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UK Energy Research Centre

Future UK Gas Security: A Position Paper

Professor Michael Bradshaw

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T **+44 (0)24 7652 4100**

E **warwickmba@wbs.ac.uk**

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Executive Summary

Natural gas plays a critical role in the UK's energy system, providing twice as much energy as electricity, thus the secure and affordable supply of natural gas is an essential element of UK energy security and a key objective of Government policy. The starting proposition for this report is that Brexit is coming at a time when there are already major challenges to the UK's future gas security.

This report deploys two aspects of previous UKERC research on UK gas security: first, a supply chain approach to assessing UK gas security; and second, a whole systems approach that places current and future gas demand within the context of the decarbonisation of the UK's energy system. This is because there are key uncertainties in the wider system that have important implications for future gas demand. It is in this context that the Brexit decision has created additional uncertainty at a time when the UK energy sector needs to make critical investment decisions. In the current situation we can conceive of a 'Brexit Interregnum' whereby important decisions and policies are delayed because of the demands of the Brexit negotiations.

This report has three objectives:

- To identify the key challenges facing the UK's natural gas market;
- To understand the role that EU policies and institutions currently play in the operations of the UK's natural gas market; and,
- To identify the potential impact of Brexit and the key issues that should be addressed in a post-Brexit 'UK Gas Security Strategy.'

Energy security is one of those terms that has spawned a substantial academic and policy literature seeking to define and measure it. This report uses a definition from former DECC's (2012) *Energy Security Strategy* that: "energy security is about ensuring that we have access to the energy services (physical security) at prices that avoid excessive volatility (price security). It is also assumed that the future role of gas must be compliant with the Climate Change Act (2008) and its associated Carbon Budgets. The report deploys a supply chain approach to analyse three dimensions of future gas security: upstream security of supply, midstream infrastructures, and downstream security of demand.

Upstream Security of Supply

In a relatively short period of time the UK has gone from being self-sufficient to being a significant importer of natural gas. Today the UK imports about half of the natural gas that it consumes, but with falling domestic production the level of import dependence is set to increase during the 2020s. The UK benefits from a diversity of sources of supply and has more than sufficient physical infrastructure to import the gas that it needs; however, growing import dependence does expose the UK to the volatility of the wider European gas market and the global market for Liquefied Natural Gas (LNG). In the context of Brexit, this report reached four conclusions. First, that in today's liberalised market there is a limit to what the UK government is willing and able to do to ensure physical security of supply. Second, at present, the majority of the UK's gas imports come from with the EU's Internal Energy Market (IEM), which is supplied by both indigenous and non-EU sources. Third, if, in the future, the UK were outside the IEM it would not benefit from energy solidarity measures or the EU's energy diplomacy; equally it would be unable to influence the EU's energy policies. However, because of its integration into the northwest European gas market, its gas security would be significantly affected by the success or otherwise of the EU's policies and actions. Finally, in the face of falling domestic production, it is likely that the UK will become more dependant on imported LNG, which will expose it to global price competition and volatility.

Midstream Security of Supply

The midstream includes the hard infrastructure: the gas pipeline system (onshore and offshore), the three LNG terminals, the various gas storage facilities and the three interconnectors. It also includes the soft infrastructure of the National Balancing Point (NBP) that is the virtual trading location for the sale, purchase and exchange of natural gas in the UK, and the gas governance regime that includes the UK regulator (Ofgem) and the EU Organisations (ACER and ENTSOG) that regulate the UK's participation in the IEM. The midstream is critical to ensuring gas security, but even without Brexit it faces significant challenges that result from rising import dependence, the consequences of the low carbon energy transition and the aging of assets. The three combine to create a situation where new investment is required to increase the flexibility of the system at a time when there is growing uncertainty over the future role of gas in the UK's energy mix. Brexit introduces a new set of concerns and implications. It is widely accepted that the UK's membership of the EU's IEM has enhanced energy security and benefitted consumers. This report identifies a number of midstream issues that need to considered in relation to future gas security: the need for a more holistic assessment that considers the integrity of both the onshore and offshore gas pipeline systems, the implications of greater reliance on LNG for gas flows, and the adequacy of gas storage capacity. There are also a set of issues that relate specifically to the Brexit negotiations: the future status of the interconnectors, the status of the NBP relative to other European hubs, future cooperation on gas security with the Republic of Ireland, and the future governance of the UK's gas system and its relationship with the EU's IEM.

Downstream Security of Demand

The majority of studies of energy security have focused on upstream security of supply, but more recently, as the low carbon transition has gathered momentum, there has been increasing interest in security of future demand as a challenge to the integrity of the gas supply chain. At present, gas demand is split three ways between power generation, domestic consumers (for heating and cooking) and industry (as a source of heat and a raw material). Since the 1990s, the switch from coal to natural gas has played a major role in delivering a large part of the UK's fall in Carbon Dioxide emissions. So much so, that the UK has limited remaining capacity to use gas to decarbonise the power generation mix. At the same time, around 85% of UK households use natural gas for domestic heating. But, if the UK is to meet its ambitious decarbonisation targets it must find a low carbon source of heat, which will have a significant impact on future gas demand. Both industry and academic research shows that without a means of mitigating the carbon dioxide emissions from natural gas combustion there must be a dramatic decline is gas usage by 2050. The deployment of carbon capture and storage (CCS) and carbon capture usage and storage (CCUS) is seen as a key technology for 'decarbonising' natural gas that also creates the possibility of using natural gas (methane) as a feedstock for a future hydrogen economy that can help to decarbonise domestic heat and the transport sector. At present, the owners of the UK's gas pipeline infrastructure are promoting such a narrative to retain a role for their services. In this context, the key upstream issues to consider in relation to future gas security are: the impact of climate change policy on future gas demand; the prospects for the commercial deployment CCS/CCUS; and, the fact that uncertainty over the future role of gas acts as a disincentive to investment in the current infrastructure. Brexit complicates matters due to uncertainty over any future realignment of climate change policy and the carbon trading system. More generally, the 'Brexit Interregnum' stands in the way of a 'gas by design' approach that lays out a clear role for the industry in the low carbon transition, rather than the current 'gas by default' approach that assumes that the natural gas industry can fill the gap when there are policy failures elsewhere.

Brexit and Future UK Gas Security

Today natural gas is the most important source of energy for the UK, but future gas security could be challenged by the medium-term prospect of increasing import dependence, due to declining domestic production, and the longer-term prospect of falling demand due to climate change policy. This creates a degree of uncertainty that makes it difficult to justify investments in the supply chain to maintain existing capacity, let alone deliver new sources of flexibility. Brexit only serves to exaggerate the level of uncertainty. Gas will continue to flow post-Brexit, but consumers may have to pay more for it to guarantee security. Longer term, it is not the outcome of Brexit that poses a threat to UK gas security, but the failure of the Government to provide a clear roadmap for the role of gas in the low carbon transition.

1. Introduction

Natural gas plays a critical role in the UK's energy system, providing twice as much energy as electricity, thus the secure and affordable supply of natural gas is an essential element of UK energy security and a key objective of government policy. In 2017 natural gas accounted for almost 40% of total inland energy consumption (on a primary fuel input basis), compared to 24.1% back in 1990 (BEIS 2018, 14). In 2017, natural gas was used to generate 49.7% of the electricity consumed in the UK. Total gas demand is split three ways between: electricity generation (33.4%), domestic use (34.9%) and the energy industry, other industry and services (31.7%).

The starting proposition for this paper is that Brexit is coming at a time when there are already major challenges to the UK's future gas security. Furthermore, the EU is currently seeking to achieve greater integration through the pursuit of its Energy Union agenda that includes the creation of a single European Internal Energy Market (IEM) for electricity and gas and new measures to promote gas security. Thus, even before Brexit, there were issues to address within the UK's gas market and new policies emanating from Brussels that further complicated the situation. This paper builds on previous UKERC-funded research on the 'UK's Global Gas Challenge' (Bradshaw et al. 2014) and the 'Future Role of Gas in the UK' (McGlade et al. 2016). Together, these two papers provide a substantive research base that has highlighted the challenges for UK gas security in the context of increasing import dependence and the complexities facing the future role of gas in the UK's energy mix following the Climate Change Act (2008) and its associated carbon budgets.

This paper deploys two aspects of previous UKERC research on UK gas security: first, a supply chain approach to assessing UK gas security; and second, a whole systems approach that places current and future natural gas demand within the wider context of the decarbonisation of the UK's energy system.[1] This is because there are key uncertainties in the wider system that have important implications for future gas demand. For example, the planned phase out of unabated coal power generation by 2025; the progress of the construction of a new fleet of nuclear power stations; the rate of growth of renewable electricity generation and advances in storage technologies, the success of policies to decarbonise domestic heat, and the determination to address urban air pollution and reduce carbon emissions in the transport sector.

All of this would be challenging enough, especially when one considers that the natural gas industry is a long-term business that makes large investments that deliver a return over decades rather than years. The Brexit decision has created additional uncertainty at a time when the UK energy sector needs to make critical investment decisions.[2] In the current situation, we can conceive of a 'Brexit Interregnum' whereby important decisions and policies are delayed because of the demands of the Brexit negotiations (Bradshaw 2017). Agreement on a transition period from the 29th March 2019 to the 31st December 2020 may result in an 'orderly withdrawal', but it also extends the period before the UK can implement independent energy security and climate policies. This paper pulls together insights from the presentations and discussions at a series of events (three Gas Security Forums and a daylong Conference) funded by the University of Warwick's ESRC Impact Acceleration Account[3] to achieve three objectives in the hope that this will inform the Brexit negotiations and the formulation of a post-Brexit UK Energy and Climate

1 The terms UK and GB are used interchangeably in this this paper, but strictly speaking the government and the industry talk about the GB energy system (England, Wales and Scotland) as Northern Ireland is considered part of a separate all-Ireland system.

2 Energy industry leaders mentioned the issue of uncertainty on numerous occasions when giving evidence to a House of Lords Select Committee on the European Union, Energy and Environment Sub-Committee hearing on Brexit: energy security on Wednesday 6 September 2017. A transcript and video can be found at: https://www.parliament.uk/business/committees/committees-a-z/lords-select/eu-energy-environment-subcommittee/inquiries/parliament-2017/brexit-energy-security/

3 The ESRC Impact Acceleration Account (IAA) supports a range of activities to maximise the potential for impact from social sciences research. This can include engagement activities to facilitate impact from established research, as well as meetings and workshops to develop new research ideas and partnerships with non-academic collaborators.

Change Strategy:

- To identify the key challenges facing the UK's natural gas market;
- To understand the role that EU policies and institutions currently play in the operation of the UK's natural gas market; and,
- To identify the potential impact of Brexit and the key issues that should be addressed in a post-Brexit 'UK Gas Security Strategy.'

1.1 A Supply Chain Approach to UK Gas Security

The academic and policy literature on energy security has been overly focused on upstream matters of physical security of supply, in other words securing sufficient gas to satisfy domestic demand. The supply chain approach was adopted in our previous work to provide a more holistic assessment of the dimensions of gas security and to provide links to a whole systems assessment of the role of natural gas. Table 1 summarises the findings of our research back in 2014. The aim here is to update our supply chain analysis and consider the potential impact of Brexit on future UK gas security.

The structure of this paper is shaped by this supply chain approach: starting with upstream security of supply, moving on to the midstream and the role of critical infrastructure, governance and the UK's gas price—the National Balancing Point (NBP)—and ending with a consideration of security of demand and the current and future role of natural gas in the UK's energy system in the context of decarbonisation.

Table 1. A Supply Chain Approach to UK Gas Security

Geopolitics		Dimensions	Issues
Upstream	Security of Supply	• Resource Base • Technology • Investment	• UK Continental Shelf (UKCS) • Norwegian Continental Shelf (NCS) • Europe – Russia/North Africa • LNG Supply • Unconventional Gas
Midstream	Security of Transport (Transit)	• Processing • Transportation • Storage	• Liquefield Natural Gas (LNG) Terminals • Interconnectors • National Transmission System (NTS) • Storage • National Balancing Point (NBP)
Downstream	Security of Demand	• Power Generation • Industrial Use • Domestic Use	• Role of gas in UK energy strategy • Intermittency and Capacity Markets • UK Carbon Floor Price & EU Emission Trading System (EU ETS) • Carbon Capture & Storage (CCS)

Source: Bradshaw et al. (2014, 33).

1.2 Defining Energy Security

Energy security is one of those terms that has spawned a substantial academic and policy literature seeking to define and measure it. The International Energy Agency (IEA 2017) currently defines it as: "the uninterrupted availability of energy sources at an affordable price." It then goes on to state that:

"Energy security has many dimensions: long-term energy security mainly deals with timely investments to supply energy in line with economic developments and sustainable environmental needs. Short-term energy security focuses on the ability of the energy system to react promptly to sudden changes within the supply-demand balance. Lack of energy security is thus linked to the negative economic and social impacts of either physical unavailability of energy, or prices that are not competitive or are overly volatile."

1.3 The EU's Energy Security Strategy

In response to the Russia-Ukraine gas disputes and the prospect of increasing energy import dependence, in 2014 the European Commission (2014) published its *Energy Security Strategy*. The Strategy included a number of short-term measures to address gas security; as well as five actions to address long-term security of supply disruptions:

- Increasing energy efficiency and reaching the proposed 2030 energy and climate goals;
- Increasing energy production in the EU and diversifying supplier countries and routes;
- Completing the internal energy market (for electricity and gas) and building missing infrastructure links to respond quickly to supply disruptions and redirect energy across the EU to where it is needed;
- Speaking with one voice on external policy; and,
- Strengthening emergency and solidarity mechanisms and protecting critical infrastructure.

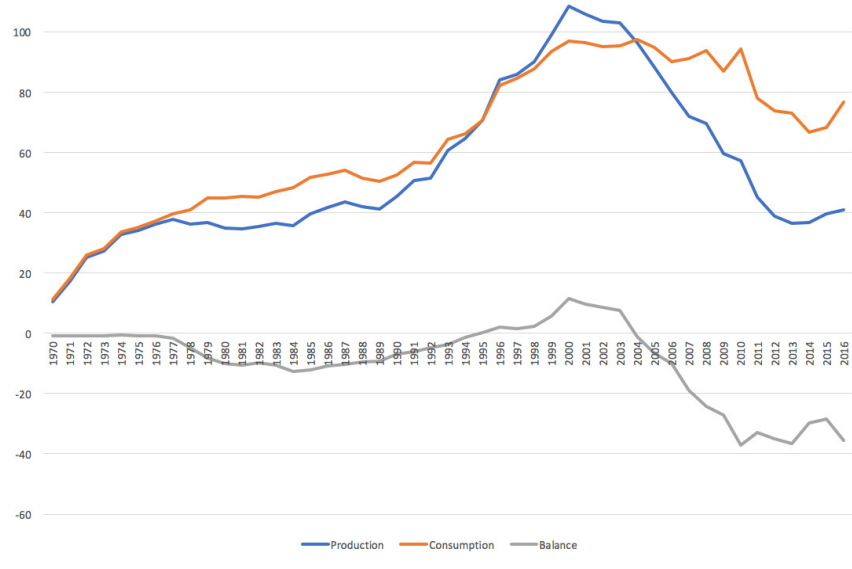
None of these actions challenge the UK's interests and, because of its geography and prudent investment in infrastructure, it has easily met the EU's security of supply tests (Forum discussions did question the effectiveness of the current N-1 test).[4] The resilience of the UK's system has wider implications for EU gas security as it serves as a western gateway for Norwegian gas and LNG to enter the European market and Ireland is dependent on supplies through the GB network. However, the construction of additional LNG import facilities and a new pipeline from Norway to Northwest Europe are reducing the gateway role of the GB network. The NBP also serves a key role as a benchmark price that combines the influence of domestic and Norwegian pipeline supply and the global LNG in a market where the price is discovered by gas-to-gas competition.

This means that should the UK find itself outside of the Internal Energy Market (IEM), it would not only present a challenge to the UK, but also a loss of resilience for the EU and a major challenge for Ireland. The potential issues are made clear in the European Commission's (2017a) new security of gas supply regulation that introduces the 'solidarity principle', whereby: "in the event of a severe gas crisis, neighbouring member states will help out to ensure gas supply to households and essential social services" remain. The EU's measures also include closer regional cooperation and greater transparency (in relation to long-term contracts). This means that for the EU, as much as the UK, there is good reason to reach an accommodation whereby the UK remains fully integrated with the IEM (this is also true for the electricity market).

1.4 Defining UK Energy Security

Our aim here is to analyse the gas security situation in the UK at present and up until the mid-2020s. Recently BEIS (2017b), in its *Clean Growth Strategy* suggested that: "energy security is about ensuring secure, reliable, uninterrupted supplies of consumers, and having a system that can effectively and efficiently respond and adapt to changes and shocks. It is made of three characteristics: flexibility, adequacy and resilience." Recent research by UKERC (Watson et al. 2018) has also highlighted the complex relationship between energy security and the low carbon transition. The conclusions of this report will return to these issues, but for the purposes of this analysis, the former DECC's (2012) more focused distinction between *physical security of supply* and *price security of supply* is important. Thus, according to the former DECC: "energy security is about ensuring that we have access to the energy services we need (physical security) at prices that avoid excessive volatility (price security)." The emphasis on energy services is important because consumers are most concerned about the cost of their heating and cooling, lighting and transportation etc., rather than specific energy resources. It is also the case that most consumers have little knowledge of the complex systems that deliver their energy services to the point of consumption. In the UK, at least, consumers assume 24/7 availability of natural gas for cooking and heating, with little concern for where it comes from, but considerable sensitivity about how much they must pay for it. As was made clear this winter, any threat to physical gas security results in apocryphal media coverage about "running out of gas." But, from a political and policy perspective, price security is the paramount concern and already UK consumers are having to pay more for their natural gas imports than they might have done due to a fall in the value of Sterling after the Brexit referendum.

Figure 1: The UK's Gas Balance: 1970-2016 (Source of data: BP 2017)



4 The N-1 test assesses the ability of the GB gas system to withstand the loss of its largest piece of infrastructure, both LNG terminals at Milford Haven and the associated southwest Wales gas pipeline.

2. Upstream Security of Supply

In a relatively short period of time the UK has gone from being more than self-sufficient in natural gas to a net importer and now imports around half of the natural gas that it consumes.

However, domestic offshore production is projected to continue to decline and, unless there is substantial new onshore production, the level of import dependence will increase significantly by the end of the 2020s. This in itself is not necessarily a problem, as we shall see, the UK currently has a relatively diversified supply situation, although the increasing cost of imports does impact on the country's balance-of-payments. According to the Office of National Statistics, in 2016 the net cost of the UK's gas imports was over £5 billion.[5]

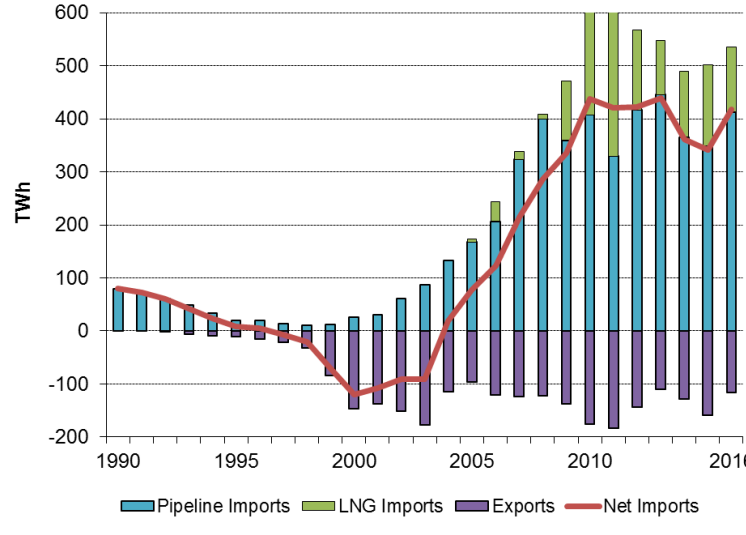
2.1 UK Gas Security of Supply

The first UK Gas Security Forum was primarily concerned with the issue of physical security of supply, from where and how the UK secures the physical supplies of natural gas needed to satisfy domestic demand and export obligations. The issue of price security was discussed in the second meeting in relation to the future of the UK gas price and is the subject of a later section of this report. Figure 1 shows a familiar story, following the discovery of oil and gas on the UK continental shelf (UKCS), the country embarked on a 'dash for gas', first in the domestic and industrial sectors and then, post 1990, in power generation. Unfortunately, North Sea production peaked in 2000, and while gas demand plateaued and then declined the inevitable result has been an increase in the level of import dependency. In recent years, there has been increased volatility as gas demand in power generation faltered in the face of cheaper coal, but recently there has been a modest rebound in production on the UKCS (2016 was up 3% on 2015 levels). According to BEIS (2017c), in 2016 domestic natural gas production was 63% lower than the record level of 2000. That year, gas demand was down 23% compared to 2000, and the level of gas import dependence was 47%. To put this in perspective, Eurostat data for 2015, showed that the UK had the fifth lowest level of import dependence (41.1 %) and that the EU28's overall gas import dependence was 69.1% (European Commission 2017b, 72). Fortunately, in anticipation of increased import dependency, the gas industry built a substantial import infrastructure—interconnectors and LNG import terminals—such that today there are no physical capacity constraints on meeting the UK's gas import needs, although there may be constraints on the ability of the National Transmission System (NTS) to move gas around GB in extreme situations (more on this later).

2.2 Increasing Import Dependence

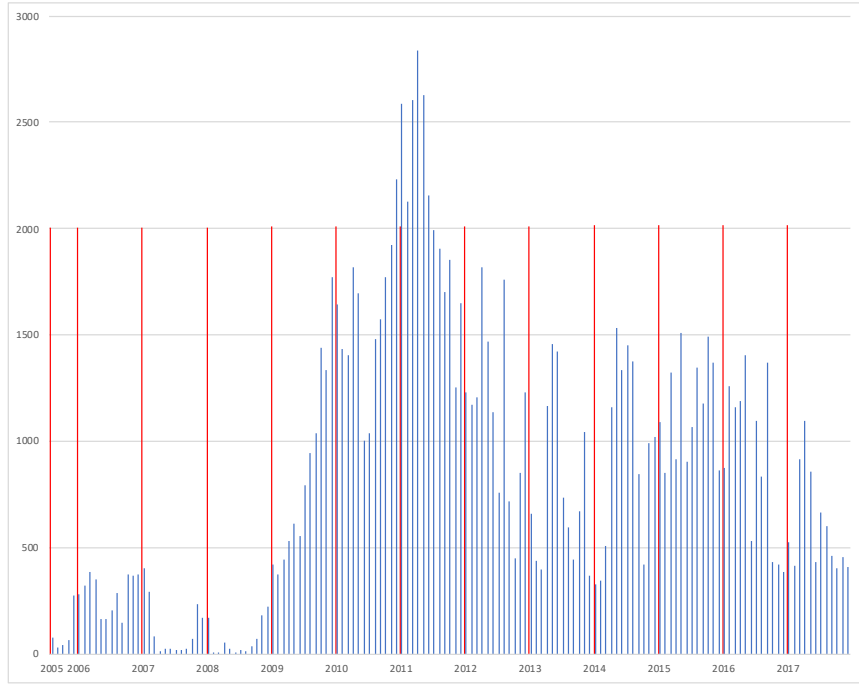
As Figure 2 illustrates, since the turn of the century the UK has significantly expanded the volume of natural gas that it imports. Today there are three sources of natural gas imports: pipeline gas from Norway, pipeline gas imports via two interconnectors originating in Belgium (IUK) and the Netherlands (BBL) and Liquefied Natural Gas (LNG) imports via three terminals, two at Milford Haven (South Hook and Dragon) and one at the Isle of Grain. A fourth, much smaller, floating storage regasification unit (FSRU) facility on Teesside was decommissioned in 2015, but the Swiss commodities trading company Trafigura is reported to be investing $ 30 million to bring it back into service by mid-2018. The three operational terminals have a combined import capacity of 36.4 million tonnes of LNG per annum (49.2 bcma), which is equivalent to almost 65% of total gas consumption in the UK.

Figure 2: UK Trade in Natural Gas: 1990-2016 (Source: BEIS 2017a, 24)



5 https://www.ons.gov.uk/businessindustryandtrade/internationaltrade/timeseries/p4rk/mq10

Figure 3: UK LNG Imports 2005 to 2017, million cubic metres (monthly) (Source of data: BEIS 2018)



Provisional data for 2017 (BEIS 2018) show that Norway accounted for 75.1% of UK gas imports, pipelines from Belgium and the Netherlands, 5.5% and 4.0% respectively, with the remaining 15.4% arriving as LNG. Norway's gas exports to Europe were at record levels in 2017 and LNG deliveries to the UK fell by a third, so reliance on Norway increased by 10% over 2016. In 2017, 84.6% of the UK's gas imports originated from states that are members of the EU's IEM, as Norway is a member through the European Economic Area (EEA) Agreement (and EFTA). Imports of Norwegian gas are currently hard-wired into the UK's gas supply system through pipelines that flow directly to the UK. This raises questions about the future legal status of Norway-UK gas trade as Norway is not a member of the EU's Customs Union. However, Norway's former energy minister, Tord Lien, recently stated that: "There is no reason to believe that market access for Norwegian gas exports to Britain will be effected by Brexit" (reported in Bowden 2017, 5). A recent analysis by Hall (2018) notes that Norway's net gas production reached a record high of 122 bcm in 2017. Hall's analysis examines the Norwegian Petroleum Directorate's revised projections to show output between 121 and 123 bcm a year between 2018 and 2022, declining to 112 bcm in 2025 and then stabilising between 90-92 bcm a year in 2030-35. Hall concludes that these forecasts are plausible and that the risk of not achieving them to about 2027 is low. Beyond then new discoveries are needed to maintain production. As UKCS production continues to decline, the UK will become ever-more reliant on production from the NCS both as the major source of pipeline imports, but also as a source of some flexibility. But what would happen if the UK's current access to continental gas markets were made complex and costlier by Brexit? Norway's export capacity to continental Europe will be expanded in 2022 by the Baltic pipeline that will link to Denmark and Poland and this could also reduce the use of the UK as a transit route for Norwegian gas in the EU.

The interconnectors link the UK market to the northwest European gas market; while the LNG terminals link the UK to an increasingly globalised LNG market (both are the subject of more discussion in the next section on the midstream). Figure 3 above shows the monthly volumes of LNG imports into the UK since 2005. The impact of Fukushima on the global LNG market is apparent to see. After mid-2011, increased LNG demand in Japan, in a tight LNG market, resulted in a reorientation of LNG flows away from Europe to Asia. A situation enabled by the fact that the UK does not rely on significant levels of firm long-term LNG contracts and LNG suppliers must accept the UK gas price, rather than the oil indexed prices that are prevalent on Asian markets. This appears to have happened again in 2017 when higher prices in Asia (largely as a result of surging Chinese demand) meant reduced cargoes for Europe.

The behaviour of Qatar is critical as it is the major supplier to the UK and has invested in the South Hook terminal. It uses its position as a swing producer between the Atlantic and Pacific basins to ensure that it received an 'Asian Premium' for the oil-indexed LNG it supplied to Asian customers. This meant that it continued to supply some LNG to European markets to sustain prices in Asia. Figure 3 also shows that in recent years LNG deliveries have tended to be counter-cyclical, arriving in the early summer. As the LNG market is expected to be significantly over-supplied for some years to come—due mainly to new production coming on-stream in Australia, Russia and the United States—there is the possibility of increased LNG supplies coming to the UK and the EU more generally. In 2017 there was little evidence of this as China significantly increased its LNG imports and new buyers appeared on the market. However, there is still significant new LNG supply to come, but it is also expected that Europe's major pipeline suppliers—Norway

and Russia—will seek to defend their market share. Whatever the eventual outcome, the direction of travel suggests that the UK gas market, providing the price is right, should be able to secure the LNG imports that it needs into the mid 2020s; however, beyond that there may be a tightening of the market necessitating higher prices to attract the necessary deliveries.

2.3 The Role of Russian Gas

The question "how much Russian gas does the UK import?" has recently taken on new significance given the nerve agent attack in Salisbury and the subsequent significant deterioration of UK-Russia relations. The honest answer is that we don't know, as until recently the only way that Russian gas could physically enter the UK was via the two interconnectors and that is recorded as coming from Belgium or the Netherlands (more on this below). However, it is likely that those imports are back filled by deliveries of Russian pipeline gas to northwest Europe and we have previously argued that the construction of the Nordstream pipeline has improved the UK's gas security by increasing the liquidity of the northwest European gas market (Bradshaw et al. 2014). In response to the issue of Russian gas being raised in Prime Minister's Question Time, BEIS said that it estimates that less than 1% of UK gas comes from Russia and that the UK is in no way reliant on it.[6] Analysis by Sharples (2018) suggests that the situation is more complicated, in large part due to the trading activities of Gazprom's trading affiliates (Gazprom Marketing and Trading is currently based in London) that buy and sell gas for the European market, some of which comes to the UK. Furthermore, since the start up on 5th December 2017 of Novatek's Yamal LNG projects, deliveries of Russian LNG have arrived in Europe, with some coming to the UK. According to Sharples (2018, 22), three deliveries of Yamal LNG have arrived in the UK in the first quarter of 2018, but cargoes also arrived from Norway, Qatar and the US. However, Yamal exports will come under existing long-term contracts from April 2018 onwards, but it will also remain active in the spot market and it is unclear whether any of the project partners (which includes France's Total and China's CNCP) or other off-takes (which included Gazprom Marketing and Trading, Spain's Gas Natural, Shell and France's Engie) will deliver LNG to the UK. The fact that one shipment to Grain LNG was subsequently re-loaded and sent to the eastern US demonstrates that these LNG flows are part of an increasingly integrated global market and whether or not spot cargoes arrive in the UK is dependent upon a host of commercial factors (Bridge and Bradshaw 2017).

The bottom line is that at present the UK is not reliant on imports of natural gas from Russia; however, in recent years—despite the difficult geopolitical situation—Russia has actually increased the volume of pipeline gas it sells to Europe. European Commission (2018) data show that in 2017 Russia accounted for 43% of extra-EU imports (Norway was 34%) at around 162 bcm. This means that although the UK is not directly dependent on Russian gas supplies the significance of Russian imports to wider EU gas security means that any disruption of Russian supplies to the EU market would have a knock on effect on prices in the the UK and in the future may impact the ability of the UK to attract gas from EU markets. Put another way, in a post-Brexit world the UK will have to rely on the EU's energy diplomacy to maintain good relations with Russia and any disruption might impact on the UK's trade with the EU.

2.4 Dutch Gas Production

The plight of Dutch gas production at the Groningen gas field is yet another complication. Increased seismic activity since 2008 has resulted in a cap being placed on production since 2014, and as a consequence its ability to provide flexible supply has been significantly eroded, which is already impacting on gas markets in northwest Europe (Honoré 2017). On 1st February 2018 the Dutch regulator recommended that production be cut to 12 bcm over the next 4 years, down from 21.6 bcm, which is 60% lower than the peak in 2014. Most recently, on 29th March, the Dutch Government announced that production will be completely terminated by 2030. The full ramifications of the situation—for the shareholders in the field, their customers and the Dutch Government—remain uncertain as it has become a major political issue in the Netherlands. It is also complicated by the fact that Groningen produces low calorific gas (L-Gas) for the domestic market and neighbouring countries (this gas is not supplied to the UK). Thus, the Dutch gas industry has the challenge of producing L-Gas to satisfy existing customers and also to meet future contractual obligations. This can be converted to H-Gas (high calorific gas) or H-Gas can be processed to become L-Gas, but neither is cost free and the latter faces capacity constraints. The northwest European market faces a loss of 10 bcm of domestic supply. The immediate response of the Dutch Government has been to plan to reduce the country's reliance on natural gas. In this context, it is noteworthy that the BBL interconnector has recently announced that it will invest in physical reverse flow so that from 2019 it will be able to export gas from the UK to the Netherlands. This reflects increasing summer demand for export capacity following the closure of Rough but may also reflect the consequences of falling production at Groningen.

2.5 Prospects for the Future

The UKCS has been hard hit by the downturn in oil prices and although significant progress has been made in reducing costs and improving efficiency, it is now a mature basin

6 Salisbury attack: How much of the UK's gas comes from Russia? http://www.bbc.co.uk/news/business-43421431

in the early throes of decommissioning. The latest projections by the UK's Oil and Gas Authority (2017) chart a continuing decline in production. Their short-term median projection to 2022 suggests total production of 29.7 bcm, compared to 41 bcm in 2016, as reported by BP in their 2017 statistical review. Thereafter, they assume a decline of 5% a year. Their calculations then use BEIS' *Updated Energy and Emissions Projections: 2016* to arrive at projections for future gas import dependence. On that basis they project that by 2025 import dependence will have risen to 64%, reaching 70% by 2030 and 75% by 2035. Clearly, the future of UKCS production is an important unknown in terms of future UK gas security. In their *Economic Report 2017,* Oil & Gas UK (2017) noted that the most immediate impact of Brexit—the fall in Sterling—meant that 'UK exports became more competitive overnight and more attractive to foreign buyers.' Their analysis of the longer-term highlights the fact that natural resources, such as oil and gas, are typically subject to low or zero tariffs, but future trade in goods and services used by the UK oil and gas industry might be subject to tariffs, increasing the cost of trade. Oil & Gas UK (2017, 32) have recommended that the UK Government prioritises the following during Brexit negotiations: maintain 'frictionless' access to markets and labour; maintain a strong voice in Europe [for the oil and gas industry]; and, protect energy trading and the internal energy market. Anything that adds cost and uncertainty for investors on the UKCS is bound to result in greater gas security concerns for the UK in the 2020s.

The only other possibility in terms of future domestic gas production is an increase in the currently very modest levels of onshore production through the exploitation of shale gas resources, alongside the development of Biomethane and bioSNG (Synthetic Natural Gas). While Biomethane is currently growing in importance at a local scale, it is unlikely to have a significant impact on UK gas security in the short-term. The future role of shale gas is a controversial issue, to say the least, and the industry is still only in the very early stages of exploration, with Cuadrilla currently drilling the first significant well at its Preston New Road site in Lancashire. On May 17th 2018, the Government restated its commitment to supporting shale gas exploration in a Written Statement to both houses.[7] In the statement Greg Clarke, Secretary of State for Business, Energy and Industrial Strategy, affirmed that "Shale gas development is of national importance" and stated that: "…we believe that it is right to utilise our domestic gas resources to maximum extent and exploring further the potential of onshore gas production from shale rock formations in the UK, where it is economically efficient, and where environmental impacts are robustly regulated." The statement then went on to suggest various ways in which the regulatory regime and planning process might be changed to accelerate the exploration phase. However, given that we are still at the very early stages of exploration, it would not be prudent to count on significant domestic shale gas production in the near term, though it remains a possibility in the medium term. The industry's trade association, UK Onshore Oil and Gas, has suggested that a domestic shale gas industry operating approximately 400 well pads between 2020 and 2035 could reduce the UK's gas import dependency by 50% (UKOOG 2017). Nonetheless, all the current signs point in the direction of increased gas import dependency in the 2020s, but just how much gas the UK will need to import in the future will be determined by the level of future gas demand, which is the subject of the final section of this report.

2.6 Exports and Interconnection

A final complication is that the UK is also a gas exporter. The UK exports principally to Belgium and Ireland, there are also modest deliveries of gas from UK fields directly to the Netherlands. The trade with Belgium relates to the IUK interconnector that is physically reversible and enables gas traders to sell to European markets, as well as import European gas. At present the BBL interconnector only enables physical imports, but, as noted above, that is set to change. The presence of the interconnectors enables the UK to act as a gas bridge to Europe by bringing in Norwegian pipeline gas and LNG, which is then exported to the continental European market. In doing so, the UK contributes to EU gas security. Exports to Ireland are a different matter as, until recently, Ireland was almost entirely dependent on the UK for its gas. In 2014, the UK supplied 96% of the gas used in Ireland (Sustainable Energy Authority Ireland 2016). However, the development of the Corrib offshore gas field has reduced the level of imports, which fell by a third between 2015 and 2016. Production from Corrib is expected to peak at 3.5 bcm in the next two years, at which point it will account for 60% of Irish supply, but production will fall back in the 2020s, increasing import dependence. The Irish Government recently banned shale gas development. In the context of Brexit, the future of UK gas exports to Ireland remains an important issue to consider and this is discussed in the next section.

2.7 States and Markets

So far, our discussions have been largely framed in terms of country A trading with country B; thus, the UK imports its natural gas from Norway, Qatar and via interconnectors originating in Belgium and the Netherlands. However, the reality is that it is companies that execute the trade and own the enabling infrastructure (Bouzarovski

7 https://www.parliament.uk/business/publications/written-questions-answers-statements/written-statement/Commons/2018-05-17/HCWS690

et al. 2015). That said, the state is also heavily involved in gas markets, both as a regulator and as an owner. For example, the key Norwegian companies involved in supplying gas to the UK are Gassco, which owns the pipelines and is 100% state-owned and Statoil, which is Norway's national oil and gas company that is 67% state-owned. Equally, Qatar's LNG business is 100% owned by Qatar Petroleum on behalf of the Qatari state, though it has developed an LNG industry through a series of joint ventures with international oil companies. Russia's monopoly pipeline gas exporter, Gazprom, is 51% state-owned. In contrast, the upstream industry in the UK is entirely privately owned, the domestic gas sector is completely privatised, and the domestic gas market is liberalised with the price determined by gas-on-gas competition (more on this below). Consequently, the UK Government relies on a regulator Ofgem—the Office of Gas and Electricity Markets—which has the function of "protecting the interests of existing and future electricity and gas customers;" and this includes "promoting security of supply and sustainability." However, the UK Government is increasingly intervening in the energy market—more specifically the electricity market—to promote both energy security (the Capacity Market), sustainability (Contracts for Difference) and affordability with the passing of the Domestic Gas and Electricity (Tariff Cap) Bill that will require Ofgem to cap domestic energy tariffs until at least the end of 2020 (Hinson 2018).

The EU has leaned heavily on the UK experience in the design of the policies aimed at creating a single European market for electricity and gas. Thus, to date at least, EU gas market regulation has tended to complement developments in the UK. But just as the UK Government has limited direct influence over its privatised energy system, so the EU has limited power to force EU member states to implement its energy and climate policies. It is for this reason, that the EU has focused on deploying competition policy to create a single European energy market; knowing full well that member states will protect sovereignty over their national energy mix. Instead, as noted above, the EU promotes cooperation, interconnection and energy solidarity and marks progress through agreeing to targets relating to renewable energy, energy efficiency and emissions for 2020 and 2030.

A final factor to consider is the fact that much of the UK energy system is owned by foreign (EU or otherwise) companies that face global competition. Again, the forces of globalisation are implicated in the inability of individual states to influence the security of their energy supplies. The EU's response has been to promote what it terms *energy diplomacy* and to seek to use its market power to influence the terms on which non-member states and their companies trade with it. The most obvious case being the European Commission's pursuit of Gazprom in relation to competition policy and compliance with the Third Energy Package; which has resulted in the Russian company finally agreeing to play by the EU's rules (Stern and Yafimava 2017). However, this may also be because Gazprom has finally realised that as the marginal supplier of pipeline gas to Europe it is in a strong position to maintain its market share, even if a percentage of that gas is then re-exported to the Ukraine. Equally, it has failed to develop a significant LNG industry and is struggling to develop its pipeline trade to Asia; thus, Europe remains its most important export market (Henderson and Sharples 2018).

2.8 Assessing UK Gas Security

Each year the relevant government department and Ofgem produce a *Statutory Security of Supply Report*. The most recent BEIS/Ofgem report (2017, 17) reached the following conclusion in relation to upstream security of supply:

"GB's gas system has delivered security to date and is expected to continue to function well, with a diverse range of supply sources and sufficient delivery capacity to meet demand. The UK Continental Shelf (UKCS) remains a major source of gas in the GB market, with supplies also coming from a variety of international partners via pipelines and Liquid Natural Gas (LNG) cargoes. There are a range of future supply outlooks, but all show sufficient gas available from the combination of domestic, regional and global markets."

On Brexit, the report said the following (BEIS/Ofgem 2017, 3):

"The UK is seeking a deep and special future partnership with the EU on energy. A well-functioning energy market is of vital importance for the European economy and the well-being of citizens. The UK will work to ensure that our future partnership is successful at ensuring efficiency of trade."

In October 2017, BEIS (2017c) published a strategic assessment of Great Britain's gas security of supply , supported by a modelling exercise conducted by Cambridge Economic Policy Associates (CEPA 2017). The CEPA report modelled the impact of a range of supply shocks under different demand scenarios. The main findings of CEPA's (2017, 3-4) analysis are:

- "The GB system is resilient to almost all significant individual shocks under normal demand conditions;"
- "Where there is an extreme shock to global LNG markets, GB demand can be met if GB consumers are willing to pay for it;"

- "GB demand will be met in circumstances where there is an extreme disruption to Russian gas supplies to Europe (for a 12-month period) if GB consumers are willing to pay for it;" and
- "As long as GB consumers are willing to pay sufficiently for scarce gas supplies, only in the most extreme (and highly unlikely) scenarios…considered might there be some unmet demand."

They concluded that: "The main insight from this work is that price is the primary determinant of whether sufficient gas is available to meet GB demand, but in some instances the availability of adequate import capacity and key infrastructure may also be critical." Although the work was carried out before the closure of the Rough storage facility was announced, the scenarios did consider such a situation; however, the analysis did not account for the potential impact of Brexit in terms of access to the EU market. The findings make clear the importance of the distinction between physical security and price security. The GB system can secure sufficient gas in an emergency situation as long as consumers are willing to pay the price needed to attract the necessary gas in competition with other consumers in Europe and globally. In their strategic assessment, BEIS (2017c, 3) note that future gas demand is likely to fall due to energy efficiency measures, heat decarbonisation and electricity generation; that import dependence will increase, but that there will be an increase in the worldwide availability of LNG. Their overall conclusion was that:

"We find that the diversity of supply and the available capacity underpin the strength of the GB system. The 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 infrastructure to maintain the capacity and diversity which underpins our security. We are secure now, and the GB system is well placed to continue to be secure and robust in a range of supply and demand outcomes over the next two decades."

These statements represent a strong commitment of faith in the ability of the market to deliver security of supply, but at what price? Events this winter, plus the tenor of discussions at the Gas Security Forum and at a Stakeholder Workshop held by BEIS in March 2018 suggest that many in the industry—as well as industrial consumers of gas—feel that there needs to be greater consideration of price security and what the current challenges to the GB gas market might mean for future affordability and industrial competitiveness.

2.9 Security of Supply Brexit Challenges

Returning to our core concern with upstream security of gas supply, it is possible to reach a number of conclusions: first, today in a liberalised market there is a limit to what the UK Government is willing and able to do to ensure physical security of supply; second, at present, the majority of the UK's gas imports come from within the IEM, which is supplied by both indigenous and non-EU sources; and third, if in the future, the UK were outside the IEM it would not benefit from energy solidarity measures or the EU's energy diplomacy; equally it would be unable to influence the EU's energy policies. But, because of its integration into the northwest European gas market, its gas security would still be significantly affected by the success or otherwise of the EU's policies and actions. Finally, in the face of falling domestic production, it is likely that the UK will become more reliant on imported LNG, which will expose it to global price competition and volatility. It is in this context that we can identify the following gas security challenges that need to be considered in the context of Brexit and a future gas security strategy:

- Prospects for future gas production on the UKCS;
- Prospects for domestic onshore production from Biomethane, bioSNG and shale gas;
- The future gas trading relationship with Norway;
- The consequences of declining production in the Netherlands
- The UK's future gas trading relationships within the northwest European gas market;
- Developments in the global LNG market that impact on the availability and affordability of imports to the UK; and,
- The efficacy of the current N-1 assessment of gas security.[8]

8 Regulation (EU) 2017/1938 of the European Parliament and of the Council of 25 October 2017 concerning measures to safeguard the security of gas supply and repealing Regulation (EU) No 994/2010 (Text with EEA relevance.)

3. Midstream Security Challenges: Sustaining Critical Infrastructure

This section considers the critical infrastructures—both hard and soft—that are necessary to link gas suppliers to end users.

The hard infrastructure includes: the gas pipeline systems (offshore and onshore), the three LNG terminals, the various gas storage facilities and the three interconnectors. The soft infrastructure includes: the NBP—the virtual trading location for the sale, purchase and exchange of natural gas in the UK—and the gas governance infrastructure that includes the UK regulator (Ofgem) and the EU organisations (ACER and ENTSOG) that regulate the UK's participation in the internal energy market. In many ways, this is the most complex, but least studied, aspect of UK gas security. It is also the aspect of the UK's gas supply chain that is most prone to technical failures that result in gas supply emergencies (Skea et al. 2012). Events of this winter (2017/18) demonstrate that multiple infrastructure failures (as in the Baumgarten/Forties/Troll failures in December 2017) can stretch the system and that when they are coupled with unexpectedly high demand (as with the 1st/2nd March 2018 cold snap) they can result in a Gas Deficit Warning due to falling pressures on the NTS.[9] Furthermore, as the infrastructure ages, the likelihood of technical failure increases, as does the cost of maintenance. The following section describes the various elements of the midstream, assesses their current status, and considers the potential impacts of Brexit and the challenges they face in relation to future UK gas security.

Figure 4: Monthly GB gas supply 2011 to 2016 (billion cubic metres)
(Source: National Grid 2017b, based on BEIS Energy Trends data)

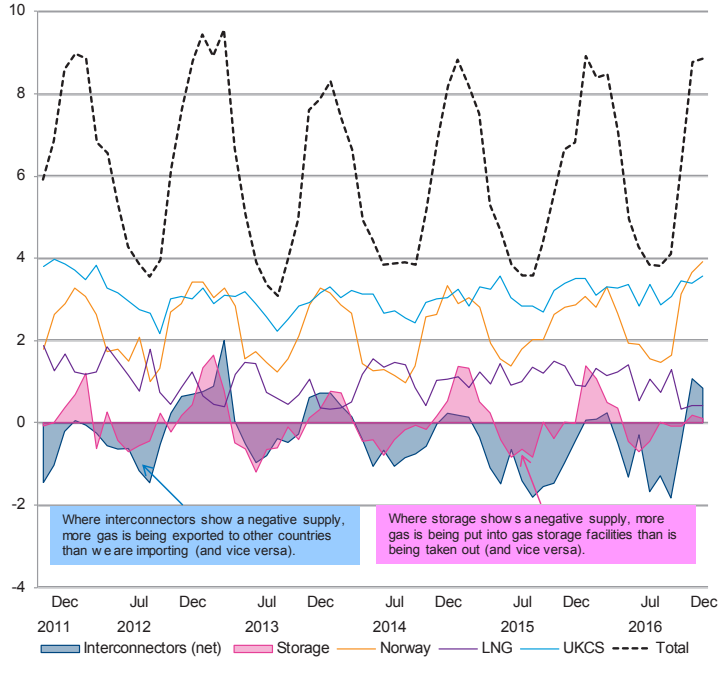


Figure 4 demonstrates the challenge that the midstream has to manage, namely the seasonality of GB gas demand, which is driven largely by high winter demand for domestic heating. All the indications are that the difference between summer and winter gas demand is likely to increase as renewable electricity generation—solar and wind—push gas out of the power generation mix. It also demonstrates the roles played by the different elements of the midstream described above, the relative importance of which was made clear in the first section on upstream security of supply.

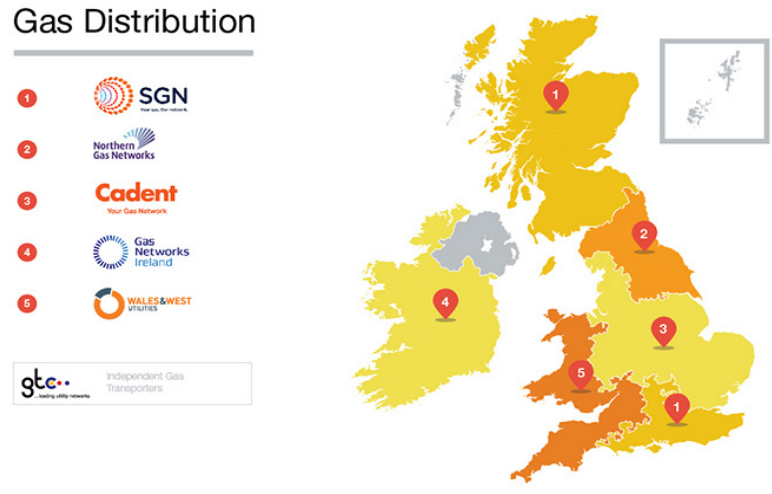
3.1 Import Pipelines

The UK's pipeline infrastructure, as shown in Figure 5, can be divided into three elements: first, the pipelines that bring gas ashore from producing fields in the UKCS and NCS (what National Grid calls beach supplies); second, the pipelines that move gas around the UK—the 7,600 km of the high pressure National Transmission System (NTS); and third, the 280,000 km of high, medium and low-pressure pipes that make up the gas distribution network (GDN) that delivers gas to consumers (the network is divided into 12 Local Distribution Zones or LDZs). Dodds and McDowall (2013) present a useful description

9 Both these events are explored in detail in Bradshaw and Solman (2018).

Figure 5: The National Gas Transmissions System
(Source: BEIS 2017d, 97)

Figure 6: Gas Distribution Networks
(Source: http://www.energynetworks.org/info/faqs/gas-distribution-map.html)



of the low-pressure gas network and the future prospects for the GDN. This section focuses on the domestic pipelines, as the interconnectors are best dealt with separately once LNG and storage have been discussed.

When it comes to the assessment of the UK's gas security of supply, there is an understandable focus on those elements of infrastructure that deliver imports (and some exports) to the UK. Three issues are worth noting here: first, relative to total gas consumption (76.7 bcm) and total imports (41.0 bcm) in 2016 (BP 2017), the total gas import capacity of 147.6 bcm (three LNG terminals: 48.1 bcm; three pipelines from the NCS: 58.3 bcm; two interconnectors: 41.2 bcm) would seem more than adequate; second, all that capacity is in private ownership; and third, the vast majority of it is in foreign ownership. This means that the UK Government has limited direct influence over the UK's gas import assets—although they can use regulations to impose obligations to deliver security of supply—and their financial performance must meet the expectations of their private, and largely foreign shareholders. The age of the infrastructure means that the pipelines are now sunk assets, but they still need to cover their short-run operating costs and maintainance. Furthermore, projects to expand capacity or improve flexibility, must be supported by a sound business case, as well as the approval of the regulator. As a result, their longevity is linked to market conditions and their financial solvency and not the state's energy security concerns.

The focus on import assets when assessing security of supply excludes the pipelines and other infrastructures necessary to deliver gas from the UKCS (some of Gassco's pipelines also rely on it and Norwegian gas is also being shipped through the UKCS's infrastructure). This is a significant oversight as we know that declining levels of offshore production will threaten the integrity of that infrastructure. The Wood Review (2014, 44) recommended: "…the Regulator [now the Oil & Gas Authority] to identify critical infrastructure, monitor its capacity, track current throughput and potential volumes within its catchment area, and be cognisant of the commercial drivers needed to sustain such infrastructure." In their own *National Preventive Action Plan: Gas*, BEIS (2016, 7) lists the Wood Review among the 'risk reduction measures' for the security of gas supply. As noted earlier, Brexit has increased the uncertainty surrounding the future of the UKCS, making an already challenging situation more difficult; thus, it would seem sensible to include the critical infrastructures that deliver domestic offshore production in future assessments of UK gas security. After all, maintaining UK production reduces the need to import, with associated balance of payments benefits. Equally, there is a need to monitor the status, performance and future plans for the pipelines that are owned by the Norwegian state-owned company Gassco.

3.2 Onshore Pipelines

Once landed in GB at the various reception terminals shown in Figure 5, gas is moved around the UK using the NTS and the GDN. According to a 2015 study by the then DECC (2015, 6), between 2010 and 2014 around £ 300 million was invested to ensure the safety and reliability of the NTS, supporting around 4,000 jobs a year and over the same period £ 3.8 billion was invested in GB gas networks, supporting around 11,500 jobs. In the case of the latter, much of this investment was related to the ongoing programme of replacing metal pipes with plastic alternatives (known as the Iron Mains Replacement Programme or IMRP).[10] Thus, the onshore gas network is a substantial economic asset in its own right, and significant ongoing investment is required not only to maintain it, but also increase its flexibility in the light of the changing geography and temporality of gas flows. In this context, that same DECC report identified three challenges for the networks: 1) increasing imports as domestic resources decline; 2) increasing variability of gas demand in line with renewable generation and 3) an aging infrastructure, that is less safe and reliable. The NTS that distributes gas directly to the GDNs, larger power stations and industrial users is owned and operated by National Grid as the system operator (TSO); while the GDN is divided among four companies that own the 8 regional networks (see Figure 6 above).

10 See: http://www.hse.gov.uk/gas/supply/mainsreplacement/index.htm

- Cadent Gas Ltd—West Midlands, North West, East of England and North London.
- Northern Gas Networks Ltd—North East England (including Yorkshire and North Cumbria)
- Wales & West Utilities – Wales and South West England
- SGN—Scotland and Southern England (including South London)

Because the gas network and distribution systems operate as national and regional monopolies they are regulated by Ofgem, which in turn must follow EU regulations (Network Codes) in relation to gas market operations. This begs the question, what will be the nature of the regulatory system that governs the UK's gas networks post-Brexit and what will happen subsequently? Should the regulatory regimes in the UK and EU start to diverge this may have implications for future UK gas security, as well as the willingness of foreign companies to invest in and operate UK network assets.

3.3 LNG Import Terminals

In anticipation of the decline in production from the UKCS, in the early 2000s the industry built three LNG import terminals, plus the much smaller 'GasPort,' the world's first dockside floating regasification facility, was installed on Teesside (operated by Excelerate Energy between 2007 and 2015). The fundamentals of the UK's LNG import infrastructure are presented in Table 2. The total send-out capacity is 48.1 bcm, which is significant when you consider that total gas consumption in the UK was 2016 was 76.7 bcm. However, according to BP (2017), total LNG imports into the UK in 2016 were only 10.5 bcm, which represents 21.8% of total LNG send-out capacity and only 13.7% of total UK consumption. This suggests that, at present, the UK's LNG import capacity is an under-utilised asset. Table 3 shows LNG imports by terminal.

Each of the three terminals has a different ownership structure and business model. In the case of Grain LNG, National Grid owns the terminal but has entered into long-term contracts with a range of customers who pay for capacity. All of the primary capacity at the terminal has been auctioned through open season processes and is fully contracted. In phase one, BP and the Algerian state-owned company Sonatrach were awarded a 20-year contract for 3.3 mtpa of LNG throughput capacity per annum. In phase 2, in 2008, an additional capacity of 6.5 mtpa was awarded to Centrica, GDF Suez and Sonatrach. Finally, in 2010, 5 mtpa of capacity was awarded to E.ON (Germany), Iberdrola (Spain) and Centrica. National Grid receives payment whether or not its customers use its facility and the level of utilisation and send out is determined by commercial decisions made by the individual companies.

The South Hook LNG terminal is the largest, and by far the most active (see Table 3) and is part of an integrated supply chain that brings Qatari LNG to the UK. The terminal is run by the South Hook LNG Terminal Company that is a joint venture linked to the Qatar II project at Ras Laffan that is owned by Qatar Petroleum (70%) and ExxonMobil (30%). South Hook Gas is responsible for importing the LNG to the terminal and it is marketed via ExxonMobil Gas Marketing Europe. Whether or not LNG cargoes arrive in the UK is determined by Qatar Petroleum whose ultimate responsibility is to maximise revenue for the Qatari state. Thus, the UK competes against the world's other LNG-importing countries to attract LNG from Qatar. South Hook also offers third party access to terminal capacity, and in addition to the joint venture partners, is reported to have supply agreements with ConocoPhillips, Axpo, Chevron and Trafigura. Most recently, in May 2018, South Hook received permission from the Joint Office of Gas Transporters, which administers the rules for transporting gas in Britain, to broaden the specification of the gas that it handles at its terminal.[11] Raising the oxygen limits will allow greater diversity of future cargoes at the South Hook LNG terminal. This raises a wider issue of the role of the Gas Safety (Management) Regulations of 1996 (GSRM) that reflect the quality of North Sea Gas production. With domestic production declining and new sources of gas being imported (and produced onshore) there is a need to adjust the GSRM to remove the cost of processing at import terminals to match pipeline specifications. Whether or not gas leaves the terminal in Milford Haven is determined by market conditions in the UK and NW Europe. As

Table 2: The UK's LNG Import Infrastructure

Facility	Date	Owner	Location	Send-Out Capacity (bcm/year)	Max flow rate (Million m3/day)
Isle of Grain	2005	National Grid	Isle of Grain	19.5	56
South Hook LNG	2009	Qatar Pet. Intl.-67.5% ExxonMobil-24.15% Total-8.35%	Milford Haven	21	58
Dragon LNG	2009	Petronas-50% Shell (BG)-50%	Milford Haven	7.6	21

Source: BEIS (2017d, Chp 4.6) *DUKES: Natural Gas*

11 https://www.rigzone.com/news/wire/uks_top_qatari_lng_importer_seeks_to_broaden_supply_as_cargoes_slump-18-may-2018-154661-article/

both ExxonMobil and Qatar Petroleum are involved in the joint venture that is building the Golden Pass LNG plant at Sabine Pass on the Gulf of Mexico, it is possible that in the future the South Hook terminal will provide another route for US LNG to access the UK and European markets. However, US LNG is already arriving in the UK, last July the first delivery from Cherniere Energy's plant at Sabine Pass—the first to start operation—was delivered to Grain LNG.

The final terminal, Dragon LNG, started operations as a 50/50 joint venture between the Malaysian state-owned company Petronas and BG (UK); however, following Shell's acquisition of BG in 2015, it is now jointly owned by Petronas and Shell. The two companies are independently responsible for sourcing their LNG and also for marketing it. Like South Hook, Dragon also advertises third party access on its website. In 2016, Petronas LNG UK signed a five-year sales and purchase agreement with Qatargas to supply 1.1 million tons of LNG a year, extending a previous contract that was due to expire. The LNG will be supplied from Qatargas 4, which is a joint venture between Qatar Petroleum (70%) and Shell (30%). It remains to be seen what impact Shell's involvement in Dragon LNG will have on LNG imports into the UK. Shell delivered the first cargo from the US Cove Point LNG plant on the east coast to the Dragon terminal in late March 2018. As a global aggregator, it has access to a substantial LNG portfolio, it is also in a partnership with Gazprom to build the Baltic LNG terminal that might provide access to Russian gas without having to transit the NW European pipeline system, which might be an attractive proposition post-Brexit.

The cold snap in late-February and early March 2018 drew heavily on the UK's LNG stocks and—as discussed earlier and for different reasons—focused media attention on where the UK gets its LNG from.[12] Ordinarily, Qatar supplies the vast majority of LNG imports (12 cargoes in 2017), but in early 2018 new sources of supply have dominated with 4 Qatari arrivals compared to 9 from other countries. So far, the UK has received two cargoes each from the US, Russia, and Trinidad and Tobago, with one cargo coming from Egypt. It is also the case that regasification at South Hook is lower than usual whilst activity at Grain and Dragon is higher. The South Hook terminal also suffered technical problems during the cold snap that limited its ability to send out gas. The lower levels of Qatari activity partially reflect maintenance on the LNG trains at Ras Laffan, as well as the strong draw on spot LNG from China this winter. China's LNG imports in March 2018 were up 39% on the previous year.

However, early summer is a period when Asian winter heating demand is over and summer cooling demand has yet to ramp up. Traditionally, this is when LNG deliveries return to Europe to fill up the tanks after the winter. Given the strong demand for gas in Europe this winter, the current levels of activity are to be expected. These deliveries also demonstrate that there are new sources of LNG supply for the UK to draw on, but also that in the winter there is strong competition for LNG cargoes. Data from National Grid show that average storage levels across the three LNG terminals during the winter have fallen in recent years, from 67% in 2014/15 to 53% in 2016/17. At the same time, there is significant variation in storage levels within the winter period: in 2016/17 the minimum was 19% and the maximum was 75%. Data on National Grid's *Prevailing View* website show that prior to the February-March cold snap storage levels were at 40% and they fell to around 15% as a result of the cold-weather demand. Had the initial levels been lower, or the duration of the cold snap longer, then the supply situation could have been even tighter. In any event, it clearly demonstrates that it is erroneous to consider the full storage capacity of the three LNG terminals as being available in a gas emergency or a period of high demand. Equally, the UK's LNG storage infrastructure is a valuable asset and perhaps more should be done to encourage additional

Table 3: LNG imports by terminal: 2009-2016 (GWh)

LNG Imports via:	2009	2010	2011	2012	2013	2014	2015	2016
Dragon (*Milford Haven*)	10,185	19,383	28,790	1,819	968	3,326	8,014	4,079
Isle of Grain (*Isle of Grain*)	51,240	60,667	86,357	38,196	15,664	13,808	14,224	22,152
South Hook (*Milford Haven*)	49,988	126,796	159,646	110,082	85,989	106,776	130,169	96,079
Total LNG	**112,238**	**206,846**	**274,794**	**150,097**	**102,620**	**123,910**	**152,406**	**122,310**

Source BEIS (2017d, Chp 4.6) *DUKES: Natural Gas*

12 'Qatar has supplied less than half the UK's LNG so far in 2018,' S&P Global Platts. Available at: https://www.platts.com/latest-news/natural-gas/london/qatar-has-supplied-less-than-half-the-uks-lng-26935986

participation in the market through greater use of the existing terminal capacity?

Returning to the question of ownership, the UK's LNG terminals are integrated into global supply chains that are owned and operated by international companies, some of whom are state-owned. Furthermore, the global LNG trade is also getting more complex with trading companies buying and selling cargoes and switching destinations at short notice to seek out the highest price. However, there is only modest involvement by UK companies, with the most significant factor being National Grid's ownership of the Isle of Grain Terminal, but it does not buy or sell LNG. Another key point is that a large part of the UK's contracted LNG portfolio is flexible, it can be redirected should another buyer prove more attractive (IEA 2017, 73). As discussed earlier, this explains the fall in LNG deliveries in the period between 2011 and 2014. Prices in Asia then fell due to the dominance of oil indexation and the beginnings of oversupply and a buyer's market. But, in 2016/17 the market tightened due to unexpected LNG demand growth in China and LNG deliveries to the UK fell again. It is still expected that new supplies from Australia, Russia and the US will result in more of a buyer's market in coming years. But, if falling domestic production and/or a rebound in demand results in increased reliance on LNG imports, it is clear that consumers will be in global competition for their natural gas supplies, which will have implications both for physical and price security of supply.

3.4 Gas Storage Facilities

Relative to most large gas consuming countries, the UK has a modest amount of storage capacity (less than 6% of annual demand compared to storage in Germany, France and Italy that covers about 20% of annual demand), even more so given the closure of the Rough site. This low level of storage is for historical reasons as it was possible to surge production from the UKCS to meet unexpected demand increases. This capability is long gone, although, as noted earlier, the Norwegian fields that supply the UK can increase supplies when needed in the winter months. Nonetheless, over the years there has been a good deal of debate about whether or not the Government should intervene to incentivise more gas storage (Redpoint 2013). The traditional business case for gas storage relies on a significant price spread between summer and winter months that allows cheap summer gas to be purchased and then stored and sold for higher winter prices, with the difference financing the storage facility and a return on investment. The problem is that the summer-winter spread is no longer sufficient to support investment in new storage capacity and the Government sees no case to incentivise additional storage and industry sees no business case to invest in it. But, might this change post Brexit?

Historically, the UK's storage capacity has been comprised of one long-range storage facility—the depleted gas field of Rough offshore the Yorkshire coast, and eight medium-range storage facilities that are mainly onshore salt caverns (Table 4). The total capacity was 4.5 bcm and the maximum output from storage has been 162 mcm/d; however, as noted earlier the Rough storage facility is no longer receiving gas and will draw-down on its cushion gas over the next few years, before closing. The Rough facility, when fully operational, was able to supply the NTS for 90 days and was an important additional source of gas supplies in the winter months. Without Rough, the UK only has 1.4bcm of storage capacity with a maximum output of 117 mcm/d. The medium-range storage facilities offer a

Table 4: UK Gas Storage Sites (as of 1st November 2016)

Owner	Site	Location	Space (bcm)	Start date	Maximum delivery (mm^3/day)	Type	Status
Centrica Storage Ltd.	Rough	Southern N. Sea	3.30	1985	41	Depleted field	Long
SSE and Statoil	Aldbrough	East Yorkshire	0.30	2009	40	Salt cavern	Medium
E.ON	Holford	Cheshire	0.20		22	Salt cavern	Medium
SSE	Homsea	East Yorkshire	0.30	1979	18	Salt cavern	Medium
EDF Trading	Holehouse Farm	Cheshire	0.02	2004-08	5	Salt cavern	Medium
Humbly Grove Energy	Humbly Grove	Hampshire	0.30	2005	7	Depleted field	Medium
Scottish Power	Hatfield Moor	South Yorkshire	0.07	2000	1.8	Depleted field	Medium
EDF Energy	Hill Top Farm	Cheshire	0.05	2011	12	Salt Cavern	Medium
Storenergy	Stublach	Cheshire	0.20	2013-16	15	Salt Cavern	Medium

Source: BEIS (2017c, 108)

Table 5: Interconnectors to continental Europe

Name	Border Point	Capacity (bcma)	Maximum Flow Rate (mm³/day)	Owner	Start-up
BBL	Bacton	15.7	53	Uniper (20 %), Fluxys (20 %), Gasunie (60 %) (Gazprom option of 9 %)	2006
IUK	Bacton	25.5	72	Fluxys UK Ltd. (37 %),, Gasbridge 1 B.V. (24 %), Gasbridge 2 B.V. (24, Fluxys Interconnector Ltd. (15 %)	1998

*Gasbridge 1 BV an Gasbridge 2 BV are both 50/50 joint ventures between Fluxys Europe BV and SNAM S.p.a. Europe. Source: BEIS (2017c) and IUK Website

different service to the system and run on a different business model as they will empty and re-fill many times in a winter period to exploit short-term volatility, providing flexibility. But daily price volatility has also fallen and while there are numerous new storage facilities with planning permission, limited new capacity has been added in the last few years.

The market has had dress rehearsals for the loss of Rough, as there have been periods in the past when it was unavailable and last winter (2016/17) it was operating at lower capacity. National Grid (2017c) reports that in the 2016/17 winter storage supplied only 6% of gas demand and the average daily flow from storage was 5 mcm/day, with a maximum of 23 mcm/day, which was approximately half that of previous years. But, National Grid (2017c, 50) also noted that there was no precedent for the low level of gas that will be available from Rough in the 2017/18 winter. The recent analysis by CEPA (2017) did consider a number of scenarios without Rough and concluded that its loss would not be a major threat to UK gas security as there are other sources of flexible supply. While there is industry concern that the Government should be doing more to incentivise investment in new storage, BEIS and Ofgem are clear that it is up to the market to invest in additional capacity if it is warranted. However, it does seem likely that there will be increased price volatility and price hikes in the winter months as a market response to the need to source flexible supply. Large industrial consumers of natural gas will have to factor this into their business planning. Ultimately, such volatility may improve the economics of the other sources of flexibility—medium range storage and the interconnectors—and may also make the UK more attractive to LNG shippers in the winter months.

One further reason for the lack of concern is that there is surplus storage capacity on the continent and supplies can be accessed via the interconnectors. But, the economics of gas storage facilities on the continent are equally challenging and some may close. Furthermore, as we shall see below, the interconnectors face challenges of their own.

3.5 Interconnectors to Continental Europe

The NTS is connected to three interconnectors, two of which—IUK and BBL—link the NBP market area to continental Europe (see Table 5). The third pipeline—the Moffat interconnector—links the NTS to the Isle of Man, Northern Ireland and the Republic of Ireland. In this section, the initial discussion focuses on IUK and BBL and their role in supporting GB gas security. It then turns to the issue of the UK's future relationship with the Republic of Ireland. The IUK dates back to the early 1990s, a time when the UK had plentiful supplies of gas from the UKCS and was looking at ways to monetise that gas. In 1994, an independent company, Interconnector UK Limited (IUK), was created to finance, build and operate the pipeline. The pipeline began operations in 1998 and provides physical bi-directional flow that links the UK and Belgian markets via a 235-km pipeline that runs from Bacton to Zebrugge. It has a capacity of 20 bcma in export mode and had an initial import capacity of 8.5 bcma, which has since been expanded to 25.5 bcma. The project was innovative in that it connected two gas markets, rather than a source of gas supply to a market. Both the interconnectors have operated on a merchant licence that allows them to set the prices for the services that they provide, which differs from most pipelines that operate on the basis of a regulated price. However, to mitigate risk, the traditional business model for both IUK and BBL has been based on the sale of long term contracts, that guarantee their income and shift the risk to the shippers. Over time, the ownership structure of IUK has changed and today the Belgium TSO Fluxys is the dominant shareholder, in part through their joint venture with SNAM the Italian gas TSO. The presence of a Quebec-based pension fund reflected the fact that the combination of long-term contracts and a liquid gas market provided a secure source of income for the shareholders. But, that business model is no longer permissible under EU regulations, although a new allocation mechanism is being introduced. The most immediate response has been a further change in ownership with the pension fund selling its share to the other partners for some £75 million, leaving Fluxys and its subsidiaries with 76.22% and SNAM with 22.68%.

The BBL pipeline was built in 2006, after the UK market had become a net importer of gas and provides a connection between the Dutch gas market—Title Transfer Facility or TTF—and the NBP market area. The BBL Company operates a 235-km pipeline that links Balgzand in the Netherlands with Bacton. The company was established in 2004 and the majority shareholder is the Dutch company Gasunie, the other shareholders are the German company Uniper Ruhrgas (a subsidiary of E. On) and Fluxys. At present, the BBL pipeline only provides services to import gas from the Netherlands to the UK and its capacity is 15.7 bcma. Thus, the two interconnectors compete for the import market, but only IUK provides physical export capacity. However, BBL has been the more active—deliveries are 5-6 times higher—of the two in the import market because it connects to the TTF market that is far more liquid than the Belgium Zebrugge (ZEE) gas trading hub (Heather and Petrovich 2017). Like, IUK, it has relied on long-term contracts, which came to an end in December 2016. This has come at the same time as problems at the Dutch gas field at Groningen—discussed earlier—are resulting in a significant reduction in production and a loss of seasonal flexibility for the Dutch market. For technical reasons, the Groningen field does not produce gas that can be directly supplied to the BBL pipeline, but the loss of domestic production might have a knock-on effect on the availability of gas for export (Honoré 2017). The two factors together might explain why since December 2016 flows through BBL have fallen significantly. National Grid (2017c, 54) reports that historically flows through BBL have been driven less by the price spread between NBP and TTF, than by long-term contracts. The IUK's contracts expire 1st October 2018, making the future behaviour of the two interconnectors more difficult to predict. As noted earlier, BBL is investing in physical reverse flow capability and by Autumn 2019 it will be able to export gas from the UK. During the events of Winter 2017/18 the role of the interconnectors was constrained. Firstly, on 12th December 2017, National Grid restricted their flow into the UK because of congestion on the NTS moving gas from the south to the north, and secondly, on 1st March 2018 high gas prices on continental markets—also due to the cold weather—limited the amount of gas coming to the UK. These events suggest that the interconnectors cannot necessarily be expected to flow at full capacity when there is a technical failure and/or gas emergency in the GB market that results in high prices.

The two interconnectors are regulated through the Third Energy Package of the EU, introduced in 2009, and its main regulatory body is ACER (Agency for the Cooperation of Energy Regulators). The day-to-day running and regulation is carried out by the national regulators, Ofgem for the UK, CREG in Belgium for IUK and ACM in the Netherlands for BBL. There are three European network codes which provide the guidelines for operation of the interconnectors: Capacity Allocation Mechanism (CAM) code; Interoperability and Data Exchange (INT) code; and the Tariff (TAR) code. The interconnectors' merchant model is somewhat anomalous on the wider landscape of the EU gas market and they have found themselves at odds with regulatory reforms targeting long-term contracts, but—as noted above—progress is being made on devising a new allocation mechanism. Viewed from the perspective of UK gas security, the interconnectors contribute to both physical and price security of supply. In terms of physical supply, they provide access to additional supplies of gas from continental Europe during the winter months that supplement beach supplies and storage and LNG. In terms of price security, IUK provides shippers of gas in the UK access to the continental market, which is important for Norwegian pipeline gas and the LNG terminals. This service has become even more important since the loss of Rough and in the summer of 2017 IUK export flows were at a very high level. The import capacity of IUK and BBL provides access to cheaper gas supplies from the continent when the NBP price is high, thus moderating price spikes and reducing volatility. There is plenty of analysis that shows the convergence of gas prices across the N W European trading hubs and the interconnectors are essential to this market integration (Petrovich 2015, 2016). Ironically, this convergence and the reduction in price volatility has actually reduced the price spreads between hubs and with it the arbitrage opportunities that are an essential source of income for the shippers who pay for interconnector access. In this context, the loss of the guaranteed income provided by long-term contracts may be difficult to replace with income from short-term services simply because there is less demand.

It is in this context of uncertainty that Brexit adds another layer of complexity. If, when the UK leaves the EU, it leaves the IEM, then the status of the interconnectors will change. They will no longer be two pipelines that connect two gas markets within the IEM, rather they will connect the EU to a third party—the UK. This raises the question as to whose regulations they will operate under. In simple terms, we can conceive of BBL as being a Dutch asset—that operates in Euros—that connects the TTF to the NBP. The recent announcement of the merger of BBL with the Gasunie Transport Service (GTS), extending the TTF market area to the NBP market area, makes clear this status. Although the merger is being sold on the basis of improved efficiency, in the context of Brexit it is making a clear statement that BBL wishes to continue to fall under EU regulation. The response of IUK to the current uncertainty has been

to make a case for greater flexibility for merchant assets, including the ability to sell long-term contracts. It is also seeking greater recognition from the UK regulator for the social benefits it provides to UK consumers. Despite its foreign ownership, we can perceive of IUK as a UK asset—that operates in Pounds Sterling—that connects the UK's NBP market to the continental market. The reality for IUK is that until the UK leaves the EU—meaning that it is no longer subject to EU regulations—it must seek an accommodation within the current EU regulatory framework. Furthermore, a transitional arrangement could see EU regulations governing the UK's gas market beyond March 2019 to December 2020.

A further complication has arisen as a consequence of the European Commission's hostility towards the Nordstream-2 pipeline that is being developed by a consortium led by Gazprom. At present, the EU's Third Package does not extend to offshore pipelines; however, the European Commission (2017) is proposing to amend the Gas Directive (2009/73/EC) to establish common rules for pipelines entering the European internal gas market. The Commission maintains that it is not practical to have different regulatory regimes apply at the two ends of the same pipeline. This proposal impacts upon all existing pipelines crossing into EU jurisdiction across a sea border and it explicitly states that: "The proposal may also have an impact—post-Brexit—on pipeline connecting the UK with EU member states." This suggests that as part of the Brexit process it will be necessary for the UK to make agreements with regulators in Belgium and the Netherland to ensure that the two interconnectors operate in a manner that is: "not detrimental to competition, the functioning of the market and security of supply in the Union." At the same time, agreements must address the legitimate energy security concerns of the UK.

3.6 Interconnection to Ireland

The third interconnector between the GB market and island of Ireland adds further complication. The island of Ireland is connected to the UK via three separate subsea interconnector pipelines. Two connect directly to the Republic of Ireland and a third to Northern Ireland that supplies the north and south via a common pipeline network. The first interconnector pipe was built in 1994 and the second in 2002 and they have a combined capacity of 31 mcm/day. That the island of Ireland operates a unified electricity market and two distinct, but connected, gas networks is a key factor in the Brexit negotiations. The Irish TSO Gas Networks Ireland (GNI) owns and operates the Moffat Interconnector through GNI (UK) Ltd. and works in close cooperation with National Grid. A new 50km pipeline is currently under construction in Scotland to twin the pipeline onshore leg. Natural gas plays a crucial role in the energy mix of the Republic of Ireland, in 2015 natural gas provided 27% of Ireland's total primary energy requirement and was used to produce an average of 49% of its electricity between 2012 and 2016 (ERVIA 2017). Historically, between 2008 and 2015, Moffat supplied 94% of the gas in the GNI system. However, in 2015 the Corrib offshore field started production and in 2016-17 the reliance on Moffat fell to 46%, with Corrib accounting for 49% of supplies. But, the Corrib field is expected to peak and decline quite rapidly, and it is forecast that by the mid-2020s dependence on Moffat could return to 78%. Clearly, Ireland's reliance on the Moffat interconnector infrastructure means that on its own it fails the EU's N-1 test, consequently, Ireland and the UK cooperate through the UK and Ireland Emergency Group Forum and produce a Joint Risk Assessment and a Joint Preventative Action Plan (CER 2016). The current action plan will expire at the end of 2018 and post-Brexit, Ireland will be highly dependent on a non-EU state for its gas supply and for access to the continental gas market via IUK and BBL. Equally, consumers in Northern Ireland and the Isle of Man are 100% dependent on gas supplied by infrastructure owned by GNI. In their discussions with the Irish Government, GNI (2017) identified two key concerns: first, the future divergence between UK and EU gas regulations, and second, how Ireland will continue to comply with the EU Security of Gas Supply Regulation. There are two intergovernmental agreements between the UK and Ireland (entry into force 1993 and 2006) that require an agreed protocol for dealing with gas emergencies affecting UK and Ireland and this will remain in place post-Brexit. The wider issue is how will Ireland operate its gas network and ensure gas security in its new-found position of being an exclave that is highly dependent on a non-member state for its energy security (there are similar issues with electricity). There have long been plans to build an LNG plant at Shannon (and a second at Cork) and now there is talk of a gas pipeline to France, but while these options might improve physical security of supply that would come at a cost. There is also a feasibility study underway in relation to adding physical reverse flow to allow exports from Ireland. The more efficient outcome would be to allow the current situation to prevail, but any resolution that is reached as part of a broader agreement on the island of Ireland, may also have implications for the future regulation of IUK and BBL.

3.7 The National Balancing Point

The UK has a privatised and liberalised gas market that relies on gas-on-gas competition to link suppliers and consumers and to discover a daily gas price, in pence per therm, which is known as the National Balancing Point or NBP. The NBP originated in the late 1990s and is the longest-standing, and, until recently, the most developed and liquid gas hub in the European market. Because of NBP's history and liquidity it has also

served as a benchmark price for European gas, but that role has now been taken by the Dutch TTF price. Until relatively recently, the majority of gas traded on the continental market was dominated by oil indexed, long-term contracts, but EU regulatory reform has supported the movement toward gas-on-gas competition and trading hubs. At present, the centrepiece of this process is the implementation of Third Package and support for the construction of key infrastructures to remove physical barriers to the creation of a single European gas market as part of the IEM. It is worth repeating that this direction of travel is based, in large part, on the UK experience.

The resilience of the NBP is crucial for the UK's gas security. The latest BEIS/Ofgem (2017, 3) *Statutory Security of Supply Report 2017* states at the onset that: "Retaining a well-functioning competitive and resilient energy system after leaving the EU is a priority." It then goes on to state: "The UK is seeking a deep and special future partnership with the EU on energy. A well-functioning energy market is of vital importance for the European economy and the well-being of citizens. The UK will work to ensure that our future relationship is successful at ensuring efficiency of trade." Events during the 2017/18 winter demonstrate that the market is capable of sending price signals that increase supply, but there are also concerns that the loss of flexibility due to falling domestic production and increased reliance on medium-range storage, LNG and interconnector supply might result in greater short-term volatility in response to technical problems and increased demand due to weather events. Most large-scale, long-term buyers, such as the power generators—are able to use long-term contracts to hedge against such events, but smaller utility companies and industrial users might find themselves exposed to increased costs. There is also the view (Bros 2017) that post-Brexit the NBP may need to trade at a premium to TTF to attract gas to the GB market, but this depends on the nature of the UK's trading relationship with the EU's IEM post-Brexit. In short, gas will continue to flow, but it may be at a higher price to UK consumers than would have been the case had the UK remained within the EU.

3.8 Future EU/UK Gas Governance

It is widely understood in the EU that UK stakeholders have been influential in shaping and maintaining the current emphasis on creating a fully-functioning Internal Energy Market (IEM) for electricity and gas. However, membership of that market is linked to the EU's Customs Union and the jurisdiction of the European Court of Justice (ECJ). The current position of the UK's Conservative Government suggests that post-Brexit the UK will not be part of the Customs Union and will not be subject to the ECJ, and this suggests that it cannot be part of the IEM. Furthermore, the claim that Brexit is about reclaiming sovereignty suggests that the UK will have its own set of gas market regulations. This raises questions about future gas governance that have serious implications for Ofgem, as the regulator, and for the owners of gas infrastructure.

At present, Ofgem is a member of the Agency for the Cooperation of Energy Regulators (ACER) that was created by the Third Energy Package to further the progress of the single energy market. It ensures that market integration and the harmonisation of regulatory frameworks are achieved within the framework of the EU's energy policy objectives. The second institution is the Council of European Energy Regulators (CEER) that is a private association of European regulators which seeks to promote the interests of national regulators. The third institution is the European Network of Transmission System Operators for Gas

Table 6: Participation in EU Regulatory Bodies

	ACER	CEER	ENTSOG
EU Member State (e.g. France)	Membership possible	Membership possible	Membership possible
EEA (e.g. Norway)	Associate membership theoretically possible with EU agreement*	Membership possible	Associate membership possible with EU agreement*
Energy Community (e.g. Ukraine)	Associate membership theoretically possible with EU agreement*	Associate membership possible **	Associate membership possible with EU agreement*
Bilateral Treaty (e.g. Switzerland)	Associate membership theoretically possible with EU agreement*	Associate membership possible **	Associate membership possible with EU agreement*
WTO (e.g. Morocco)	Associate membership theoretically possible with EU agreement*	Associate membership possible **	Associate membership possible with EU agreement*

Note: * No such agreement has ever been adopted by the EU with any country; ** Under current rules, this would appear to be realistically possible only if the UK were to re-join the EFTA. Source: DG for Internal Policies (2017, 51)

(ENTSOG) whose role is to facilitate and enhance cooperation between national gas transmission system operators (TSOs) across Europe in order to ensure the development of a pan-European transmission system in line with the European Union's energy goals. At present, the UK members of ENTSOG are: Gas Networks Ireland (UK Limited), Interconnector UK, National Grid and Premier Transmission Limited (Northern Ireland). The BBL Company is a Dutch member and Norway has observer status. The role of ENTSOG is to develop the network codes that set out the rules for gas market integration and system operation and development, covering subjects such as capacity allocation, network connection and operational security. Thus, membership of both ACER and ENTSOG is critical in terms of shaping how the single gas market operates and evolves. The key question is what will happen to the status of the UK regulator and asset owners post-Brexit? Table 6 lays out the different ways in which countries can participate in EU regulatory bodies.

The UK Government's current negotiating position that it will not remain part of the EU's Customs Union or re-join the EFTA, but will seek a new trading relationship, creates significant uncertainty in terms of its ability to influence the future development of the IEM. A recent study by the Confederation of British Industry (2018, 60-63) that examined the potential sectoral impact of Brexit reached the following conclusions that are of relevance for gas security:

- Alignment with the EU energy and climate change rules will help achieve secure, affordable and low-carbon energy supply for customers.
- Barrier-free access and appropriate regulatory convergence with the Internal Energy Market will be important to ensure that the UK and the EU can continue to trade energy effectively.
- The UK's ongoing influence in key EU agencies and bodies would allow both sides to manage regulatory alignment and ensure the energy sector continues to flourish across Europe.
- The UK should ensure full participation with the EU ETS until the end of 2020, with at least equivalence thereafter, to help UK's efforts to decarbonise.
- In a rapidly changing world, a close relationship between the UK and the EU on energy and climate change objectives is in the interests of both sides.

The findings amount to a recommendation to maintain as much of the status quo as possible; however, an optimistic reading of Table 6 suggests that it would require an unprecedented level of agreement on the part of the EU to grant the UK anything other than observer status and even that would require a change to membership rules. Thus, if the Government persists with its current negotiating position, the best that the UK can hope for is 'access without influence,' being a 'rule taker', rather than a 'rule maker.' The UK has been a strong influence in favour of market liberalisation, but it is possible that without that influence future EU energy policy may move away from market-based solutions. The introduction of the notion of 'energy solidarity' is evidence of such a trend. The EU's position is that Brexit does not present a threat to the remaining Member States' energy security, but the same cannot be said for the UK. Furthermore, one must question how much sovereignty has been recovered if the UK is forced to maintain regulatory convergence—compliance with EU regulations—to guarantee frictionless access to the IEM?

3.9 Midstream Brexit Challenges

As noted at the onset, even without Brexit the UK's Midstream infrastructure faces significant challenges that result from rising import dependence, the consequences of the low carbon energy transition and the aging of assets. However, there can be no doubt that the uncertainty created by Brexit introduces a new set of concerns and complications. It is widely accepted that the UK's membership of the EU's IEM has enhanced energy security and benefitted consumers. This analysis suggests that the following issues must be considered during the Brexit negotiations and addressed in a future UK Gas security strategy:

- The need for a more holistic assessment of energy security that considers the importance of integrity of the offshore infrastructure on the UKCS and the onshore NTS and GDNs.
- The implications of greater reliance on LNG as a source of flexible supply to UK customers.
- The adequacy of the UK's gas storage capacity after the closure of Rough.
- The future status and viability of IUK and BBL as critical sources of flexibility and, in the case of IUK, an export channel to the continental European market.
- The future status of NBP relative to other European gas hubs, particularly TTF.
- The future of cooperation on gas security with the Republic of Ireland.
- The future governance of the UK's gas system and its relationship with the EU's IEM.

4. Downstream Security of Demand

The majority of studies of energy security focus on Upstream security of supply, while some consider the resilience of the Midstream infrastructure to deliver sufficient gas to customers.

But, more recently, as the low-carbon transition has gathered momentum, there has been increasing interest in security of future demand as a challenge to the integrity of the gas supply chain. However, investment in maintaining, let alone expanding, aging gas infrastructures is made all the more complicated by the possibility of significant future demand destruction leading to the stranding of assets (Bradshaw 2018). The UK's natural gas consumption peaked at 97.4 bcma in 2004—the year it became a net importer—and in the following decade average annual demand was around 94 bcm. After 2010 demand started to fall and reached a low of 66.7 bcm in 2014, 31% down on the 2004 peak, only to recover to 76.7 bcm by 2016 (BP 2017). Given the importance of winter weather conditions, it is natural to expect year-on-year variation in gas demand, but there are also other factors that explain the recent fall and recovery in demand. A combination of high gas prices and low carbon prices enabled coal to regain a share of the power generation market in 2013-14; but as gas prices themselves fell and the carbon floor price (explained below) remained in place, gas regained its share of the power market at the expense of coal. However, renewable generation—wind and solar—has also continued to grow faster than expected, changing the role of gas in the power generation mix and reducing the load on gas-fired power stations (with some being moth-balled).

Going forward, the decision to close all non-abated coal fired generation by 2025 may result in more robust gas demand, but much will depend on the growth of low-carbon generation, improvements in energy efficiency and demand reduction, and the pace of development of electricity storage technology all of which might depress demand for gas in power (see WWF/Sandbag (2018) for the case against increased gas power generation). One final key uncertainty is the rate of progress of nuclear new-build and the ability of existing nuclear power stations to remain in service. Further delays and early retirements might result in additional demand for baseload power generation that could favour gas. All this serves to highlight the importance of a whole system approach to gas security. But, as we shall see, the future of gas is about a lot more than gas in power, and it should also be remembered that the responsibility for decarbonisation falls on the entire economy, particularly heat and transport, not just the power sector.

4.1 The Current Role of Natural Gas

As noted at the onset of this report, at present, natural gas consumption in the UK is currently split three ways with power stations consuming 29.8% of total gas flows in 2016 (see Figure 7), domestic consumers (for heating and cooking) consumed 31.2% of total gas flow, and the iron and steel, non-energy use (feedstock) and other industries account for 9.9%. Overall, in 2016, natural gas met nearly two-thirds of UK domestic energy demand, including providing just over half the fuel for electricity generation (BEIS 2017d, 89). Thus, natural gas security is also critical to electricity security of supply, but it is also important to remember that two-thirds of gas consumption lies outside the power sector.

Nevertheless, the greatest attention has been paid to the role of gas in power because this is where the impact of climate change and air pollution policies have been significant in constraining the use of coal, and where the rapid growth of renewable, low-carbon electricity has started to impact. Further decarbonisation of the power sector will be required if the UK is to meet its carbon reduction targets, but the decarbonisation of domestic heat represents the most significant challenge (Woodman and Lowes 2018). While not all areas of the UK have access to pipeline gas, around 84% of UK households use natural gas for domestic heating, and over 60% have gas hobs and 30% gas ovens.[13] In the vast majority of instances this involves an individual household boiler that produces hot water for space heating and the provision of hot water. Although there are some district heating systems, it seems the case that UK households like the autonomy of having their own boiler, which is an important factor in considering alternative low carbon heating solutions. In industry, natural gas is both a feedstock and a source of heat, with many industrial processes requiring a level of heating that is best delivered by gas. In this context, the decarbonisation of power generation can be seen as the easiest first option.

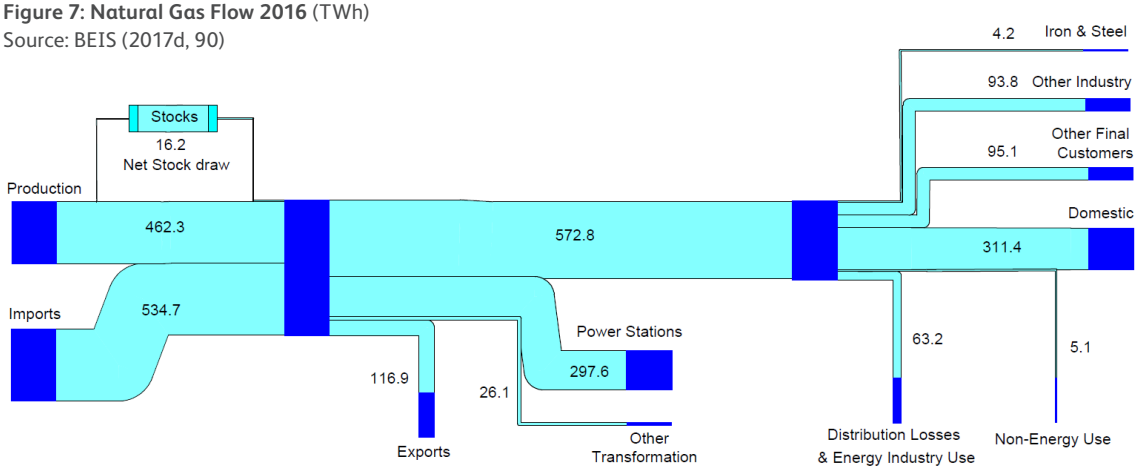
Figure 8 shows the changing power generation fuel mix since 1990, when natural gas was first allowed as a fuel for power generation. The so-called 'dash for gas' is clear to see, with the share of natural gas climbing from next to nothing in 1990—as it was considered too valuable to be used to generate electricity—to just over 34% in 2000. Thereafter, we see the impact of fuel-switching between gas and coal, with coal having a last gasp, before gas regains its position. The question is what happens next?

4.2 The Future Role of Natural Gas

In recent years there has been much talk of the role of natural gas as a 'bridge' to

13 http://www.ukoog.org.uk/the-natural-gas-coalition/gas-use-in-the-home

Figure 7: Natural Gas Flow 2016 (TWh)
Source: BEIS (2017d, 90)



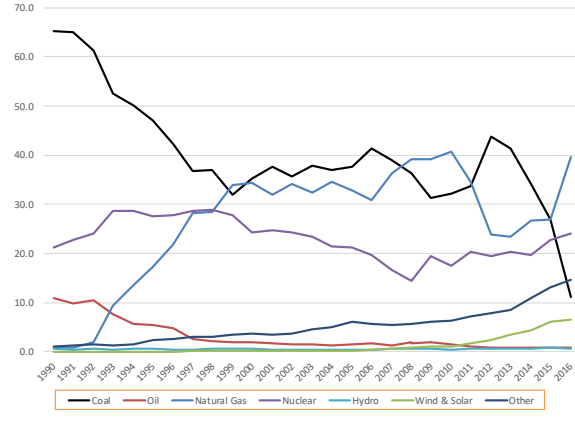
a future low carbon system. The rationale being that as natural gas emits about 40% the level of CO2 that coal does per unit of energy produced when used to generate power, does not produce SO2 and emits negligible fine particulate matter, switching from coal to gas can reduce greenhouse gases and, address the growing problem of urban air pollution. An earlier UKERC project (McGlade et al. 2014) explored the notion of the 'gas bridge' at a global scale and concluded that for certain regions—mainly those currently dominated by coal fired power generation—there was potential for gas to act as a bridge, but only for a limited period of time as deep decarbonisation would eventually require the removal of natural gas. It also demonstrated the importance of carbon capture and storage (CCS) in keeping gas in the mix.[14] The project did not explicitly consider the air pollution co-benefits of switching from coal to gas.

The global modelling approach was not appropriate for a detailed analysis of the UK situation and our more recent research uses two different models to investigate the sensitivities around GHG emissions reduction and future UK gas demand. The full details can be found in the UKERC report *The Future Role of Gas in the UK* (McGlade at al. 2016), while a more condensed version has recently been published in the journal *Energy Policy* (McGlade et al. 2018). Here I report the key findings of one of the modelling exercises, the aim being to highlight the range of possible outcomes and the key drivers influencing future gas demand.

The UK Times model was used to explore a number of different scenarios. Here I report on three of those scenarios: *Maintain* that assumes the UK sticks with its current climate change policies and carbon budgets that call for an 80% reduction in GHG emissions by 2050, over 1990 levels; *Maintain (tech failure)* that assumes that the 80% reduction has to be achieved without access to carbon capture and storage (CCS) technology; and *Abandon* that assumes climate change policy is downgraded in the late 2010s—perhaps in response to the outcome of Brexit—meaning limits on emissions beyond the 3rd Carbon Budget (2018-22) are not implemented. Figure 9 shows the resulting levels of future gas consumption.

As one might expect, abandoning the 2050 target allows more gas to be consumed (83% of the 2010 level), but the maintain scenario also results in a significant amount of gas in the mix (46% of the 2010 level). However,

Figure 8: Fuel Input for Power Generation
Source of data: BEIS (2017d)



14 More recent policy discussion seems to talk in terms of carbon capture, utilisation and storage (CCUS), both terms are used in this briefing.

Figure 9: Gas Consumption Over Time in Abandon, Maintain and Maintain (Tech Fail).
Source: McGlade et al. (2018, 461)

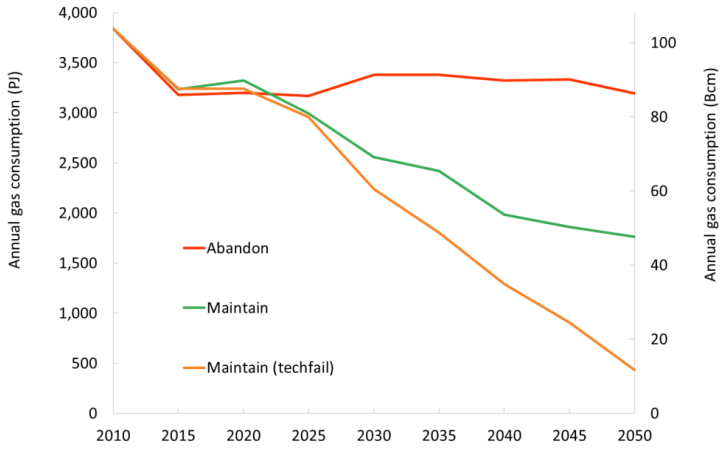
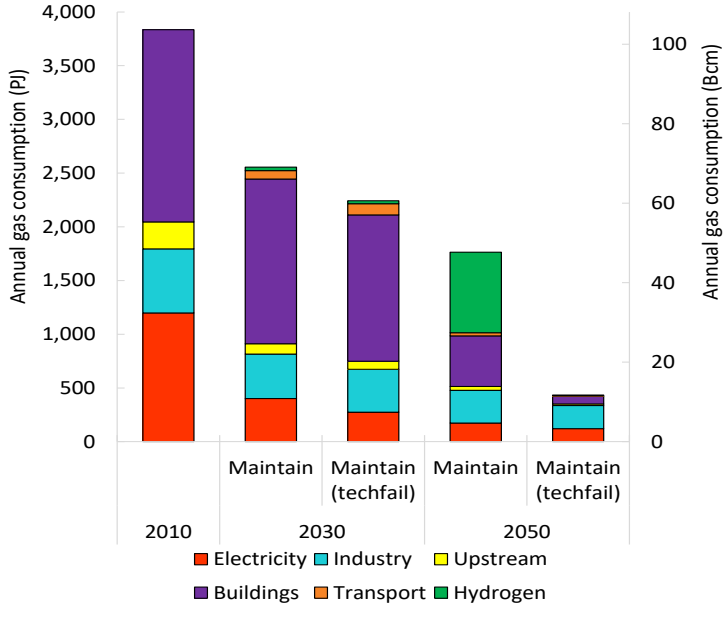


Figure 10: Sectoral Gas Use in Scenarios that meet the 2050 target.
Source: McGlade et al. (2018, 459)



without CCS gas consumption falls to around 12 bcm, a 90% reduction on 2010 levels. To understand these results, it is important to examine the role that natural gas is playing in the energy system under the different scenarios. Figure 10 shows the role of gas in 2016 and its predicted role under the two scenarios that meet the 2050 target.

The model results show a significant reduction in gas demand in power generation by 2030, and then between 2030 and 2050 the emphasis is upon reducing gas use in domestic heat (buildings). However, there is a significant difference between the two scenarios in 2050 and this is because under the *Maintain Scenario*, which has access to CCS, natural gas becomes the basis for hydrogen production to be used in domestic heating and transport. That option is absent in the *Maintain (tech fail)* scenario because of the absence of CCS, which is needed to store the carbon dioxide produced by the steam reforming of methane to produce hydrogen. In both scenarios there is still demand in industry and a modest amount of gas in power to provide back-up for renewable intermittency.

The findings of this analysis are clear, if the UK sticks with its current climate policy and carbon budgets this will constrain gas consumption, initially in the late 2020s in power generation, and then in the 2030s and beyond in buildings. But, if CCS is available there is an alternative future that uses natural gas to fuel a hydrogen economy and to decarbonise gas-fired power generation to support renewable generation.

4.3 National Grid's Future Energy Scenarios

The National Grid's Future Energy Scenarios (FES) provide an industry view of possible futures for natural gas in the GB energy system. As the owner and operator of the NTS they have an obvious interest in how

much gas is consumed in the UK. Their 2017 FES presented four scenarios: *Two Degrees*—where the UK's carbon reduction targets are achieved; *Slow Progression*—where low economic growth and affordability result in focus on cost efficient longer-term environmental policies; *Steady State*—a business as usual scenario with a focus on security of supply at a low cost for consumers; and, *Consumer Power*—a world with high economic growth where consumers have little inclination to become environmentally friendly. There is not the space here to explore the FES in detail, our major concern is what the various scenarios mean for future gas demand. It is noteworthy that only one of their scenarios—*Two Degrees*—meets the Government's 2050 target (the 2018 FES will have two scenarios that meet the target) .

Two Scenarios—*Steady State* and *Consumer Power*—show a modest increase in gas demand in the 2020s and then plateau at a slightly lower level; gas remains relatively inexpensive and, with a limited decarbonisation agenda, it is not challenged. Both scenarios retain over 70% of 2010 gas demand in 2050. The other two scenarios show significant reductions in future demand: *Two Degrees* because climate policy promotes a reduction in gas usage across the economy, but particularly in power and heat (2050 demand is 46.6% of 2010). In the case of *Slow Progression*, where economic growth is low, gas is relatively expensive, which promotes decarbonisation of power generation (2050 demand is 46.4% of 2010). The key drivers would appear to be the level of commitment to decarbonise power generation and the success in decarbonising heat (heat pumps replacing gas boilers, combined with improvements in insulation), conditioned by the ability and/or willingness to make the necessary investments.

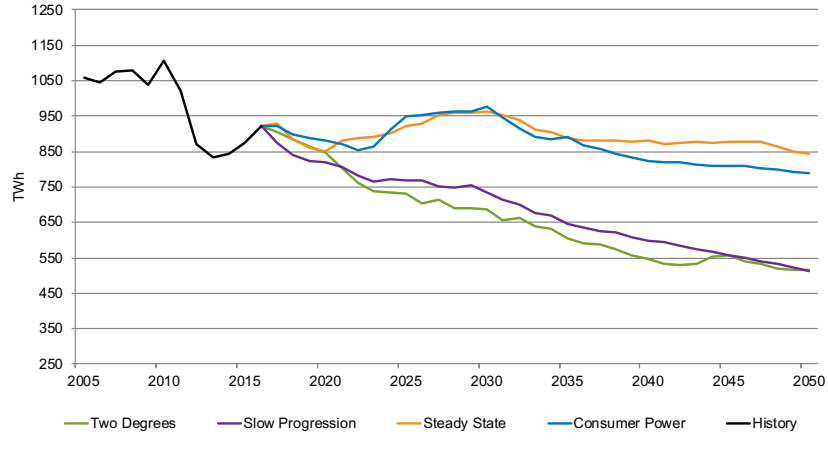
The FES 2017 also considers a number of sensitivities that are also part of their initiative on *The Future of Gas* (National Grid 2017a). Of particular interest is their 'Decarbonised Gas' analysis that explores using hydrogen for heating and transport, which parallels UKERC's *Maintain* scenario. In their sensitivity analysis hydrogen is produced from natural gas, in combination with CCS, providing heating for some cities. The analysis explores converting 17 cities, outside of those gas boilers would still be used for heating as the analysis is presented as an alternative to electric heating. The net result is that gas demand is comparable with the highest ever levels of demand in the early 2000s (130% of 2016 levels). Of this 55% is used for conversion to hydrogen, which provides 28% of total domestic heating demand by 2050. In addition, gas plus CCS provides backup for renewable intermittency, reducing the need for new nuclear capacity. This solution meets the 2050 carbon reduction goals, but the big problem is that the vast majority of gas demand needs to be met by imports. The current import infrastructure should be large enough to handle it; but, there would undoubtedly be increased concerns about upstream security of supply with such a high level of import dependence.

In early 2018 National Grid (2018, 2-3) published the findings of their research and consultations on the future of gas and amongst their key messages are:

- Through all of our analysis we are yet to identify a credible scenario that meets the 2050 carbon targets without gas.
- In all potential pathways to 2050, decarbonising gas and the gas networks can unlock new opportunities for the UK economy, improving air quality and reducing carbon emissions for many decades to come.
- Action is required now to remove the policy gaps and barriers to decarbonising gas to ensure that the gas market and networks evolve in the most effective way.

They point out that decarbonising gas has implications across the entire energy system and requires a whole energy system approach. As the operator of the NTS,

Figure 11: Future Gas Demand in FES 2017
Source: National Grid (2017a,)



National Grid has the difficult balancing act of meeting current challenges to gas security, while providing for new opportunities, such as the hydrogen economy and biogases, as well as Carbon Capture Usage and Storage (CCUS). They foresee a future of gas that requires: "a more flexible gas grid capable of flowing pure hydrogen, natural gas and blends of gases including hydrogen, natural gas and biogas in different areas; partnering a low-carbon electricity network." What their work makes clear is that 'business as usual' is not the future for the gas network and that while active experimentation is needed today, by the early 2020s the Government needs to provide clarity on its preferred decarbonisation pathway, meantime it is important that options are kept open with regards to the future of the NTS.

4.4 Other Views of the Future of Gas

There are a number of other analyses that have explored potential futures for natural gas. As the owner of the NTS, it is not surprising that National Grid should be exploring the sensitives around the future role of gas. The same is also true of those companies that own and operate the various gas distribution networks (GDNs) as they have an obvious interest in seeing gas remain part of the energy mix. They are the ones promoting the narrative around using the existing distribution network to transport hydrogen, made all the more possible by the replacement of iron pipes by polyurethane.

In 2016, KPMG (2016) produced a report entitled *2050 Energy Scenarios: The UK Gas Networks in a 2050 whole energy system*. The report was commissioned by the Energy Networks Association and KPMG worked in association with Kiwa Gastech, a company involved in the hydrogen sector. The study examined the cost effective and practical future alternatives for the decarbonisation of heat by 2050 with a particular focus on the future role of gas and its subsequent impact on gas networks. They developed four scenarios, all of which meet the 2050 decarbonisation target. They based their demand assumptions on the Gone Green scenario in National Grid's FES 2015. Their concern is not so much the level of future gas demand, but the consequences of the different scenarios for the GDNs.

Their first scenario was *Evolution of Gas Networks* in which gas was still the main heating fuel, but the majority of customers converted to hydrogen produced from natural gas (with CCS), transport was also mostly decarbonised, and the GDNs are mostly used for hydrogen distribution across the country. The second scenario was *Prosumer* where heat was decarbonised with a mixture of self-generating heat and storage and electric heating, the majority of transport was decarbonised and the GDNs were not used. The third scenario was *Diversified Energy Sources* where a mixture of different technologies was used in different areas of the country, heat was partially decarbonised with a mixture of biomass sources, heat networks, gas and electric heating, transport was partially decarbonised and the GDNs were only used in half the country. The fourth, and final, scenario was *Electric Future* in which heat was electrified and power generation was completely decarbonised, the majority of transport was decarbonised and the GDNs were not used. The *Evolution of Gas Networks* scenario was presented as the most technically feasible and most cost effective, followed by the *Diversified Energy* scenario. For the purpose of the current discussion we can note that decarbonised gas can remain part of the energy mix, but it requires the availability of CCS and it will also require considerable policy support from Government (more on this below). The most immediate requirement is a demonstration project.

The *H21 Leeds City Gate project* is being developed by Northern Gas Networks (2017) and aims to demonstrate the feasibility, from both a technical and economic viewpoint, of converting the existing natural gas network in Leeds to 100% hydrogen. The project participants have shown that: the gas network has the correct capacity for such a conversion; that it can be converted incrementally with minimal disruption to customers; that minimal new infrastructure will be required compared to alternatives; and, that existing heat demand for Leeds can be met via steam methane reforming and salt cavern storage (of CO2) using technology in use around the world today.

The *Liverpool-Manchester Hydrogen Cluster* seeks to build on the H21 study by developing a deliverable project that is cost effective and provides meaningful emissions reductions (Progressive Energy 2017). This project is a regional scale solution that maps onto the GDN owned and operated by Cadent. It leverages the existing industrial capacity in the region and proposes to reduce the carbon intensity of the GDN by blending hydrogen at 10-20% volume in the natural gas supply. This solution does not require customers to change their appliances. At the same time, hydrogen would be supplied to 10-15 industrial sites via a new pipeline infrastructure to allow combustion on high hydrogen/natural gas mixtures. The availability of hydrogen in the region also contributes to the decarbonisation of the transport sector. Finally, a low-cost CCS infrastructure is developed using existing natural gas production facilities and depleted fields in the East Irish Sea off the coast of Merseyside. To progress this vision, Cadent is leading the *HyDeploy* project that is carrying out live trials of natural gas blended with hydrogen at Keele University as the University owns and operates its own gas network.

All of these projects, and others not reviewed here, represent an initiative by the gas distribution industry to respond to the need to decarbonise gas.[15] Their proposition is that repurposing the existing gas networks presents the least cost option to decarbonising heat, and potentially transport. The proponents of the hydrogen option maintain it results in the least disruption for consumers, but it is dependent on the availability of CCS and requires strong government policy support. However, the decarbonisation of domestic heat is recognised by Government as one of the key challenges facing the UK's energy sector and many alternative pathways are now being considered that present an alternative to the incumbent, natural gas (see Lowes, Woodman and Clark 2018).

4.5 Decarbonised Gas

The current transition is necessitated by the challenge of climate change and the need to decarbonise the energy system. Thus, the first factor to consider in the context of Brexit is the Government's continuing commitment to the Climate Change Act (2008) and the associated carbon budgets. These policies are not a consequence of EU policy, in fact the UK's climate change policy is more ambitious in terms of outcome, though less prescriptive in terms of the pathways to achieving its targets. There remains all party support for the Climate Change Act, but it may be that a bad economic outcome from Brexit might lead to a reconsideration of the costs associated with energy system transformation. The result being relaxation of the carbon budgets, akin to UKERC's Abandon scenario, resulting in more unabated gas in power generation, but, potentially reduced enthusiasm for decarbonised gas.

The EU's Emission Trading System (ETS) was introduced in 2005 and is the central pillar of the EU's climate change policy. However, the ETS, in which the UK makes up 10% of the market, has been plagued with problems and in 2013 the UK Government introduced its own Carbon Floor Price (CFP) to supplement the ETS-generated cost of carbon to set a more predictable lowest price for electricity generators thereby incentivising low carbon investment. In 2014 the CFP was frozen at £18/tCO2 to limit the competitive disadvantage to UK business vis-à-vis the rest of the EU where the ETS carbon price was lower and also to reduce energy bills for consumers. In 2016 this freeze was extended to 2021. However, as demonstrated earlier, in recent years the CPF has been effective in driving coal out of power generation, and this has supported gas demand.

Because the ETS falls under the jurisdiction of the European Court of Justice, the UK Government's current 'red lines' would suggest that from 2021—assuming a 21-month transition period from March 2019—full UK membership of the ETS is unlikely. However, the UK Government has recently reiterated its commitment to carbon pricing. Given that the UK's policy on carbon pricing is more effective than the ETS at promoting decarbonisation, although reforms of the latter are underway and its current phase ends in 2020, it is safe to assume that some form of carbon price will continue in the UK beyond 2021. However, its precise nature and its relationship to the EU's ETS remain unclear. In their recent report the CBI (2018, 63) suggests that after 2020: "…, the UK should either continue its participation in the EU ETS, provided it maintains its influence on any future reforms and has access to the associated innovation funds, or establish an appropriate domestic approach, aligned with the EU system."

If we conclude that, whatever the outcome of Brexit, the UK government will remain committed to the Climate Change Act (2008) and will maintain policies that support a low-carbon energy transition, the question then remains what role might gas play in that future policy landscape? Previous UKERC research has criticised the various UK Governments of late for pursuing an implicit strategy of 'gas by default,' rather than 'gas by design.' The notion of 'gas by default' means that the gas sector is relied on to 'be there' when other elements of energy policy fail to deliver, without explicit policies to address the uncertainties facing the gas sector as a result of the low carbon transition. By contrast, a 'gas by design' approach would build on the situation presented above to ensure sufficient gas power generation and continued investment in the gas networks in the early 2020s, while putting in place a strategy to decarbonise the gas system and to retain the gas networks. Two recent Government Policy statements—*The Clean Growth Strategy* (BEIS 2017b) and *The Industrial Strategy* (BEIS 2017c)—provide an opportunity to assess the current Government's thinking in relation to the gas sector.

The *Clean Growth Strategy* considers three possible pathways beyond the Fifth Carbon Budget (2028-32): an electricity pathway (based on renewables and nuclear), a hydrogen pathway (using natural gas and CCUS), and an emissions removal pathway (sustainable biomass plus CCUS). Modest amounts of funding are identified to enable the gas networks to develop and demonstrate new technologies, as well as new operating and commercial arrangements. Given the importance of CCUS as an 'enabling technology' to two of these pathways, new funding is provided in this area. The UK Government has a chequered history in relation to CCS/CCUS, having cancelled a £ 1 billion CCS competition, at short notice, in 2015 (Oxburgh 2016). Now the Government plans to convene a CCUS Cost Challenge Taskforce that builds on

15 See for example, SGN's Oban and Hydrogen 100 projects: https://www.sgn.co.uk/Innovation/Innovation/

the success of the Wind Cost Reduction Taskforce. They will also create a new Ministerial-led CCUS Council with industry to review progress and priorities. Finally, the Government will spend up to £100 million from the BEIS Energy Innovation Programme to support industry and CCUS innovation and deployment in the UK. While these measures are welcome, some would see it as 'too little, too late' and it is unlikely to regain the momentum lost by the cancellation of the 2015 Competition.

The *Industrial Strategy* picks up the narrative and promises to explore: 'the long-term options for clean heating and the many potential uses of low carbon hydrogen' (BEIS 2017e, 45). Later this is linked to CCUS and the hydrogen economy, but the numerous references to energy are preceded by terms such as 'clean', 'smart' and 'affordable.' This is understandable, but it leads to a 'mind the gap' problem as the future of the gas industry is tied to technology that is not yet available (CCS/CCUS) as a possible pathway to a hydrogen economy in the 2030s. The problem is that there remains a policy gap in terms of sustaining the gas industry in the 2020s when unabated coal is scheduled to close, there is uncertainty over the status of nuclear power and renewables penetration is undermining the traditional business model for gas-in-power. One final factor to consider is that the use of hydrogen in heating could result in an increase in gas consumption, requiring investment in the midstream infrastructure and raising concerns about energy security.

4.6 Brexit and the Future Role of Gas

The current uncertainties around the future role of gas in the UK's energy mix pre-date the decision to leave the EU. The failure to deliver a 'gas by design' strategy is long-standing but is now complicated by uncertainties around issues like the future of carbon pricing and commitment to the Climate Change Act (2008). At the moment, the Government is committed to both, but a bad economic outcome from Brexit may change attitudes in the early 2020s. The Government's recent policy documents provide support for exploring a possible hydrogen pathway to decarbonising heat at the same time as exploring other heat decarbonisation options, and renewed support for CCUS; but these are not part of a comprehensive strategy that considers the challenges to the gas industry over the coming decade. This is strange when you consider that in 2016 natural gas provided 40% of the UK's primary energy! At present, the demands of Brexit are imposing a huge opportunity cost on the policy-making capacity of Government and the danger is that we will arrive at the end of the transition period in 2021 having missed opportunities to lay the foundations of a 'gas by design' approach that ensures the UK gas industry is able to respond to challenges in the 2020s associated with an aging infrastructure and growing import dependence, and is then unprepared to play a new role in the future low-carbon economy in the 2030s and beyond. The key upstream issues to consider in relation to future UK gas security are:

- The impact climate change policy and its associated carbon budgets on future gas demand.
- The commercial deployment of CCS/CCUS as it is critical to maintaining natural gas in the power generation mix and essential to a future methane/hydrogen decarbonisation mix.
- That the uncertainty over the future role of gas acts as a discentive to investment in the current infrastructure, which could result in increased technical failures and a lack of flexibility.
- The implications of any post-Brexit realignment of current climate change policy for the gas system.
- The urgent need to devise a medium-to long-term vision for the role of natural gas in the UK's future energy mix.

4. Conclusions: Brexit and Future UK Gas Security

This project has three objectives: first, to identify the key challenges facing the UK's natural gas market; second, to understand the role that EU policies and institutions currently play in the operation of the UK's natural gas market; and third, to identify the potential impact of Brexit and the key issues that should be addressed in a post-Brexit 'UK Gas Security Strategy.'

A combined supply chain and whole systems approach has been used to analyse specific aspects of the UK gas industry and to place it in the wider context of the UK's energy and climate policies. Table 7 provides a summary of the key issues and updates our previous analysis (Bradshaw et al. 2014) taking into consideration the potential impact of Brexit. Discussions at the UK Gas Security Forum and the conference on 'Future UK Gas Security' tended to see Brexit as a 'threat escalator' that made the existing challenges harder to resolve because it generates uncertainty at a time when critical challenges need to be addressed. With less than a year to go, we still lack clarity as to the nature of the UK's future trading relationship with the EU. The current Government position that the UK will be leaving the Customs Union suggests that the UK will also no longer be within the IEM and that it will no longer be able to influence the EU energy and climate strategies but will still have to accommodate them within any future trading relationship. Rather than repeat the details of the findings from each section in this report, this concluding section uses the notion of the energy trilemma, which still guides the UK Government's energy policy, to summarise the key findings.

The energy trilemma remains at the heart of the UK's energy policy and calls for secure supplies of energy (services) that are also affordable and environmentally sustainable. It is possible to map the three dimensions of the trilemma to identify a 'UK Gas Security Trilemma.'

The first dimension of the trilemma—energy security—is driven by increasing import dependency that will result from the continued decline of domestic production. The actual level of dependency will be determined by future demand, but it is clear that during the 2020s the UK will become increasingly dependent on imported sources of natural gas. Table 7 makes clear the key challenges that will result. At present, the UK is largely dependent on pipeline imports from Norway, supplemented with LNG imports from Qatar, with the balance being supplied by continental Europe via the two interconnectors. In the Future Energy Scenarios, National Grid talks of 'generic imports' which relates to an increasing level of imports needed to satisfy demand whose origins are unknown. During the 2020s it seems likely that Norway will be able to maintain current levels of supply to the UK, but more and more of future demand will have to be met either by increased imports from continental Europe or increased reliance on imported LNG. In both cases, there is sufficient infrastructure capacity to enable this; the uncertainties lie in relation to the UK's future trading relationship with the EU's IEM post-Brexit and future developments in the global LNG market. These uncertainties will be reflected in the price that consumers have to pay to attract gas to the UK. As noted in our previous work (Bradshaw et al. 2014) the UK is effectively globalising its gas security and will be increasingly exposed to developments in the global LNG market

Table 7: Supply Chain Assessment of UK Gas Security 2018

	Geopolitics	Dimensions	Issues
Upstream	Security of Supply	• Resource Base • Technology • Investment	• Future UKCS production • Future NCS exports to GB • Growing EU import dependence • Trends in the global LNG market • Prospects for Biomethane & bioSNG • Prospects for shale gas
Midstream	Security of Transport (Transit)	• Processing • Transportation • Storage	• UKCS infrastructure • Utilisation of LNG Terminals • Availability of Domestic Storage • Status of Interconnectors to EU • Flexibility of the NTS • Status of Gas Distribution Networks • Status of NBP • EU/UK gas governance
Downstream	Security of Demand	• Power Generation • Industrial Use • Domestic Use	• Future role of gas in UK energy strategy • Intermittency and Capacity Markets • Carbon Floor Price & ETS membership • Carbon Capture (Usage) & Storage

and in the European gas market, with little ability to influence either. It is in this context that the UK Government maintains that it is important to maximise gas production from the UKCS, whilst also exploring for shale gas onshore.

The second dimension of the trilemma relates to the affordability of energy (services). At present, UK consumers benefit from a competitive gas market, but that is dependent on the ability of the midstream infrastructure to transport gas from sources of supply to points of consumption to balance the market. The analysis in this report suggests that this is the area facing the greatest challenges and where Brexit creates the greatest uncertainty. As noted by the former DECC (2015, 6), these challenges relate to: rising import dependency, increasing variability in demand as a result of renewable power generation, and an aging infrastructure. Put simply, the gas system is being asked to move gas in new directions over shorter periods of time, which is demanding greater flexibility from a system that was essentially designed to move gas onshore and south from fields in the North Sea. The loss of the Rough storage facility means that the GB market no longer has a domestic source of seasonal storage. This means that the market must now rely on a modest amount of medium-range storage, some flexible supply from Norway, the LNG terminals and the interconnectors to bolster supply in time of technical failure and/or increased demand. The events of this past winter suggest that the market is capable of sending the necessary signals to secure more gas, but at a price.

There are also wider energy system changes that need to be considered. The closure of unabated coal powered generation by 2025 will mean a loss of storage and flexibility in the electricity market that has implications for gas demand. Equally, the increased reliance on renewable generation exposes the UK to weather-related supply challenges. It is clear that the cold snap at the beginning of March 2018 would have been much more challenging had coal-fired generation not been available and the cold weather accompanied by a lack of wind. The availability of coal and the strong winds meant that the amount of gas used for power generation was significantly lower than it would otherwise have been. Equally, the reliance on LNG as a source of flexible supply is problematic as it is dependent on how much 'gas is in the tank' at the time of a gas emergency. Furthermore, the terminals themselves are subject to technical failure and it takes weeks, not days, to secure additional LNG supplies, often at high cost. The final source of flexibility, the interconnectors, face regulatory challenges and an uncertain future due to Brexit and ongoing changes in the gas market. Furthermore, their ability to flow gas into the UK can be constrained by congestion on the NTS. This suggests that from an energy security perspective the resilience and flexibility of the NTS, and associated offshore and onshore pipeline infrastructures, should be considered in any assessment of UK gas security.

The events of this winter suggest that the UK market may be increasingly exposed to short-term price volatility and there are concerns that this will only increase if the market is reliant on the interconnectors and LNG supplies to provide flexibility. The current debate has focused on the closure of Rough and whether or not the Government should incentivise investment in new seasonal storage. There are mixed opinions among industry players, but the position of BEIS and Ofgem is clear, they do not see a case for intervention as the market will send the necessary signals to support investment in storage if it is needed. However, should Brexit increase the friction of trade with the EU—more likely through regulatory problems than tariffs—then this position may need to be revisited. The reality remains that a gas supply emergency and high prices are political problems, not a market failure. More generally, the challenge is that the midstream will continue to require additional investment simply to maintain its existing capacity, let alone provide new sources of flexibility and resilience. It is difficult to justify such investments when the future role of gas in the UK remains uncertain.

The final element of the trilemma relates to environmental sustainability. This is not just about climate change and decarbonisation, but also the wider environmental impacts of the gas supply chain. Analysis makes clear that if the UK is to remain within its legally binding emission targets it must constrain future consumption of natural gas. The UK is in a unique position in that it has already significantly reduced the carbon intensity of its electricity system as a consequence of the 'dash for gas' in the 1990s. Now it is seeking to legislate the removal of coal from power generation by 2025. This means that, from 2025 onwards, gas will be the most carbon intensive source of power. There is no longer a case that gas can be a bridge to a low carbon future by replacing coal, as coal will soon be gone. Rather, gas can only maintain a role in the UK's energy system through decarbonisation. This is reliant on the availability of CCS/CCUS technology to remove and store the emissions associated with gas power generation and also to enable the use of natural gas as a feedstock for a hydrogen economy. There are other sources of decarbonised gas—biogas and the use of renewable energy to produce hydrogen—but,

for the moment at least, these remain small scale solutions. The problem is that without access to CCS/CCUS natural gas demand must fall significantly between now and 2050, which provides little incentive to invest in new infrastructure.

Furthermore, the investment timelines are such that decisions will need to be made in the early 2020s to deliver the decarbonised gas system that will be needed in the 2030s and beyond. If one assumes that the UK will keep its commitment to the Climate Change Act (2008), then Brexit is not an issue here as the UK's climate ambitions exceed those of the EU. In fact, one could argue that post-Brexit the UK could devise a policy framework better suited to its national needs. However, there is little evidence that the UK Government has a sense of urgency in relation to the development of CCS/CCUS.

A final factor to consider is that the highly polarised debate around shale gas development, and more recently the events of this winter, have highlighted the extensive role of natural gas in the UK energy mix with many suggesting that the only long-term solution is to reduce its usage. At the same time, the shale gas debate has heightened concerns about the fugitive emissions associated with the natural gas supply chain. While there is a logic to this argument, it does nothing to maintain the flexible, adequate and resilient gas supply chain that will certainly be required in the 2020s.

Today natural gas is the most important source of energy for the UK, but future gas security could be challenged by the medium-term prospect of increasing import dependence, due to declining domestic production, and the longer-term prospect of falling demand due to climate change policy. This creates a degree of uncertainty that makes it difficult to justify investments in the supply chain to maintain existing capacity, let alone deliver new sources of flexibility. Brexit only serves to exaggerate the level of uncertainty. Gas will continue to flow post-Brexit, but consumers may have to pay more for it to guarantee security. Longer term, it is not the outcome of Brexit that poses a threat to UK gas security, but the failure of the Government to provide a clear roadmap for the role of gas in the low carbon transition.

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Warwick Business School
The University of Warwick
Coventry CV4 7AL UK

T +44 (0)24 7657 5820

E michael.bradshaw@wbs.ac.uk

W wbs.ac.uk