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Demand for storage of natural gas in northwestern Europe.
Trends 2005 to 2030[‡]

Felix Höffler[*] Madjid Kübler[#]

March 2, 2007

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 between 10 (with no strategic storage) and 29 (with 10 per cent strategic storage for imports from non-EU countries) billion cubic meter of working gas volume will be required, in addition to the existing 40 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 1995-2005. We provide different scenarios to check for the robustness of our results. We discuss the impact of third-party access to storage facilities on incentives to close the storage gap, as well as policy implications of strategic storage obligations.

Keywords: Seasonal swing, strategic storage obligations, third-party access,

JEL-Classification: L98, L51, Q41

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1. Introduction

Natural gas is the strongest growing primary energy source in western Europe. According to the EU Commission, the consumption of natural gas increased on average by 3.4 per cent per annum between 1995 and 2005 in the EU-15 member states. Total primary energy consumption grew only at 1.2 per cent in the same period (EU Commission 2006, p. 76). While growth is projected to slow down, natural gas is forecasted to exhibit above average growth (with a compound annual growth [CAGR] of 0.6 per cent, compared to 0.2 per cent CAGR for the total primary energy consumption for 2005—2030).[1]

Since natural gas is largely used for heating, consumption is subject to a significant seasonal swing. In northwestern Europe[2] (NWE) approximately two-thirds of the gas is consumed during the winter (October till March). Residentials consume about 90 per cent of their overall gas during the winter period.[3] For local gas providers, it is therefore not uncommon to have daily peaks in gas delivery in the winter amounting to more than 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 forecast for the overall gas consumption in the countries of NWE until 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 our base year 2005, we project the additional demand for storage to be 21.3 BCM by 2030. If there was no excess capacity in

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[1] Only renewables are projected to grow faster, at 3.2 per cent p.a, but from a far lower level.

[2] Northwestern Europe, in the definition of the paper, comprises Belgium, Denmark, France, Germany, the Netherlands, Switzerland, and the UK.

[3] This is well documented for Germany; see "AK Energiebilanzen, Endenergieverbrauch in Deutschland 2004", Energie Spezial, 27.4.2006, Table 3 and 4.

storage WGV by 2005, this would be identical to necessary additions to the existing installed volume of WGV. However, data on the actual usage of storages indicate some idle capacity by 2005. Assuming that 20 per cent of the WGV was not used by 2005 (which probably biases forecasts towards an underestimation of the storage gap), the required additional storage volume amounts to 10.2 BCM by 2030. This is equal to about 25 per cent of the currently installed WGV of 40.5 BCM.

Supply interruptions on long-distance transport routes – for technical reasons or for political reasons – are a risk for the security-of-supply, which, due to the changing structure of gas supply of NWE, will become more pronounced. If NWE countries wanted to hold strategic stocks of gas (similar to oil) in the order of 5 per cent (10 per cent) of Non-EU imports, this gap would increase to 19.6 BCM (29 BCM), since strategic stock blocks capacities for the usual operational supply of flexibility.

Closing the gap seems less to be a technological problem than a problem of providing the right framework for investments in storage. In a functioning market for flexibility, an "operational" storage gap of 10.2 BCM can probably be closed by market forces. Increasing shortage increases prices and thereby investment incentives. However, regulation of storage – which is often necessary to open the overall gas market to new entrants – tends to reduce investment incentives. Therefore, European legislation allows for exemptions from regulation for new investments. Our analysis tends to support the view that such exemptions are indeed sensible.

It is more difficult to design the right framework for supplying the far larger amount of storage required for strategic security of supply considerations. Most likely, this will lead to a split of the market into a regulated part (for covering security of supply obligations) and an unregulated part (for usual operational usage of storage). To account the interdependencies between the two market segments will be a major task for the future.

Most closely related to our work is a working paper by the Clingendael International Energy Programme (2006). It reports results on a similar forecast for future storage needs for the whole of Europe.[4] 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. Cornot-Gandolphe (2003) 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

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[4] An additional volume of 2 BCM p.a. is mentioned. However, the time horizon for this forecast is not quite clear. In addition, due to the different regional focus, the figures are not comparable to ours.

(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 (iv) 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. Section five discusses additional factors not covered in the quantitative analysis. Section six concludes and proposes policy implications.

2. Status quo of flexibility provision in NWE

The focus of our analysis is NWE, which accounted for 71 per cent of the final gas consumption in western Europe (EU 15 plus Switzerland) in 2005 (see footnote 2 for the regional definition of NWE). 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.[5]

The gas demand of these mature gas markets is heavily driven by the 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 NWE. Both countries use approximately two-thirds of their gas in the winter months (October to March).

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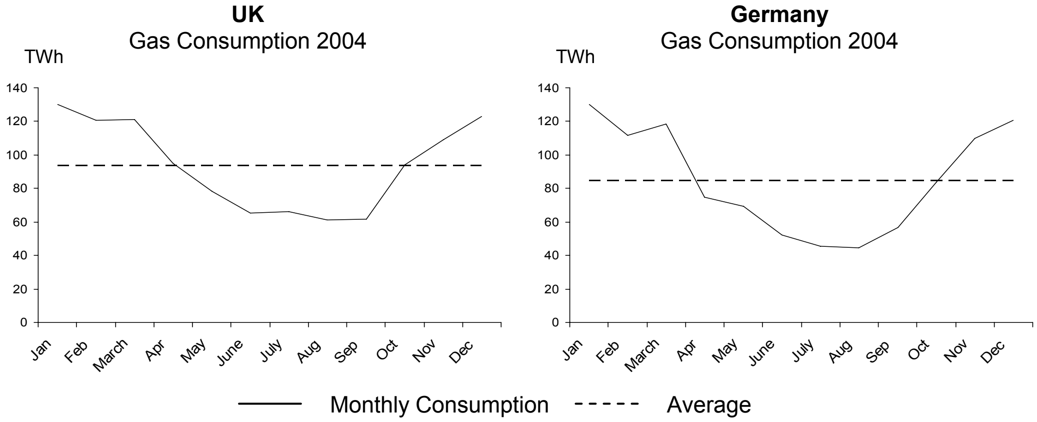
[5] Norway produces a large amount of gas from the North Sea, but has virtually no gas consumption of its own. Eastern and southeastern European countries (including Austria) always used to be heavily dependent on Russian gas and had to provide flexibility through storage. Thus, there is no qualitative 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.

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 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 implies an assumption of 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 with heating in the summer (like they can do by, e.g., substituting telephone calls in peak hours with off-peak calls). Also, industrial demand is unlikely to exhibit the flexibility required to substitute production in the winter with production in the summer.

There are essentially three ways to meet the seasonal swing demand: first, by flexible gas 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.[6]

Each alternative is costly. The 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 to their maximum capacity all the time is the most cost-effective method of energy production. Also, production has to be differentiated into pure gas production and associated gas production; in the latter,

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[6] 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 it is best suited for short-term peak shaving.

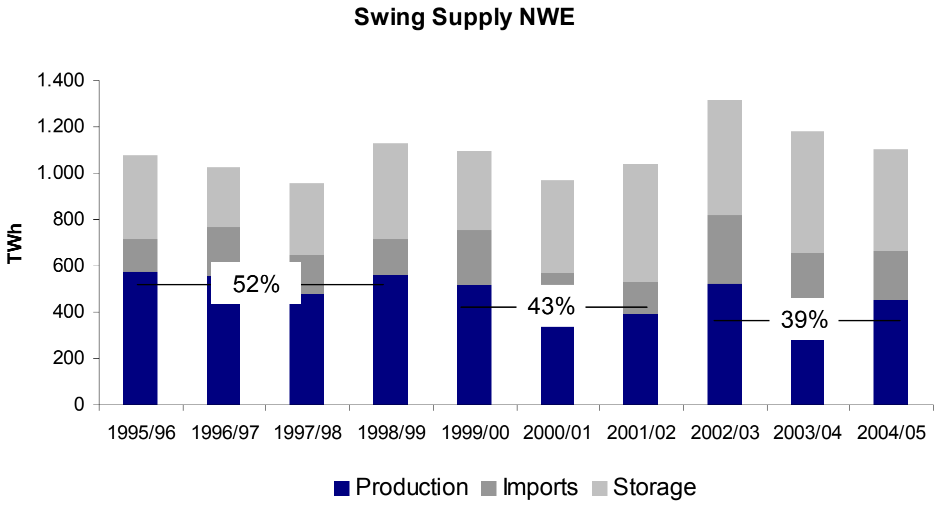
the production schedule is driven by the oil production. In addition, many fields have technical limitations to the variation in output.

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; they also require significant investments.

Figure 2 shows how, in the 1995-2005[7] 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.

Figure 2: Swing Supply in NWE 1995-2004



Source: International Energy Agency 'Natural Gas Balance'; own calculations

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 52 per cent of the swing supply, its contribution declined to 39 per cent at the end. Since the share of import swing remained stable at about 20 per cent, the contribution of storage rose from about 30 per cent to more than 40 per cent.

The larest part of swing from indigenous production stems from the Netherlands (in 2004/05: approximately 64 per cent), in particular from one large gas field in

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[7] For these and all other calculations, we use a usual "gas year", i.e. 1995/96 accounts for the time from October 1995 to September 1996.

Groningen, which is very well suited to provide flexibility (in 2003 Groningen accounted for 48 per cent of all production swing in NWE).[8]

While production swing is concentrated in the Netherlands, most storage facilities are located in Germany. According to the International Gas Union (IGU 2006), in 2005 the overall WGV in NWE was 40.5 BCM, with 19.2 BCM located in Germany. Storage capacities were increased in Germany by about 80 per cent between 1995 and 2005. This increase implies that the maximum storage WGV in NWE is now well above the level of storage currently used. For example, even in the relatively cold winter 2005/06, with low temperatures at the end of the heating period, only 58 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 6 BCM WGV, equivalent to 15 per cent of existing volume (IGU 2006).[9] 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.

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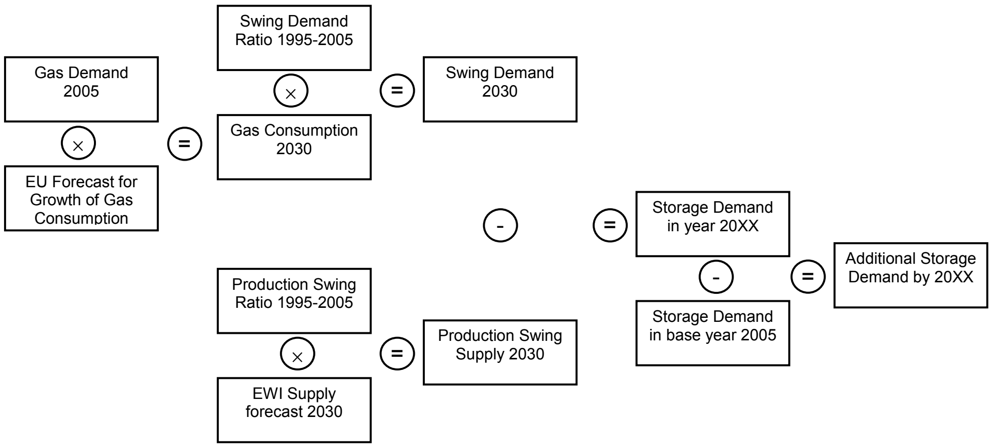
[8] This figure is calculated using the Dutch regulator’s data, cited by Frontier Economics (2005, 28) and the IEA data “Natural Gas Balance” for 2003.

[9] There are substantial differences between the data of the IGU and the IEA concerning the operational and planned WGV. While the IGU figures are higher for the installed volume, the IEA reports far higher figures for planned facilities, namely 18 BCM in 2004 (IEA Natural Gas Information, Edition 2005). We rely on the IGU data since they are more recent.

Figure 3: Approach for extrapolation



We rely on the demand forecast by the EU for the gas demand of each of the member countries (see Figure 1). The overall growth in the region is relatively low, with an annual growth rate of only 0.4 per cent.

To derive the swing that results from this gas demand, we apply the maximum "swing ratio" observed over the period 1995/6-2004/5. 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 1995/6-2004/5.

Restricting attention to observations from 1995/6-2004/5 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 the Netherlands it was the coldest winter in the last 30 years).

Figure 4: Temperature Data for NWE (average winter temperature, C°)

	Winter	Coldest Winter in …. years				
	1995/96	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	4.8	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.[10] 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.

On the supply side, we borrow estimations from Bothe and Seeliger (2005).[11] They use the EUGAS model, which assumes a least cost provision of gas. They 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 that a competitive supply of natural gas and a price inelastic demand for natural gas are assumed.

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 1995/6-2004/5, use the average and just multiply the result by 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.

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[10] IEA (2004) Security of Gas Supply in Open Markets, p. 345-346. Other countries, like Denmark, the Netherlands, Spain, and the UK, have similar obligations.

[11] 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. Thus, the figures used in our paper differ from (but are consistent with) the aggregate figures Bothe and Seeliger report in their Figure 3, p. 4.

We finally compare the swing demand to the swing supply from production and consumption to derive the additional demand for storage.[12] This is just the difference between the calculated values for the future compared to our base year 2005.

4. Results

We present four kinds of results. We start by providing the extrapolation for the additional storage demand, as described in Section three. We then discuss reasonable assumptions on structural changes to derive a more realistic forecast. In a third step, we add additional considerations regarding the security of supply. Finally, we discuss whether the assumption that all additional storage demand needs to be covered by additional storage is warranted or whether some of it might be met by capacities already installed but currently left idle.

Extrapolation

With an aggregated annual growth rate of 0.4 per cent, the gas demand will amount to 3.393 TWh in 2030. Using the (maximum) swing ratio from the period 1995-2005, this translates into a swing demand of 1.233 TWh (see Figure 5).

Figure 5: Swing Demand in 2030

	Average consumption 03-05	CAGR	Gas demand 2030	Max. swing ratio 95/96-04/05	Swing demand 2030
	(1)	(2)	(3)	(4)	(5) = (3) x (4)
unit	TWh	CAGR (%)	TWh	Ratio	TWh
NWE	**3.393**	**0,4%**	**3.733**		**1233,0**
Belgium	166	0,6%	192	0,31	59,8
Denmark	60	0,8%	74	0,31	22,9
France	524	0,3%	563	0,46	258,7
Germany	1.029	0,4%	1.139	0,35	404,1
Netherlands	465	0,1%	480	0,31	150,3
Switzerland	35	1,0%	46	0,44	20,1
UK	1.114	0,4%	1.240	0,26	317,0

Source: EU, Energy and Transport, Trends to 2030; IEA Natural Gas Balances; own calculations.

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 possible to meet 56 per cent of the demand). The majority now comes from more distant sources, mainly from Russia and other former CIS: 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),

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[12] Already planned additional storage projects are deducted, since they are equivalent to a "negative swing demand". We assume that all projects known in 2006 will be fully on stream by 2015.

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 Figure 6 we use the average swing ratio of production from 1995-2005 to derive the (maximum) swing supply from production in 2030.

Figure 6: Swing Supply from Production 2030

	Gas Supply 2030	Average Swing Ratio 95/96 - 04/05	Swing Supply 2030
	(1)	(2)	(1) x (2)
	TWh	Ratio	TWh
NWE	704	0,23	159
Norway	863	0,10	84
Russia and ex-CIS	1.305	0,03	43
Middle East	216	0,05	11
Africa	646	0,05	32
Total	**3.733**		**328**

Source: Gas Supply 2030, based on the EU forecast and the supply split by Bothe and Seeliger 2005; own calculations for swing supply.

Comparing the values of Table 2 and Table 1 shows that at least 905 TWh of swing will have to be provided by storage in 2030. Compared to similar calculations for our base year 2005 (resulting in a storage demand of 25.1 BCM), this implies an additional storage demand of 14.2 BCM in WGV.[13]

Adjustments

So far we have assumed that the swing capability of endogenous production, as well as of imports remains, constant over time. This is clearly unrealistic for both sources of 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”. The reason for the reduced swing capability is the reduction in pressure due to the depletion of the gas fields. Though, technically, swing can still be produced, it becomes increasingly expensive, since the natural pressure has to be substituted by technological equipment. We therefore assume a reduction of the swing ratio of 50 per cent for all indigenous gas production in NWE.

A similar argument applies to gas imports, which, as Figure 6 shows, also provide some swing. However, in the future, gas will come from far more distant

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[13] 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. Note that, 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.

fields in Russia or Norway, which reduces the swing capability of these sources. Again, we assume a reduction of 50 per cent by the year 2030 for this source of swing.[14]

These assumptions lead to a far more realistic outcome which, for further reference, we will call "Adjusted Scenario".

Security of Supply

Due to the increasing dependence on imports from distant fields, supply interruptions are becoming an increasingly important issue for NWE. Supply interruptions may be due to technical problems, but also to terrorist attacks, or there may be political reasons for them.

The supply interruptions (of oil and gas) due to conflicts between Russia and Belarus (in Winter 2006/07) as well as between Russia and Ukraine (Winter 2005/06), have increased the sensitivity of the EU and its member countries to this issue. 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.[15] This might revive plans in the European Union to oblige member states to hold strategic gas stocks (European Commission 2004, 68). Currently, no such obligation exists on the European level. However, some member countries actively address this issue. 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. Spain forces importers to diversify their portfolios such that no import company receives more than 60 per cent from one source.

However, none of the countries in NWE has such an obligation in place. Where storage obligations exist, they are meant as a compulsory buffer against extreme weather conditions. Sources of supply do not matter.[16]

In our forecast model, any such obligation would come on top of the storage demand we have so far calculated. Strategic stock blocks storage capacities meant for operational use, that is, those meant to meet the calculated seasonal swing demand. The strategic stock must be available in particular in the winter, when the vulnerability of the import countries is largest. We calculate a strategic stock at 5 per cent of the non-EU imports, excluding Norway (i.e. Norwegian imports are treated as exempted from storage obligations).

Figure 7 summarizes the results. It highlights that adjusted assumption on the swing capability of imports and indigenous production increase the storage demand from 14.2 BCM to 21.3 BCM. Taking a 5 per cent buffer for non-EU imports into account on top of that, a realistic forecast of the additional demand for storage is of

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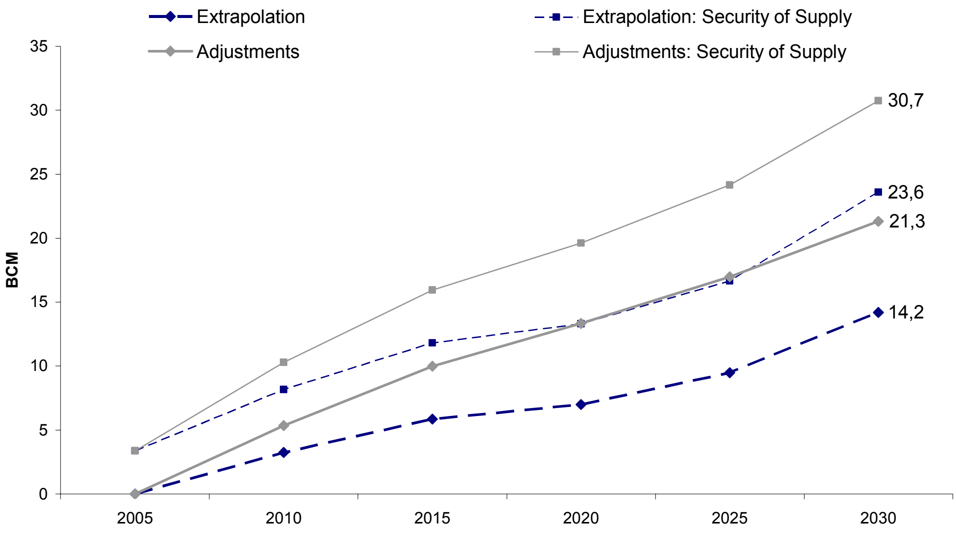
[14] A similar assumption is made in CIEP (2006), p. 12.

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

[16] Belgium, Denmark, France, the Netherlands, and the UK have such obligations, usually requiring gas suppliers to be able to supply under the hardest weather conditions in the last 50 years. For Germany, no such obligation exists. See IEA (2004, b), p. 345-346.

the order of 31 BCM, equivalent to 75 per cent of the currently installed WGV in NWE.

Figure 7: Additional Storage Demand (Compared to 2005)



Excess Capacities in 2005

The calculated additional storage demand would require additional storages to be built only if all facilities were used up to capacity in the base year 2005. This, however, is not clear.

It has been frequently observed that only a relatively small fraction of the WGV is, on average, actually used. CIEP (2006, p. 9) reports average utilization rates of between 40 and 70 per cent over the last 20 years, though with a clear tendency towards increased usage.

In Germany, the largest storage provider in NWE, in the period from 1994/95-2004/05, 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. Usually it takes a couple of years before a underground storage is fully filled for the first time. However, even of the gas filled during the summer, 40 per cent has not been used.[17]

One obvious explanation for the low utilization rates observed is the need to hold stocks for extreme weather conditions. It is in general difficult to derive how much additional storage is necessary to meet extreme weather conditions, e.g., the coldest winter in the last 50 years. Even in the very cold winter 1995/96 (compare

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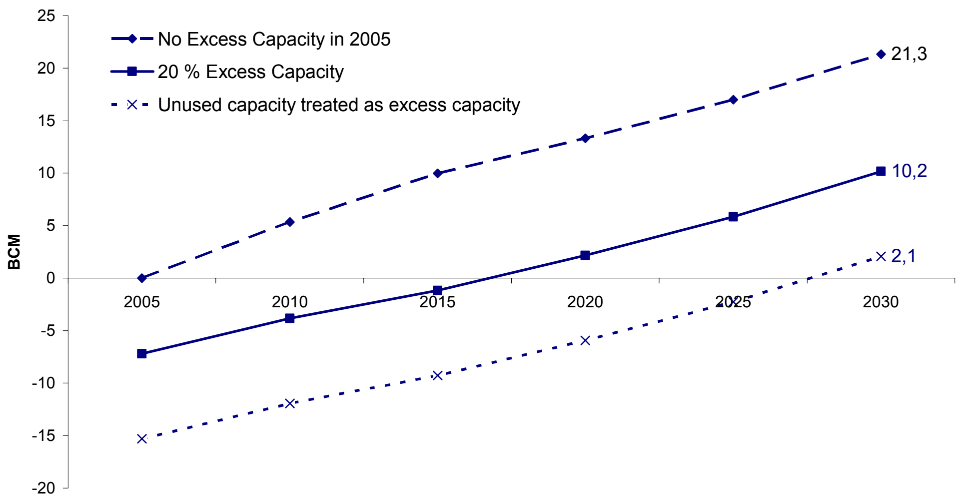
[17] These calculations are based on data by the German authorities "Niedersächsisches Landesamt für Bodenforschung (NLfB)", http://www.nlfb.de.

Figure 4), the utilization rate in Germany was only at 66 per cent.[18] According to CIEP (2006) it was slightly above 60 per cent in the whole of Europe.

The opposite extreme to assuming no excess capacities in 2005 would be to assume that all capacity that was not actually used in 2005 is excess capacity (this would be equivalent to assuming that gas suppliers do not take additional provisions for extreme weather conditions, compared to our base period 1995/96 to 2004/05).

Between the two extremes, we take the middle road. A buffer of the order of 40 per cent of the installed WGV for extreme weather conditions seems rather high; since we do not want to exaggerate the "storage gap", and since some of the rather new storages might not yet be filled up to full capacity, we will assume some level of "idle capacity" in the base period. We will assume idle capacity of 20 per cent of the installed WGV for 2005 (equivalent to 8.1 BCM). This is a rather conservative assumption; that is, it does not exaggerate the storage gap.[19]

Figure 8: Effect of assumptions on excess capacity in the base year



In Figure 8 we depict the results for the actual "storage gap" (negative values reflect an excess supply). As has already been shown, when assuming no idle capacities in 2005, our adjusted extrapolation yields a storage gap of 21.3 BCM by

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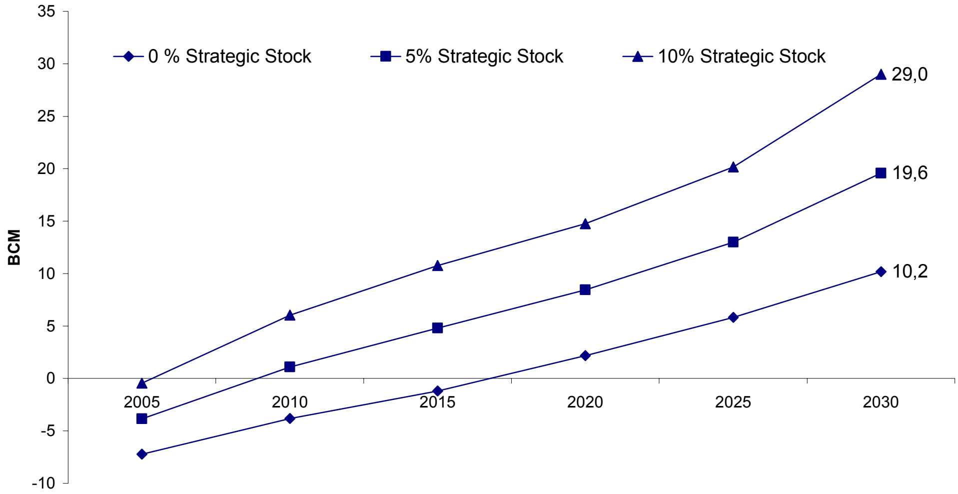
[18] Storages were, however, virtually empty on March 31, 1996. The reason for this was not only the hard winter but also the fact that the fill level at the beginning of the winter was unusually low (66 per cent on September 30, 1995, compared to a long-term average of about 80 per cent).

[19] Note that there could be also other reasons for the "idle capacity". Our simplified approach treats storages as being available for demand in the whole region, independent of the location of the storage. This is not realistic. Thus, additional storage has to be held due to uneven developments of storage supply and demand across NWE.

2030 (without accounting for strategic stock considerations). The opposite extreme, calculating all currently not used storages as “idle”, yields the opposite result: there will be an excess storage supply for almost every year until 2030. Our middle-of-the-road estimates forecast a gap of 10.2 BCM by 2030. Storages would become scarce only after 2015.

If we take the middle road as a realistic scenario, we can calculate the effect of strategic stock obligations for this case. The results are shown in Figure 9. An obligation to stock 5 per cent of imports from Russia, CIS, Africa, and the Rest of the World (but not from Norway) would almost double the storage gap by 2030. It would require an addition of 50 per cent of the currently installed WGV in NWE. Storage would be a scarce resource, even short-term, by 2010. Higher stock obligations, like 10 per cent, obviously make the problem of shortage in WGV even more pronounced.

Figure 9: Strategic Stock Obligations in the Realistic Scenario



5. Discussion

Figure 9 conveys two main insights. First, in the absence of severe supply interruptions, the existing and planned storage is sufficient to cover mid-term flexibility requirements, even if the supply structure changes to incorporate more distant sources. Second, if special provision is desired for considerations of supply security, facilities will not be sufficient in the near-term. Since it usually takes five to ten year to compete storage projects,[20] projects aiming to develop new facilities need to be started rather soon.

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[20] See, for example, IGU, Report of Working Committee 2 “Underground Storage” at the 22nd World Gas Conference, Tokyo, 2003, p. 118.

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

Gas demand structure There is considerable uncertainty about the extent to which the structure of gas demand will change due to an increase of gas-to-power. Although electricity demand can also show some seasonal cyclicality, increased usage for gas-to-power is likely to decrease the (relative) demand for seasonal swing. We have accounted for this by using the growth rates of the final energy consumption for our forecast (which exclude the use of gas for electricity production). However, for the whole forecast period, the figures for final energy consumption do not differ significantly from the forecasts for the total energy supply of gas (the latter is even slightly smaller at 0.3 per cent p.a. for the period 2005 to 2030 in the EU forecast for NWE).[21] Thus, projected changes in the gas demand structure are relatively small, and therefore our results are unlikely to be affected by this.

Liquefied natural gas (LNG) Nearly all countries in NWE are trying to diversify their import portfolio via imports of LNG. LNG is often used as an instrument to supply short-term flexibility ("LNG peak shaving"), and it might, in principle, also be used to supply seasonal swing. However, NWE competes for LNG in the Atlantic Basin with North America, i.e. with a large demand that shows similar seasonal demand patterns. Thus, LNG will probably remain a relatively expensive form of swing supply.

Liberalization Natural gas markets will probably be subject to significant changes 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, it may be that not all physically available capacity will actually be available. Therefore, our forecast tends to underestimate actual shortages in the markets.

Withdrawal capacity 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 storage.

Gas quality 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.

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[21] The IEA forecasts are slightly different, but not in terms of order of magnitude. For NWE without UK (no forecasts are available for UK for the year 2030 from IEA), final consumption is projected to grow at 0.6 per cent p.a. versus total energy supply by 1.1 per cent p.a.

Regional availability Although it makes sense to treat NWE as a single region, and although market integration will also make some progress in the market for gas storage, optimal positioning of storage will remain near the location of consumers. A storage site in northern Germany is of little immediate use to balance seasonal swing in southern France. Again, such considerations show that our figures tend to underestimate the storage gap.

Market distortions in gas supply We used the data from Bothe and Seeliger (2005), who assume least cost provision, 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 geo-strategic reasons. The large pipeline project ("Nord Stream") 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.

CO_2 Storage There is a lively discussion about the extent to which underground storage facilities can be used for the long-term storage of CO_2. Technologically, this seems to be possible (Shi and Durucan 2005), although it is not yet clear whether such storage of emissions would be considered equivalent to an avoidance of emissions (if it were, the storage value for such use would be equivalent to the avoided cost of CO_2 allowances). This is potentially an additional, competing demand for WGV.

Therefore, accounting for these additional, but difficult to quantify aspects would tend to even increase the storage gap. Our calculations hence are to be understood as 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 this will cause few problems in midterm, beyond 2015/20, a significant storage gap will arise. We project the gap to increase to about 10 BCM WGV by 2030, even without strategic stock obligations. With such obligations, the gap will increases to 20 (5 per cent of non-EU imports) or almost 30 BCM WGV (10 per cent of non-EU imports). Although such forecasts are based on strong assumptions, the choice of assumptions is such that this is likely to be a lower bound for the storage gap.

Thus, the question arises: How can the gap be closed? Although underground storage requires certain geological conditions, and therefore such facilities cannot arbitrarily be increased, the geology in NWE will probably not be a limiting factor. With the UK perhaps being an exemption, NWE has various places still suitable for salt caverns, and an obvious opportunity is to use the depleted gas fields. The question is rather the cost of building new storages (e.g., offshore gas fields could be turned into gas storage facilities, though at much higher cost than onshore fields or salt caverns) and the economic incentive to do so.

Market solutions for the "operational" storage gap

The storage gap stemming from the need to provide seasonal swing could probably largely be closed by a market mechanism. Our forecast method did not account for any price adjustments, although these are likely. Storage becomes scarce and hence prices will go up; this, in turn, increases incentives to invest in storage (or into alternative sources of swing, or to reduce the seasonality of swing demand). The time horizon – a gap not earlier than 2010/15 – also allows a timely reaction.

This 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 companies) indicates this. Private investment incentives might nevertheless be adversely affected by the regulation of storage.

Access to storage is regulated since it serves similar purposes to the balancing of energy in electricity markets: Market entry without access to flexibility is very difficult. Thus, in order to open the gas market to competition, it is very important to ensure access to storage for entrants.

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 (ERGEG 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.[22]

Another issue related to the liberalization of gas markets is the integration of storages in the transport system. Due to the industry history, storages and networks are often part of the same fully integrated gas company in NWE. Thus, unfavorable conditions for transport to and from storages can serve the same purposes as unfavorable conditions for storage usage. Thus, it is important to (i) establish competition-friendly conditions for the integration of storage in the transport

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

system, (ii) avoid overpriced transport fees as such, and (iii) enforce effective unbundling of storage operations from transport operations.[23]

Solutions for the "strategic" storage gap

How could strategic stock be supplied? The additional volume is probably too high to allow us to expect that sufficient storage could be made available near-term. Furthermore, the organization of the storage market is more controversial in this case. The lowest level of state intervention would consist of imposing storage obligations on import companies – and it would leave the rest to the market. This would put storage operators in a favorable position and probably generate, at least short-term, large windfall profits. Long term, however, high price levels for storage would attract additional entrants into the storage market, and it would create high incentives to substitute gas from source with storage obligations with sources without such obligations (or incentives to switch to other fuels).

An alternative system, practiced, for example, by Spain, is to essentially split the market into a regulated and an unregulated segment.[24] In Spain, each gas company has a storage obligation. The transmission system operator, also responsible for the organization of storage, allocates available storage volumes to the companies, which have to pay regulated fees for the storage. These fees cover the variable cost of storage. The fixed costs are reimbursed separately at regulated conditions. This is similar to the practice with regard to strategic oil reserves.

Such a system prevents the gas companies from a "cost shock" and the resulting windfall profits for the storage owners. It requires a certain degree of centralization (e.g., with a transmission system operator) and ongoing regulatory intervention. Furthermore, it raises questions with regard to the relation between the regulated and the unregulated part of the market. Typically, it will not be the case the whole sites are either dedicated to strategic storage or to commercial storage. Rather, facilities will be virtually split into an unregulated and a regulated part. This raises the question how to allocate cost between the two if, e.g., the tariff for the regulated part is regulated at a cost plus basis, while the unregulated part is subject only to a negotiated third party access regime.

Further question are: Can capacities on the unregulated market substitute for covering strategic reserve obligations? Can operators in the regulated market also make offers in the unregulated market? Are operators on the regulated market guaranteed full utilization of their capacities? If so, does the regulated tariff act as a lower bound for the unregulated part of the market? Can storages of other EU countries be used to satisfy storage obligations?

Furthermore, a drawback of regulation is the danger that a part of the cost of storage will be socialized among all system users. Thus, private incentives to

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[23] In particular the latter can be seen as a shortcoming of current EU legislation, which requires neither legal nor ownership unbundling for storage operations but only accounting separation; see EU Directive 2003/55/EC (26. June 2003), Art. 17 no. 3.

[24] See the First Final Disposition of Royal Decree 1716/2004 (July 23rd, 2004). For the actual operation of the system, see the System Operator Enagas' annual report 2006 on gas movements, p. 47-54, downloadable under http://www.enagas.es.

reduce exposure to supply sources with strategic reserve obligations are biased downwards.

Strategic storage obligations will probably require state intervention beyond the mere imposition of storage quotas. Such intervention has to carefully balance the effects between the regulated (strategic stock) part of the market and the unregulated market for flexibility.

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Appendix

Figure 10: Swing Ratios

	Swing Demand			Swing Supply	
	Average	Maximum	Stand. dev.	Average	Stand. dev.
Belgium	0,25	0,31	0,03	-	-
Denmark	0,28	0,31	0,02	0,15	0,06
France	0,41	0,46	0,03	0,04	0,07
Germany	0,31	0,35	0,02	0,17	0,05
Netherlands	0,28	0,31	0,02	0,36	0,05
Switzerland	0,40	0,44	0,03	-	-
UK	0,24	0,26	0,02	0,16	0,04
Norway	-	-	-	0,10	0,07
Russia and ex-CIS	-	-	-	0,03	0,04
Middle East	-	-	-	0,05	0,06
Africa	-	-	-	0,05	0,06

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.

Figure 11: Details Adjusted Scenario

1. Adjusted Scenario without Strategic Stock

Storage Gap		2005	2010	2015	2020	2025	2030
Assuming no excess capacity in 2005	BCM	0,0	5,4	10,0	13,3	17,0	21,3
Assuming 20% excess capacity	BCM	-7,2	-3,8	-1,2	2,2	5,8	10,2
Assuming unused capacity = excess capacity	BCM	-15,3	-11,9	-9,3	-5,9	-2,3	2,1

2. Adjusted Scenario with 5% Strategic Stock

Storage Gap		2005	2010	2015	2020	2025	2030
Assuming no excess capacity in 2005	BCM	3,4	10,3	16,0	19,6	24,2	30,7
Assuming 20% excess capacity	BCM	-3,8	1,1	4,8	8,5	13,0	19,6
Assuming unused capacity = excess capacity	BCM	-11,9	-7,0	-3,3	0,4	4,9	11,5

3. Adjusted Scenario with 10% Strategic Stock

Storage Gap		2005	2010	2015	2020	2025	2030
Assuming no excess capacity in 2005	BCM	6,8	15,2	21,9	25,9	31,3	40,2
Assuming 20% excess capacity	BCM	-0,5	6,0	10,8	14,8	20,2	29,0
Assuming unused capacity = excess capacity	BCM	-8,6	-2,1	2,7	6,7	12,1	20,9