The Future Of Fuel

What the future holds for the UK's mains gas network

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Introduction
How do we decarbonise gas?

The world of international climate change agreements may seem a million miles from the lives of most of us. But by agreeing to play our role in global carbon reduction targets, the UK has embarked upon a process of change that will affect everyone. The reality is that change is coming to what we drive, how we produce our electricity, and how we heat our homes and hot water.

Residential heat and hot water use contribute 14 per cent of current UK carbon emissions, nearly 70 million tonnes a year, and the UK will not meet its international and legal obligations if this figure is not substantially reduced. The big question is, how?

Around 85 per cent of UK households currently use natural gas (methane) supplied through a vast underground network of pipes, the gas grid. It is a secure way of delivering energy to the home; gas is currently four times cheaper than the electric equivalent (per kWh) and is convenient to use to meet our needs. The argument raging in the energy world is whether to rip out these central heating systems; make the whole gas grid redundant and switch to electricity for heat, or seek ways to reduce the carbon from the gas network.

Numerous studies have shown that switching to electricity is a more expensive option for the UK and it will struggle to meet demand in a cold snap. With 40,000 excess winter deaths already each year, it is a deadly gamble. According to top consultants KPMG, this "all-electric" approach will cost each household an extra £12,000 to deliver. Can we afford this?

So companies like Worcester Bosch have looked to see how the existing gas grid can use low carbon gas, with boilers and central heating systems, to keep us warm. The use of biomethane and synthetic natural gas, as by-products from our waste, is a sensible early move to make. More progressive options being explored include blending a proportion of hydrogen gas into the existing grid (hydrogen gives off no carbon emissions). Ultimately, the gas grid could even be converted to run on hydrogen. Importantly, these options all use our existing central heating systems and compatible boilers.

Low carbon gas in our homes will be the cheapest, most secure, and most flexible source of energy we can deploy. The fact that it meets our international obligations too, should be something we welcome.

Mike Foster,
CEO of the Energy
& Utilities Alliance

EUA
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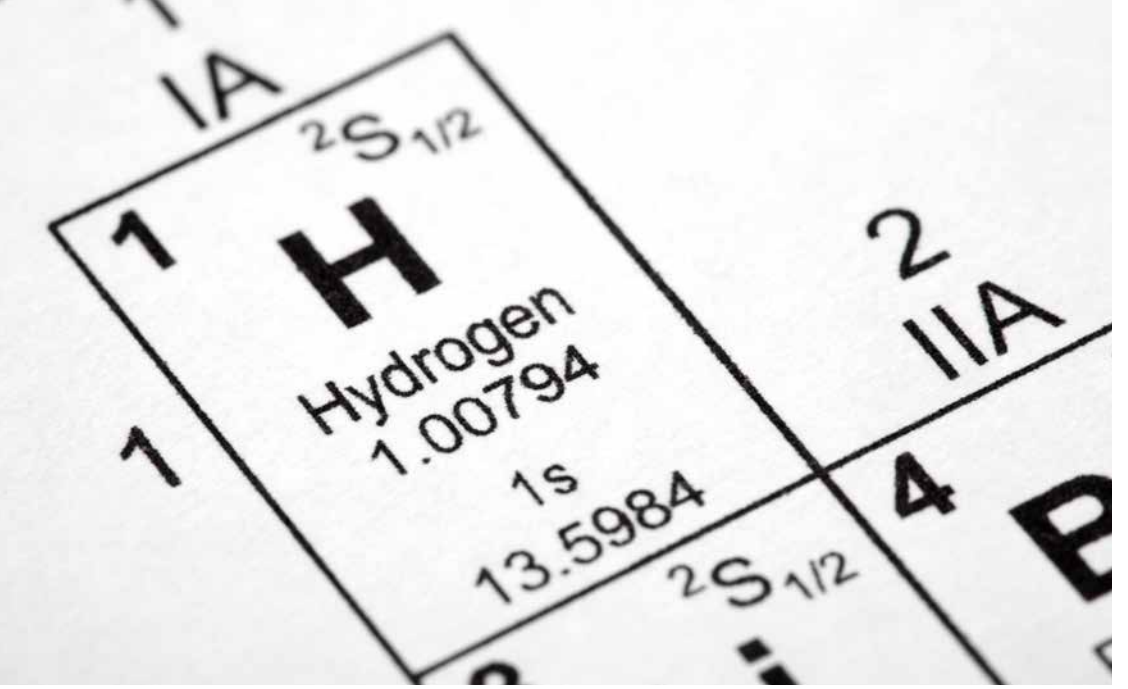


Why hydrogen?

The Government has announced plans to decarbonise heat and hot water generation by 2050. This, in reality, leaves two possible options; we either electrify all homes and replace fossil fuelled boilers with electric heat pumps, or we decarbonise the natural gas supply with a low-or zero-carbon alternative such as hydrogen.

Whilst estimates for the cost of these options may vary, it has become clear that electrification would cost around 3 times the as much as decarbonising the gas supply.

So, if we are to seriously consider how we decarbonise gas, the logical place to start would be with the chemical make-up of the gas we currently use for heating and cooking within the home. After all, decarbonisation is all about removing as much carbon as possible from the gas we burn.

Removing the carbon atom

A significant characteristic of the natural gas that runs through our network is that it is methane-rich. Because methane (CH_4) gives off carbon dioxide (CO_2) and water (H_2O) when it burns, the dream scenario would be to simply remove the carbon atom. By only burning the hydrogen atoms, we could eliminate both the CO_2 and carbon monoxide (CO) produced by the country's boilers.

While that may sound too good to be true, the idea might not be quite as implausible as many may think.

In 2016, Northern Gas Networks produced the H21 Leeds City Gate report. The study detailed exactly what would be required to take the gas distribution network of a city, in this case Leeds, and convert it to hydrogen.

Using our existing infrastructure

Not only did the report find that this kind of solution could work in practice but, because both methane and hydrogen flow in a similar way, we could even keep our existing gas infrastructure. By fortunate coincidence, the UK is currently halfway through a 35-year process to replace its iron gas pipes with polythene, which means every single one of the country's gas pipes will soon be the perfect material for carrying hydrogen. This would minimise both the time taken to carry out any kind of conversion and, perhaps more importantly, the cost passed on to the taxpayer.

Could Heat Pumps be an Alternative?

Hydrogen isn't the only alternative being looked into as a solution to our carbon problem.

The Committee on Climate Change (CCC) has ambitions to use heat pumps, powered by electricity, as a way of lowering the heating emissions of homes. Energy Performance Certificate (EPC) figures show how this isn't a solution for many properties however, both on or off the gas grid.

The Figures

EPC figures published by the Ministry of Housing, Communities & Local Government show that 3,276,000 properties fall within the EPC band C rating, some 3,223,000 of these have a condensing boiler.

It is likely many of the 3,223,000 properties with a condensing boiler in band C are only in band C because they have a condensing boiler installed. One of the ways of jumping one clear band within the EPC methodology is to replace a non-condensing boiler with a condensing version. This means that many of the properties in band C are really constructed to band D levels of fabric and therefore unsuitable as they stand for a heat pump installation.

Out of the 11,937,860 properties registered that have a boiler installed, there are 1,048,380, (8.8%) with suitable insulation levels, and 10,889,480, (91.2%) unsuitable. Even if you presume all band C properties with condensing boilers are suitable, 7,665,771, (64.2%) still aren't.

When combined with the off-gas grid figures, 12,587,860 properties in total are using a boiler as the main heating source. At best, 3,350,573, (26.6%) fall within band A-C, and 9,237,287, (73.4%) do not. At worst it could be much lower, with 8.9% in band A-C from a fabric perspective, and 91.1% band D and below.

On top of the figures, many homes will not have the space to install a heat pump and a hot water cylinder. Existing heating system pipework aren't sized to be compatible with the low temperatures that a heat pump operates at and will likely need to be replaced.

While heating needs to be decarbonised it must be remembered that it's the fuel that carries the carbon, not the boiler. Let's not change the heating system and instead change the fuel type.

Such an approach would not only allow a boiler to be kept as the lead heating technology within a property, but would also offer extremely low carbon, high temperature heating – with no need for insulation levels to be changed, or heating systems to be overhauled. While extending this nationwide may yet be many years away, early indications suggest the approach is certainly feasible, not least because hydrogen can be produced as a by-product of other industrial processes, such as nuclear power generation or hydropower.

The first 'big switch'

The prospect of converting the country's gas supply is not an entirely unfamiliar concept either. In the 1970's, we converted the country's entire gas network from Town gas (which actually contained around 55% hydrogen) to natural gas in a bid to establish a more sustainable fuel supply. In other words, we've done it before, so there's no reason why we couldn't do it again.

The UK is a gas-fuelled nation with successful industry and an established infrastructure that works incredibly well. Why not use our network buried in the ground and remove the carbon?

Martyn Bridges, Director of Technical Communication and Product Management - Worcester Bosch

Making a Greener Boiler

Although it is feasible to produce and transport hydrogen on a wide scale, one big question remains: is it possible to make a hydrogen boiler?

The opportunities

The positive news for our industry is that technologies for the safe and reliable combustion of hydrogen already exist. While there is no question that significant steps will be involved in applying these to domestic appliances, boiler manufacturers have a proven track record of bringing new technologies to market, most notably the introduction of condensing boilers in the early 2000's.

Crucially, a hydrogen-fuelled boiler would require no change to the way the end user operates the appliance, or the manner in which it would be installed. This also brings with it an opportunity for a new generation of hydrogen-ready appliances to be introduced, initially running on natural gas, before being switched over to hydrogen once the full infrastructure is in place.

The challenges

Naturally, such a shift would require both financial and logistical support. Firstly, early funding would be required for the research and development needed to bring hydrogen appliances to market. At the same time, there would also need to be a commitment from the government to a longer-term plan that would support infrastructure change, regulation, and ongoing governance in terms of installation and product approval standards.

Practical questions will need to be answered too. For example, as hydrogen burns at a faster rate than methane, can we use a standard burner to achieve the same controlled energy release that we have now? If the glow of a hydrogen flame is much harder to see, how will the boiler detect it to register that the burner is working as it should? Each of these questions – and many more besides – would need to be answered via an in-depth research and development programme.

Despite some inevitable challenges, there can be no doubt that hydrogen has real potential for the future of the UK's heating sector – from the environmental benefits of eliminating domestic CO_2 production, to the practical benefits of integrating our electricity and gas networks. More encouragingly, many of the issues mentioned are practical problems to which our engineers can find sensible solutions.

In fact, Worcester is already leading the way with its own investigations into developing the technology we will need to create the UK's first domestic hydrogen boiler.

With that in mind, installers can be rest assured that our objective will not be limited to designing an appliance that delivers heating and hot water comfort as efficiently and effectively as those used today. It also extends to ensuring any conversion process will be as easy as possible for the country's homeowners and heating engineers.

Martyn Bridges,
Director of Technical Communication and Product Management - Worcester Bosch

Inside Story
The Technical Challenge

Flashback Prevention

Hydrogen has a higher flame speed than natural gas. One of the key technical advances in hydrogen boilers are burners which can hold a stable hydrogen flame against its high speed.

Gas-Air Ratio Control

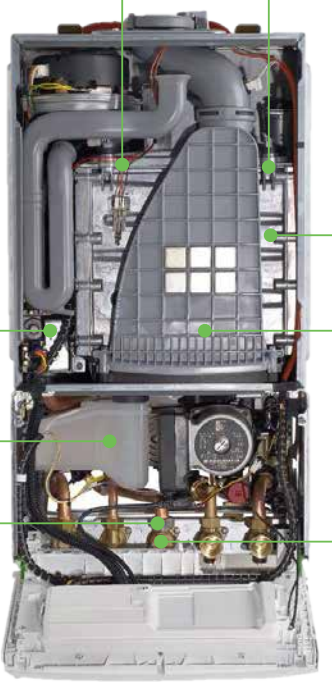
Hydrogen has very similar energy-flow properties to natural gas, so the new components will be very similar.

Condensate

Hydrogen produces significantly more condensate than natural gas. This has little consequence but must be considered in heat cell design.

Materials Compatibility

At the low pressures used in domestic boilers, most materials currently used for natural gas will also be suitable for hydrogen.



Flame Detection

Hydrogen flames are invisible and create no electrical signal, but we can detect it by it's ultra-violet (UV) emissions.

Conversion

In order to minimise the impact of conversion on end-users and installers, boilers will be developed to be quickly and easily re-configured for hydrogen on conversion day.

Performance

Hydrogen appliances will perform very similarly to natural gas boilers in terms output, efficiency and emissions. The products of combustion are very clean.

Gas-Tightness

Hydrogen has a small molecule size and is a very seeking gas. However, energy leakage rates are very similar to natural gas and there is unlikely to be a need for significant re-engineering.

Hydrogen vs. Natural Gas
A Comparison

	Hydrogen	Natural Gas
Does it smell?	Work is underway to identify new odorants for hydrogen. To start with, it will smell exactly like gas does today.	No. A harmless odorant is added to give gas its odour.
Does it produce carbon monoxide?	No. Hydrogen gives off no carbon emissions when burned.	Yes. Natural gas contains carbon, which when burned produces CO.
Are the CO_2 emissions different?	Burning hydrogen doesn't produce CO_2.	Burning natural gas does produce some CO_2.
Can you see the flame?	Only just! Hydrogen burns almost invisibly, but appliances will be redesigned to make burning visible.	Yes. A healthy gas flame will be blue in colour, but if that flame isn't getting enough oxygen it will appear yellow or orange.
What boiler types are available?	Combi, system and regular boiler types will be available	Combi, system and regular boiler types are all available
Is it man made?	Yes and no. It occurs naturally on Earth, but not in large enough quantities. It is therefore generated from other compounds like gas or water.	No. Natural gas is a fossil fuel.
Can you have cookers and fires?	Yes. Hydrogen will be able to fuel all types of heating appliances safely.	Yes, you can.
Is it heavier than air?	No. Hydrogen is lighter than air.	No. Natural gas is lighter than air.

Your Questions Answered

What would be a realistic plan and timetable for batch manufacture of hydrogen appliances?

Appliances have to be fully developed and approved before even small quantities can be manufactured, and the production facilities for small batch assembly are similar to those for a flexible manufacturer of larger quantities. Although the scope for accelerating small batch manufacture is limited, appliances could be manufactured within about 4 years from the start of any development project.

Would manufacturing these products require significant changes to a factory?

Manufacturing a larger number of different product variants will significantly affect manufacturing facilities and operations.

There would also be an impact on testing, both for manufacturing and quality control, as a new fuel would need to be introduced. Some tests would also need to be carried out for both natural gas and hydrogen.

Will new standards and codes for appliances be needed?

Yes. In the short term, the following will need to be developed:

- Qualification scheme for Installers / Service Technicians
- Updates to installation standards
- A route for product approval under the Gas Appliance Regulation
- Confirmation of primary energy factor for Energy Labelling

In the medium term, the harmonised product approval standards under the Gas Appliance Regulation would also need to be updated.

What barriers are there to developing a supply chain, and what incentives could overcome these barriers?

While the UK is the only European country considering such a conversion, components specific to hydrogen appliances will constitute a relatively small proportion of total production for most component manufacturers. This creates a challenge in justifying development costs of new parts for hydrogen appliances, which could prevent, or severely delay, the development of a supply chain. Finding a way for government funding to flow down to suppliers for component development projects may help, however these suppliers may be based outside the UK.

How will the safety of hydrogen as a combustible fuel be ensured?

An odorant would need to be added to hydrogen, to replicate the current natural gas odour and minimise any negative impact on public confidence. Although flame visibility is not necessary for heating and hot water appliances, methods of making the flame visible will be required for other applications such as cooking appliances or gas fires.

How long would it take to install the appliance in a home?

The installation time will be very similar to current natural gas appliances. However, hydrogen readiness will also apply to the gas supply pipe, and the gas meter.

Could an independent Gas Safe engineer be expected to convert a number of different manufacturers' appliances? To what extent could a conversion kit be standardised?

It is not possible for a current, natural gas-firing boiler to be converted to burn 100% hydrogen gas, however it may be possible for them to use smaller blends of perhaps 20% hydrogen in methane. When the volume of hydrogen within the blend is high requires a dedicated hydrogen boiler. However, it is possible that a "hydrogen ready" boiler may burn natural gas up until the point when the gas gets switched to hydrogen.

How would the industry ensure there are enough qualified personnel to install and maintain hydrogen appliances?

A regionalised information and training schedule will be required to train the right professionals in the right places at the right times, and the subject area would also need to be integrated into apprenticeship training programmes. Affordability and access to training and re-qualification for Gas Safe installers will be key, as will the early engagement and education of businesses ranging from self-employed engineers and SMEs, to national installer groups.

What Next? A Roadmap Towards a Sustainable Gas Network

If the ultimate objective is to decarbonise heat, it would be very short-sighted to try and do so by removing gas from 26 million homes.

Gas Infrastructure

The UK's established gas infrastructure has worked incredibly well for many years, which presents us with a massive opportunity. We can leave it untouched, replacing only the chemical make-up of matter running through it to a carbon-free alternative.

Appliances

The technology needed to make domestic appliances compatible with hydrogen is relatively straightforward, but the reality is that the process would also come at a cost. Political will is vital if we are to use hydrogen as a means to achieving our goal of carbon reduction.

So, what should the next steps be if we're to really back hydrogen as the future of our mains gas network?

1 Early funding for the research and development needed to bring hydrogen appliances to market.

2 A longer-term commitment to infrastructure change, regulation, and ongoing governance in terms of installation and product approval standards.

3 Early engagement with, and financial support for, the heating engineers required to train and/or requalify.

Sensible solution

As a nation, we are hugely successful at making effective use of gas in our buildings and specifically, our homes.

Therefore, it seems the most sensible route forward would be for us to maintain this proven infrastructure and decarbonise gas. After all, why fix something that isn't broken?

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