage provider in NWE in the period from 1994-2004, only about 50 per cent of storage was utilized. Part of the underutilization might be due to the fact that storage has been built for future purposes; this might be reflected in the fact that roughly 20 per cent of the WGV has not even been filled with gas. But even of the gas filled during the summer, 40 per cent has not been used.<sup>10</sup> Assuming a buffer of 40 per cent might, however, be too high. In the 1990s, many new storage facilities came on stream and it often takes several years before the storage is filled up to the maximum level. Discussions with market participants suggest that a buffer of 15 per cent seems to be a reasonable proxy. Thus, we assume an additional 15 per cent buffer for considerations of the security of supply.

A buffer might be held not only for extreme temperatures but also for political reasons. The increasing dependence on imports from outside the European Union raises concerns. During the conflict between Russia and the Ukraine in the winter of 2005/2006, gas deliveries to Western Europe at times dropped by one-third.<sup>11</sup> This might revive plans in the European Union to oblige member states to hold strategic gas stocks (European Commission 2004, 68). France, Italy, and Spain already hold such reserves. In Italy, gas suppliers have to hold 10 per cent of their imports from non-EU countries as strategic reserves. Such obligations block storage facilities used for the normal swing provision.

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10 These calculations are based on data by the German authorities “Niedersächsisches Landesamt für Bodenfor- schung (NLfB)”, <http://www.nlfb.de>.

11 Press release, Austrian Ministry of Economic Affairs, 5 January 2006. In an interview with the German television on January 5, 2006, the Minister of Economic Affairs, Martenstein, mentioned that at some points in time deliveries were only half the usual volume.

If one adds these considerations, the storage gap increases significantly. Even when assuming a buffer of 15 per cent of the extra swing capability (equivalent to 12.8 BCM of WGV in 2030) as a provision for hard winters and 5 per cent of the strategic stock for non-EU imports (equivalent to 13.7 BCM of WGV in 2030), the gap rises to 33.6 BCM. Holding 10 per cent of non-EU imports as strategic stock would require 27 BCM of the strategic stock in total; and this seems virtually impossible.

## **Adjustments and Simulations**

So far we have assumed that no major structural changes will arise with respect to the supply and demand of flexibility. This serves well as a benchmark, but tends to underestimate the “storage gap”. Thus, in this section, we make some alternative assumptions on key parameters. Furthermore, we want to account for the uncertainty in the predictions by using Monte Carlo simulations. We do so by using ad hoc assumptions on the distributions of the main underlying parameters.

**SWING DEMAND:** It might be argued that taking the maximum swing ratio of the last ten years as a measure might overstate the demand for flexibility in the future. Much of the additional demand that is forecasted is due to power production, which might have less swing (we will discuss this argument briefly in the next section). Furthermore, global warming might reduce the gas consumption in the winter.<sup>12</sup> To account for this possible increase in this input variable, we take a uniform distribution for the swing ratio for each country with the average from 1995-2004 as the lower bound and the maximum from 1995-2004 as the upper bound for the distribution.

**SWING SUPPLY:** Our assumptions so far clearly overstate the ability to supply swing. For example, for the Dutch production, we have assumed a constant swing capability, although the Dutch Ministry of Economic Affairs (2005, 11) assumes that, by 2030, “the reservoir pressure will no longer be high enough for the [Groningen] field to act as a swing supplier”. Since both extremes (constant swing supply capability and no swing capability) are rather unlikely, we take a normal distribution with a mean equal to half of the maximum value observed from 1995-2004 and a (small) standard deviation of 0.035, leaving only extremely little probability weight on extreme realizations.

**PLANNED STORAGE:** Finally, it may be that not all of the planned storage facilities will be built. Therefore we use a uniform distribution, with boundaries at 50 per cent and 100 per cent of the planned WGV.

**CONSUMPTION GROWTH:** The EIA has calculated three different scenarios for the energy consumption in Western Europe. So far we have used the base line scenario with a growth rate of 1.8 per cent per year. The EIA’s high growth scenario predicts 2.2 per cent growth in gas con-

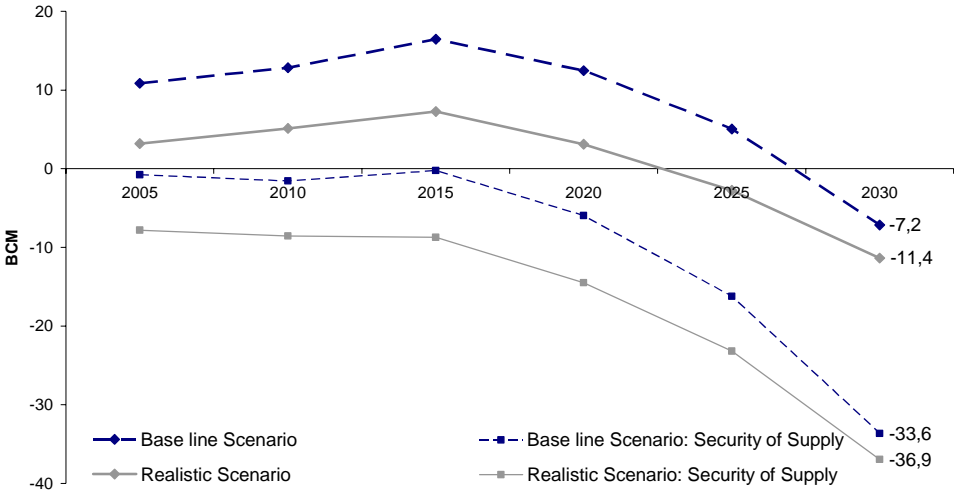
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12 The reverse, however, is also possible: Global warming could cause the gulf stream to collapse, resulting in colder winters in NWE (see McCarthy et.al., 2001, p. 948).

sumption, while its low growth scenario predicts 1.6 per cent growth. We account for this by taking an extreme value distribution with a location parameter of 0.018 and a shape parameter of 0.001 (implying a mean of 1.8 per cent and, again, putting only very little probability mass on extreme realizations;  $prob(x > 2,2\%) = 0.02$  and  $prob(x < 1.6\%) = 0.01$ ).

These alternative assumptions yield a larger storage gap. The expected values are depicted by the solid lines in Figure 5. Both versions, with and without additional considerations regarding supply security, are depicted. Even without additional provisions for supply security, the expected value of the storage gap rises to 11.4 BCM for 2030.

**Figure 5: Storage Delta<sup>13</sup>**  
 (positive = excess supply, negative = storage gap)

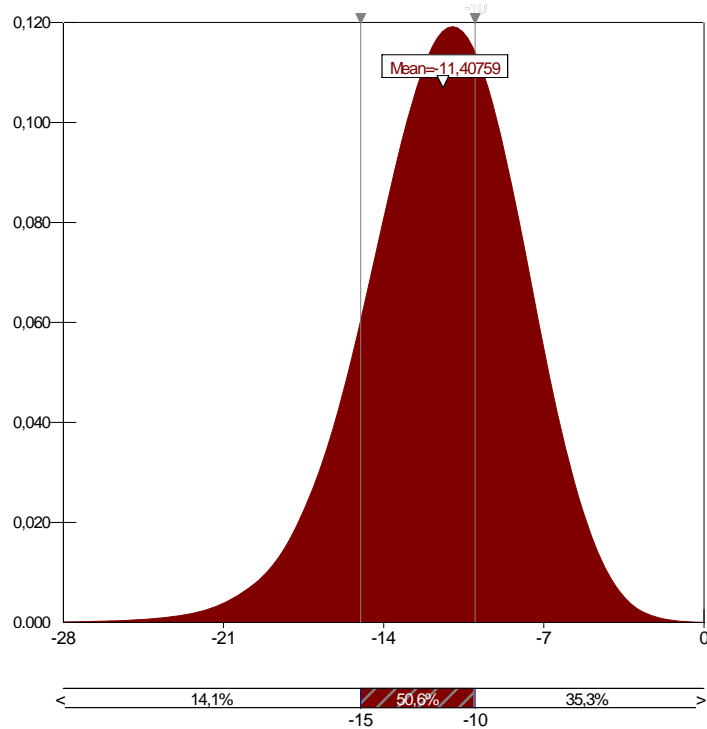


A Monte Carlo analysis with respect to the prospective storage gap in 2030 (base line scenario) indicates that the probability of having excess storage in 2030 if no additional projects are initiated in the meanwhile is virtually zero. With a probability of roughly two-thirds, the gap will be larger than 10 BCM, and there is still significant probability for a gap in excess of 15 BCM (0.141).

13 Our calculation assumes that planned storages become operational continuously until 2015.



**Figure 6: Distribution of Storage Gap<sup>14</sup>**  
**Realistic scenario (w/o security of supply)**



## 5. Discussion

Figure 5 conveys three main insights. First, in the absence of severe supply interruptions and very strong winters, the existing and planned storage is sufficient to cover mid-term flexibility requirements, even if the supply structure changes towards more distant sources. Second, if special provision is desired for considerations of supply security, facilities will just be sufficient for the next ten years and a significant gap will open afterwards. Third, the time structure shows that the development is highly non-linear. While the situation will be relatively stable until 2015/20, a sharp decline is to be expected afterwards. Since storage projects can take up to 10 year to be completed, this indicates that projects to develop new facilities need to be started rather soon. Once there is a shortage of flexibility, this shortage will accelerate quickly.

In our analysis, we have left out a multitude of additional effects. Here we want to discuss some of the most important ones.

The IEA (2005, I.17), as well as the EIA (2005, 42), assume that the main driver in the growth in natural gas consumption will be gas-fired power plants. One might therefore argue that the additional demand will require less flexibility since it is not meant for the heating market. This need not be the case. Currently, most gas-fired power plants can be profitable only when combined as

<sup>14</sup> Monte Carlo Simulation, using @Risk® software, 1,000,000 iterations. Clearly, assuming the independence of the four parameters is a strong assumption. In particular, price signals will cause dependencies. We discuss effects from price signals in the final section.

heat and power plants. Many of them are heat-led, i.e. their main purpose is to produce heat, and they can produce electricity at competitive prices only if they can sell heat at the same time. This would again lead to a strong swing in this sort of gas demand.

Natural gas markets will probably be subject to significant change in the next decades due to the ongoing liberalization. Strategic considerations will become more important. The fact that storage access is regulated already indicates that storage might not be a competitive market, as it is implicitly treated in our model. Storage operators, in particular if they are part of an integrated gas company, might try to withhold capacity from the market. Thus, not all physically available capacity might actually be available.

Throughout the paper, we have only considered the mere size of the storage. However, another important precondition for the provision of flexibility is the withdrawal capacity, i.e. the ability to quickly release and fill the storage units. This can impose additional restrictions on the capability to quickly enough meet demand in the winter, and it is likely to cause additional requirements for more storage.

Currently, in NWE, in particular in the Netherlands and Germany, two gas qualities are in use, H-gas and L-gas. Although L-gas will probably fade out by 2030, at least in the transition period, flexibility for both gas qualities must be available. This could increase the demand for storage within the transition period.

Finally, we used the data from Bothe and Seeliger (2005), who assume least cost, i.e. the competitive sourcing of natural gas. As they show this has not been the case in the past. Relatively cheap indigenous production has been superseded by Russian gas, mainly for political reasons. The large pipeline project (“Baltic Pipe”) between Russia and Germany indicates that this bias might also be relevant for the future. This, again, would increase the storage gap, since even more gas would come from Russia, providing less swing than is calculated in our base line case.

Therefore, accounting for these additional, but difficult to quantify aspects, would tend to even increase the storage gap. Our calculations hence tend to be a lower bound for the storage gap.

## **6. Conclusion**

Seasonality in gas demand requires flexibility in the supply of gas. In NWE, flexible indigenous production has to be replaced by less flexible imports from far distant fields. The additional flexibility has to be provided by gas storage facilities. While in midterm this will cause few problems, beyond 2015/20, a significant storage gap will quickly arise, in particular if consideration of supply security are accounted for. This is not surprising since new storage facilities might be planned in the future which will become operational after 2015. However, it highlights that such additional facilities will indeed be required – or the increase projected for natural gas consumption will not be feasible.

Since future needs could require almost twice the current level of storage in NWE, the question arises as to how to meet this challenge. Technologically, underground storage requires certain geological conditions, and therefore they cannot arbitrarily be increased. One obvious opportunity is to use the depleted gas fields. This will probably be a major source for future storage. However, it is neither technologically nor economically viable to convert many of the gas fields into storage sites, in particular in the UK.

Apart from the technological issues, price mechanisms could mitigate the development of shortages. Increasing prices for flexibility should reduce demand and increase supply in a well functioning market. High prices for flexibility would imply higher gas prices in the winter and might therefore reduce the gas consumption (i.e. gas consumption would not grow as strongly as assumed in all current scenarios). Alternatively, high prices for flexibility might increase the incentive for industrial customers to enter into interruptible contracts.

This, however, requires well functioning markets for flexibility, in particular a well functioning market for storage services. Although the storage business requires high sunk costs, it does not seem to be a natural monopoly. The high number of different operators in Germany (i.e. 14) indicates this. Problems for a well functioning (competitive) market might nevertheless arise from connecting storage with the transportation network. Gas transportation and distribution is more likely to be a natural monopoly. Due to the industry history, storages and networks are often part of the same fully integrated gas company in NWE. In order to deter entry, incumbents might not only use the transportation and distribution infrastructure, but also deny access to storage facilities.

In Article 19 of its Gas Directive, the European Union (2003) therefore has established third-party access (TPA) to storage in order to facilitate downstream competition in the gas market. While the Gas Directive also allows for regulated TPA, all member countries so far have opted for the alternative, namely, negotiated TPA. Regulators have coordinated to recommend that the focus should be on the obligation to provide access on non-discriminatory terms and with transparency about tariff methodologies (REGEG 2004).

Although this regulation is rather light-handed, it limits the storage operator's control rights and therefore reduces future profits and consequently incentives to invest in storage facilities. The European Union has accounted for this: the Gas Directive in Article 22 allows for the exemption of new storage facilities from TPA regulation under the condition that "the investment must enhance competition in gas supply and enhance security of supply". Given the predicted future scarcity of storage amounts, such an exemption seems to make sense. However, it highlights that there is a trade-off between establishing short-term competition in the downstream market and investment incentives in storage facilities.<sup>15</sup>

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15 One could even argue that abandoning storage TPA is required, since even if new facilities are exempted, their return on invest is depressed if TPA reduces the market price. This, however, would probably be detrimental to opening the gas market to competition.

While TPA is similar across EU countries, national approaches to the organization of the gas industry differ, in particular between the two major gas producers, the Netherlands and the UK. The UK follows a decentralized approach, favoring a large number of private gas suppliers. In the Netherlands there is far more state intervention. The Dutch Ministry of Economic Affairs expressly pursues a strategy of preserving the swing capability of the Groningen field for the future; this implies tight production ceilings for this field (Dutch Ministry of Economic Affairs 2005, 10). Furthermore, since almost all swing production comes from the Groningen field, the swing supply is highly concentrated,<sup>16</sup> while, in the UK and Germany, it is (potentially) more competitive.

Since swing from production, like the reserves themselves, is an exhaustible resource, results from the economics of depletable resources might apply. Standard results of the Hotelling model for depletable resources suggest that monopolistic supply tends to extract less resources in the beginning, leaving more for the future, compared to competitive settings.<sup>17</sup> From this perspective, the Dutch approach seems to better provide for future needs for flexibility. However, it also suggests a trade-off between the security of supply and the sufficient provision of flexibility, on the one hand, and more (downstream) competition, on the other.

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16 NAM, the operator of the Groningen field, is a 50-50 subsidiary of Shell and ExxonMobil. However, the state strongly influences contracts regarding NAM's exploitation of the Groningen field. Furthermore, all three gas storage facilities are owned by Gasunie, a fifty per cent subsidiary of the Dutch state. See IEA 2004a, 67.

17 Few general results are available. Faster depletion by a monopolist can be shown under constant demand elasticity and under linear demand in the presence of an exploitation cost. Without an exploitation cost, a monopolist chooses the same exploitation path as the one that results from perfect competition (Sweeny 1993, 838-841).

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## Appendix

**Table 3: Swing Ratios**

	Swing Demand			Swing Supply	
	Average	Maximum	Stand. dev.	Average	Stand. dev.
Belgium	0,260	0,287	0,031	-	-
Denmark	0,304	0,364	0,025	0,170	0,038
France	0,415	0,469	0,028	0,039	0,069
Germany	0,324	0,359	0,021	0,178	0,044
Netherlands	0,284	0,340	0,030	0,357	0,040
Switzerland	0,406	0,470	0,030	-	-
UK	0,258	0,335	0,035	0,178	0,067
Norway	-	-	-	0,117	0,053
Russia and ex-GUS	-	-	-	0,032	0,036
Middle East	-	-	-	0,032	0,036
Africa	-	-	-	0,040	0,040

Swing ratios are defined as: sum of winter quantities – sum of summer quantities, where summer = April to September, and winter = October to March.

Belgium and Switzerland do not have indigenous production.

The value for “Africa” equals the value for Algeria, the only African country with exports to NWE for the whole period 1995 – 2004. Since all other imports are far more distant, this tends to overestimate the swing capability of African imports.

For the Middle East, no country has imported for more than five years in the period 1995 – 2004. Thus, we approximate the Middle East value by the values of Russia.

**Table 3: Base case scenario**

		2030 Base line	2030 Realistic
Swing Demand	TWh	1965,0	1819,8
Swing Supply	TWh	1800,4	1558,2
Indig. Production	TWh	280,9	140,8
Imports	TWh	254,1	254,6
Storage	TWh	1265,4	1162,8
Delta Swing	TWh	-164,6	-261,6
"Storage gap"	BCM	-7,2	-11,4

**Table 4: Security of Supply Scenarios**

		2030 Base line	2030 Realistic
Swing Demand	TWh	1965,0	1819,8
Additional Buffer	TWh	294,8	273,0
	BCM	12,8	11,9
Strategic Stock	TWh	314,5	315,1
	BCM	13,7	13,7
Swing Supply	TWh	1800,4	1558,2
Indig. Production	TWh	280,9	140,8
Imports	TWh	254,1	254,6
Storage	TWh	1265,4	1162,8
Delta Swing	TWh	-773,8	-849,7
"Storage gap"	BCM	-33,6	-36,9