The Green Gas Book

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The Green Gas Book is produced by the Parliamentary Labour Party Energy and Climate Change Committee as a contribution to policy development in low carbon energy

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Foreword

Lisa Nandy MP and Caroline Flint MP

Earlier this year, Britain's dependence on gas for power generation hit a five-year high. More than a third of our electricity is now regularly generated using gas, and the vast majority of families in Britain heat their homes using gas too. This reliance on gas puts the future role of the fuel at the heart of the debate around the kind of energy economy we want to build.

How much of this fuel we use, and where we source supplies from, will have implications for our national security, our prosperity, and for the health of our natural environment. Heating represents a third of the UK's carbon pollution and the Energy Secretary's chief scientist recently warned, "Perhaps the greatest challenge to meeting our long-term emissions target is decarbonising our heating system."

Britain has been incredibly lucky to have benefited from gas from the North Sea. Our own world-leading oil and gas industry has generated thousands of skilled jobs, raised tens of billions in tax revenues that have helped fund our public services, and offered secure and stable supplies of gas which in turn have enabled us to cut our dependence on imports.

Now that North Sea production is declining, more than half our gas is coming from imports and that figure is set to rise substantially. Britain is increasingly turning to Norway and other European neighbours as well as countries further afield like Russia and Qatar in order to source the gas we need. The government is also pursuing the possibility that the UK could develop new indigenous sources of gas using fracking, which is controversial. Ministers have not only failed to provide safeguards to reduce the risks to drinking water sources and sensitive parts of the countryside, but have also threatened to overrule communities who object.

So is there another home-grown gas supply that is being overlooked, despite its potential to create new jobs, to lower imports, and to cut our environmental footprint all at the same time?

It is this exciting prospect which is explored by experts and industry pioneers in these pages.

Turning certain rubbish materials and farm and food waste into various types of biogas – 'green gas' – holds the potential to cut costs, radically reduce pollution, and decrease our reliance on imports. Crucially, using more green gas could make a real impact on the decarbonisation of heat without the need to overhaul our national gas pipeline and heat delivery infrastructure and without significant technical barriers.

Before he became Prime Minister, David Cameron and his team pledged to put biogas production at the centre of their energy strategy. The Conservatives even suggested green gas could replace all EU gas imports from Russia by 2020, and meet up to half of UK household demand. Instead, under the Tories it is providing only a tiny fraction of the gas we currently use, and whilst some progress in developing green gas production has been made with the assistance of the Renewable Heat Incentive, the vast bulk of its potential remains untapped.

In a leaked letter, the Energy Secretary recently acknowledged to her Cabinet colleagues that the UK is falling behind the rest of Europe when it comes to using renewable heat sources, admitting that as a consequence the UK is on course to miss a 2020 legally-binding target on clean energy.

Yet even now, the government have no strategy for deploying more green gas. Grasping this untapped potential would help us build a cleaner economy, and it would ensure that families continue to spend money in the UK – rather than on imports – that could help us to create jobs and opportunities for young people here in Britain.

For our energy security, the environment and the economy, green gas has the potential to help us pragmatically solve the immense energy and climate challenges we face. It deserves our full support.

Green Gas for an Affordable, Secure and Sustainable Future

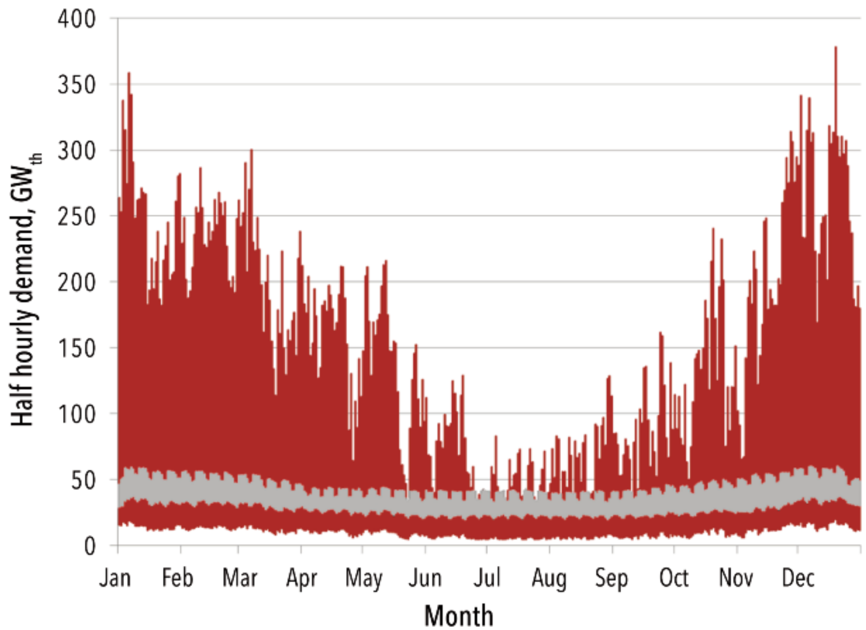
Mike Foster

King Canute could not turn back the tides; he acknowledged his powers were limited. Similarly, UK politicians must recognise that our geographic location, climate and weather patterns are major determinants of future energy policy and that they can try but will fail to alter them. The energy trilemma, a phrase that rightly suggests the difficulty in balancing the competing demands of affordability, reliability and sustainability, should be set against the UK's particular energy needs.

Gas has, for the past two hundred years, been a fuel that has offered the UK flexibility – be it for street lighting; industrial processes; power generation or heat demand. Gas in the UK used to be manufactured, when it was "town gas" and then from the 1960s converted to "natural gas". As a result of its abundance, the UK has the world's leading gas grid infrastructure in place, directly supplying the energy to heat 85 per cent of UK homes. The next century could be about "green" gas.

Gas currently accounts nearly 50 per cent of non-transport UK primary energy needs – for power generation and heat. If offers the flexibility to back-up renewables (wind and solar) when our weather patterns dictate and can be used as baseload too, if nuclear becomes unaffordable. But the environmental cost is that gas accounts for 40 per cent of the UK's greenhouse gas emissions. This needs to change and green gas is therefore central to the UK's future energy mix.

When it comes to heat, gas is the UK's fuel of choice, and for good reasons. The much-used graph (below) by Robert Sansom of Imperial College, demonstrates better than words can, the challenge. Heat demand is seasonal, no surprise there, but its peaks during the winter either need to be met by supply or people will go cold. The latter is no policy prescription that any sensible politician advocates. So having the energy, in whatever shape, available at short notice to meet peak demand, whilst not having supply sitting idle for much of the year has to be the energy outcome of choice. In 2010, the Coalition Government suggested heat demand could be met by switching from gas to an all-electric solution. The same graph also shows the levels of current electricity demand. As you can see, whilst there is variation across seasons, days and hours the peaks and troughs are nowhere near as great.



Synthesised national half hourly heat demand (red) for 2010 and actual half hourly national electricity demand (blue). Source: Dr Robert Sansom.

So whilst baseload power generation, either through nuclear or renewables (with gas backup) can cater for the UK's electricity demand, building additional generating capacity to deal with heat demand as well, is simply unaffordable.

Even after an major energy efficiency retro-fit in 26 million homes and businesses, it is estimated that to meet peak heat demand would require the equivalent of 30 new nuclear power stations, or 100 additional inter-connectors, 60,000 additional wind turbines (with back up) or every UK home to have solar PV (again with back up). On top of that, the UK's current distribution networks could not cope with such extra demands on them. A switch from gas to electric requires householders to fit alternative heating systems – yes that means ripping out gas boilers, pipes and radiators as these systems are different to those using electric heating appliances. These are costly changes that consumers can ill-afford. A recent study of Bridgend, produced by Wales and West Utilities, suggest that 81 per cent of households simply do not have the cash at their disposal to make that investment, without massive subsidies. The UK would also need to be entirely re-wired, from power station to the home to keep people warm and meet the UK's climate change obligation. That cost would also be borne by the consumer (voter). E&Y estimate the current additional cost per household, to increase sub-station capacity is £290 (urban) and £390 (rural).

All the time, underground and becoming redundant with an all-electric scenario sits the UK's gas distribution grid. Developed over the years, updated with PPE (the yellow plastic stuff you see) rather than iron pipework, the all-electric scenario renders this valuable piece of UK infrastructure unnecessary. And yet, it currently meets the heating needs of 85 per cent of UK homes – politicians meddling with this do so at their peril.

So if gas can be supplied to the vast majority of homes, meeting peak heat demands, in a cost effective manner then surely it makes sense to see how this source of energy can become "green".

There is no definition of what "green" gas is; indeed this is part of the attraction in that there is no winner or silver bullet but instead a range of green gases. Perhaps "low carbon" gas is a better description in that it is what it says; it has lower carbon dioxide emissions when used compared to natural gas (methane). As an aside, on a "well-to-home" basis, natural gas carbon emissions vary – primarily due to the transportation process used – with UK-sourced natural gas having half the carbon intensity of LNG imported from Qatar and nearly a third the carbon intensity of gas sourced from Russia.

First off the blocks is biomethane. This is the gas captured from waste processing, typically anaerobic digestion. The technology is proven, it has worked for years. In my former Worcester constituency, for years the warm water of the swimming pool in St Johns was heated by the gas from the neighbouring sewerage plant. Anaerobic digesters are increasingly commonplace in rural areas as the farming industry uses the non-domestic Renewable Heat Incentive to support generation of biomethane. The gas generated is then used locally, often to generate electricity which can be fed into the grid. Companies like Severn Trent have taken a further step, and clean up the biomethane to inject the "green" methane into the gas grid at their sewerage works in Minworth, on the outskirts of Birmingham. By the end of 2015, some 2TWh/annum was injected into the gas network, equating to around 155,000 homes.

Rural homes have often been seen as the obvious target for alternative energy sources. Industry has responded by developing biopropane as an alternative to LPG used in around 170,000 UK homes and businesses that are off the gas grid. The biopropane is made from a waste product, hence its "green" qualification and it requires no change to either the boiler or heating system as the gas is identical in its composition. Calor plan to start marketing biopropane in 2017 to their LPG customers. EUA have calculated that carbon emissions could be cut by 83 per cent if consumers switch from LPG to biopropane.

Following on from biomethane, is Synthetic (or Substitute) Natural Gas (SNG). This is a methane-based gas, created artificially rather than being extracted from the ground. It achieves "green" status because it uses waste materials, usually sent to landfill or incineration, to create the gas. The process is technically complex, it involves Advanced Plasma technology in effect heating the waste to very high temperatures, generating gas that is then captured for use. Ofgem have recently awarded National Grid funding to develop a commercial scale plant in Swindon, having seen the success of smaller trials of the technology. The alternative use of waste gives the gas its "green" credentials. The Swindon plant envisages supplying gas for HGVs but there is nothing to stop it being fed into the gas grid for everyday use once it is blended to reach the gas quality standards required.

Studies by National Grid suggest up to a third of current UK domestic demand for gas can be met from bioSNG, around 100TWh/annum. If progress towards greater energy efficiency in our homes and workplaces continues, they suggest by 2050 a 30 per cent reduction in gas demand could be achieved. This leaves around a third of current UK demand to be met from natural gas, but by 2050, this means half the UK's domestic gas supply could be green gas.

There is an important debate around bioenergy – growing crops for energy and not food, but using UK marginal arable land, or grassland, could provide a valuable source of feedstock for bioSNG plants. Estimates vary, but 200TWh of green gas supply is at the more prudent end of the scale.

A typical bioSNG plant is around half the size of a local authority household-waste incinerator, for the same volume of waste is uses. Its emissions are cleaner; it will last 25 years and create around 100 jobs in the construction phase and permanently employ around fifty skilled engineers to run it. It provides for more jobs than landfilling does and the UK would be using its waste and not in some cases exporting it!

Work undertaken by the Future Energy Scenario team at National Grid, suggests that any outstanding requirement for natural gas to meet domestic demand would meet our 2050 climate change obligation of an 80 per cent reduction in greenhouse gases. The only decisions the UK needs to make are how they use the green gas, and where do they get the natural gas from (but that's another issue).

But what if the UK wants to go greener? What if the above estimates are too optimistic, how can we keep homes warm and the planet safe? So next in the queue, but not last, is hydrogen.

Hydrogen is currently produced from natural gas using Steam Methane Reforming, where the carbon can then be captured. The beauty of using hydrogen is that when the gas is combusted it does not give off carbon dioxide. It is the ultimate green gas. What's more, it can be produced using the process of electrolysis, from excess wind power at a time the electricity grid does not require its use. Hydrogen can be transported through existing PPE pipes and only minor modifications required to appliances.

The question is how much hydrogen is used and in what manner? It is possible, within existing gas quality guidelines, to mix up to 2 per cent of hydrogen into the blend that flows through the gas grid. Some studies suggest that up to 20 per cent might be feasible – remember this makes the overall mix of gas "greener". However, Northern Gas Networks are conducting a feasibility study into 100 per cent hydrogen through the gas grid. Their Leeds 21 study is arousing considerable interest within the industry on the basis that it envisages using the existing gas grid, conventional heating systems such as central heating in the home but in a completely carbon free way. The way in which the gas grid grew up from localised supply to a national infrastructure enables the potential switch to be made in an organised manner. For those of a certain age, similar to the 1960s switch from towns to natural gas. Already appliance manufacturers are discussing the implications for their products. It could well be that swapping a central heating boiler's burner, in each home, is an affordable option compared to other means of tackling the trilemma.

This essay is not designed to reach the conclusion that one single option can solve the UK's future energy needs, whilst being affordable and green. The reality is that a range of options is likely to provide the answer. What is essential though, is that the UK recognises the climatic challenges its geographical location burdens it with and that the existing gas grid provides a mechanism for delivering the desired outcome. Green gas, either lower carbon from source, using waste products or hydrogen offers a way forward. It means not turning our back on gas; nor limiting its use solely as a short-term solution.

Green Heat. Home Grown.

Caroline Flint

Expanding renewable energy and seizing the potential to create a new energy industrial revolution was always part of Labour's vision when I was Shadow Secretary of State for Energy and Climate Change from 2011-15.

In 2013, I questioned why the conversation was always dominated by power – the production of green electricity – but never heat?

Policy-making in the UK – and indeed across Europe – has been lopsided. Attention and investment has focused upon how to clean up electricity. For some time we have neglected tackling the other major pillar of our energy mix: gas.

If 80% of UK homes are heated by gas, and the UK has one of the most advanced gas networks in the world, then we need a clean heat strategy.

Even if 1% of the housing stock was rebuilt every year up to 2050, much of that existing gas-using housing stock will remain up to and beyond 2050.

Alongside vision, we need to address the practicalities: the cost to the consumer, the costs of changing energy use, the adaptation of existing infrastructure.

We are Europe's third largest natural gas producer, yet our consumption far outstrips our resource. We import 45 per cent of the gas we use, a figure increasing as UK fields decline. Efficiency measures such as insulation and double glazing are a vital part of lowering carbon emissions by reducing consumption (and consumers' bills). Yet this can only take us so far.

Heating accounts for half of UK energy consumption and a third of the UK's carbon emissions. Responding to the challenge cannot be ignored.

Had Labour been elected in 2015, I would have charged National Grid with undertaking a review of the UK's heat production, in particular, greening the gas supply.

So, given we are not the Government, National Grid's latest report – the Future of Gas, is most welcome.

This chapter will consider the UK's potential for greening our gas supply; for a home grown alternative to the huge volume of gas imported each year; and what Government could do to make it happen.

LOCAL, HOME-GROWN ENERGY

A cold day on a farm near the South Yorkshire village of Hatfield Woodhouse finds me peering through the porthole of an airtight vessel that is fed 100tonnes per day of maize and other crops to see a bubbling cake-mix slowly moving.

This is the biodigester tank, and over the next forty days, the crops are mixed slowly by huge paddles with a lot of water and kept at 37°C – the temperature of a cow's stomach. Just like a cow's digestive system, this process produces methane.

This is Future Biogas' renewable gas plant, known locally as Vulcan Renewables.

The gas is known as biogas, because it is naturally occurring from anaerobic digestion (AD). The digester consumes 25,000 tonnes of material annually, a feedstock grown for this purpose, not waste products. From this, the biomethane produced will heat the equivalent of 3,000 homes in the winter months, 60,000 in the summer months.

But the destination of this gas is not homes. Along with the production from nine other plants, it has been purchased by M&S, whose stores are to be heated by renewable energy.

Passing through Hatfield Woodhouse, you might notice the Vulcan plant from the road, because of two great domes (think James Bond, Moonraker) that store the gas. What you don't see is that this is a partnership in home-grown energy.

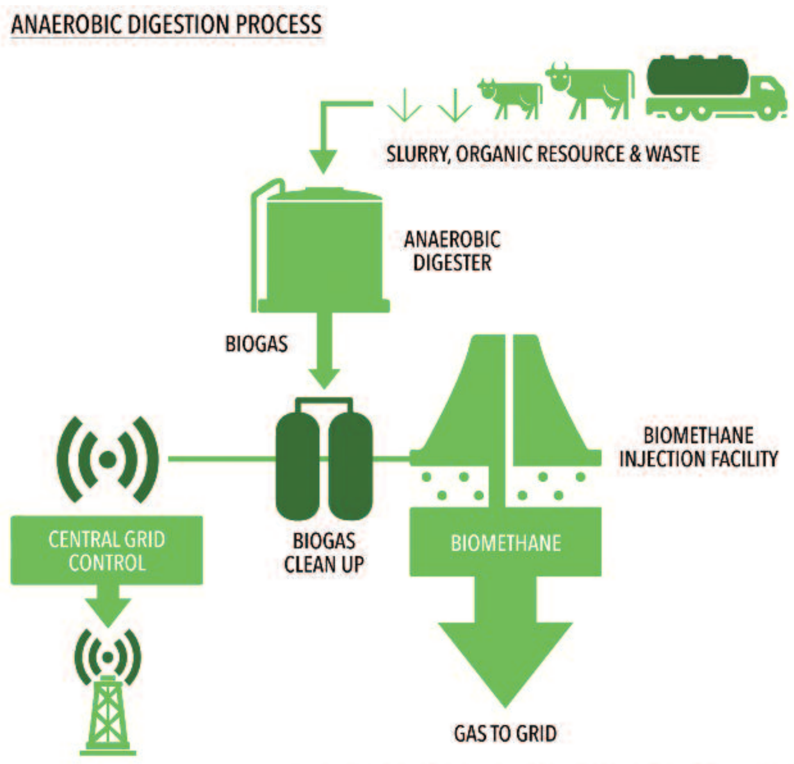
A local couple farm 600 acres and, apart from the rent they receive for this plant sitting on their land, 75% of their production goes to fuel this green gas plant. They work co-operatively with local farmers within a ten mile radius.

In return, contributing farmers take away organic manure, a residue of the process. Some also use the organic liquid fertiliser from the digester, which is injected under the roots of plants.

Before the biogas is put into the grid via a local gas link, carbon dioxide is separated from the methane. The purity of the CO_2 allows this to be sold to the drinks industry. Propane is mixed in with biomethane to increase the energy content to meet National Grid's requirements.

In Don Valley, this is the contribution of one firm and forty farmers. £9million invested in the plant, using mainly German and French technology, but the jobs and supply chains are increasingly local.

One case of home grown gas, put straight into the UK's grid. But what is the full potential for a home grown/produced gas to replace our natural gas consumption?



From National Grid: *The Future of Gas - Supply of Renewable Gas*, February 2016

THE UK'S TARGET FOR RENEWABLE ENERGY – WHERE'S THE HEAT?

The European Union has set itself the target of producing 20% of its energy from renewable sources by 2020.

To achieve this, each country in the EU has its own target to meet. The target for member states vary depending on a number of factors. The UK has been asked to procure 15% of its energy consumption from renewable sources in 2020.

The Government's own targets were clarified when Ministers confirmed in November 2015 that our 15% renewable energy target would be comprised of 30% of UK electricity, and 12% of UK heat, being from renewable sources. The transport sector also has a target of 10% of energy from renewable sources.

Given that our homes, electricity generation and road transport accounts for most of the UK's emissions, these targets make sense.

According to FullFact, "the main bulk of the progress has been made in electricity, with 17.8% of it coming from renewable sources in 2014, up from 7.4% in 2010. By contrast, progress towards renewable energy in transport and heating has been slower, with only 4.8% of energy in both heat and transport coming from renewable sources in 2014."

Thanks largely to the last Labour government, renewable electricity – largely wind power – has moved forward. But greening our heat supply is lagging behind.

THE THIRTY PER CENT VISION

The UK currently imports 45% of gas. The Anaerobic Digestion and Bioresources Association forecasts this could rise by one third, just in this parliament. If UK policy doesn't change, National Grid predict imports could be as high as 60% by 2050. The UK population will also grow in the next thirty years, so demand for gas will continue.

On the flip side, National Grid forecasts that green gas could produce 30-50% of domestic gas demand in the future.

So where are we now? And how does the UK reach the National Grid forecast?

First, 172 on-farm AD plants currently mirror the Don Valley example, producing enough heat for 240,000 homes.

A further 50 biomethane plants generate enough heat for 155,000 homes.

Dwarfing this are some 447 AD plants generating electricity from biogas. 556MW each year, electricity for 750,000 homes.

The problem is that taking biogas and using it to power turbines to generate electricity is considerably less efficient than using the gas to heat homes.

The subsidies available from Government to help grow low carbon energy have distorted the investment, leading to far more electricity generation than green gas.

This policy needs to change.

In 2014, I said "There are no technical or safety barriers to delivering green gas which cannot be overcome". National Grid's latest report confirms this. National Grid suggests bio-SNG, a process described in Mike Foster's chapter, could offer ten times more green gas than AD, with the potential to increase the annual production of renewable gas in the UK to 100 TWh – a massive 30 to 50 per cent of future domestic demand.

The opening of the UK's largest gasification plant on Teesside is imminent, processing up to 350,000 tonnes of waste per year – enough to heat 50,000 homes. If early commercial ventures succeed, supported by good policy, this would fundamentally change our gas supply.

Unlike almost every other technology, once in the grid, there are no adaptations that have to incur at the level of the street or home.

The key to producing gas on such a scale? Diverting domestic waste from landfill to local bio-SNG gas plants.

52% of domestic waste goes to landfill – costing £65 per tonne. A further 8% is exported to Europe. The availability and cost of domestic waste makes it commercially viable as alternative source of natural gas.

The UK's growing population ensures domestic waste is likely to remain plentiful, and may increase. This alternative should be a highly attractive option for government investment and support.

WHAT DO THE POLITICIANS NEED TO DO?

The potential for green gas is not disputed.

The technologies are far less challenging than, for example, carbon capture and storage, and sites are more compact than, say, an onshore windfarm. The average bio-SNG plant would be about eight hectares, easily located on industrial parks, commonplace on the edge of most towns.
The challenges for real world politicians are several, but none are insurmountable. Actions could include:

- **PUBLIC UNDERSTANDING**

First, updating public attitudes towards the nature of waste. As a Member of Parliament, I am all too aware that any facility with the term "waste" in the title will arouse local mistrust, action-groups, and campaigners. Our communities will need a different appreciation that domestic waste, and human waste flushed down our loos, provide material for clean energy.

Just as the public learned about the virtues of recycling, so they need to appreciate that the waste used in biogas plants is not harmful.

We all have a right to ask why we pay to shovel waste into landfill, which could create biogas. And if water companies used their waste, could we not hope to see a reduction in water bills?

- **LONG TERM INVESTMENT**

This Government and the last have patchy records of support for investment in renewables, undermining investment.

The current support regime, the Renewable Heat Incentive, is set to cost just over £1billion per annum by 2020. Experts do not believe this offers the financial incentives to enable steady growth, which in time ensures the green gas industry can stand on its own two feet.

Failure to do so will only be welcomed by Qatar, Russia and other nations that export gas to the UK.

- **NATIONAL PRIORITY, LOCAL DELIVERY**

England needs to require the collection of food waste separately, to provide a ready feed stock for local plants, similar to that in the devolved administrations. The permission for green gas plants, which can be accommodated on typical industrial parks and away from residential areas, could be identified by the Government and the Infrastructure Commission as a national infrastructure priority.

Appropriate guidance, could speed up planning decisions, and green light a new strategy for waste in urban areas.

- **GREENING TRANSPORT**

Biomethane plants already produce enough green gas to fuel 10% of the nation's buses. Leading firms, such as the John Lewis Partnership (the parent company of Waitrose), are already committing themselves to gas-powered vehicles. For diesel fleets to be replaced by gas-powered vehicles, requires networks of gas filling stations, and this requires Government policy, not simply a market-led response.

LOOKING TO A LOW-CARBON FUTURE

Rather than thousands of UK homes benefitting from green gas, it should be millions.

It is within the capacity of Government to revolutionise our gas supply; to complete the circle from farming to food, to waste, to gas.

The policy goals sound simple, but above all they require three things from Government:

First, consistency. The Government's ambition should be to establish a consensus that ties in opposition parties, and creates a long-term continuity of policy.

Secondly, Government departments need to serve the wider goal. This policy does not begin and end with DECC. It is about:

- planning strategy, creating templates for local government and public bodies to reshape their waste strategies;
- creating a road transport infrastructure that enables the next generation of low carbon HGVs to grow;
- supporting diversification in farming, and promoting home-grown energy;
- developing innovative financial incentives, not just subsidies.

Thirdly, Government must lead a public engagement exercise to explain a new role for waste in a clean energy future.

Green gas, an oft-overlooked pillar of the energy mix, offers a positive and pragmatic alternative to natural gas use, by utilising existing infrastructure whilst reducing both natural gas usage and carbon emissions.

It can help us to better deal with our waste and, provides greater energy security. Bold action now to support such a transition could set us on a path to fundamentally change our consumption of an entire fossil fuel.

On that cold day, as I stood on top of the digester tank at the heart of this local energy hub, watching local farmers deliver feedstock, I was reminded of a longstanding environmental message: Think global, act local.

Replacing gas from Qatar with gas from Doncaster, and playing our part to act against climate change – that seems to me a local contribution to a global problem. I'm convinced this challenge can be met.

The Future of the Gas Networks

Tony Glover

The UK's commitment to reducing carbon emissions, bolstered by last year's Paris Agreement, will have significant ramifications for our power, heat and transport sectors. Our energy networks are vital facilitators of the UK's transition to a low carbon economy, enabling the connection of new renewable sources of gas and electricity and pioneering the innovative technologies which will be required for affordable and secure energy in a sustainable future.

Meeting the challenge of decarbonisation will require an approach which considers the relationship between interdependent sectors of the economy alongside factors like cost, security and, crucially, the role of the customer in the energy transition. As the representative body for the UK's gas and electricity networks, Energy Networks Association is well placed to analyse the whole energy system in this way, without bias towards any energy source.

Whilst there is uncertainty around what our energy system will look like in 2050, any holistic consideration demonstrates clearly that our gas networks will have a vital role to play in the coming years; not just in an affordable progression to a low carbon economy, but also as a long term part of a sustainable energy mix through the injection of green gas into the grid.

The UK benefits from one of the longest established and most comprehensive gas networks in the world, serving 85% of domestic properties. It is an extremely valuable asset and a feat of engineering which has helped industry to grow and has provided an affordable way to heat our homes over many decades. In the coming years it will support the transition to a low carbon economy by enabling peak energy demand to be met and mitigating the impact of increased load on the electricity network from electric heat and electric vehicles.

Research commissioned by ENA has revealed that without a role for gas, the reinforcement of the electricity network to handle increased load and greater seasonal peaks from heat demand is projected to cost £16-28bn to 2050. The report found that if gas plays a role in a balanced transition to a zero carbon future it will reduce the cost of additional investment in the electricity network by £8billion. This figure does not consider significant additional costs of removing gas from the mix such as new generation capacity, decommissioning of the gas network or upgrading domestic appliances.

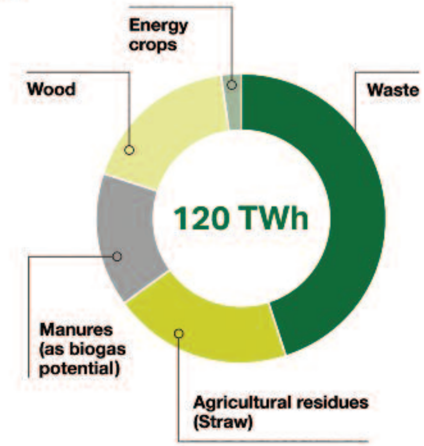
The significant cost pressures which would result from removing gas from the energy mix would also have implications for the level of fuel poverty in the UK. Heating your home by gas saves consumers over £400 per annum compared to alternatives. A study carried out by Wales and West Utilities considered the decarbonisation challenges from a consumer perspective, and found that in a typical British town, over 80% of customers had little or no financial means of moving away from gas heating to more expensive alternatives, and would therefore require a significant amount of subsidy if they were to do so.

It is important to consider this vital transitional role because without the gas networks, the UK's wider 'green' objectives will not be achievable; either technically or economically.

In addition to playing an essential role in the coming years, the gas network can also contribute to the UK's long term, low carbon future. Recent developments in green gas technology have opened up a variety of exciting opportunities in our energy landscape and the networks will be crucial to unlocking this potential. Our gas networks and the Gas Distribution Network (GDN) companies responsible for maintaining and operating them are facilitating the development of the green gas technology which is the focus of this publication.

There are a number of sources of green gas, such as biomethane and hydrogen, which can be used in our networks to provide heat and fuel for transport, and offer a range of benefits alongside their contribution to reducing carbon emissions. GDNs are leading innovation projects which are providing technical understanding of green gas injection into the grid, as well as demonstrating commercial potential and highlighting necessary regulatory changes to encourage growth in the sector.

POTENTIAL SOURCE OF RENEWABLE GAS



Expressed as energy per annum

Data from National Grid:
The Future of Gas – Supply of Renewable Gas, February 2016

BIOGAS

Biomethane injection into the grid has seen rapid growth in recent years, driven by GDN innovation and Government support through the Renewable Heat Incentive (RHI). Since 2011 the UK has become the fastest growing and most innovative biomethane in market in Europe, with fifty sites now connected to the gas network.

The use of carbon neutral biomethane has the potential to make a significant contribution to the UK's climate change targets. The Government's target is for 12% of heat demand to be met by renewable sources by 2020, and biomethane has the potential to meet over 10% of domestic UK heat demand by that year.

As well as contributing to a reduction in carbon emissions, the injection of biomethane into the grid offers wider benefits to the whole energy system in terms of affordability, security and customer choice.

Unlike other low carbon heat options, such as electric heat pumps or heat networks, the use of biomethane utilises existing infrastructure and requires no expansion of the gas or electricity network, saving customers money. By removing the need to build new infrastructure, there is an added economic benefit in minimising disruption to road users and businesses from new developments. Furthermore, biomethane does not require new domestic appliances to be installed, meaning further cost savings for bill payers and making it an attractive option from the perspective of customers.

In addition to environmental and financial benefits of biomethane to grid, it offers a source of domestic gas which increases the diversity and security of supply, reducing the UK's reliance on foreign imports.

Alongside biomethane, GDNs are investigating ways to make efficient use of domestic waste in meeting heat demand. Through the Gas Network Innovation Competition established by Ofgem, National Grid Gas Distribution has launched a project looking at turning household waste into gas which can be injected into the network. The project is developing a demonstration plant in Swindon, which processes refuse derived fuel into pipeline-quality bio-substitute natural gas (BioSNG) that is indistinguishable from 'normal' gas used for heating and cooking.

HYDROGEN

Of the various forms of green gas which could be injected into the network, hydrogen offers another area of exciting potential. While there are still uncertainties surrounding its availability and cost it could play a significant role in meeting future heating requirements, as it does in Hong Kong where 49% of gas mix is hydrogen.

Hydrogen would offer many of the same benefits as biogas in terms of making use of existing infrastructure to decarbonise UK heat demand. It would leave no carbon footprint as the combustion of hydrogen with oxygen results in water and heat whilst studies have shown that customers existing appliances could operate safely with up to 10% hydrogen concentration.

As they discuss in their chapter, Northern Gas Networks and its partners are leading an innovative trial, H21 Leeds Citygate, which aims to investigate the challenges, benefits, risks and opportunities of converting the existing gas network in a major UK city, Leeds, to a hydrogen network. The study is designed as a blue print which would be transferable to other UK cities, where the decarbonisation of heat, transportation and electricity is more challenging but also provides the biggest return on carbon reduction.

The injection of hydrogen into the gas network also has potential benefits in terms of energy storage and a solution to the intermittency of wind generation. Known as 'Power to Gas' technology, excess electricity generated from wind can be converted into hydrogen gas through a process of electrolysis and stored in the gas network to meet heat demand. National Grid estimate that the gas network currently has up to 650GWh of storage, and even if all the UK wind generation were to be stored in this way it would use only 5% of the grid. The storage capacity of the gas network will become increasingly important to our energy system as the proportion of UK electricity generation from intermittent renewables grows in the coming years.

GAS IN VEHICLES

Tackling emissions in the transport sector will clearly be vital if the UK is to meet its ambitious carbon reduction targets, and it is in this area where the use of low carbon gas in vehicles can make another important contribution. This will be particularly important in the transportation of heavy goods, as HGVs cannot run on electricity.

HGVs account for 20% of the UK's carbon emissions and these vehicles cannot operate on electricity. Natural Gas Vehicles (NGVs) not only produce lower levels of greenhouse gas than diesel engine alternatives, but could also provide up to 40% fuel cost savings compared with diesel. Gas vehicles could provide up to 28% reduction in CO2 emissions in the transportation of goods in the UK. There is also a compelling case for the use of zero carbon hydrogen vehicles, which would cut greenhouse gas emissions and provide significant air quality improvements in urban areas in the short term.

GDNs are investing in the infrastructure necessary to support increased use of gas vehicles in the UK. National Grid have connected the UK's first high pressure, public-access Compressed Natural Gas filling station for HGVs at Leyland, which is capable of 'fast filling' over 500 HGVs a day. John Lewis Partnership has signed up to use the station for refuelling its fleet of HGV's as part of the company's commitment to reducing its carbon footprint. Northern Gas Networks are also working with Leeds City Council on a similar CNG project.

NEXT STEPS

By making use of our existing network infrastructure to facilitate the various applications of green gas there is a clear opportunity to reduce heat and transport emissions in a way that is affordable and secure.

Whilst there has been encouraging growth and development in a number of areas, further support from the Government will be required if the full potential of green gas injection into the grid is to be realised.

For example, recent growth in the biomethane to grid market has been supported by the Government's RHI scheme. Uncertainty around the future of the RHI risks harming investor confidence and undermining the impressive growth in the sector, at a time when the cost of this technology is falling.

An innovation project being undertaken by SGN is looking to highlight another policy area which could be addressed to encourage growth in the green gas market. In the Scottish community of Oban, the GDN is testing different compositions of gas throughout the network to see how it performs with customers' domestic appliances.

The aim of the project is to demonstrate that the UK gas quality regulations (The Wobbe Index) could be safely widened. Current regulations are based on the composition of North Sea gas, and green gases such as biomethane require expensive processing in order to meet existing standards. If the Oban project does demonstrate that national standards could be safely revised then it would open up the market to a more diverse range of energy sources by removing processing costs and improving the comparative economic case for green gas injection. SGN estimate that revising the Wobbe Index could save the industry £325 million each year and result in lower prices for consumers. The project will report its findings to the regulator Ofgem this summer.

ENA's Gas Futures Group has appointed KPMG to carry out an independent analysis of the future of gas and the networks in the UK energy system, alongside a range of alternative scenarios. The study will consider the main drivers and trends that will impact on the long term development of the energy system, including the potential for green gas to play a significant role in the transition to a low carbon economy. This analysis will feed into a report to be produced by ENA later in 2016, and will contribute to the debate on this important policy area, as the UK energy industry enters a defining period over the next few years.

Growing the UK's Green Gas Sector

Dr. Kiara Zennaro, Clare Wenner and Syed Ahmed

Anaerobic digestion is a natural process where plant and animal materials are broken down by micro-organisms in an air-tight tank, or digester. A wide range of organic materials are suitable for AD, including food waste, slurry and manure, as well as crops and crop residues.

This process releases a methane rich biogas that can be used to generate renewable heat, power and transport fuel. Biogas can be used directly on-site to produce electricity and/or heat in conventional boilers or combined heat and power systems (CHP).

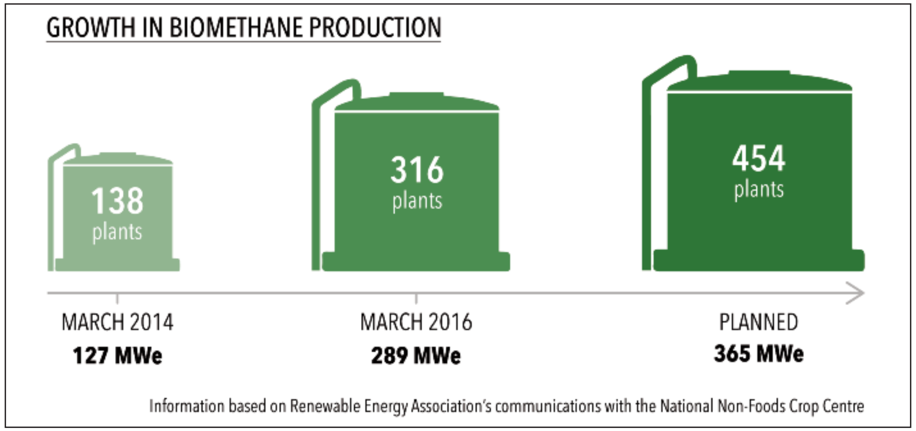
Increasingly, biogas is now being upgraded to grid quality gas (biomethane), and injected into the national gas network, where it can be stored until needed then used for heating, power or as a green transport fuel. Biomethane can help decarbonise gas supply, just in the same way as renewable electricity decarbonises power generation. It can also be supplied directly as green vehicle fuel for use in the transport sector, capable of reducing carbon, as well as NO_X and particulate emissions.

Development of AD has come a long way over the past years in the UK, with over 300 plants now operational[1], and a total installed electrical capacity of 289 MWe. According to the latest data provided by the NNFCC on AD deployment in the UK (April 2016), there are further 454 plants under development with an associated installed capacity of just over 365 MWe.[2]

With just over 2 million tonnes of food wastes (out of 16 million tonnes generated each year) and less than 1 million tonnes of manures/slurries (out of 90 million tonnes generated each year) currently going to AD[3] the biogas

1. Excluding those within the wastewater sector. Source: NNFCC, March 2016.
2. NNFCC communication to REA.
3. Anaerobic Digestion deployment in the United Kingdom: second annual report published, NNFCC, 22 April 2015

sector has still a long way to go before its full potential can be fulfilled.



Biomethane: long-distance, storable energy carrier

The UK's reliance on gas as its primary heating fuel requires Government to support the development of a UK biomethane – or green gas – sector and it is clear the gas network can play an important role in decarbonising heat through the use of renewables gases such as biomethane, combined with other new forms of sustainable methane such as Bio-SNG[4] and power to gas (P2G)[5].

Biomethane can be stored in the gas grid and used when and where needed, without the need for costly grid reinforcement[6]. Energy distributed through the gas grid is also delivered more efficiently to the end consumer than through the electricity grid[7], with lower transmission losses.

4. Bio-SNG is a term used to refer to a combustible gas that has been created by the thermochemical process of gasification of organic material. It is composed predominately of methane, hydrogen, carbon monoxide and carbon dioxide.
5. Power to gas (often abbreviated P2G) is an emerging technology that converts electrical power to a gas fuel.
6. Electricity grid constraints and the urgent need for reinforcement at many locations are hindering new electrical generation across large areas of the UK. This makes obtaining a connection both costly and uncertain. Unless the government invests in new grid capacity, deployment of CHP based AD and other renewable energy technologies will grind to a halt.
7. Roughly 90% efficiency rate when you convert gas into heating or cooking or energy use in a home, compared to roughly 30% efficiency from using the gas on site for electricity only.

A successful story for biomethane deployment in Europe and in the UK

The biomethane sector has experienced significant expansion in Europe over the past few years, reaching 282 plants across Europe with a total annual production of 1.3 billion m^3 in 2013[8]. There are currently over 100 biomethane projects operating in Germany alone, and very active markets in the Netherlands and France.

The Renewable Heat Incentive (RHI), introduced in 2011, is the primary policy supporting biomethane projects in the UK. Before its introduction there were no full scale biomethane plants in operation, but the RHI has kick-started the UK biomethane to grid (BtG) sector which has gone from strength to strength since the first commercial BtG plant was commissioned at Poundbury[9] in 2012.

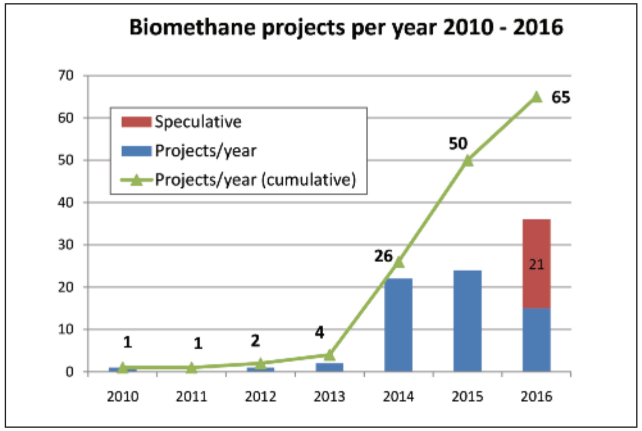
As shown in the first chart on the following page, 50 projects were completed by end of 2015, injecting approximately 2.5 TWh of biomethane into the gas grid enough to meet the heating and cooking needs of more than 150,000 homes. There are a further 14 plants in build, most of which will be completed by March 2016. Industry estimates that approximately 3 TWh of renewable gas will have been delivered into the gas grid by the UK biomethane sector by March 2016. In 2015, the UK was the fastest growing biomethane market in the world.

As shown overleaf, most of the projects that have been developed (61%) are agricultural plants that treat crop feedstocks, crop residues and livestock slurries/manures. 28% treat food wastes from municipal and commercial sources and only 9% treat sewage sludges.

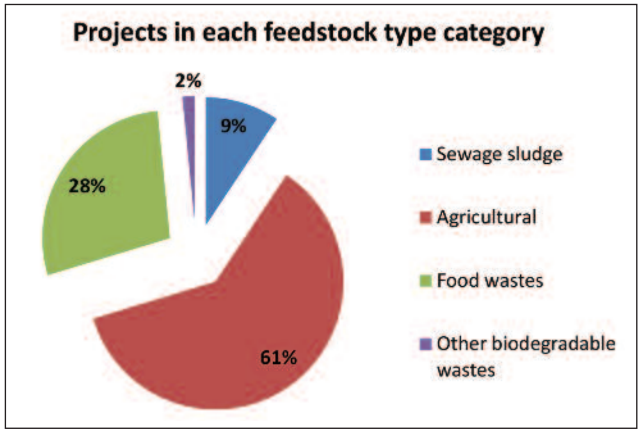
Not only has the RHI been successful in bringing forward biomethane projects, but it has also underpinned job creation, and encouraged innovation in the

8. According to the latest report published by European Biogas Association, http://european-biogas.eu/.
9. Poundbury was a joint venture between the Duchy of Cornwall and JV Energen.

sector. It is estimated that the low carbon heat sector supports 32,000[10] high skilled jobs across biomass, heat pumps, biomethane and solar thermal technologies.



According to REA's publication REVIEW[11] with a turnover of £350m, the AD sector in 2013/14 provided 2,828 jobs across 148 companies in the supply chain (manufacturing, construction and installation, plant operation and biogas applications), representing a 7.3% increase in employment compared to the previous year.



10. UK renewable energy jobs grow over 7 times faster than national average employment growth, see http://www.r-e-a.net/news/uk-renewable-energy-jobs-grow-over-7-times-faster-than-national-average-employment-growth
11. REVIEW 2015, Renewable Energy Association

The RHI has stimulated business investment in the range of £100 – £300m, supporting the development of competitive supply chains, with nine biomethane equipment providers currently active in the UK. Gas grid Entry Unit costs have already been reduced by 50% in the last 5 years and there is potential for further cost reductions, so long as Government continues to provide **a stable support mechanism at the right level for industry**, to ensure the market continues to grow with confidence.

On 3 March 2016, DECC released the long awaited consultation on the RHI reform. In the consultation the Government acknowledges that biogas and biomethane have an important role both now and in the longer term, in decarbonising heat and the gas grid, reducing greenhouse gas emissions from waste and agriculture, and supporting jobs in rural areas. The consultation indicates that the Government's ambition is to see an annual deployment of 20 biomethane plants by 2021.

The RHI for biomethane provides excellent value for money for the taxpayer, having been closely scrutinised in 2014 when DECC undertook their biomethane injection to grid tariff review[12]. This led to a framework for biomethane that was working very effectively and was delivering low carbon, cost-effective heat. The changes to the biomethane tariff structure that came into effect in February 2015 should avoid risk of over-compensating very large plants and market intelligence indicates that this is already having the effect of ensuring that plants are not oversized. However the degression mechanism built within the scheme and associated degression trigger levels are resulting in dramatic, unintended reductions in the tariffs for biomethane, which may result in the second half of 2016, tariff levels that are no longer viable with a significant risk of undermining growth in this new and exciting sector.

For projects with long lead times, tariff uncertainty is one of the biggest constraints and the risk of the given tariff being reduced at the commissioning

12. RHI biomethane injection to grid tariff review, DECC, May 2014

date constitutes a significant barrier. Therefore, the BtG industry re-iterates that tariff guarantees at financial close for projects with longer lead times are absolutely vital[13].

Green Gas Innovation

The gas distribution industry has been a strong supporter of biomethane as they see its use as instrumental in helping decarbonise the heat, transport and power sectors. National Grid and Gas Distribution Network Operators (GNDOs) are currently supporting a number of significant innovative biomethane projects to deliver cost reductions, including:

- ReFood Widnes – believed to be the largest "food waste to Biomethane" plant in the world;
- Future Biogas Holkham – first example of project arranging the Local Transmission System (LTS) Connection itself;
- Severn Trent Minworth – injecting biomethane into the 17 bar grid - as this has very high flows, no additional propane is normally required to be added;
- Vale Green, Rotherdale and Wight Farms – captures and stores liquid CO2 from energy processes onsite which is then used in greenhouses for enhanced growing of tomatoes;
- Five Fords – first use of membrane plant for sewage derived biogas;
- Euston – injection into 42 bar LTS which is 7 km from the AD Plant.

The REA is planning to publish case studies of biomethane projects in Spring 2016, including the projects mentioned above.

13. REA's response to the Government's consultation on RHI Tariff Guarantees can be found here.

Biomethane market potential

The biomethane sector has only just started to develop and has significant scope to increase the production of the UK's green gas resource. There is continuing interest in the field, with a number of projects under consideration. Industry estimates that another 100 BtG projects as a minimum could be developed by end of 2020. However, for the sector to continue to develop and grow, the industry needs a stable support framework from Government.

National Grid's 2015 Future Energy Scenarios[14] report highlights the potential for a 10-fold increase in the number of green gas connections to the grid over the next decade, indicating a possible 416 connections by 2025 and 700 connections by 2035. This equates to approximately 40 TWh/year of green gas from AD injected to the grid by 2035, around 5% of the total UK gas demand and around 10% of the UK domestic gas demand. More recent industry

POTENTIAL RENEWABLE GAS PRODUCTION SCENARIOS
volume of upgraded biomethane

	2020 (BASELINE) million m^3	2020 (STRETCH) million m^3
Sewage / waste water	270	629
Manure - dairy and cattle	254	507
Agricultural waste	234	967
Food waste	729	1,333
Biodegradeable waste	1,042	8,328
Wood waste	1,253	2,697
Miscanthus	1,845	3,971
TOTAL	**5,625**	**18,432**
% of total UK Gas Demand (~97bcm)	5%	18%
% of Residential Gas Demand (~35bcm)	15%	48%

Source: National Grid, *The Potential for Renewable Gas in the UK*, January 2009

14. Future Energy Scenarios 2015, National Grid, July 2015

estimates, which also include other renewable gases such as Bio-substitute natural gas (BioSNG) and Power to Gas (P2G), suggest that the full potential of renewable gas may be over twice this level. Additionally, as UK gas demand continues to decrease, this proportion could become much higher.

Delivering carbon savings

The REA has supported the introduction of sustainability criteria to be applied to biomethane as it is vital to be able to demonstrate that public money is being spent to deliver real environmental benefits. The UK is leading the way in Europe with the introduction of sustainability criteria for biomethane. The introduction of mandatory sustainability criteria under the RHI[15] mean that from 5 October 2015 only biomethane that delivers **60% GHG savings** compared with the EU fossil fuel average can receive the RHI. Emission savings are likely to be even more significant as the fuel that biomethane will increasingly displace is higher carbon intensive imported Liquefied Natural Gas (LNG). Boosting the development of biomethane can not only diversify the UK's security of energy supply, but also support the Government's 2020 commitment to meet 15 per cent of final energy demand from renewables, and the achievement of the UK's carbon budget targets[16].

Green Gas Certificates

Founded in 2011, the Green Gas Certification Scheme (GGCS) is a not-for-profit, industry led initiative, that tracks biomethane through the supply chain to provide certainty for those that buy it. The GGCS tracks each unit of green gas from its injection into the distribution grid, to any trades, to its sale to a consumer, or group of consumers. It tracks the contractual rather than physical flows to ensure there is no double-counting from production to end use.

15. Non Domestic RHI Sustainability Self-Reporting Guidance, Ofgem, 5 October 2015
16. https://www.ofgem.gov.uk/ofgem-publications/64019/biomethanearenewablegassourcefs.pdf

Each kWh of green gas is labelled electronically with a unique identifier known as a Renewable Gas Guarantee of Origin (RGGO). This identifier contains information about where, when and how this gas was produced. When consumers buy green gas the RGGO is their guarantee that the gas is authentic and has not been sold to anyone else.

Anyone involved in the biomethane supply chain can take part in the Green Gas Certification Scheme. The key participants are green gas producers who register the gas they have injected into the grid, and suppliers and other traders who register the gas sale contracts they have agreed.

In contrast to EU markets where Green Gas Certificates have been used for some time, the UK market is only just now developing. The GGCS has seen rapid growth in its membership over the past year[17] with over 20 biomethane schemes now registered with the scheme and increasing interest in green gas products from both the energy market and end consumers. In addition, areas of interest where Green Gas Certificates use is now being explored include:

- Since 2014 Green Gas Certificates can be utilised by bus operators to access funding under the Department for Transport's Low Carbon Emission Bus (LCEB) Bus Service Operators Grant (BSOG)[18].
- All UK quoted companies are required to report on their GHG emissions as part of their annual Directors' Report[19]. In February 2014, Defra consulted on proposals to amend their guidance for this GHG reporting allowing companies to report purchases of biomethane provided they hold certificates showing that this gas has been injected into the grid. Defra has not, however, published its final decision to this consultation[20].
- The World Resources Institute (WRI) Greenhouse Gas Protocol[21] is the

17. See www.greengas.org.uk for further information.
18. See Certification of dedicated gas buses as low carbon emission buses, DfT, December 2013
19. As part of the Companies Act 2006 (Strategic Report and Directors' Report) Regulations 2013.
20. See https://consult.defra.gov.uk/climate-change/ac04ad33
21. http://www.ghgprotocol.org/

- most widely used international accounting tool to quantify and manage GHG emissions. The GGCS has recently commissioned Ecofys to explore opportunities for Green Gas Certificates in the GHG Protocol in response to recent changes to the WRI's guidance, which now specifically reference the use of biomethane to grid[22].
- New build developments are also examining the potential of using Green Gas Certificates as part of their carbon and energy strategies, especially where Combined Heat and Power (CHP) and/or district energy systems are being proposed.

The Green Gas Certification Scheme is continuing to work with industry and Government to highlight the huge potential that exists for biomethane to grid across a wide range of economic sectors.

Biomethane in transport

Biomethane could play an important role in the transport sector, where it can deliver significant carbon savings and reductions in NOx and particulate emissions to help achieve zero emission vehicles by 2050. The REA has been asked to lead on Advanced Fuels/Renewable Gases with the Department for Transport (DfT) and are working closely with all stakeholders to ensure that the role biomethane can play in the transport sector – in particular in displacing diesel in HGVs and buses – is recognised and the right policy framework is put in place to deploy more biomethane to transport. The REA has published a report on the *Use of Gaseous Fuels in Transport*[23] which argues that the supply of renewable gases for transport has been underestimated and that the UK needs a clear and long-term strategy for the use of renewable biomethane in transport, as well as support for the development of vehicle technology.

22. See WRI Press Release http://ghgprotocol.org/node/458, 20 January 2015
23. Currently available to REA Members at www.r-e-a.net. The report is to be published on UK Biomethane Day (20 April 2016)

Conclusions

The Biomethane to Grid sector has huge potential in the UK, as has been demonstrated by its rapid growth in a few short years. A dynamic new UK industry has been established around the innovative production of renewable gas, which is actively supported by major industry businesses in the gas distribution sector.

Further opportunities are now being explored around the production of Bio-SNG and Power to Gas (P2G) – and there exists significant potential for the use of green gas in the transport sector to help decarbonise emissions, and help tackle air quality pollution. The production of green gas has the potential to provide significant benefits to the UK economy however over the period to 2020, this is dependent on a **stable Government support mechanism, at the right level**, to ensure the market continues to grow with confidence

Green Grass, Green Gas

Dale Vince

Ecotricity began life in 1995, born of the realisation that the conventional way of making electricity, by burning fossil fuels, was the biggest single source of climate change. Our proposed solution was a new kind of electricity, the green kind.

We were the world's first green electricity company, and while the technology to make green electricity was relatively new, we could see a potential future where all electricity was made this way – utilizing the Wind, Sun and Sea.

What we couldn't see was a renewable alternative for gas, and for many years we held the view that we had to simply wean ourselves off of this rather versatile energy source, and shift heat loads from gas to electricity.

That changed for us in 2010 when we bumped into the concept of green gas – gas made by the anaerobic digestion of organic material, which could then be 'scrubbed up' and put into the gas grid. It was a direct parallel to green electricity. And our missing link.

There was no green gas available in Britain at that time. The gas we'd found was a by-product of a factory in Holland.

We introduced the green gas concept to Britain that year with our green gas tariff, and in the process we took a big evolutionary step: we moved from being a green electricity company to a fully-fledged green energy company, from having half the answer to having the whole answer. It was one of our most exciting moments.

At the same time, we set about making plans to build our own sources of green gas in Britain using our ‘bills into mills’ model – the tagline that describes quite well our core approach, harnessing our customers’ energy bills to build new green energy mills.

The main issue we struggled with was feedstock, what to put into our green gas mills. At one end of the spectrum we could see food waste, at the other end energy crops.

Food waste is arguably better used to make gas than being sent to landfill, but it’s not without its drawbacks. As with waste to energy schemes, one of the big downsides is the long term nature of waste contracts that prevent progressive steps to actually reduce food waste – something vitally important. And for a company that campaigns as we do for the end of meat and dairy consumption, for environmental, ethical and health reasons, the blurred lines between animal and plant food waste presented another problem.

At the other end of the spectrum, energy crops had their own very obvious problems – the use of land that would otherwise be used to grow food and the intensive agriculture approach intrinsic to it – that are at the root of so much environmental degradation and species depletion in Britain today. The Earth has lost half its wildlife in the last forty years. Over a similar period on UK farmland (which covers 75% of our country), bird species have fallen by half and butterflies by one third.

Energy crops were definitely out for us.

Food waste seemed at least possible in limited circumstances and we carried on investigating technologies for AD and gas scrubbing while looking for sites and making all the usual development steps.

Then, a couple of years ago, we came across a new idea that held the answer to the feedstock problem and so much more, something that brought a whole new dimension to the potential that making green gas had to offer.

The idea is to use grass as the feedstock.

Grass has many advantages. One of the biggest is the quality of the fuel – using grass can yield twice as much gas per tonne of feedstock than food waste, and the gas is cleaner and significantly easier to ‘scrub up’ to grid quality.

Grass can be grown on marginal farmland and it can be grown as a break crop on food producing land. It doesn’t need to compete with food grown for human consumption.

It’s not based on intensive farming or a monoculture either, it needs no artificial fertilizers or pesticides – and in the process of growing it we’ll create wildlife habitats, making room for nature. Those new habitats are desperately needed in Britain.

Grass for gas also offers the potential for farmers to diversify from raising animals for human consumption – an industry that is not only in decline and economically very challenging, but one that produces a significant amount of the world’s climate change gases.

Over 50% of global greenhouse gas emissions are caused by animal agriculture, according to a report published by the Worldwatch Institute. The United Nations says that farming livestock is “one of the top two or three most significant contributors to the most serious environmental problems, at every scale from local to global”.

Making green gas, creating room for nature and reducing emissions from livestock through farming diversification, is a win on multiple fronts.

An added benefit of the system is that all of the fertilizer required for the land on which we will grow our grass is produced as a by-product of our gas mills – it's a closed loop system in that respect, and in the process takes the land into organic status.

The other major feature of this new approach is one of resource scale.

Looking at data from DEFRA on the amount of the various land types available in Britain, there is enough land available for us to make enough green gas to power all of the homes in Britain – our entire domestic consumption. That's a high level view and there will be constraints that we can't yet see, for any given site or area – but it's a big potential target.

This would take 5,000 of our proposed gas mills, which are each 10MW in capacity. Each of them uses 5,000 acres of land, ideally within a short radius – and, coincidentally, each will produce enough gas to power 5,000 homes. An acre per home to make our own gas is an interesting metric.

The benefits of this potential level of green gas development are significant. Through feedstock contracts, each gas mill will contribute £3m per year, or £60 million in their operating lifetime, to the local economy.

With some 30 jobs per gas mill, we're looking at the creation of 150,000 new and sustainable jobs, vast areas of land turned into wildlife habitats (25 million acres), and the avoided cost of £8billion a year in fossil fuels going up in smoke.

If green gas can pull its weight in this way, we have the added advantage of not needing to switch significant heat loads from gas to electricity, meaning we need to make less electricity – we get a blended outcome, a mixture of technologies.

Making our gas from grass at anything like this scale would be a significant boost to efforts to abate climate change, to more sustainable farming and food production and to making Britain more energy independent – as well as a significant part of our nascent green economy.

Looking to the more immediate future, by 2020, Britain needs to meet 12% of its heating demand through renewable energy. The latest figures from the Department of Energy and Climate Change show that we're currently at 4.9%, meaning we have a shortfall of 7.1%, or 42.5 TWh per year.

Grass-fed green gas mills could plug this gap. It would take just over 500 of them, or 10% of what we could theoretically build in Britain. In the process we'd create 15,000 new jobs and put £1.5billion each year into local economies.

There's not much holding us back. The technology to turn grass into gas is mature: anaerobic digestion has been around a long time. Gas scrubbing units are less established, but it's not rocket science.

The one thing this new industry needs is consistent government support through the Renewable Heat Incentive (RHI). This government's record on renewable energy is not good, but with the major benefits of green gas accruing to the farming community, and it being able to plug the gap in our 2020 target, perhaps this is one form of renewable energy that will buck the trend.

As I write this, the government is consulting on changes to the RHI. One of the proposed changes is to limit, or stop altogether, any crop content in the feedstock of gas mills. If this means energy crops, we're all for it: the problems with that are well understood and the government is right to seek to control its use. What the definition of crop shouldn't include, however, is grass – as it's not a crop for human consumption and has none of the problems that stem from energy crop agriculture.

It’s a big opportunity for Britain - using grass as a feedstock to make our own gas. It’s a new idea too – so new that the danger is the government will overlook it and kill it off along with energy crops. Let’s hope not.

As Bob Dylan almost said, the answer, my friend, is growin’ in the wind.

The historic role of hydrogen in town gas: the prospects for a hydrogen mix in green gas, sources of future hydrogen production, hydrogen injection into the system

Dr. Keith MacLean

Introduction

Recently, there has been a real buzz of excitement about the prospects of a ‘new’ fuel: hydrogen. It is variously proposed in the transport sector for use in fuel-cell vehicles, and as one of the potential routes to decarbonise heat, if low pressure gas networks can be repurposed to transport it. Yet, unbeknown to many of us, hydrogen was historically one of the main constituents of town gas, which was used in the UK for lighting and then heating from the 1800s up until the 1970s, when it was replaced by natural gas, which became available in large quantities and at an attractive price from the UK’s North Sea fields. So in some regards, we are actually moving back to the future in considering hydrogen again as a domestic fuel.

A brief history of hydrogen

Hydrogen was first discovered more than 500 years ago, but it was in 1766 that Cavendish first identified it as a unique substance that he called “inflammable air”. In 1808, Lavoisier gave the substance the name it is known by today, hydrogen, which means “water-forming” in Greek. It was also around this time that hydrogen started to be more widely utilised as a component of the many forms of manufactured gas, collectively known as town gas, for light and heat – a purpose for which it is still used today, for example, in parts of China and, as Tony Glover notes in his chapter, in Hong Kong.

In the 1950s, NASA began using hydrogen as fuel for space craft, including those that went to the moon, and its use continued as the source of power for the Space Shuttles.

Today, hydrogen is used extensively – it is a key component in manufacturing ammonia, methanol, petrol and heating oil. It is also used to make fertilizers, glass, refined metals, vitamins, cosmetics, semiconductor circuits, soaps, lubricants, cleaners, margarine, peanut butter and rocket fuel.

The emergence and production of town gas

Town gas started to be widely used as a means of illumination in the United Kingdom in the early 19th century, initially in factories and subsequently for street lighting. The UK led the way in such developments – the London and Westminster Gas, Light and Coke Company was founded in 1813 and, by the early 1820s, plant to produce gas for lighting were also established in many other cities.

From the mid-19th Century, town gas was also adopted for use in domestic lighting, although this came under threat through the development of the electric light bulb in the 1880s, and led town gas purveyors to develop additional uses and markets for their product, such as heating and cooking.

The main production process used up until the mid-20th century was coal carbonisation, where coal is heated at high temperature with a limited air supply to produce town gas. This is made up of about 50% hydrogen, various hydrocarbons, like methane, and carbon monoxide. This process was the major source of town gas until after the First World War when an increasing proportion was produced by alternative means from cheap refinery products using reforming plants, where the hydrocarbon source was combined at temperature with steam to produce hydrogen and carbon dioxide. Steam methane reformation (SMR) is today the most common and cost effective means to produce hydrogen using natural gas as a feedstock.

The production process was carried out by private organisations right across the country in the local 'gasworks'. In the 1930s, there were over 1,800 medium and large scale units in the UK. The plant was generally situated within urban areas where the gas was used, but could also be found at steel works and coking plants. This approach led to an incomplete patchwork of independent networks, which tended to prioritise connections to the more affluent areas – it was not until 1949 that the industry was nationalised into 12 regional gas boards and the national Gas Council.

The potential re-emergence of hydrogen for decarbonisation

The UK now faces a particularly difficult challenge to decarbonise its heat supply – it is starting with the lowest levels of renewable heating in the EU, it has some of the worst housing with regard to energy efficiency, and consumers are generally very happy with the existing gas boilers, installed in nearly 85% of homes, and are therefore likely to be resistant to significant change.

Despite many early models and aspirations suggesting that decarbonisation would happen through electrification with heat pumps and district heating, early levels of uptake have been disappointing and indicate that significant barriers must be overcome if they are to become more widespread.

Owners of the UKs gas networks have been understandably concerned about the implications of such projections for the future of their business, if these alternatives were to make serious inroads into heat provision. To counter this, they have been examining the potential to convert their low pressure distribution networks to deliver hydrogen, either in its pure form, or as a blend alongside natural gas.

It would be politically very attractive if it were possible to repurpose the gas grids to deliver hydrogen to the home. This could avoid much of the additional cost and disruption that would occur by having to install and/or reinforce alternative infrastructures to provide heat. Additionally, because domestic heating appliances could be readily converted to run on hydrogen well in advance of any switch-over, the disruption to householders for the transition could be kept to a minimum – something comparable with an annual service - after which both the operation and 'heat experience' would be the same as before.

The technical challenge for hydrogen distribution

Historically there have been doubts about the suitability of hydrogen for transport in the gas networks – it is a very small molecule and can escape very easily from unsuitable containment. It is therefore not appropriate for use in many parts of the gas system, particularly those, like the transmission network, which operate at high pressure where hydrogen can be pushed into the metal of the pipework causing it to become brittle and potentially to fail.

However, quite fortuitously, over 100,000km of the low pressure metal in the local distribution network in towns and cities are already being replaced with polythene pipes as part of the Iron Mains Replacement Programme. This is well underway and due to complete by 2032. Even with hydrogen, the losses from such pipework would be very low, at about 0.001%. Furthermore, since hydrogen dissipates and rises very quickly, even this would not lead to any dangerous accumulations over time.

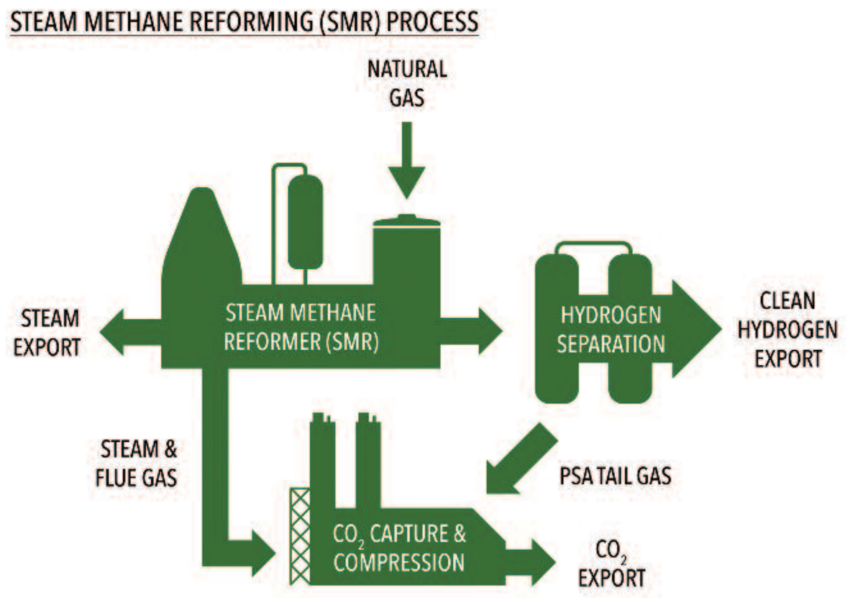
This is not to say that there would not be issues arising from such a changeover – just as there were in the 1960s and 1970s with the conversion from town to natural gas. Hydrogen is odourless and, because it is lighter than air and escapes rapidly, will be difficult to odourise. For safety reasons, pungent sulphur compounds are added to natural gas to give it its characteristic smell, but these would not be suitable for use with hydrogen – due to the different densities they would quickly separate from each other. In addition, sulphur could poison the catalysts used in the fuel cells which are a potential alternative means to generate domestic heat and power using hydrogen, or could be used in vehicles that might also wish to take advantage of local hydrogen supplies. Hydrogen burns with no visible flame which might restrict its use in open flame appliances like hobs or fires because of safety concerns. Public acceptance may also become an issue.

Hydrogen supply

As mentioned elsewhere in this book, two different means of large scale hydrogen production have been developed – Steam Methane Reformation (SMR) with Carbon Capture and Storage (CCS), and electrolysis.

SMR is currently the most common and lowest cost means of producing hydrogen. However, the main by-product of the process is carbon dioxide, so it is essential that CCS is a viable option, both technically and economically, to ensure that this is truly a low carbon alternative to natural gas.

Building upon existing experience and knowledge, Air Products are developing a second SMR + CCS plant in Port Arthur, Texas. Including cost allowances for the efficiency losses, the capital equipment and the CO2 storage, estimates show this process would deliver hydrogen at a cost at least double the wholesale cost of natural gas. This would mean the delivered retail price to the consumer in the UK would be about 60% above current levels for gas. It is worth noting that the delivered retail cost of electricity is currently about three times that of gas. Cost and efficiency improvements may be possible, but an extra cost to cover the energy used in the process, the capital and running costs of the SMR and CCS equipment will always keep the cost higher than that of the raw material – natural gas.



Source: Carbon Capture and Storage Association, *Hydrogen Production using Steam Methane Reforming (SMR) with Carbon Capture and Storage (CCS).* CO_2 can be captured from the Reformer flue gas and/or directly from the PSA tail gas before it is recycled to the reformer. The CO_2 capture rate is dependent on the configuration of the process.

Electrolysis is an alternative means of production which can be virtually carbon free, but only if a zero-carbon source of electricity is used. At current electricity grid intensity of just under 400gCO2/kWh, hydrogen would have a carbon intensity nearer 500gCO2/kWh after efficiency losses are considered – this compares with natural gas for heating at less than 200gCO2/kWh.

At current UK cost levels, the combination of the electricity cost and the efficiency losses, means that hydrogen production is three to four times as expensive as SMR + CCS. However, considering that in the US, the levelised costs of electricity from onshore wind is coming in as low as £30-60/MWh and, for solar PV, between £45-60/MWh, there could certainly be potential for this to become a more cost effective alternative.

Perhaps the more significant challenge for either approach would be the scale of production needed to satisfy the domestic heat demand, which on average is about double the size of the electricity sector, and at winter peak more than five times greater, as can be seen from Sansom's graph (p.12).

From this diagram it can also clearly be seen that excess electricity at times of high wind and solar production, would hardly make any noticeable difference to the supply needs of the heat sector, particularly when it is most needed in the winter.

Hydrogen requires about three times the space to store when compared to natural gas. With the added technical limitations on transporting hydrogen in pipes at anything other than the local level, it would seem logical for its production and storage to be much more localised, in the same way that it was for town gas. This is the assumption behind the current work of Northern Gas Networks to develop a detailed technical and economic plan for the potential conversion of Leeds to hydrogen.

Storage

Hydrogen can be stored in much the same ways that natural gas is – either in or around the network for the short term, or in salt caverns and depleted reservoirs for long term, seasonal storage. The current gas system provides storage capacity of over 50,000GWh, whereas the electricity system has only 30GWh in the form of pumped storage. Furthermore, long term gas storage costs start at about £30/MWh, whereas electricity is >£60,000/MWh. Even taking into account that the capacity for hydrogen will be about a third, and the cost three times greater than that of natural gas, these vast differences to electricity will remain and make it essential to look at the overall system costs and practicalities of future heat provision which, despite best efforts in energy efficiency, will still require very significant flexibility and capacity to deal with the seasonal swings. At the moment, other than perhaps some forms of biomass, hydrogen appears to be the only means of providing large scale, long duration and lower cost storage.

Pure or blended?

Current regulations only allow for 0.1% by volume of hydrogen to be blended into gas supplies. Since the level is much higher in other countries, like Germany where it is over 10%, there appears to be no insurmountable technical or safety reasons for this low limit. Upper ends of estimates of what could be added before adjustments would be required to appliances are about 20% by volume. However, although hydrogen has a high energy density by weight, it has a very low density by volume – about one third of natural gas. Therefore, even 20% by volume would only be equivalent to 6% by energy.

Considering the supply side and network developments needed to enable hydrogen use in any quantity, it may make better technical and economic sense to convert to 100% hydrogen in a limited number of locations, rather than to convert many more areas for a blended solution, especially if this remains limited to such low levels.

Summary

Repurposing the gas networks to transport hydrogen could be an attractive means of delivering low carbon heat for those 85% of properties connected to the gas grid. This would minimise disruption to households and around the networks, as well as maintaining a significant storage capacity in the system to deal with seasonal variations in demand. The main challenge would be the ability to produce sufficient volumes of hydrogen at an acceptable price.

Northern Gas Networks: H21 Leeds City Gate Project

Mark Horsley

The need to reduce carbon emissions is a global and a national priority and the UK is committed to achieving a reduction of 80% of the 1990 levels by 2050. As the UK transitions to a low carbon economy, there are numerous scenarios that could play a part in the future UK energy mix. Gas currently contributes over 35% of the UK's energy needs and is seen as an important transitional fuel as the UK moves to a low carbon economy.

Through the 'H21 Leeds City Gate' project, Northern Gas Networks (NGN) has been examining a scenario where gas and the UK gas networks play a direct role in reducing carbon emissions via the creation of hydrogen from natural gas (Methane). The combustion of hydrogen with oxygen results in water and heat, therefore if a decarbonised form of hydrogen can be made available via renewable sources, it can decarbonise the gas grid.

This project has gained national recognition as a potentially realistic pathway to the decarbonisation of heat across the UK, having proved, via a desktop exercise, that the current gas network in the UK (specifically Leeds) is sufficiently sized to convert to hydrogen. If the hydrogen economy is to commence in the UK it is likely, and indeed geographically necessary, that Leeds would be the first city to convert.

The project has been spearheaded by NGN's Innovations and Engineering teams, drawing in expertise from KIWA Gastec (around the feasibility of developing suitable appliances) and AMEC Foster Wheeler (around the creation and supply of the required quantities of hydrogen). The results of the H21 Leeds City Gate project are anticipated for public release in May/June 2016. These will provide evidence that one of the UKs biggest cites can be converted to hydrogen as well as the associated costs, financing model and a programme for the next stages of delivery.

Now that there is confidence that hydrogen conversion is technically possible, the next step is to carry out an enabling programme, which will provide even higher levels of confidence. This programme will include a range of technical, regulatory/social, live trials and strategic rollout work packages across the Northern Powerhouse region over a five-year period. This will ideally lead towards the conversion of the Leeds gas network to hydrogen and the subsequent rollout of hydrogen conversion across the UK.

If approved, in the short term, this programme would deliver new jobs and research capabilities. In the long term, it would represent a mainstream supply of zero carbon energy bringing with it significant opportunities for job creation, inward investment and manufacturing.

Why invest in hydrogen?

With 80-90% of UK domestic consumers on gas, there is already a suitable network in place, one that, as noted in the previous chapter, has been undergoing a c.£1 billion per annum (UK wide) upgrade by replacing ageing metal pipes with the new below two bar PE system. The new system needs no fundamental modification to distribute alternative forms of gas. This upgrade, which has been HSE driven based on reducing risk form gas leaks, is now over 50% complete and much greater than that in the major cities.

As UK North Sea gas deposits decline, the onset of unconventional gases, including biomethane, shale and coal bed methane, coupled with LNG imports, mean there is no long-term predicted shortage of methane supplies to the UK.

Decarbonising the gas grid 'at scale', i.e. generating huge volumes of decarbonised gas, is the challenge. Simplistically, burning hydrogen (produces water + heat) is greener than burning methane (produces carbon dioxide + water + heat), but how do we generate enough hydrogen?

Manufactured from methane, hydrogen production is only green if you capture the carbon produced and it can be moved to long-term storage.

This methane to hydrogen process can be achieved on a mass scale by using Steam Methane Reforming technology. And we also have the "Power to Gas" process of generating hydrogen through electrolysis mentioned elsewhere, bringing with it side benefits such as the potential to reduce the stand-down time for wind farm turbines.

Is it safe?

Several projects have been undertaken recently to prove the safety of an all hydrogen system, most notably hyhouse. The findings indicate that hydrogen as a fuel gas poses slightly different, but not more significant risks than methane. It is also important to note that town gas (used for 150 years up until conversion in the 1960/70s) was 50% hydrogen.

Hydrogen has been safely produced, stored, transported and used in large amounts in industry around the world for some considerable time.

Hydrogen buses are already operating in Aberdeen and Toyota's recent introduction of the world's first Hydrogen powered car, the Mirai, and Hyundai's new iX35 demonstrate the enormous confidence behind hydrogen as a viable and safe green fuel source.

Why Leeds?

As the UK's third largest city, Leeds has a significant demand and a complex gas infrastructure. Proving that a conversion is technically possible for Leeds would serve as a blueprint for viability for every other major UK city.

And geographically, Leeds is perfectly placed.

Once created via Steam Methane Reforming (SMR) technology, the hydrogen produced would need to be stored in salt caverns to account for the inter-seasonal swings in gas demand. The North East & Yorkshire coast has the largest area of salt in the UK making it ideal for the starting point of the hydrogen economy. There are already SMRs and salt caverns in Teesside and caverns in Hull, both located within NGN's distribution area. In addition the UKs most viable Carbon Capture and Storage (CCS) field, Goldeneye, is also located off the North east coast

In Leeds, there is already a real appetite to embark on the H21 project enabling process. Leeds City Region LEP has put H21 as a key priority for its Strategic Economic Plan so that it can be designed to benefit from synergies with existing city regional delivery programmes. The LEP are currently seeking a potential devolution of national funding to establish the H21 project team in Leeds, which would help to maximise the economic benefit in the local area and develop a global innovation hotspot for hydrogen and unconventional gas.

With Leeds up and running, it would then be possible to ramp up production and storage incrementally and attach the next major conurbation and so on...

What are the major challenges?

Key questions considered as part of NGN's work to date have been:

- Is the network in Leeds an appropriate size for hydrogen conversion?
- How safe is hydrogen? How might it behave differently to natural gas? Can it be odorised, for example?
- Can sufficient hydrogen be generated from SMRs?
- What is the best way of storing hydrogen? Will the salt caverns used to store natural gas be able to contain hydrogen in the same way?
- Is it feasible to convert appliances across the city to support the project?
- Can we connect a new high-pressure hydrogen pipeline to transport gas produced in Teesside to Leeds?
- Is it possible to do all of this without significantly increasing customers' bills?
- What needs to change from a legislative perspective in order to support the ongoing exploration of hydrogen as a viable green fuel source?

So can we really do this?

Gas as a fuel source in the UK has a two hundred year old history. At the start, town gas was produced locally across the UK, first from coal and then from oil, and it was roughly 50% hydrogen.

As other authors have mentioned, in the 1960s and 70s, the whole of the UK underwent conversion to natural gas, representing a massive undertaking from a technical and logistical point of view. At the peak of this programme, 2.33 million appliances were being converted every year. In other words, we've done it before.

And here in the UK, the infrastructure and the technology already exist.

The project has certainly piqued interest on a national level. In September 2015, DECC's Chief Scientific Advisor visited NGN to find out more and in January 2016, the project Manager, NGN's Head of Energy Futures was seconded to DECC as Technical Adviser – Future of the Gas Networks. Meanwhile, interest from government, academic and consumer quarters continues to increase.

Affordable?

The UK-wide town gas to natural gas conversion required the whole of the UK to convert in the space of ten years. However, the H21 concept can be rolled out incrementally and will therefore become commercially affordable. An affordable rollout would also be assisted by the current regulatory business plan process, which would mean the cost of this conversion would be socialised across the UK to reduce localised impact.

Finally, increasing investment in hydrogen conversion would be balanced out with reduced national investment in mains replacement (Repex) as this programme draws towards completion in 2030. The new PE pipe is significantly more efficient than the metal pipes it replaces, meaning the cost of emergency and repair activities (Opex) will also decline.

It could, therefore, be possible that customers will still see a net reduction in their bill despite the cost of rolling out the hydrogen economy.

Replicable?

It is indicated that, if designed properly, the UK could operate a dual gas system with a significant proportion operating on hydrogen and the remainder operating on a combination of biomethane /bio SNG and fossil-based methane, thus achieving holistic decarbonisation of the whole system.

Other implications?

If this hydrogen conversion strategy was to work to its full potential, it would not just see the decarbonisation of heat (30% of UK carbon), but alongside electricity it could also help decarbonise transport, fuel the new breed of hydrogen cars and potentially support greener electricity production through facilitating the use of in-house mini CHP units or even hydrogen power stations.

Size of economic impact?

The potential economic impact is exponential.

The successful delivery of a national hydrogen conversion will generate a number of strategic and wider benefits for the UK including:

- Securing a reliable and flexible energy supply.
- Delivering a low-carbon economy.
- Developing a competitive advantage in the world market for low carbon technology

So how do we get there?

While the project team is technically confident all this is achievable, there are additional enabling investigations necessary; part of the next steps that will be detailed in the forthcoming H21 roadmap includes delivery of 57 enabling projects.

A lot depends on ensuring that an adequate carbon capture and storage (CCS) infrastructure is in place and that legislation supports the effective operation of this. Currently, despite a real appetite from major industrial operators in Teesside to collaboratively explore effective carbon capture solutions, the withdrawal of Treasury support has potentially put this at risk.

Meanwhile, although Toyota and Hyundai's new 100% green hydrogen vehicles are now available, current UK legislation limiting the use of hydrogen means there's nowhere to fill them and no support for organisations looking to enable hydrogen manufacture and supply.

The gas industry has a unique opportunity to collaboratively build a case for reviewing this legislation by supporting the roll out of hydrogen filling stations, thereby offering a stable fuel source, and by exploring the process for converting natural gas to hydrogen and providing a viable storage medium for excess hydrogen production.

Supply of Renewable Gas

Tony Nixon

As we've seen elsewhere in this book, the gas industry in the UK has been able to demonstrate it can facilitate the development of a renewable gas market through anaerobic digestion with over 50 plants connected producing enough gas to supply 155,000 homes (2TWh per annum) since 2013. National Grid and its partners have taken this to the next level in scale with the development of Bio Substitute Natural Gas (BioSNG). This technology can secure low carbon heat to millions of homes in a cost effective way for between a third to a half of all domestic customers served today.

How it works

The BioSNG process involves a number of stages and chemical processes to convert the waste into syngas and then convert into methane product and carbon dioxide by-product.

The three main process blocks are:

1. Gasification – production of synthesis gas (syngas) from biomass-rich waste-derived fuels, followed by cooling, cleaning and polishing.
2. Methanation – including water-gas shift and methanation of the clean synthesis gas – both established technologies.
3. Upgrading and distribution – ensuring product meets grid standards and injecting it into the grid.

Feedstocks: is the source of energy sustainable?

Various experts have reviewed the availability of feedstocks including the Climate Change Committee. In their report on Bioenergy, they concluded that a reasonable share of potential sustainable bioenergy supply could extend to 200 TWh of primary energy demand in 2050, which would equate to between 70% to 100% of future domestic demand.

The dominant source of indigenous biomass is from waste and agricultural residues. These are seen as reliable feedstocks into the future as waste generation is unlikely to reduce significantly, even with increased recycling, as that will be countered by population growth.

Demonstration and Commercialisation

To showcase the potential of BioSNG, National Grid Gas Distribution, advanced waste to energy and fuels company Advanced Plasma Power, clean energy firm Progressive Energy and Schmack Carbotech have built a test plant at Advanced Plasma Power's headquarters in Swindon.

This test plant is designed to demonstrate the technical potential of producing green gas, and has moved the technology from concept to reality. It will also act as a test bed to optimise the overall performance of the system.

Work has now started on a full commercial demonstration plant in order to encourage the roll-out of a large number of BioSNG plants across the UK. The commercial demonstration plant will be capable of heating 1600 homes or fuelling 75 heavy goods vehicles. It will enable the industry to better understand the contractual, commercial and engineering issues related to the construction and operation of such facilities, the offtake of the fuels it produces and the supply of feedstocks.

Ultimately it will help inform policy and investment decisions so that engineering contractors are willing to supply BioSNG facilities under a fixed price.

Realistically we envisage BioSNG and anaerobic digestion facilities contributing in total around 80 to 120 TWh of renewable gas for injection into the gas grid, which combined with the above measures would result in renewable gas supplies for half our domestic energy needs. We believe this is a great opportunity to take further.

Addressing the gap

Should we choose the above path to decarbonising heat, the next stages would be to consider the introduction of Hydrogen into the existing gas networks across our cities and towns in the UK.

Hydrogen is produced effectively today, most commonly through Steam Methane Reforming, which allows natural gas to be turned into hydrogen and the carbon extracted. Combined with Carbon Capture and Storage the hydrogen produced under this process would be equivalent to other renewable sources.

The gas industry is leading on a number of projects to demonstrate the viability and flexibility that already exists to introduce hydrogen safely into the network.

National Grid has requested funding through the RIIO Network Innovation Competition, run by Ofgem, to demonstrate the capabilities of the network.

The objective is to demonstrate that natural gas containing levels of hydrogen beyond those in the Gas Safety (Management) Regulations can be distributed and utilised safely & efficiently in a representative section of the UK distribution network. Working in partnership with Keele University and utilising the existing gas infrastructure on site the project has the potential to facilitate 25TWh of decarbonised heat, and more by unlocking extensive hydrogen use as exemplified by the Leeds H21 project developed by Northern Gas Networks.

Find out more about National Grids views on the Future of Gas at www.nationalgrid.com/futureofgas

From National Grid: *The Future of Gas – Supply of Renewable Gas*, February 2016

How Green Gas Can Decarbonise Off-Grid Rural Britain

Paul Blacklock

The countryside presents policy makers with different and difficult energy challenges - in terms of building fabric and technology suitability. Calor argues that a focused and practical carbon reduction strategy for rural off gas grid communities is required. So what needs to happen?

Rural households and businesses face more complex fuel options and housing types than their on-grid counterparts. In the UK, around 2 million rural households are located off the gas grid and largely rely on heating oil, solid fuel, electricity and liquefied petroleum gas (LPG) to heat their homes.

Attempts to date to decarbonise this sector through the deployment of renewable heating systems have been extremely limited in their success. This has been largely due to the high capital cost of the options available – ranging from around £6000 to £25000 – and the disruptive nature of the installations.

Despite this the Government is still wedded to these same technologies which have largely failed the countryside. As evidence of this, in its recent RHI consultation, DECC did not include new renewable solutions despite their lower cost and "hassle" factors. One of these options is the rural "green gas" – bioLPG.

BioLPG is derived from a range of production processes, including anaerobic digestion, that use a variety of biological materials as feedstock. This means that it is both renewable – in that it prevents the depletion of finite fossil fuel stocks – and is a low-carbon fuel, since growing the feedstock itself takes carbon dioxide out of the atmosphere. In use, bioLPG is identical to conventional LPG and therefore has the benefit of being able to be blended and used by all existing LPG equipment in any concentration up to 100%.

BioLPG could make significant headway in meeting the UK's renewable and carbon targets. It is estimated that 171,000 British homes use LPG to heat their homes. According to analysis from the Energy & Utilities Alliance, bioLPG would be "a sensible policy option in the LPG heating sector", reducing carbon emissions from residential LPG use to just 17% of current levels. Their analysis also shows that bioLPG could reduce carbon at approximately 40% of the cost to Government of the current RHI.

Importantly, the introduction of bioLPG would cause minimal cost and disruption for consumers living off-grid. Alternative technologies, such as electric heat pumps, can require new radiators and other upgrades in order to allow for a lower temperature heating circuit. BioLPG however acts as a "drop-in" replacement for traditional LPG, requiring no expensive heating system upgrades for hard-pressed rural consumers.

With increasing pressure on Government to increase carbon savings at a low cost, there has never been a greater window of opportunity to open up a market for bioLPG in the off-grid sector. The Labour Party should take the lead by supporting the introduction of bioLPG for off-grid homes and businesses.

However, the countryside needs more than just "green gas" technology options, such as bioLPG, if Labour is to address the policy failures which have consistently denied rural householders the same opportunities to reduce their heating costs and carbon emissions as have been available in urban areas.

It is evident that instead of providing support, Government policy continues to actively disadvantage rural off gas grid householders. Previous schemes aimed at helping householders reduce their energy consumption and carbon emissions almost completely bypassed the countryside, largely due to poor policy design. Action is needed now to ensure that rural off gas grid communities not only contribute to the cost of delivering energy policy, but actually start to see some benefits.

Labour has a strong track record in delivering consumer-friendly and innovative policies which reduce carbon emissions in a hassle-free and cost effective way. It was a Labour Government which mandated the installation of highly efficient condensing boilers in British homes back in 2005. It was also Labour which launched the extremely successful boiler scrappage scheme in 2010 which took 125,000 inefficient old boilers out of homes early i.e. before they failed, and resulted in a significant reduction in bills and carbon emissions.

The deployment of bioLPG in the countryside, as part of the Labour Party's green gas strategy, would continue this tradition and ensure that people living in rural areas have the same opportunity to access drop-in renewable energies as exists in urban areas with biomethane via the natural gas grid.

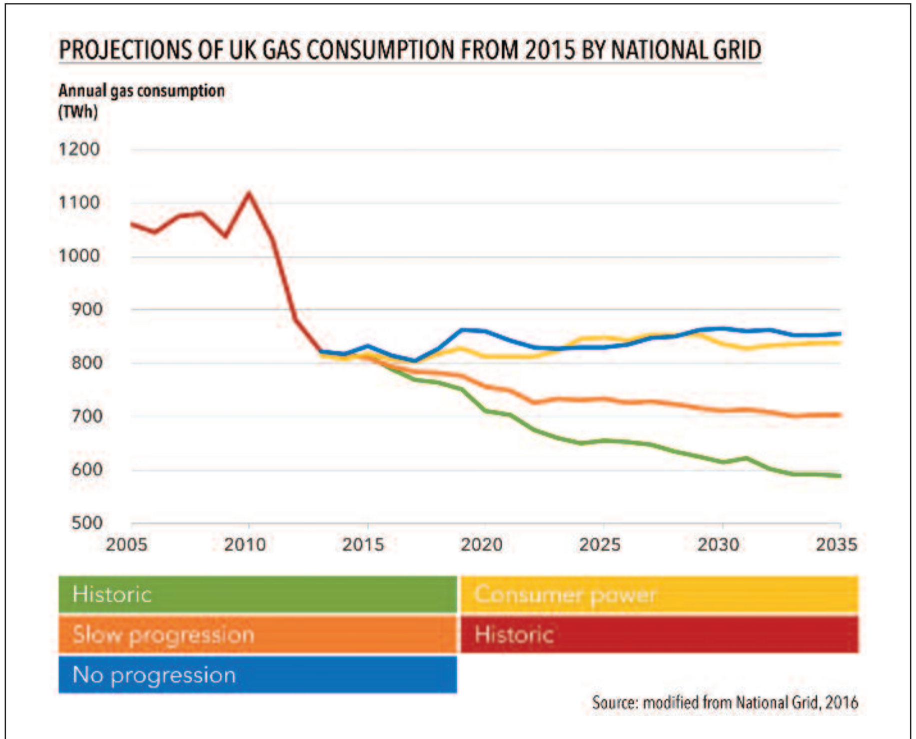
1. Energy & Utilities Alliance, Biopropane for the off-grid sector, January 2016

Decarbonising Heat - The Role of 'Green Gas'

Dr. Alan Whitehead

If we are serious about reaching and maintaining the targets we have set ourselves in the UK for energy decarbonisation as a leading element of the drive towards our commitment of an 80% reduction in CO_2 emissions by 2050, then we cannot avoid the big question of how we decarbonise heat. For all the talk of how we are decarbonising electricity generation, we cannot get very far without taking the 47% of final energy that we consume for heat as seriously: and all the signs presently are that we are not. In the report on the 5th Carbon Budget up for adoption by the Government in the summer of 2016, the Committee on Climate Change envisages that, by 2030, heat in 13% of homes and about half of business demand should be coming from low carbon sources and we are at present a long way away from a trajectory that will do this by that date. Right now, whilst the UK is meeting or exceeding its EU renewable electricity targets for 2020, we are failing badly on sub targets for renewable heat. Heat is the Cinderella of decarbonisation measures as far as energy goes.

Targets for electricity generation are meetable currently because, as far as this sector goes, there is still some slack in the decarbonisation roadmap. Not only can substantial carbon savings be made by pushing further forward with renewable deployment as a generating source, but it can be made increasingly efficient as a contributor with developing storage arrangements, and more effective through demand side measures that eke out what is supplied to greater effect. And of course taking coal off the system for energy generation, even if it is replaced by gas, makes substantial carbon savings in the short term. It should be noted though that this works only up to the early 2030s, when the demands of further decarbonisation mean that gas in the electricity generating system will need to be curtailed progressively unless it is accompanied by carbon capture and storage. We should also be wary of longer term arguments about gas being a future 'bridging fuel' on electricity decarbonisation, because in the UK certainly it has already taken up most of its space as a bridging fuel by its role, over the forty years in replacing coal as a prime source of generation fuel. In the decade from 1990, 22GW of new gas-fired power stations were built, and over the same period coal use for power dropped by 40%, a transition that has yet to run its course in many other major energy economies, such as the US and China. As far as heat is concerned, the transition was made even earlier. Between 1970 and 1980 natural gas replaced coal in for heating in the residential and services sector to the extent that coal use fell by 70%, gas use tripled, and emissions dropped by 15%.



But now with heat, we face almost the same position as we were with coal in power stations in the late 1980s, except there seem precious few instruments to proceed with decarbonisation, which has to come. Gas is overwhelmingly the fuel providing heating and hot water in homes. 79% of the energy we consume in homes goes on heating and hot water – far more than on lighting and power, and 81% of this comes from gas. Only 7% of our heating and hot water is electrified.

It has been possible to make some carbon savings on heat by, for example, regulating a move from old style boilers to condensing boilers as the main domestic heat delivery vehicle, and through applied domestic and commercial energy efficiency and insulation programmes in Britain's housing and commercial stock. Raising the SAP rating of Britain's housing stock by 15% over a ten year period (impacting overwhelmingly on heat efficiency in homes) was one of the unsung successes of the last Labour Government, and further savings could be made with a similarly dedicated programme of energy efficiency measures in the less efficient sectors of Britain's housing stock such as the 7 million solid wall properties still leaking heat prodigiously.

But even so, there at the centre of the whole sector stands gas. It is utilised in heating homes and industrial plant more carbon efficiently than the use of gas for generation, granted (boilers use gas far more effectively to produce heat than gas generation does to produce electricity – an estimated 195 gm/kwh of CO2 emissions against a current electricity generating average of about 400gms/kwh) but on present reckoning it is not about to go away as a primary means of providing heat. And if it doesn't or is not substantially reduced over the next twenty years, than we have locked ourselves into permanently missing our climate change targets: and of course, we can't plug CCS onto the millions of homes currently burning gas to heat themselves even if we had a programme available to do so for large generating plant.

Of course substantial thought has gone into how to crack this conundrum. But it is fair to say that most of it concerns how to dissolve the problem, and not how to tackle it head on. The problem is, for example, substantially dissolved if the assumption is made that, in the longer term future, there simply won't be any (or much) in the way of home heating fuelled by gas. This is, essentially the longer term position that initially the Committee on Climate Change took in its scenarios for decarbonisation leading to 2050; and generally speaking remains the Government position on long term heat strategy, most recently set out in the DECC paper 'The Future of Heating' in 2012. It is envisaged under this line of thought that Britain decouples itself from gas as a heating source – that heat is, in essence, electrified over the next thirty years. Air source and ground source heat pumps were envisaged as playing a considerable role in this process. But the assumptions that have to be made in putting forward this scenario immediately point to its shortcomings.

Firstly, the amount of additional capacity in electricity generation that would need to be envisaged would be simply enormous, as the famous chart from Robert Sansom demonstrates (see p.12) – because the variation in demand for fuel on heating vastly exceeds that of the variation for electrical power for other uses. It goes without saying that this additional capacity would itself have to be low carbon, or the sums would not work. Indeed the 'future of heat' report envisages potentially a 'doubling of current capacity by 2050 to support increased electrification in heating, transport and industry'. What that might mean, especially in the light of the acknowledged difference in demand during the day for electricity and heat is daunting. Various estimates of the additional capacity that would have to be built into the system to meet both that huge variation in daily and seasonal demand for heat and the level of demand overall have been made, but Mike Foster's (p.12) estimate of 30 new nuclear power stations or 100 additional interconnectors (assuming there is low carbon energy at the other end) makes the central point; it is not a practical proposition.

Secondly, the expense and disruption involved in ripping out boilers across the country and replacing them with electrical heating devices seems a less than optimum use of resource over the period, if alternatives are available and

Thirdly, such a changeover would have to assume no future for what is, as contributors to this book have pointed out, the world's longest and most connected system of gas mains, delivering a heat source that by and large people in the UK are content with.

So, assuming that we cannot, on a reasonably feasible basis, wish gas away from heat, what to do instead? And this is where I think the contributions made to this book together start to look like a serious alternative solution. That is, one way or another, most of the gas that presently supports our domestic and commercial heating becomes itself a low carbon source of supply, but uses in the main, existing or relatively inexpensively modified means of delivery to heat our homes and offices. The obvious advantage to this line of thinking is that, if feasible, it results in a substantial decarbonisation of heat by essentially using the infrastructure that is already there:

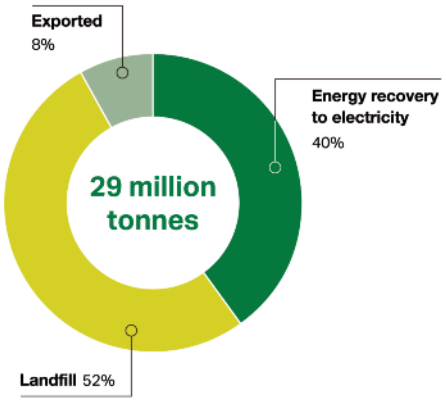
- gas mains, which are already in the process of being changed substantially to polyurethane piping which is far more leak-proof and can take a higher degree of gas such as hydrogen within their networks
- boilers which, even with a considerable change in supply, require only minor modifications to work sustainably (think for a moment about the nationwide, but relatively trouble-free adjustments that accompanied the move from town gas to natural gas between 1966 and 1977) and indeed, in earlier stages working with just a modification of the mix that goes into our mains anyway
- bottled biogas for off-grid customers, something that Calor Gas among others, is already involved in promoting

The main line of objection to this notion has been in the past that it is simply a fanciful idea, born from a misunderstanding of the numbers involved. A few farm AD plants putting a few cubic metres of gas into the system would not make up for the huge volume of mineral gas going into our heating systems. But this objection is itself prone to the charge of misunderstanding. What has become clearer in recent years, and which is also set out lucidly in a number of contributions to this book, is that, whilst there is no easy switch with which to wish away mineral gas, there are collectively, a number of what might be as '10% solutions' which between them, go quite a long way towards meeting much of the likely demand for gas as a fuel for domestic and commercial heating. And whilst all of these solutions have different advantages, limitations and drawbacks, it does look as if, collectively, they pose a few gentler and less disruptive challenge than ripping everything out and starting again with heat pumps. (By the way, I have nothing against heat pumps, which can certainly play a real role in decarbonising heat. I just do not think that the almost complete reliance placed on the technology as the way forward for heat decarbonisation was ever justified or is justified now.)

So what might these 10% solutions look like and what real contribution might they make? And here we should note that rather than talking about 'green gas' more strictly speaking, we should define the discussion as 'green gases' with different roles and different strengths. And before that, additions to the armoury of approaches to heat decarbonisation ought to be noted. One '10% solution' clearly has to be the development of district heating schemes using combined heat and power, which can be fuelled by gas, but also by biomass, green gas or other sources such as geothermal heat. District Heating, where it is retrofitted, clearly does remove boilers, and in terms of its contribution is better suited to new build and to mixed heat loads including large industrial or commercial space heating. Its disadvantage is that CHP in reality requires a relatively high level of offtake density to perform effectively, and is not really a very effective vehicle where densities are low or where domestic load variations cannot be compensated by other more stable users such as industrial plant: but it can certainly be counted in as a 10% contributor. Indeed, the recent level of expressions of interest to the DECC development fund programme for district heating shows that with the right level of support, there is a bright future for such schemes in our cities and larger towns. And heat pump fans, let's not entirely discount the idea that in some new build particularly, heat pump technology could play a role in helping the decarbonisation process along. Finally, lest we forget, energy efficiency in domestic buildings will play a substantial role in driving down the demand for gas in domestic buildings in any event. It ought to be remembered that all projections of future gas use show substantial downward curves: National Grid's 'Future Energy Scenarios', show in general a 33% reduction in gas consumption between now and 2035. Replacing a substantial proportion of that lower consumption is the goal, not switching on current levels.

That replacement in the earlier period can clearly be undertaken by injection into the grid of biomethane, produced by AD plants using a variety of organic wastes and energy crops for the AD process. Using grass clippings for AD biogas production, as set out by Dale Vince of Ecotricity in his contribution, looks particularly innovative and promising. The plant at Poundbury, Dorset is already injecting 850 cu m/h of gas into the gas grid, and as Zennaro, Wenner and Ahmed make clear in their contribution to this book, some 300 plants are now producing biogas (not all of it injected into the system) and over 450 plants are under development. The issue with biomethane is the extent to which it can be carried in the present gas mix without requiring modification of equipment, and an upper limit of about 10% looks to be about feasible. This problem is not shared by the production of syngas, covered by Mike Foster and Tony Nixon in their contributions to this book. Syngas (bioSNG) is generated largely by gasification of residual waste streams, much of which would otherwise have gone to landfill. It is identical in chemistry to natural gas, and could therefore in principle be injected into the system exponentially. National Grid has commissioned an at-scale syngas plant at Swindon, and in principle, syngas plants could scale up to introduce perhaps a 30% replacement level; bounded only by the extent to which production would rely on the continuous supply of relevant feedstock in relation to other uses higher up the waste hierarchy such as recycling and reuse.

WHERE OUR NON-RECYCLED WASTE GOES



Data from National Grid:
The Future of Gas – Supply of Renewable Gas, February 2016

In the longer term, hydrogen (covered extensively by Keith MacLean in his chapter) can clearly play a substantial role as a 'green gas' either as a component of gas supply (remembering that it did, as a component of town gas do so many years ago) or as a replacement fuel on its own. It is bounded particularly by its higher leakage propensity, the need to make adjustments to equipment if even more than a few per cent of hydrogen is on the system, and by its likely large scale production scenarios, which to a considerable extent follow from the establishment of CCS as a component of energy generation. Developments in the use of 'spare' electricity generated from renewables and other sources for the purpose of electrolysing water to create

very low carbon hydrogen may well run in parallel with CCS development, assuming we get ourselves back on track in the UK after the debacle of the cancellation of the two CCS pilots until recently poised to be under way. The development, as heralded by the Leeds Citygate project, of district systems piped using suitable materials and supplying to already adjusted equipment means that in specific areas a full hydrogen 'green gas' economy could be maintained.

These are all now real prospects, at scale and potentially supplying the volume of gas required to make a substantial dent in the existing use of gas for domestic and commercial heating. As reports show there is a long term role for some natural gas in both generation and domestic and commercial heating, either in the context of larger contribution with CCS, or in smaller quantities as a long term back up fuel to other means of supply.

Two things, finally, stand out as remarkable. One is the quiet progress, with very little practical incentive or encouragement of green gas production and use in recent years, when it was largely officially discounted as having any role to play in future low carbon energy strategies. The other is the extent to which, despite this, there remains no serious framework or strategy within which green gas as an essential component of heat decarbonisation can be taken forward. Even the Renewable Heat Incentive, quietly of use in developing some of the early biogas plants, looks set to allocate only a small proportion of a limited total underwriting to 'green gas' related projects after 2016. A proper strategy is now in my view essential to develop with components in it as set out by Caroline Flint in her chapter, and one that properly sets the longer term cost benefits of green gas into strategic context. It ought to be down to the present government to get this going: a future Labour Government would I am sure put such a strategy into place.

References:

- National Grid, The Future of Gas – Supply of Renewable Gas (February 2015)
- DECC, The Future of Heating – A Strategic Framework for Low Carbon Heat in the UK (March 2012)
- McGlade, Pye, Watson, Bradshaw and Ekins, UKERC, The Future of Natural Gas in the UK (February 2016)

About the Contributors

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- **Caroline Flint** is Chair of Labour's Parliamentary Committee on Energy and Climate Change and serves on the House of Commons' Public Accounts Committee. A former employment, housing, health and foreign office minister under the last Labour government, Caroline served as Labour's Shadow Secretary of State for Energy and Climate Change from 2011 to 2015.

- **Tony Glover** has a background in Whitehall and Westminster, having worked for two chief whips as well as a spell in 10 Downing Street. Since 2003 he has worked at the Energy Networks Association (ENA) and is currently Director of Policy where he is responsible for the Communications, Policy, Regulation, European and Gas teams.

- **Dr. Kiara Zennaro** has over ten years of experience in the biowaste treatment sector including anaerobic digestion. She has been head of Biogas at the Renewable Energy Association since 2015, representing the UK anaerobic digestion industry, and lobbying the UK Government to secure the best policy and regulatory framework for expanding the production of green gas in the UK.

- **Syed Ahmed** has close to 20 years working in the sustainable energy industry, in a wide variety of roles and organisations ranging from Friends of the Earth, the Combined Heat and Power Association, the Greater London Authority and Arup. Syed has been a policy advisor to the Green Gas Certification Scheme for three years, developing opportunities for the wider take up of biomethane through policy and market instruments.

- **Clare Wenner** took on the work on transport for the Renewable Energy Association in 2005 and has been Head of Renewable Transport since 2007. Clare's work has majored on the development of renewable transport fuels in the UK and has been very closely involved with the implementation in the UK of the EU Renewable Energy and Fuel Quality Directives.

- **Dale Vince** is founder of Ecotricity, the world's first green energy company. With Ecotricity, he introduced green electricity and green gas to Britain and installed the Electric Highway, Europe's leading network of electric car charging points. He is also chairman of Forest Green Rovers. Dale was made an OBE for services to the environment in 2004.

- **Dr. Keith MacLean** has advised both the UK and Scottish Governments on energy policy. He is currently Chair of the Energy Research Partnership and Chair of UKERC's Advisory Board. He has been a director of the UK Business Council for Sustainable Energy and its successor, Energy UK, as well as Scottish Renewables, the Micropower Council, BWEA and EWEA. Keith is founding director of Providence Policy where he works as an independent energy advisor.

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- **Paul Blacklock** joined Calor in 1985 and since 2009, has been their Head of Strategy and Corporate Affairs. Calor was first established in 1935 and has since grown to become the UK's leading supplier of LPG. Calor does more than three quarters of its business in the countryside and so has a deep interest in rural energy issues.

- **Dr. Alan Whitehead** has served on the Select Committees for Environment, Transports and the Regions; Energy and Climate Change; and the Environmental Audit Committee as well as a number of bill committees. He chaired the Associate Parliamentary Renewable and Sustainable Energy Group, co-chaired the Associate Parliamentary Sustainable Resource Group and served as Shadow Energy and Climate Change Minister.

Notes

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