



Department for  
Business, Energy  
& Industrial Strategy

# GAS SECURITY OF SUPPLY

A strategic assessment of Great Britain's  
gas security of supply



October 2017

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## Executive summary

**Energy security is a priority for government. Affordable and secure energy supplies are essential for our economic success.**

Natural gas provides the main source for heating homes and businesses in Great Britain (GB). It is also a major primary energy source for industry and an essential fuel source for electricity generation as well as being a feedstock for some industrial applications. In 2016 natural gas accounted for nearly 39% of all the UK's primary fuel consumption<sup>1</sup>.

This report provides a detailed evaluation of the long term security of one of our critical energy sources. It brings together conclusions from a number of recent assessments from government, the regulator, system operator and private sector to examine the security of gas supply over the next 20 years. In particular it is supported by a detailed analysis from external consultants, Cambridge Economic Policy Analysts (CEPA), of gas security in the face of unlikely but significant geopolitical 'black swan' (i.e. rare and unpredictable) shocks that could disrupt supply.

GB benefits from a strong, liquid market which has delivered a system built on supply diversity. This, coupled with spare capacity, means we have never suffered a gas deficit emergency and GB is resilient to multiple infrastructure failures.

The gas system in GB has evolved with changing patterns of demand and supply, and will continue to change. GB is a net importer of gas, with the proportion growing since 2004<sup>2</sup>. This is set to continue primarily due to the long-term decline in gas coming from the UK Continental Shelf (UKCS) and increase in worldwide availability of Liquefied Natural Gas (LNG). Demand is likely to be impacted by energy efficiency measures, heat decarbonisation and electricity generation.

Our analysis finds that the market will adapt to these changes in supply and demand. This means that GB will have enough import capacity to deliver even in high demand scenarios, and will have the resilience to cope with severe shocks to the system. Even under the most severe, very low probability shocks, our analysis suggests that our system is robust.

We find that the diversity of supply and the available capacity underpin the strength of the GB system. This system must be supported by a market that continues to be price responsive, allowing the GB market to attract sources of gas when they are needed. In the longer term, a strong market incentivises investment in the infrastructure to maintain the capacity and diversity which underpins our security.

We are secure now, and the GB gas system is well placed to continue to be secure and robust in a range of supply and demand outcomes over the next two decades.

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<sup>1</sup> See table 1E in BEIS (2017) *Digest of United Kingdom Energy Statistics (DUKES)*. Available at: [www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/637823/DUKES\\_2017.pdf](http://www.gov.uk/government/uploads/system/uploads/attachment_data/file/637823/DUKES_2017.pdf)

<sup>2</sup> Oil and Gas Authority (October 2016) *UKCS Oil and Gas Production Projections*. Available at: [www.ogauthority.co.uk/data-centre/data-downloads-and-publications/production-projections/](http://www.ogauthority.co.uk/data-centre/data-downloads-and-publications/production-projections/)

## Rough closure

Whilst the CEPA (2017) report was concluded before the announcement<sup>3</sup> in June 2017 of the planned closure of the Rough gas storage site, the scenarios considered within the report examine the impact of Rough closing.

As such, the announcement of Rough's planned closure is not considered to have impacted the findings of the CEPA (2017) report, or of this assessment. As this assessment outlines, current and forecast levels of GB supply and storage infrastructure are sufficient to meet all customer demand in all but the most extreme cases.

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<sup>3</sup> [www.centrica.com/news/cessation-storage-operations-rough](http://www.centrica.com/news/cessation-storage-operations-rough)

## Current GB gas system

The GB gas system is made up of a diverse range of supply sources with sufficient capacity to meet the demands of users: be they electricity generation, industrial, residential or other sectors.

Gas supply and demand needs to balance on a daily basis, requiring a flexible system that can respond to demand peaks. Gas shippers are incentivised to keep the system in balance through a regime that penalises them for over or under supplying. This encourages not only balancing of market positions on a daily basis, but use of other mechanisms (such as storage and supply contracts) to guarantee that they will be able to balance their positions into the future. The gas market therefore incentivises both sufficient gas to meet peak demand and sufficiently diverse and robust capacity to deliver it.

The supply side is made up of three main sources: gas pipelines direct from production fields, primarily the UKCS and Norway; Liquefied Natural Gas (LNG) imported by ship from a range of global locations and interconnectors transferring gas from the continental European gas network. Gas storage, while not strictly a supply source, can act as a supply source at times of high demand.

In assessing gas security we therefore need to consider if there is sufficient gas available, capacity to deliver it, sufficient system flexibility to respond to peaks in demand, and a market which responds effectively to price signals.

### Assessing current levels of gas security

The GB gas system is subject to regular assessments of security of supply (through National Grid's twice-yearly 'Outlook' publications, the biennial European gas risk assessment and ad-hoc assessments such as Ofgem's 2012<sup>4</sup> gas security report). These assessments demonstrate that GB's gas system is able to respond effectively to unexpected changes in supply and demand. It is secure in the face of all but the most extreme and unlikely shocks, with diversity of supply being identified as a primary contributor to this robustness. Together these assessments show that the GB system has high levels of security:

- **the range of supply diversity available to the UK markets (including storage) can deliver 130million cubic metres per day above the maximum daily demand we expect to see once in every 20 years of 472 million cubic metres per day<sup>5</sup>;**
- **even for a higher daily demand (expected once in 50 years) combined with an infrastructure loss, the market could adequately deal with this shock with an effective demand side response<sup>6</sup> from large users**

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<sup>4</sup> Ofgem (2012)

<sup>5</sup> National Grid (2016b) based on a 1 in 20 peak day. The highest ever gas demand was 465mcm/d in January 2010.

<sup>6</sup> Demand Side Response is a demand management technique where users volunteer to reduce their gas usage in exchange for a payment. It is focused on large gas users only, not domestic consumers.

- **if the UK were to lose its single largest piece of gas infrastructure, the wide range of supply sources available mean that it would still have 27% more capacity than it needs** to deliver maximum daily demand seen once in 20 years<sup>7</sup>.
- **between 60% and 70% of supply capacity would have to be lost before supplies to domestic consumers would be interrupted**<sup>8</sup>. A 60% loss in supply capacity would represent losing all LNG supply, all imports from Belgium and Netherlands, and a loss of fifty per cent of current UK production.
- **at average demand levels, there is sufficient capability for the GB gas system to meet all required demand**, both domestic and expected exports to continental Europe and Ireland, for all disruption scenarios relating to the Russia-Ukraine dispute.<sup>9</sup>

## Case studies: flexibility and resilience in practice

There has never been a gas deficit emergency<sup>10</sup> in GB or UK (where supplies to consumers have been interrupted), signalling the high levels of gas security we have experienced to date.

GB has shown itself to be resilient and responsive to actual restrictions to gas supply infrastructure. National Grid has identified case studies where there have been potentially significant disruptions to supply<sup>11</sup>, which demonstrate the ability of the GB gas market to respond and absorb the impacts of these disruptions without consumer detriment.

A failure of the IUK interconnector in 2013 provides such an example of a market reaction to a short-term supply disruption (within-day). On 22 March 2013, the coldest March since 1962, IUK experienced an outage early in the day. The price rose rapidly, bringing on supplies from storage and LNG, with prices falling back as the supply situation eased and IUK came back online before the end of the gas day (Figure 1).

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<sup>7</sup> BEIS (2016)

<sup>8</sup> Ofgem (2012)

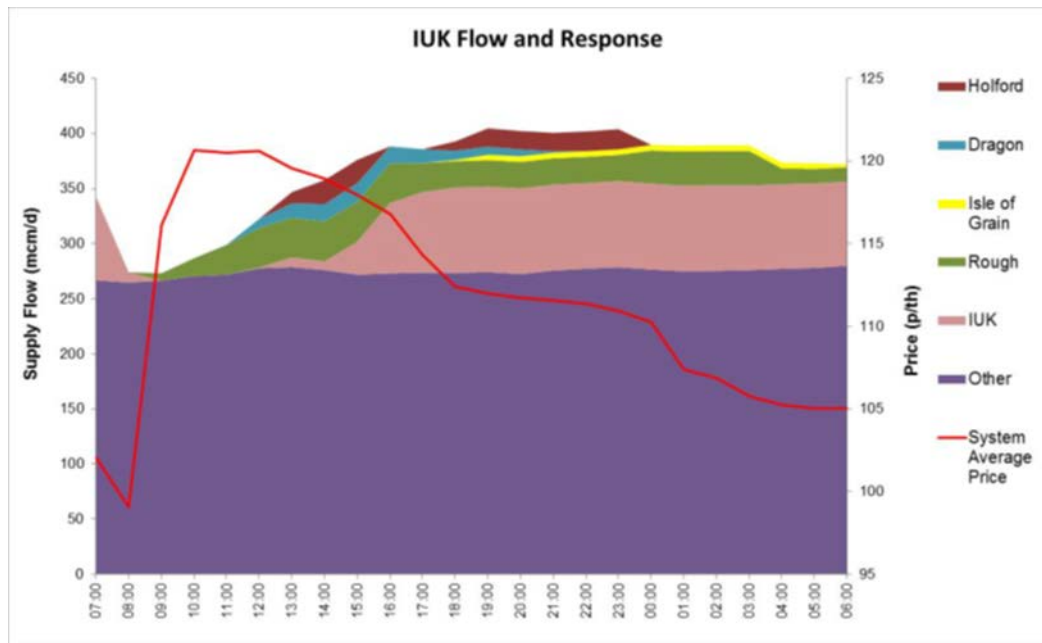
<sup>9</sup> BEIS and National Grid assessments supported by Ofgem contributing to European Commission (October 2014) *Communication from the Commission to the European Parliament and the Council on the short term resilience of the European gas system: Preparedness for a possible disruption of supplies from the East during the fall and winter of 2014/2015*. Available at:

[https://ec.europa.eu/energy/sites/ener/files/documents/2014\\_stresstests\\_com\\_en.pdf](https://ec.europa.eu/energy/sites/ener/files/documents/2014_stresstests_com_en.pdf)

<sup>10</sup> A Gas Deficit Emergency is a type of Gas Supply Emergency arising as a result of insufficient deliveries of gas being available to meet required demand on the gas system; or as a result of a potential or actual breach of a safety monitor.

<sup>11</sup> Further detail and analysis is available in BEIS (2016).

**Figure 1 - Price and flow response following IUK outage, March 2013**



Source: National Grid

An outage at the Rough storage facility in early 2006 demonstrates market response to a longer-lasting disruption. In February 2006, a fire at the Rough storage facility halted withdrawals between February and June. Rough had been a major supply source in the first half of the winter but the market responded to the price increases, in particular through short and medium range storage and interconnectors.

In both these cases, the market responded to the supply failure, reacting appropriately to price signals, bringing on additional supply and ensuring that there were no supply interruptions.

## Conclusion

GB has always experienced, and continues to experience, high levels of security of gas supplies. The strength of the GB gas system is built on supply diversity and capacity.

As UKCS has declined, this diversity has grown and now includes additional pipelines from Norway and Europe; LNG import terminals; and new storage facilities. Furthermore, as the system has developed, it has provided spare capacity on the system as shown in the most recent National Grid Winter Outlook<sup>12</sup> analysis. This means that we are resilient to multiple infrastructure failures. As Ofgem reported in 2012<sup>13</sup>, we would have to lose between 60% and 70% of supply infrastructure before supplies to domestic customers would be interrupted.

The diversity provides alternative routes for the gas in the event that one fails and the available capacity means that those alternative routes can cope with the additional flow. This has meant that, to date, there has never been a period when the supply of available gas is not sufficient to meet GB demand (a “gas deficit emergency”). Even where there have been infrastructure incidents, such as major infrastructure outages, they have been limited, and the market has reacted effectively to bring forward supplies.

<sup>12</sup> National Grid (2017b)

<sup>13</sup> Ofgem (2012) p6

**Summary of current GB gas security**

- There has never been a gas deficit emergency.
- The strength of the GB gas system is built on supply diversity.
- There is currently spare capacity on the gas system.
- We are resilient to multiple infrastructure failures.



## Future transition of the energy system

The gas system in GB has evolved in response to the changing demand and supply context. GB is now a net importer of gas, with the proportion growing since 2004<sup>14</sup>. GB benefits from a strong, liquid market which has delivered a system built on supply diversity. This, coupled with spare capacity, means we have never suffered a gas deficit emergency (where there is insufficient supply to meet demand) and GB is resilient to multiple infrastructure failures.

The supply and demand balance in GB will continue to change. Change in supply will be driven primarily by long-term decline in UKCS output and increase in LNG availability. Demand will mostly be impacted by energy efficiency measures, heat decarbonisation and electricity generation demand.

In order to estimate the level of security in the future we need to understand the demand trends and model their cumulative impact on gas demand. We then need to consider how supply sources will develop and whether they will have the capacity to meet this demand.

### Demand and supply scenarios

This report draws on National Grid's Future Energy Scenarios 2017<sup>15</sup> to frame the bounds of supply and demand.

- The “Steady State” scenario has the highest gas demand (excluding exports) towards 2035, with some energy efficiency gains, but with continued use of gas for both heating and power generation.
- The “Two Degrees” scenario has the lowest gas demand, where gas use is reduced to meet emissions reduction targets.

### Changing demand

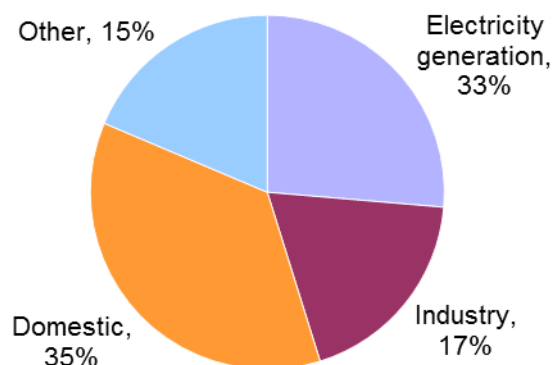
An understanding of future levels of gas demand, and the drivers of demand, are important to making an assessment of gas security going forward. There are three key demand sectors: domestic, industrial, and electricity generation. Each has its own drivers and consequences for the future. These are discussed below.

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<sup>14</sup> Oil and Gas Authority (October 2016) UKCS Oil and Gas Production Projections. Available at: [www.ogauthority.co.uk/data-centre/data-downloads-and-publications/production-projections/](http://www.ogauthority.co.uk/data-centre/data-downloads-and-publications/production-projections/)

<sup>15</sup> National Grid (2017a)

**Figure 2 - UK annual gas consumption by sector in 2016**



Source: Digest of UK Energy Statistics (BEIS, 2017)

### Domestic heating

Domestic use is the largest demand segment. Around 98% of gas in UK homes is used for heating<sup>16</sup>, making it the single largest use of gas<sup>17</sup>. Domestic heat, therefore, is an important factor in gas demand overall.

Widespread installation of energy efficiency measures has meant that median gas usage in all property types has fallen over the past decade.<sup>18</sup> National Grid expects to see continued efficiency gains over the next two decades under all scenarios. Under the high demand scenarios these efficiency gains offset new connections, meaning a net zero increase in gas demand. Under the lowest domestic gas demand scenario (Two Degrees) these efficiency gains would be greater and would be expected to lead to a net fall in domestic gas consumption.

In their Future Energy Scenarios, National Grid forecast domestic gas consumption of around 185TWh (in the Two Degrees scenario) and 322TWh (in the Steady State scenario) in the mid-2030s. This compares with 333TWh in 2016.

### Electricity

Electricity generation currently accounts for just over a quarter of gas demand. In all scenarios gas generation is expected to play a role, particularly as a flexible generation alongside renewables; and as coal is phased-out. In the high gas demand scenario we expect to see an increase in gas demand from more gas generation online. Under the low demand scenario, higher deployment of low carbon technologies is likely to lead to a lower demand for gas generation.

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<sup>16</sup> Space heating and water heating

<sup>17</sup> See Data Table 1.04 in BEIS (July 2017) Energy Consumption in the UK (ECUK) 2017. Available at: [www.gov.uk/government/statistics/energy-consumption-in-the-uk](http://www.gov.uk/government/statistics/energy-consumption-in-the-uk)

<sup>18</sup> BEIS (June 2016) National Energy Efficiency Data-Framework (NEED): summary of analysis 2016. 0. Available at: [www.gov.uk/government/statistics/national-energy-efficiency-data-framework-need-report-summary-of-analysis-2016](http://www.gov.uk/government/statistics/national-energy-efficiency-data-framework-need-report-summary-of-analysis-2016)

National Grid's Future Energy Scenarios forecast that electricity generation demand will change from 249TWh in 2016 to around 46TWh (in the Two Degrees scenario) and 225TWh (in the Steady State scenario) by the mid-2030s.

### Industry

Industrial demand is currently around 17%, so any changes here, particularly efficiencies, will have a smaller effect than in the domestic sector. Under all scenarios, National Grid forecasts that industrial gas demand will continue to decline. This is largely due to the electrification of low-grade heat and due to a general reduction in GB industry over time.

National Grid forecasts industrial gas demand declining from around 187TWh in 2016 to around 175TWh (in the Two Degrees scenario) and 170TWh (in the Steady State scenario) by the mid-2030s.

### Changing demand – summary

The extent and speed of decarbonisation of both electricity and heat is significant amongst the wide range of drivers that together will impact on GB gas consumption.

Under most projections, gas demand is not expected to rise; however, it is still expected to be an important part of the energy mix in the next two decades, remaining at least two thirds of current demand.

Current GB gas demand is around 923TWh per annum<sup>19</sup>, having fallen from around 1,000TWh a decade ago and a peak of around 1,100TWh in 2010<sup>20</sup>. National Grid (2017) forecast gas demand of between 604TWh and 891TWh in 2035.

### Modelling demand

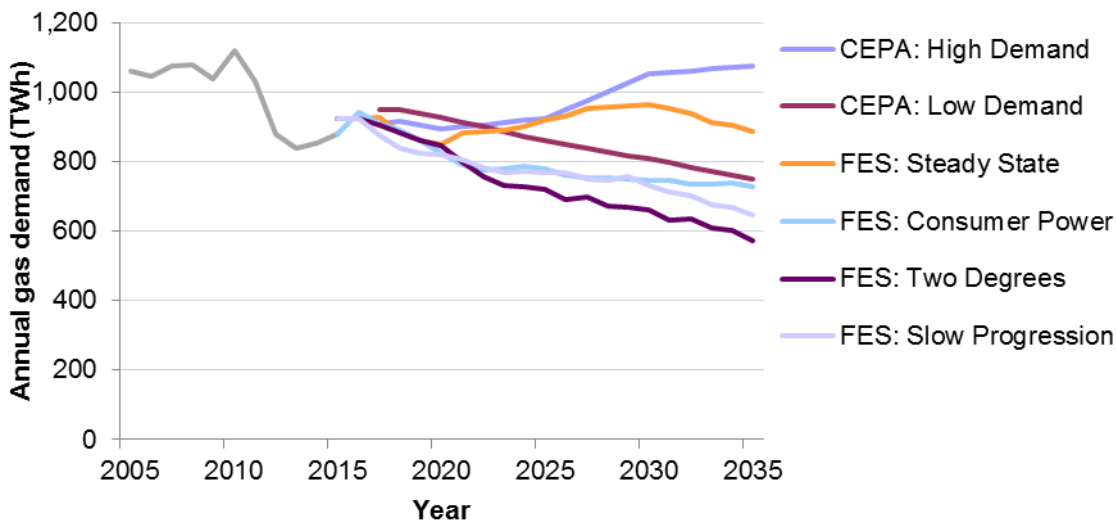
As part of this exercise to review GB gas security, we asked CEPA to undertake some analysis to inform our thinking. Their report is published alongside this report. CEPA have modelled two demand scenarios. The High Demand scenario is higher than that of the National Grid Future Energy Scenarios and allows for higher domestic gas consumption and demand for electricity generation. When assessing security of supply this is a cautious approach – a markedly higher demand than would otherwise be expected. Figure 3 compares the demand numbers across the different models.

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<sup>19</sup> In 2016: from National Grid Future Energy Scenarios 2017

<sup>20</sup> See table 4.1 in BEIS (2016) *Digest of United Kingdom Energy Statistics (DUKES)*. Available at: [www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/577712/DUKES\\_2016\\_FINAL.pdf](http://www.gov.uk/government/uploads/system/uploads/attachment_data/file/577712/DUKES_2016_FINAL.pdf)

**Figure 3 - GB annual demand 2005 to 2035 (TWh)**

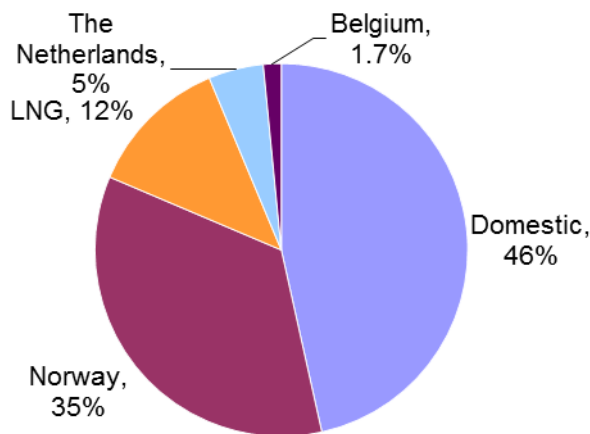


Sources: Future Energy Scenarios (National Grid, 2017a); A Review of Gas Security of Supply within Great Britain’s Gas Market – from the Present to 2035 (CEPA, 2017)

## Changing supply

GB’s sources of natural gas have changed over time. While we cannot, and do not need to, predict the future supply mix, making an assessment of future security of supply requires an understanding of all of our available supply sources, how they may change over time, and what their potential is to supply the GB market (including any risks and benefits). These factors are discussed below. Figure 4 shows the breakdown of gas by source for 2016.

**Figure 4 - UK gas supply in 2016 by source**



Source: Digest of UK Energy Statistics (BEIS, 2017)

## UKCS production

The single most fundamental change in the GB gas market is the decline in UKCS output. From 2004 GB became a net importer of gas. The Oil and Gas Authority projects that gas from the UKCS will supply approximately 24% of demand in 2035, down from 48% in 2016 . This means that there will continue be a significant shift in the supply balance over the next 20 years as UKCS output continues to decline. As a result of this shift, GB has already increased

imports, and demand has declined. As discussed above and below, we expect both trends to continue. Furthermore, exploiting new domestic resources would provide another source of gas as UKCS output declines.

### **Pipeline and interconnectors**

GB has received pipeline imports since before we were a net importer of gas. However, the volume of pipeline imports has been rising steadily, from 1.5 bcm imported in 2000 to 38.3 bcm in 2016<sup>21</sup>.

Pipeline imports are an important part of the system and will continue to be over the next 20 years. Depending on the source, they provide either strong reliable baseload supplies or responsive flexible supplies, responding to price signals.

In considering the future potential, there is some scope for the expansion of pipeline supplies. However, this is subject to the economics of the wider European gas market.

Norwegian imports currently run close to full capacity during the winter months. While there may be scope for expansion of capacity over existing infrastructure, significant expansion is likely to require high levels of investment, and therefore a sustained high gas price in GB, to be economic.

Sustained high price differences, beyond current levels, between GB and the continent are a likely prerequisite of any further expansion of interconnector capacity.

### **Liquefied Natural Gas (LNG)**

LNG is growing in importance both in GB and globally. Since 2005, LNG supply has grown and provided around 12% of UK demand in 2016<sup>22</sup> (although this varies year on year depending on a number of factors).

There is good evidence to suggest that LNG as a supply source has sufficient flexibility over the long term to fill the gap left by declining UKCS production (although other sources may compete with LNG for this role as described in the rest of this section). GB currently has a lot more LNG regasification capacity than it uses annually<sup>23</sup>. CEPA (2017) estimate that the market will continue to develop LNG as the key supply source and has the potential and capability to contribute up to 60% of GB demand by 2035.

As LNG is traded on a global market, the global context over the next 20 years has a bearing on the security and reliability we can expect from LNG as a supply source. A significant increase in Australian and US LNG capacity is expected; and the global LNG market is expected to be well supplied through the early 2020s, with supply driving demand<sup>21</sup>. GB is likely to benefit from the increased LNG from these suppliers.

There is sufficient gas globally, but supply of LNG will be reliant on sufficient levels of LNG projects coming online to meet demand, and new and sustained demand to drive investment in such projects. A section of this new demand is likely to be price sensitive, with markets that will

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<sup>21</sup> Oil and Gas Authority (October 2016) UKCS Oil and Gas Production Projections. Available at: [www.ogauthority.co.uk/data-centre/data-downloads-and-publications/production-projections/](http://www.ogauthority.co.uk/data-centre/data-downloads-and-publications/production-projections/)

<sup>22</sup> BEIS (2017) [www.gov.uk/government/statistics/gas-section-4-energy-trends](http://www.gov.uk/government/statistics/gas-section-4-energy-trends)

<sup>23</sup> National Grid (2017a)

fuel switch as gas prices rise, allowing the supplies of LNG to move to higher-priced markets when there is a constraint elsewhere in the market.

### Gas storage

Gas storage is not strictly speaking a 'source' of gas but is an important source of system flexibility.

Storage takes in gas when it is low priced (usually at times of over-supply such as in the summer) and returns it to the system when prices are high (usually during peak demand). Some storage operates over short timescales (days/weeks) while other facilities exploit longer term seasonal differences. GB storage does not operate as a 'strategic reserve' of gas – providing a large volume of gas to be used in case of an emergency but otherwise not utilised. Instead, the value of storage lies in its ability to operate flexibly in response to relatively short term price signals and ultimately reduce price volatility.

Storage relies on the variations in gas price over time (the spreads). For long range storage, this is summer-winter (seasonal) spreads and for short range storage it is a combination of seasonal and shorter term spreads. Volatility in the gas market has declined, which can be explained by the diversity of sources and capacity of infrastructure. In particular, seasonal spreads have declined significantly. While short range volatility may improve in the medium term, bringing on new short-range gas storage, the increased diversity of gas sources throughout the year makes it unlikely that high seasonal volatility will return. Nonetheless, we will continue to monitor the value of long-term storage as the dynamics of the gas market continue to evolve.

### Other domestic supply

Developing new sources of domestic supply may provide new sources of gas while reducing the reliance on imports.

The government believes that shale gas has the potential to play a crucial role in the GB energy system. It could also help to rebalance the economy and reduce carbon emissions as it is a cleaner source of energy than coal. The development of shale gas could provide a valuable new source of gas for the GB market at a time when gas supplies from the UKCS are forecast to decline. Whilst the government is optimistic about the potential for shale gas in the UK, given the industry is currently in an exploratory stage, it is not yet known how much of the UK shale gas resource will ultimately be recoverable. In order to provide a conservative estimate of supply, supply forecasts used in CEPA (2017), assume no shale contributions in the forecast period. We will update these forecasts moving forward and any shale projects that do come forward will be in addition to supply already forecast.

Biomethane is another potential source, manufacturing gas from waste or energy crops. National Grid (2017) assumes that by 2050 around 13% of GB gas demand will be met by biomethane under the Two Degrees scenario.

Hydrogen could play a role in replacing or blending natural gas. Further work is required to understand the impact on energy security from increasing hydrogen production and use.

## Modelling future supply trends

CEPA (2017) modelled demand and supply driven by factors within the model. These therefore represent possible future supply balances, rather than a forecast. The actual supply balance will depend on a range of factors as discussed above.

## Conclusion

The liberalised gas market has responded effectively to changing supply and conditions in the past, most recently the decline in UKCS output. Since 2005 (after GB became a net importer), the GB market has delivered significantly, including three additional pipelines with Norway; an upgrade to the Belgian interconnector; commission of an interconnector with the Netherlands; and investment in 4 Liquefied Natural Gas (LNG) regasification facilities.

The gas market is continually evolving. Driven by the continuing decline in UKCS output, from 53% of GB demand in 2016 to forecasts of around 21% by 2035, the GB supply balance will continue to change over the next 20 years. While gas demand is unlikely to rise significantly over the next 20 years there will still be significant demand out to 2035. National Grid forecasts put gas demand between 604TWh and 891TWh by 2035 (compared to 923TWh in 2016).

In this supply and demand context, analysis shows that there will be capacity for supply to meet demand, although this could evolve in different ways. LNG has the capacity to increase to make-up the decline in UKCS, CEPA modelling shows that LNG has the capacity to meet up to 60% of GB demand by 2035; although a portion could be displaced by other sources depending on the economics.

Pipelines will remain an important source of supply flexibility over the next 20 years, in the absence of significant changes in gas prices or spreads between GB and European gas markets; significant new pipeline capacity is unlikely to be economic.

Shale gas has the potential to play an important role in the energy system in the future by increasing supply diversity.

### Future transition - summary

- The liberalised gas market has responded effectively to changing supply and conditions in the past, most recently the decline in UKCS output.
- Gas demand is unlikely to rise significantly over the next 20 years but there will still be significant demand out to 2035.
- GB supply balance will continue to change over the next 20 years.
- LNG has the capacity to increase to make-up the decline in UKCS.
- Pipelines will remain an important source of supply flexibility over the next 20 years.
- Shale has the potential to increase supply diversity in the future.



## Future levels of GB gas security

Future security of supply needs to be considered in two dimensions: a base case to assess whether the gas system has the capacity to balance supply and demand under 'normal' conditions, and stress testing, looking at the impact of supply or demand shocks (or a combination) on the gas system.

The base case provides information on the gas system under normal circumstances and the ability to cope with a range of demand and supply variance within each scenario (such as cold winters).

Stress testing the system involves modelling increasingly severe shock scenarios on the system, such as unexpected rises in demand (due to a severe cold snap for example) or sudden changes in supply (for example a major infrastructure outage).

A relatively simple stress test is the 'N-1' scenario, which considers what happens to the system if the largest single piece of infrastructure fails. In the latest assessment the UK achieved an N-1 score of 127% meaning that GB has 27% more infrastructure than is required to meet demand we would expect to see once in 20 years even if the single largest piece of infrastructure fails.

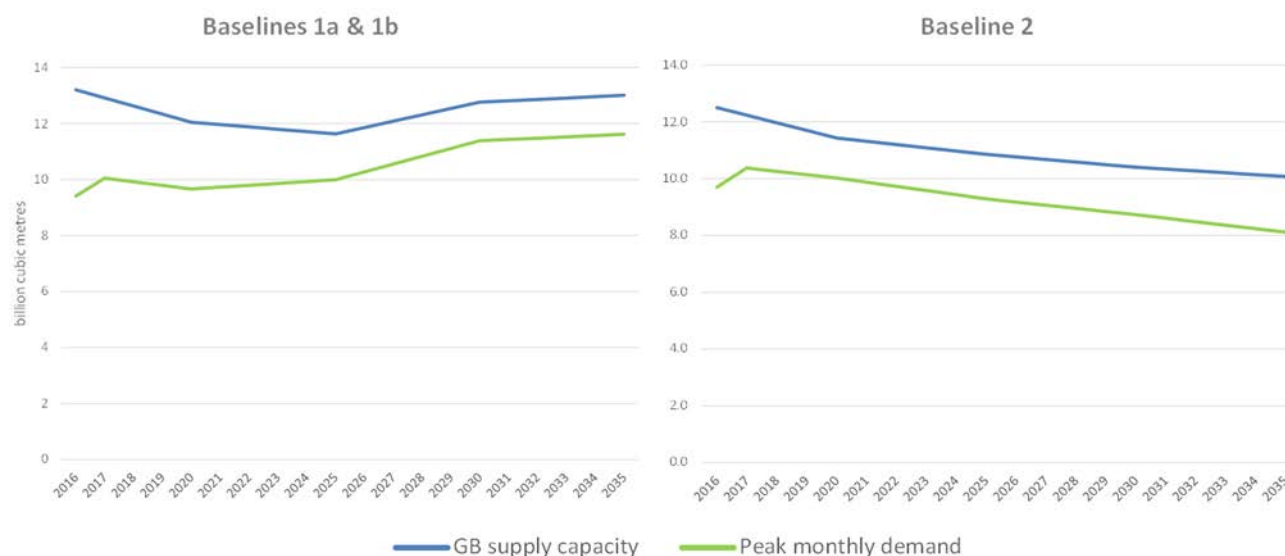
To test the limits of the system, we need to use highly unlikely 'black swan' scenarios (single events or combinations of events) to detect potential failure points. Once these scenarios have been modelled we can consider both the likelihood and impact of them occurring to make an assessment of security. The more unlikely the shock required to reach this breaking point the more secure the system. This is the approach taken in the stress tests below.

### Baseline security in the future

GB is secure in baseline scenarios under both high and low demand conditions. Consistent with other studies (such as Pöyry (2014)), the baselines show that under normal conditions (i.e. no major infrastructure failures) there is a good amount of additional supply relative to demand (margin) despite some rationalisation of capacity in both scenarios.



**Figures 5 and 6 - GB capacity margins Baseline 1a/1b<sup>24</sup> (high demand) and Baseline 2<sup>25</sup> (low demand)**



Source: CEPA (2017)

## Stress testing the gas system

Looking forward, we need to understand how robust our supply and demand scenarios are. We wanted to test the system against highly unlikely ‘black swan’ events to identify potential failure points to highlight residual risks or areas for further action.

Ofgem modelled stress tests on the system in 2012 as part of the Gas security of supply report and in 2014 (undertaken by Pöyry) as part of a cost benefit analysis into a demand side response mechanism. The Ofgem security of supply report modelled a number of stress tests with most extreme tests modelling infrastructure shocks up to a simultaneous loss of 50% of non-storage supply infrastructure. The Pöyry (2014) study modelled a number of stress scenarios.

In generating the shock events the reports showed that:

- reasonable assumptions for probabilities of infrastructure and supply outage made the chance of interruptions extremely small<sup>26</sup>;
- it requires an unlikely combination of multiple infrastructure failures and an usually cold winter in order to generate unmet demand<sup>27</sup>; and
- the size of non-storage supply infrastructure failure required was significant (and of very low probability) before non-domestic or domestic customers might be affected<sup>28</sup>.

<sup>24</sup> **Baseline Scenario 1a**—based on the IEA’s “Current Policies Scenario” (“CPS”). This scenario projects increasing global and GB gas demand out to 2035, and also assumes that the Rough gas storage facility is operational until 2035; **Baseline Scenario 1b**—based on the same IEA CPS set of assumptions as in Scenario 1a, but assumes that the Rough storage facility is closed from 2016.

<sup>25</sup> **Baseline Scenario 2**—based on the IEA’s “450 Scenario” (“450”). This projects decreasing European and GB gas demand and stagnant global demand from 2025 onwards. The Rough storage facility is closed in this scenario.

<sup>26</sup> Ofgem (2012)

<sup>27</sup> Pöyry (2014)

These reports concluded that:

- current and forecast levels of GB supply and storage infrastructure are sufficient to meet all customer demand in all but the most extreme cases<sup>29</sup>;
- in all scenarios, even with high demand, there are no interruptions before 2020. The low demand scenario does not generate any unserved demand between now and 2030<sup>30</sup>; and
- effective market operation (responding to price signals) in times of system stress, was shown to be important to delivering this security<sup>31</sup>.

## Security of gas supply – CEPA (2017)

The CEPA (2017) study published alongside this report specifically looks at, low-likelihood shocks. Bearing in mind the decline in UKCS output and the expectation in increasing imports, this study focussed specifically on long-duration geopolitical shocks, lasting twelve months in order to cover an entire gas year.

The report concluded that the GB gas market is highly resilient, with demand likely to be met in all but the most extreme combination of events. The following sections summarise key elements of the report.

### Development of the modelled scenarios

The modelling was run under high and low demand baselines. Under the low demand baselines, there was no unmet demand, so the discussion that follows applies only to the high demand baseline.

We conducted workshops with stakeholders where we discussed risks to gas supply and demand over the next 20 years to find the “best to test” shocks to model. Modelled shocks were chosen not because they were thought likely (or more likely than other shocks). Rather, they were chosen as proxies for a range of shocks of a particular type that could be large enough to represent the impact of ‘black swan’ events. The scenarios are all highly unlikely and should be considered theoretical rather than representative of a potential reality.

The three scenarios chosen were:

- a large and sustained global LNG disruption scenario;
- a large and sustained global supply shock scenario, affecting the whole of Europe; and
- a large and sustained global supply shock coupled with a major and sustained GB infrastructure outage

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<sup>28</sup> Ofgem (2012)

<sup>29</sup> Ofgem (2012)

<sup>30</sup> Pöyry (2014)

<sup>31</sup> Ofgem (2012)

## Likelihood of shocks occurring

All of the shocks modelled are proxies for ‘black swan’ type events. These shocks are highly unlikely to occur, and the scale and duration is even more unlikely. Furthermore, the supply shock combined with an infrastructure outage is a combination of two highly unlikely events.

In all three shocks, we have modelled an event which is likely to have much bigger economic, geopolitical, and even national security impacts than simply disruption to gas supplies. It is therefore likely, that the main mitigations to these risks would reach further than the gas system. In addition:

- Russia is heavily dependent on gas exports for budgetary revenues, and kept up sales, remaining a reliable supplier throughout the Cold War. Furthermore, Russia’s pipeline network serving Europe has considerable over-capacity, so a major catastrophe affecting one pipeline can be mitigated largely by resupply via an alternate route.
- There is no operational connection between Qatar and North Africa and weak political connections. Closure of the Straits of Hormuz is quite unlikely because of their critical importance for both gas and oil for the whole region; in effect a state of war would have to exist and then it’s unlikely the Straits would stay closed for long.
- Since 2000, there has been a gas infrastructure outage roughly every 1-2 years, although these have not always been full outages, and no occurrences of simultaneous failures have been experienced. Pöyry (2014) puts the probability of a failure at Bacton or Milford Haven at 2%. Given that CEPA (2017) models these two highly unlikely shocks occurring together, this simultaneity significantly reduces the likelihood of this scenario occurring.

## Outcome of stress tests

The shocks were modelled against high and low demand baselines<sup>32</sup> in 2025 – this is close enough to the present day to provide confidence that the future will look similar to the modelled baselines and is far enough into the future to enable any resulting policy decisions to take effect.

### *Global LNG disruption scenario*

The results showed that GB could maintain supplies of gas under this scenario with no involuntary interruption to any sector of demand (power, industrial or domestic), although we would expect to see some degree of price response, especially in the industrial sector as this sector tends to be the most exposed to short-term changes in wholesale prices. There is sufficient flexibility in the growing LNG market to adjust LNG flows to balance demand and Europe would also be able to increase pipeline imports.

### *Global supply shock scenario, affecting the whole of Europe*

Where pipeline imports to Europe are impacted, the results show that there is no unmet demand for any consumer sector within GB, such that even a voluntary response is not necessary. As the European gas system is also in stress in this scenario due to the cessation

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<sup>32</sup> The high demand baseline is taken from the IEA “Current Policies Scenario” which considers only those policies for which implementing measures were formally adopted by mid-2015. The low-demand baseline is based on the IEA 450 scenario and assumes policies with a trajectory of emissions reduction to meet the global limit of a 2 degree rise in global temperatures.

of pipeline supplies, GB must raise its prices to a sufficient level to attract gas from other markets<sup>33</sup>.

In order to cope with the supply shortfall from Europe, GB LNG imports rise significantly, reaching maximum capacity to bridge the supply gap. There is a similar response from the European gas markets, but as described above, there is sufficient flexibility in the growing LNG market to adjust flows.

### *Global supply shock coupled with major GB infrastructure outage*

This shock is the coincidence of two unlikely shocks occurring at the same time – a major European supply disruption and a major outage at key import infrastructure at the highest demand point of the year. This unlikely combination of events leads to small amounts of unmet demand for all consumer groups as the modelled constraint at Isle of Grain LNG terminal restricts the amount of LNG that can be imported.

That said, unmet non-daily metered demand (which includes all domestic demand) is minimal (a total of 0.01bcm); and given that the model does not take into account demand side response and other possible actions, it is likely that steps could be taken to mitigate such a small loss.

It is likely that the loss of economic output as a result of any of the economic shocks modelled in this report will significantly reduce gas demand that year and will make it far less likely that gas supply is constrained. In these circumstances, the challenge would be addressing the political and economic effects of the shock, not the consequential tightening of gas supply margins.

## Key findings for future security

### **Markets must function and give strong price signals**

Markets must be able to respond effectively to price signals to be able to secure supplies in the short term and ensure the infrastructure is available to secure supplies over the longer term.

Both Ofgem (2012) and CEPA (2017) indicated the importance of the market operating efficiently to minimise any impacts of a severe shock, in particular the ability for prices to rise sufficiently to bring in more marginal sources of gas.

Over the longer term, allowing prices to respond effectively will support the infrastructure that provides capacity and flexibility that reduces the chance of interruption of supplies thereby supporting security of gas supplies.

### **Responsiveness and flexibility**

We also find that over the next twenty years, the gas system will require effective sources of price responsive flexibility to respond to changing demand patterns throughout the year and to be able to respond to changes in supply, from small interruptions through to major shocks. We have a flexible gas system that responds well now, and as the supply and demand context develops over the next twenty years, flexible sources of gas will need to continue to develop.

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<sup>33</sup> A few pence per therm above the European price to account from the commodity entry charge

Pipeline gas (from Norway) and interconnectors (with Belgium and the Netherlands) in particular are a useful source of flexibility within the system.

Once the LNG market has adjusted to a shock, it should be able to provide a steady stream of cargos in response to the shock. However, the response can be limited by the speed with which the market can respond to a shock. Pipelines and interconnectors have the benefit of being able to respond quickly. However, where there is regional stress, pipeline imports may be limited.

Improving the diversion times for LNG (such as making contract renegotiations more efficient) will reduce the time lag for acquiring additional supplies.

Storage also has the capability to provide a source of flexible capacity in the intervening period.

### Timing of shocks

Even with the large supply and infrastructure shocks, unmet demand is concentrated in the high demand periods of the year (i.e. winter), with the summer period being largely unaffected.

### Storage

As the gas system changes, the role of storage on the system is also changing in response to the gas system and the gas market. On a day to day basis, storage provides value to the system by providing a source of flexibility and responding to short-run changes in supply and demand on the system.

However, gas storage is not a strategic reserve for use in the case of a gas emergency. The ability of storage to respond to a shock is limited by the total storage stocks available (a function of its capacity and how full it is at the time the shock occurs); the speed of depletion of stocks; whether it can refill during a shock; and the aggregate daily deliverability of those storage stocks. Keeping a strategic supply of gas out of the market only for emergency use is poor value for money due to the cost of maintaining the asset and holding that gas out of the market<sup>34</sup>.

### Conclusion

As UKCS production declines, import capacity becomes an important consideration. GB's good levels of capacity, particularly import capacity over the next 20 years mean that in both the high and low demand scenarios, we maintain a healthy capacity margin out to 2035. This is despite some closures in response to prevailing market conditions, but overall security of supply remains unaffected: in the high demand scenario, there is a slight tightening of capacity as demand rises in the mid-2020s, accompanied by new investment; and in the low-demand some capacity closes as demand falls.

Where there are shocks to the system, modelling results show that GB is highly resilient. Under low demand scenarios, modelling shows no un-met demand. In high demand scenarios, GB has enough import capacity and diverse import capacity to meet demand even under stressed conditions. CEPA (2017) showed that even under the unlikely scenarios of global

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<sup>34</sup> Redpoint Energy (2013) for DECC

pipeline disruptions or global LNG disruptions, there is sufficient import flexibility to meet demand.

When testing the limits of the system, modelling demonstrates the high degree of resilience of the system. Even under high demand scenarios the system is highly resilient with interruptions only occurring under highly unlikely, severe conditions. In the CEPA study, only one of three of the unlikely shocks – where the shock is compounded by an unlikely coincident infrastructure failure – generated unserved demand. In the Ofgem 2012 security of supply report, interruptions only occur after the equivalent of 50% of non-storage supplies are interrupted; and the Pöyry study (2014) finds a “1 in 50” winter, compounded by an infrastructure failure (of 1% to 2% probability of occurring), would cause supply interruption.

### **Future levels of gas security – conclusions**

- In both the high and low demand scenarios, we maintain a healthy capacity margin out to 2035.
- In both the high and low demand scenarios, there is some closing of capacity as the market adjusts to the changing market conditions, but this does not affect security of supply.
- Under low-demand scenarios, the GB system is highly resilient into the future.
- GB has enough import capacity and diverse import capacity to meet demand even under stressed conditions.
- Even under high demand scenarios the system is highly resilient with interruptions only occurring under highly unlikely, severe conditions.

# Headline conclusions

## How secure are we?

It is clear that we are secure in the short term, and that the gas system is well placed to respond to a wide range of demand and supply scenarios well into the future. While there are possibilities of exploiting new domestic resources, the reality is that an increasing proportion of gas consumption will need to be met through imports. Modelling shows that while we need to be vigilant to the world market, the GB gas market is able to withstand all but the most extreme shocks and still maintain supplies to protected (non-daily metered) customers.

### **We will be able to meet demand from available supply under all but the most extreme circumstances**

Looking to the future, increasing energy efficiency and improvements in technology mean that gas demand is not expected to rise significantly in the next 20 years. Even in the highest demand scenarios (such as that modelled in CEPA (2017)), gas demand rises only modestly from levels seen today.

There will be sufficient global production to meet global demand for gas and there will be sufficient import infrastructure in GB to meet peak demand.

### **The gas system has evolved and will continue to do so**

The GB gas system is undergoing a transition as domestic supplies decline. This has altered the dynamics of the market requiring new approaches to managing and exploiting demand especially around peaks.

Diversity rather than domestic supply has become the basis of our security of supply. This diversity is apparent not only in the different sources but the use of innovative and adaptable business models within those.

Government's role is to monitor the assumptions underlying this report to ensure they hold true in the evolving market, and take action if they do not, and to ensure that innovation is supported with barriers removed.

### **The gas system is resilient to all but the most extreme, unlikely shocks**

While the modelled shocks in CEPA (2017) are high impact, the likelihood of them occurring is extremely low. This is consistent with previous studies which concluded that the risk of a gas deficit emergency is very small.

However, this does not mean that we should be complacent. The studies undertaken so far on security of gas supplies provide insights into what becomes most important in a shock situation:

- Price is a strong driver of security, the market needs to operate effectively and we must avoid unnecessary constraints;
- This encourages flexibility in the market and allows flexible assets to respond appropriately and effectively;



- This can also be supported by effective demand response, especially through an effective demand side response mechanism; and
- LNG delivers a truly global gas market in which GB is well positioned; we should seek to further consolidate this position.

## Key components of security

### What does the new system look like?

As UKCS declines, current modelling suggests that pipeline supplies will remain stable and LNG supply can increase to ensure demand is met, providing a diverse range of supply sources. However, short term flexibility will be vital to maintain secure supplies, and this will require diverse sources of flexibility from storage, interconnectors and LNG.

### New domestic sources are beneficial for gas security

Additional domestic sources (such as shale) would be beneficial to GB. They could reduce reliance on imports, have the potential to bring economic benefits by rebalancing the economy, and would increase the diversity of supply available to the GB market.

### LNG has flexibility to balance supply and demand over the long term

By 2035 LNG has sufficient flexibility (in the long term, taking into account the expansion in global liquefaction capacity) to become the principle supply source. Norwegian supply will still be an important source of gas; and continental imports will provide a key source of seasonal flexibility, particularly in scenarios where there is no longer any long-range storage available in the market.

### LNG is flexible, and we must ensure its flexibility develops

The widespread availability of liquefaction capacity and the expectation that this will increase in the future mean that there will be a liquid market that is ready to respond in a shock.

In other words, in the first few days, there may be some scope for re-diversion of cargoes that are near to a market in distress, although if there is regional distress this may be limited. However, in a long-run shock, the LNG market will adjust and provide a steady stream of cargoes to the distressed market as long as is necessary.

The key limitation therefore is that “there will be a time delay before additional un-programmed LNG cargoes arrive at UK terminals following the onset of a stress situation”<sup>35</sup>. A key mitigating factor is diversity of supply, including existing LNG stocks in the distressed country which may be able to cover a gap.

### System diversity and flexibility continues to be important

The gas system requires flexibility to respond to changing supply and demand patterns. There is a role for a range of sources of flexibility, exploiting different aspects of the gas market. Pipeline gas from Norway and Interconnectors from Europe will remain important sources of gas and gas storage will continue to have an important role.

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<sup>35</sup> Poten & Partners (2017)



## **The role of price and markets**

A market that functions effectively and provides strong price signals ensures security in the short-term by attracting sources of gas when they are needed, and in the longer term by supporting gas infrastructure.

# Next steps

## Summary

The conclusions lead to a number of next steps. It reinforces some work that is currently underway (such as the widening of the gas quality (WOBBE) standards), provides an indicator of further work that should be done in the near term, and of some areas that should be kept under review in the future.

## Ensure a robust, well-functioning market

We need to ensure that the market has the right incentives to deliver the right infrastructure, keep that infrastructure operational and replace it where necessary. This requires strong incentives to secure supplies and allow redundant infrastructure to be replaced with more appropriate infrastructure. We must also ensure that our gas trading relationships across the world are maintained.

### Market functioning

Markets must be well developed and liquid enough to deliver gas when required during times of high demand. Trading platforms need to be robust and supported to perform during times of stress with a strong legal and regulatory underpinning. We must be confident that our regulatory framework ensures that physical gas is delivered even under times of stress.

Ofgem's Significant Code Review (SCR), and in particular allowing the cashout price to rise to the value of lost load, helps to ensure that the market is incentivised to provide security of supply.

### A continued close gas trading relationship with Europe

Efficient market trading of gas with Europe can assure good security of supply and efficient allocation of gas resources during times of system stress.

## Ensure the development of the LNG market and further development of GB as a mature gas hub

As LNG becomes a larger proportion of our supply, the flexibility of LNG as a supply source will become more crucial. This improves our gas security and provides an opportunity to develop GB's position as an import and trading hub for the entry of LNG to Europe.

### Development of LNG markets

The evidence to date suggests this market is developing in the GB's interests and we will be engaging closely with industry stakeholders to understand the role government can take to ensure it continues on this track. We should ensure the right incentives on shippers, support LNG flexibility, promote GB as an LNG hub for our own use and as an entry point to Europe (which will in turn support the interconnectors), and to remove barriers and reduce costs.

## **Reducing costs and increasing attractiveness of GB market**

Making it cheaper to land LNG will make GB a more attractive destination and reduce consumer bills. Current gas standards, set narrowly for the characteristics of North Sea gas, are being reviewed by the Health and Safety Executive (HSE) and could result in wider gas standards which would allow 90% (up from 10%) of LNG into GB<sup>36</sup> without processing. It is suggested the value could exceed £300m pa by 2020<sup>37</sup>.

## **Monitoring of LNG markets**

LNG is secure globally with significant amounts available from a range of exporting countries. However, the delay in reaching GB shores reduces its impact during the first few days of a shock. Government could support the development of the LNG market to reduce future turnaround times through international fora. However, it is important that we monitor developments in the LNG market and act on the risks it presents.

## **Exploit opportunities to reduce reliance on imported gas**

Although it is likely that imports will become an increasing proportion of supply, it is beneficial to seek economic opportunities to reduce the need to import gas through exploiting indigenous resources or reducing demand.

## **Continue to explore indigenous resources**

While our security of supply does not depend on new indigenous supplies, if they can be exploited economically, shale gas and biomethane would provide valuable additional supplies, reducing our reliance on imports and contributing to economic growth.

## **Further action on energy efficiency**

Energy security does not depend on further improvements in energy efficiency. However, as well as delivering their primary objective, improvements in this space would reduce exposure to shocks through lower demand.

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<sup>36</sup> SGN (October 2016) Opening Up The Gas Market. Available at: [www.sgn.co.uk/uploadedFiles/Marketing/Pages/Publications/Docs-Innovation-Oban/SGN\\_Gas\\_Market\\_Report\\_Full-report-2016-170116.pdf](http://www.sgn.co.uk/uploadedFiles/Marketing/Pages/Publications/Docs-Innovation-Oban/SGN_Gas_Market_Report_Full-report-2016-170116.pdf)

<sup>37</sup> SGN (October 2016) Opening Up The Gas Market. Available at: [www.sgn.co.uk/uploadedFiles/Marketing/Pages/Publications/Docs-Innovation-Oban/SGN\\_Gas\\_Market\\_Report\\_Full-report-2016-170116.pdf](http://www.sgn.co.uk/uploadedFiles/Marketing/Pages/Publications/Docs-Innovation-Oban/SGN_Gas_Market_Report_Full-report-2016-170116.pdf)

## Bibliography

Cambridge Economic Policy Associates Ltd (CEPA), (2017), *A Review of Gas Security of Supply within Great Britain's Gas Market – from the Present to 2035*.

Department for Business, Energy & Industrial Strategy (BEIS), (2016), *UK Risk Assessment on Security of Gas Supply: Report completed for EU Regulation 994/2010*. Available at: [www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/560125/UK\\_Risk\\_Assessment\\_Gas\\_BEIS\\_template\\_Final\\_4\\_.pdf](http://www.gov.uk/government/uploads/system/uploads/attachment_data/file/560125/UK_Risk_Assessment_Gas_BEIS_template_Final_4_.pdf)

Department for Business, Energy & Industrial Strategy (BEIS), (2017), *Energy Trends*. Available at: [www.gov.uk/government/statistics/gas-section-4-energy-trends](http://www.gov.uk/government/statistics/gas-section-4-energy-trends)

Ofgem, (2012), *Gas Security of Supply Report*. Available at: <https://www.ofgem.gov.uk/ofgem-publications/40204/gas-sos-report-pdf>

Ofgem, (2014), *Gas Significant Code Review Impact Assessment for Final Policy Decision*. Available at: [www.ofgem.gov.uk/ofgem-publications/85999/1402gasscria-pdf](http://www.ofgem.gov.uk/ofgem-publications/85999/1402gasscria-pdf)

National Grid, (2016a), *Future Energy Scenarios*. Available at: [www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/FES/Documents-archive/](http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/FES/Documents-archive/)

National Grid, (2016b), *Winter Outlook Report 2016/17*. Available at: [www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/FES/Winter-Outlook/](http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/FES/Winter-Outlook/)

National Grid, (2017a), *Future Energy Scenarios*. Available at: <http://fes.nationalgrid.com/fes-document/>

National Grid (2017b), *Winter Review and Consultation, 2017*. Available at: [www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/FES/Winter-Outlook/](http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/FES/Winter-Outlook/)

Poten & Partners, (2017), *LNG Market Outlook Responsiveness of LNG*.

Pöyry, (2014), *Gas SCR – Cost-Benefit Analysis for a Demand-Side Response Mechanism*. Available at: [www.ofgem.gov.uk/ofgem-publications/85990/poyrygasscrdsrdbafinalreportv20-pdf](http://www.ofgem.gov.uk/ofgem-publications/85990/poyrygasscrdsrdbafinalreportv20-pdf)

Redpoint Energy, (2011), *Gas security of supply Significant Code Review: Economic modelling*. Available at: [www.ofgem.gov.uk/ofgem-publications/40959/redpoint-energy-gas-security-supply-significant-code-review-economic-modelling.pdf](http://www.ofgem.gov.uk/ofgem-publications/40959/redpoint-energy-gas-security-supply-significant-code-review-economic-modelling.pdf)

Redpoint Energy, (2013), *The impact of gas market interventions on energy security*. Available at: [www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/236757/DECC\\_FI\\_Final\\_report\\_09072013.pdf](http://www.gov.uk/government/uploads/system/uploads/attachment_data/file/236757/DECC_FI_Final_report_09072013.pdf)



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