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Working paper series : REFGOV-IFM -16

European FP6 – Integrated Project
Coordinated by the Centre for Philosophy of Law – Université Catholique de Louvain – http://refgov.cpdr.ucl.ac.be
WP –IFM-16

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Abstract :

This paper analyses the lack of investment incentives in large seasonal storage in the UK, such as offshore depleted gas fields. We explain why there are so few investment decisions in seasonal storage capacity in a liberalised gas market and we highlight regulatory challenges to increase investments incentives in the UK. Investments in seasonal storage (*e.g.* depleted gas fields with large volume) are required to compensate the decline of the UK swing fields that were used to cope with the seasonal gas demand fluctuation. However, seasonal storage facilities imply huge sunk costs and a long lead time to build. Investors face different uncertainties over investment costs and revenues that undermine investment decision to convert offshore depleted gas fields (large volume) into seasonal storage facility. Particularly, investing in a new seasonal storage may compress the winter/summer prices that make economically unattractive the investment. The UK storage regulation does not provide satisfactory incentives to invest in new seasonal storage. Regulatory remedies could be implemented in order to make convergent private interests of investors and society's needs.

Keywords: Seasonal storage, gas, security of supply, uncertainty, investments.

Introduction

This paper analyses the lack of investment incentives in large seasonal storage in the UK, such as offshore depleted gas fields. We will explain why there are so few investment decisions in seasonal storage capacity in a liberalised gas market and we will highlight regulatory challenges to increase investments incentives in the UK.

During the winter 2005/06, the lack of sufficient storage capacity was emphasized when the UK gas market experimented gas supply shortages leading to unprecedented high prices on the wholesale and balancing markets. This gas crisis was due to the conjunction of several factors: an exceptional winter with four cold snaps leading to a higher demand combined with a decreasing swing capacity of UKCS gas fields and an under-utilisation of import capacity, which lead to a tighter demand/supply balance than expected. The failure of the largest storage facility (Rough) by mid-February worsened the scenario. Even if several measures of demand side response were put in place to cope with exceptional winter peak demand, this crisis has highlighted the fragility of the UK gas system.

Even before this gas crisis, many debates about security of supply have pointed out the lack of storage capacity. For instance, at the end of October 2005, Digby Jones, head of the Community of Britsh Industry (CBI), complained that the lack of gas storage capacity could lead the UK business to being restricted to a "three day week". In a report commissioned by the UK Offshore Operators Association (UKOOA), Ilex agues that the markets have not delivered the right price signals for investors in seasonal storage (lack of visibility and liquidity) and that a second seasonal storage would have reduced gas prices to final customers and increased security of supply (Ilex [2005]).

Investment in storage capacity still remains an issue for the UK, particularly investment in seasonal storage. In the UK, there are three kinds of storage facilities which perform different functions. First, there is only one seasonal storage facility: Rough, a partially depleted offshore gas field owned and operated by Centrica[1]. Seasonal storage serves to adjust supply and demand to cope with seasonal demand. Secondly, there are also four small-scale storage facilities (salt caverns and onshore depleted fields) that have less volume of gas and a higher output capacity than Rough. They provide short-term flexibility during cold snaps. This kind of storage is also used to profit from the price differential between summer and winter and to benefit from the high volatility on the spot and balancing markets. Thirdly, there are four LNG peak-shaving units that are used only in extreme winter peak days, when very high deliverability and small volume are required (CIEP [2006]).

[1] Rough was converted into a storage facility by British Gas. In 2001, Dynegy purchased Rough and Hornsea from BG. In 2003, Centrica acquired Rough from Dynegy.

This paper focuses only on seasonal storage. Investments in seasonal storage (*e.g.* depleted gas fields with large volume) are required to compensate the decline of the UK swing fields that were used to cope with the seasonal gas demand fluctuation. However, seasonal storage facilities imply huge sunk costs and a long lead time to build. Investors face different uncertainties over investment costs and revenues. Because investors seek protection to reduce their risks and recover all their total investments costs, these uncertainties undermine their investments decision to convert offshore depleted gas fields (large volume) into seasonal storage facility. Without enough *ex ante* safeguards, they will not invest in this type of assets because the risk of *ex post* opportunism remains too high. An alternative strategy is to postpone the investment in order to obtain better information or to have less uncertainty over investment costs and income.

Section 1 explains that the need for a new seasonal storage facility in the UK is linked to the decline of swing capacity to cope with seasonal demand fluctuation. Section 2 highlights the fact that weak incentives for investing in seasonal storage in the UK derives from the conjunction of two uncertainties: one over costs and one over income. Uncertainty modifies investors' incentives and as a result they will not invest in the type of storage that the society needs. Section 3 shows that the UK regulatory framework does not reduce investors' uncertainty and highlights regulatory challenges to strengthen investors' incentives.

1. The need for a new seasonal storage in the UK

The need of new seasonal storage is linked to the decline of the UK current swing capacity. Swing capacity is the flexibility of supply source to manage the increase of demand in winter and the decrease of demand in summer. According to the Department of Trade and Industry (DTI), the winter total demand was around twice the summer total demand in 2005, and winter demand of domestic customers was fourfold the summer one. Gas demand follows a seasonal path: a high demand in winter and a low demand in summer.

There are essentially two sources of seasonal swing in the UK: swing in UKCS (United Kingdom Continental Shelf) gas production and use of storage facilities. Since the UK become more reliant on gas imports, swing capacity provided by UKCS gas fields have declined. The current production swing capacity declines. New imports pipeline or LNG terminals will not add significant swing capacity to the UK gas market.

In the mean time, the UK has one of the lowest storage capacity in Europe, with around 13 days of average demand. Even if there are new planned storage facilities, there will remain only one seasonal storage facility (Rough). As interruptible customers, small-scale storage facilities provide indispensable flexibility tools to manage short-term winter peak demand. However, small-scale storage facilities do not hold sufficient gas in store to manage the seasonal demand. An important source of swing capacity is seasonal storage (offshore depleted gas fields) to cope with the increase of demand in winter related to the summer one.

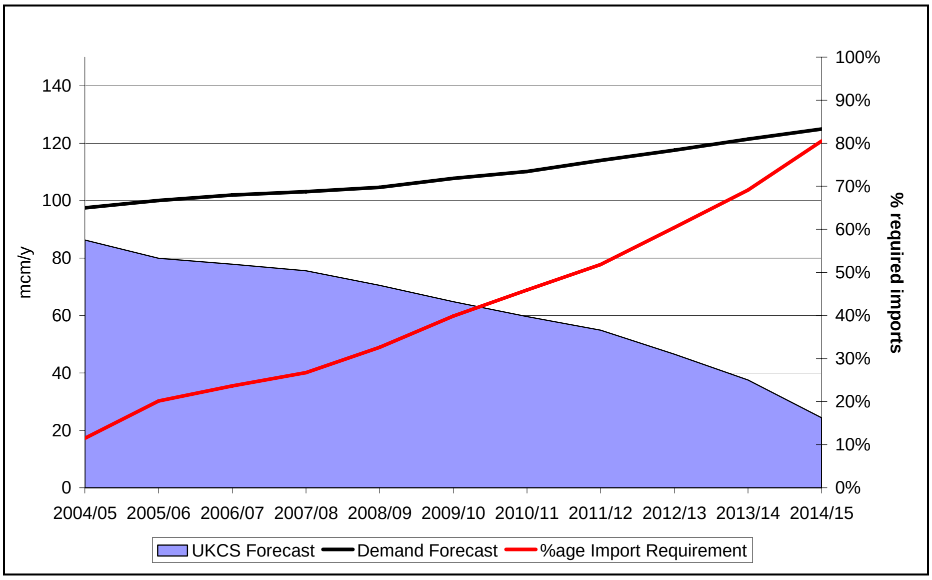
1.1. Current swing capacity declines

The UK current capacity to manage seasonal demand fluctuations declines. We first look at the depletion of the swing production. UKCS gas fields will not provide as much as swing capacity they provided to manage the seasonal demand fluctuation in the UK. We will secondly shed some light on the UK low storage capacity level and its limited capability to provide additional swing capacity. Rough storage provides around 10% of winter demand. New planned storage facilities are solely small-scale storage facilities and they will not replace sufficiently the decline of the UKCS swing production. The issues of how to compensate the decline of the current UKCS swing production remains still unanswered.

First source of swing capacity: UKCS gas fields

The first source of swing was provided by UKCS gas fields. Since the beginning of the 1990s, their swing capacity has decreased because of the decline of UK production. The UK has traditionally used the Morecambe Bay gas fields and the Sean fields to cope with seasonal demand fluctuation. In winter, these fields increase their production in order to cover the demand variation, whereas in summer they decrease or stop producing. However, the swing of gas production in the UK is declining because of the depletion of these gas fields (*cf.* figure below).

Figure 1: The UK's dependence on imports (2004-2015)



Source : National Grid [2005a]

The UK's import dependence will increase as the UK gas production will decline: in 2010, import will represent around 50 % of demand and in 2015 around 80 % (National Grid [2005a]). In 2004, the UK became a net gas importer after a decade of self-sufficiency (UKOOA [2005])[2]. UKCS gas production has been supplemented by growing imports by direct pipelines (Vesterled link and Continental Interconnector) and by the Isle of Grain LNG terminal[3]. Current projects of LNG terminals and import pipelines will further strengthen the UK's gas import capacity[4]. However, gas imports will not add significant swing capacity. Supply and transportation contracts do not allow large flexibility. Pipeline operators and gas field operators seek to have a constant high load factor in winter but also in summer.

Therefore, these contracts do not provide a high rate of flexibility between summer and winter supply. Another question related to these new infrastructures projects is how far they will be used. New import capacity does not mean that gas volume will

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[2] As the UK becomes more reliant on gas imports, this situation raises inexorably questions about security of supply. The UK will be exposed to several new risks that are well known for other European importer countries such as France, Germany or Italy: source dependence, transit dependence, facility dependence, timing of investments and investments in assurance assets (Joskow [2005], IEA [2004], NERA [2002a], Stern [2002]).

[3] The terminal received its first LNG cargo in July 2005 arriving from Algeria.

[4] New import capacity could attain more than 110 bcm/year around 2010. These new projects include the Langeled line (25 bcm/y), the Tampen Link (10 bcm/y), the Balzan Bacton Line (14 bcm/y), the Interconnector's expansion (additional 16.5 bcm/y), and several LNG terminals such as Isle of Grain extension (additional 15bcm/y), South Hook LNG (21 bcm/y) or Dragon LNG (12 bcm/y) (National Grid [2005a]).

automatically flow into the UK at maximum rates in these infrastructures. It will depend on the supply contracts, the European gas market and on the LNG global markets. Examples of flows in the Interconnector during the winter 2005/06 has shown that even if import capacities were available, the gas did not flows to the UK despite a positive price differentials between the UK and Europe.

The UKCS gas fields are the first source of swing capacity, but they will not provide as much as winter supply flexibility they provided. In the mean time, gas imports will not add sufficient capacity swing mainly because of the stringent delivery requirements in transportation and supply contracts. Therefore, the UK will require more swing capacity because of the decline of the UKCS swing capacity and the increase of import reliance.

Second source of swing capacity: storage facilities

Besides UKCS gas fields, the second source of swing is seasonal storage. In the UK, storage is less developed than in other European countries. The current British level of storage capacity is relatively low compared to other European countries. Storage capacity represented only 3.5% of annual demand or only 12.8 days of average demand in 2004. In European gas importing countries, the level of storage is much higher. For instance, in France, in Germany or in Italy, storage capacity represents between 18.8% and 23.7% of demand or between 57.7 and 86.5 days of average demand (*cf.* table).

Table 1: Gas Storage capacity in Europe (2004)

	Working Capacity (mcm)	**Imports dependence (% of demand)**	**Storage/demand (% of demand)**	**Storage/import (% of imports)**	**Days equivalent of average daily demand**
Austria	2820	93.6%	31.4%	33.5 %	114.6
France	10800	96.5%	23.7%	24.6 %	86.5
Germany	18934	89.0%	18.7%	21.0 %	68.3
Italy	12743	84.2%	15.8%	18,8 %	57.7
Spain	2121	99.8%	7.9%	7.9 %	28.7
Netherlands	2478	36.7%	4.8%	13.1 %	17.6
Belgium	635	98.9%	3.7%	3.8 %	13.6
UK	3586	11.8%	3.5%	29.6 %	12.8

Source : IEA [2005].

The UK has always had a low level of storage capacity because of two main factors. First, the UK's swing production could cover the seasonal increase of gas demand associated with Rough storage. Secondly, the UK was self-sufficient. There was enough national production capacity to secure gas supply all over the year. Interruption of external supplies was not an issue (AIE [2004]).

In the UK, Rough is the largest UK gas storage facility and it accounts for 72% of UK total storage capacity in 2006[5]. It can supply up to 10% of average demand in winter. Rough is the sole long-duration storage in the UK (*ca.* 70 days) with a very large volume of gas and a relatively low deliverability rates. Other storage facilities are mainly used few days during cold snaps of gas in store (*cf.* appendix). They do not hold enough volume of gas to cover the winter demand fluctuation.

Furthermore, the UK is "Rough-dependent" to manage normal seasonal fluctuation in order to complement swing production from the North Sea gas fields. In February 2006, Rough went out of service for several weeks whereas the UK faced a tight supply/demand situation. The closure of this seasonal storage has highlighted the fragility and the vulnerability of the UK gas system and its reliance on Rough to meet the winter demand beside the swing production fields. As a result, wholesale gas prices surged to unanticipated level (up to 250 p/therm on the balancing market) and National Grid issued several balancing alerts.

As the UK will be more reliant on gas imports, additional swing capacity will be required to compensate the decline of the UK gas fields in order to cover the seasonal demand variation. A new seasonal storage facility would provide new supply flexibility in winter to meet the demand fluctuation.

1.2. Assessement of UK storage requirement

We have seen that the two UK traditional sources will not be sufficient to manage the seasonal demand fluctuation. Imports will not add sufficient swing capacity to offset the depletion of the UKCS gas fields. We will assess now if new investments in storage will be sufficient and what will be the additional needed storage capacity in the UK.

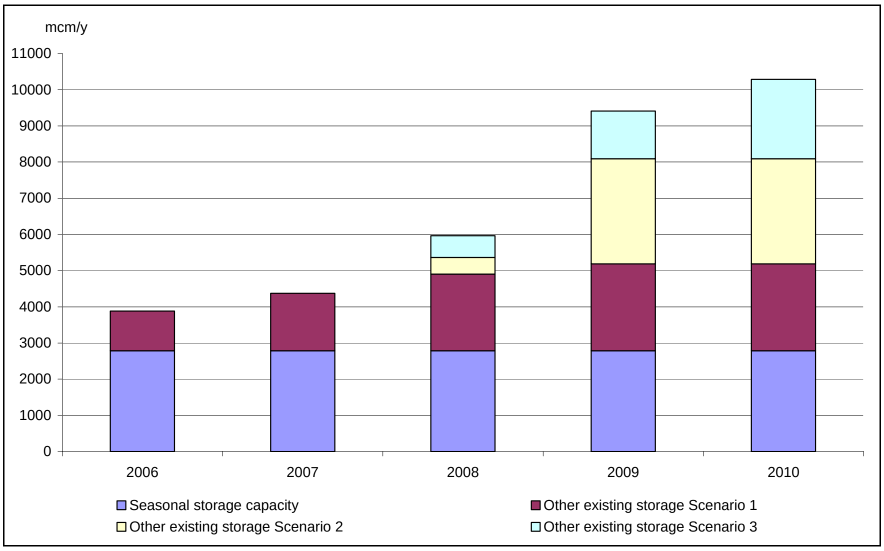
Increase of gas storage capacity by volume

In the UK, investments in new storage facilities arise. Our graph below shows three possible different scenarios of new storage capacity until 2010 based on the available data (*cf.* appendix). Scenario 1 assumes that only storage that are under construction or that wait for planning permissions will be realised until 2010. Scenario 2 assumes that all storage with available technical data on volume and maximum daily output, including storage facilities that are at the conceptual or initial stage, will be realised. This second scenario does not take into account several storage projects in onshore gas depleted fields such as Albury phase 2 or Bletchingley. Finally, scenario 3 is the more

[5] Before the opening of the Humbly Grove storage at the autumn 2005, Rough accounted for 80 % of total UK storage by volume.

optimistic. It assumes that all publicly announced projects will be realised without any delays or difficulties to obtain building permissions. For scenarios 1 and 2, storage capacity could reach the level of storage capacity of scenario 3 in 2010 but after 2010 with delays of three or more years.

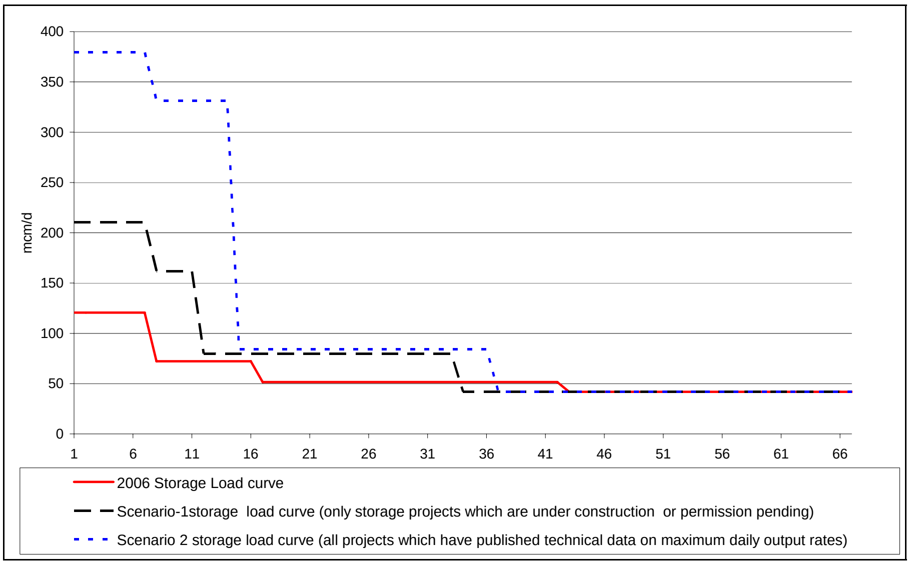
Figure 2: Potential increase of storage capacity in the UK (2006-2010)



Our graphs shows that a great uncertainty remains about the actual storage capacity that will be add until 2010. In the more optimistic scenario, UK storage capacity should increase from 3.9 bcm/y in 2006 to more than 10 bcm/y in 2010 in the more optimistic scenario. New storage facilities should add around 6 bcm of storage capacity if all the planned projects are realised. However, some promoters face difficulties to obtain compulsory building permission form local governments, because of the opposition of some neighbouring associations. For instance, Canatxx's project in Fleetwood is delayed because the local government of Lancashire has rejected the project due to its potential environmental impacts and the risk of gas leak. These difficulties increase building lead times of many onshore storage facilities. In our more pessimistic scenario (scenario 1), storage capacity should only be around 5.2 bcm/y in 2010, whereas in scenario 2, storage capacity should be around 8.1 bcm.

However, the UK storage portfolio will be dominate by small-scale storage facilities and Rough will remain the only large-scale facility capable of managing seasonal demand variation. The following graph compares future load curves of scenarios 1 and 2 with the storage load curve of 2006. Because of the lack of technical data, it is not possible to draw the same storage load curve for scenario 3.

Figure 3: UK storage load curve in 2010



In both scenarios, storage facilities in salt caverns will increase their share in the UK storage portfolio. In scenario 2, the increase of salt cavern facility is more salient than in scenario 1. However, small-scale storage facilities do not play individually a significant role to cope with the seasonal demand variation, even if aggregating all these projects increase the volume of gas available in winter (CIEP [2006]). They do not hold sufficient number of gas stocks to provide enough flexibility to meet seasonal demand (Ilex [2005]). These new small-scale storage facilities will be used to cover daily peak gas demand during cold snaps and they will also be used for trading and balancing needs.

The second interesting point of our graph is the increase of storage facilities in onshore depleted gas fields. In 2006, this type of storage is quite marginal in the supply of gas during winter. Whereas this type of storage has relatively a low volume of gas in store and a low daily output rate, they will be able to deliver gas to the UK gas system for around 35 days at maximum daily rates. This means that they would play an increasing role in managing seasonal demand during at least half of winter and increasing their role in additional swing capacity.

The last point that is shown by our graph is that in all scenarios, including scenario 3, there is no investment in seasonal storage with large volume of gas in store which would complement Rough to meet the seasonal demand fluctuation during all winter. Between 2006 and 2010, seasonal storage capacity will remain at the same level by volume, around 3 bcm of storage capacity. Nonetheless, seasonal storage should account for less than 30% of UK total storage capacity in 2010, whereas it accounts for 72% in 2006.

Assessment of UK gas storage capacity in 2010 and beyond

Another question arises: what is the storage requirement for the UK for 2010 and beyond? We use three criteria to assess the need of storage capacity for the UK (*cf.* table below) in an European perspective. The first criterion is to compare the storage capacity with demand. The second criterion is to measure how many days of average annual gas demand will be in store. The last criterion is to calculate the storage/import ratio. This storage/import ratio is equal to the storage capacity divided by the volume of gas imports.

Table 2: Comparison of storage capacity and demand between 2006 and 2010

		2006	2007	2008	2009	2010
Storage/demand (% of demand)	**Scenario 1**	3.8%	4.2%	4.7%	4.8%	4.7%
	Scenario 2	3.8%	4.2%	5.1%	7.5%	7.3%
	Scenario 3	3.8%	4.2%	5.7%	8.7%	9.3%
Number of average daily gas demand in store (in days)	**Scenario 1**	13.9	15.5	17.1	17.6	17.2
	Scenario 2	13.9	15.5	18.7	27.4	26.8
	Scenario 3	13.9	15.5	20.8	31.9	34.1
Storage/imports ratio	**Scenario 1**	19.2%	18.2%	17.8%	15.2%	12.1%
	Scenario 2	19.2%	18.2%	19.4%	23.7%	18.8%
	Scenario 3	19.2%	18.2%	21.6%	27.5%	23.9%

Despite new investments in storage, the UK storage level in terms of demand will remain lower than other European importing countries. In France, Italy and Germany, storage level is between 15 and 24% (*cf.* table 1). In scenario 3, the UK storage level will represent around 9.3% of demand in 2010, whereas in 2006 storage accounts for only 3.8% of demand. In scenario 1 and 2, storage will also increase relative to 2006 but the storage will remain at a lower level, respectively at 4.7% of demand and 7.3%. Beyond 2010, the UK will become more reliant on gas imports and UK swing production will decline. This means that the UK will have to increase their storage level capacity to obtain a higher storage/demand level as the demand will continue to grow.

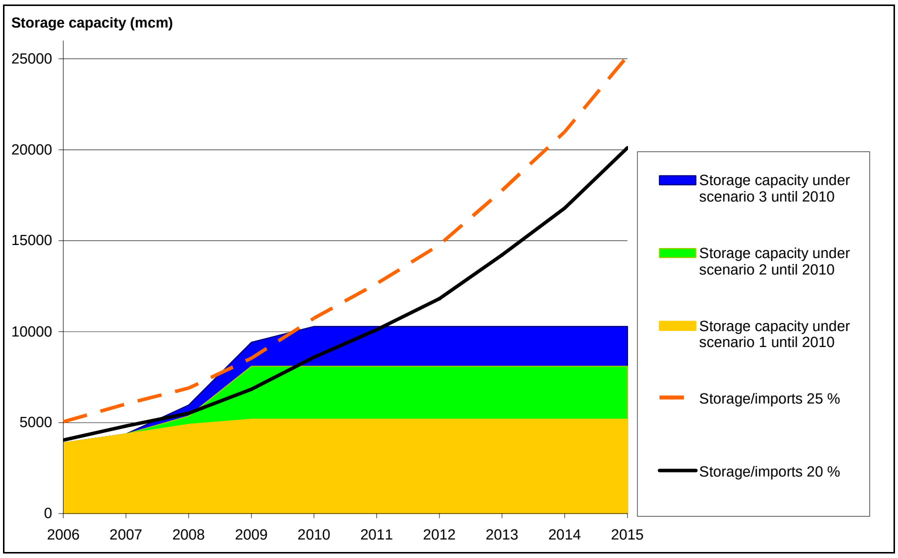
In number of days of average demand, the UK remains still below the level of France, Germany or Italy (respectively 86, 68 and 58 days in 2004). In our more optimistic scenario, the UK should have 34 days of average gas demand in store in 2010 if all storage projects are built. However, if all the projects are not realised, the UK would have less days of average demand in store. According to our scenario 1 and 2, the UK would have only respectively 17 days of average daily demand or 27 days. This means that the UK will remain far below the French, Italian or German level of days of gas in store.

The third criterion assesses the UK storage requirement by comparing its storage/import ratio with those of countries that are net importer of gas, such France, Germany or Italy. In these importing countries, some 20 to 25% of annual gas import demand is stored at the beginning of winter (*cf.* table 2). As the UK becomes more reliant on gas imports, the volume of gas in store will be crucial if one of the major supply sources fails to deliver gas during the winter.

In all scenarios, the UK storage/imports ratio is less than 20% in 2006 and 2007 and diverges for the three scenarios from 2008. In scenario 3, this ratio would increase and remain in the range of 20-25%. In scenario 2, the increase f the ratio is lesser, but the ratio remains around 20%. In the worst scenario, this ratio will decrease and be around 12% in 2010. As the UK will import more gas, this means that the increase of investment in storage capacity in all three scenarios should be pursued after 2010.

In order to assess the required additional storage capacity in the UK, we assume that the storage/import ratio should remain between 20 and 25% from 2010, like in other importing countries. Our graph below is based the imports data given by National Grid [2005a].

Figure 4: Storage requirement in the UK



Our graph shows that new investments in storage capacity will be required to offset the increase of gas imports in the UK to maintain its storage/imports ration in a range of 20 and 25%. In 2015, storage capacity should be around 20 and 25 bcm whereas in 2006, whereas the UK accounts less than 5 bcm of storage capacity. In our three scenarios, the current investments are not sufficient and the UK will require more storage capacity. According to our best-case scenario (scenario 3), the UK would require an additional storage capacity of 10 or 15 bcm between 2010 and 2015. In our worst case (scenario 1), the UK would need between 15 and 20 bcm of additional storage capacity between 2010 and 2015, if some of the current projects are not finalised or are delayed. Even if scenarios 1 and 2 could reach the level of storage of scenario 3 with three or four or more years of delays, there will not be sufficient and new investments in storage will be required.

Whereas the UK will rely on more gas imports and the swing capacity of UKCS production fields will continue to decline, a new Rough-sized storage (a seasonal storage) would provide additional storage capacity but above all additional swing capacity to manage the seasonal fluctuation. A seasonal storage facility provides an additional source of gas during the winter. It would complete gas supply from Rough, UKCS production fields and imports. Because this type of storage has large volume of inventories, it could supply the markets wither larger volume and during longer period than salt caverns and onshore depleted fields storage.

In European importing countries, large-scale storage is an essential means to manage the seasonality of gas demand. In these countries, seasonal storage facilities provide the required swing capacity to cope with their demand fluctuation. In these countries, seasonal storage represents a large fraction of their storage portfolio. Former state-owned monopolies invested in storage facilities with large volume of gas in order to avoid supply disruption but also to meet the seasonality in demand. Long-term take-or-pay contracts were also an important driver in their decision to invest seasonal storage. European companies were incited to increase their volumes of seasonal storage because they would have had to pay even if the gas was not delivered. Seasonal storage facilities were a flexibility tools to adjust supply and demand taking into account the stringent contractual obligations of supply.

Furthermore, an increase of imported gas rises the need of seasonal storage, because this kind of storage is complementary with new import pipelines and LNG terminals. The import pipelines from Norway and the Netherlands, the increase of the Interconnector capacity and the construction of new LNG terminals will add import capacity in the UK. During summer when the network transportation and demand is low, gas can be stored for winter withdrawals. Additional seasonal storage would increase the flexibility of users of pipelines and LNG terminals, which can not have sufficient flexibility in their contracts with producers and infrastructures' operators to meet winter demand. Because the UK will need more gas storage capacity and it will be more reliant on imports, a second seasonal storage facility would add flexibility tools to manage seasonal demand fluctuation taking into account constraints of supply contracts.

In this section, we have shown that the UK will need more swing capacity to manage the seasonal demand fluctuation. As the UK will become more reliant on imports, UKCS gas fields, that have provided swing capacity, should not provide enough seasonal flexibility any longer. In the mean time, storage capacity, that can add also swing capacity, should increase. However, in the three scenarios that we presented, investments in new storage capacity will be required, particularly in large-scale storage. Storage investments have only focused on small-scale storage facilities and there is no proposal to convert an offshore depleted gas fields into a seasonal storage. The next of this paper is to determine if investors in seasonal storage have faced weak incentives.

2. Weak investment incentives for a new seasonal storage facility in the UK

Why is there no investment project in a new seasonal storage in the UK? Even if there is need for additional swing capacity, investments in seasonal storage facilities can only occur if investors are confident about recovering totally their investment costs and securing a return on their investment. Investors will be exposed to greater *ex post* opportunism when they invest in converting a depleted gas field to a storage facility than when they invest in salt cavern storage units. This is due to the amount of sunk costs involved and the lead times to develop the new storage.

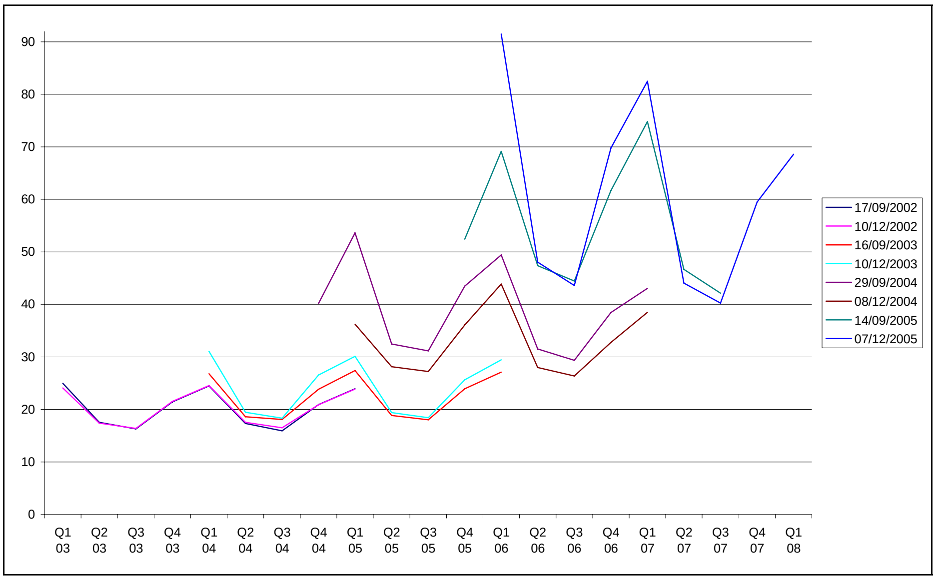
There are at least two uncertainties that undermine investors' incentives to invest in large gas storage infrastructures: uncertainty over investment costs and future flow of income. As uncertainty reduces investor's incentives, investors prefer either not to invest or delay their decision or choose another investment in a storage facility less risky. For the UK, the result is an under-investment in seasonal storage. As long as the investors' incentives will not coincide with the social need of seasonal storage, the under-investment in seasonal storage will remain.

2.1. Uncertainty over investment costs

Because investment in seasonal storage involves huge sunk costs and a long lead time, investment costs of seasonal storage facilities will affect investors' incentives. Investments in seasonal storage are capital-intensive (Cornot-Gandolphe [1995], Dri-Wefa [2002], IGU [2003], Ilex [2005]). Cushion gas (i.e. the volume of gas required to maintain reservoir pressure) increase the costs of storage for depleted gas fields. The costs of the cushion gas are particularly crucial in the amount of investment costs. Cushion gas can vary between 50 and 85% of total initial investments cost according to the gas price promoters pay. Ilex [2005] estimated the cost of cushion gas required for a Rough-sized facility (3 bcm) would be up to € 3 billion (£ 2 billion), with a gas price of 50 p/th, whereas this cost would be around € 1.2 billion (£ 0.8 billion) with a gas price of 20 p/th.

As a consequence of the uncertain share of cushion gas cost in total investment costs, investors face a great uncertainty about the amount of the initial investment costs. This is due to the long lead time to convert an offshore depleted gas fields into a seasonal storage and the lack of liquidity and visibility of the UK forward gas markets. The lead time to build a new seasonal storage is between 5 and 10 years. Investors do not know in advance how much they will buy their cushion gas. This risk could be mitigated if forward markets provided clear and reliable long-term price signals to investors.

Figure 5: Examples of forward curves between 2002 and 2005 (p/th)



Source : IPE, Platts

However, in the UK, the forward gas markets do not deliver clear long-term prices signals. If the UK gas forward market is liquid two years forward, it is illiquid beyond two or three years. The greatest volume of trade is concentrated into the first year forward (Global Insight [2005]). For investors, they would require a liquid forward market between 5 and 10 years after the investment decision but also beyond.

Furthermore, levels of prices on the UK forward gas market did not reflect the actual gas prices. As the graph above shows, UK forward price in 2002 or in 2003 for 2005 were far below the actual prices on the wholesale gas markets. This means that investors in a large seasonal storage cannot rely on the forward gas markets to assess their total investments costs.

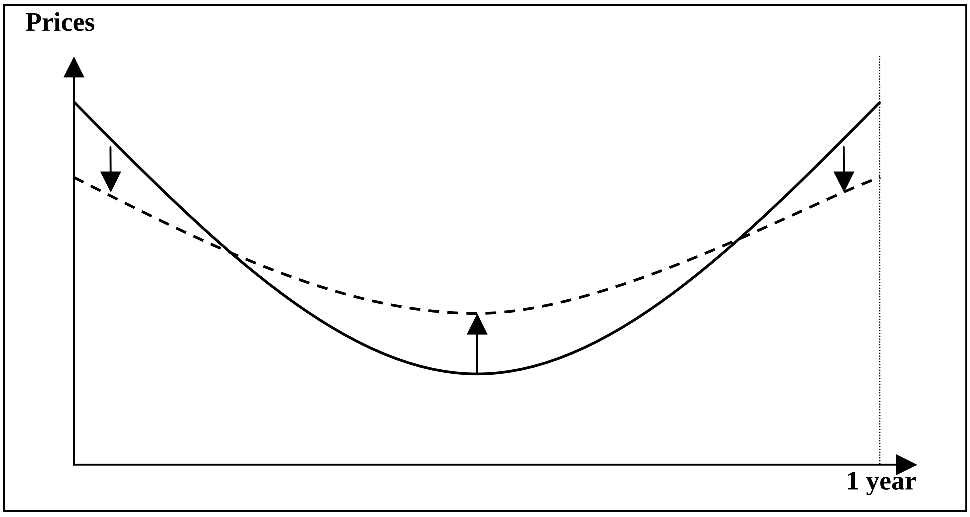
Uncertainty over total investments costs is the first uncertainty that investors in a depleted gas fields have to bear. This is uncertainty reduce the economic attractiveness of converting a depleted gas fields into seasonal storage.

2.2. Uncertainty over storage revenues

If investors face uncertainty over investments costs, they also have to bear the uncertainty over expected flow of income. While storage investment involves sunk costs, investors require that investment costs would be recovered with their future expected cash flow. Otherwise, if they expect not to recover their costs, they will have a disincentive to invest in seasonal storage. Investors will have the choice between different alternatives; they could either postpone the investment or decide not to invest or choose another less risky storage investment. In the UK, storage prices are not guaranteed by any prices regulation (rate-of-return or price cap). Hence, storage prices are market-based prices. Market valuation of seasonal storage is based on the differential between forward gas prices in summer and winter (FERC [2004]).

A new seasonal storage should have some effects on the level of winter/summer price spreads. Seasonal storage contributes to shrink the winter/summer price differential as they have a relatively large volume of gas. The graph below shows how a large seasonal storage affects gas prices and the winter/summer spread.

Figure 6: Impact on prices of seasonal storage



As the graph shows, *ceteris paribus*, seasonal storage has two different impacts on the wholesale gas prices in summer and in winter because of their large volume of gas (Ilex [2005]). On the first hand, injections of gas in storage increase the gas prices in summer because demand of gas will increase on the wholesale market. A seasonal storage increases individually daily demand of gas in summer because it can store large volume of gas. For example, maximum demand of a Rough-sized storage represent between 5 and 7% of average summer daily demand On the other hand, additional available gas in winter should reduce prices on the gas market, because there is more available gas in the market. As a result, winter/summer spreads could be reduced after the opening of a new seasonal storage.

Because the potential price effect of the new seasonal storage, investors will not choose to build a new seasonal storage even if there would be a gain of welfare for all the gas customers. Increasing storage capacity could crush the seasonal price spreads, that would decrease the expected profitability of the new storage.

Uncertainty over storage income worsens the investor's incentives. This uncertainty over future flow of income has also to be combined with uncertainty over investments costs. If an investor buy its cushion gas at a very high price and start to sell his service with a very low winter/summer spread, he should rather make loss than profits. Even if the winter/summer spread is high, the differential should be high enough to offset the costs. As this investor do not know what we will be neither the prices of the gas nor the level of the winter/summer price spread, the opportunity to invest in a seasonal storage with high sunk cost will be reduce. Consequently, investors should prefer invest in less risky storage or delay their decisions rather than investing in a storage facility with a high probability of loss.

Even if there is a social need for a second seasonal storage, uncertainties over investments costs and storage revenues have limited the incentives of investors. These uncertainties should persist because investors do not have enough safeguards to ensure that they will recover their costs and secure the return on investments.

3. Storage regulatory challenges

We have already seen that there is a need for additional swing capacity in the UK and a new seasonal storage would provide an important part of the required flexibility. However, investors do not have enough incentives to invest in seasonal storage facility. Storage regulatory frameworks may have a profound impact on investment decision and financing arrangements. Regulation can mitigate risks over demand (*e.g.* storage obligations) and risks over future revenues (*e.g.* price regulation). The regulatory framework can also be maladapted and give weak incentives to invest. For instance, in the USA, FERC has recognised that the storage regulatory framework gave strong incentives (rate-of-return regulation) for investors in seasonal storage, whereas it gave poor incentives for small-scale storage with high output rates (FERC [2004, 2005]).

In the UK, regulation could act on the investors' incentives and mitigate their uncertainties in order to make convergent private interest and public interest. A market-friendly energy policy should intervene whereas the objectives of policy maker diverge from those of market participants and they cannot be achieved by market forces (Newbery [2006]).

3.1. Impact of the regulatory framework on investment incentives

The UK has implemented a negotiated regime for third party access (TPA) to storage with an exemption regime since 2000 (OFGEM [2004]). The regulator, OFGEM, can exempt storage facilities from all or some TPA provisions. In both cases, operators could charge market-based prices. Negotiated TPA regime for a new seasonal storage facility means that once constructed, all storage capacity should be made available to any company on a non-discriminatory basis. However, tariffs and conditions are not imposed by regulator, but they are directly set by the operators of storage facilities. Under the exemption regime, storage operators can also discriminate between users and they could book all the storage capacity for themselves. However, the exemption regime raises market power issues, particularly in the case where a company with a dominant market position would ask for an exemption for a seasonal storage (Jones [2004]).

TPA exemptions may cover all or parts of the new infrastructures and may be applied for a limited period of time. Furthermore, the exemption may be associated with procompetitive measures, such as use-it-or-lose-it obligations, a competitive secondary storage capacity markets, etc. The UK exemption regime complies with the article 22 of the European directive 2003/55/EC that permits exemptions to be given to major new gas infrastructures if the use of the facility by other persons is not necessary for the operation of an economically efficient gas market or if the six requirements contained in the Gas Act are met (CEER [2005]). The six exemptions requirements are the followings: (1) the facility will promote security of supply; (2) the level of risk is such that the investment would not be or would not have been made without the exemption; (3) the facility is or is to be owned by a person other than the gas transporter who operates or will operate the pipeline system connected or to be connected to the facility; (4) charges will be levied on users of the facility; (5) the exemption will not be detrimental to competition, the operation of an economically efficient gas market or the functioning of the pipeline system; and (6) the European Commission will be content with the exemption (OFGEM [2004]).

Over the nine operational storage facilities in the UK, only Rough and Hornsea are both subject to the negotiated TPA requirements. All the other operational storages have been granted an exemption[6]. Among the projects of storage facilities, several projects have also been granted an exemption: for instance the facilities of Hatfield Moore and of Hole House.

What are the consequences of this storage regulatory framework on investors' incentives in seasonal storage? In the UK, the regulatory regime does not provide to private investors any safeguards against demand and costs recovery. There are neither suppliers' storage obligations nor price regulation of storage services. Under negotiated TPA regime and the exemption regime, storage operators should charge what the market could bear in order to recover their sunk costs. This regulatory regime left unchanged uncertainty over investments costs and over income. This means also that the UK storage regulatory could be maladapted for seasonal storage, whereas it could provide enough incentives for other type storage facilities such as short-term and medium-term storage which have attracted all the investments.

3.2. New storage regulatory challenges

If there is a social need for seasonal storage and private investors have no opportunity of profits, regulation could reduce investors' uncertainty or create incentives to invest. Regulation may support that owners of offshore depleted offshore gas fields should launch an open season and sign long term contracts with future storage users. Regulation may also secure demand and income of storage operators.

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[6] For instance, the storage facility of Humbly Grove has been granted a TPA exemption. The promoter, StarEnergy, signed an exclusive contract with Vitol for the use the full capacity of the storage until at least 2009.

- **Promoting open season and long-term storage contracts**

Regulation may incite owners of depleted offshore gas fields to launch open seasons to sign long term contract with future users. Open seasons are widely used in the USA to build new pipelines (NERA [2002b]) and there are few examples in Europe (*e.g.* BBL pipeline). The term "open season" refers to the process through which promoters of a new storage facility assess the interest in their projects and ask potential users to sign up long-term contracts and financial commitments. All the capacity should be allocated on a non-discriminatory basis. At the end of the open season, promoters that would have enough future users will start the building of the new storage facilities. Investment risks are shared by facility's future users.

- **Securing storage demand**

Another possible regulatory remedy would be to secure storage demand through storage obligations. In the UK, this kind of regulation has already been implemented for renewable energy within the framework of the Renewable Obligations that electricity suppliers have to comply with. In 2002, the European Union Committee of the House of Lords recommended that there should be a mandatory storage capacity obligation on companies supplying gas to UK customers (European Union Committee [2002]). With storage obligations, each supplier would have an obligation to have a certain percentage of their supply already in store at the beginning of each winter. This percentage could be progressive and based on the import dependency of the UK and the customers portfolio of each. The storage obligation could take into account for each supplier the profile of their customers' portfolios, particularly households and non-daily metered customers.

For investors in seasonal storage, these obligations will guarantee that partial or total gas capacity will be used by gas suppliers to comply with their obligations of security of supply. However, remaining unused capacity will be available for supplier to manage also their seasonal demand fluctuation. This type of obligations does not guarantee that all costs will be recovered but it guarantees that the storage will be used. It will depend on the level of the storage obligations.

Long-term storage contracts are compatible with storage obligations. Both mechanisms will mitigate the uncertainties over demand and cost recovery and they will be complementary to increase incentives for investors in seasonal storage.

- **Securing storage operator's income**

Another regulatory solution would be to secure income of storage operators by setting a minimum revenue for this seasonal storage. Regulation will have to implement a specific funding mechanism that will subsidise the storage operator in order to avoid loss and increase investors' incentives. This regulatory regime would provide a high level of assurance to the investors that they will recover their sunk costs through regulated tariffs. However, this remedy should create a market distortion between storage operators.

Regulation can act on investment incentives. There would be a public interest to implement a regulatory framework which will consider that under-investment in seasonal storage would affect social welfare. Because of the long lead time to develop new seasonal storage, regulation has to anticipate the consequence of the lack of seasonal storage in the UK on the social welfare. Public authorities have a range of possible measures to make convergent the private interest of investors and the public interest.

Conclusion

The goal of the paper was to analyse the lack of investment incentives in large seasonal storage in the UK. We have first shed some lights on the need for new seasonal storage capacity in the UK. This derives from the fact that the two traditional sources of flexibility to manage seasonal demand fluctuation will not be sufficient anymore. In the mean time, the UK will be more dependent on gas imports. This also raises the question of security of supply. Secondly, we have then explained that investors have weak incentives to invest in seasonal storage, because they face great uncertainty over investment costs and future revenues. The result is that uncertain lead investors not to invest in seasonal storage and under-investment in seasonal storage remains in the UK. Finally, if the regulatory framework could in principle reduce uncertainty and increase investors' incentives, the UK regulation do not provide a satisfactory answer for investors. Hence, we have shown that possible regulatory remedies could be implemented in order to make convergent private interest of investors and public investors. However, without an actual willingness of public authorities, under-investment in seasonal should remain as long as investors will have weak incentives to invest in seasonal storage.

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Appendix 1 : Storage capacity in the UK

Operational storage facilities in the UK					
Storage Facilities	**Type of storage**	**Working gas capacity (mcm)**	**Maximum deliverability rates (mcm/d)**	**Duration (days)**	***TPA***
Rough	Offshore depleted field	2850	43	66.3 days	*TPA*
Hornsea	Salt Caverns	330	18.5	17.8 days	*TPA*
Humbly Grove	Onshore depleted field	300	7.5	40 days	*Exempt*
Partington	LNG	104	20.2	5.1 days	*Exempt*
Hatfield Moor	Onshore depleted field	120	2.4	50 days	*Exempt*
Avonmouth	LNG	81	14.4	5.6 days	*Exempt*
Glenmavis	LNG	25	9,6	2.6 days	*Exempt*
Dynevor Arms	LNG	28	4,5	6.2 days	*Exempt*
Hole House	Salt Caverns	30	2.8	10.7 days	*Exempt*

(./.. see page 24)

(../.) ***Appendix 1 : Storage capacity in the UK (2nd part of the table)***

Projects of storage facilities in the UK					
Storage Facilities	**Type of storage**	**Working gas capacity (mcm)**	**Maximum deliverability rates (mcm/d)**	**Status**	***Date***
Aldbrough	Salt Caverns	420	40	Under construction	*2007/08*
Hole House phase 2	Salt Caverns	30	2.8	Under construction	*2008/09*
Byley	Salt Caverns	165	16	Under construction	*2008/09*
Welton	Onshore depleted field	435	9	Planning permission pending	*2008/09*
Caythorpe	Onshore depleted field	200	8.5	Planning permission pending	*2007*
Albury Phase 1	Onshore depleted field	160	11	Initial stage	*2008/09*
Stublach	Salt Caverns	550	33	Initial stage	*2009*
Saltfleetby	Onshore depleted field	600	n.a	Initial stage	*2009*
Portland	Salt Caverns	330	18	Intial Stage	*2008*
Fleetwood	Salt Caverns	1700	114	Initial Stage	*2009/10*
Albury Phase 2	Onshore depleted field	715	n.a	Conceptual	*2009/10*
Bletchingley	Onshore depleted field	875	n.a	Conceptual	*2009*
Gainsborough	Onshore depleted field	240	3,5	Conceptual	*n.a*
Gateway Project 1	Salt Caverns	270	n.a	Conceptual	*2010/11*
Gateway Project	*Offshore depleted field*	*700*	*n.a*	*Conceptual*	*2010/11*

Source: National Grid, OFGEM, Platts