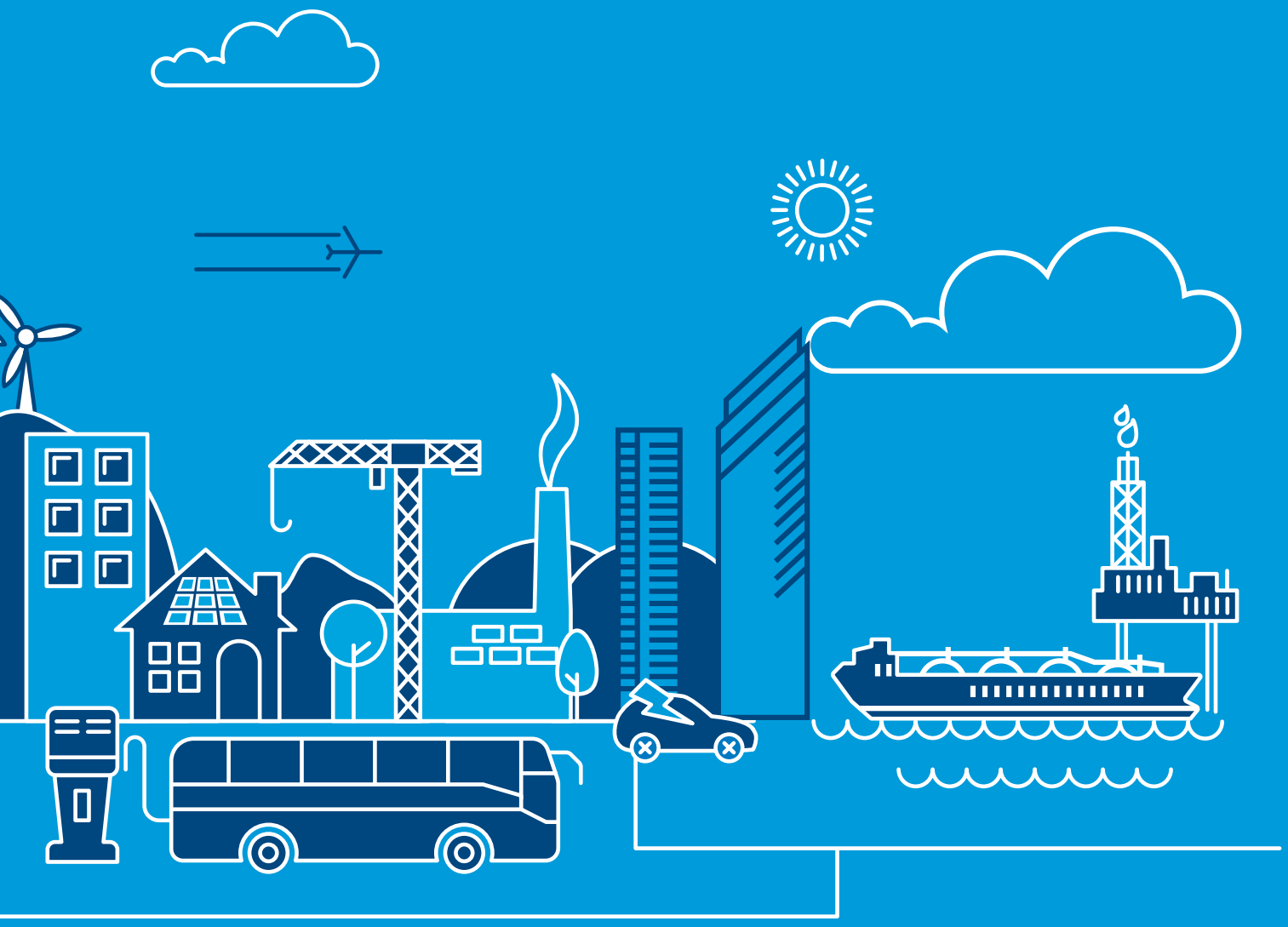
March 2018

nationalgrid

The Future of Gas

How gas can support a low carbon future



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01 Foreword

by Nicola Shaw CBE UK Executive Director

It gives me great pleasure to introduce The Future of Gas: How gas can support a low carbon future. We launched the Future of Gas programme in November 2016 to develop insights on the future role of gas and the gas transmission system, in order to support and inform the UK's transition to a low carbon economy. This document captures extensive research and stakeholder engagement[1], building on our July 2017 Progress Report, and presents our view of the future of gas. We would like to thank everyone who has contributed to the programme, in particular those listed at the end of this document.

Our purpose at National Grid is to bring energy to life, in its simplest form that means getting the heat, light and power that customers rely on to their homes and businesses. But life also means supporting the communities that we are part of and live amongst to support the economic growth and sustainability of wider society. This purpose forms the foundations of the Future of Gas programme.

Gas plays a crucial part of our energy mix. Eight out of ten of us rely on gas for home heating. In fact around 60,000 new domestic connections are made to the gas networks each year. Around 30 per cent of Britain's gas goes to industrial and commercial use where gas is not only a heat source but a feedstock. Gas-fired generation makes up around 40 per cent of the electricity generated. Our gas transmission infrastructure delivers three times the annual energy delivered by the electricity networks.

Gas is important for us personally, for our economy and our industrial competitiveness. However, the current world needs to evolve if we are to meet our climate change goals in the future. This was the reason for starting our programme on the future of gas.

You can see lots of evidence of how public policy and innovation has driven change in the electricity space. We've made great progress on decarbonising power but wider transport, heat and industrial use need to be tackled next. These were areas that were recognised as important but harder to reach parts of the UK economy in the Government's Clean Growth Strategy published last year. Unabated natural gas use must decline if we are to meet our carbon targets but all roads look difficult and complex with challenging political decisions needed. So how do we move forward?

We created the future of gas programme to understand the views of stakeholders, to test the capabilities of our network and understand the risks and opportunities for gas going forwards. Since November 2016 we have met with over 150 stakeholders, through our own workshops, bilateral meetings or at various industry fora. We have sought to understand new technology development and the significant body of work being produced on the new technological options.

We have also tried to test ourselves at National Grid. We developed divergent views of the future with high electrification and decarbonised gas sensitivities. These were published in last year's Future Energy Scenarios and explored further in this document. Each sensitivity was designed to meet our 2050 targets but also there to test our thinking about what could be the ends of the envelope for the transmission network with highest and lowest credible demands for gas and how we might operate a network in those situations. This document includes those divergent views of the future, the triggers and signposts that we would be looking for and the potential actions within each one. We have also set out the themes that you told us were the most important to you and should be to us. These are Decarbonisation, Whole Energy System and Future Networks and Markets.

There is no silver bullet. Until some of the new technologies get tested, commercialised and deployed, such as hydrogen and carbon capture utilisation and storage, we have heard a clear message from stakeholders not to shut down options too early. This does not mean gold plating, but ensuring the gas market and networks evolve in the most effective way for consumers, based on an evidenced view of the future. For National Grid and the gas distribution companies, it means understanding the role of the gas networks in supporting new innovations and where those UK assets can be adapted and repurposed in the optimal way where it's required.

Decarbonising gas and the supporting networks can be used to meet the UK's 2050 carbon targets and support the UK's Clean Growth Strategy. They can unlock future opportunities to develop the hydrogen economy, utilise biogases on the gas grid, and develop heat networks to reduce emissions. Coupled with the development and deployment of carbon capture use and storage, this creates a platform for the UK to be a world leader in climate action.

We look forward to continuing to work with policy makers, regulators, industry and stakeholders to progress the actions needed to ensure that gas is able to fulfil its crucial role in providing secure, low cost and low carbon heat, power and transport in a key partnership with electricity in a decarbonised world.

The conclusions we have developed as a result of our Future of Gas programme take into account all the great work being progressed in the energy sector and explain what we believe the future for gas and the gas transmission system to be. We are excited to share our view of the future of gas with you.

02 Introduction and key messages

The Climate Change Act 2008 requires the UK to have reduced carbon emissions by at least 80% by 2050 from 1990 levels. This needs to be achieved while maintaining security of supply and providing energy at lowest cost to consumers. The UK can lead the world in taking climate action, with businesses and society coming together to deliver the ambitions set out in the Government's Clean Growth Strategy.

The gas market and the gas networks play an important role across the UK economy today, providing heat and fuel to homes, businesses and industries across the country. Eight out of ten homes currently use gas for heat[2], and the gas networks deliver three times the energy delivered by the electricity networks[3]. The demand for heat is not going down, with around 60,000 new consumers connecting to the gas network every year, and crucially 96,000 gas connections have been made since 2007 specifically to address fuel poverty[4].

During the Future of Gas programme we engaged with around 150 stakeholders to gather evidence, discuss, understand and stress-test the role of gas in the UK's transition to a low carbon economy. **Through all of our analysis we are yet to identify a credible scenario that meets the 2050 carbon targets without gas.**

It is clear that **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.**

We have identified a spectrum of opportunities to support the low carbon transition. **Action is needed 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.** At one end of the spectrum, we have identified options for infrastructure that can be effective in all pathways to 2050. At the other end, potential innovation, technology or policy shifts would require developing the UK's current infrastructure in a different way.

We have considered the scale of the challenge against three key themes:

- the decarbonisation of heat, transport and industry;
- whole energy system; and
- future networks and markets.

This document sets out our view of potential solutions to the challenges, including what National Grid will do and our recommended actions for policy makers. We have also examined the crucial role of Carbon Capture, Usage and Storage (CCUS).

The ability to keep options open is key, where doing so is economically sensible in the short term, while governments, regulators and the energy industry work together to investigate solutions and make critical decisions regarding the most effective evolution of the energy system. Decisions on decarbonisation need to consider all impacts on the end consumers, such as practicality, cost, disruption and acceptability. It is also essential to understand the interactions decarbonising gas creates between other sectors, such as heat, transport, industry and electricity generation, and the significant implications of those for gas and electricity distribution and transmission networks.

Decarbonising gas has implications across the energy sector, **so a whole energy system approach is needed to address the energy trilemma of energy security of supply, affordability and sustainability.** Consumers will continue to need access to secure, affordable energy for heat, power, transport and industry. Energy infrastructure will need to connect new sources, such as renewables, hydrogen and biogases, in order to meet our future energy needs. The energy system needs to be agile to coordinate across these different energy forms. For example, gas has a particularly important role in meeting the peak heat requirements of end consumers and in balancing the volatility of renewable electricity generation. Whole energy system thinking is fundamental to achieving this critical energy partnership.

Maintaining an attractive GB gas market and an accessible, agile gas network is a worthwhile investment. As supplies from the UK Continental Shelf (UKCS) decline, maintaining an attractive GB gas market will allow security of supply to be provided at best value for consumers. While the future is uncertain, there are options to support this transition period with least regrets, such as supporting the health of the energy network assets. The gas market and networks are increasingly supporting new opportunities for the hydrogen economy and biogases, as well as for CCUS. **There are already exciting innovations and projects being proposed across the UK.**

The UK is in a strong position to show international leadership and innovation in the transition to a low carbon economy, while delivering new industrial opportunities. Through the commitments in the UK's Clean Growth Strategy, new opportunities are quickly emerging to show world leadership in technology, infrastructure and expertise in new areas such hydrogen and biogases, CCUS and decarbonised heat. UK companies are leading the way, with proposals for buses that run on biogas and hydrogen-powered cities, to industrial clusters capturing and abating their carbon emissions. UK oil and gas infrastructure and expertise provides a unique advantage to export technology,

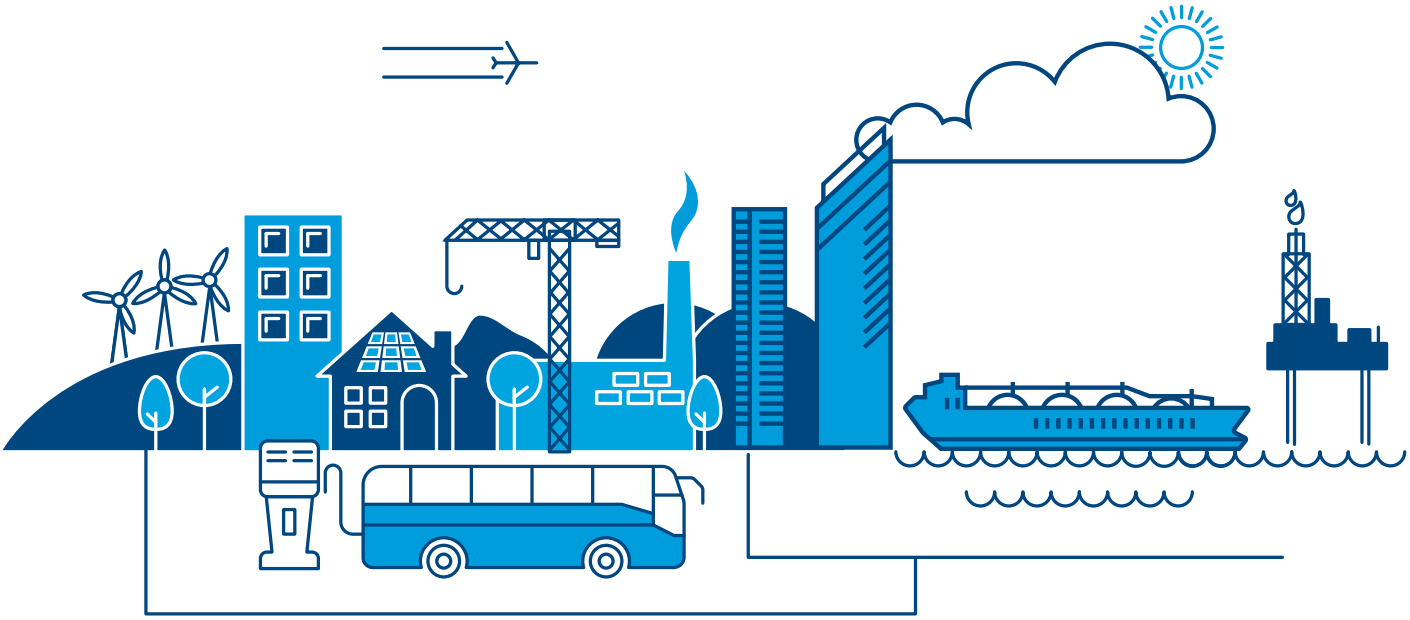
skills and services from this industry. Some of the UK assets that have provided oil and gas to the nation can be re-purposed to permanently and safely store carbon dioxide, given the global attraction of the UK's geology for this type of permanent carbon storage.

We believe that the UK can lead the world in decarbonisation. Gas and the gas networks can play a key part in achieving this, and in supporting new opportunities across the economy. Gas will be a major part of the solution to decarbonising heat and transport, improving air quality, supporting a strong UK economy, and delivering security of energy supply.

Policy makers, regulators and the industry have the opportunity to come together now to create a smooth transition to decarbonised gas, which will support not only the low carbon transition, but a low carbon future that delivers for all consumers.

How can gas and electricity be critical partners in a low carbon world?

- partnering gas generation with renewable generation to balance the electricity network;
- making increasing use of excess renewable generation, when available, to produce hydrogen via electrolysis;
- continuing to provide energy across GB through cost-effective seasonal agility and supporting daily demand peaks at low cost, avoiding over-investment in generation that could rarely be used;
- continuing to provide UK industry with an affordable source of heat and an important feedstock for manufacturing processes;
- investing in a more flexible GB gas grid, capable of flowing pure hydrogen, natural gas, and blends of gases including hydrogen, natural gas and biogases in different areas; partnering a low-carbon electricity network;
- producing hydrogen at scale, using natural gas alongside Carbon Capture, Usage and Storage (CCUS), for the decarbonisation of heat, industry, and transport;
- decarbonising buses and commercial vehicles using a mix of biogases and natural gas in the short term, in tandem with the electrification of cars, making significant inroads into air quality improvements; and
- developing world-leading carbon transportation and storage facilities, leveraging more than 100 years of carbon storage capacity and a world-class oil and gas industry to help store it.



03 A summary of our Future of Gas programme

The engagement programme to inform our thinking about the future of gas has been extensive, to ensure we have sought, heard and taken account of the views and expectations of a wide range of stakeholders. The diagram below illustrates how the Future of Gas programme used those inputs alongside our expertise to shape our view and arrive at the themes, recommendations and actions set out in this document.

Inputs to our programme	Workshops with stakeholders	Bilateral Meetings	Research	Conferences	Internal National Grid expertise
What we heard	The scale of the challenge to meet 2050 carbon targets	Our stakeholder priorities	Current and future technology and innovation activity	Potential policy opportunities	
Outputs in this document	Our view for gas out to 2050	Potential scenarios without gas in the future	Policy recommendations and timelines	Actions for National Grid to meet stakeholder expectations	

Since publishing our July 2017 Progress Report, we have continued our conversations with stakeholders to test and develop our understanding of their view of the future, to explore our emerging thinking with them, and to consider the important future role of gas and the National Transmission System (NTS) in more detail.

November 2016:
'Future of Gas: A Transmission Perspective'[5] document and Customer Seminar[6] launched the Future of Gas programme.

February and March 2017:
Workshops[7] on what the future could hold, including barriers, risks and challenges – themed around heat, supply, industrial demand, gas and electricity interactions.

July 2017:
'Future of Gas: Progress Report'[8] provided an insight into our discussions with stakeholders. It explained that gas has a vital role to play in the decarbonised UK future.

September 2017:
Workshop[9] to seek feedback on our progress; this confirmed broad agreement with our beliefs about the future and captured opinions on this emerging thinking to help us to shape the next phase of our work.

October 2017:
Building on the detail in the July 2017 Progress Report, we published three website articles[10] that set out three views of what the future of energy might look like and the roles that gas and the gas network could play.

October and November 2017:
We ran workshops at the National Grid Future Energy Scenarios[11] events and as part of National Grid's programme to consider "Shaping the Future of Gas Transmission"[12], exploring elements of the future of gas, the implications of the Clean Growth Strategy, and the future role of the NTS.

November 2017:
Sponsored a discussion facilitated by Baringa Partners, and alongside Eurogas and ENTSOG (the European Network of Transmission System Operators for Gas) reflecting on the future of gas in Europe[13]. The event included gas industry participants from across Europe.

March 2018:
The Future of Gas: How gas can support a low carbon future published setting out our view for gas out to 2050, policy recommendations and actions for National Grid.

In addition to the above we have met with individual stakeholders, engaged through industry forums and roundtable discussions, and participated in conferences. We have explored which aspects of gas supply and the transmission system are important to businesses and supply chains now, and how they anticipate their needs changing.

All of these engagement activities, combined with research and our internal expertise have enabled us to develop the timelines, actions and policy recommendations detailed in section 5.

Shaping the Future of Gas Transmission

We have worked with our stakeholders to understand their priorities for the Gas Transmission System, now and into the future. The stakeholder priorities that will shape the Gas Transmission System of the future were shared in January 2018[14] and will be further refined over the coming months. Engagement with our stakeholders will be central to the creation of our business plan submission to Ofgem and we will provide details of this collaborative approach in the spring.

Stakeholder priorities

Industrial and Domestic consumer priorities …

I want to use energy as and when I want

I want an affordable energy bill

…are delivered through our stakeholder priorities…

I want to take gas on and off the Transmission system where and when I want	I want all the information I need to run my business, and to understand what you do and why	I want to connect to the Transmission System	I want the gas system to be safe
I want you to protect the Transmission system from cyber and external threats	I want you to leave a positive impact on our communities and the environment	I want you to facilitate the energy system of the future – Innovating to meet the challenges of an uncertain future	I want you to be efficient and affordable

…these were developed by consulting with

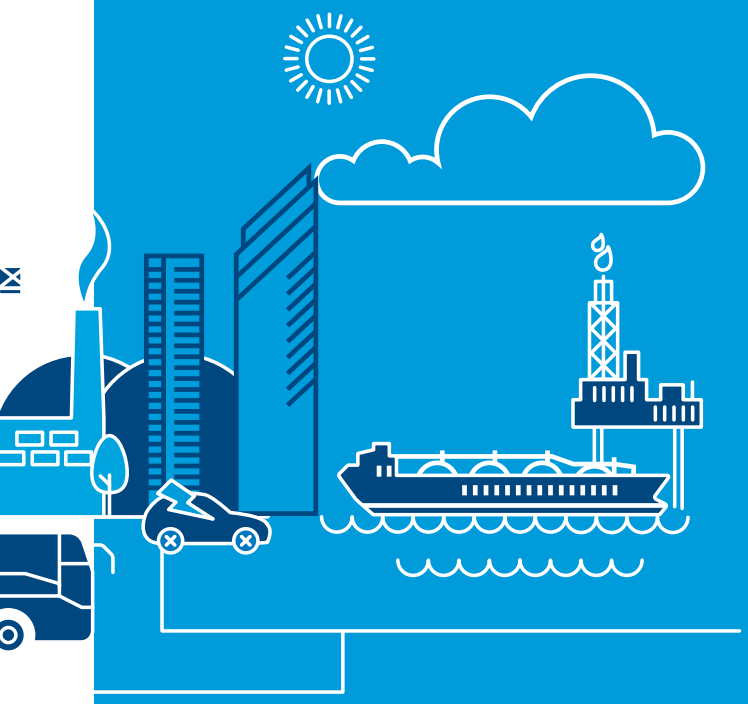
Consumers | Landowners | Other networks | Customers | Think tanks and academics | Government | Industry bodies | Interest Groups

National Grid's Future Energy Scenarios (FES)

National Grid publishes FES annually, setting out potential pathways to the future. In the rapidly changing energy landscape it is important that we continually check that our scenarios are a credible representation of the future. This helps us to understand and be responsive to the needs of our stakeholders as policy, technology, the economy and society evolve.

In the 2017 FES and in our July 2017 Progress Report we introduced possible high (Decarbonised Gas), low (High Electrification) and mid-case (Two Degrees) demand levels for gas across three very different views of the future. We have tested the boundaries of the NTS by considering how it might need to operate in each of these worlds.

We have enhanced our scenarios for 2018 after engaging widely with our stakeholders and drawing on our own experience and insights. We will share further information on the FES website[15] when available.



Gas Future Operability Planning (GFOP)

The aim of our GFOP document is to describe how the changing energy landscape and changing requirements may affect the future capability and operability of the NTS out to 2050.

GFOP assesses the impacts on our network of a range of views of the future articulated in FES. It aims to set the direction for solutions, not prescribe them, across codes, services and assets. We will continue to work with all interested parties to make sure that the right commercial options, operational arrangements and physical asset investments are considered across the NTS, building on the conclusions of the Future of Gas programme.

GFOP will be published quarterly and will focus on topics that are important to the gas industry, such as the impact of gas-fired electricity generation on the operability of the NTS, as gas plant is increasingly used to balance intermittent electricity generation. After each publication we will host webinars and events to gather your feedback and views on what we should investigate next.

We have already started this debate with our stakeholders at a variety of industry forums, and look forward to continuing this.

04 The impacts of the Future of Gas sensitivities

We used the three different gas demand sensitivities developed as part of FES 2017, all of which meet the UK's carbon reduction targets, to support our Future of Gas programme.

1. **Low demand case – High Electrification**
2. **Mid demand case – Two Degrees**
3. **High demand case – Decarbonised Gas**

We tested the boundaries of the National Transmission System (NTS) by considering how it might need to operate in each of these divergent views of the future. During October 2017 we published three articles on our Future of Gas website[16], describing the energy landscape within each pathway.

We have summarised the sensitivities below. The following page provides an overview of the role of gas under the two divergent views of low gas demand (High Electrification) and high gas demand (Decarbonised Gas).

High Electrification

This sensitivity adopts an ambitious approach to the electrification of heat, decarbonisation of transport with electric vehicles and hydrogen fuel cells, and a very high roll out of renewable generation.

In this sensitivity electricity provides the majority heating needs of residential and commercial properties but peak heat demand is supplemented by gas boilers and there are some high temperature industrial processes where gas will still be required.

Achieving this sensitivity will require considerable government support and intervention.

Two Degrees

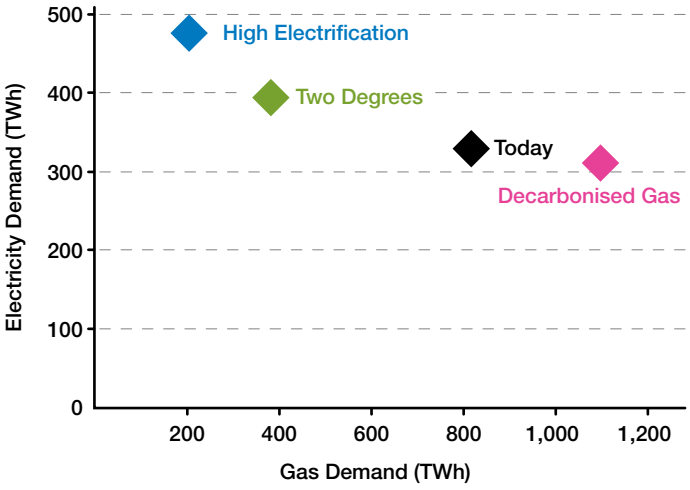
This is one of our core Future Energy Scenarios. The 2050 carbon reduction target is met through a cost optimal approach across electricity, transport and heating. CCS-enabled generation is deployed along with nuclear and renewable technologies. There is electrification of heat, although supported by more green gas, reducing the total requirements for electrification in order to hit the 2050 target.

Decarbonised Gas

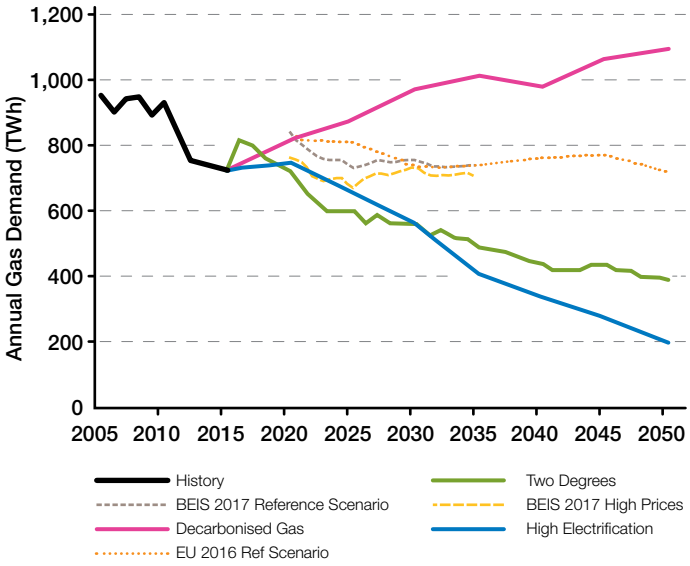
This sensitivity meets the 2050 carbon reduction target without a wholesale switch to electric heating. Heating in some cities is provided by burning hydrogen rather than natural gas. The hydrogen is created from natural gas using a process that allows carbon to be captured, leaving a fuel with very low net carbon emissions. Using this low carbon fuel means that heating can be decarbonised without a large scale roll out of heat pumps. Outside converted cities, the majority of consumers can continue to use natural gas. CCS is essential for this sensitivity to be achieved, both in hydrogen production and at gas fired power stations.

This sensitivity also sees hydrogen being used for transport and a large deployment of gas fired generation with CCS supporting a high roll out of renewable capacity, without the need for nuclear generation.

Comparison of gas and electricity demand in 2050 in the FOG Sensitivities



Gas demand to 2050 in the FOG sensitivities



High Electrification

Whilst annual demand is lower, gas still has a critical role in a High Electrification world:

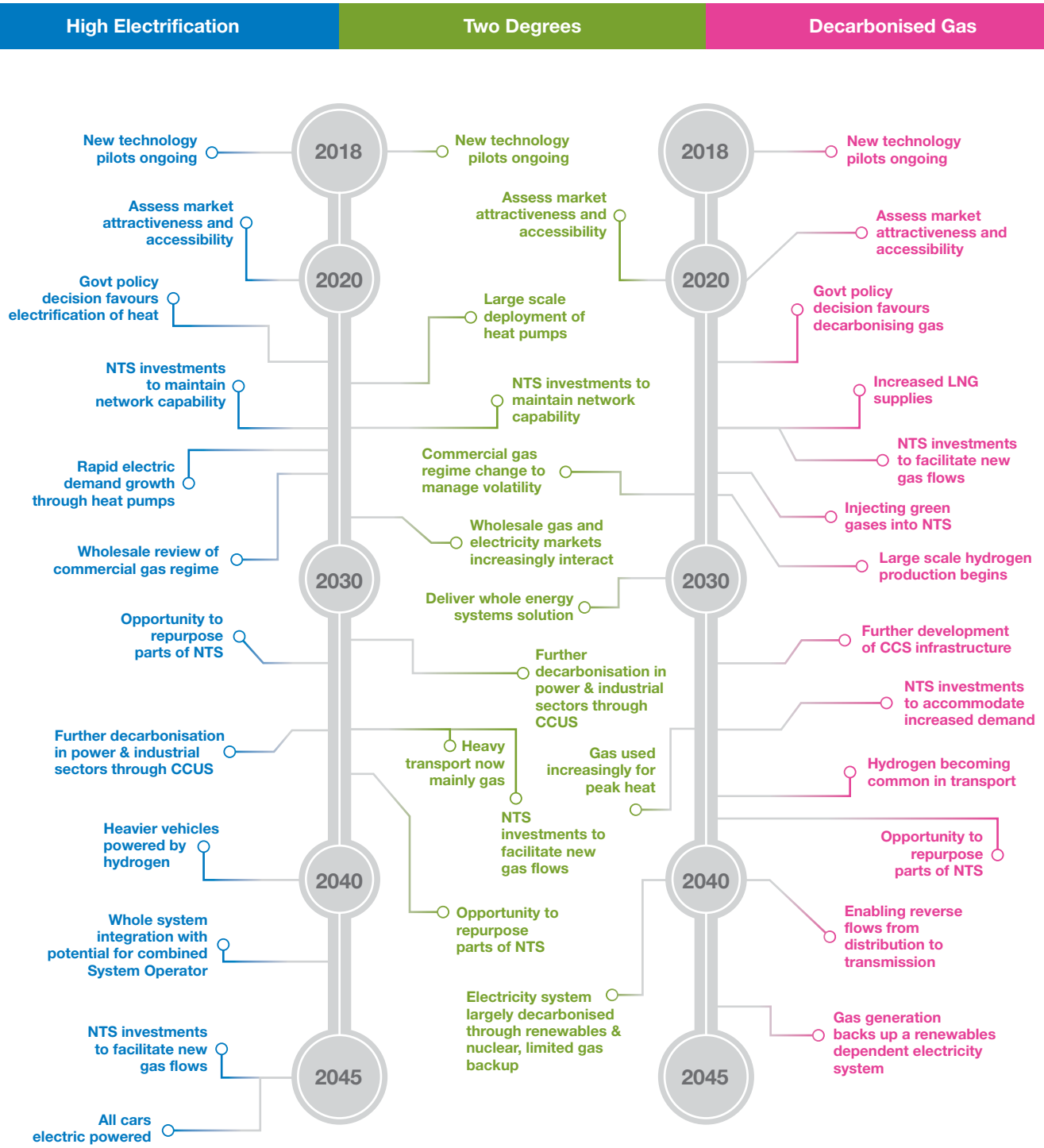
- Although heat pumps will be the heating technology of choice, gas will be used in hybrid heat pumps, as peak heat demand will be supplemented by output from a gas boiler.
- Electric vehicles will dominate the private car market. However, HGVs are powered by hydrogen gas fuel cells, the hydrogen being generated by electrolysis and transported using a network.
- Power generation is almost completely decarbonised but 21GW of gas with Carbon Capture and Storage is needed to support the intermittency of renewables.
- Gas is still required for industrial processes such as steel or glass making where high temperature heat is still needed, or where natural gas is used as a raw material.
- Gas demand would reduce from 880 TWh to 200 TWh in 2050.

Decarbonised Gas

Hydrogen created from natural gas is the key contributor, allowing the heat and transport sectors to contribute towards the long-term green ambition:

- As well as hydrogen, other green gases such as biomethane and bioSNG play an important role outside the converted cities where the majority of consumers continue to use natural gas.
- Use of greener gases for heat means that heating can be decarbonised without a large scale rollout of heat pumps.
- Heating in some cities is converted to hydrogen to meet the decarbonisation challenge. This is produced from natural gas via Steam Methane Reformation.
- This sensitivity maximises the use of gas and therefore does not include nuclear generation, this means that power generation includes 43 GW of gas with CCS and also supports the intermittency of renewables.
- Gas demand would increase to 1,100 TWh/year.

How could the decarbonisation road-map look to 2050 in our sensitivities?



What this could mean for gas markets and networks

Gas is used for winter peaking, but there is a need to revise our market rules, tools & asset use to meet the needs of our customers in this changing energy market landscape.

Gas will still play an important role if the sector can attract imports, innovate to meet customer needs and become more responsive to the electricity market.

In a gas based future, change for transmission is incremental, however the gas regime will need to adapt and invest to facilitate new supply and demand technologies.

Using the sensitivities to understand the impact on the network

We have used these sensitivities as a basis to understand the challenges our network could face in wide-ranging supply and demand scenarios, and to start considering the right mix of actions to tackle the challenges that may arise. The diagram on page 12 shows what we would see happen under each sensitivity and illustrates areas of possible focus for National Grid.

Full details on the actions can be found in section 5 (under the "What National Grid will do" headings).

Our analysis provides a snapshot of the possible impacts the different pathways will have on the gas market and network. Assessing the correct course of action to take as we navigate the low carbon transition is a complex process, as issues can be approached in multiple ways. Options might include amending regulatory frameworks (e.g. the Uniform Network Code, and/or our Licence), changing processes, investing in our assets or repurposing our network. Any proposal needs to have considered a multifaceted approach (including safety, policy, regulation, economics, engineering and systems) while also dealing with the underlying uncertainty.

By considering the potential actions in each of our Future of Gas sensitivities, we highlighted two distinct areas for us to develop further:

1) Actions which were in all sensitivities

Based on our analysis, there are a significant number of potential actions in all three versions of the future. These actions are the right things to do now and we are committing to undertake more detailed work with industry stakeholders to identify specific actions towards decarbonisation. We look forward to discussing an industry change plan with stakeholders in the coming months.

2) Actions which would be needed in specific sensitivities

Given the uncertainty which exists today around future technology development and deployment, we identified actions which would be needed only if specific circumstances became reality. To understand which pathway GB is heading towards, and be ready in time to prepare for it, we have developed a series of signposts to look out for, out to 2050. We are committed to working with stakeholders to inform an enhanced, more agile and integrated change plan, in order to understand when a particular action has been triggered and bring forward proposals for the industry.

Are there potential scenarios without gas in the future?

In developing our view for the future of gas, we have also considered what you would need to believe for a future with no gas and no gas networks.

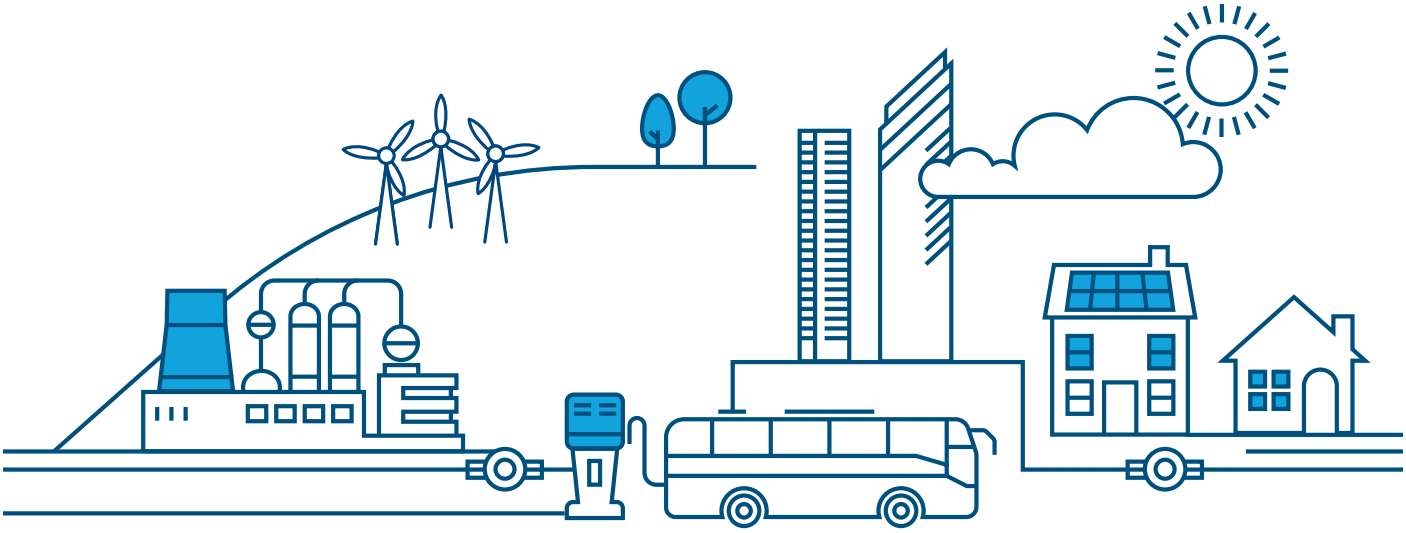
Meeting the UK energy needs without gas or a gas network is an enormous challenge. The gas networks deliver three times the energy delivered by the electricity networks. During 2016/17 the total gas demand across the year was 884TWh compared to 284TWh of electricity demand over the same period[17].

A future without gas would require significant changes to be made to meet the needs of domestic heating, industrial uses of gas and balancing the electricity system. Through our work, we have identified no credible scenarios without gas due to the many roles that it plays across the UK economy.

The scale of the challenge to replace gas in domestic heating, industry and electricity balancing

No gas for domestic heat	Government would need to be willing to drive change through a consistent, long term national policy to move the 8 out of 10 homes currently using gas towards an alternative such as electric heat pumps that would require significant upfront investment and ongoing increased energy costs. The public would have to accept these increased costs and the disruption involved in changing their heating system. Significant advances in heat technology and domestic thermal efficiency[18] would be needed to ensure that home heat can be maintained at the levels that people have come to expect and solutions are suitable for different housing types and ages. There would need to be a national rollout strategy for low carbon heat, converting 20,000 homes a week, from 2025 to 2050, to an entirely electric heat source with no hybrid (gas/electric) heat pumps. Based on energy prices over recent months, reliance on an entirely electric heat source would be significantly more expensive than hybrid or gas based systems. Considerable investment would be needed in the electricity transmission and distribution networks, and in electricity generation (including removal of gas fired plant), to support peak heat demand levels. Some form of seasonal, economically viable energy storage would be required, particularly for meeting winter demand. The highest recorded gas demand, in January 2010, is 450mcm (approximately 4.95TWh).
No industrial consumption of gas	Annual industrial and commercial demand for gas was 234.8TWh in 2016[19]. There would need to be an effective, economically viable alternative established for high temperature industrial processes, and an alternative to gas where it is currently used as a raw material in manufacturing processes.
Power generation and electricity system balancing without gas	An effective mechanism for balancing the electricity network would need to be developed in the absence of gas fired plants providing flexible generation and black start[20] capability at short notice.

05 Key themes to consider for the future of gas



In our July 2017 Progress Report, we committed to develop a view of what we believe the future could hold, based on what we have seen, heard and considered. Building this view has enabled us to evolve our thoughts on what National Grid needs to do as a result, and develop a number of recommended actions for policy makers. This section will cover these areas in more detail.

The scale of the decarbonisation challenge should not be underestimated, particularly in decarbonising heat. The concepts, proposals and suggestions below are intended to help meet these challenges in the most pragmatic way.

This section is divided into three key themes:

1. **Decarbonisation** of heat, transport and industry
2. **Whole Energy System**
3. **Future Networks and Markets**

For each theme, we have set out:

- the context and the scale of the challenge, with our view of potential solutions;
- a summary of what National Grid will do, including our view of the right things to do now and how we plan to continue the conversation with our stakeholders, including working with them to develop our business plan for the Gas Transmission System of the Future;
- the key signposts that would trigger us to take further action[21];
- our public policy recommendations; and
- how the timeline for policy decisions and action could emerge.

In developing the public policy recommendations, we recognise the need to achieve affordable and secure supplies of energy, and have considered the requirements and aims set out in national policy, including:

- the UK Government's Industrial Strategy[22], Clean Growth Strategy[23], and air quality plans[24];
- regional and local energy strategies, such as those developed by the devolved governments[25] and city mayors[26]; and
- Ofgem's new strategy for regulating the future energy system[27].

Together, these policies aim to drive growth in the UK economy as we decarbonise. Innovation will be key to decarbonisation, helping the UK to establish itself as a world leader in the low carbon transition, and capturing the national and international opportunities for the UK economy by leading developments in technologies, services and approach. Resource has been dedicated to early stage innovation but focus is needed on large scale demonstration and commercialisation to drive cost reductions needed ahead of deployment.

"While the move towards clean growth is clear, oil and gas remains one of the most productive sectors of the UK economy, supporting 200,000 jobs directly and in the supply chain."

HM Government, Industrial Strategy: Building a Britain fit for the future (November 2017)

Given the criticality of this technology in meeting the 2050 carbon targets in the most cost effective way, we have also included our views on Carbon Capture, Usage and Storage (CCUS).

5.1 Decarbonisation of heat

The challenge:

This is the most difficult area to decarbonise for a number of reasons, in particular because of the amount of energy required but also the direct impact on the end consumer in terms of change, infrastructure and cost. Currently 80% of the UK's 26 million homes use gas for heat[28], and this is responsible for over a quarter of current UK carbon emissions. 80% of current housing stock will still be in use in 2050[29]. If decarbonisation of heat is to be successful, around 20,000 homes per week for the 25 years from 2025 to 2050 will need to move to a low carbon heat source. That will need considerable coordination and communication, commitment of resource, a reliable supply chain and willingness of the end consumer to change. National Energy Action recently highlighted that the decarbonisation of heat could put an additional 2.6m homes into fuel poverty[30]. However, it will probably not be easy to persuade consumers to actively pursue a low carbon alternative to gas heating which is significantly more expensive, disruptive and potentially less effective.

"The decarbonisation of heat is arguably the biggest challenge facing UK energy policy over the next few decades."

Ofgem's Future Insights Series – The Decarbonisation of Heat (November 2016)

The potential solutions:

It looks likely that, instead of a single solution to decarbonising heat, a combination of solutions will develop including decarbonised gases such as hydrogen and biogases, alongside electric heat pumps, Combined Heat and Power facilities (CHP); and district heat networks. Improvements in energy efficiency will also play an important role. Investigations into all of these options are ongoing, with considerations including the cost, the age, type and ownership of properties, and the geographical location.

Hydrogen for heat is gaining momentum and we believe that hydrogen will play a role in the future. It is seen as an attractive option for meeting the decarbonisation targets due to the potential lower cost and level of disruption compared to other routes. In 2016, KPMG reported the cost of decarbonisation via conversion to decarbonised gas (including hydrogen) at around a third of the cost of full electrification, largely due to its ability to manage inter-seasonal demand fluctuations[31]. Many gas distribution networks have already embarked on ambitious hydrogen projects, including Leeds H21, HyNet NW and Hydeploy.

Our Decarbonised Gas sensitivity built on the Leeds H21 project and showed that 2050 carbon targets can be reached by using hydrogen for heat in major cities, with contributions from biomethane and bio substitute natural gas (bioSNG) for use alongside natural gas in rural or off-grid areas. Crucially in these projects, CCUS will be required because the large scale production of hydrogen is based on the reformation of methane, a process which requires carbon to be captured and stored as the hydrogen is produced.

"The least disruptive way to decarbonise the majority of domestic heating is likely to be through using the existing natural gas network to deliver hydrogen instead of methane."

Policy Exchange, Small Modular Reactors: The next big thing in energy? (January 2018)

As an alternative, there are two main routes to electrify heat – heat pumps and hybrid heating systems, with heat pumps being favoured currently. Heat pumps use energy very efficiently. We are expecting a significant amount of hybrid heating systems to be used, which consist of a heat pump supplemented by a gas boiler. In this case there would still be a crucial role for gas in delivering peak heat requirements on colder days, even if annual gas demand is much lower[32].

High electrification is likely to be more expensive, and more disruptive in terms of within-building infrastructure, thermal efficiency requirements, and electricity network reinforcement. Peak electricity demand is currently up to 60 GW, but peak winter heat demand is 350 GW. Electrifying heating would therefore require enormous increases in generating capacity and electricity network infrastructure, much of which would lie idle in the summer when heating is not needed. Using the gas system has the potential to reduce the volume of generation and reinforcement work required.

What National Grid will do:

Collaborating to deliver stakeholder priorities

Stakeholders have told us that heat needs to be decarbonised in the most affordable, convenient and least disruptive way. They consider that technological development is required to enable consumers to use alternative heating methods, while utilising existing assets and infrastructure which is likely to represent good value for the consumer. Stakeholders want National Grid to facilitate the energy system of the future while innovating to meet the challenges that uncertainty would bring.

We believe that the gas system will play a critical role in the decarbonisation of heat, so we plan to be active in its development. In addition, we will innovate and facilitate others' innovation, creating opportunities for the NTS and the wider industry through the transmission of biogases and hydrogen, supported by CCUS. Therefore, we plan to increase our activities associated with pursuing a decarbonised future for the NTS. This will include:

- exploring the creation and storage of biogases in further detail through our sponsorship of the Carbon Connect Future Of Gas work;
- exploring possible different hydrogen market models and what they would mean for the operation of the gas system; and
- studying the impact of increased hydrogen levels on our assets, to determine the potential role of the NTS in a hydrogen economy.

Continuing the conversation

In addition to the actions above, we will:

- work with the gas distribution networks to support their various hydrogen projects;
- participate in European forums to ensure that our view for heat is compatible with the wider interconnected markets;
- enhance our analysis of a decarbonised future by exploring the role the gas system has to play in our Future Energy Scenarios 2018; in line with the latest industry developments; and
- understand the interaction of our markets with emerging frameworks such as CCUS and hydrogen.

Triggers for potential future work

In the event that any of the existing (or new) hydrogen projects (such as Leeds H21, HyDeploy or HyNet NW) reach implementation stage, we will need to consider the:

- specific impacts on our network and market in terms of demand dynamics and the associated operability requirements; and
- implications for our 1 in 20 peak planning standards, in light of the differing energy contents of hydrogen and methane.

In the event of a High Electrification pathway, we may see a decline in the numbers of consumers utilising gas, which would prompt us to:

- review the ongoing affordability of the network and the impact on our customers under the existing charging regime;
- consider whether the potential decommissioning or repurposing of specific NTS assets is a realistic and cost effective option; and
- consider the best approach to managing a diminishing gas market, given the impacts on the UK economy.

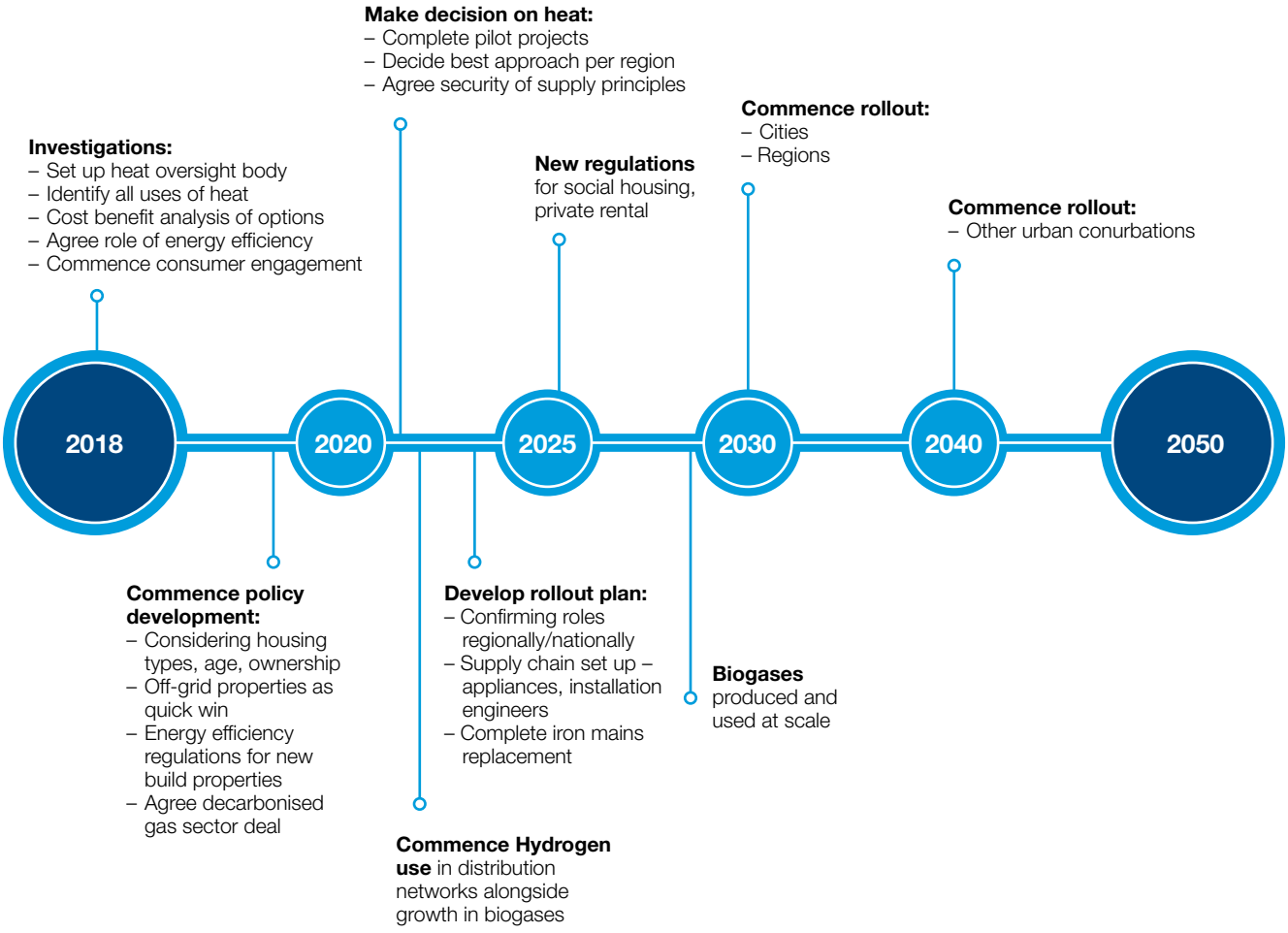
Policy recommendations:

We welcome the commitment from the Department for Business, Energy and Industrial Strategy (BEIS) to achieve a clear and shared understanding of the potential, as well as the costs, benefits and implications of different pathways, for the long term decarbonisation of heat. Significant levels of innovation will be required to allow technologies to be scaled up. Therefore, we agree with BEIS' commitment in the Clean Growth Strategy that the work is needed in this Parliament to set up decisions in the first half of the next decade about the long term future of heat. However, the timescales and process for subsequent decision-making remains unclear. We agree with stakeholders that active experimentation is needed today to demonstrate and de-risk the various pathways to inform and deliver clear policy decisions in the early 2020s.

Our recommendations for the decarbonisation of heat are that:

- the Government provides clarity on its preferred pathway as soon as possible, in order to give industry the confidence to invest. Decisions are needed in the early 2020s to meet the 2050 targets. Publishing a timeline for public policy decision making on heat would be helpful in the meantime;
- while there are some benefits to decisions being made, communicated and rolled-out regionally or nationally, we recommend a UK-wide oversight body be established to ensure overall efficiency, cost effectiveness and fairness. The oversight body would be responsible for:
  - coordinating the right time to commence engagement with the consumer on heat decarbonisation. It currently does not form a part of the public narrative in the same way that decarbonisation of transport does. Too early and there are no solutions to offer; too late and scale of the roll-out is unassailable and emissions targets will not be reached;
  - considering the optimal solutions in terms of their impact upon, and acceptability by, the end consumer, both in terms of disruption (inside and outside of the home) and cost (due to fuel poverty implications and UK industrial competitiveness);
  - making decisions on who should pay for the transition, the innovation required to get there, and for the likely increase in ongoing energy costs associated with decarbonised heat, owning and implementing any associated frameworks; and
  - working with regional and devolved authorities to ensure the right solutions in the right areas.
- the Government and regulators continue to support investment into further research and testing of the role of green gases. This will help to ensure that decisions about the decarbonisation of heat are based on full consideration of the costs and practicalities of all available options.
- options are kept open with regards to the future of the NTS until the pathways are clear, to support a range of future energy outcomes.

Potential timeline



5.2 Decarbonisation of transport

The challenge:

Transport accounts for 40% of UK energy consumption[33] and 26% of UK green house gas (GHG) emissions[34]; therefore decarbonising transport with gas (and electricity) must be an early priority. It is more straightforward than heat, in part because it is already underway and in part because vehicles are changed far more often than consumers change their heat source. While the future for transport is likely to be multi fuel for several decades, transitioning heavier vehicles to natural gas from diesel, alongside cars to battery electric will make significant air quality and carbon improvements in the short term.

We are witnessing an increasing air quality debate in the UK and the population are becoming increasingly concerned. A 2016 report from the Royal College of Physicians[35] attributed 40,000 deaths per year in the UK to poor air quality levels. We have seen recent announcements that the UK will ban the sale of new petrol and diesel cars from 2040, with the Scottish Government pledging a phase out across Scotland by 2032. And most recently, the UK Government has announced its intention to end diesel-only trains being used on Britain's railways by 2040.

Tremendous progress is being made, with motor manufacturers increasingly focusing their efforts on electric or hybrid cars, but the commercial vehicle fleet also has a part to play. The 120,000 HGVs on UK roads represent about 5% of vehicle miles, but consume around 25% of road diesel, making them responsible for around 16% of roadside NOx[36]. Although the UK Government's Automotive Sector Deal confirms support for electric vehicles through investment in charging infrastructure, plug in car grants and a hydrogen transport programme, there remains no clear direction on haulage, public transport, marine, or air transport, where electrification is a far less attractive option.

At the same time, low carbon infrastructure is lacking, which may impact cross border haulage as other countries decarbonise their trucks. There are currently less than 50 natural gas filling stations in the UK[37], with the majority of these being private facilities not available for open use. Given that the majority of gas transportation infrastructure already exists, it would not be a major undertaking to add additional public filling stations.

Many European countries have already progressed this, for example in Italy the number of Compressed Natural Gas (CNG) filling stations is more than 1000[38], with more than one million natural gas vehicles in circulation[39]. In Ireland, Gas Networks Ireland (GNI) is planning a €75m investment to roll out up to 70 filling stations for gas vehicles, focusing on commercial transport and haulage, including within Dublin Port which is due to become operational by the end of 2018.

There is a risk that if the UK does not act, its limited gas refuelling infrastructure will begin to become a blocker for international freight and logistics companies which are expected to utilise the economic and environmental advantages of new dedicated gas vehicles when they enter the market in 2018.

The potential solutions:

While passenger cars and light commercial road transport is likely to rely on electricity and potentially hydrogen, future fuels for other forms of transport will differ with gas set to play a significant role in decarbonisation.

HGVs typically have a short ownership period which provides an opportunity for an early, quick win through gas. Gas is the only solution available today to begin decarbonising HGVs. When compared with the newest EuroVI diesel HGVs, using natural gas reduces NOx emissions by 41%[40], particulate emissions by up to 96%[41], well-to-wheel GHG emissions by 84% (if using biomethane)[42], and noise by around 50%[43]. They are also commercially viable today, with significant total cost of ownership benefits for fleet operators. The NTS can provide access to the cheapest, cleanest and most reliable source of gas and minimise the need for costly and energy-intensive compression.

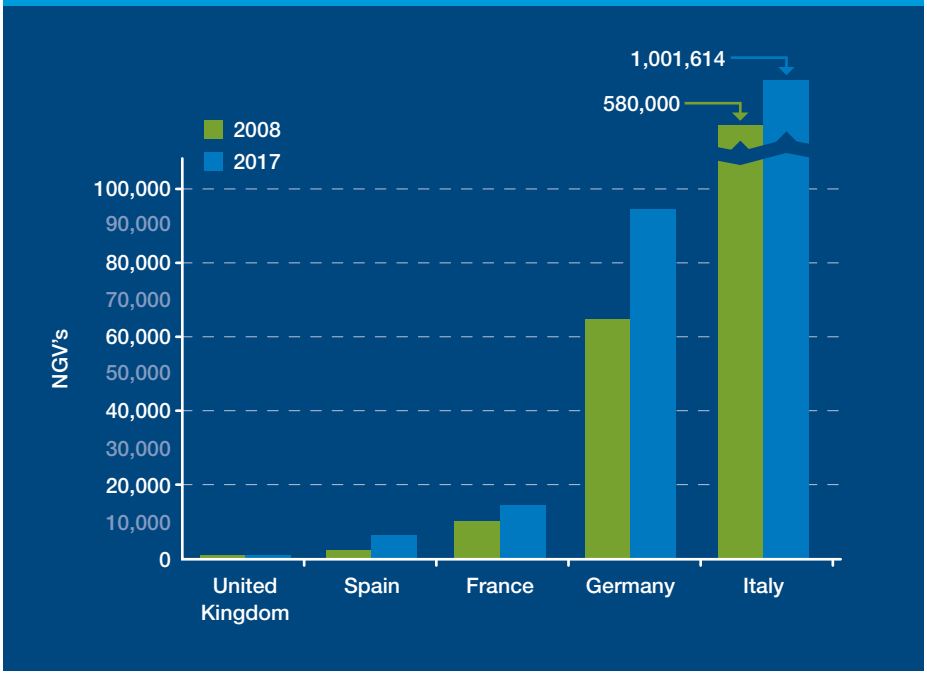
In the maritime sector, Liquefied Natural Gas (LNG) also looks set to play a significant role. With global sulphur limits reducing from 2020, LNG looks set to provide a cost effective and well developed low carbon alternative to the highly polluting heavy fuel oils typically used today. National Grid's Isle of Grain LNG terminal is developing a facility that will allow the use of LNG in the marine and industrial sectors. The facility is expected to go live in 2019/20 and offer open market accessibility to support market growth.

"The preferred solution from an environmental compliance perspective is the use of LNG as a fuel[44]."

International Maritime Association

We are also seeing a number of governments and local authorities investigating the role that hydrogen can play in buses and medium sized service vehicles. In Germany, there are investigations into hydrogen in trains but Japan is leading the way with an ambitious hydrogen vehicle roll-out programme that will source hydrogen produced from the gasification of Australian coal, combining this process Carbon Capture and Storage in order to capture emissions. The pure hydrogen would then be shipped to Japan in tankers specifically designed for transporting liquid hydrogen.

Natural Gas Vehicles (NGV's) in Selected EU Countries



What National Grid will do:

Collaborating to deliver stakeholder priorities

Our stakeholders have told us that gas has a key role to play in decarbonising transport, that it is already happening and it should be a priority. They think we should support the building of infrastructure for refuelling and the associated policies. We believe that gas represents the best opportunity to start decarbonising heavier vehicles today, so we plan to be active in its development. This will include:

- taking a leading role with the gas vehicle sector to provide accurate and up to date empirical information that is needed to enable policy makers to commit to a diesel-to-gas transition;
- continuing with work to understand the role of the NTS in this area. The intention is to understand customer needs in developing our approach to transporting high pressure gas supply to forecourts, realising the benefits of NTS-connected refuelling stations. This will include identification of the optimised locations in GB for fuelling stations connected to off the NTS and exploring the opportunities for infrastructure investments at refuelling stations to support station owners/operators;
- proving the potential for Project CLoCC (our Customer Low Cost Connections project) through connecting pilot customers, facilitating quicker, lower cost connections to the NTS;
- actively participating in GB and European forums to ensure gas is recognised as a viable solution for transport as future emissions standards are set; and
- continuing our investment in our LNG facilities to support on and offshore market growth, including both a small vessel loading facility and expansion of our road truck loading facility.

Continuing the conversation

We are engaging with a wide range of stakeholders to explore the practical steps that will be needed in order to unlock the benefits and opportunities from reducing transport emissions. We will also engage through our various GB and EU memberships including the Natural Gas Vehicle Network.

Triggers for potential future work:

There is a significant link between hydrogen vehicles and the easy availability of hydrogen supply. If we see the development of a nationwide hydrogen economy, we would consider what investments are needed to facilitate likely supply and demand changes on the NTS, and the impact of a large number of new hydrogen fuelling stations.

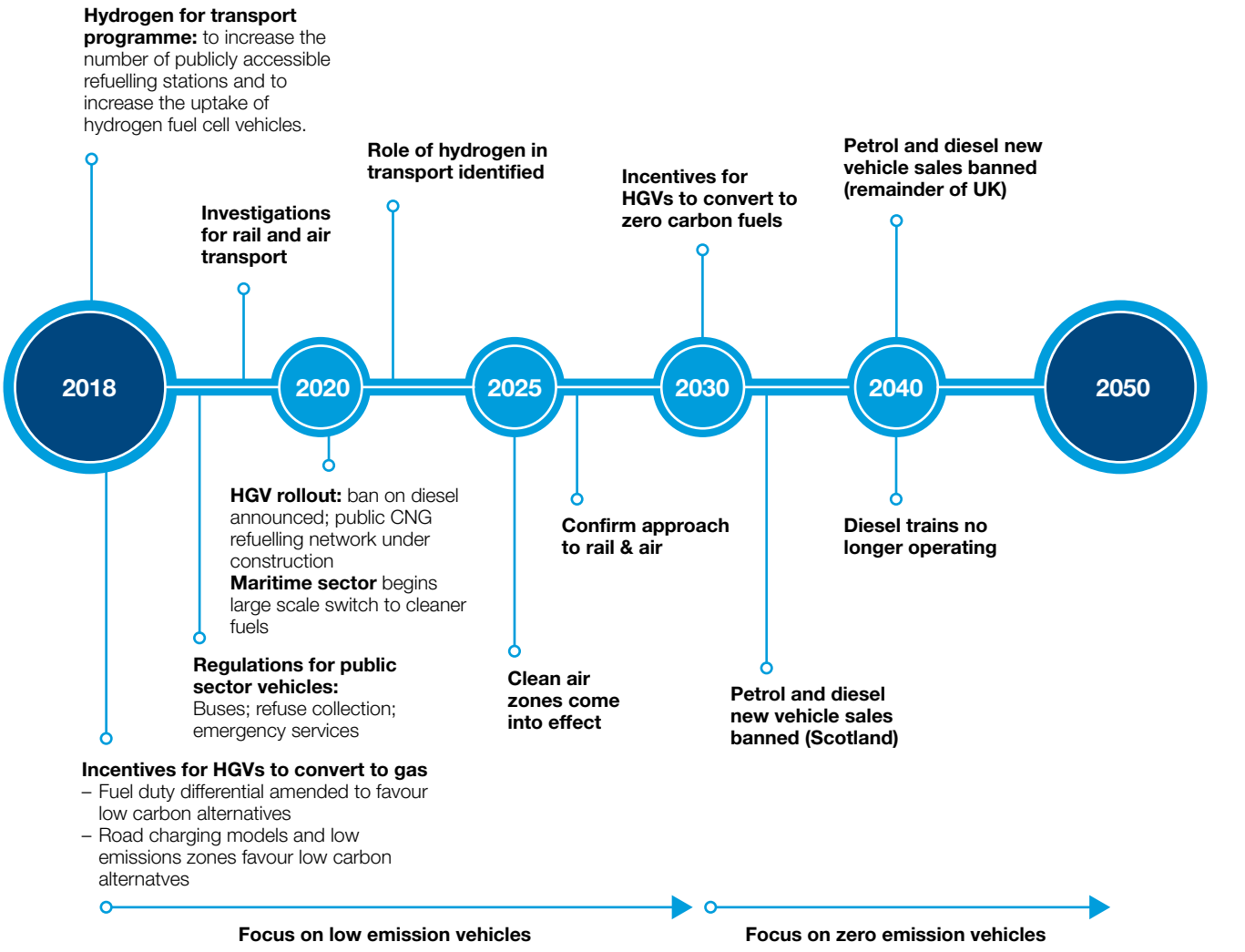
If we see a significant move to battery electric for cars, it may result in us needing to reinforce the gas system to meet peak charging demand. Similarly, in response to an increased uptake of natural gas vehicles we would need to consider how to facilitate connections for refuelling stations where and when customers want them.

Policy recommendations:

Our recommendations for the decarbonisation of transport are that:

- coordinated action is needed between the Government and regional and local authorities to encourage gas as a means of reducing carbon emissions from heavier vehicles such as HGVs and buses. This could include incentives and taxation arrangements to send signals to fleet operators encouraging them to switch from diesel to natural gas;
- with the support of mayors, cities such as London should lead the way in developing the role of hydrogen in public transport, in particular buses, as an early effective action to reduce NOx emissions;
- motorists need the UK Government to provide far greater certainty about fuel duty on gas-based fuels, and for them to ensure that the fuel duty differential favours gas;
- the UK Government should ensure that future road charging models and low emissions zones favour the use of low and zero carbon alternatives; and
- the UK Government should support increased awareness and provide additional clarity where required to help provide confidence to business and industrial users to switch to alternative fuel technology.

Potential timeline



5.3 Decarbonisation of industry

The challenge:

The UK government's Industrial Decarbonisation and Energy Efficiency Action Plans Summary[45], states that industry is responsible for nearly a quarter of UK emissions, so helping industrial sectors to decarbonise can make an important contribution to meeting our climate change commitments.

Gas is used in a range of industrial processes, either for heat or as a raw material, and is therefore critical to supporting the wider economy and retaining GB's global competitiveness. Industries such as ceramics, glass, brick-making, chemicals and fertiliser manufacturing are dependent upon gas as a reliable source of energy, or a raw material that is competitively priced. They bring money into the UK, create jobs, and are the foundation industries that support the UK's supply chains.

During our stakeholder engagement, industrial customers told us that there is currently no viable, affordable, decarbonised alternative to gas for many processes. There was also concern that any significant move away from gas in areas such as heat would lead to increases in both capital and operational expenditure for industrial and commercial users, impacting global competitiveness.

"The chemical industry is energy intensive, competes globally for product market share and inward investment, and has already done much to improve the energy efficiency of our existing production assets. Our contribution is therefore critically dependent on secure and competitive energy supplies and cost effective carbon reduction schemes which do not leave us internationally exposed."

Chemical Industries Association, Energy and Climate Change Policy Position Statement (June 2017)

"We need to find alternatives to industrial fuels which are energy intensive to produce, without increasing cost or reducing performance. The cost of CCUS technologies will need to fall."

HM Government, The Clean Growth Strategy: Leading the way to a low carbon future (October 2017)

The potential solutions:

The UK Government's Industrial Decarbonisation and Energy Efficiency Action Plans set out the five core elements needed to support decarbonisation in this area, namely: access to finance; knowledge sharing and innovation; Carbon Capture Usage and Storage (CCUS); industrial site clustering; and investigating the use of biomass. Industries that use electricity could commit to a 100% renewables goal but there are those for whom electricity is not a suitable source of energy.

Given the dependence on gas in many industrial processes, decarbonising the gas sector appears to be the most attractive option for many sections of industry. Options being developed include decarbonising gas through hydrogen, biogases and CCUS. Certain regions have taken a particular lead in this regard, such as the HyNet NW, Teesside Collective and Grangemouth industrial complex, all of which are developing integrated decarbonisation projects including CCUS.

The decarbonisation of industrial processes can also be supported by the use of Combined Heat and Power (CHP) – the simultaneous generation of heat and power in a single process. CHP has been identified as an effective and low-cost abatement measure for industry for the 5th carbon budget period[46]. In addition to gas, the number of biomass CHP plants is growing, and hydrogen fuelled CHP is in development. There is significant potential for CHP in energy intensive industries and other sectors of the economy, and where CHP plants could supply more than one industrial site.

What National Grid will do:

Collaborating to deliver stakeholder priorities

Many industrial consumers have told us that their business is effectively non-interruptible and they need gas to be delivered reliably, where and when they want it, at an affordable price. Given the uncertainty about exactly how industry will decarbonise, stakeholders agreed that keeping options open to support a range of future energy outcomes for the NTS was preferable and significantly more efficient than decommissioning and potentially later needing to rebuild parts of the existing NTS.

We plan to work more closely with industrial consumers to understand how decarbonising the gas sector can meet their needs. This will include how to accommodate their needs as flows change, or as hydrogen and CCUS develop, and to understand the implications on their businesses of any changes to gas quality and other parts of the current market regime.

Continuing the conversation

We believe that gas has a key role to play in industrial decarbonisation, and we will continue liaising closely with industry to understand and support their future energy requirements. We will be:

- advocating for the important economic role of gas in both GB and Europe;
- working with industrial consumers to understand the implications for their businesses of gas network charging, alongside their options and alternatives as gas decarbonises, bringing forward supportive proposals where possible; and
- developing a flexible asset strategy alongside an understanding of the role of the NTS in delivering key innovation in this area.

Triggers for potential future work

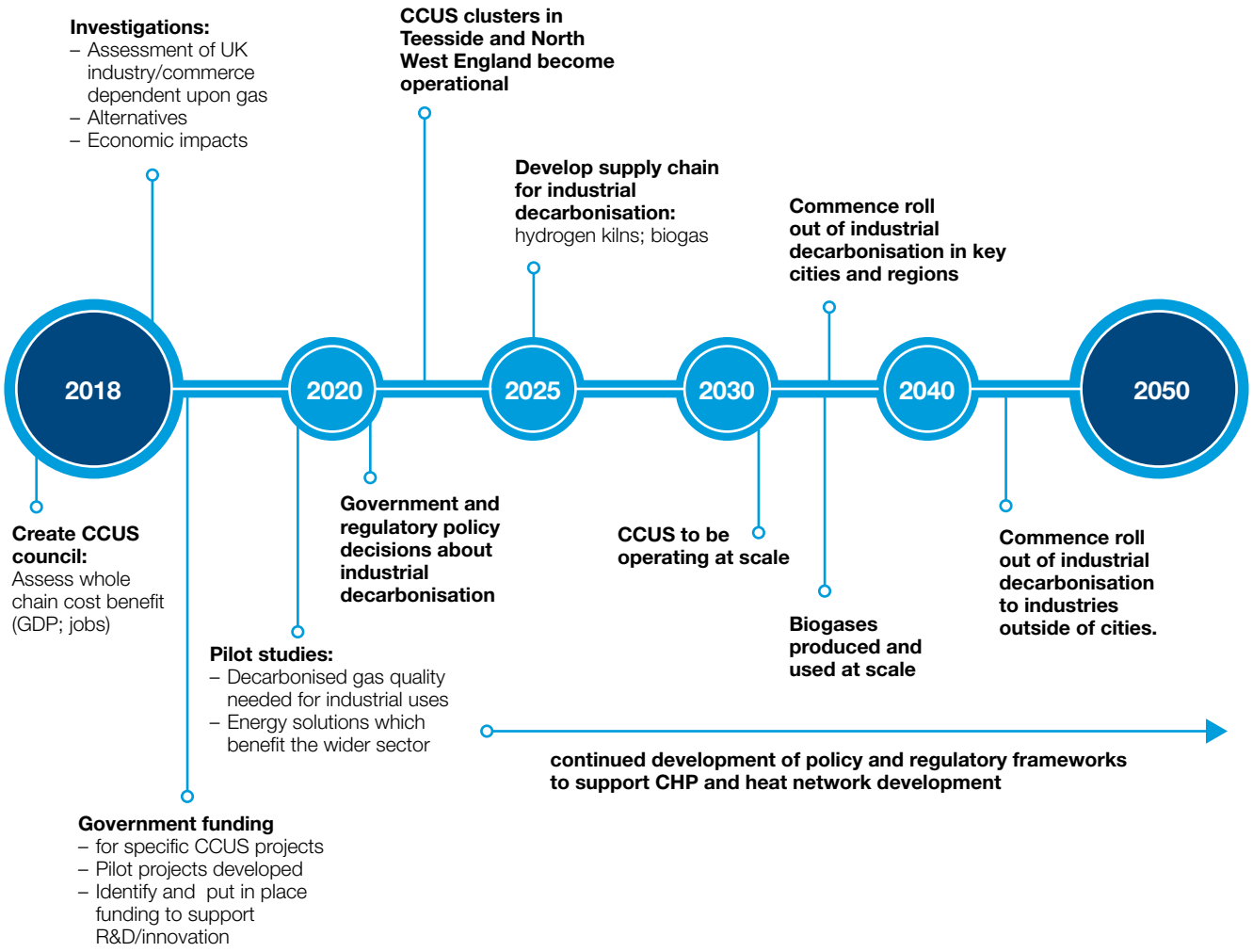
A significant downward trend in the use of gas, including a decline in the consumer base, would lead us to review our current charging models with the intention of ensuring the continued viability of gas for the wider UK economy.

Policy recommendations:

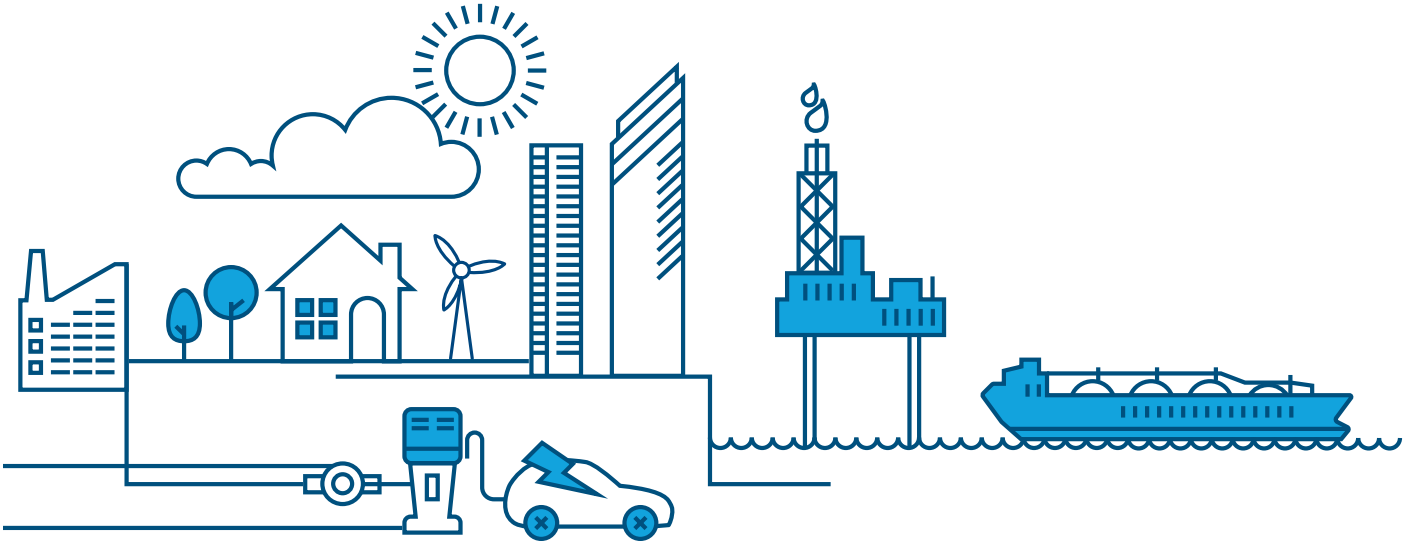
We are supportive of recent announcements related to both industrial decarbonisation and CCUS, and also recommend that:

- maintaining a strong UK economy is important, especially with the uncertainty of a post-Brexit future. Therefore, any decisions about the wider role of gas (such as for heat) need to be made holistically alongside an understanding of the impact of this decision on industrial usage and hence the wider UK economy; appointing a lead official with cross-departmental coverage will be helpful – this is covered in more detail under 'Whole Energy System' below; and
- there are many opportunities for CHP but, for energy intensive businesses, the high upfront capital costs and long term contracts currently create barriers to development. The Government should consider what can be done in this area.

Potential timeline



5.4 Whole energy system



The challenge:

There is increased volatility in the operation of the energy systems. This is due to decarbonisation, decentralisation and global markets changing the sources and locations of where our energy comes from. Gas provides electricity security of supply in the UK in the form of fast responding, flexible generation to support growing volatility from renewable generation sources. As this increases in the future, the ability to work across all energy systems will become much more important.

This includes the gas transmission and distribution systems where there is also strong potential for increased interactions. Currently the majority of biogases are expected to inject around the country at distribution level. If biogas volumes grow to become as significant as some stakeholders are forecasting, it would impact the NTS by potentially reducing the demand or if the distribution networks are over-supplied they may want to push gas onto the transmission network. However this reverse flow is not currently possible.

Similarly, there has been an increase in embedded electricity generation, which has the potential to impact the gas demand in a distribution network and further distort the traditional industry boundaries. Should gas distribution networks convert to hydrogen there will be further implications for the NTS and electricity networks.

If we consider storage, the gas system provides the majority of inter-seasonal flexibility through its capability to supply large volumes of energy on the coldest winter days. Within day, the gas inside the NTS itself acts as a critical store of flexible energy. As the gas system operator we support the whole energy system by using this flexibility to allow the system pressures to fluctuate within allowable boundaries, enabling our customers to respond quickly to within day demand changes without the need to input supply on a moment-to-moment basis.

The potential solutions:

A 2017 report from Imperial College London and Cardiff University[47] investigated the benefits of adopting a fully integrated, flexible approach to operating the gas and electricity networks. The results indicate there would be significant overall system benefits and cited flexibility as the key area of focus. This included a combination of flexible gas power stations, multi-directional compressors, demand side response, electricity and gas storage, and power-to-gas (using surplus electricity from renewable sources for electrolysis to create hydrogen from water).

There is also a need to consider the role of energy storage more holistically. Whilst batteries are growing in importance, they can only store a fraction of the energy that the gas system provides today at a far lower cost than even the lowest cost electricity storage.

This increasing dependence, requires a step change in our level of whole system thinking. The energy networks, Ofgem and government need to understand all of the potential interactions; working in isolation may lead to the development of sub-optimal or inefficient whole energy system solutions. The gas and electricity System Operators (SO) have a unique perspective and position to help support whole system thinking. By operating as one SO, with gas and electricity working together, National Grid SO can bring insights and leadership to the energy transition that will benefit UK consumers and the economy.

"In developing energy policy, the whole system must always be considered. Electricity, heat and transport, although quite different in their characteristics, are all part of the UK's energy system and are equally important, with complex interactions between them: targets will only be met by addressing all aspects of the system."

Royal Academy of Engineering: A critical time for UK Energy Policy - what must be done now to deliver the UK's future energy system (October 2015).

What National Grid will do:

Collaborating to deliver stakeholder priorities

Our stakeholders have been clear that they want us to facilitate the whole energy system of the future. They believe that we are in a unique position to lead on whole energy system thinking because our role operating both gas and electricity transmission systems enables better holistic decision making. Over the coming years we will work with our stakeholders to explore the most appropriate solutions. This will include:

- investigating the best way to continue to utilise the within day storage that the gas system offers, supporting our customers' needs in a way which is equitable to the users of all energy systems. This will include consideration of how the role of the NTS as an energy store should be recognised or valued through our regulatory regimes;
- continuing to assess the impacts of increasing gas and electricity interactions on gas system operability in more detail through our quarterly GFOP publication, including understanding where significant changes to the service we can provide are likely to occur and triggering work in advance to identify potential solutions; and
- increasing our whole system modelling capabilities.

Continuing the conversation

In order to develop a whole energy system approach to our gas and electricity activities, we will investigate, alongside industry and UK Government, what National Grid can do to support a low carbon gas sector deal, as outlined in the Industrial Strategy.

Triggers for potential future work

If we see a significant increase in biogas injected onto the distribution networks, which risks exceeding their flow capacity, we will need to understand the potential scale of reverse flows onto the NTS and what physical and commercial changes would be required to accommodate those.

In the event that our on-going investigations show that a richer hydrogen blend can be accommodated in the NTS alongside a continued high penetration of renewables we will need to understand the potential for power to gas hydrogen production on the GB electricity system and consider how the gas and electricity regimes can adapt to facilitate it.

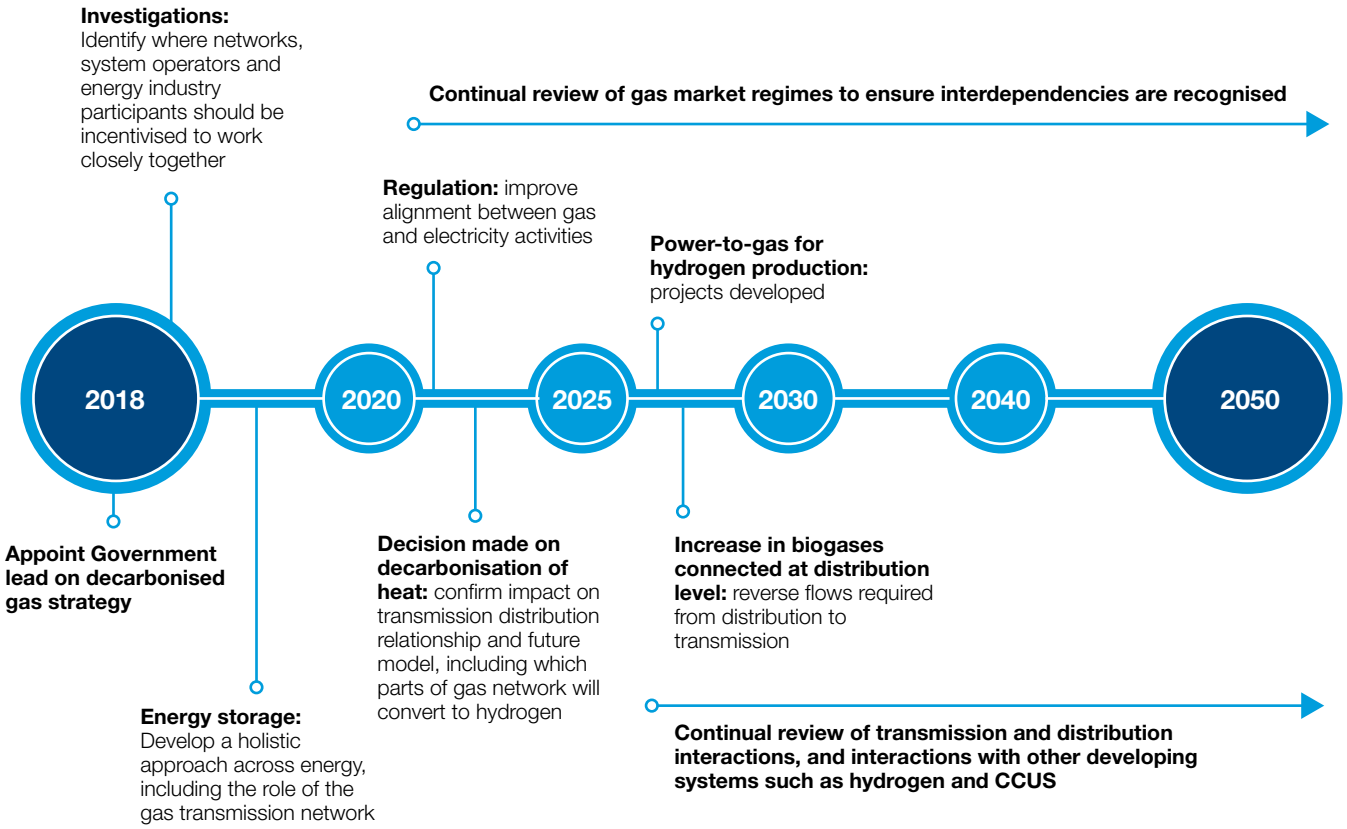
If we see a significant downward trend in the use of gas for heat and industrial and commercial uses, alongside an increase in gas fired power stations connecting to the NTS we would need to understand how the gas market regime could be modified to become more focused on supporting the needs of the electricity system.

Policy recommendations:

At present, there is no one person or team in government looking at the role of gas and its decarbonisation as part of the future whole energy system. We believe there is clear merit in taking a more holistic approach in order to manage the wide range of approaches and achieve the most efficient outcomes. Our recommendations for the whole energy system are that:

- The Government appoints a lead official to cover cross-departmental issues relating to the role of decarbonised gas in the whole energy system; and
- The Government and Ofgem work with the energy industry to identify the key areas where networks, system operators and energy industry participants should look at removing barriers to working more closely together. We have already started to consider this from a transmission perspective and will work with Ofgem to support further activity in this area.

Potential timeline



5.5 Future networks and markets

The challenge:

Historically, GB gas supplies have consisted almost exclusively of UK-based gas production. Today our dependency on imports to satisfy demand has grown to around 55%. We are now part of a truly global gas market, reliant on Norway, continental Europe, and global liquefied natural gas (LNG) supplies to meet our needs. By 2050, this import dependency is expected to increase as the UK Continental Shelf (UKCS) supplies declines. In our mid-case gas demand scenarios, Two Degrees, it increases to around 87%. Alongside this, rapidly developing biogas production could become a major contributor going forwards.

Networks

The majority of the NTS was constructed to support flows patterns in the latter part of the twentieth century, but our stakeholders have told us that the way they want to use our network is changing and the products we provide may not meet their needs in the future. This is highlighted not only by the changing supply mix, but also through increased demand side volatility. We are already experiencing more significant fluctuations in gas stock 'swing' as supply, demand and storage follow new and different profiles. We expect this to become more pronounced in the future.

Predicting, on a daily basis, where supplies will enter the system and moving that gas around to ensure the right pressures at the right times for our customers is becoming an increasing challenge for our control room operators. Changing supply patterns have meant that we have to utilise more compression to move gas around the system (compressor use increased from 19,993 hours in 2013/14 to 72,959 hours in 2016/17).

Changing the way the network is used makes it more challenging to maintain a balanced system when using a framework built on end of day balancing obligations. The magnitude of within-day gas system stock swings has almost doubled over the past two decades and there is a notable trend for our more commercially responsive customers to reconcile their positions later in the gas day.

Markets

Becoming more dependent on imported gas supplies means there is a need to maintain a well-functioning GB gas market in order to attract gas from other diverse, affordable sources. The need for continued price competitiveness (whether it be natural gas or as part of a future transition to decarbonised gas) means that the whole regime needs to continue to be fit for purpose as gas shippers and new entrants change the way they source, deliver and price their gas.

Considering where in the world gas is to come from, it is important to bear in mind how to minimise any commercial, technical or regulatory barriers that make the GB market less attractive including, where appropriate, gas quality issues. There is anecdotal evidence that the current gas quality standards are beginning to constitute a barrier to entry for declining UKCS fields and other global sources of supply. For example, the specification of imported LNG is generally outside GB regulations and it is estimated that bringing these gases to within GB specification could cost consumers up to £325 million a year. The gas distribution networks have already proved that wider specification gas (such as biomethane) is safe for domestic consumers.

Whilst opening up the GB market to accept wider sources and types of gas would seem sensible and potentially reduce (or avoid) some costs, we must also consider whether there would be adverse implications for some users and for the assets involved. New localised blending services to make gas quality suitable for certain processes may be an option.

The potential solutions:

The gas industry has an important role in helping the UK to meet its future decarbonised energy needs, whilst maintaining great value for money. Facilitating the networks and markets of the future will rely on optimising access to the NTS, delivering products and services which meet the requirements of the gas industry participants and gas consumers. This will enable new supplies, meet demand, and ensure that the system is utilised most efficiently. This will require easier access to the NTS, for new technologies and innovation. Specifically, stakeholders have identified a need to review capacity and charging arrangements, gas quality and connectivity arrangements as well as to consider the attractiveness of the GB market.

> **"The existing gas infrastructure ... is well equipped to face the challenges of the future: it can cope with the evolution that the gas demand will undergo to achieve the climate targets..."**
>
> ENTSOG Ten Year Network Development Plan 2017 (April 2017)

What National Grid will do:

Collaborating to deliver stakeholder priorities

In line with one of our stakeholders' priorities we must ensure that our customers can take gas on and off the transmission system and connect or disconnect where and when they need to. Given the increased global competition for gas supplies there is a need to continue to evolve our arrangements to ensure that our legacy access and charging arrangements reflect the current needs of all consumers and stakeholders and do not provide artificial barriers to entry. To ensure that our future networks and markets can deliver this we need to:

- provide products, services and a network which facilitate our role in balancing the network safely, while managing fluctuating, unpredictable supply and demand patterns within day, seasonally and from year to year;
- make it easier and cheaper to connect to our network by delivering our Customer Low Cost Connections project (CLoCC);

- understand the health of our assets, what investments are needed and, in the longer term, whether we need to decommission or repurpose and assets in response to increasing imports and a reduction in North to South flows; and
- agree a long term gas market change plan with industry and Ofgem to ensure we are developing the markets appropriately.

Continuing the conversation

We will continue to facilitate industry debate on the nature of future energy networks and markets. In particular, this will include ongoing involvement in the review of gas quality and the Gas Safety Management Regulations (GS(M)R) that is being facilitated by the Energy Networks Association (ENA) and the Institution of Gas Engineers and Managers (IGEM). Gas is widely acknowledged as the cleanest of the fossil fuels, so restricting gas supplies or making them more expensive could also reduce our ability to facilitate an efficient and economic transition to a lower carbon economy. These reviews could also be a stepping stone towards facilitating a more fundamental change in gas composition such as to facilitate more biogas or hydrogen.

Triggers for potential future work:

In the event of increasingly volatile swings in supply and demand which lead to increasing system imbalances, we would need to consider a wholesale review of the balancing regime, alongside NTS investments which would support more flexible operations.

In the event of significant growth in flexible gas fired power stations connecting to the NTS, we would seek to develop a more responsive and flexible regime and/or network considering transparency, capacity and balancing.

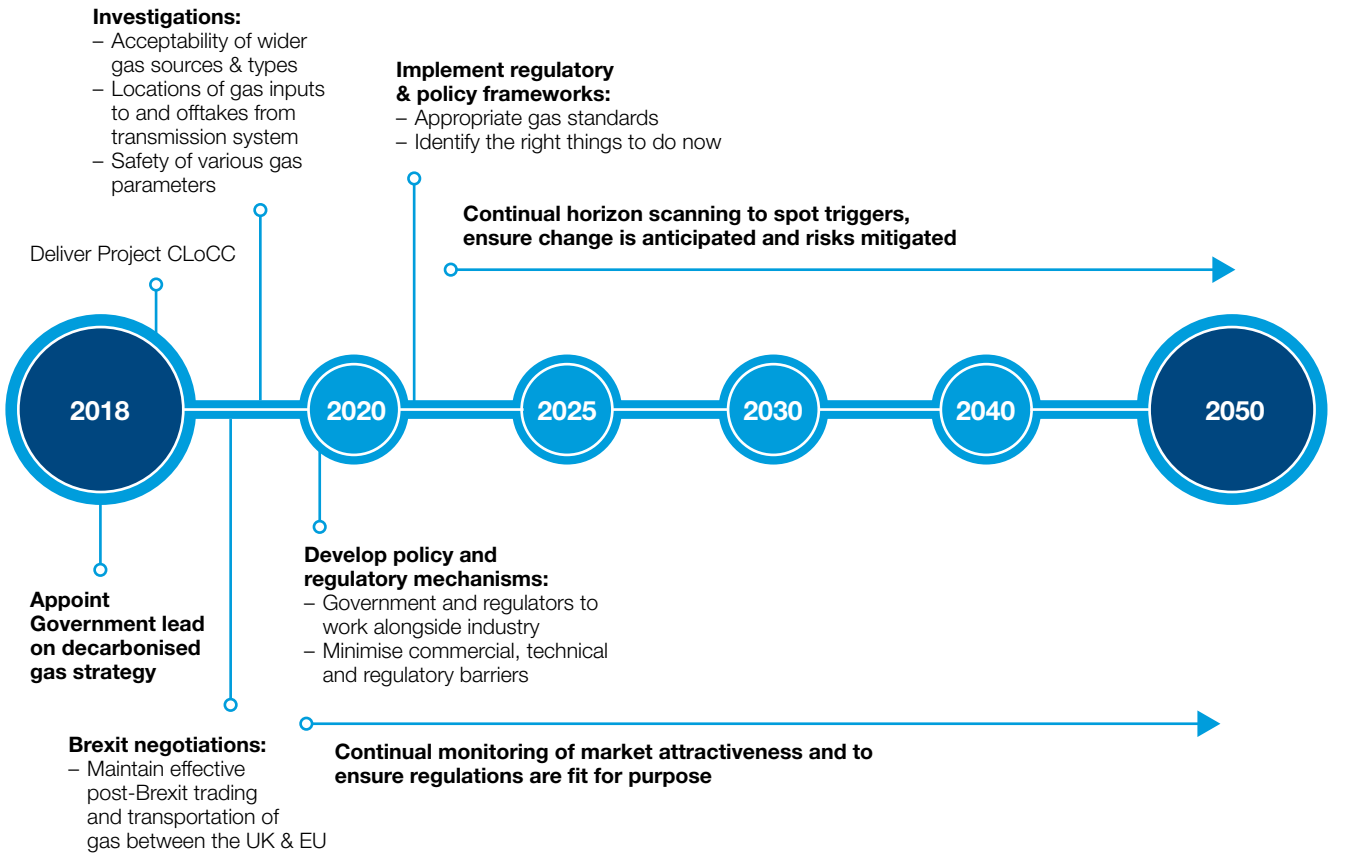
In the longer term, as the whole energy system evolves, decarbonisation continues, and gas flows change, we may need to consider whether and surplus assets can be repurposed to support new uses such as hydrogen, Carbon Capture Usage and Storage (CCUS) or storage.

Policy recommendations:

Given the degree of uncertainty over the future, we recommend the Government act to provide confidence in the gas industry and the market. This means being clear that it is committed to decarbonising gas, and why this is essential. In doing so, we recommend Government develop a decarbonisation of gas strategy, managed by the lead official mentioned under 'Whole Energy System' above and by working closely with industry and regulators. We recommend that:

- in the short term, and in the absence of policy clarity on issues such as the future role of hydrogen and CCUS, we can still take steps to incrementally increase penetration of decarbonised gas;
- those negotiating the longer term, post-Brexit, arrangements with the EU consider any unintended negative consequences of making the trading and transportation of gas between the UK and EU more difficult or expensive; and
- the Government and regulators work alongside industry to undertake proactive consideration of appropriate gas standards. This could include reviewing the gas quality standard to include higher proportions of hydrogen in gas blends, and carbon transportation specifications. There are also measurement needs, yet to be defined, such as the high purity hydrogen requirement for transport.

Potential timeline



5.6 The crucial role of Carbon Capture Usage and Storage (CCUS)

Our stakeholders have repeatedly told us that CCUS is critical to decarbonisation and the ongoing use of gas because it can support the decarbonisation of:

- power by capturing emissions from either fossil fuel power stations or the fuel inputted into them;
- heat and transport through capturing the carbon from Steam Methane Reforming, or other hydrogen production methods, for the production of hydrogen at scale; and
- industry by capturing emissions at source or supporting a move towards a hydrogen economy.

CCUS technologies and techniques involve capturing the carbon dioxide emissions produced by fossil fuels or industrial processes, preventing the emissions from entering the atmosphere. The carbon dioxide can then be transported, by pipeline or shipping, and permanently and safely stored in geological formations. Opportunities are also being explored to reuse the carbon dioxide captured to create commercially viable products. These products, such as bio-oils, chemicals, fertilisers and fuels, could replace fossil fuel based products to further reduce greenhouse gas emissions.

CCUS was included in our FES 2017 in the only one of the four core scenarios that met the 2050 carbon reduction targets (Two Degrees), as it is essential to ensure the carbon reduction target is met in the most cost-effective way [48]. More recently, the Clean Growth Strategy[49] put usage of the captured carbon on the agenda too.

In its central lowest cost scenarios, the Committee on Climate Change suggests around 20 Million Tonnes CO_2 ($MtCO_2$) being stored annually in 2035 from a mixture of gas power, industry and gas derived hydrogen. Looking further ahead, the Carbon Capture and Storage Association (CCSA) believe that the lowest cost route indicates that a UK CCUS sector may have to store or use 100 $MtCO_2$ each year by 2050. Establishing an industry of this scale by 2050 would require the UK to build infrastructure to support the capture, transportation and storage of, on average, an additional 5 $MtCO_2$ each year through the 2030s and out to 2050[50].

Recent government commitments to CCUS are important, as the vast majority of stakeholders agree that CCUS is needed at scale to achieve cost effective climate policies. In particular, the Clean Growth Strategy[51] acknowledges a broad international consensus that CCUS has a vital future role in reducing emissions and commits to demonstrating international leadership in CCUS to maximise its industrial opportunity. The Scottish Energy Strategy[52] also commits to encouraging investment in key industrial clusters, such as Grangemouth, where energy efficiency, bio-technology and CCUS could offer significant opportunities for decarbonisation and economic growth.

CCUS could have wider economic benefits. In October 2017 Summit Power released a comprehensive study[53] looking at how east coast carbon capture and storage opportunities can boost the UK economy. The results suggest that advancing carbon capture in the UK could create 225,000 jobs and generate £163bn in benefits at a cost of only £34bn between now and 2060.

Our pathways demonstrate the same conclusion as the Committee on Climate Change (CCC) on the 'no CCUS' pathway set out in the Clean Growth Strategy, and the importance of CCUS on cost-effective decarbonisation. Given the favourable geography and infrastructure, alongside our historic oil and gas capabilities, the UK has the opportunity to deliver clean economic growth as a world leader in this important technology.

> **"The Government should not plan to meet the 2050 target without CCS. The Government should set out plans in 2018 that kick-start a UK CCS industry in the 2020s."**
>
> Committee on Climate Change, An Independent Assessment of the UK's Clean Growth Strategy (January 2018)

What National Grid will do:

National Grid will facilitate the development of CCUS through open discussions with developers and trade associations and participation in BEIS' work on CCUS, as announced in the Clean Growth Strategy. If there is continued progress and successful demonstration and deployment of CCUS in the UK, including government support or an agreed commercial model, we would need to understand the impacts on the gas system operator and on the operation of the NTS and the interactions between our frameworks and any emerging frameworks such as those for hydrogen and CCUS.

Policy recommendations:

We are supportive of recent announcements related to CCUS, and also recommend that:

- the Government's CCUS programme be followed with a clear commitment and ambitious deployment pathway, with funding for specific projects in this parliament;
- the first projects begin operating in the 2020s so that CCUS is available at scale by the 2030s. This is deliverable but requires consistent, stable policy and regulation, and a clear pathway to maturity; and
- existing UK infrastructure and topology be used, as far as is possible, in order to keep costs down and maintain UK skills levels as well as offshore capabilities.

CCUS is a critical technology to enable the cost-effective decarbonisation of gas. Its development will facilitate the production of hydrogen and therefore the uncertainty around it must be removed if industry is to invest in hydrogen technology and infrastructure.

06 Conclusion

This document concludes our Future of Gas programme. We have analysed and summarised everything we have learnt and set out the challenges and opportunities for gas, but most importantly we have set out that gas can be used to meet the UK's 2050 carbon targets in the most cost effective way. It will be a major part of the solution to decarbonising heat and transport, improving air quality, supporting a strong UK economy, and delivering security of energy supply.

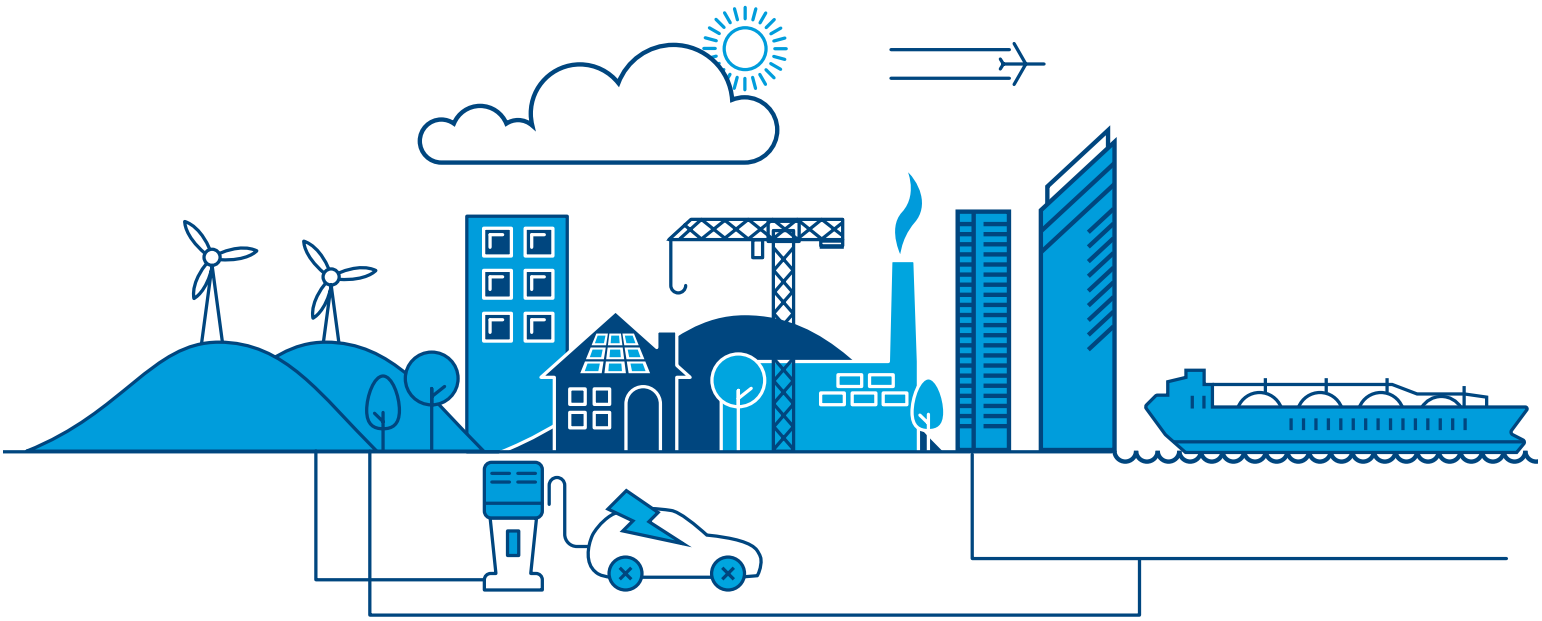
In setting out how gas can support a low carbon future we have shown that gas and electricity will be in a critical partnership and will work together to achieve decarbonisation.

There are already exciting innovations and projects being proposed across the UK to unlock new decarbonisation and industrial opportunities. The UK is in a strong position to lead the world in climate action by decarbonising gas, utilising its existing strengths from the oil and gas sectors, as well as new emerging opportunities through innovation, technology and services.

Our analysis and evidence shows that decarbonising gas and the supporting networks can be used to meet the UK's 2050 carbon targets and improve air quality in the most cost effective way. It also shows the vital role that gas plays in delivering energy to consumers now and into the future.

Action is needed now to ensure that the gas market and networks evolve in the most effective way to unlock these opportunities. Key to developing the new opportunities from the low carbon transition will be removing the policy gaps and barriers to decarbonising gas.

Policy makers, regulators and the industry have the opportunity to come together now to create a smooth transition to decarbonised gas, which will support not only the low carbon transition, but a low carbon future that delivers for all consumers.



07 Continuing the conversation

Future of gas

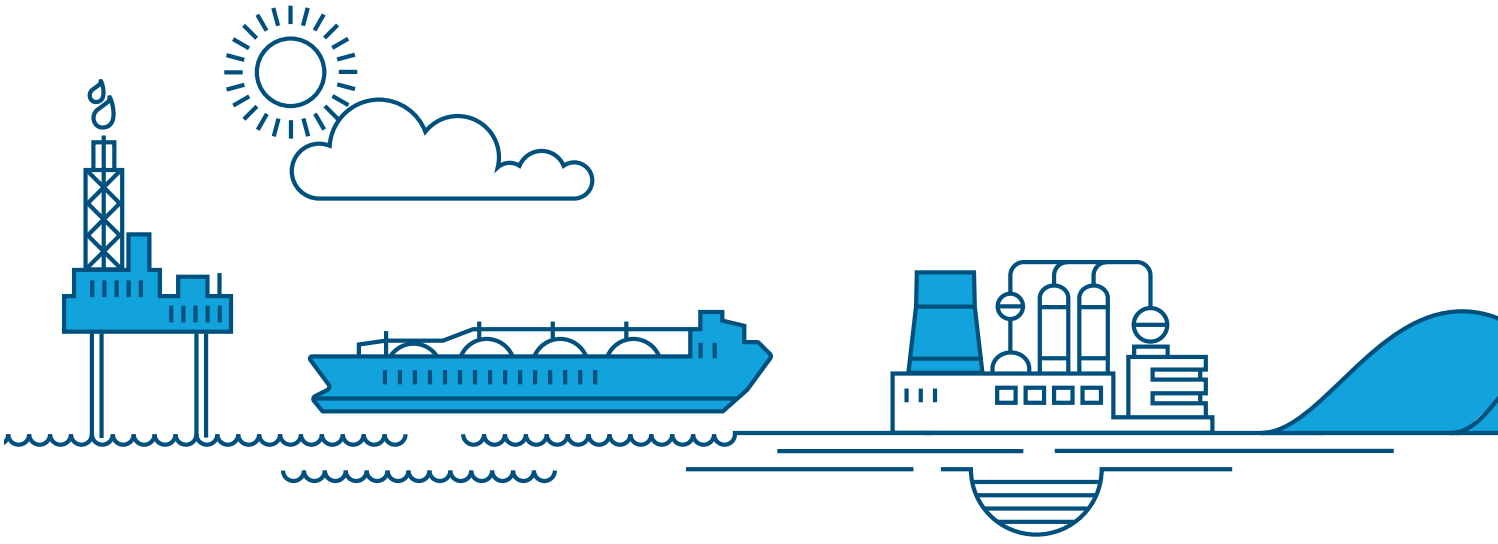
We welcome the opportunity to further develop our thoughts on the future of gas with stakeholders and look forward to engaging on the themes and potential actions explored in this document.

Future of the Gas Transmission System

Having worked with our stakeholders to explore the future of gas and understand their priorities for the Gas Transmission System, we will use these as we build our business plan to ensure that we focus on delivering what is most important. In Spring, we will launch the next phase of our business planning activities where we will work with our stakeholders to gather insight directly into shaping our business plan in line with many of the themes identified in this document. More information will be available in the Spring.

How to get involved

Should you wish to get in touch with us, whether to provide feedback on this document, to work together in meeting the decarbonisation challenge or to join us in co-creating our business plan to deliver the Gas Transmission System of the future please get in touch with the team as detailed on the following page.



What are your thoughts on the content of this document?

There is a comments section on our website futureofgas.uk

Twitter debate using #futureofgas

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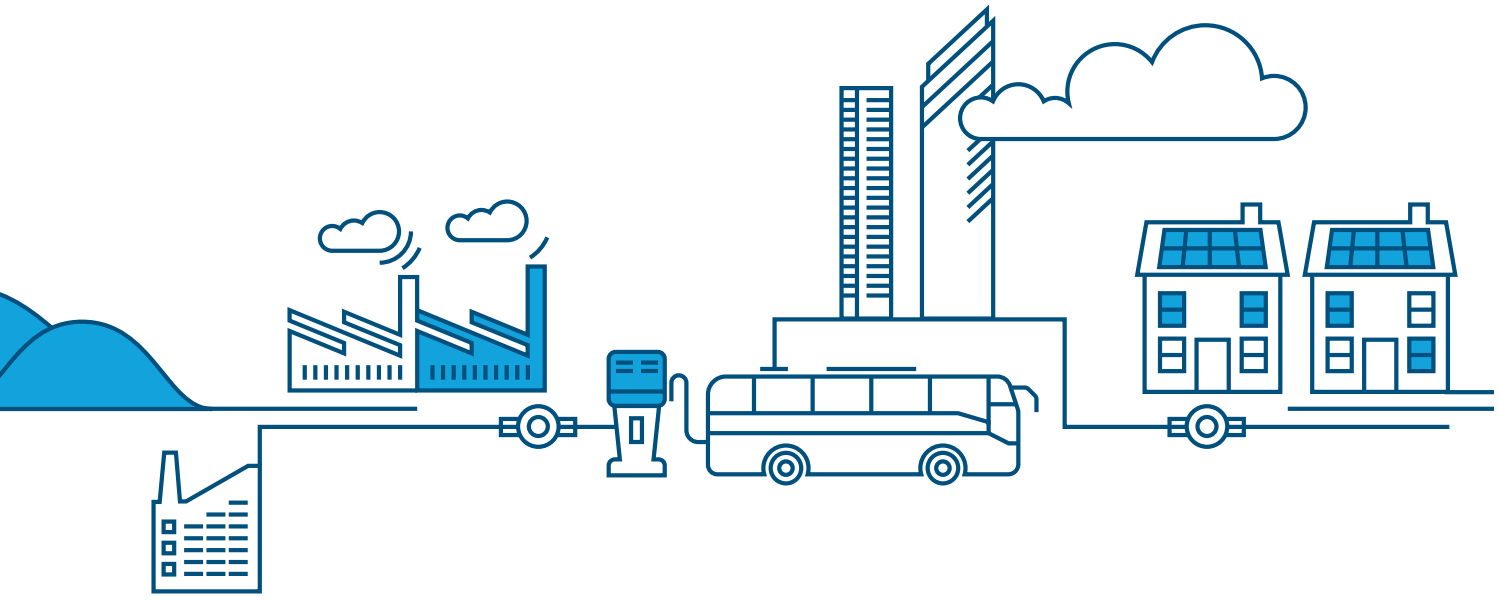

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1 References to stakeholders include customers, unless we are referring specifically to a direct customer relationship.

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10 http://futureofgas.uk/category/documents/

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12 http://www.talkingnetworkstx.com/shaping-the-future-of-the-gas-transmission-network.aspx

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14 http://consense.opendebate.co.uk/files/nationalgrid/transmission/Shaping_the_GTS_of_the_future_Webinar.pdf

15 http://fes.nationalgrid.com/

16 futureofgas.uk

17 https://www.nationalgrid.com/group/about-us/annual-report-and-accounts

18 Improving thermal energy efficiency is always desirable to reduce both carbon (assuming a carbon based heat source) and costs to the end consumer. However, GB housing stock has significant amounts of homes that are starting from a low thermal efficiency base (majority of homes are Energy Performance Certification class D and lower) and hence would take a substantial amount of work to raise standards to current building regulations or higher. In many cases the required works are relatively expensive (solid wall insulation) and would only pay back over the long term. Technologies such as heat pumps provide relatively low volumes of heat through continuous provision, therefore relying on well-insulated dwellings to be effective. Alternatives to heat pumps and highly insulated buildings (i.e. use of other low carbon sources such as biogas or hydrogen) can be coupled with technology that can rapidly heat homes and hence rely less on insulation improvements.

19 http://fes.nationalgrid.com/media/1256/2017-fes-charts-v22.xlsx

20 Black start is the procedure National Grid uses to restore power in the event of total or partial shutdown of the National Electricity Transmission System https://www.nationalgrid.com/uk/electricity/balancing-services/system-security-services/black-start

21 In an uncertain world, an ability to ensure proactive horizon scanning becomes critical. In National Grid we are introducing a new process to ensure we do this effectively, so that we know the key signposts to look out for and identify trigger points that prompt us to act.

22 https://www.gov.uk/government/publications/industrial-strategy-building-a-britain-fit-for-the-future

23 https://www.gov.uk/government/publications/clean-growth-strategy

24 https://www.gov.uk/government/publications/air-quality-plan-for-nitrogen-dioxide-no2-in-uk-2017

25 http://www.gov.scot/Resource/0052/00529523.pdf; https://www.theccc.org.uk/wp-content/uploads/2017/12/CCC-Building-a-low-carbon-economy-in-Wales-Setting-Welsh-climate-targets.pdf

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43 http://www.r-e-a.net/upload/Martin_Flach.pdf

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50 CCSA recommendations for CCUS in the Clean Growth Plan, July 2017

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09 Contributors

With many thanks to everyone who has taken the time to speak with us since November 2016.

- Accenture
- Addleshaw Goddard
- Age UK
- Air Liquide
- All Party Parliamentary Group for Renewable and Sustainability Energy
- AMEC – Amec Foster Wheeler
- Anaerobic Digestion and Bioresources Association
- Aqua Consulting
- Arcadis
- Arup
- Baker Hughes
- Baringa Partners
- BBL
- Department for Business, Energy and Industrial Strategy
- Blizzard Utilities
- BP Gas
- British Ceramic Confederation
- Cadent
- Calor Gas
- CAM – CamGas
- CAS – Cas Gas
- Campaign for Better Transport
- Capgemini
- Carbon Connect
- CCS Association – Carbon Capture & Storage Association
- Centre on Regulation in Europe
- Centrica
- ChamoConocoPhillips
- Chamois Metrology Ltd
- Chemical Industries Association
- Citizens Advice
- Clingendael Energy
- CNG Fuels
- CNG Services Ltd
- Committee on Climate Change
- Corona Energy
- Cosmo Tech
- Costain
- Council of European Energy Regulators
- CVSL – Claims Validation Services Limited
- Decarbonised Gas Alliance
- Department for Transport
- DHL
- DNV GL
- Drax
- E.ON
- E3G
- E4tech
- EDF Energy
- Electricity Supply Board
- Electro Route
- Element Energy
- Energy Networks Association
- Engie
- ENI
- Energy Technologies Institute
- Energy UK
- Energy and Utilities Alliance
- ENTSOG
- Enzen
- Ervia
- EUI – European University Institute
- Eurogas
- EU Skills
- Fast Flow
- First Utility
- Fisher German
- Frontier Economics
- Gas Naturally
- Gas Networks Ireland
- Gasrec
- Gazprom
- GERG
- GIE – Gas Infrastructure Europe
- Grain LNG
- Greenpeace
- GRT Gaz
- HSE – Health & Safety Executive
- Health and Safety Laboratory
- ICIS
- IGEM – Institution of Gas Engineers and Managers
- Imperial Academy
- Imperial College
- Inflection Point Energy Consulting
- Infragas - PSP
- Institute of Welsh Affairs
- Investec
- IOGP – International Association of Oil and Gas Producers
- IUK – Interconnector UK
- Iveco
- Juran
- KPMG
- Lagoni engineering
- LeFevre Consulting
- Liv Astri Hovem
- London Energy Consulting
- Major Energy Users Council (MEUC)
- Manufacturing Technology Centre
- Murphy Group
- National Farmers Union
- National Infrastructure Commission
- Natural Gas Vehicle Network
- New Power
- Northern Gas Networks
- Office for Low Emission Vehicles (OLEV)
- Ofgem
- Oil & Gas UK
- Orrick
- Oxford Institute of Energy Studies
- Pale Blue Dot
- Pöyry Management Consulting
- Premtech
- Premier Oil
- Renewable Energy Association
- Repsol Sinopec
- RWE npower
- Sainsbury
- Scania
- Scottish Government
- Scottish Power
- SEPA – Scottish Environment Protection Agency (SEPA)
- SGN
- Sheffield University
- Shell
- Society of Motor Manufacturers & Traders
- SNAM – Snam Rete Gas
- South Hook Gas
- Statoil
- St George's University
- Storengy
- Sue Ellwoods Ltd
- TAP – Trans Adriatic Pipeline
- Tarmac
- Teradata
- TGE px
- The Clancy Group
- UK Shale Gas
- UK Onshore Oil and Gas
- Uniper Energy
- UPS
- Visa
- Volvo
- Wales & West Utilities
- Warwick Business School
- Waters Wye Associates
- Welsh Government
- Wood PLC
- WRC PLC

10 Summary of recommended policy actions

Through our extensive work we have developed a number of public policy recommendations which, coupled with the current aims set out in national policy, will help drive growth in the UK economy as we decarbonise. Our main policy recommendations are summarised below; please refer to Section 5 for full details.

Decarbonisation of heat

Our recommendations for the decarbonisation of heat are that:

- the Government provides clarity on its preferred pathway to the decarbonisation of heat as soon as possible, in order to give industry the confidence to invest. Decisions are needed in the early 2020s to meet the 2050 targets. Publishing a timeline for public policy decision making on heat would be helpful in the meantime;
- while there are some benefits to decisions being made, communicated and rolled-out regionally or nationally, we recommend a UK-wide oversight body be established to ensure overall efficiency, cost effectiveness and fairness. The oversight body would be responsible for:
  - coordinating the right time to commence engagement with the consumer on heat decarbonisation. It currently does not form a part of the public narrative in the same way that decarbonisation of transport does. Too early and there are no solutions to offer; too late and scale of the roll-out is unassailable and emissions targets will not be reached;
  - considering the optimal solutions in terms of their impact upon, and acceptability by, the end consumer, both in terms of disruption (inside and outside of the home) and cost (due to fuel poverty implications and UK industrial competitiveness);
  - making decisions on who should pay for the transition, the innovation required to get there, and for the likely increase in ongoing energy costs associated with decarbonised heat, owning and implementing any associated frameworks; and
  - working with regional and devolved authorities to ensure the right solutions in the right areas.
- the Government and regulators should continue to support investment into further research and testing of the role of green gases. This will help to ensure that decisions about the decarbonisation of heat are based on full consideration of the costs and practicalities of all available options;
- options are kept open with regards to the future of the NTS until the pathways are clear, to support a range of future energy outcomes.

Decarbonisation of transport

Our recommendations for the decarbonisation of transport are that:

- coordinated action is needed between the Government and regional and local authorities to encourage gas as a means of reducing carbon emissions from heavier vehicles such as HGVs and buses. This could include incentives and taxation arrangements to send signals to fleet operators encouraging them to switch from diesel to natural gas;
- with the support of mayors, cities such as London should lead the way in developing the role of hydrogen in public transport, in particular buses, as a an early effective action to reduce NOx emissions;
- motorists need the UK Government to provide far greater certainty about fuel duty on gas-based fuels, and for them to ensure that the fuel duty differential favours gas;
- the UK Government should ensure that future road charging models and low emissions zones favour the use of low and zero carbon alternatives; and
- the UK Government should support increased awareness and provide additional clarity where required to help provide confidence to business and industrial users to switch to alternative fuel technology.

Decarbonisation of industry

We are supportive of recent announcements related to both industrial decarbonisation and CCUS, and also recommend that:

- maintaining a strong UK economy is important, especially with the uncertainty of a post-Brexit future. Therefore, any decisions about the wider role of gas (such as for heat) need to be made holistically alongside an understanding of the impact of this decision on industrial usage and hence the wider UK economy;
- appointing a lead official with cross-departmental coverage will be helpful – this is covered in more detail under ‘Whole Energy System’ below; and
- there are many opportunities for CHP but, for Energy Intensive businesses, the high upfront capital costs and long term contracts currently create barriers to development. The Government should consider what can be done in this area.

Whole energy system

Our recommendations for the whole energy system are that:

- the Government appoints a lead official to cover cross-departmental issues relating to the role of decarbonised gas in the whole energy system; and
- the Government and Ofgem work with the energy industry to identify the key areas where networks, system operators and energy industry participants should look at removing barriers to working more closely together. We have already started to consider this from a transmission perspective and will work with Ofgem to support further activity in this area.

Future networks and markets

We recommend that the Government develops a decarbonisation of gas strategy, managed by the lead official mentioned under 'Whole Energy System' above and by working closely with industry and regulators. We recommend that:

- in the short term, and in the absence of policy clarity on issues such as the future role of hydrogen and CCUS, we can still take 'low-regret' steps to incrementally increase penetration of decarbonised gas;
- those negotiating the longer term, post-Brexit, arrangements with the EU consider any unintended negative consequences of making the trading and transportation of gas between the UK and EU more difficult or expensive; and
- the Government and regulators work alongside industry to undertake proactive consideration of appropriate gas standards. This could include reviewing the gas quality standard to include higher proportions of hydrogen in gas blends, and carbon transportation specifications. There are also measurement needs, yet to be defined, such as the high purity hydrogen requirement for transport.

Carbon Capture Usage and Storage

We are supportive of recent announcements related to CCUS, and also recommend that:

- the Government's CCUS programme be followed with a clear commitment and ambitious deployment pathway, with funding for specific projects in this parliament;
- the first projects begin operating in the 2020s so that CCUS is available at scale by the 2030s. This is deliverable but requires consistent, stable policy and regulation, and a clear pathway to maturity; and
- existing UK infrastructure and topology be used, as far as is possible, in order to keep costs down and maintain UK skills levels as well as offshore capabilities.

CCUS is a critical technology to enable the cost-effective decarbonisation of gas. Its development will facilitate the production of hydrogen and therefore the uncertainty around it must be removed if industry is to invest in hydrogen technology and infrastructure.

11 Summary of actions National Grid will take

In addition to our policy recommendations we have set out a number of actions that National Grid will undertake, including our view of the right things to do now and how we plan to continue the conversation with our stakeholders. These actions are summarised below; please refer to section 5 for full details.

Decarbonisation of heat

We believe that the gas system will play a critical role in the decarbonisation of heat, so we plan to be active in its development. In addition, we will innovate and facilitate others' innovation, creating opportunities for the NTS and the wider industry through the transmission of biogases and hydrogen, supported by CCUS. Therefore, we plan to increase our activities associated with pursuing a decarbonised future for the NTS. This will include:

- exploring the creation and storage of biogases in further detail through our sponsorship of the Carbon Connect Future Of Gas work;
- exploring possible different hydrogen market models and what they would mean for the operation of the gas system; and
- studying the impact of increased hydrogen levels on our assets, to determine the potential role of the NTS in a hydrogen economy.

Continuing the conversation

In addition to the actions above, we will:

- work with the gas distribution networks to support their various hydrogen projects;
- participate in European forums to ensure that our view for heat is compatible with the wider interconnected markets;
- enhance our analysis of a decarbonised future by exploring the role the gas system has to play in our Future Energy Scenarios 2018; in line with the latest industry developments; and
- understand the interaction of our markets with emerging frameworks such as CCUS and hydrogen.

Decarbonisation of transport

We believe that gas represents the best opportunity to start decarbonising heavier vehicles today, so we plan to be active in its development. This will include:

- taking a leading role with the gas vehicle sector to provide timely, accurate and up to date empirical information that is needed to enable policy makers to commit to a diesel-to-gas transition;
- continuing with work to understand the role of the NTS in this area. The intention is to understand customer needs in developing our approach to transporting high pressure gas supply to forecourts, realising the benefits of NTS-connected refuelling stations. This will include identification of the optimised locations in GB for fuelling stations connected to the NTS and exploring the opportunities for infrastructure investments at refuelling stations to support station owners/operators;
- proving the potential for Project CLoCC (our Customer Low Cost Connections project) through connecting pilot customers, facilitating quicker, lower cost connections to the NTS;
- actively participating in GB and European forums to ensure gas is recognised as a viable solution for transport as future emissions standards are set; and
- continuing our investment in our LNG facilities to support on and offshore market growth, including both a small vessel loading facility and expansion of our road truck loading facility.

Continuing the conversation

We are engaging with a wide range of stakeholders to explore the practical steps that will be needed in order to unlock the benefits and opportunities from reducing transport emissions. We will also engage through our various GB and EU memberships including the Natural Gas Vehicle Network.

Decarbonisation of industry

Given the uncertainty about exactly how industry will decarbonise, stakeholders agreed that keeping options open to support a range of future energy outcomes for the NTS is the best option for the near term. We will work closely with industrial consumers to understand how decarbonising the gas sector can meet their needs.

Continuing the conversation

We believe that gas has a key role to play in industrial decarbonisation. We will be:

- advocating for the important economic role of gas in both GB and Europe;
- working with industrial consumers to understand the implications for their businesses of gas network charging, alongside their options and alternatives as gas decarbonises, bringing forward supportive proposals where possible; and
- developing a flexible asset strategy alongside an understanding of the role of the NTS in delivering key innovation in this area.

Whole energy system

Our stakeholders have been clear that they want us to facilitate the whole energy system of the future. They believe that we are in a unique position to lead on whole energy system thinking because our role operating both gas and electricity transmission systems enables better holistic decision making. Over the coming years we will work with our stakeholders to explore the most appropriate solutions. This will include:

- investigating the best way to continue to utilise the within day storage that the gas system offers, supporting our customers' needs in a way which is equitable to the users of all energy systems. This will include consideration of how the role of the NTS as an energy store should be recognised or valued through our regulatory regimes;

- continuing to assess the impacts of increasing gas and electricity interactions on gas system operability in more detail through our quarterly GFOP publication, including understanding where significant changes to the service we can provide are likely to occur and triggering work in advance to identify potential solutions; and
- increasing our whole system modelling capabilities.

Continuing the conversation

In order to develop a whole energy system approach to our gas and electricity activities, we will investigate, alongside industry and UK Government, what National Grid can do to support a low carbon gas sector deal, as outlined in the Industrial Strategy.

Future networks and markets

In line with one of our stakeholders' priorities we must ensure that our customers can take gas on and off the transmission system and connect or disconnect where and when they need to. Given the increased global competition for gas supplies there is a need to continue to evolve our arrangements to ensure that our legacy access and charging arrangements reflect the current needs of all consumers and stakeholders and do not provide artificial barriers to entry. To ensure that our future networks and markets can deliver this we need to:

- provide products, services and a network which facilitate our role in balancing the network safely, while managing fluctuating, unpredictable supply and demand patterns within day, seasonally and from year to year;
- make it easier and cheaper to connect to our network by delivering our Customer Low Cost Connections project (CLoCC);
- in the longer term, understand the health of our assets, what investments are needed and whether we need to decommission or repurpose any assets in response to increasing imports and a reduction in North to South flows; and
- agree a long term gas market change plan with industry and Ofgem to ensure we are developing the markets appropriately.

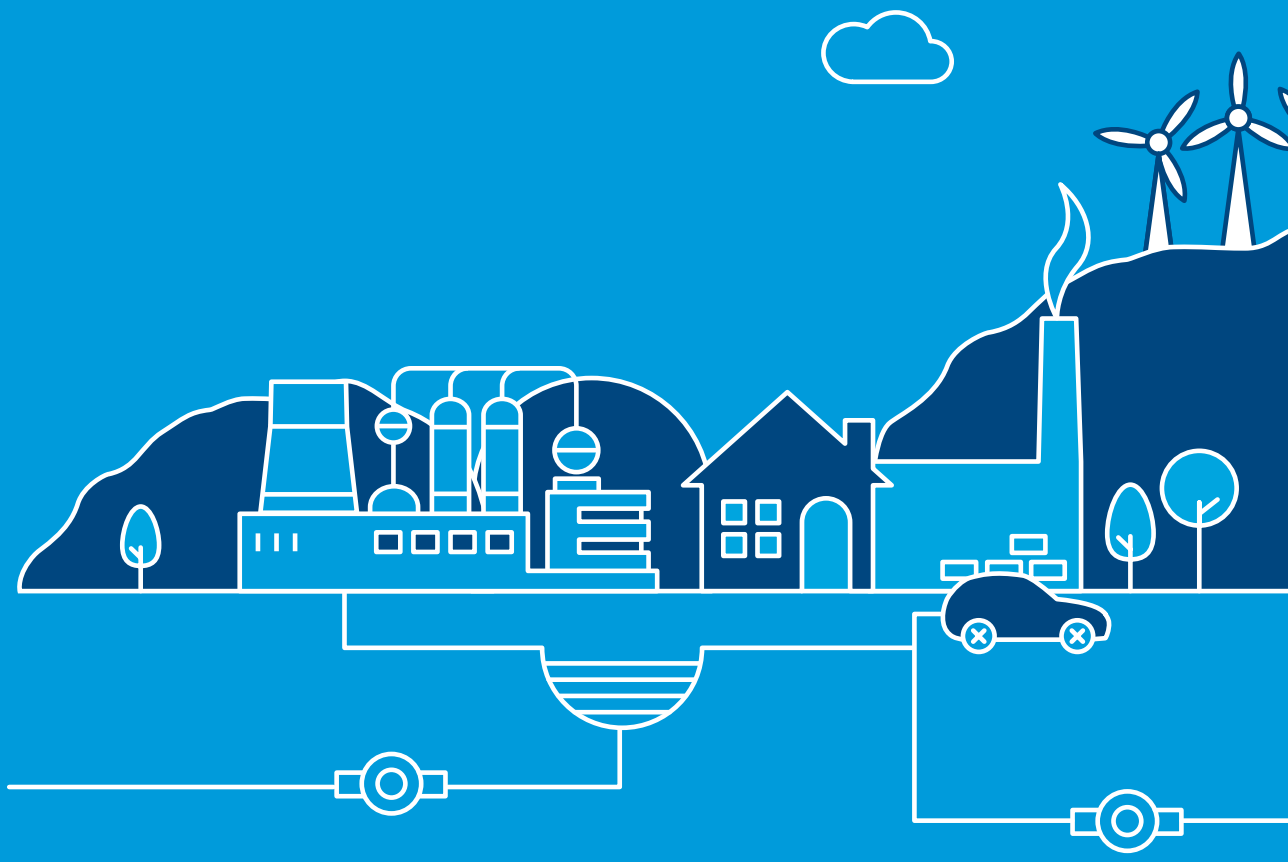
Continuing the conversation

We will continue to facilitate industry debate on the nature of future energy networks and markets. In particular, this will include ongoing involvement in the review of gas quality and the Gas Safety Management Regulations (GS(M)R) that is being facilitated by the Energy Networks Association (ENA) and the Institution of Gas Engineers and Managers (IGEM). Gas is widely acknowledged as the cleanest of the fossil fuels, so restricting gas supplies or making them more expensive could also reduce our ability to facilitate an efficient and economic transition to a lower carbon economy. These reviews could also be a stepping stone towards facilitating a more fundamental change in gas composition such as to facilitate more biogas or hydrogen.

Carbon Capture Usage and Storage

National Grid will facilitate the development of CCUS through open discussions with developers and trade associations, and participation in BEIS' work on CCUS as announced in the Clean Growth Strategy. If there is continued progress and successful demonstration and deployment of CCUS in the UK, including government support or an agreed commercial model, we would need to understand the impacts on the gas system operator and on the operation of the NTS and the interactions between our frameworks and any emerging frameworks such as those for hydrogen and CCUS.

For more information, and all project publications, please visit **futureofgas.uk**



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