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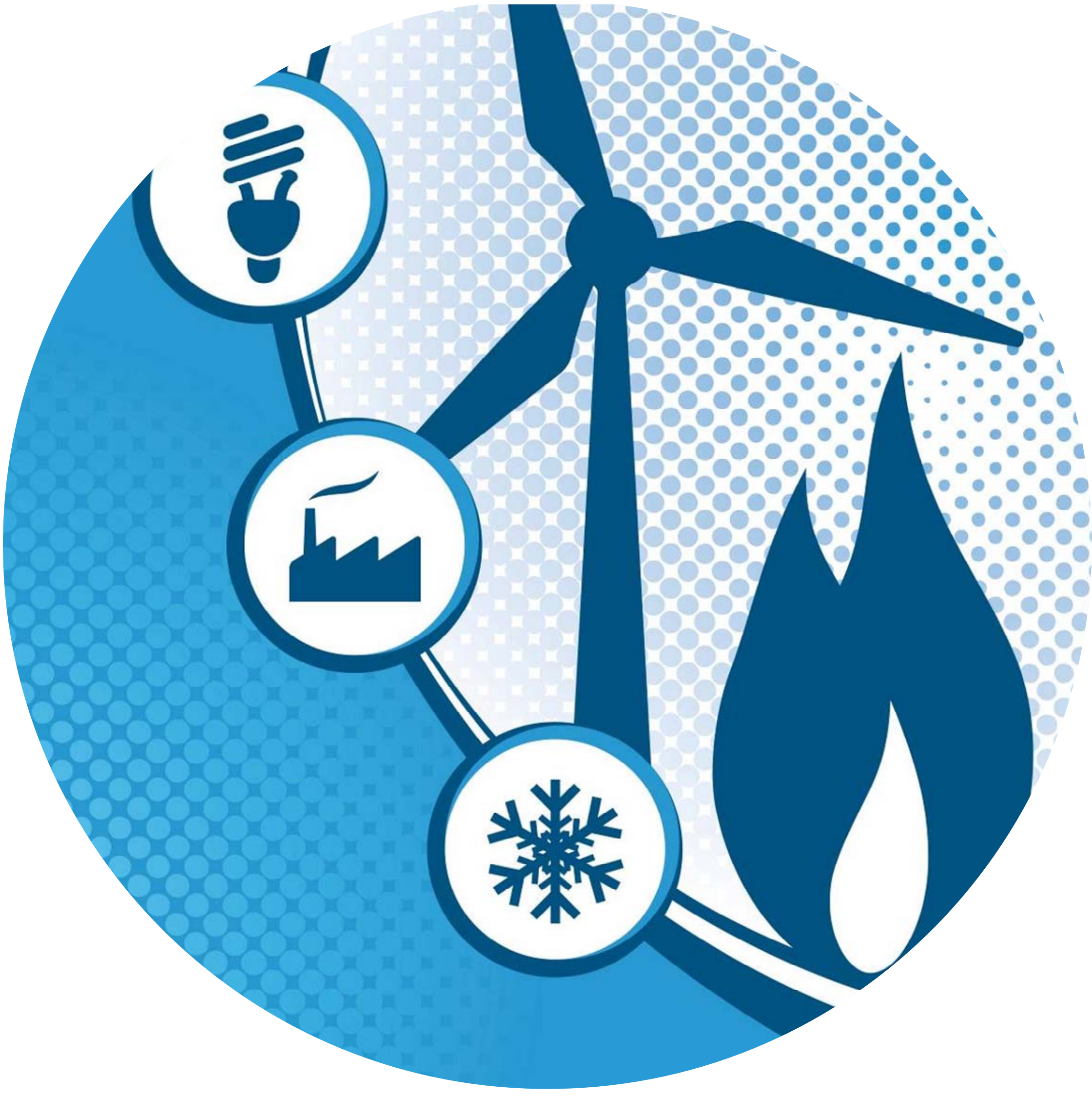
HOW WIND GENERATION COULD TRANSFORM GAS MARKETS IN GREAT BRITAIN AND IRELAND

A multi-client study
Public summary

June 2010



IMPLICATIONS OF WIND INTERMITTENCY ON GB AND IRISH GAS MARKETS

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1. INTRODUCTION

Over the last few years, energy markets around the world have been in a great state of flux. Changes arising from high commodity prices, concerns over security of supply, a sharp drop in demand resulting from the recession, and most recently the arrival of cheap and apparently plentiful shale gas have taxed policymakers, regulators and market participants alike.

An additional driver for change, which may have even more impact than all the above, stems from efforts made by many nations to avert climate change. Both the UK and the Republic of Ireland have set ambitious targets to reduce the countries' carbon dioxide emissions and there is a general expectation that wind generation will bear the brunt of the burden.

While there remains much speculation on the pathway leading to this date, estimates of the amount of wind required to meet the countries' targets range between 6-8GW on the island of Ireland and 35-45GW in Great Britain by 2030.

When there are large amounts of wind generation in electricity markets, their requirements for gas will be quite different: the intermittent output from windfarms will cause an almost equal and opposite intermittent requirement for gas for CCGTs.

In 2009, Pöyry carried out a detailed quantitative examination of the impact of these levels of wind in the British and Irish markets. While that study provided some startling insights into the commercial and physical nature of the markets, it did not look at the consequent impact on the gas market. This summary report shows how we have now filled that gap through a second major multi-client study.

Making such an evaluation was complicated by the need to incorporate considerable changes expected in the supply of gas to Britain and Ireland, and how gas storage, LNG supply, pipeline gas and greater interconnection combine and interact to meet the challenge of supplying intermittent gas to the electricity markets. We were interested in the shape of this market, what the future investment environment might look like, and how radical might the role of 'storage' be.

In order to properly answer the question sophisticated models were built to work in tandem with those built in the course of the electricity wind intermittency study and thousands of man-hours have been invested in a project that has taken over six months.

1.1 Acknowledgements

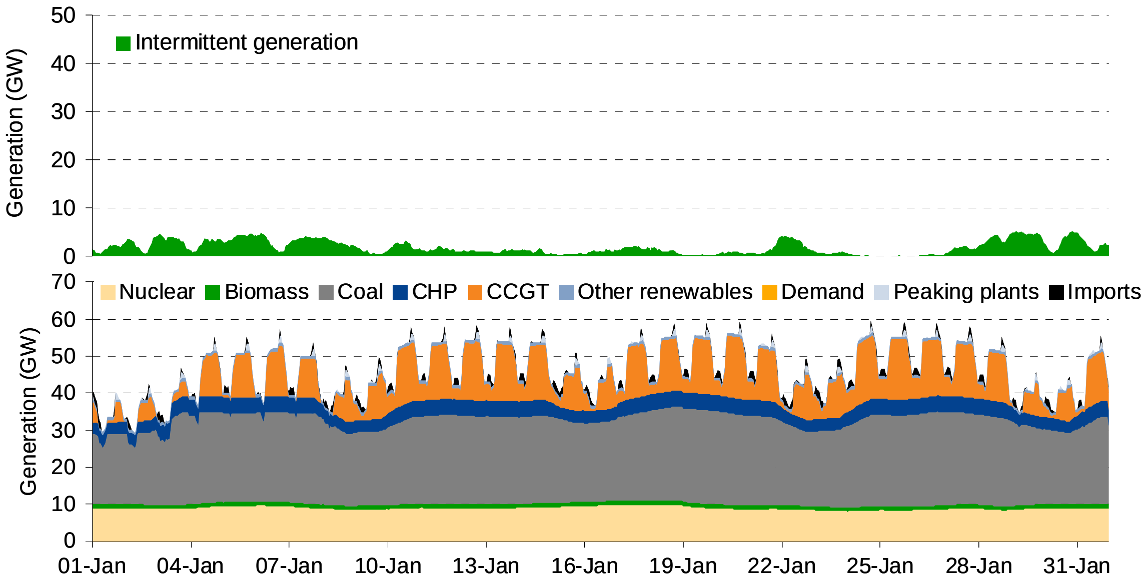
The project has been a major undertaking for a large team of people and would not have been possible without the support and advice of the following founder members:
Bord Gáis Energy Supply, Bord Gáis Networks, Centrica Storage, ExxonMobil, Gaslink and GDF Suez.

2. WHAT IS GAS INTERMITTENCY?

Models developed by Pöyry using historical weather patterns allow analysis of how thermal power stations and windfarms will operate in the future down to an hourly basis.

Figure 1 shows how the pattern of electricity generation by plant type would have been in January 2010 assuming the weather patterns from January 2000 repeated themselves. Generation from intermittent sources (largely wind, shown in green) is quite limited, with a maximum of 4GW of generation during the month. Generation from thermal plant – such as coal in grey and CCGTs in orange – is relatively predictable, with some gas plant generating at baseload, whilst others two-shift (on during the day and off overnight).

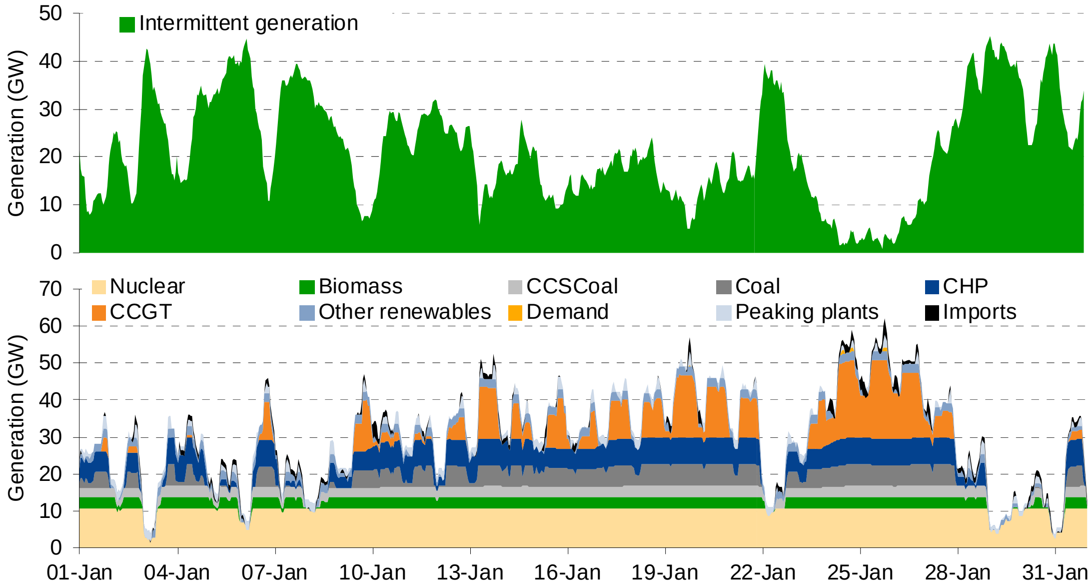
Figure 1 – Electricity generation in 2010 in Great Britain



Hourly generation for intermittency (wind, wave and tidal) and conventional plant. Assumes weather patterns of January 2000

Looking forward to 2030, Figure 2 shows how the thermal generation system in GB would look with 43GW of wind generation (again assuming the same weather patterns of January 2000). Intermittent generation is now dominant on the system and the entire installed thermal capacity has to 'flex' in response to the wind. For the CCGTs on the system, this means very unpredictable running patterns, with no plant running for days at a time, and then all of them running together when the weather is calm.

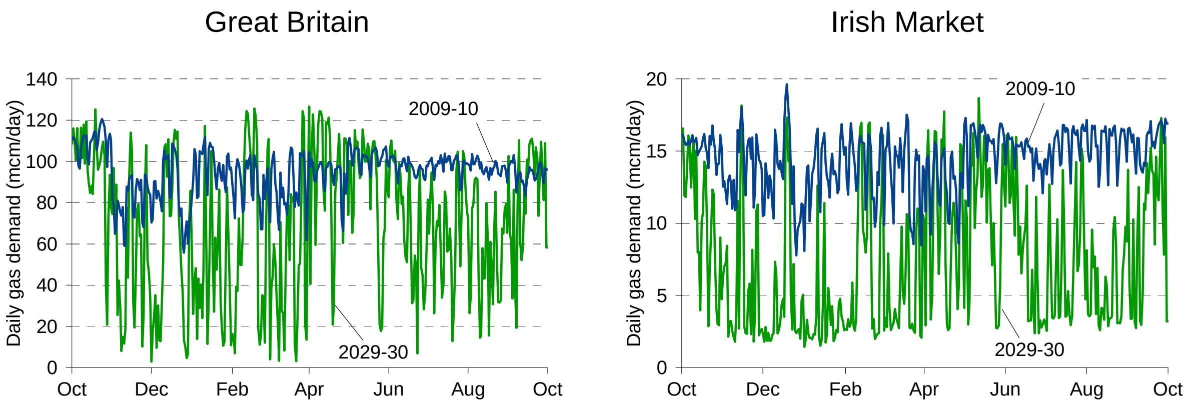
Figure 2 – Electricity generation in 2030 in Great Britain



Hourly generation for intermittency (wind, wave and tidal) and conventional plant. Assumes weather patterns of January 2000. Nuclear turns down to minimum-stable generation as a result of subsidies paid to wind generators.

Such a pattern of generation will have a knock-on effect on the gas market and we will see a new phenomenon in the gas market – 'gas intermittency'. Figure 3 shows 'gas intermittency' across an entire year for the power sector, using the daily basis on which the gas market operates. While the demand shows far higher volatility in 2030, there are also significant swings in demand across the year – far greater than has been the case in the past.

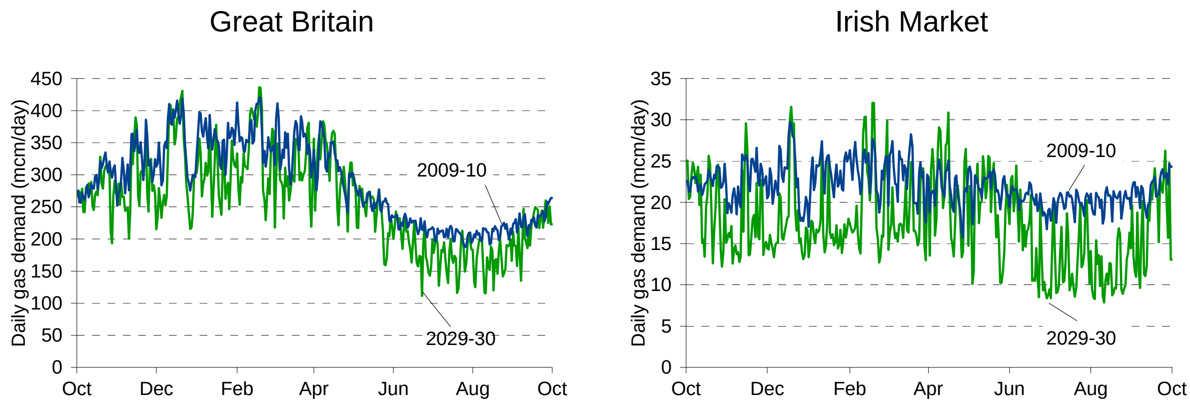
Figure 3 – Evolution of the power sector gas demand in GB and Irish markets



Gas years run from October to September: gas year 2009-10 starts on 1 October 2009 and ends on 30 September 2010
The charts show gas demand with the weather of gas year 2007-08, in a scenario with high build of renewables and CCGTs.

These variations are diluted somewhat by the requirements for gas from residential, commercial and industrial customers, which are driven mainly by temperature, weather and periods of shutdown over weekends and holidays. Figure 4 below shows the total demand when all four sectors are combined. Our analysis on the requirements of the gas market is based on the total demand, and as the subsequent parts of this report show, the changes are large.

Figure 4 – Changes in total gas demand



Gas years run from October to September: gas year 2009-10 starts on 1 October 2009 and ends on 30 September 2010
The charts show gas demand with the weather of gas year 2007-08, in a scenario with high build of renewables and CCGTs.

3. THE GAS MARKET IN 2020 AND 2030

One challenge for this project was to factor in the way in which the more intermittent requirements for gas would be met by sources of supply that are likely to be very different to today.

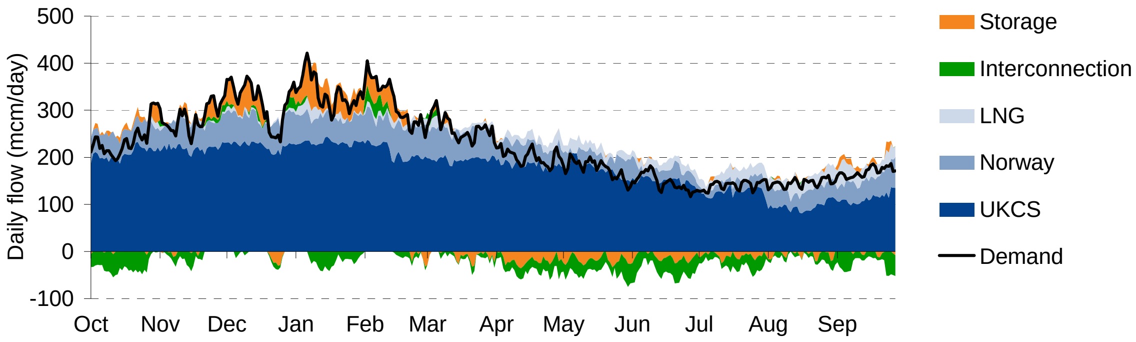
In the late 1990s, Britain was fully self-sufficient in gas, with large supplies from the UK Continental Shelf in the North Sea and Irish Sea. Gas prices were relatively low and supply abundant. With such reserves available offshore, an interconnector between the UK and Belgium was completed in 1998 to allow the UK to export to other markets, yet from 2000 onwards the UK's indigenous gas supplies have been in decline, and at a faster rate than previously envisaged.

Following a period of market tightness in the middle of the 2000s, several major infrastructural developments have changed the situation once more. Two large pipelines have been built: the Langeled pipeline from Norway is capable of bringing in around a quarter of UK supply requirements as well as a new interconnector from the Netherlands. These, together with reinforcements to the existing interconnector to Belgium all allow far more gas imports by pipeline. Also, a series of new LNG terminals now allow the country to bring in gas from suppliers around the world, for example from Qatar, Algeria or Trinidad. Together, all these have also diversified the mix of supply considerably.

It is helpful to consider the UK gas market in a new transitional phase, where much of the new infrastructure to supply our needs for the next 20 years has been built or is under construction, but it is not clear how it will be used and how the market will change as a result. This report investigates how this supply portfolio may respond in the light of more intermittent demand for gas.

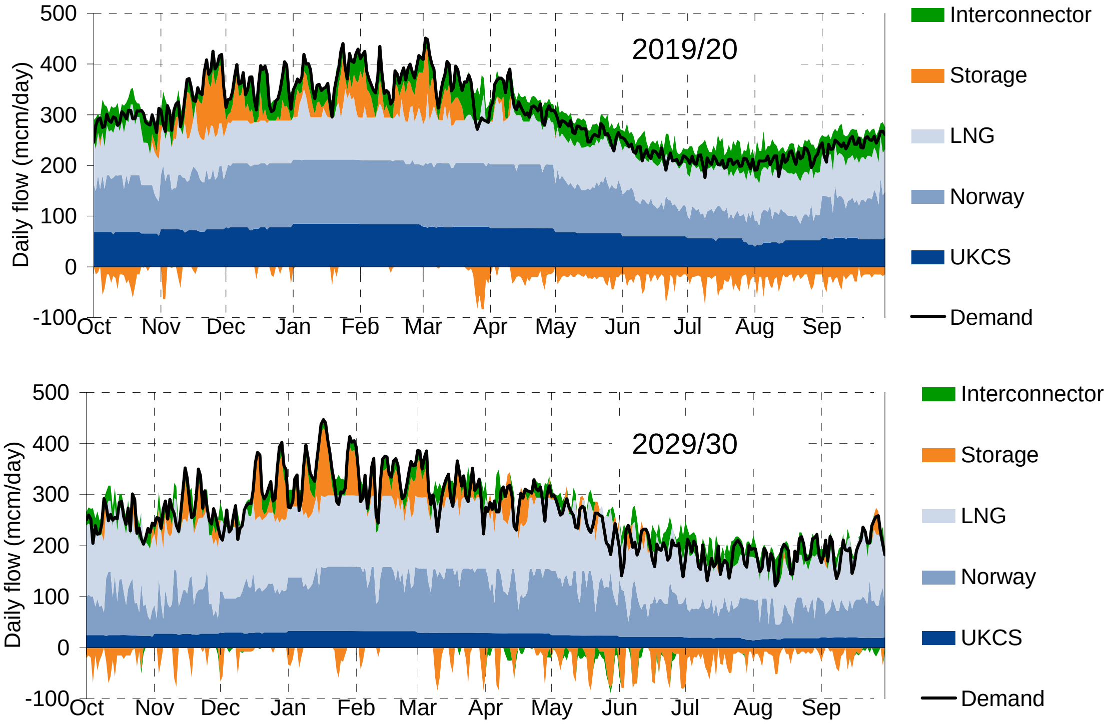
To illustrate this, Figure 5 and Figure 6 show the way in which the growing impact of intermittency will be met by a changing supply scene. Figure 5 shows the current supply and demand picture for 2008/09. The predominant source of supply is the UKCS in dark blue. Additionally, there is gas from Norway and via LNG from sources such as North Africa and Qatar in light blue. Finally, to supply winter periods, gas storage plays an important role. The supplies in excess of the demand line are either exports or injection into storage, which are also shown below the zero line.

Figure 5 – Daily supply mix in 2008/09 (for Great Britain)



Shows actual flows. Demand represents gas consumed in Great Britain.

Figure 6 – Daily supply mix in 2019/20 and 2029/30 (for Great Britain)



Results from our modelling work.

However, both the changing demand and changing supply will alter this picture in the future. Figure 6 shows one of the many market scenarios investigated in this report for the scene in 2020 and 2030: this particular scenario is based on relatively high deployment of wind generation, meeting the 2020 target and continuing beyond it, combined with further build of gas-fired CCGTs.

Several features of the picture painted by Figure 6 are of note: in this scenario while demand is slightly higher than now it is much more volatile than in the past; against declining UKCS supply, Norway, interconnector flows and LNG account for a far greater share; finally storage plays a far more important role, both for seasonal variations and balancing the additional variability caused by the wind.

Developing an understanding how the different sources interact in the future will be important to all players in the market, such as suppliers, large customers, infrastructure owners and regulators. The interaction of the intermittent demand for gas and various sources of supply will not only determine the extent to which new investment is required, it will also test the current market arrangements.

4. GAS STORAGE IN BRITAIN

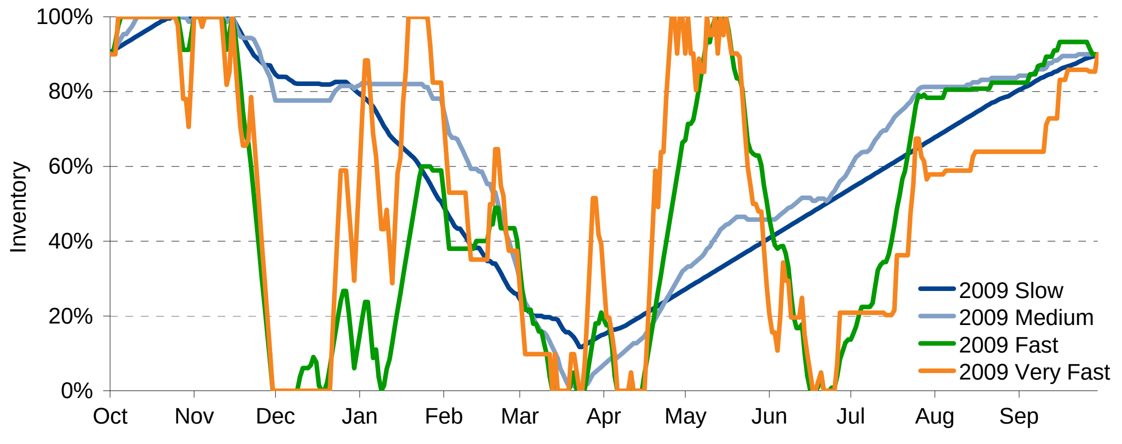
Seasonal demand from requirements for heating mean that gas demand is considerably higher in winter than in summer. Historically the 'swing' in the UK has been largely met by a combination of flexibility in offshore fields and the seasonal storage of the Rough facility. Some gas fields have particularly high flexibility – Morecombe in the Irish Sea, Troll in Norway and Groningen in the Netherlands – but many more are limited by the economics of associated oil production, geological constraints, or simply the discounted value of production giving strong incentives to produce gas today rather than hold it in the ground for 10 to 20 years.

The ability of upstream producers to provide the 'swing' and the relative abundance of indigenous production has meant that Britain has historically required proportionately smaller amounts of gas storage than many other countries.

Looking into the future the need for storage, and the timescales on which it is able to switch from injection to production, will be affected by both the nature of the demand (i.e. from wind intermittency on the electricity system) and the flexibility of supplies that are very different in nature to today.

This study, for the first time has investigated these effects, and these show the importance of the role that LNG will play, and the increasingly active scene for gas storage. This is illustrated in Figure 7, which shows the results of the gas storage modelling and how differing types of storage facility behave in different ways depending on their rates of injection and withdrawal.

Figure 7 – Example of utilisation of gas storage facilities



Storage simulation based on gas modelling.

Although LNG production in countries such as Qatar is relatively flat, with large liquefaction plants working best at a constant rate, supplies may be seasonal to the UK as they can be sent to different parts of the world at different times of the year. Historically, there have been higher deliveries of LNG to European markets during the winter months, and less during the summer, balanced by the opposite to the US.

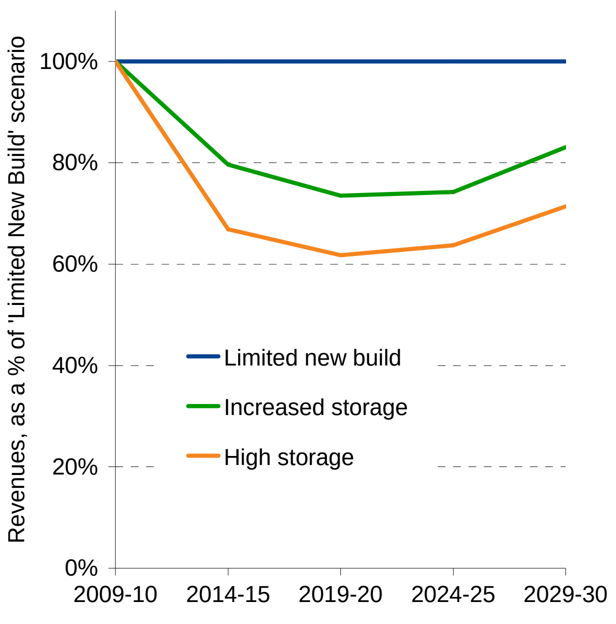
Our work has examined in detail how LNG flows may change into the future, to a granularity of modelling of supply and demand on a daily basis. It is clear that both LNG and gas storage are major contributors to seasonal swing – and indeed there is competition between the two types of supply.

It is also likely that the US market will play an increasingly important role in the future in determining prices in GB. Remarkably, factors such as the availability of storage in the US can have a direct effect on gas prices in Europe, as can more structural issues such as the cost of buying gas storage. To some extent, this is already the case but it will become much more important in the future.

The storage scene is even more complicated: the study indicated that revenues, in particular for fast-cycle storage which is able to respond in similar timescales to the wind intermittency, would increase as more wind generation is built. Seasonal storage is not able to capture so much this value.

We took the opportunity to examine the incremental impact of building more storage facilities on earlier ones. Intuitively it would be expected that the value of storage will be high if only limited storage is available, but as more is constructed, the value of each facility will drop.

Figure 8 – Effect of overbuild of storage on revenues



This study is the first to quantify the extent to which storage facilities affect each others' utilisation and revenues. Figure 8 compares three different scenarios, and how revenues could fall by almost 40% in the more extreme case.

In practice the effect on revenues for storage facilities is not as severe as might be expected because the way that interconnection between GB and the Continent mitigates the flows. Britain operates as part of a much larger NW European market, and as a result, storage facilities built in GB can also supply flexibility to the NW European market. Equally, significant build of gas storage on the Continent could affect the GB market and reduce revenues for GB storage facilities, as gas can be taken from storage on the Continent allowing more gas to be imported into the GB market.

Thus the future value of gas storage facilities revolves around a complex interaction between competing sources for flexibility: LNG and the worldwide gas market, interconnection and gas storage on the Continent, and direct competition from storage facilities in the UK market.

5. HOW IS IRELAND AFFECTED?

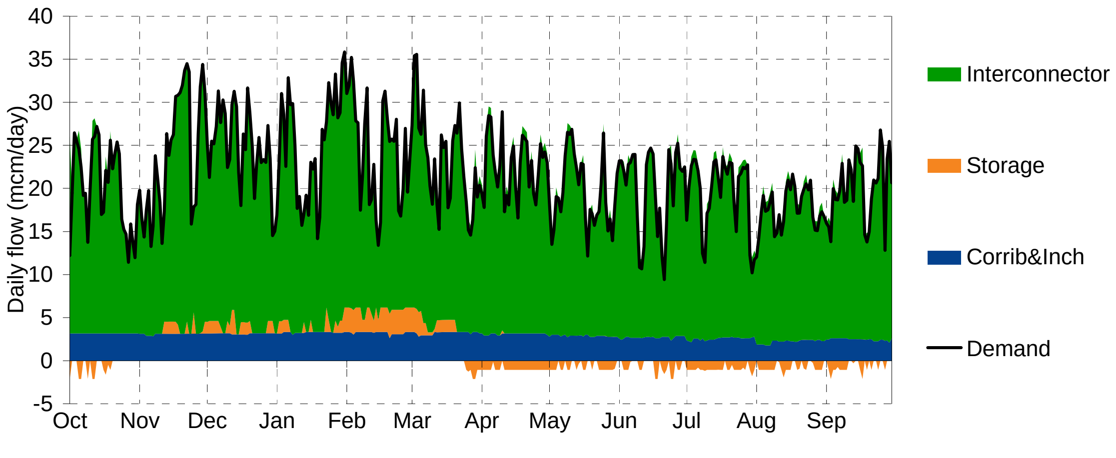
The Irish gas market – comprising both Northern Ireland and the Republic of Ireland – is much smaller than that in GB, with most of the gas currently supplied from GB via three interconnectors – two to the Republic and one to Northern Ireland. As highlighted in our work on intermittency on electricity markets[1], the impact of wind generation in the Irish market is far more significant; wind generation is more strongly correlated in the smaller geographical area and so periods of high or low wind generation across the country are more likely.

Wind generation's impact on the Irish gas market will depend on the amount of gas-fired CCGTs that are built in the future, although current policy direction would suggest that gas-fired plant is likely to be called on to 'soak up' much of the effect of wind. Since the power sector represents half of gas demand in the Irish market rather than the third in Great Britain, its impact will be greater. Thus gas demand becomes more volatile in Ireland than in Britain at lower levels of wind deployment and the seasonality of gas demand is likely to flatten, as there is more wind generation in winter than in summer.

If significant amounts of wind generation are installed, overall gas demand is likely to fall, as gas-fired plant are displaced by wind generation. However, gas demand volatility will increase, which could lead to lower annual gas demand, but higher peak day gas demand.

A typical pattern of gas demand and supplies is shown in Figure 9 for 2020, assuming limited new infrastructure is built. The majority of the supplies to the Irish market come from interconnection from Scotland, with some indigenous supplies and some gas storage.

Figure 9 – Flows to the Irish market in 2020



[1] 'Implications of Intermittency of electricity markets of GB and Ireland', Pöyry Energy Consulting, May 2009. A public version of the report is available at www.ilexenergy.com

There are currently proposals to build a new LNG terminal in Shannon, and gas storage projects in Larne. It is not clear at this stage which, if either, of the gas storage or LNG projects will go ahead.

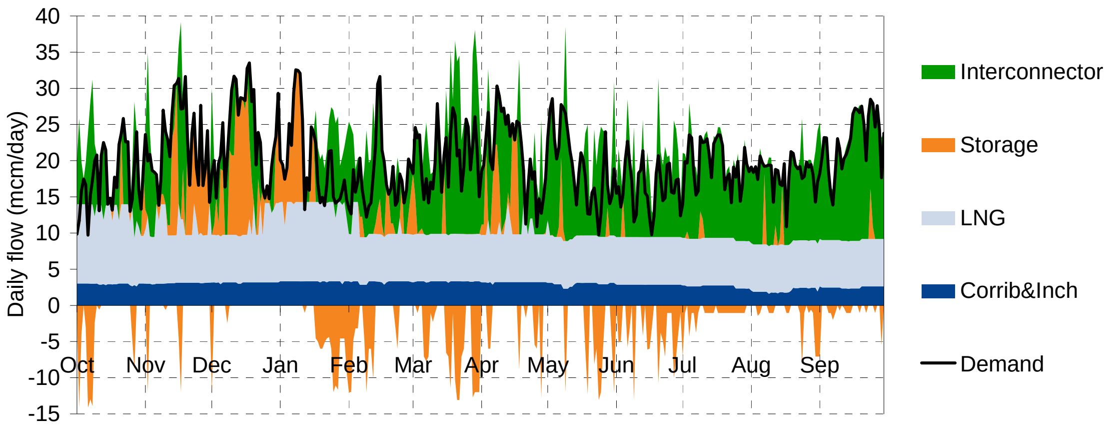
Building an LNG terminal would certainly increase security of supply for the Irish market, as LNG could be delivered directly to the Irish market and bypass GB entirely. Our analysis suggests that a LNG terminal in Ireland would probably operate at a higher load factor than a similar facility in GB, as costs associated with interconnection could be avoided.

A sizeable gas storage facility in the Irish market would also boost security of supply, although the size of the facility could be important. A facility that is too big risks reducing its future revenue in a similar manner to overbuild of facilities in the GB market.

However, building both a storage facility and an LNG terminal may result in an oversupply of flexibility to the market.

Figure 10 shows how flows to the Irish market in 2020 might look if both a LNG terminal in Shannon and a gas storage facility at Larne were built. In this case, gas flows from the interconnection from GB are sharply curtailed, with significant supplies from LNG.

Figure 10 – Flows in the Irish market with Shannon LNG built by 2020



6. WITHIN-DAY EFFECTS AND MARKET ARRANGEMENTS

A separate area of analysis examined the impact of the intermittency of wind on the within-day gas market, to understand the extent to which within-day gas demand volatility would change, and hence the extent to which new sources of within-day flexibility may be required.

Most gas markets have a daily requirement for balancing supply and demand, and there is no need to balance the system on a second-by-second basis as is the case for electricity. This is because gas is stored within the transmission system as linepack, and this allows demand to be higher than supply during the day within a certain tolerance, provided that supply is greater than demand overnight to replace the linepack that has been used.

Rather than modelling the gas transmission system in detail, and considering the gas pressure, temperature and flows at points on the system, we concentrated on understanding how the requirements for flexibility on the system may change over time, and the location of the likely changes.

To do this, we modelled the current and future requirement for flow-flex[2]. Flow-flex is used by National Grid as a measure of the requirements within-day for flexibility of gas supplies. In understanding how it may evolve in the future, we modelled hourly demand for gas from the power generation sector (including starts and part-loading of plant) using our previous work on hour-by-hour electricity output. This then allowed us to model how gas demand requirements on an hourly basis will change in the future, depending on the amount of wind generation and the number and location of CCGTs on the system.

Figure 11 shows an output from that analysis, giving the load duration curves of flow-flex requirement at ten year intervals to 2030. These charts stack flow-flex from the highest day to the lowest day. The higher the flow-flex requirement on any given day, the more stressed the system is and the higher the requirements for within-day sources of flexibility such as linepack, storage and supply modulation.

In GB, the overall requirements for flow-flex rise from 2010 to 2030 in a scenario where there is significant build of both wind farms and CCGTs, with the peak requirement rising by 75% by 2030. The Irish market shows a more complex picture, with peak flow-flex requirements rising from 2010 to 2030, but off-peak days (such as summer) reducing. This is due to rising wind penetration driving down the load factors of gas plant.

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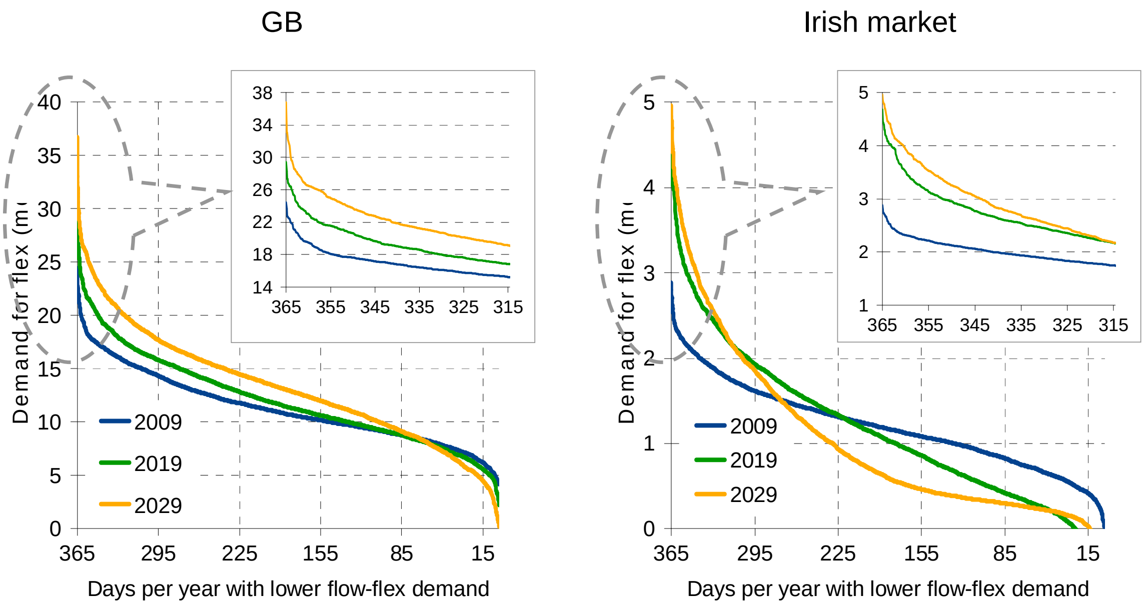
2 Defined as the average flow rate over the first 16 hours of the gas day compared to the average flow rate over the whole day.

Figure 11 – Load duration curve for flow-flex in GB and Irish market



Results taken from a scenario with high deployment of CCGTs and wind generation.

It is difficult to draw any conclusions on the severity of breaches compared to current indications of flow-flex capacity without very detailed hydraulic modelling of the whole gas transmission system, and we cannot assert whether or not the system will become stressed, or whether this is within the capability of the existing system. We can however deduce from our analysis that wind intermittency will lead to the system needing to be used in a more flexible way.

As a result of intermittency, it is quite possible that the balancing and nomination performance of shippers may deteriorate as a result of rapid and unpredictable demand changes. It may well lead to an increase in operational uncertainty on the part of the System Operators. However, we believe that it is too soon to consider changes to market arrangements as a result of intermittency because the effects will be gradual and are still some years ahead. Nevertheless, it is likely that some changes to the market arrangements will be required in due course.

7. CONCLUDING REMARKS

Visualising the future and trying to understand how markets may evolve is fraught with difficulties. This work has given a snapshot of how the future may look for gas markets if significant wind generation is built as part of the drive towards decarbonisation and the 2020 renewable targets.

To answer the questions posed at the beginning of this project, we have created an extremely sophisticated gas model that allows simulation of historical weather patterns projected into the future, the supplies that are required to meet the demand, and captures the inherent uncertainty of the decisions made in a market.

From the work, we now understand how gas demand may evolve in the future, and the extent to which it will become more volatile as a consequence of low carbon policies. The interactions between the electricity market and the gas market will become increasingly important, with wind generation affecting not only the electricity system but the gas system too.

Whilst demand is changing, the supply-side is also moving: the rapid decline of the UKCS and the challenges of increasing imports via LNG and pipelines mean that the market is already very different to that of a few years ago, and will keep changing into the future.

Increased volatility of demand and declining supplies creates opportunities – there will be need for more day-to-day and within-day flexibility of supplies, and seasonal swing. Some of this may be supplied by new storage facilities, some from interconnection and some from LNG – and a functioning gas market will incentivise all these supplies to flow when necessary.

Of course, gas markets are highly competitive, and if a situation where overbuild of storage occurs it would be one where the utilisation and value of storage drops sharply. Equally, a situation where there is limited build of storage facilities could lead to growing value for provision of day-to-day flexibility and swing.

The Irish gas market will be affected more by wind intermittency and sooner than the GB market, as power generation forms a larger share of gas demand. However, many of these issues will be relieved by being well-interconnected to the British market.

Within-day, requirements on the grid to manage linepack will increase and the network will have to be operated more flexibly; however, there does not appear to be a need for any immediate action to change market arrangements, such as a move to shorter balancing periods.

In an uncertain world, there are many factors that could lead to different outcomes. However, this work has given an unprecedented insight into what might happen in the next 20 years in the GB and Irish gas markets.

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QUALITY AND DOCUMENT CONTROL

Quality control		Report's unique identifier: 2010/264
Role	Name	Date
Author(s):	James Cox	June 2010
	Michel Martin	
Approved by:	Andrew Morris	June 2010
QC review by:	Beverly King	June 2010

Document control			
Version no.	Unique id.	Principal changes	Date
V1_0		Public report	1 June 2010

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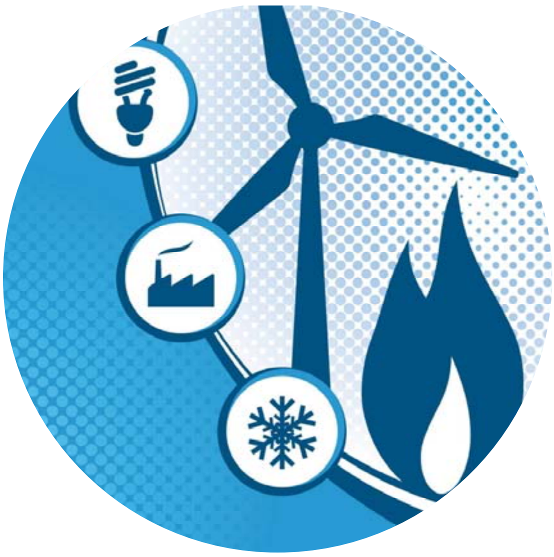

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