The European Market for Seasonal Storage

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Abbreviations

bcm	billion cubic metres (equivalent to one thousand million cubic meters)
DGF	depleted gas field
EU	European Union
GGPSSO	Guidelines for Good Practice for System Storage Operators
IEA	International Energy Agency
LNG	liquefied natural gas
mcm	million cubic meters
OECD	Organisation for Economic Co-operation and Development
TPA	third party access
UNECE	United Nations Economic Commission for Europe
UK	United Kingdom
WEO	World Energy Outlook

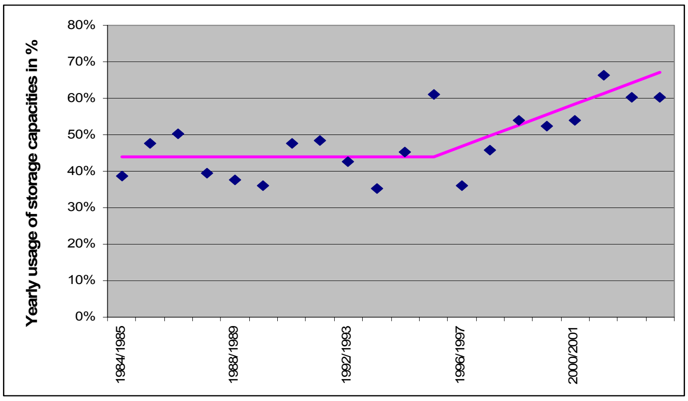
Summary

Gas demand varies over time – across years, seasons, weeks, and different times of the day. Because gas cannot be stored at the point of consumption, these demand fluctuations have to be met by supply.

Producers of gas in general and certainly those incurring high production and/or transport costs (due to long distances and/or technically challenging transport routes) aim at producing and delivering a constant rate of gas that is close to their production potential in order to recoup their large investments. So-called *flexibility instruments* manage the difference between variable gas demand and baseload production (the amount of gas produced at a steady rate). The flexibility market depends largely upon gas storage, which has two important characteristics:

- *deliverability* – the amount of gas per hour that can be produced from a storage facility, e.g. on a (very) cold day, adding to the baseload supply;
- *volume* – the amount of gas that can be supplied from storage during a long (cold) period above the baseload supply.

This study focuses on the means necessary to balance the seasonal differences between summer and winter gas demand for which the provision of *volume* is most important. Currently, the extra volume needed in winter, additional to baseload production, originates mainly from large storage and flexible gas fields, the latter in particular located in the Netherlands and the UK.



Average utilization of storage facilities on the rise
(OECD Europe)

During the next decades, production from domestic gas fields, as well as the flexibility afforded by these fields, will decline whilst the European gas market is expected to grow significantly. To bridge the resulting supply gap more baseload imports from remote areas outside the European Union will be needed. This will result in a much higher European demand for seasonal flexibility. It is hard to envisage how this can be provided by any other means but storage. To balance seasonal fluctuations rather large storage volumes are required. Large storage facilities are therefore often labelled as **seasonal storage**. Generally, the most suitable facilities for seasonal storage are depleted gas fields and aquifers as they offer large storage volumes more cost-efficiently than other options such as cavern storage. Our study estimates that additional storage requirements up to 2025 could be in the order of 45 to 60 bcm of working volume, meaning an almost doubling of current volumes. Storage projects currently underway in OECD Europe appear to fall short of requirements, as estimated by our study.

For a number of years, the pace of developing new storage facilities has slowed, particularly in comparison to the growth of rather inflexible long distance imports, and usage rates of existing storage facilities have increased. The security of supply situation has apparently become tighter. In March 2005, a number of countries including Belgium, France, Italy, Spain and the UK reported problems in gas supply due to unexpectedly low storage levels. During the winter of 2005-2006, similar problems occurred in Italy and Spain, while in the UK a comparatively limited endowment of storage capacity contributed to a doubling of gas prices.

Industry players currently seem to focus mainly on storage facilities with relatively small volume and high deliverability. These facilities are used to provide short-term flexibility (up to a few weeks) during cold snaps and for trading purposes to benefit from temporary gas price differentials.

Individually, they do not play a significant role in meeting seasonal storage requirements. However, as an aggregate of many rather small projects, significant storage volumes can be provided. These will likely bear higher costs than equal volumes provided by a few large projects making use of depleted fields or aquifers.

Seasonal storage volume is critically important for longer-term security of energy supply during winter periods in Europe, and will also enhance the ability of Europe to attract new gas supplies. In spot priced based markets, a relative shortage of storage volumes will result in very volatile and high gas prices during wintertime while in traditional markets, with pricing based on indexation to oil product prices, gas suppliers might be forced to cut supplies to individual customers. A possible scenario for both markets is that lack of storage volume could result in a massive and lengthy interruption of gas supply to industrial users and eventually even a curtailment of supplies to residential customers.

Current investment behaviour could have several causes. For instance, seasonal storage facilities require large incremental investments (€ 700+ million) whereas caverns can be added in smaller units (in the order of € 40 million each), limiting the risk exposure for individual investors. Seasonal storage facilities have very long development lead times (five to eight years) and are thus vulnerable to future market developments and changes in regulatory regimes. Acquiring depleted gas fields to convert them into storage facilities might be complex in certain markets, further increasing lead times.

In the view of these uncertainties, EU governments can contribute to improving the investment climate by making clear choices in setting security of supply norms and assigning responsibilities for unambiguously meeting these norms. The necessary implementation of Directive 2004/67/EC on security of natural gas supply offers an occasion to do so.

1

Introduction

European demand for gas will grow in the years to come. Simultaneously, gas production in Europe will decrease and imported gas will be needed to replace indigenous production.

Gas demand is not constant during the year. There are variations in demand on different timescales ranging from seasonal to hourly. Variations in demand are characterised by two main parameters: working volume and deliverability. **Working volume** – *the amount of gas that can be supplied above the baseload production volume during a long (cold) period* – is primarily needed to cope with the summer-winter pattern of gas consumption. Most of the summer-winter pattern comes from the temperature sensitive gas consumption by households and service industries. Gas usage by industry and the power sector are more evenly spread throughout the year and need less working volume. **Deliverability**[1] – *the amount of gas per hour that can be generated on a (very) cold day above the baseload capacity* – is the ability to produce large volumes during short periods, e.g. for extremely cold days, or during peak periods during a day.

In this paper we argue that a large amount of additional working volume will be required over the coming years. First, flexible European production will be replaced by long-distance import gas, and second, the gas market is expected to grow further.

Today's market appears focus mainly on caverns for storage volume. Caverns have little working volume but are ideal for trading purposes. Consequently, Europe may be facing a deficit in working volume, i.e. the ability to cope with seasonal changes in demand. This paper aims to widen the discussion of this matter and give rise to this concern by setting out a broad analysis, exploring the market drivers for seasonal storage and identifying the public interest issues for this market.

Chapter 2 gives an overview of demand for and supply characteristics of gas flexibility. Chapter 3 describes the role of gas storage facilities in the gas market. Chapter 4 reviews the economics of storage facilities, and chapter 5 assesses competition and the investment climate. Finally, chapter 6 provides an outlook on what is needed to send the right signals to potential investors in large working volume (seasonal) gas storage facilities.

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[1] Deliverability is sometime referred to as flexible capacity. However there are also examples in literature where the word capacity is used to indicate working volume. To avoid confusion the term deliverability is used throughout this paper.

2

Demand and supply flexibility

2.1. Market demand for supply flexibility

In Europe, natural gas is mainly used for domestic and commercial space heating and cooking (40%). The remainder is used for industrial processes (30%), power generation (25%) and by the chemical sector (5%). Demand for gas displays a strongly time-dependent pattern. In particular, this is the case for space heating and to a lesser extent, for industrial processes and power generation. In general terms, there are five recurring time-dependent patterns: annual, seasonal, weekly, daily and hourly.

- **Annual**: some years are average, others warm, cold or extremely cold. During years of strong economic growth, gas consumption grows strongly as well, whereas lower economic growth may result in relatively stagnant gas consumption.
- **Seasonal**: gas space heating occurs mainly in wintertime. During the summer holiday season, industry and the power sector require less gas.
- **Weekly**: demand for gas varies from week-to-week due to temperature changes and holidays.
- **Daily**: the day-to-day pattern is most prominently observed in the power sector, where demand for electricity is much stronger on working days than weekends. A similar pattern occurs in smaller industries for which production on weekends and during short holiday periods such as Christmas is typically limited.
- **Hourly**: the shortest time pattern. Peak gas demand for heating and power production takes place in the morning, with a secondary peak at the end of the afternoon. At night, gas demand is relatively low.

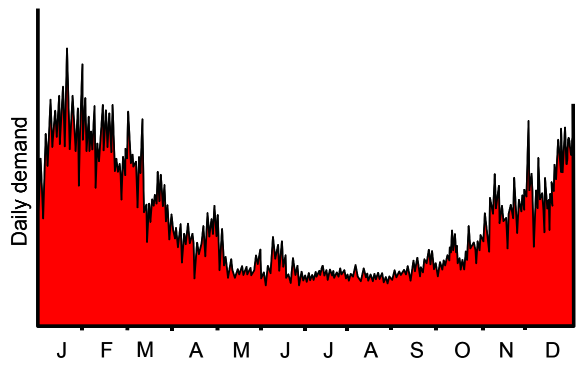

Figure 1: Typical gas demand profile over the course of a year

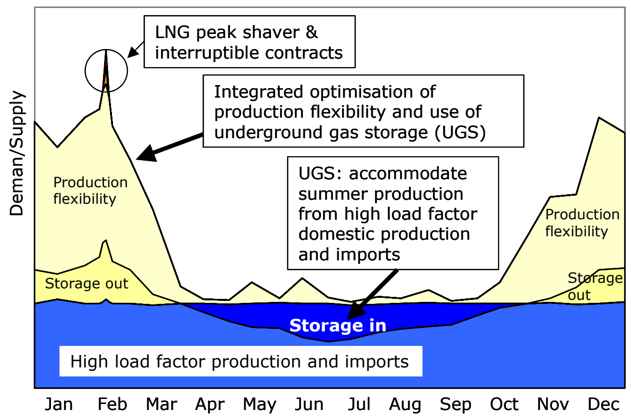

Figure 2: Schematic of annual demand, production and use of seasonal storage

Figure 1 depicts a typical gas demand pattern in the Netherlands over the course of a year from which the monthly and seasonal use patterns can be observed. The figure illustrates both the short-term demand variations and a typical seasonal pattern. Data on monthly gas demand for various European countries show that under normal winter temperatures monthly gas demand in winter is about three times higher than in summer. For the UK this ratio is about two, because the summer-winter temperature differential is much lower than on the continent.[2]

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[2] Stern, J., (2004), 'UK gas security: time to get serious', *Energy Policy* 32, pp. 1967-1979.

2.2. Flexibility in supply

Suppliers,[3] who deliver gas to consumers, require flexibility in their portfolio to satisfy the variable off-take of these consumers. Clearly, consumer on-site gas storage is generally not an option.

Ways to meet flexibility demand

Production flexibility

Purchase contracts with producers usually form the backbone of a supplier's portfolio of flexibility instruments. Typically, these contracts contain provisions to allow the supplier to take more gas in winter months than in summer months. The flexibility of these contracts is limited and depends largely on the distances from the field to the market. Contracts with indigenous producers in the Netherlands and the UK generally contain more flexibility (typically 120-150%[4]) than contracts with producers in remote countries like Russia and Algeria (typically 110-120%).[5]

Seasonal storage

The next building block of a supplier's portfolio of flexibility instruments is seasonal storage. Seasonal storage facilities are relatively large and are filled in summer over the course of several months and emptied in winter, also over a (albeit shorter) period of several months. Seasonal storage facilities have a large working volume but comparatively little output capacity. They are usually depleted gas or oil fields[6] (DGF), which have been converted into gas storage facilities. In some countries, e.g. France, aquifers are used for this purpose. Because aquifer storage facilities take a long time to develop,[7] depleted gas fields – if available – are the preferred option. Figure 2 illustrates the process (not to scale) of summertime filling and wintertime production and depletion. Typically, the filling (send-in) season of these large storage facilities takes about six months, while the production (send-out) season is two to three months.

Although depleted field and aquifer storage facilities are mainly used to cope with the summer-winter demand differential, they can have additional purposes, such as to support the production level of gas fields in times of low demand and/or to serve as a strategic stock, or to counter-balance major disruptions in gas supply.

Seasonal storage facilities have three main characteristics: (working) volume, send-out capacity and send-in capacity. These gas storage facilities vary in size and other properties. For the purpose of this paper, the typical working volume of a seasonal storage, with full economies of scale is about 2 billion m^3 (bcm). Such a storage facility will have a send out capacity of approximately 30 million m^3/day, sufficient for the gas supply to one million households on a relatively cold winter day.

Gas caverns

Gas caverns are storage facilities created in salt layers. On average, they have less working volume than depleted field storage facilities and are mainly used for peak supply. A cavern storage facility can be envisioned as a large underground gas bottle. Caverns can be filled and emptied much faster than seasonal storage facilities. A typical send-out period is 10-30 days. The send-in period may be similar. Generally, a cavern storage facility consists of a number of individual salt caverns, each with a (working) volume of 30-70 million cubic metres and a send-out capacity of about 2-4 million m^3/day. Gas caverns are mainly used to cover the coldest days in a winter. Because of the relatively high send-in capacity, gas caverns may be (partly) re-filled on winter days with relatively low gas demand. This

[3] For the purpose of this paper, suppliers are gas merchants and resellers, buying mostly from producers and selling gas to distributors and consumers.

[4] This percentage is the maximum daily production compared to the average daily production over the year.

[5] Asche, F., Osmundsen, P., Tveterås, R., (2002), 'European Market Integration for Gas? Volume flexibility and political risk,' *Energy Economics,* Vol. 24, pp.249-265.

[6] Although the phrase *depleted field* is often used to describe gas storage in a reservoir, it is also possible to convert a partly produced – or even unproduced – gas field into a storage facility. This may even be the preferred option. An example is the Grijpskerk underground gas storage in the Netherlands.

[7] Knowledge of a specific aquifer needs to be developed, and suitability for gas storage needs to be tested. For the case of a depleted gas field, reservoir knowledge is available from the exploration and production phases.

will increase the total number of send-out days. However, it should be noted that during a period with a demand above baseload (e.g. because of cold weather), there may be insufficient gas on the market to economically re-fill the caverns.

In liberalised markets, gas caverns have become much more popular. Because of the relative large send-in and send-out capacities, they are well suited to achieving benefits from temporary price differentials, which occur in a spot market. Due to their small scale, cavern storage facilities require less investment and can be built in stages, one after the other, with limited incremental costs for each new cavern. Many of the new storage facilities currently planned for Europe are caverns.

Interruptible contracts
Interruptible contracts are an additional flexibility instrument in a supplier's portfolio. These require contractual arrangements with consumers to allow the supplier to reduce or stop gas deliveries for a certain period. Industrial and power consumers have traditionally enjoyed price discounts for using this option. Consequently, many of them have back up facilities to replace gas with (mainly) fuel oil. It is also an option for an industry to reduce or suspend production when gas supply is interrupted. Apart from perhaps the power and aluminium industries, gas costs are usually only a small part of the overall variable costs and switching to oil in many cases is restricted by environmental legislation. Therefore, for most industries, suspending production will not make much economic sense. The only exception might be during periods of extremely high spot gas prices.

LNG storage
LNG storage[8] is used when high deliverability is required with a small working volume. This type of storage is typically reserved for a few extremely cold winter days, which may occur only once every so many years. Subsequent refilling of the LNG tanks may take a half-year or longer. Storage of a cubic meter of gas in liquid form is very expensive compared to the storage of the same cubic meter of gas in a cavern or a depleted gas field. LNG storage facilities are used because of their high send-out capacity, making them ideally suited to cover the rare, extreme winter peaks.

Low pressure storage
The smallest size of storage facilities are located close to the consumer with the principal function of assisting in the supply of the hourly off-take pattern of households and power stations. In the UK, such low-pressure gas shelters are operated. In Germany, there are the so-called *Röhrenspeichers*. These are pieces of large standard gas pipeline placed underground and fitted with a compressor to fill during the night hours and be emptied during weekday mornings and afternoons. The send-out period of a Röhrenspeicher is in the order of 12 hours.

Line pack
Storage in transport systems is called line pack. Increasing the pressure in a pipeline will force it to contain more gas per cubic metre. A decrease in pressure reduces the amount of contained gas. Thus, by varying the pressure in a transport pipeline, the gas content can be varied. Line pack is mainly used to balance the transport system against unexpected variations in production, import or consumption. If the line pack is larger than required for this function, the additional line pack can be used in the market. How much additional line pack is available depends on the use of the transport system. In summertime, there will be more additional line pack available for shippers than in wintertime. Furthermore, over-investment in transport capacity leads to additional line pack, although this is expensive compared with other flexibility instruments. Nevertheless, based on investments for a growing gas market, additional line pack may be temporarily available as investments are usually executed as step changes. In addition to the line pack required for the integrity of the transport system, there may be more line pack available that can be used by shippers to help to balance their portfolios. Line pack has, by nature, an (almost) infinite send-out capacity, but very limited working volume.

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[8] LNG storage facilities are quite different from LNG import terminals. The latter are built to receive liquefied gas from overseas. To recover the costs of the full LNG cycle (liquefaction, transport and terminal), they need to be used almost continuously. This causes LNG receiving terminals to supply baseload gas with only limited flexibility. However, depending on gas prices and re-routing of cargo, LNG might become more flexible.

Overview
Table 1 summarises the various flexibility instruments used by suppliers as described above. Obviously, the delineations in the table are fluid.

Flexibility Instrument	Annual	Seasonal	Weekly	Daily	Hourly
Long distance production flexibility	Yes	Yes	Yes	No	No
Short distance production flexibility	Yes	Yes	Yes	Yes	No
Underground storage (fields & aquifers)	No	Yes	Yes	Yes	No
Underground storage (caverns)	No	No[9]	Yes	Yes	Yes
Interruptible contracts	No	No	Yes	Yes	Yes
LNG storage (peak shaving)	No	No	No	Yes	Yes
Small scale local compressed gas	No	No	No	Yes	Yes
Line pack	No	No	No	No	Yes

Table 1: Overview of flexibility segmentation[10]

It should be noted that flexibility instruments such as production flexibility and storage require sufficient transport capacity to bring the gas to the market when needed. New storage developments will therefore generally require development of additional transmission capacity as well.

2.3. Supply of storage volume and opportunities for The Netherlands

Almost all European countries have storage facilities (see Figure 3). The type of storage facility used is mainly determined by the availability of suitable gas fields, aquifers and salt layers. The preferred option for seasonal storage facilities is depleted gas fields (see below; also Tables 2 and 4). Consequently, in regions with gas fields such as Germany, Italy and the Netherlands, seasonal storage facilities are typically of the DGF type. In other European regions, aquifers are used. Caverns are more evenly spread throughout Europe. Not all DGF storage facilities are large. In particular, in Southern Germany, gas fields tend to be small and so are the storage facilities. Opportunities for converting depleted fields into storage facilities mainly occur in Northern Germany, the Netherlands, and the UK (see Figure 4). In contrast, Belgium, France and Southern Germany have very few gas fields that could be transformed into storages. In general, the fields in the Netherlands and Northern Germany are close to existing infrastructure, although substantial investments in additional pipeline capacity are likely to be needed, in line with a need for more infrastructure in Europe to cope with the growing volume of gas. The potential of converting UK gas fields is less clear: the fields may be more costly to convert into storage facilities due to their offshore locations, but their proximity to the UK market offers a transport cost advantage over Dutch and German sites.

In conclusion, given the availability of depleted gas fields, the infrastructure and the location, the Netherlands should be able to provide seasonal flexibility to Belgium, parts of France and Germany and possibly the UK.

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[9] A sufficiently large number of cavern storage facilities can also offer substantial working volume and contribute significantly to seasonal flexibility. However, seasonal flexibility is most probably provided more efficiently by large storage facilities in depleted gas or oil fields or aquifers.

[10] Spot gas markets form an additional, non-physical instrument for flexibility. By selling and buying spot gas products, a supplier can develop a portfolio with the required characteristics: selling and buying in the intra day market can meet sudden changes in the gas demand; buying and selling of day ahead gas or 'weekend gas' can meet weekly and daily changes; and seasonal flexibility can be obtained by buying and selling monthly or seasonal gas products.

Some claim that the presence of a spot market adds flexibility to the market. Others believe that it is just a market place for the sale and purchase of existing (physical) flexibility, and by itself is not a source of gas flexibility. Finally, some experts believe that a gas market with a spot market will need more storage facilities than a gas market without because in the first instance, storage facilities are also used for price arbitrage. See for example: Geczy, C.C., Minton, B.A., Schrand, C., (1999), Choices Among Alternative Risk Management Strategies: Evidence for the Natural Gas Industry, 028-99, The Rodney L. White Center for Financial Research, The Wharton School, University of Pennsylvania, November.

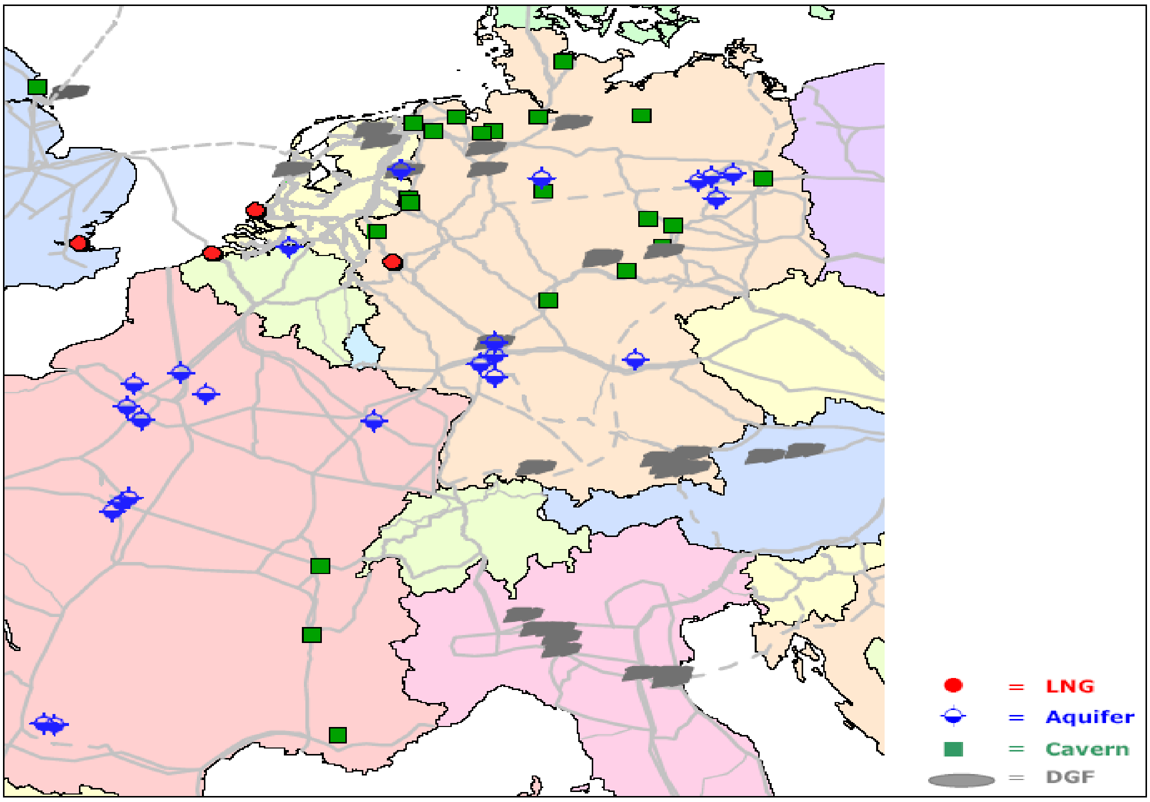

Figure 3: Distribution of gas storage facilities in North-West Europe[11]

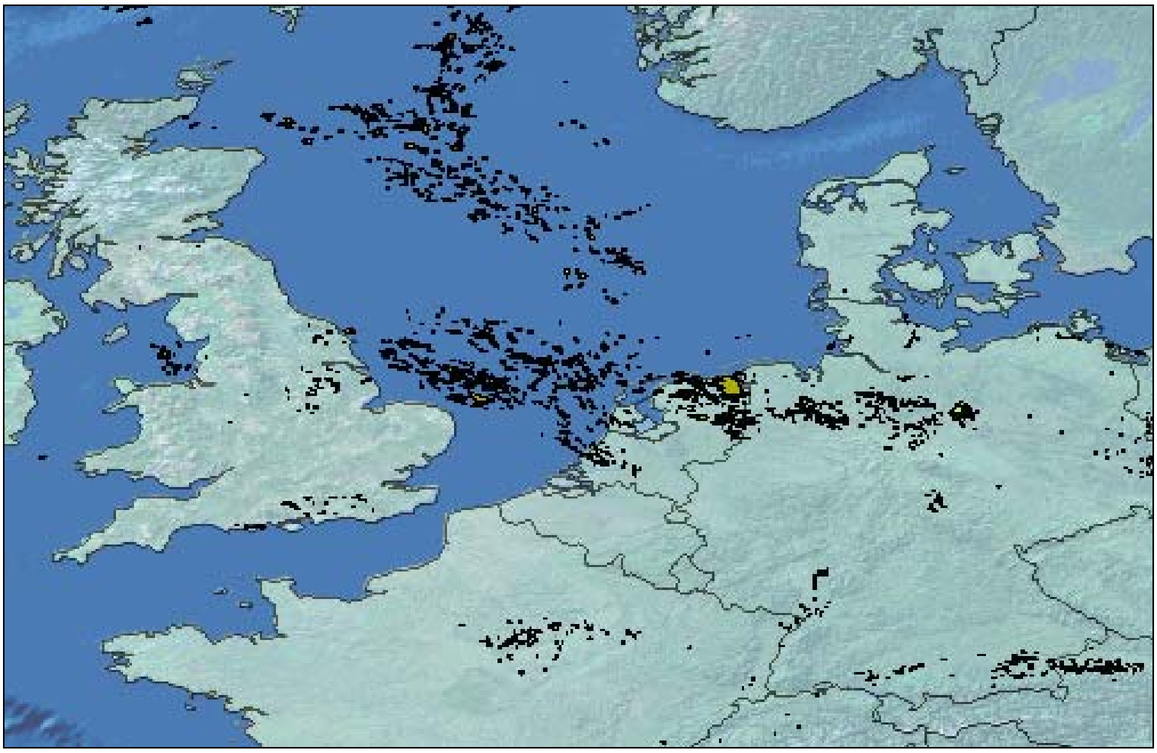

Figure 4: Oil and gas fields in North-West Europe[12]

[11] Source: Gasunie, <http://www.gasunie.nl>.

[12] Source: Nederlandse Aardolie Maatschappij (NAM), <http://www.nam.nl/>.

3

Demand and supply of gas from storage facilities

3.1. Demand for storage volume

Storage facilities bridge the gap between production and consumption. When consumption is higher than production the difference is produced by storage facilities. Likewise, storage facilities are filled during periods when production is higher than consumption. The International Energy Agency (IEA) provides per country statistical data on production, imports, demand and storage usage on a monthly basis. Figure 4 depicts such data for OECD Europe for 2003.

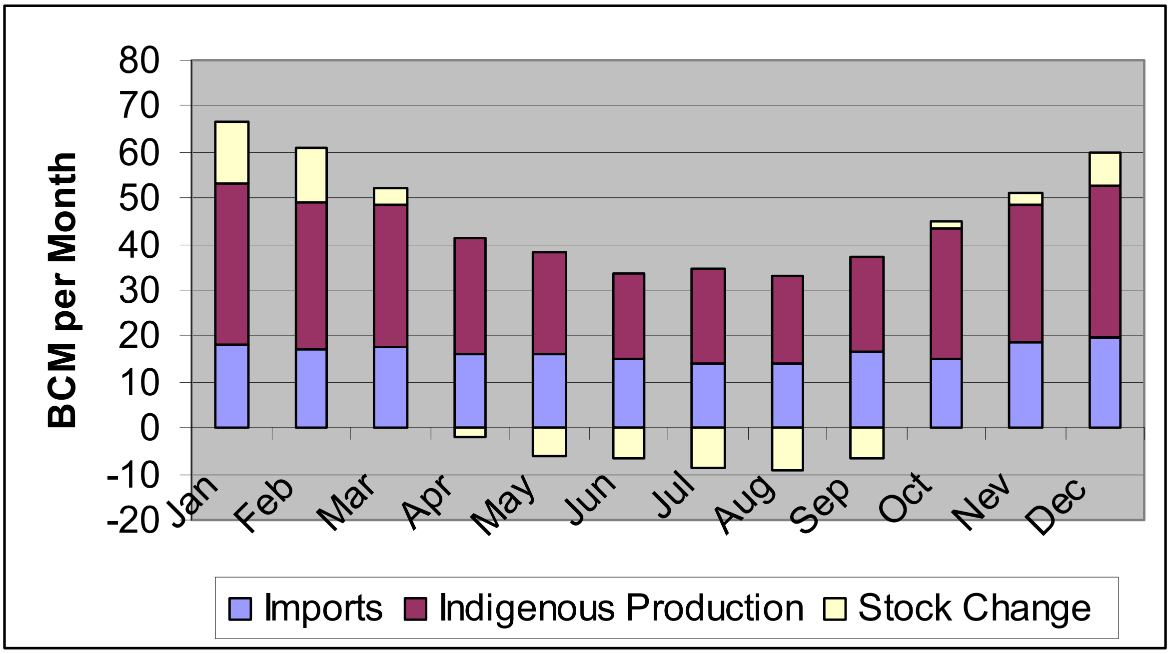

Figure 5: Monthly volumes of production, import and stock usage for OECD Europe (2003)[13]

Figure 5 illustrates, for 2003, that monthly gas demand in Europe varied between 35 bcm and 65 bcm. From the figure it can be seen that part of the summer production was used to fill up gas storage. Imports are relatively stable and vary between 15 and 20 bcm. Indigenous production (mainly from the UK, the Netherlands and Norway) more or less follows the demand pattern and varies between 20 and 35 bcm. Net monthly stock withdrawals from storage facilities occur between October and March, while storage facilities are filled during the summer months. The total withdrawal during 2003-2004 was 40 bcm. Winter temperatures for 2003-2004 were normal, had it been colder, storage withdrawals would have been significantly larger.

The IEA have produced monthly statistics on storage use covering many years. Figure 6 presents the total storage withdrawals during wintertime for 1986-2004 in the European OECD countries. The figure illustrates a steady increase in the use of storage volumes by approximately 8% per year. During the same period, the gas market grew from 300 bcm to 600 bcm, representing a demand growth of approximately 4% per year. The main reason for increase of storage use outperforming the growth of

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[13] International Energy Agency (IEA), *Natural Gas Balances and Trade – Historical* (database), 1984-2004, IEA/OECD, Paris. Illustration courtesy of A. Correljé, Delft University of Technology.

demand for gas is that gross production flexibility (indigenous production and import) slowly but steadily decreased from about 145% to 125%.[14]

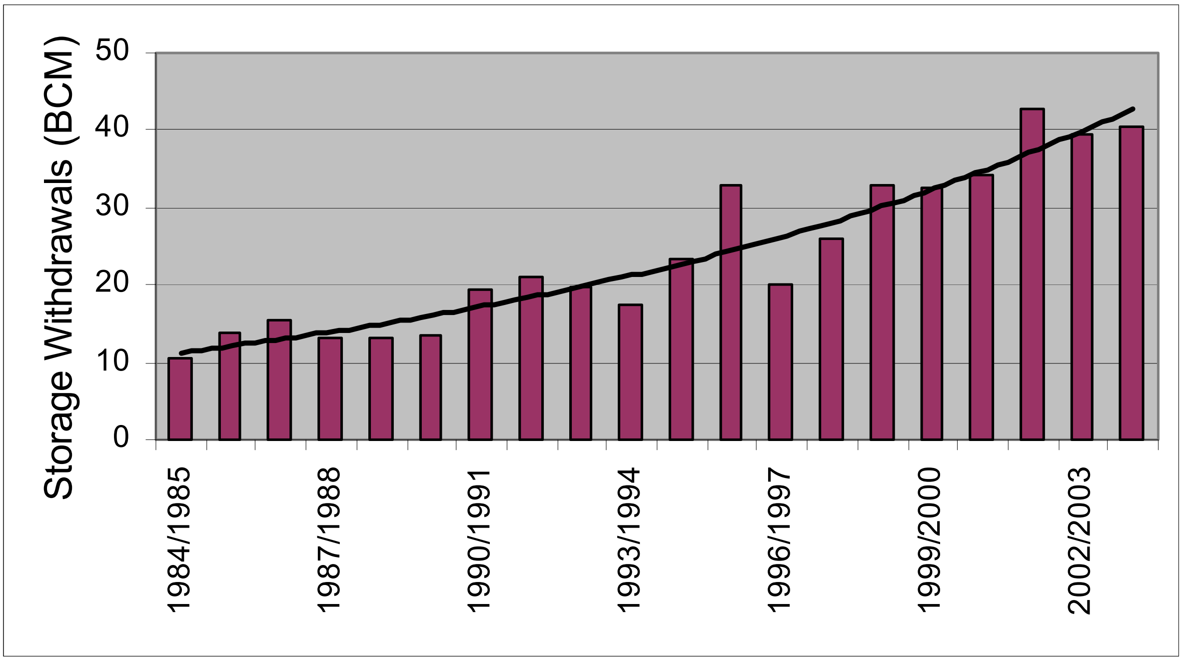

Figure 6: Net stock withdrawals per winter in bcm[15]

Figure 6 also shows some variation due to temperature differences over the years. For instance, the winter of 1995-1996 was relatively cold and consequently there was a high storage withdrawal, some 35% above the average. During a lengthy and very cold winter, such as 1962-1963, storage requirements could be considerably more than 35% above the average.[16]

The likelihood of an extraordinarily severe winter determines the amount of seasonal volume that should be in place at the beginning of any winter. This probability is a very important element in the planning of any gas supplier. Since winters during the last decade have been relatively mild – a fact generally attributed to global climate change – many argue that a 1962-1963 winter will never again occur. Conversely, there also is speculation that global climate change may alter the direction of the warm Gulf Stream resulting in an opposite effect, and others hold the opinion that Europe will begin to experience even more severe winters than in the past. There are no guidelines from governments on whether plans for gas delivery should be able to meet a lengthy 1963-type winter.

Figure 7 depicts the annual use of storage volume as a percentage of the total installed volume (including strategic volume[17]). For years in which the total installed volume data was not available (see Figure 8), it has been deduced via interpolation. Figure 7 shows that until 2000, with the

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[14] Gross production flexibility is defined as the quotient of the maximum Production Volume and the Mean Production Volume on a monthly basis. Source: Monthly IEA data.

[15] This figure is based on realised monthly data published by the IEA. Illustration courtesy A. Correljé, Delft University of Technology.

[16] A comparison, based on KNMI data, between 1963 and 1996 for station De Bilt (Netherlands) is given below (http://www.knmi.nl/).

	1963	1996
Coldest 20 days (average)	–8.2°C	–5.4°C
Coldest 60 days (average)	–5.1°C	–2.4°C

[17] Strategic volume refers to government controlled stocks that are not available to the market, but which are maintained as an insurance against major interruptions to supply.

exception of the rather cold winter of 1995-1996, annual use of storage facilities was below 50%. However, since 1999, the use of storage volume in all winters exceeded 50% and appears to be gradually increasing. Note that all winters since 1995-1996 have been relatively warm.

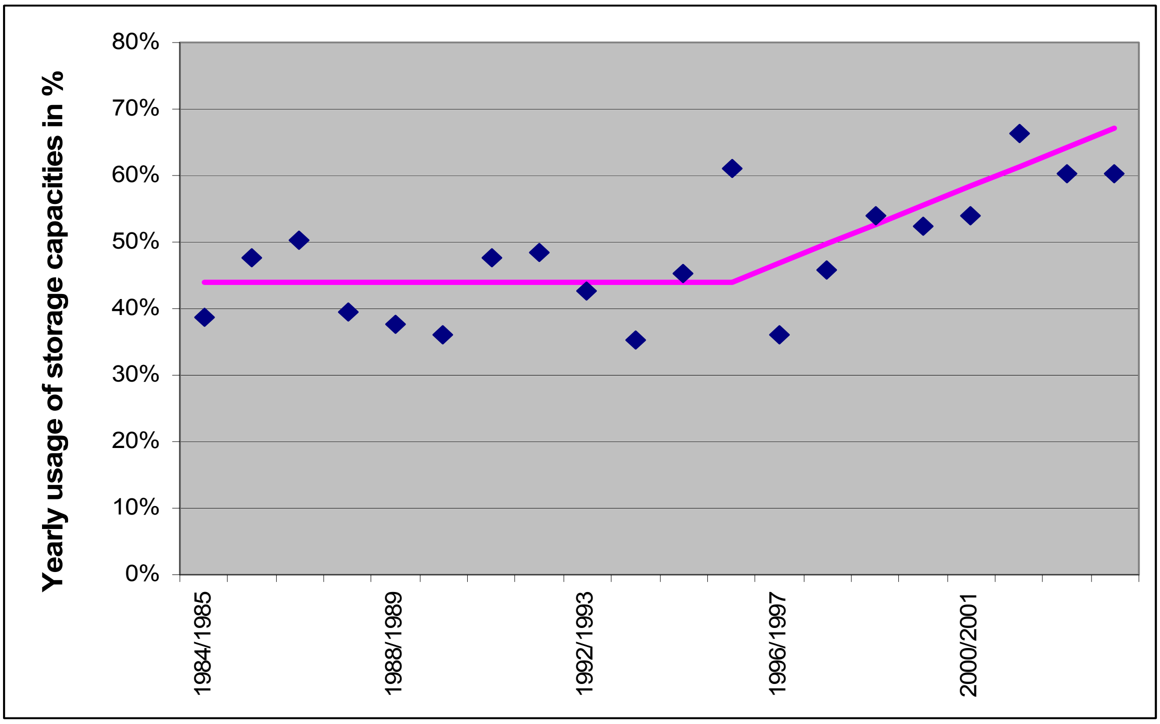

Figure 7: Annual usage of total storage volume (incl. strategic stocks)

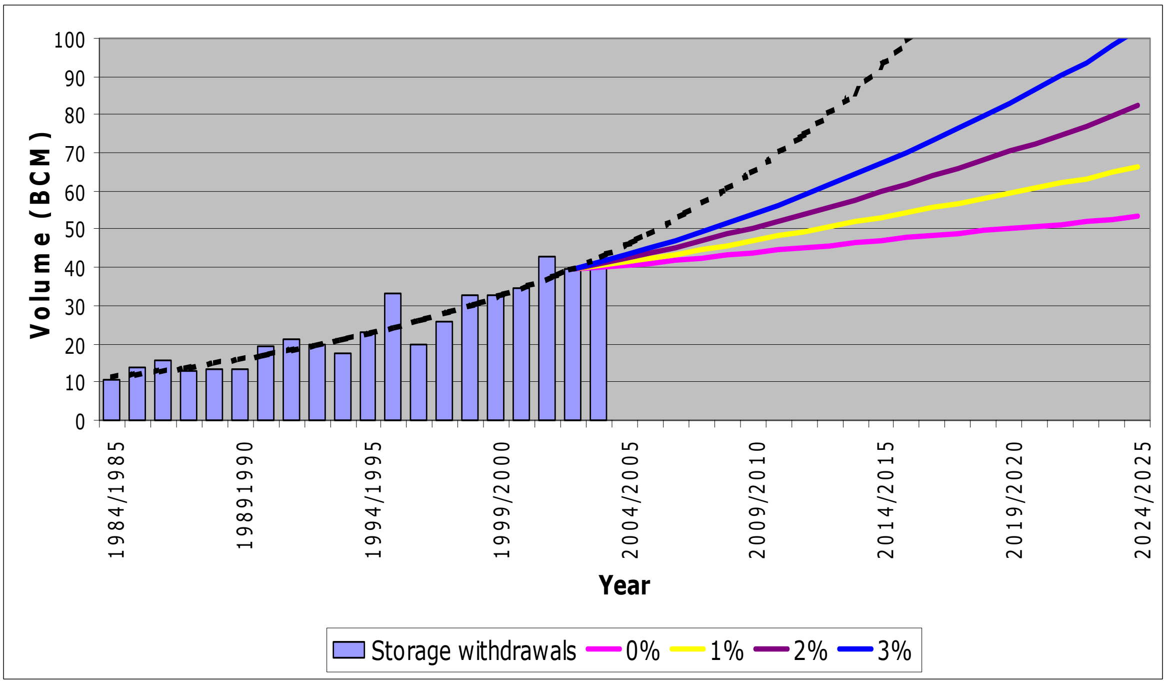

Figure 8: Required working volume for average winters under different demand growth assumptions[18]

[18] Based on extrapolation of 2003-2004 IEA data, courtesy A. Correljé, Delft University of Technology.

3.2. Future demand for storage volume

The increase in demand for flexibility services, notably provided by storage facilities, is expected to continue after 2010. Gas demand will continue to grow and gross production flexibility (indigenous production and imports) will decrease further.[19] Figure 8 illustrates calculations that have been used to examine the effect of these factors on future required storage volumes. To this end, IEA 2003-2004 data were extrapolated into the future. It was assumed that production flexibility would decline in a linear fashion over the next 20 years from 125% to 110%, while gas market growth is varied between 0% and 3% per year, and while the pattern of market demand for flexibility remains unchanged.

Figure 8 shows that a gas market growth rate of 2% per year (only half the growth rate for 1986-2003), combined with the expected decline in production flexibility, results in annual storage working volume requirements from 40 bcm in 2003 to more than double that amount in 2025.[20]

As noted above, average winter temperatures can vary substantially from year-to-year. The extrapolation as illustrated in Figures 6 and 8 was based on average storage withdrawals during the period of 1984-2004. If it is assumed that during extremely cold winters demand for storage withdrawals could be 50% higher than average, catering to that potential demand would require additional storage volume of approximately 60 bcm by 2025 for the 2% growth scenario.

In relation to this, two factors need to be addressed:

- the probability of cold winters occurring; and
- the question of whether it is economically efficient to use storage facilities to cater to volume needs during rare very cold winters or whether other means might be more appropriate.

This analysis does not take into account the effects of existing or new measures to hold strategic stocks. Security of supply measures are still left up to individual states with their very different energy portfolios and security risks.[21] We define strategic stocks as stocks that are not available to the market, but which are intended as an insurance against disruptions to deliveries from major supply sources. The use of strategic stocks is controlled in one way or the other by government. Strategic stocks as defined above are present in Italy, Spain and Hungary.[22]

We estimate the current level of strategic stocks to be at around 10 bcm. Given that current European storage capacity is about 70 bcm and on basis of the 40 bcm stock withdrawals during 2003, this would imply that about 20 bcm of storage volume is available to the OECD Europe market to cope with severe winters. This current safety margin might however be unevenly distributed across Europe. Moreover, storage facilities might not be completely filled at the beginning of the withdrawal season (see below).

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[19] European gas demand is projected to increase annually by 2-3% up to 2020. For a recent overview of European gas demand projections see Tönjes, C., (2005),'Gas to Power in Europe', IGU/EDI/CIEP Discussion Paper, April, <http://www.clingendael.nl/publications/2005/20050400_ciep_misc_gas-to-power-in-europe.pdf>.
For an overview of the development of European gas supply see Clingendael International Energy Programme, (2004), 'Natural gas supply for the EU in the short to medium term', Clingendael Energy Paper, March, <http://www.clingendael.nl/publications/2004/20040300_ciep_paper.pdf>.

[20] The growth rate of gas consumption is dependent on the use of gas in the power sector. In this regard, a 2% growth rate represents a scenario in which there is little growth of gas consumption in the power sector, while a 3% growth rate presents a scenario with moderate growth.

[21] Between 2002 and 2020, imports to Europe will more than double from approximately 200 bcm/year to about 500 bcm/year (International Energy Agency [IEA], (2005), *World Energy Outlook 2005 – Middle East and North Africa Insights,* IEA Publications). If European countries were to require a strategic volume stock of 30 days of average annual imports (for oil, 90 days), these increased imports would require additional European strategic storage volume of about 30 bcm (accounting for existing strategic stocks in Italy and Hungary).

[22] In Italy, any importer must hold 10% of annually imported volume from any non-EU source as a strategic stock (International Energy Agency [IEA], (2002), *Energy policies of IEA countries. Italy*, p.190). In Spain, suppliers must hold stocks equivalent to at least 35 days of consumption (International Energy Agency [IEA], (2005), *Energy policies of IEA countries. Spain*, p.92).

3.3. Supply of storage volume: a potential shortfall?

Figure 9 presents the actual build-up of storage volume in OECD Europe since 1970. Further, the figure presents the build-up of inflexible baseload production from Norway and from sources outside Europe. In general terms the figure suggests that in the past, there was a fixed 1-3 correlation between the storage volume (including strategic storage facilities) and the amount of baseload production. Assuming that the flexibility of the inland production (UK and the Netherlands) equals the demand flexibility, such a relation could be expected. It is anticipated that inland production flexibility in Europe will decrease quickly because many UK gas fields are in rapid decline.

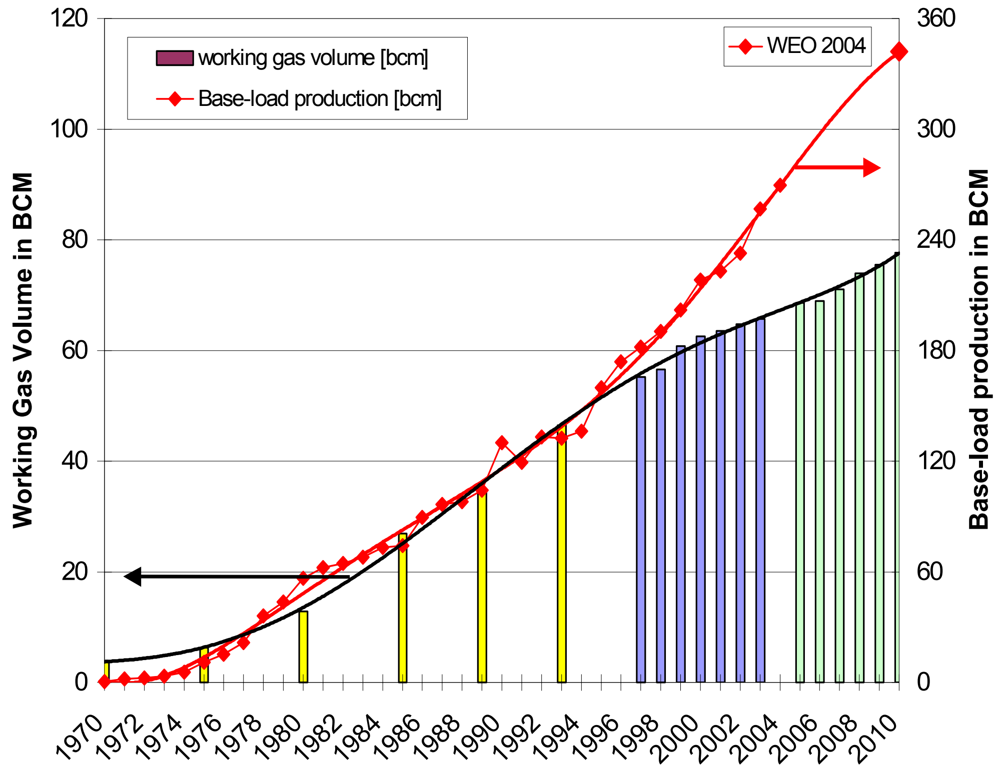

Figure 9. Build-up of the storage working volume in OECD Europe in relation to the total baseload production for Europe from Norway, Russia and Algeria[23]

Since 1999, Figure 8 shows that while the amount of baseload production increased more rapidly than before, the growth of storage volume actually slowed down. This observation corresponds with the observation made in Figure 7, where it was found that the use of storage facilities began to increase after 1999.

In the coming years, additions to storage volume will be limited (see the green bars in Figure 9), although there are many projects already underway and planned for in many different countries, most of these projects have relatively little working volume. At the same time, increase in baseload imports towards Europe will continue. The IEA expects that the baseload production will increase from 250 bcm in 2003 to 340 bcm in 2010.[24]

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[23] Sources: yellow bars – Cedigaz; blue bars – IEA; and green bars – new storage facilities planned and under development (analysis by CIEP on the basis of public information).

[24] International Energy Agency (IEA), (2004), *World Energy Outlook 2004*, IEA Publications. For a thorough analysis, the various regional markets in OECD Europe should be assessed individually with respect to their endowments and needs because storage facilities' circumstances vary. For instance, with respect to North-West Europe, relatively modest market growth is expected. On the other hand, most of new storage volume until 2010 will be situated outside of this area, while the decrease in production flexibility occurs just inside this area.

3.4. Meeting future demand

It is difficult to estimate whether there is sufficient storage volume in Europe. There is some optimism that spare storage volume and deliverability are still available. However, in March 2005, following a mild winter, a cold period occurred and major gas consuming countries such as France, Italy and the UK reported that their (non-strategic) storage facilities were almost empty. This could indicate that there is limited spare working volume available in Europe, a situation that might lead to supply problems in the event of an extremely cold winter. Alternatively, in this instance there may have been other reasons for gas production from storage earlier during the winter.

Liberalisation, uncertainty about regulation, diminishing flexible inland production, the growing share of power generation in the supply portfolios, and the unknown effects of the Kyoto Protocol on gas demand storage requirement makes predictions more difficult than ever. It is conceivable that growth of the gas market could be more, but also less, than 2%. Further, annual gas demand patterns might change in the future, and/or decreases in production flexibility could be faster or slower than anticipated. In any case, it is believed that in all scenarios, Europe will need significantly more storage volume in the coming years.

This assumption is based upon:

- gas market growth of about 2% a year;
- declining production flexibility from 125% to 110%; and
- an unchanged relative market demand for supply flexibility

This analysis suggests that, on average, Europe will need 2 bcm of additional storage volume per year. This is exclusive of any new requirements for strategic gas stocks. However, such an increase would only be sufficient to cover demand for seasonal storage during average winters. Catering to extreme winter needs, possibly requiring substantially higher storage withdrawals, could imply annual storage volume additions of up to 3 bcm.

4

Economics of storage facilities

4.1. Storage facility costs

The cost of storage is strongly contingent on the type of storage used and the properties of the aquifers and depleted gas fields and/or the circumstances under which salt caverns are created (e.g. whether the salt will be used or disposed of as a waste product). Because storage projects usually have long lead times, up to eight years, the applied industry cost of capital also plays a major role.

There is little information in the public domain about storage costs. Based on data provided by UNECE[25] and by Sofregaz,[26] Table 2 provides approximate cost estimates for storage facilities with a withdrawal rate of approximately 10-20 million m^3/day, based on full deployment and a capital cost of 12%. In practice, costs vary widely due to many factors, including but not limited to different geological parameters, location with respect to the transport network, total volume and the price of the cushion gas.[27] At current (2006) gas prices the typical cost of deliverability will be higher.

Type of Storage	Working Volume	Maximum Output Duration	Typical cost Working Volume	Typical cost Deliverability
	Million m^3	Hours	€/m^3/year	€/m^3/h/year
Depleted gas field	2,500	2,000	0.05	100
Aquifer	2,500	2,000	0.07	140
10 Caverns	500	500	0.13	65
LNG	50	100	0.40	40

Table 2: Approximate storage costs for various options (at a gas price of € 0.10/m^3)

From Table 2, it can be gleaned that caverns and LNG storage afford the lowest costs for deliverability, while depleted gas fields and aquifers offer the lowest costs for working volume.

To put these costs into perspective, assuming that 50% of a household's 2000 m^3 gas consumption comes from storage facilities and that this requirement is fulfilled using a mixture of both caverns and DGFs, the cost per household corresponding to the aspect of storage facilities is around €100 per year.

4.2. Transport costs of stored volume

Usually, transport of gas is required between storage facilities and the market. The transport costs are heavily contingent on the prevailing gas flow direction. When flexibility is transported in the same direction as the prevailing gas flow, additional pipelines have to be built and the full costs of these pipelines have to be paid. On the other hand, when flexibility is transported in an opposite direction to

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[25] United Nations Economic Commission for Europe (UNECE), (1999), *Study on Underground Gas Storage (UGS) in Europe and Central Asia*, Geneva: United Nations.

[26] Favret, Fabien, (2003), "Up-to-date researches and future trends in underground gas storage facilities: a state of the art review," Paper presented at the NATO, Advance Research Workshop, *Security of Natural Gas Supply through Transit Countries*, Tbilisi, Georgia, 22-24 May 2003.

[27] Cushion gas is the volume of gas in a storage facility that provides the base pressure. It stays in place during the economic life of the storage facility.

the main flow, the main flow is reduced or even halted and the only costs incurred involve the pipeline not being fully used during a certain amount of time.[28] Table 3 shows transport costs of stored volume per cubic metre. The numbers are based on a (regulated) transport tariff of €15 per m^3/h per 100 km per year. In the table, the lower cost corresponds to transport opposed to the main flow direction while the higher number corresponds to transport in the same direction of the main flow.

	Maximum output duration	**Typical storage costs working volume**	**Typical transport costs per 100 km volume**	
	Hours	€/m^3/year	€/m^3/year	
			Opposite direction	Same direction
Depleted gas field	2000	0.05	0.002	0.008
Aquifer	2000	0.07	0.002	0.008
10 Caverns	500	0.13	0.002	0.030
LNG	100	0.40	0.002	0.150

Table 3: Estimated transport costs for stored volume[29]

Transport costs do not depend on the type of storage. Cost per cubic metre varies only in terms of the time the transport system is needed. From Table 3, it appears very attractive to transport flexibility in a direction opposite to the main flow. In practice, this means that storage facilities should be built as far as possible downstream on the gas chain. Furthermore, the table illustrates that transport costs can be significant and that it makes sense to optimise not only with respect to the type of storage, but also with in terms of transport situation.

Since transport costs per cubic metre decrease with increasing output duration, the transport issue is less important for seasonal storage facilities than for caverns and LNG. Given differences in storage costs and transport costs as presented in Table 3, it can be estimated that the break-even distance for long duration storage between caverns[30] and depleted gas fields will be 500 kilometres or more. In other words, the use of caverns for seasonal storage is economically justified if storage from depleted gas fields has to travel more than 500 km. For short duration (peak) storage the break-even distance from LNG or caverns[31] may be 200 km or less.

4.3. Storage tariffs

As detailed above, storage costs vary significantly. The more or less hypothetical calculations, as presented in Table 2, contain a large range of uncertainty. An indication of actual variations in storage costs across the different types of storage facilities are shown in Figure 10. This figure presents the published storage costs per cubic metre of stored volume in various storage facilities in North-West Europe with TPA, plotted against the maximum output duration. Although little is known about the background of the various published tariffs, the figure clearly presents both the relation and the variation in the storage costs and the maximum send-out duration. Generally, LNG storage facilities and salt caverns are on the left hand side of this figure, while the depleted gas fields and aquifers are on the right hand side.

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[28] In the financial world, such an upstream movement of flexibility would be analogous to a 'swap'.

[29] Distribution costs of stored volume have not been taken into account.

[30] It should be taken into account that the costs per cubic metre of cavern storage with an output duration of 2000 hours are slightly lower than those of (normal) cavern storage with an output duration of 500 hours.

[31] Similarly, costs per cubic metre of cavern storage with an output duration of 100 hours are slightly higher than of a cavern storage with an output duration of 500 hours.

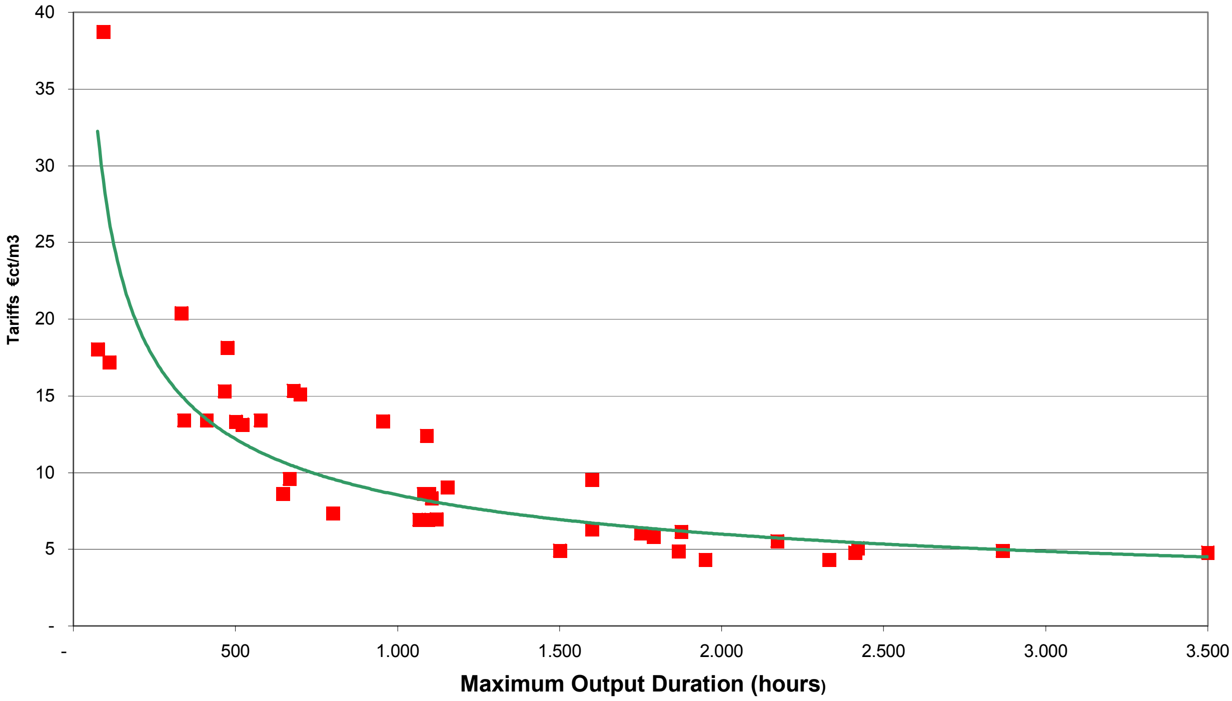

Figure 10: Storage tariffs in North-West Europe (2005)

From Figure 10, it can be observed that tariffs for most storage facilities with a maximum output duration of 2000 hours are approximately 5 € cents/m^3, while the costs for most storage facilities with a maximum output duration of about 500 hours are approximately 15 € cents/ m^3. These numbers correspond more or less with the cost estimates in Table 2.

5

Competition and investment considerations

In Europe, there are currently only a few large-scale projects, ongoing or planned, to convert depleted fields or aquifers into underground storage for seasonal volume shifts; whereas a significant number of projects focus on the development of facilities with rather low working volume and relatively high deliverability. Given the huge projected demand for new volume storage facilities, there is a risk that the required working volumes will not be provided in time. The main question is: why are these investments not taking place? This chapter addresses this question by looking at the market players and the impact of liberalisation.

In North-West Europe, two pricing models for natural gas supplies prevail. These pricing systems also influence the basis upon which storage investments are made. In the UK, gas is priced according to spot markets. Spot markets more-or-less mirror the supply/demand balance and hence price differences can be found between summer and winter, and storage investment, to a large extent, is based on the summer/winter price differential. In Continental North-West Europe, such price differentials are much less pronounced or not present at all as gas prices are mainly indexed time-lagged to oil product prices. Storage facilities cannot rely on gas market price differentials to recoup investments. Storage operators invest on the basis of their own portfolio considerations. On the purchase side, storage affords lower average purchase prices from (long-distance) producers, as producers can deliver their gas at higher load factors. On the sales side, storage investment enables the operator to accommodate the demand fluctuations of their customers and to prevent imbalance charges.

Consequently, the UK is currently seeing a variety of investors proceeding with new storage investments, including gas supply companies with their own customer base, as well as independent storage operators who rely on market price differentials to recoup their investment.

A fundamental problem for investors in new storage projects in spot price based markets is that the actual summer/winter price differential is not known very long in advance. Future markets extend to a maximum of six years and liquidity in the two prime spot price based markets, the US and the UK, is only noteworthy for the following two years. Given that a new storage facility, especially if it is a large volume storage, has a lead time of four to eight years, there is little opportunity to lock-in price spreads even during the first years of operation.

5.1. Players in the storage market

Figure 11 presents the main players in the market for working volume in Europe. ENI (Italy – via its subsidiary Stogit) and Gaz de France have the largest storage volumes at their disposal. These market leaders are followed by many other players including Gasunie, Wingas and E.ON. Not surprisingly, virtually all storage facilities in Europe are at the disposal of the main gas merchants who fit these into their supply portfolios and obligations.

To convert depleted gas fields into storage facilities, a company needs access to gas fields. This can be accomplished in essentially two ways. First, by acquiring a (partially) depleted field. In the past, large merchants such as E.ON, ENI, Gaz de France and Centrica have invested in depleted field storage. Recent examples include the acquisition of the Saltfleetby field (UK) by Wingas in December 2004 and the 2003 participation in Waalwijk (Netherlands) by Essent. Both Wingas and Essent have stated their intention to use these fields for gas storage. Second, a gas merchant can acquire use of the storage facility while the operation (and ownership) is left with an upstream producer who is already familiar with the field and its operation. Examples include the long-term arrangements in the Netherlands between Gasunie and NAM, Gasunie and BP, and more recently, in Austria between Wingas (Wintershall/Gazprom) and RAG.

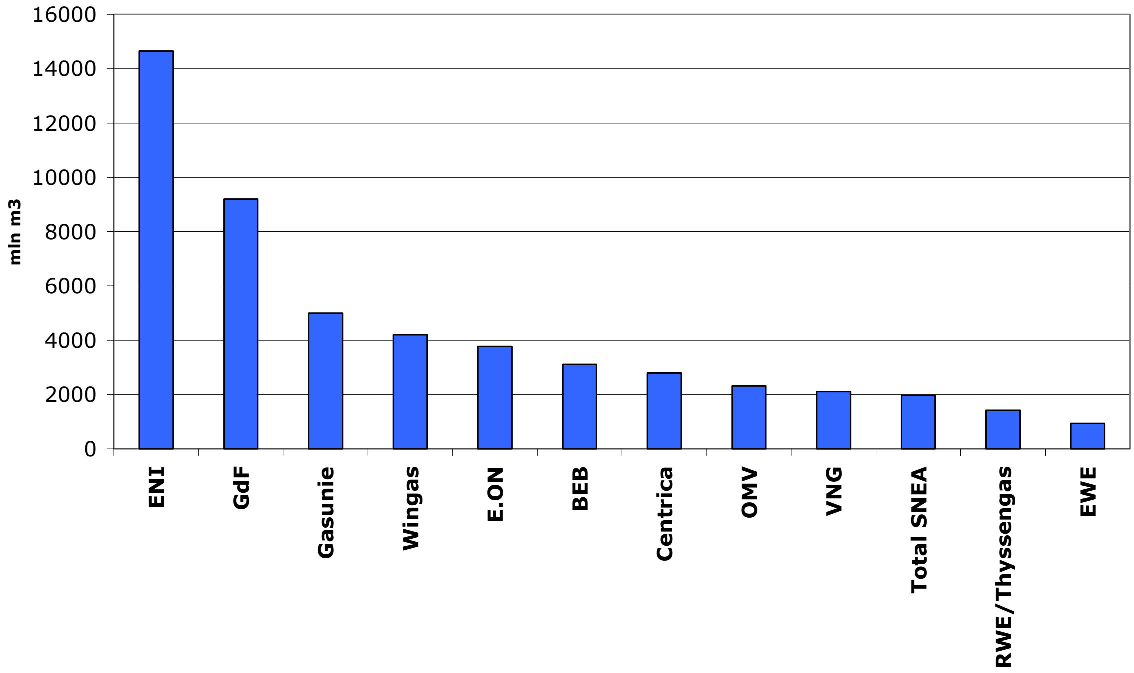

Figure 11: Main storage volume players in Europe (including strategic storage and storage for production purposes)

5.2. Investment and operational considerations in a liberalising market

Investment decisions essentially hinge on the balance between economic attractiveness and risk. With respect to the latter, liberalisation has a pronounced effect on the risk profile of a gas merchant. Generally, gas suppliers now face greater uncertainty over market share and price than prior to liberalisation, and there is also considerably more uncertainty about future legislation and regulation. The energy sector is of essential importance to a country's economy as well as the government's approval ratings. Because of this, governments often want to preserve the opportunity to intervene in the market when they deem appropriate. More credible governments establish a long-term strategic approach with regards to the energy sector. This approach translates into a stable regulatory framework that clearly assigns responsibilities – both mitigating investment risk and increasing the efficiency of the sector. In absence of such an approach, the industry will most probably react to increased risk by postponing investment decisions or demanding higher rates of return or more predictable income streams as the basis for investment decisions.[32]

The uncertainties outlined above are particularly relevant to investment in seasonal volume storage facilities given the requisite size of the initial investment and the long lead-time between the investment decision and the start of operations of the facility.[33] Table 4 presents some illustrative data for both. It should be noted that initial investment includes cushion gas that can amount to some 25% of total initial capital investment. The investment sum is calculated from the cost estimates presented in Table 2 by assuming full employment and a 12% cost of capital.[34]

[32] There are also technical risks to consider. For example, a gas reservoir may not behave as modelled and this could lead to lower performance than intended. Also, sand production may occur when withdrawing gas from a storage. It should be noted that these technical risks are fundamentally different in comparison to e.g. the development of a new pipeline.

[33] A small, depleted gas field can be developed in two to four years, assuming all permits are in place. A storage facility with several bcm of working volume can take up to eight years to develop.

[34] United Nations Economic Commission for Europe (UNECE), (1999), *Study on Underground Gas Storage (UGS) in Europe and Central Asia*, Geneva: United Nations. Calculations are based on a price for cushion gas of 10 €cents/m^3.

Type of storage	Working Volume	Cost per m^3	Typical Investment	Lead time
	million m^3	€/m^3/yr	million €	years
Depleted Gas Field	2,500	0.05	700	5-8
Aquifer	2,500	0.07	800	10-12
Cavern	50	0.13	40	1-5
LNG	50	0.40	200	5-7

Table 4: Initial investments and lead times of storage projects

From Table 4, it can be seen that investments in (single) caverns require much less capital and that lead times are shorter. As a cavern storage project can be developed in phases, market share uncertainty for a cavern is lower than for the case of depleted field storage. As stated above, development of storage also requires investment in additional transport capacity. This usually can only take place based on long-term agreements between various parties. Furthermore, given the size of investments (typically € 700 million) the number of potential investors able to commit sums of this magnitude in volume storage facilities is relatively small. The current business environment appears to favour short-term investments in caverns at the expense of investment in seasonal storage.

From an operational point of view, liberalised markets increase pressure on storage operators to minimise costs. Given the current high gas prices it is rather costly to have substantial amounts of gas left in storage at the end of the withdrawal season. Thus, the storage capacity holder has an incentive to store only as much gas as is expected to be used or that is legally required to be kept in store. This could lead to a situation in which storage capacity is not completely utilised causing supply problems if the market and/or weather conditions manifest in an unexpected way.

Many gas market players are requesting increased transparency on actual storage levels and on usage patterns of existing storage facilities in order to make better assessments of actual needs for additional storage.

5.3. Impact of European directives on gas supply

Most newcomers in the gas market do not own storage capacity. Because storage facilities play an important role in a gas supply portfolio, the EU Second Gas Directive (2003/55/EC) includes the provision of third party access (TPA) to storage facilities. Individual Member States can decide whether tariffs for storage are market-led or regulated. Under specific conditions exemptions can be granted for the TPA obligation. Such exemptions require endorsement by the European Commission.

In March 2005, the stakeholders gathered at the "Madrid Forum" voluntarily adopted detailed guidelines for TPA to storage facilities. The guidelines are based on obligations for non-discriminatory access to storage under the Second Gas Directive. Member States can determine the access regime and subsequent Guidelines for Good Practice for System Storage Operators (GGPSSO) provide harmonised rules on subjects like transparency requirements, capacity allocation and services. The objective is to facilitate the market and to increase liquidity. The GGPSSO initiative is intended to give players the opportunity to incorporate TPA storage services in their portfolios without having to invest in large storage facilities of their own. However, the GGPSSO do not address what the incentives to invest in storage will or should be.[35]

[35] For a preliminary assessment of the GPSSO see ERGEG, (2005), *ERGEG Final 2005 Report on Monitoring the implementation of the Guidelines for Good TPA Practice for Storage System Operators (GGPSSO).*

Council Directive 2004/67/EC of 26 April 2004 obliges EU Member States to formulate security of supply standards to ensure protection of household customers. Households need to be protected in the event of:

- a partial disruption of national gas supplies during a period to be determined by Member States;
- extremely cold temperatures during a nationally determined peak period; and
- in the event of an extraordinarily protracted and cold winter.

The Directive, to be implemented in Member States' national legislation by 19 May 2006, requires that responsibilities for meeting the standards be clearly assigned to the various gas market players along the value chain.

Setting standards to be met by national measures might increase clarity on how much storage volume will be needed in the future and might also generate additional investment incentives.

6

Conclusion

This analysis suggests that insufficient investment in seasonal storage (i.e. large working volumes) is being made in Europe. It is difficult to assess whether the current slow-down in investment is merely a reaction to overcapacity in storage facilities or whether the problem is of a structural nature. In any event, the long development lead time for developing seasonal storage facilities exacerbates the problem, and when shortages occur, they will not be quickly remedied. Furthermore, there is no clarity as to who will take up the challenge to invest.

There are various possible causes for under investment:

- The market may still be waiting for allocation and definition of responsibilities to cater for (very) cold winters. Arrangements for very cold winters are not necessarily economic from the perspective of the individual market player. Implementation of Directive 2004/67/EC may bring more clarity on the assignment of responsibilities and it is of utmost importance that these be clear and unambiguous in order to provide the right investment signals.
- The market may not yet have found a new way to balance and manage long-term risks. Investments in seasonal storage are costly and offer only long-term economic benefits. Development of seasonal gas storage facilities will therefore need to fit into the long-term supply-demand position of a market player, for which storage is used to manage a specific supply source and customer(s) in its portfolio. Market players can either build the storage facility themselves or contract capacity on a long-term basis with a storage operator. An important point is also that the necessary transport capacity must be (or can be made) available for a corresponding period (including potentially large, cross-border network expansions). From this perspective it is perhaps unsurprising that the only recent investments in seasonal storage were made by Gazprom jointly with Wingas.
- Uncertainty around the future regulatory regime for storage facilities and the gas spot market contribute to investment risk.
- Finally, although demand for seasonal storage will grow in the future, the exact timeframe for that demand growth and the optimum location of new storage sites remain uncertain.

Insufficient seasonal storage may lead to temporary shortages of gas and related high gas price volatility, and a larger exposure to security of supply risks. Having sufficient seasonal storage facilities would put Europe in a better position for ensuring supplies from outside Europe. Such storage capability would improve both the capital efficiency of large supply projects, such as major pipelines for long-term supplies, and the ability to capture short-term spot supplies.

This issue appears to be of sufficient importance to warrant further consideration and analysis – including from a regional perspective. Root causes for lack of investments must be identified to develop effective policy measures and to provide the right incentives for developing seasonal storage facilities as required.

Annex I: Storage projects which could be completed by 2010[36]

Working volumes in mcm

	Depleted Fields and Aquifiers	Caverns		Depleted Fields and Aquifiers	Caverns
United Kingdom			*France*		
Humbly Grove	280		Gournay-sur-Aronde	210	
Aldbrough		420	Trois Fontaines	420	
Byley		170	*Austria*		
Caythorpe	280		Haidach	2.400	
Welton	440		*Poland*		
Fleetwood		500	Wierzchowice	2.900	
Hole House Farm		27	*Netherlands*		
Saltfleetby	700		Zuidwending		200
Germany			Waalwijk	500	
Epe/Nuon		250	*Spain*		
Epe/Essent		200	Castor (offshore)	1.000	
Golzow	110				
Peckensen		80			
Nüttermoor		180			

Annex II: Suggested further reading

Federal Energy Regulatory Commission, (2004), *Current state of and issues concerning underground natural gas storage*, Staff Report. September, <http://www.ferc.gov/EventCalendar/Files/20041020081349-final-gs-report.pdf>.

ILEX Energy Consulting, (2005), *Storage, gas prices and security of supply*, October, <http://www.oilandgas.org.uk/issues/gas/ilexreport2005.pdf>.

International Energy Agency (IEA), (2002), *Flexibility in Natural Gas Supply and Demand*, <http://www.iea.org/Textbase/publications/free_new_Desc.asp?PUBS_ID=1095>.

[36] There are various new storage facilities proposed in Italy, with a combined working volume of ca 8 bcm. Permit procedures reportedly have been difficult and none of those projects has commenced construction as of February 2006. We find it highly unlikely that any of these storages are operational by 2010; however we cannot rule out that the recent supply problems in Italy leads to a removal of obstacles that currently delay these projects.