February 2017

The future of gas

Unlocking network capability

Cadent

Contents

Foreword

by Chris Train
Chief Executive of Cadent Gas Ltd

So far in this Future of Gas series, we have looked at the opportunities for gas as part of the energy mix to 2050 and its role in solving the energy trilemma. In this final chapter we focus on the gas network, the essential enabler for any future energy ambition.

Chris Train
Chief Executive of
Cadent Gas Ltd

The UK's gas networks transport gas safely and reliably to 23.2 million customers around the UK, and our customers want it to do more. We are ensuring the network is flexible enough to meet the needs of our customers today and tomorrow as we plan around population growth, demographic shifts, and reducing carbon and a reliance on fossil fuels.

As an industry, we operate within a framework of shifting external drivers and evolving customer demands. The gas network of the future will be used differently from how it is used today. It must be adaptable to accommodate new sources of gas, new entry connections and new exit connections. Since the creation of the energy system in 1926, the gas network has remained flexible, switching from Town Gas to North Sea natural gas reserves and from centralised generation to renewable sources.

The gas network is sophisticated and resilient, and can carry different types of gas, from many different sources. The existing network is 99.999 per cent reliable, and copes extremely well to meet day-to-day changes in demand as well as seasonal shifts. It is critical we give customers a reliable and affordable energy supply during peak demand.

All these factors are central to meeting the demands of the energy trilemma: affordability, sustainability and security of supply. Yet there is still more to do. Where else can we innovate? How do we deliver the most cost-effective solution? How do we deliver the least invasive result for customers? Industry analysis suggests using the existing gas infrastructure offers financial savings of up to £10,000 per household compared with the alternatives. That's got to be worth investigating.

As we move towards the future, I believe there should be an increased focus on understanding the affordability of any future energy solution, along with the diversity needed to provide security of supply.

We must now help policy makers, investors, innovators and customers understand the capability and versatility of the gas network and the role of gas in helping to power the economy of the future.

There is a clear role for Government to establish a joined up policy framework across the energy, planning and transport departments with a coherent UK-wide energy strategy that puts gas at the heart of the future. If we want to address the needs of the energy trilemma by 2050 we need to act now. In this chapter, we look at the challenges facing the UK's gas networks and identify the 'no regrets' options to unlock the UK's energy capability.

We are passionate about the gas network of the future but we cannot do this alone. The industry must work together to deliver the future of energy in the UK. We would like to hear your thoughts so please get in touch at futureofgas@cadentgas.com.

The challenge

The climate change commitments we face are very clear, so how can we deliver significant and sustainable reductions in carbon emissions up to 2050 and beyond?

To achieve this, we must consider how we both produce and consume the energy we need, and the critical role played by energy networks to deliver energy safely, reliably and affordably. We must also ensure that the actions we take reduces the two million homes currently in fuel poverty.

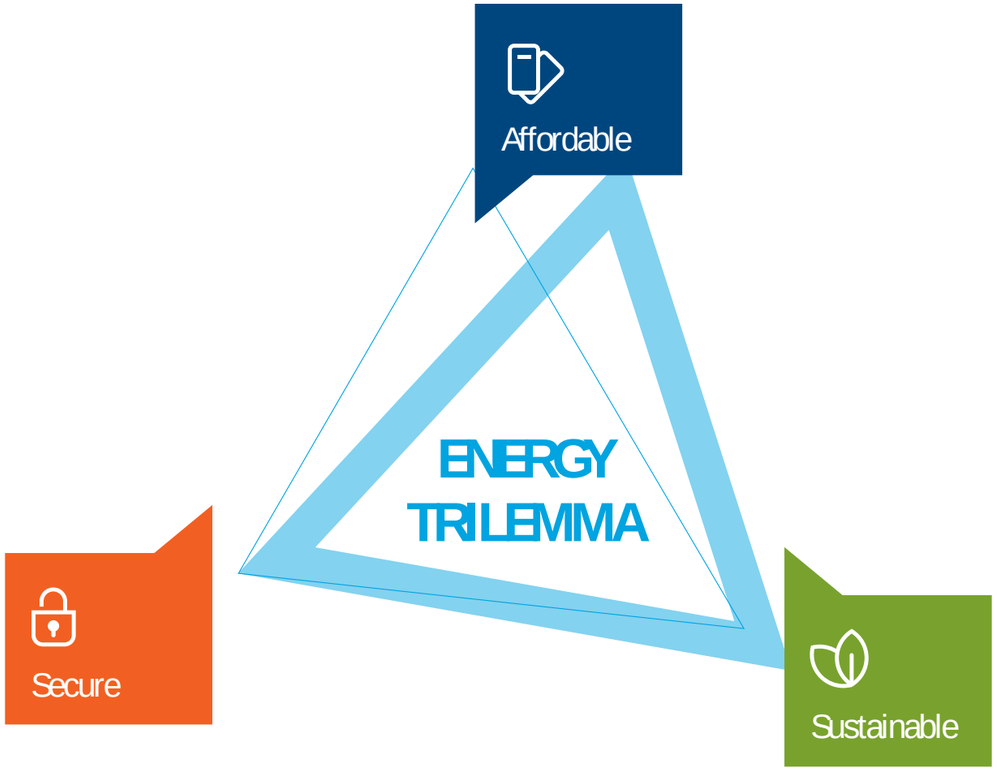
While the first great strides are being made towards a low-carbon future in electricity generation, the projected carbon reduction for the heat and transport sectors are minimal. As this is where the biggest challenge lies, we must do more if we are to deliver against our carbon commitment.

The achievements in renewable electricity are impressive, but have been possible without a direct impact on how we all live our lives. However, making changes to domestic heat and transport fuel is considerably more challenging and will require direct engagement with households, communities and businesses.

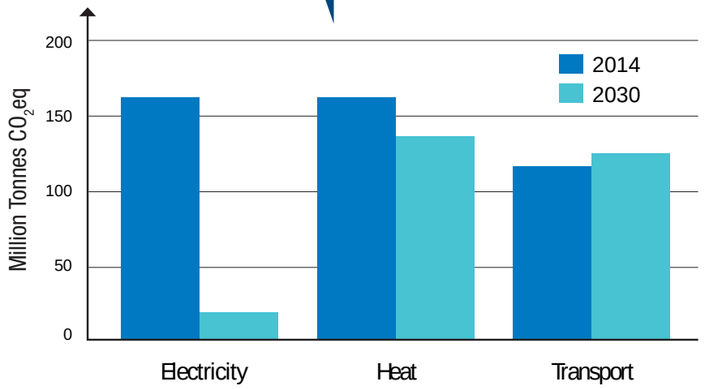
The gas network delivers more energy to homes and businesses than any other energy source. Gas is flexible, easy to store and can deal with the massive demand we face every winter. It is the energy of choice for new homes and to reduce fuel poverty. So we must do all we can to show how this valuable and extensive energy system can be used as a solution to our challenge. With 23 million homes currently connected to the gas network, finding innovative cost effective solutions that minimise the impact on the consumer must be a top priority.

Adapting the gas network

Baroness Neville Rolfe, former Energy Minister, has asked, "How far can the gas system adapt to meet the decarbonisation challenge?" We aim to answer this question in this chapter, and identify the actions required to show the full potential of the gas network as a fundamental aspect of the long term energy system we all rely on.[1]



UK carbon emissions



Good progress decarbonising the power sector, but 'almost no progress in the rest of the economy' (CCC July 2016)

The majority of customers will choose the solution that is the lowest cost and has the least impact to their existing home.

The gas network: critical for supplying energy

Before we look to the future, it is important to reflect on the evolution and adaptability of the gas network, and the critical role it plays in meeting the UK's energy demands.

Gas has been a source of energy in the UK for over 200 years, and the network on which it relies is sophisticated, versatile and resilient. During this time, the network has evolved to meet customer's needs.

History

Gas was introduced just over

200

years ago in the UK – partly a bi-product of coke manufacturing (steel production).

Town gas expanded to the 1960s. Town gas was hydrogen and methane and it served **circa 40 million appliances and 10 million homes.**

However, electricity, coal, oil all had large market shares. Nationalisation started in the 1940s, with natural gas conversion starting in the 1960s – gas replaced coal and power for heat mainly in cities.

Over 28,000km of pipes will be upgraded by 2021, and the programme will be complete by 2032.

Evolution of the network

The gas industry, and the transmission and distribution network on which it relies, underwent four major transitions throughout the 20th and 21st centuries.

1948

- Industry nationalised
- 1,062 separate gas companies merged
- 12 regional Gas Boards created and overseen by the Gas Council

1960s

- North Sea gas discovered
- UK switches from Town Gas to natural gas. Appliances converted over 10-year period as natural gas has higher energy content than town gas
- National Transmission System built to deliver North Sea natural gas across the country and linked to the local distribution networks

1980s

- Gas networks privatised
- Single transmission network and eight regional distribution network companies

2005

- Cadent (at the time National Grid Gas) sells four of its eight gas distribution networks
- Assets are now owned by several companies with prices and capital investment levels regulated by Ofgem
- Market opened to new, independent operators
- Like water and electricity markets, this created comparative regulation for gas

The demand for gas

Gas has been the leading fuel choice for consumers over the last 25 years, and is now the main fuel for heating, cooking and hot water in the UK. Accounting for over 50 per cent of total direct energy consumption, it is one-third cheaper than the alternatives.

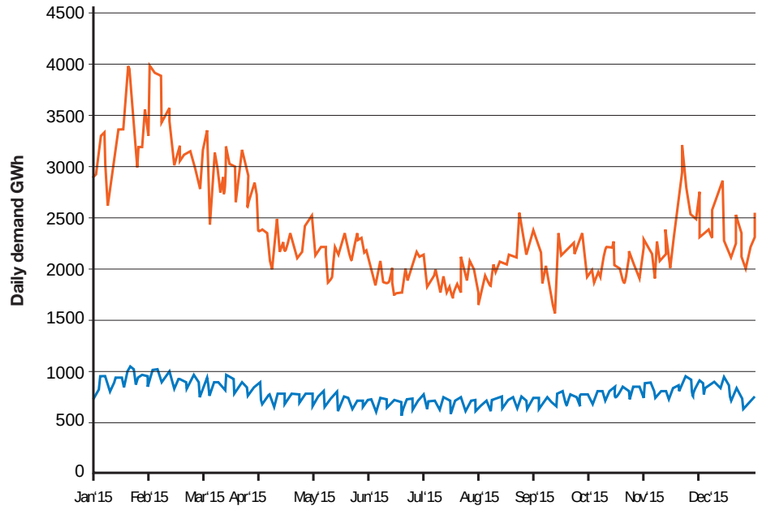
The gas network is designed to deliver gas safely and reliably to customers, including 1-in-20 peak day demand; that is a winter defined as the worst in 20 years.

It will need to remain flexible to manage peak, seasonal and exceptional demand such as severe weather and disaster scenarios. This is something that an all-electric solution is not capable of achieving.

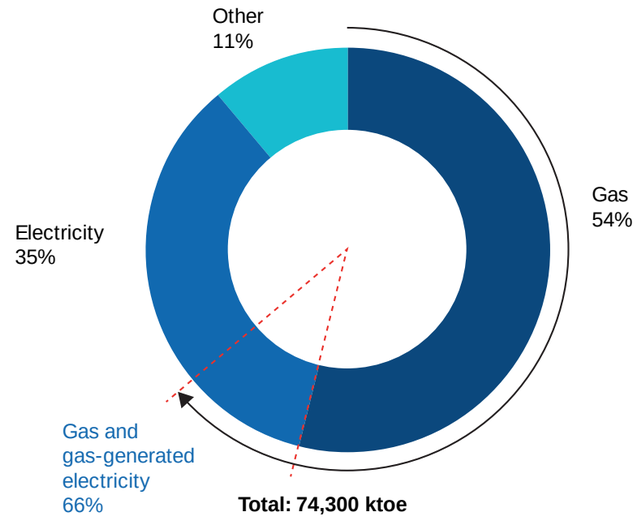
Our gas network is one of the most reliable in the world and provides 99.999 per cent security of supply. Substantial investment has been made to secure gas from fields in the North and Irish seas; through interconnectors with Ireland, Belgium and the Netherlands; and with LNG imports. Looking ahead, the UK's energy supply can become even more secure and resilient if the gas and electricity networks are used in an integrated way.

The gas network delivers a huge amount of energy to 23 million gas consumers across the UK safely, reliably and affordably.

Daily electricity and gas demand



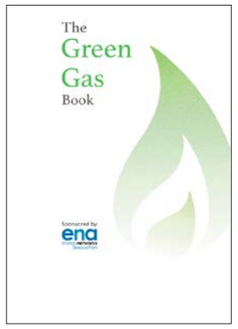
UK final non-petroleum energy consumption by fuel

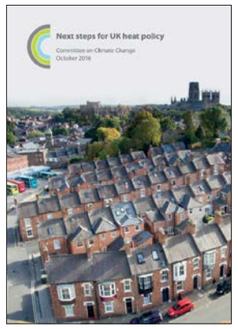


Gas is the main fuel for heating, cooking and hot water in the UK

The gas network: a low carbon future for heat

A number of independent reports published recently examine future scenarios for decarbonising heat and transport.



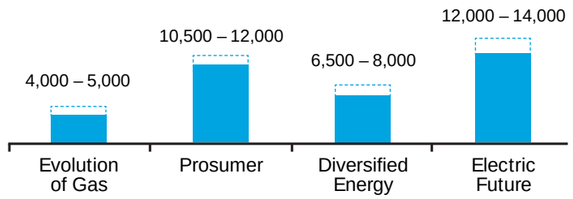


KPMG

A study by KPMG shows four possible futures, ranging from gas as the main heating fuel for most customers to electric heating systems, supplemented with a mix of current and alternative fuel usage models. The scenario with gas as the main heating fuel for most customers offers the lowest cost pathway compared with an all-electric future. This could potentially save individual households up to £10,000.[2]

Incremental cost per consumer up to 2050

£



The Policy Exchange

The Policy Exchange's report 'Too Hot to Handle', estimates it would cost around £300 billion to decarbonise heat by fitting electric heat pumps in most homes by 2050. It would also require an extra 105GW of electricity generation capacity (175 per cent of current peak electricity demand). That's the equivalent of £12,000 per household.[3]

Labour's Green Gas Book

This collection of essays explores the use of 'green gases' including biomethane, bioSNG and hydrogen as a long term solution, with the gas network delivering low-carbon heat to millions of homes.[4]

Committee on Climate Change

Decarbonising heat will require a major fuel source change, according to the Committee on Climate Change.[5] Gas is a relatively inexpensive and efficient source of energy particularly for heating, which makes up the bulk of our domestic energy requirements.

The Policy Exchange described the previous Government's heat strategy as: "…extremely expensive and difficult to achieve in practice…"

The gas network: a low carbon future for transport

Approximately 25 per cent of greenhouse gas (GHG) emissions come from transport. Around a quarter of this is produced by HGVs and buses – a disproportionately high figure when you consider they account for about 1.5 per cent of all UK road traffic. But the good news is that natural gas, and the gas network, could help significantly reduce carbon emissions, air and noise pollution.

LowCVP transport infrastructure roadmaps

A series of reports[6] published by LowCVP in 2015 set out the potential for heavy duty vehicles to use natural gas including biomethane. The roadmap below highlights key milestones and the decisions that need to be taken.

Well-to-motion emissions savings

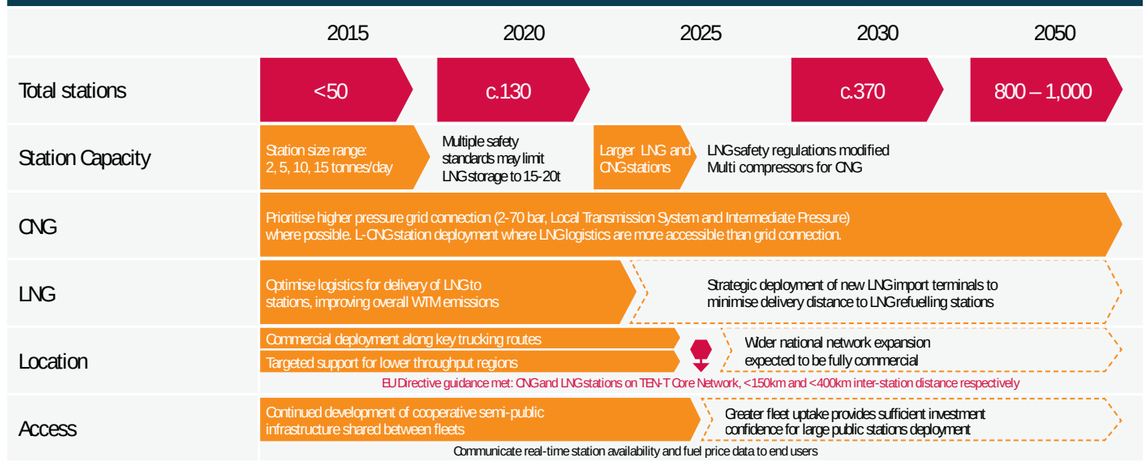
In 2015, a new CNG filling station opened in Leyland, Lancashire. An interim report published by Element Energy on the CNG filling station in Leyland, shows that the well-to-motion emission savings are 63 per cent when comparing 100 per cent biomethane with diesel.

As set out in our Transport Chapter, providing clean, quiet, affordable alternatives to diesel is a complex challenge that goes beyond simply replacing vehicle fleets or retro-fitting engines. However, the future is ours to influence and the key is working in partnership with industry, technology innovators and the Government towards a shared vision of a future transport network powered by cleaner energy.

To deliver the best possible outcome, Government policy on heat and transport needs to be joined up.

Network characteristics

Regulatory barriers will be the primary focus for enabling natural gas infrastructure, whilst a number of technical issues must also be resolved



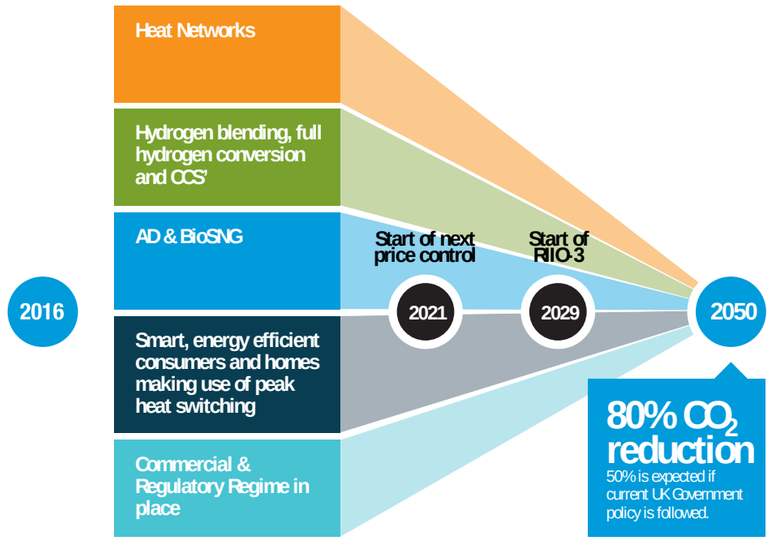
Total expected natural gas demand for transport by 2050 represents about 6 per cent of the UK's total natural gas consumption in 2015.[7]

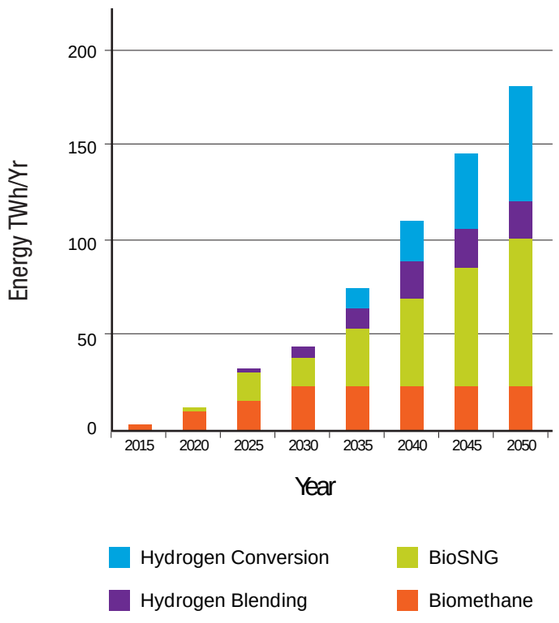
Gas: the pathway to 2050

Gas is an essential part of today's society; people like it because it's flexible, safe and cheap. However, carbon reduction targets are driving change and the energy networks need to evolve. But how can we do this? And what could the future energy network look like?

What do we need from the UK Government, our Regulators and the Industry?

- Strategic direction
- Policy
- Legislation
- Incentives
- Funding/tariff support
- Regulatory Framework
- Commercial





How would new sources of gas for heat and transport work in the future?

We looked in detail at the alternative sources of gas in the Supply of Renewable Gas chapter[8] but it is important to consider other factors that impact on their viability for heat and transport.

Hydrogen

If 'no regret' decisions on the future of the gas network are taken quickly, they could provide a platform for investment and innovation in hydrogen. This could be either hydrogen blending, which would have no impact on consumers up to a certain level of blending, or a full-scale hydrogen network.

If we get the funding and incentive arrangements right and provide long term stability, the market should be able to respond and innovate to deliver the sources of hydrogen required.

To enable hydrogen blending, and potentially pure hydrogen delivery, technical and safety standards will need to be modified. How hydrogen fits in with the regulated gas supply regime also needs considering to ensure a level playing field.

Some areas will require more investment than others to accommodate hydrogen. For example, the lower energy content of hydrogen compared with natural gas will impact network pressures, so the networks will play a key role in directing the best locations for hydrogen injection.

Carbon capture and storage (CCS)

CCS is vital for achieving cost-effective hydrogen production. It also provides benefits to other technologies such as further reducing the carbon content of BioSNG. But what investment is needed for CCS and how would it be deployed?

Anaerobic digestion (AD) and BioSNG

The performance of the market to deliver biomethane projects has been impressive, and this is against a climate of considerable uncertainty. Technology has been proven in this area with a well-developed supply chain and investment community. We have seen costs reduce through economies of scale. The performance in AD is supported by the renewable heat incentive, a Government initiative which is the first of its kind in the world.[9]

However, both AD and BioSNG require certainty of feedstock. Producing renewable gas from sewage waste via AD should be maximised because it is a reliable feedstock. So, should all sewage plants above a certain size be required to produce renewable gas by 2050?

Also, producing renewable gas from domestic and business waste would provide a strong link between population, location and feedstock availability. Should the bodies responsible for collecting domestic and business refuse be required to convert it to renewable gas? How would this benefit our ambition to reduce waste?

If Government identifies a need for a defined kWh of BioSNG, they must also take steps to secure the necessary feedstock. Likewise with crop-based feedstock for AD. This could be achieved with joined up waste and energy policies.

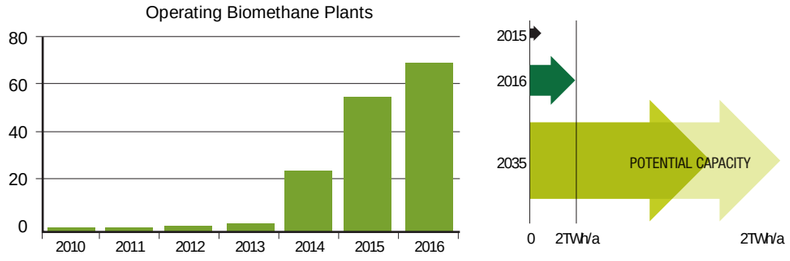
There is also the potential to convert the BioSNG process to hydrogen production.

As we saw in the Supply of Renewable Gas chapter, turning black bag waste into energy could generate enough gas to supply up to half the UK's domestic demand by 2050 and help reduce carbon. With over 50 plants currently operating, advances in biogas production from waste AD could see more than 100 plants operating in the UK soon. How can we make sure this fits into a UK-wide energy framework offering the right solution at a local level?

Heat networks

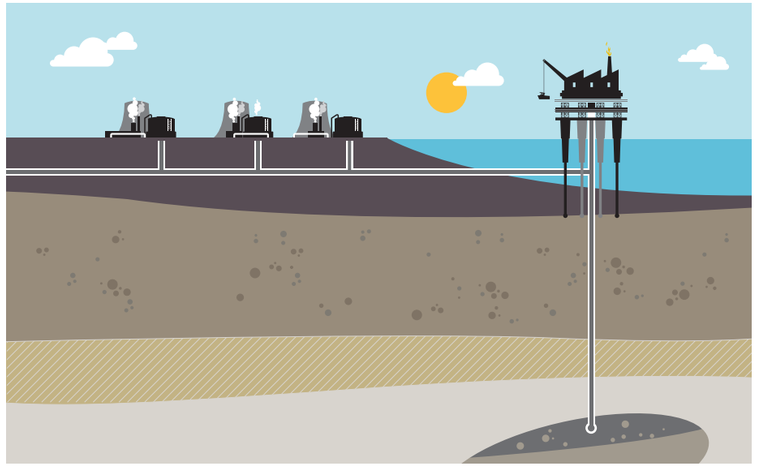
Heat networks provide heating and hot water to multiple residential properties via a network of insulated water pipes carrying residual heat from industry and commercial properties. They are an effective way to decarbonise heat in heavily urbanised areas, and new housing developments can benefit from this type of technology.

Local authorities could set the strategic context and initiate the development of district heat networks. As planning authorities and service providers,[10] they have local knowledge, organisational capacity and key functions.



Conclusion

Having undefined pathways to 2050 is both an opportunity and a challenge for the energy sector. What we absolutely do need is joined up policy across Government departments, a collaborative approach from the industry, and a 'no regrets' roadmap.



How do we create the future?

So how do we turn great ideas into reality and get from the gas network of today to the gas network of the future? Innovation across the industry is moving at a fast pace and Cadent has been investing heavily

We tend to take our infrastructure for granted because much of it is hidden from view, and the gas network is no exception. But behind the scenes, innovation is happening. We've covered many examples in previous chapters in the Future of Gas series, and here we explore some that focus on the network.

HyDeploy: testing hydrogen on a 'live' network

In 2017 Cadent Gas Ltd, along with NGN and the HyDeploy consortium, will begin a three year project at Keele University to demonstrate that a blend of hydrogen and natural gas can be distributed and utilised safely and efficiently in a distribution network without disruptive changes for customers whilst decarbonising the gas grid. This is the first practical demonstration of its kind since the UK's conversion from town gas. The university's gas network is representative of the wider UK distribution network and serves as the ideal location to host such a project.

Keele University

HyDeploy

The Northern Gas Networks H21 Leeds City Gate project is proving that converting the city's entire natural gas network to hydrogen is technically and economically feasible.

Kiwa Gastec's 'Hy House' research project in Scotland showed the risk of using hydrogen in the home was no greater than using natural gas.

h21

Commercial BioSNG demonstration plant, Swindon[11]

Cadent Gas Ltd is supporting the construction of a plant to produce renewable, low carbon BioSNG by gasification of residual household waste. Capable of heating 1600 homes or fuelling 75 HGVs, it will also help industry better understand the contractual, commercial and engineering issues related to production, fuel off-take and waste feedstock supply.

The commercial demonstration plant will provide assurance of the technology to potential investors such as waste processors and energy supply companies. With suitable Government support, BioSNG plants could be rolled out across the UK, providing a local solution to waste and a long-term large-scale source of renewable gas for home heating and transport fuel. In time BioSNG from these plants will be provided at costs competitive with natural gas prices, whilst potentially generating exports of this UK-owned technology.

Leyland CNG Filling Station[12]

In 2016, Cadent in partnership with CNG Fuels unveiled a new state of the art filling station in Lancashire capable of fueling over 500 HGVs per day with CNG directly from the high-pressure LTS.

It also supplies 100 per cent renewable biomethane (Bio-CNG) and is an important part of the UK's rapidly growing CNG refueling infrastructure. Made at anaerobic digestion plants from waste, the biomethane is delivered to the filling station through the pipeline system.

Gas Quality Review and a future billing approach

Gas Regulations[13] set out the minimum gas quality requirements to safely operate the gas network and appliances in the home. The standards were set at a time when gas came from the North Sea. Now it comes from a number of different sources, and with the potential for alternative sources such as hydrogen, the gas quality standard is being reviewed.

Also, the way customers are charged for gas energy used today is a barrier to a low carbon future, because it requires lower-carbon gases like renewable bio-methane to be enriched with high carbon

propane first. Cadent is exploring more specific ways to charge for gas energy that would promote distribution of renewable and low carbon gases and continue to charge customers for the gas energy they use. This is critical to the future of the industry.

Future Billing Methodology

Opening up the gas markets and real time energy networks

SGN have led two projects looking at changing how the gas network operates. Opening up the gas market demonstrated how the Gas Safety (Management) Regulations could be extended to allow 90 per cent more LNG to enter the network. Real time energy networks looks at how the gas network could manage a range of different gas sources and gather more information about customers' energy habits.

Bridgend future modelling and Cornwall Energy Island

Wales and West Utilities ran two projects to ascertain the feasibility and roll-out of alternative heating technologies. The project at Bridgend in 2015 focused on ground source and air source heat pumps, and local heat networks.[14] In 2016, Cornwall Energy Island examined how peak energy demand in the county could be met by other energy source, and challenges such as storing energy.[15]

Smart metering

By 2020, around 26 million homes in England, Wales and Scotland will be using a smart meter. These give customers more control over their energy use and the data can be used to help improve the efficiency of the gas distribution pipe network.

The Energy Loop[16]

The Energy Loop is an online platform designed to help consumers make the right choice based on an analysis of their circumstances and manage the installation process. The Energy Loop drives customer choice and inclusion, and transforms how people across the UK access the most efficient energy options for homes, small communities and local generation schemes.

THE ENERGY Loop

Beyond technology

It's also worth remembering that innovation goes beyond finding solutions rooted in engineering and technology. Customer acceptability; commerciality; and Government policy and regulation can make a big difference too.

If the past was dominated by a reliance on fossil fuels, the future could not look more different. The worlds of business, academia and government are working at pace to solve challenges, develop ideas and create growth in a rapidly changing energy sector full of commercial opportunities. Cadent is at the heart of this evolution.

How does the gas network support the future?

Throughout this chapter, we've seen how the network is flexible enough to respond to innovation, particularly the wealth of new gas sources coming on stream. But what needs doing to the actual gas network to take advantage of future opportunities? How do we design it to cope with new gas sources and customer demand?

Gas distribution network considerations

New entry connections

- **Reinforcement to connect new sources of gas (biogas, BioSNG and shale)**
- **CV monitoring**

As levels of gas injected directly into the network increase, it will have a greater impact on operational and investment decisions. How gas entry is charged for using the gas distribution network will have to evolve quickly, to ensure cost is reflected accurately.

New forms of pricing may also be required if it is to be used to inform the location of new energy sources. Gas injection projects will also expect to get their product to market, and may seek compensation if they start to see constraints on network capacity.

New exit connections

- **CNG fuel sector for HGVs and buses**
- **Network of CNG filling stations with CNG connections to the LTS**
- **Gas power generation**
- **Network extensions to fuel poor**

The work we've done to date on CNG vehicles (see Transport chapter[17]) found that CNG filling stations are best fed from our local transmission system because this is the most cost-effective pressure for the running costs of the compressors. We have a lot of capacity available on these systems as we are connecting more and more biomethane, and connecting more CNG filling stations would attract more biomethane supplies. By 2030, there could be as many as 370 filling stations.

We are currently seeing an increase in the number of connections of small scale electricity generators within our networks, creating more and more interconnections between electricity and gas networks. With decarbonisation of the gas grid, this principle can continue into the future using small scale reactive plants to pick up the slack from renewables and reduce the need for transmission investment within the electricity system. Using gas and electricity in the future offers options.

New use of the network

- **Heat networks**
- **Post smart services**
- **Hydrogen deployment**

The post-smart metering era will be data-rich with much more accurate consumer energy usage data. This could enable new services, including network time of use tariffs or other demand management services, providing tools to optimise the gas network's operational performance. As the operation of the network becomes much more complex with high levels of gas being injected directly into the distribution network, the physical operation of the gas system will need to become much more actively managed, with the demand side playing a vital role.

Gas powered heat networks can offer connectivity to new build developments and areas that are currently off grid.

Storage and compression

- **Needed for hydrogen conversion**
- **Opens up the network for more biomethane or shale**
- **Move gas efficiently**

To balance a future network with more incoming gas and demand in some areas, storage will be needed. We anticipate it to be similar to that used on the national transmission system for seasonal changes, which is provided by salt cavities among others. Storage would also offer the opportunity to connect more biomethane, BioSNG and hydrogen in future.

Using compressors could be the most cost-effective way to increase the amount of renewable gas in the network. Fitted at strategic locations, compressors move gas to where it is needed. This presents some design and control challenges, which are the focus of our current viability assessment.

Asset health

- **For future entry and exit connections**
- **Continue current plan to give the Network opportunity to flex to future options**

As the lower pressure network is nearly 200 years old, we are currently refreshing, replacing or removing assets. The decision on whether to refresh, replace or remove is based on usage, necessity, and ease of refurbishment.

Iron mains replacement

- **Underpinned by safety legislation**
- **Reduced GHG emissions from the network**
- **Reduced operational costs of repair and customer interruptions**
- **Enables hydrogen capability**

Cadent is currently replacing ageing metallic pipes with new polyethylene plastic pipes. This will ensure the continuation of a secure and reliable service, and reduce leakage and associated repair work. All potential pathways to decarbonisation using natural gas rely on the existing network in its current state or following the replacement programme.

If we want to convert the network to either full hydrogen or a hydrogen blend, we have to finish the mains replacement programme.

A policy framework fit for the future

If we are serious about addressing the needs of the energy trilemma, we need to work together, delivering investments at scale to drive forward change. The time to act is now. Government can help drive change across the energy industry by setting a clear, joined up policy framework with a coherent industry wide solution, integrating heat and transport decarbonisation policies.

It is policy that drives change in the energy industry. By taking a lead and developing a clear policy framework, making policy decisions and establishing a framework[18], the Government can facilitate change in the energy industry to deliver a solution that meets the needs of the energy trilemma. We believe success will be driven by government, policy makers, investors, innovators and suppliers being willing to participate and work together.

Throughout this publication, we have looked at introducing new sources of gas into the existing network, and how we can use an asset we already have at minimal extra cost. But questions about how to fund our vision remain. How do we make the best use of the gas network as quickly as we can? Where do we need to invest? Which innovations will get us there?

Government funding is needed to drive a holistic heat and transport solution, and enable local authorities to have a greater say in investment. This will help local authorities to define and adopt the best regional approach, accounting for factors such as availability of feedstocks, and the best design solutions for customers with the least-cost and lowest-impact.

Any future UK energy solution will come at a cost, but the gas network will deliver the least-cost, lowest-impact solution for both the UK and our customers.

Government policy and regulatory considerations: key enablers

- Commitment from Government to exploit existing gas resources as much as possible
- Long term certainty of RHI with BioSNG tariffs
- Coherent policy on heat for the fuel poor
- Integration of waste and heat policy at a local and national level
- Local authorities to look at waste plans and divert to gas
- Integration of decarbonising both heat and transport alongside power
- Industry collaboration, for example, on appliance development
- A RIO price control framework supporting facilitation of low carbon gas, which:
  - Stimulates innovation
  - Supports network flexibility and reliability
  - Continue investment in asset health of gas network including iron mains replacement programme. Provides targeted outputs and incentives

The cost of change

- Meeting winter peak heating demand is a critical cost driver
- Large investment will be needed to convert homes and businesses to new energy types and funding sources must be identified
- Continuing to use the gas network offers significant savings versus alternative heating sources where large investment would be needed
- Transport decarbonisation will need to take place alongside heat to minimise whole system costs

What next?

'No regrets' is a phrase commonly associated with future energy scenarios. It means we need to keep all our 2050 options open until a choice has been made. It also means that network investment, policy and legislation needs to be flexible.

The networks operate through the lens of the price control period. To achieve the required trajectory, innovation and infrastructure needs to be considered in the next network price control period.

Ahead of the next price control period, Cadent has a role as a facilitator to make sure the views of all interested parties are heard. The stakeholder landscape is wide and varied, and includes customers, network operators, energy suppliers, Government departments, innovators, consumer protection groups and the regulator Ofgem.

ofgem
Making a positive difference for energy consumers

Network Regulation
The RIIO model

Department for Environment Food & Rural Affairs

Department for Transport

Department for Business, Energy & Industrial Strategy

Engaging with our stakeholders

In this chapter and throughout the Future of Gas series, we have examined the role of gas in the energy mix to 2050 and how it can help solve the energy trilemma. This is an exciting time for the industry with many challenges and opportunities ahead. Now we'd like to engage with you during 2017 and explore how policy makers, the energy industry, innovators and others create a future that benefits everyone including customers.

We've identified some key areas for engagement, and you will have some of your own topics and questions. Please share them with us: futureofgas@cadentgas.com

Customers

- As the gas networks transition to deliver low carbon energy, how do we manage the specific customer and stakeholder requirements and expectations of the energy network?
- Could the development of innovative and flexible appliances be a game changer in the transition of the gas networks to deliver low carbon energy?
- How do we integrate addressing fuel poverty as a central objective within the transition to low carbon heating?

AD and BioSNG

- How do we best facilitate the production of renewable gas to heat homes and reduce transport emissions?

Hydrogen and CCS

- What is the potential for hydrogen blending in the existing network and what are the constraints?
- How would the network have to adapt for a full-scale conversion to 100 per cent hydrogen?
- What investment is needed for CCS and how would it be deployed?

Transport

- How do we create a network of gas transport infrastructure?

Heat networks

- How does the gas network best interact with heat networks?

The gas network

- How do we best design the network to cope with new sources of gas and gas demand?
- How do we develop the right pricing structure and safety regulations?

References

1. https://www.gov.uk/government/speeches/baroness-neville-rolfes-speech-at-the-policy-exchanges-heat-summit

2. Arapostathis, 2011

3. https://www.ucl.ac.uk/energy-models/models/uk-markal/dodds-_-mcdowall-2013-future-gas-networks--energy-policy

4. https://www.theccc.org.uk/tackling-climate-change/reducing-carbon-emissions/carbon-budgets-and-targets/

5. http://www.energynetworks.org/assets/files/gas/futures/KPMGper cent20Futureper cent20ofper cent20Gasper cent20Mainper cent20reportper cent20plusper cent20appendicesper cent20FINAL.pdf

6. https://policyexchange.org.uk/wp-content/uploads/2016/11/PEXJ4810_Too_hot_to_handle_09_16-V2-WEB.pdf

7. Next Steps for UK Heat Policy, published October 2016, https://www.theccc.org.uk/publication/next-steps-for-uk-heat-policy/

8. http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=45609 (Renewable gas chapter)

9. http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=8589935584 (Transport Chapter)

10. http://www.energysavingtrust.org.uk/scotland/grants-loans/renewables/renewable-heat-incentive

11. http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=45609 (Renewable Gas Chapter

12. http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=858993558 (Transport Chapter)4

13. Schedule 3, GS(M)R 1996

14.http://www.energynetworks.org/assets/files/gas/futures/KPMG%20Future%20of%20Gas%20Main%20report%20plus%20appendices%20FINAL.pdf

15.http://www.energynetworks.org/assets/files/gas/futures/KPMG%20Future%20of%20Gas%20Main%20report%20plus%20appendices%20FINAL.pdf

16. http://www2.nationalgrid.com/workarea/downloadasset.aspx?id=8589934902 (Domestic Heat Chapter)

17. http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=8589935584 (Transport Chapter)

18. https://www.theccc.org.uk/wp-content/uploads/2016/10/Future-Regulationof-the-Gas-Grid.pdf

Glossary

Anaerobic Digestion (AD): a series of biological processes in which microorganisms break down biodegradable material in the absence of oxygen to produce biomethane. The biogas produced is a mixture of carbon dioxide (CO2) and methane. What's left from the process is a nutrient-rich bio-fertiliser.

Biomethane: a naturally occurring gas produced by anaerobic digestion and defined as a green source of energy.

BioSNG: typically produced via an initial gasification step followed by gas conditioning, Synthetic Natural Gas synthesis and gas upgrading. BioSNG can be used in a similar way to biomethane (biogas) generated via anaerobic digestion. Syngas may also be converted into liquid advanced biofuels.

Carbon capture and storage (CCS): an innovative technology that can reduce levels of CO2 released into the atmosphere by capturing it at source and storing it safely and permanently deep beneath the seabed.

Compressed natural gas (CNG): made by compressing natural gas (which is mainly composed of methane, CH4), to less than 1 percent of the volume it occupies at standard atmospheric pressure. It is stored and distributed in hard containers at a pressure of 20–25 MPa (2,900–3,600 psi), usually in cylindrical or spherical shapes.

Demand side response: services that enable businesses and consumers to turn up, turn down or shift gas/electricity demand in real-time.

Fuel poverty: households with low incomes and high energy costs, where required fuel costs are above average (the national median level) and were the household to spend that amount, they would be left with a residual income below the official poverty line.

Gasification: a process that converts organic or fossil fuel based carbonaceous materials into carbon monoxide, hydrogen and carbon dioxide. This is achieved by reacting the material at high temperatures (>700 °C), without combustion, with a controlled amount of oxygen and/or steam. The resulting gas mixture is called syngas (from synthesis gas or synthetic gas).

Heat pumps: devices that takes advantage of the latent heat that exists in the air, ground or in bodies of water. Heat pumps can be used as hybrid systems, where gas is used to 'top up' and meet heat demands at peak when the heat pump is likely to run at its lowest efficiency.

Hydrogen: made (in this context) by processing natural gas through steam methane reforming and extracting the carbon. This produces hydrogen equivalent to other renewable sources, which could be used for heating and cooking.

Liquefied natural gas (LNG): a natural gas (mostly methane, CH4, with some mixture of ethane C2H6f) that has been converted to liquid form.

National Grid Future Energy Scenarios: visit http://fes.nationalgrid.com/

National transmission system: the network of gas pipelines that supply gas to about forty power stations and large industrial users from natural gas terminals situated on the coast and to gas distribution companies that supply commercial and domestic users.

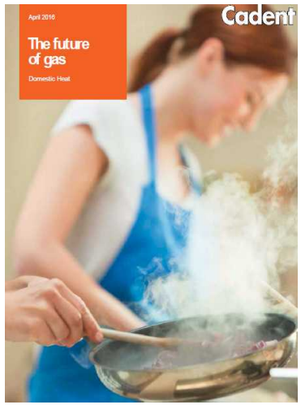
Renewable heat incentive (RHI): £76.20 per MWh is based on the period of 1 April 2015 to 1 July 2015. £58.70 per MWh applicable from 1 January 2016. Figures based on Tier 1 plants up to 40,000 MWh production per annum.

Other publications in this series

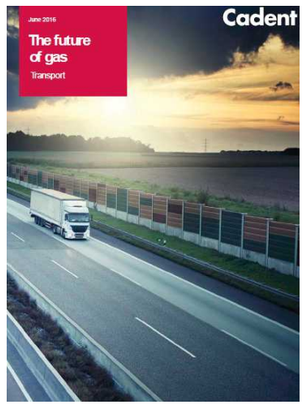
The Future of Gas series seeks to address the challenges and opportunities to help the UK move towards a low carbon economy. These include efficiency measures that customers can take to reduce their consumption, and new sources of gas that could deliver energy in a more sustainable way. Look out for the following publications:

Introduction to the Future of Gas
Overview of the challenges in meeting the UK's carbon reduction targets

Supply of renewable gas
The benefits of renewable gas in relation to the energy trilemma



Domestic heat
How gas networks can help deliver low carbon solutions to heat our homes



Transport
The potential role for gas in the HGV transport sector.

Disclaimer

This paper is intended to help and encourage discussion of some challenges facing the UK's energy needs. Any views expressed are those of the authors and do not necessarily reflect the policy or position of any organisation and/or any UK Government body unless specifically stated. It does not replace the Gas Ten Year Statement or the Electricity Ten Year Statement (or any other document containing substantially the same information as those) published respectively by Cadent Gas Ltd. and National Grid Electricity Transmission plc ("National Grid") in accordance with relevant licence conditions.

Whilst reasonable care has been taken in the preparation of this paper, no representation or warranty, either express or implied, is made as to its accuracy or completeness. Parties using the information should make their own enquiries as to accuracy and its suitability for their purposes. Save in respect of death or personal injury caused by its negligence, or fraud, or for any liability which cannot be excluded or limited in law, neither National Grid nor any other group company, nor any director or employee of any such company, shall be liable for any losses, liabilities, costs, damages or claims whatsoever as a result of the content or use of, or reliance on, any of the information in this paper.

Printed on 100% recycled paper

For more information about how to get involved please contact us at **futureofgas@cadentgas.com**

The papers will be published online a **cadentgas.com/futureofgas**