Cadent
future
Your Gas Network

Our Green Print

Future Heat for Everyone

About Cadent's report

The way we heat our homes and buildings is on the brink of a change even more radical than the original shift to central heating. It must be entirely rethought and reworked for the UK to deliver net zero by 2050. This will impact almost all UK homes and businesses, yet somehow the issue has a low public profile.

A foreword by **Ashleye Gunn**, Independent Consumer Policy Consultant and former Policy Programme Director at Which?

While the way forward is not yet entirely clear, it is clear that the associated costs and disruption will be significant, not just at the system level but for individuals. Cadent's new report, Our Green Print – Future Heat for Everyone is therefore a timely contribution. It's refreshing to see an energy company declare an interest – Cadent distributes gas – but then make a conscious effort to set that interest aside and consider the complexities of solving this challenge in the round.

Particularly important is the attention Cadent pays to consumers and their role in the transformation of heat. Energy efficiency measures and existing low carbon heating systems need to be installed at scale in the next decade while research and innovation continues, including on carbon capture and hydrogen. The evidence needed to determine the complete way forward will emerge but meanwhile delivery must accelerate. That means consumers understanding the issues, understanding their role, and stepping up to play their part. Challenging at the best of times, and even harder when few have any idea this is coming.

As Cadent points out, much of the work on decarbonising heat has focused on the economic or technical aspects. There is an assumption that consumers will get on board. It's understandable that this thinking creeps in; addressing the economic and technical aspects of the transition is complex, and of course everyone has an interest in net zero being achieved so assuming consumers will play their part seems reasonable.

Unfortunately, this ignores actual consumer behaviour. When consumers don't feel confident they don't go ahead anyway, they simply don't purchase. Decarbonising heat will only succeed if the market is designed to work for consumers. Significant barriers include cost; disruption; question marks about performance; and lack of a clear process. Each needs to be overcome.

Cost is a significant barrier. The most likely options of heat pumps or hydrogen look significantly more expensive than a gas boiler, either upfront or in the running costs. Addressing both the level and the clarity of costs is key to driving purchases. Until costs are much closer to parity with replacing and running a gas boiler the question of subsidy will remain a live issue.

Disruption is another significant concern. New boilers are usually distress purchases but installing low carbon heating will rarely be a straight replacement. Most homes will need energy efficiency measures as well as a new heating system, and that new system may need a different location and/or other adjustments such as new radiators. There needs to be serious planning for minimising the hassle factor and persuading consumers to prepare ahead of irreparable boiler breakdown.

Then there is performance – both of products and installers. 85% of households are used to quiet boilers producing near instant warmth. Cursory reading about heat pumps raises questions about noise, response times and warmth levels, while people wonder if hydrogen is safe. Credible reassurance is essential.

"When consumers don't feel confident they don't go ahead anyway, they simply don't purchase. Decarbonising heat will only succeed if the market is designed to work for consumers."

Expert, trustworthy installers of low carbon heating systems already exist, and their numbers will grow. Being sure you have found such an installer is more difficult; consumers need certainty if they are to act.

The final barrier is lack of a clear process. For many the first question will be 'Where do I start?' Without readily available, trustworthy information that clarifies the process, many simply won't get started.

These barriers are not easy to overcome. Different governments have already encountered difficulties in using policy levers to drive demand for energy efficiency. But decarbonising heat can't be achieved without mass consumer engagement; there must be a focus on creating the conditions for the market to work.

Transparency and choice are not the only prerequisites for successful consumer markets. Transparency is useless without clarity, and without comparability making a choice can feel impossible. Genuinely competitive markets have both clarity and comparability. They also tend to have innovation that benefits customers as well as the innovating company. In this report, as part of examining the challenges and potential for solving the future of heat, Cadent have combined their new consumer research with existing findings to present an in-depth picture of consumer views and set out a helpful model of the ideal customer journey. The demands of the net zero transition have stimulated innovation in the energy sector, and I hope this report will provide the springboard for successfully addressing the consumer barriers to a decarbonised future of heat for everyone.

Executive summary

It may feel as though 2050 is a long time away. But time is short. To upgrade almost every home in the UK from both an insulation and heating perspective and provide the infrastructure to deliver the energy is a very significant task, the scale of which has never been delivered before. This will require huge levels of investment – the Climate Change Committee (CCC) estimate a total of £250bn by 2050. It will also need to be done systematically and with consumers at the forefront to have a good chance of being successful.

When choices around home heating systems and investments are only made every 10 to 20 years, this means that decisions made in the next 10 years will be critical.

The scale of the change needed is unprecedented, particularly regarding the changes needed inside consumers' homes. Every single one of the 22 million homes using fossil gas today for heat and hot water will require both energy efficiency and heating retrofits – even before we consider off-grid LPG and oil properties.

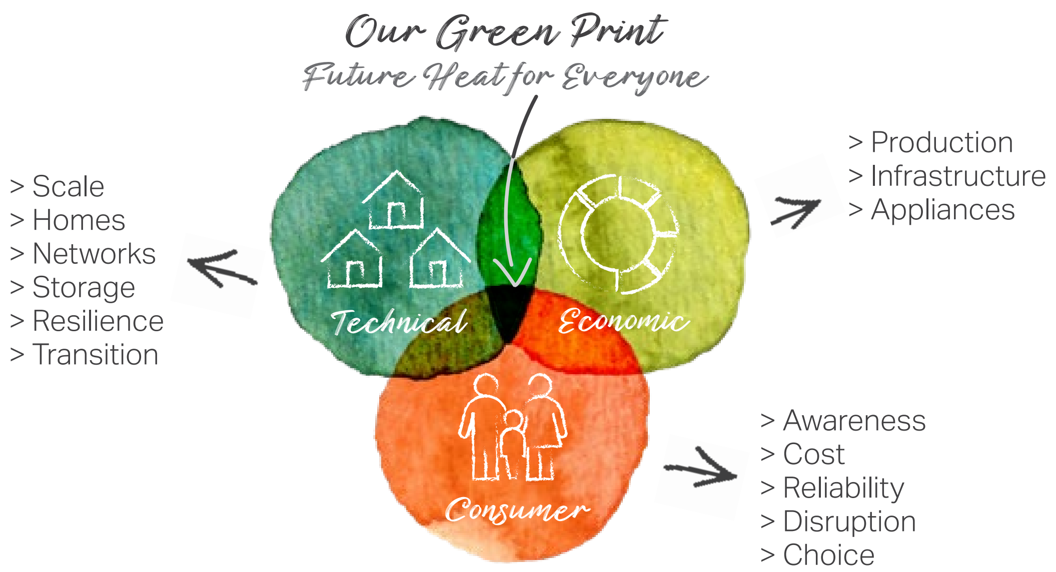
To put this in perspective, if we started today, we'd have to retrofit 67,000 homes every month from now until 2050. When compared to today's deployment rates of heat pumps at around 30,000 per year, it's clear that the scale of this challenge is huge. While the CCC have rightly outlined the importance of scaling supply chains and skills, scaling up consumer acceptability and demand will be equally as important.

There is a lot of activity developing the policy framework needed to meet this challenge, but more is needed. Some of that may be delivered by the planned Heat and Buildings Strategy and Hydrogen Strategy – neither of which had been released at the time of writing this report. Given the scale of what is needed, delivery needs to start now – on energy efficiency, heat pump deployment, heat network build-out and on ensuring hydrogen plays a central role too.

Numerous studies have been published exploring how we can achieve all of this by 2050. They have largely focused the economic and technical aspects of the transition, leaving most consumers with little understanding of the impact of such changes on consumers and their current heating systems, or the options available to them.

In this new report we take a different approach. We go beyond current thinking on the economic and technical aspects and make the case for consumers to be central to the critical decision on future heating solution and be at the heart of the transition. This is the essence of our Green Print – that the 'right answer' to the transition of heating need to consider technical issues, economics and consumers.

We look at the technical challenges in decarbonising heat, the options available and where hydrogen might – and might not – play a role. We then examine consumer wants and needs, and what this tells us about how we should go about the transition, before considering what the economics tells us – particularly how much it all might cost. Finally, and most importantly, we set out 12 specific actions that should be taken today – our Green Print for Future Heat for Everyone – considering the technical, economic and consumer aspects together, in order to make the transition to low carbon heat.



Our Green Print – Future Heat for Everyone

Prove the technical case by:

1. **Demonstrating that hydrogen is safe:** Complete the necessary steps to ensure that all the safety evidence for hydrogen in the gas network is completed – both in the gas network and in the home.
2. **Enabling the development of a hydrogen economy today:** Set production targets; develop production and carbon capture and storage business models; support industrial cluster development; accelerate hydrogen blending; mandate hydrogen-ready appliances; and successfully complete the necessary upgrades to the gas network.
3. **Prioritising innovation:** Facilitate innovation by fostering and incentivising innovation, in both the technology, and in the regulatory framework.
4. **Injecting pace into the building of infrastructure we know we will need:** Start planning now whilst building supply chains and skills in parallel. Identify ways to accelerate the planning and development processes. Enable 'learning by doing'.

Ensure consumer wants and needs are properly considered by:

5. **Ensuring consumers are central to decisions on the future of heat:** Exploit the experience of the private sector in designing policy targeting consumers. Mandate the changes needed and then allow consumers to have a voice over how that change is delivered.
6. **Ending the unnecessary 'format wars':** We need to move on from arguing about which technology will 'win' and instead work together on establishing where each technology will be deployed and how we will help consumers make the transition.
7. **Understanding consumer views on heating and beginning engagement early:** A range of parties will need to come together for this to be a success. Work needs to start now on delivering this if the transition to low carbon heat is to be successful.
8. **Being upfront with consumers on how much the transition is going to cost and how it will be paid for:** The costs of decarbonising heat are going to be significant regardless of the pathway we choose. We need to start an upfront and straightforward conversation with consumers about what that looks like and how it will be paid for.

Ensure robust economic decisions by:

9. **Creating the right incentives to decarbonise heating and deliver net zero:** Industry stands ready to invest. In order to unlock this, we need to create a market design and regulatory framework that incentivises them to do so.
10. **Stopping planning in silos:** Co-ordinate local area plans for decarbonisation across power and gas, potentially led by a new body that can ensure we do not deliver a patchwork of easy solutions without considering the impact on the whole system or of harder to decarbonise buildings.
11. **Planning for peak demand, not average demand:** Heat demand in winter periods may be nine times as much as in the summer. Winter periods also coincide with the highest incidence of dark and windless days. Our future system needs to ensure heat demand is met even in such extreme conditions.
12. **Deepening the understanding of the critical factors in the economics that will determine the energy mix:** We need to refine our analysis on the role of hydrogen as new information emerges, for example on energy efficiency deployment rates and the pace at which the price of hydrogen falls.

About Cadent

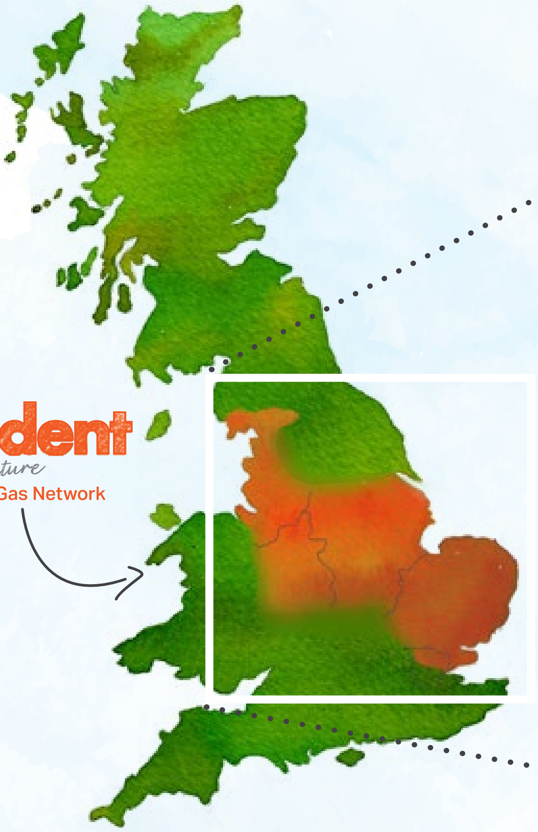
Our responsibilities and geographical reach

Cadent is the largest gas distribution company in the UK. We deliver fossil gas to 11 million homes and businesses throughout the North West, West Midlands, East Midlands, South Yorkshire, East of England and North London – helping keep consumers on our network safe and warm.

In doing this we are responsible for maintaining our network, ensuring that it operates safety and reliably for those who rely on it. We also help homes, businesses and renewable gas suppliers connect to our network.

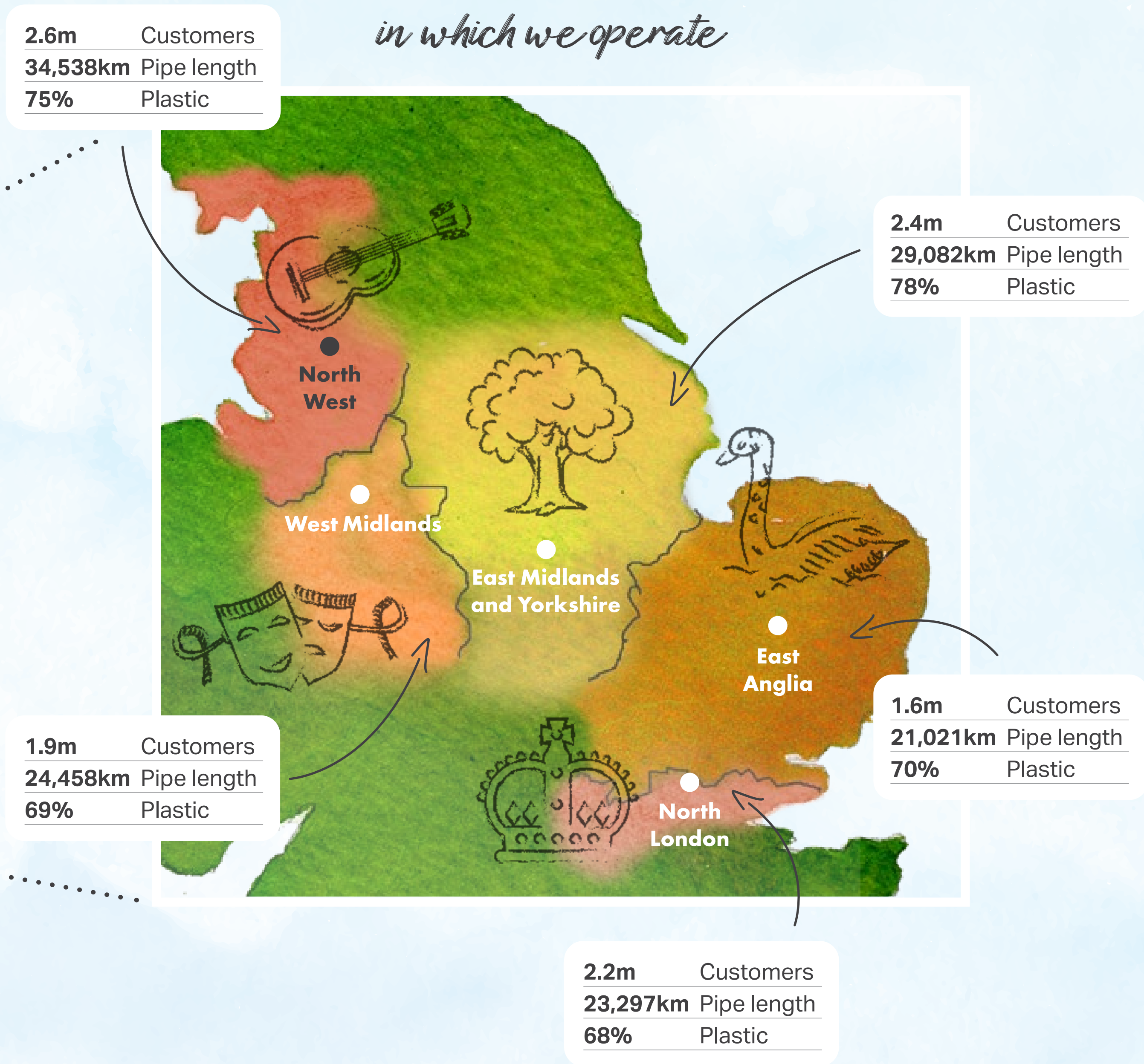
Cadent supports the commitment to net zero emissions by 2050. We know that the fossil gas we deliver through our network today is part of the problem and not part of the solution. Low carbon heating technologies need to be deployed across our network – and beyond.

Even as a gas network we are clear that there is a significant role for both heat pumps and low carbon heat networks in the future mix. We also believe that green gases such as hydrogen will be needed if we are to be successful. This requires us to consider where there might be a role for our gas distribution network and where there might not be.



Regions

in which we operate



11m	6,155	132,396km
homes and businesses connected to our network	employees helping consumers on our network keep safe and warm	of pipe across our region

"We provide the energy our customers need to stay safe, warm and connected. Our responsibility is to look after the gas pipes so they can continue to deliver safe, reliable and low carbon energy for years to come. We are continually finding smarter and more sustainable ways to develop our networks and work closely with local communities to deliver a high quality service that our 11 million customers expect. We are proud to keep the energy flowing."

Introduction

Net zero

The 2008 Climate Change Act committed the UK to reducing greenhouse gas emissions by 80% from 1990 levels by 2050. However ambitious this target was at the time, it allowed people to assume that they were in the 20%, and that somehow action to tackle climate change was the responsibility of others.

In 2019 the UK Government formally adopted the CCC's advice and amended the target to be net zero emissions by 2050. This meant that everyone needed a plan for how to decarbonise. In the context of heating, this signalled the end of any fossil fuel use in the future energy system and a consequent need for all homes and businesses to be both more energy efficient and fuelled differently.

Two years on and there is still no consensus about how this will be achieved in the context of heat and hot water for homes. There have been numerous studies assessing how we can get there, but they have generally focused on either the technical or the economic aspects of the challenge. The consumer lens of the challenge – their wants, needs and preferences – have received comparatively little attention.

Cadent future
Your Gas Network

Technical	Consumer	Economic
17%	22m	£250bn
of all UK emissions come from homes today	homes currently using fossil gas	estimated cost of heat decarbonisation in homes

Building political momentum

Whilst the CCC recently highlighted the gap between ambition and delivery, political momentum has been growing. The Government's Ten Point Plan[1] announced in November 2020 set out targets for nuclear, power generation, transport and home heating. On home heating it emphasised a focus on the production and trials of low carbon hydrogen, deployment of energy efficiency and installation of heat pumps.

The CCC themselves then published its Sixth Carbon Budget[2] in December 2020, setting out proposed emission allowances for 2033 to 2037 that would enable the UK to meet its net zero emissions target by the 2050 deadline. These proposals have since been converted into a legally binding target by Government.

The Energy White Paper[3] also published in December 2020, built on these documents by launching several consultations on the policies and standards that would be introduced to bring much of this to life. This included proposals to improve the energy efficiency of homes and deploy more low carbon heating technologies.

The Heat and Buildings strategy, which at the time of writing was still awaiting publication, is expected to set out the pathway to decarbonise buildings by focusing on the near-term solutions to improve building energy efficiency, decarbonise off gas grid properties and boost the installation of heat pump heating systems. It is also expected to set out plans that will encourage innovation and progress around hydrogen and electric solutions so that further policy decisions on heat can be made by the middle of the decade.

Timeline

The journey to net zero based around policy decisions.

Key
■ Ten Point Plan
▲ Energy White Paper
★ Sixth Carbon Budget

2021

- Launch a world class energy related products policy framework. We will push for products to use less energy, resources, and materials, saving carbon and helping households and businesses to reduce their energy bills with minimum effort ▲
- Publication of the Hydrogen Strategy, consultation on Government's preferred business models for hydrogen ■
- Set out our Heat and Buildings Strategy ▲
- Start of a Green Jobs Taskforce and National Skills Fund to support the growth of the supply chains needed to deliver all of this ▲
- Consultation on the role of hydrogen-ready appliances ▲

2022

- Finalise hydrogen business models ■
- Energy Company Obligation extended to 2026, supporting fuel poor households ▲

Key policy proposals are being developed

Collectively these documents reflect the high level of ambition the UK has about decarbonisation. However with the country set to miss its upcoming fourth and fifth carbon budgets, there is a problem: The Government's own figures show current plans still fall a long way short of what is required. How we heat homes and buildings in the future is a huge part of this problem, and the policies we have seen to date have made only small impacts. There is much more to do.

The CCC has provided a range of proposals on how to move from ambition to delivery, acknowledging in the process that buildings in the UK are diverse and relatively inefficient. The proposals included:

- Phasing out of fossil gas boilers ahead of 2035, and oil and coal heating by 2028;
- Mass adoption of heat pumps, with 5.5m in homes by 2030, including 2.2m in new homes;
- Conversion of some places to hydrogen and hybrid heating systems;
- Hydrogen trials from 2023;
- All new boilers to be hydrogen-ready from 2025;
- Net zero new buildings from 2025;
- Expansion of district heating schemes;
- Investment in driving consumer behaviour change; and
- Energy efficiency improvements across the spectrum of buildings.

These are clear and effective targets that will set the UK on the path to achieving its ambitions. There is however limited detail within the reports on how these proposals could be achieved and how consumers will be encouraged and supported in their take-up.

Whilst there has been a lot of activity developing the policy framework needed to meet this challenge, more will be needed in future. The forthcoming Heat and Buildings Strategy and Hydrogen Strategy, neither of which had been published at time of writing are expected to be key. Given the scale of the challenge ahead, it is important that delivery starts now – particularly on energy efficiency, heat pump deployment, heat network build-out and on hydrogen development.

2023

- Work with industry to complete testing necessary to allow up to 20% blending of hydrogen into the gas distribution grid for all homes on the gas grid ■
- By 2023 we will support industry to begin hydrogen heating trials in a local neighbourhood ■

2025

1GW

We are targeting 1GW of Hydrogen production capacity ■

- Potential ban on new fossil gas connections for new homes ▲
- All new gas boilers to be hydrogen ready ★
- Will support industry to begin a large village hydrogen heating trial, and set out plans for a possible pilot hydrogen town before the end of the decade ■
- Local Authority zoning for heat networks implemented ▲
- All new heat networks using low carbon sources of production ★
- All new homes to be zero carbon ★

2028

- 600,000 heat pumps installations per year by 2028 ■
- All heating system sales off the gas grid are low carbon forms of production ★
- All rented and homes for sale to reach EPC C ★

2030

2.8m

Improved energy efficiency in 2.8 million homes from Green Finance Initiative, bringing around 1.5 million homes to EPC C standard ■

- 5GW hydrogen production capacity ■
- All rented non-domestic premises to be EPC B where cost-effective ▲

2032

50%

Public sector has reduced its direct emissions by 50% compared to a 2017 baseline ▲

2033

- All mortgaged properties reach EPC C ★
- All heating sales are low carbon across the entire system ★

2035

78%

As many existing homes as possible hitting EPC C where practical, UK reaches 78% emissions reductions compared to 1990 ▲

2040

- All existing heat networks convert to forms of low carbon heat production ★

Our Green Print

Future heat for everyone

Reaching net zero will require making some difficult decisions about what solutions we choose. Whilst important, it is insufficient to simply consider these questions through technical and economic lenses – we must also ensure we fully consider the impact on customers and society.

Our Green Print – Future Heat for Everyone therefore goes beyond current thinking on the **economic** and **technical** aspects, and additionally explore how **consumers** can lie at the heart of the net zero transition in this sector.

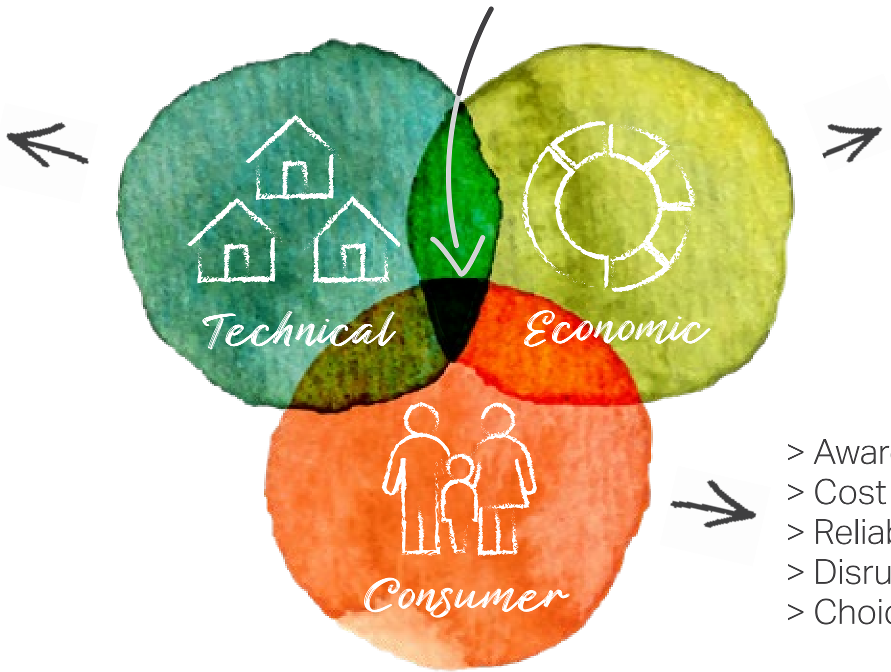
Multiple technologies will be needed

In thinking about the challenges from these three perspectives, our aim is to demonstrate how they are linked. This report does not set out all the answers, and the issues we explore are multi-faceted. We do however set out clear steps that would accelerate progress and add thoughtful direction. Our objective is to provide an accurate overview of the role that hydrogen can play and to create an informed reference document for those who are new to the topic and are interested in understanding more about it.

Our aspiration is that the development of energy policy will deliver **future low carbon heat for everyone**, leaving no home behind regardless of which technology is right for that home. We believe that multiple technologies will be needed to achieve this, and therefore welcome collaboration and discussion around this point.

Throughout this report, given the importance of distinguishing between natural gas – which is part of the problem – and 'green' gases such as hydrogen and biomethane – which are part of the solution – we will use the term 'fossil gas' instead of natural gas. We will also use the term 'green gases' to describe both hydrogen and biomethane.

Finally, although microbusinesses, small and medium sized enterprises and industrial and commercial organisations are also consumers, the focus of this report is on households.



Contents

About this document

We have considered the main heat decarbonisation options through the lenses of technical, consumer and economics. Our conclusions and recommendations – collectively forming **Our Green Print – Future Heat for Everyone** – take into account both the perspectives of key stakeholders and the market context, presenting practical steps based on a considered exploration of the issues.

Section 1

Technical

In section 1 we explore the technical aspects of decarbonising home heating, firstly setting out the scale of the challenge, then the options that are available for us to get there, and then finally looking specifically at the role hydrogen could play.

61%

of homes have poor levels of energy efficiency today

1.3m

retrofits needed each year between now and 2050

4 times

peak gas demand in winter versus electricity

How much of a challenge is this?

The challenge of delivering solutions that work

When creating Our Green Print – Future Heat for Everyone the first lens we need to assess the challenge through is the technical, ensuring what we deliver is robust, resilient and safe. And the technical challenges in decarbonising the heating systems of 22 million homes across the fossil gas network within the next 29 years is monumental. Indeed, a change of this magnitude in peoples' way of living is almost without precedent in the last 85 years.

The scale, cost and complexity of the issue means we will need a range of technical solutions. Most reports to date agree and propose that future home heating will be provided through a mixture of heat pumps, hybrid systems, hydrogen and heat networks. The question is therefore about the right mix of these technologies.

Planning for all eventualities is problematic. It would be costly and have high levels of redundancy if we hedged our bets and deployed each of these technologies in equal measure. Picking a winner for 2050 whilst stood in 2021 is both difficult and risky because there is so much uncertainty over what key variables such as fuel costs will look like in future. Moreover, the diverse and unique characteristics of individual homes across the country mean there can be no 'one size fits all' solution.

So, the real question here is: how long will it take before we really know the answer and how much uncertainty – and therefore cost – can we live with in the meantime? What value do we place on keeping options open as we decarbonise, and at what point do we need to decide what the mix of these technologies is?

Key points

80% or approximately 22 million homes use fossil gas for heat and hot water today

Transitioning all of them to low carbon heating systems in the next 29 years will be a challenge the scale which is almost without precedent in this country since WW2.

Poor insulation

Most homes today remain poorly insulated, losing heat rapidly in cold conditions. This needs to be addressed alongside the decarbonisation of heat.

Policy failures

Policy interventions are rarely straightforward, and many have failed. We need to learn from these failures.

Consumer impact

We're talking about homes, not buildings. Being aware of the personal impact this has on consumers and building that in to how we frame engagement is important.

Different solutions

Different solutions will be available at different times. This will complicate attempts to find the optimal solution in any area.

Incentives

Incentives are different depending on whether you own or rent your home. This needs to be reflected in policy development.

Resilience

Resilience needs to be built into the future system as standard – and this means planning for peak and not average heat demand.

Options

It is too soon also to pick winners. Optionality is not only desirable but necessary.

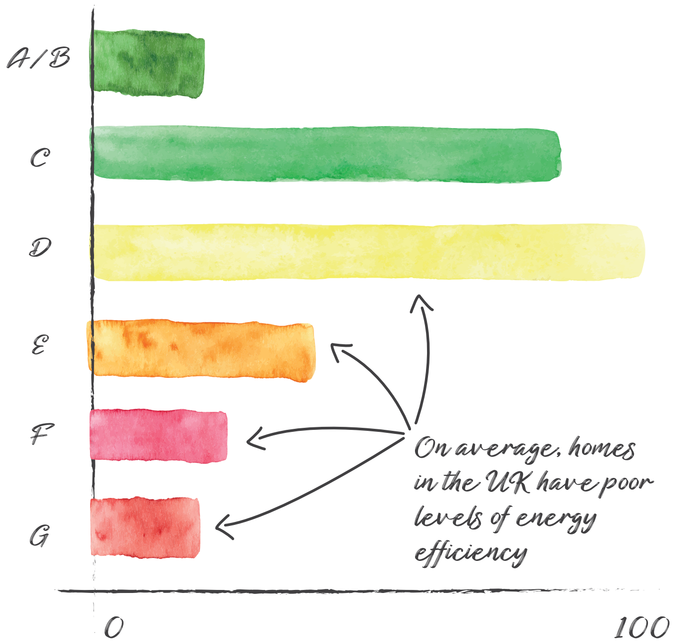
What is the scale of the problem?

The UK uses a large amount of fossil gas today – around 877 TWh in 2019, with approximately 309 TWh of that used for generating heat and hot water in domestic premises. By comparison, the entirety of the electricity used in the UK last year – by homes, industry and transportation – totalled 281 TWh.[4]

When commercial and industrial use of fossil gas is included, the UK building sector emits 87 $MtCO_2$ today.[5] The newly adopted Sixth Carbon Budget will change that, requiring a 78% reduction in those emissions against 1990 levels by 2035. This compares to a 46% reduction in the 17 years between 2019 and 2035. For comparison, the UK has only seen a 19% reduction in emissions from buildings in the 29 years between 1990 and 2019. In other words: we need to achieve more than twice as much in the next 15 years as we have done in the last 30.

EPC ratings of UK homes

%

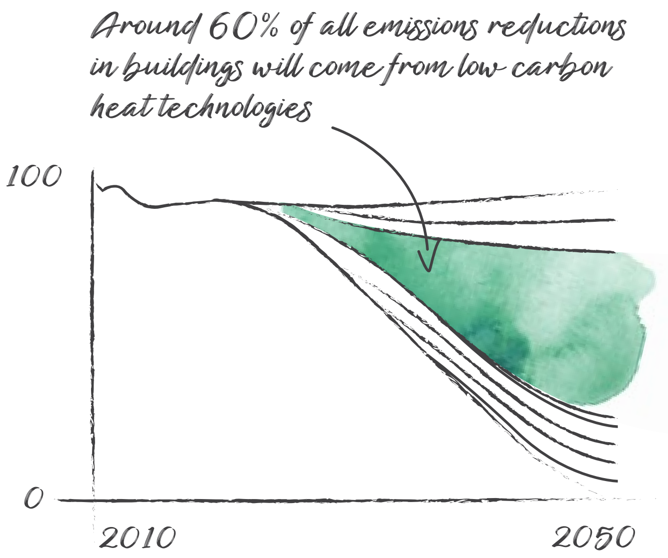


English Housing Survey, 2018-19.

We need to talk about homes

Approximately 80% of all homes that will exist in 2050 have already been built. And although there has been significant focus on improving energy efficiency levels in recent years, generally the energy performance of buildings remains relatively poor with 61% of the housing stock rated as EPC Band D or below. For households in fuel poverty, this figure is as high as 90%.[6]

The importance of low carbon heat technologies



The Committee on Climate Change, Sixth Carbon Budget (2020).

> **"In other words: we need to achieve more than twice as much in the next 15 years as we have done in the last 30."**

We need to improve the energy efficiency of homes
We support an approach that ensures that the fabric of buildings is made as energy efficient as possible. In the belief that the investment needed to bring this about will happen, we expect a significant reduction in the volumes of either electricity or green gases that will be needed to heat homes in the future.

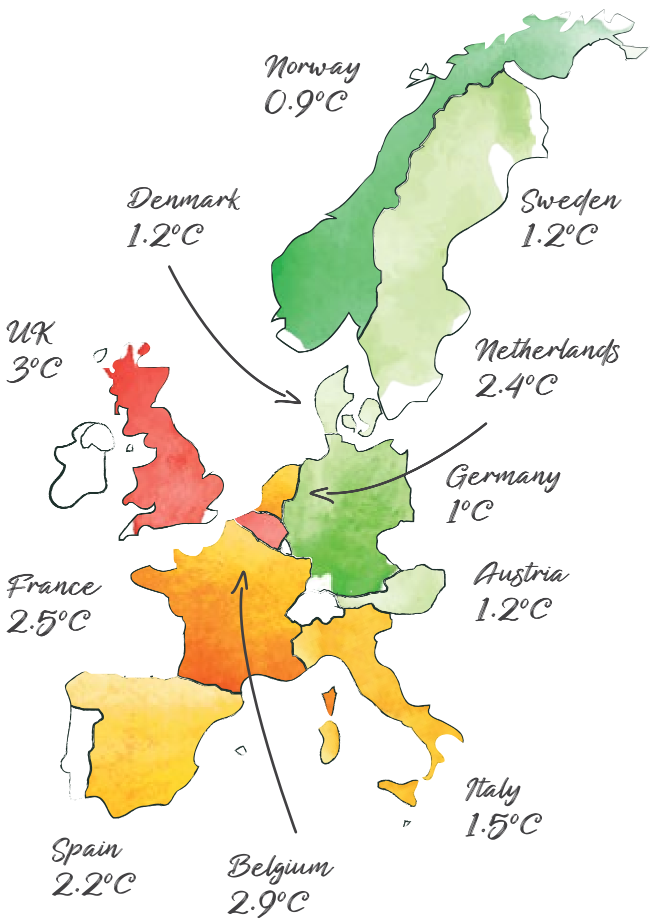
This will require significant effort, equivalent to 1.3 million homes retrofitted each year. By way of comparison, the current Energy Company Obligation (ECO) scheme is currently focused on Fuel Poor households and targets approximately 0.75m homes in the period between December 2018 and March 2022. Government has already recognised the need to scale up the level of ambition and has proposed increasing the annual ECO budget from £640m to £1bn. This will be insufficient on its own.

This will involve overcoming several challenges
There are also practical challenges to delivering the energy efficiency upgrades needed that go beyond money. The recent Green Homes Grant (GHG) highlighted both the complexities in designing energy efficiency incentives and the barriers to generating the scale of demand we will need to see. There were just 28,000 successful applications in the six months since the scheme GHG opened in September 2020, and the scheme has already been cancelled.[7]

Whilst the need to improve the energy efficiency of homes is not a challenge unique to the UK, the scale of it is a problem. Research by Tado in 2020 highlighted that UK homes may lose heat up to three times as quickly as homes in the EU, in part due to the average age of homes and the levels of energy efficiency within them.[8]

Home temperature loss after 5 hours

With a temperature of 20°C inside and 0°C outside



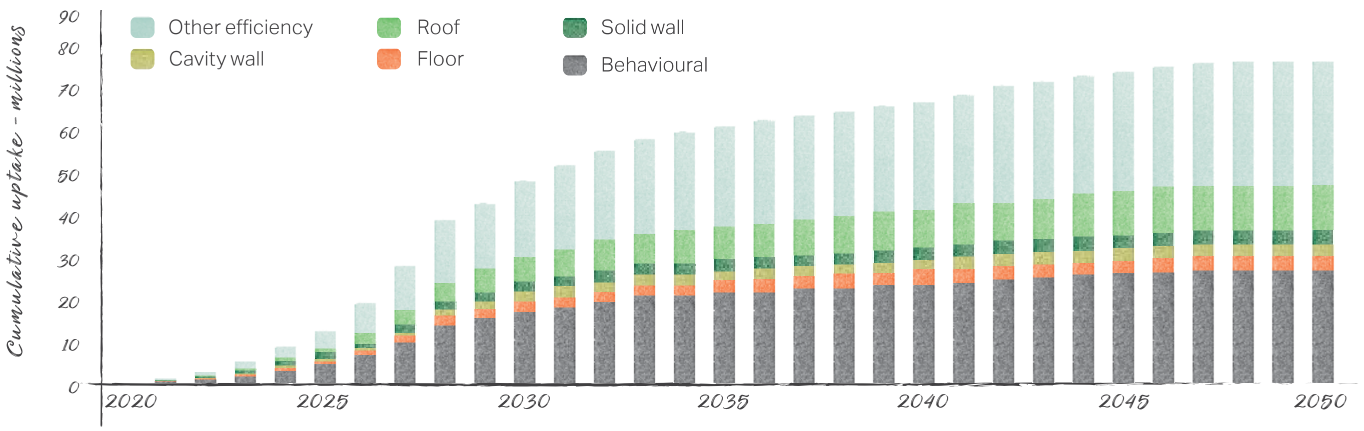
Graphic originally created, and reproduced courtesy of Tado.

History teaches us that policy interventions are not always straightforward

As we have seen in the previous section, policy interventions will be necessary to either provide the penalties or incentives needed to encourage consumers to move to low carbon forms of heating. However experience tells us that this is not straightforward and that outcomes do not always match ambition.

- The conversion from **Town Gas** to fossil gas from the North Sea between the late 1960s and the mid-1970s was remarkably successful, driven by central coordination across the value chain.
- The adoption of higher EU **appliance energy efficiency standards** has been very successful, contributing to a significant part of the reduction in electricity demand in recent years.
- The **Energy Company Obligation** has led to material investment in energy efficiency measures since its introduction in 2013. Notwithstanding this, demand for energy efficiency remains below the levels stipulated in successive CCC reports and energy suppliers subject to this are now reporting a shortfall in delivery for elements of the scheme.[9]
- The now-abandoned **Green Deal** and the recent **Green Homes Grant (GHG)** schemes have both failed to deliver on their ambitions for driving energy efficiency. Delays in processing vouchers, a neglect of supply chains and an overly complex customer journey have limited both demand and supply, highlighting the challenges of designing successful policy mechanisms.
- The **Domestic Renewable Heat Incentive (DRHI)** has had limited success in promoting heat pump installation. Approximately 60,000 heat pumps have been installed under this scheme and previous legacy arrangements, with a total annual installation rate of approximately 30,000. The stated ambition of installing up to 600,000 heat pumps per annum by 2028 will require changes to future support schemes such as the Clean Heat Grant if it is to be realised.
- The **Smart Meter** roll-out has also been beset by problems. Only 34% of all household energy meters were operating in 'smart' mode in October 2020[10]. Several barriers prevent wider adoption of smart meters, including some customer resistance, the fragmentation of roles and responsibilities and the lack of common technical standards. Whilst customer acceptance has not been the only barrier, the scheme has highlighted the challenges of generating customer demand.

Energy efficiency uptake



The Committee on Climate Change, Sixth Carbon Budget (2020).

We need start engaging consumers
The challenge of decarbonising heat will require consumer engagement and consent on a scale we have not yet achieved in energy – and perhaps any sector. It may entail short-term disruption and potentially affect the fabric of their homes. It may also cost more. Designing policy in this context will be more challenging than if changes could simply be made at a system level – far away from customers' homes – as is the case with the decarbonisation of the electricity sector.

We can learn from experience
We need to learn from the past. In our view, this means that policy interventions aimed at households need to:

> include both regulatory and economic measures;
> keep things simple and avoid undue complexity;
> have regard to supply chains and delivery, as well as customer choice itself;
> consider the specific needs of the fuel poor and vulnerable, to ensure a just transition in which disadvantaged groups are not 'left behind';
> make it easy for ordinary households to adopt low carbon heating, without needing a detailed understanding of energy technologies before they can be confident to make a start;
> have longevity to enable certainty in the supply chain; and
> have single accountability for delivery wherever possible.

These requirements need to build on a conversation with consumers on why change is needed, what it means for them, the options available, the pros and cons of each and how they can access the help and support needed to guide them through the transition. Given the need for action now on the decarbonisation of heat, the **urgency with which this conversation is now needed is extreme.**

A question of timing

Whilst we know that future low carbon heating is likely to involve a mix of heat pumps, low carbon heat networks and hydrogen, each of these options is at a different stage of development and will be available for deployment at different times.

Heat pumps are available today – albeit at a cost which many people may consider unaffordable. It is reasonable to ask how long it will take the installed real-world cost to come down to levels that will encourage the demand many anticipate.

Building supply chains matters
It is also reasonable to ask how long it will take to build the supply chains, installation and energy efficiency retrofit capacity necessary to deliver on these ambitions. There are approximately 1,000 heat pump installers in the UK today installing around 30,000 heat pumps each year today. In order to achieve the Government's target of 600,000 heat pump installations per year by 2028 we will need to increase the number of trained installers by around thirty times![11]
There is no clarity yet however on how this will be achieved.

30x increase

In order to achieve the Government's target of 600,000 heat pump installations per year by 2028 we will need to increase the number of trained installers by around 30 times

Heat networks will play a specific role
Heat networks have existed in the UK for decades, although the market remains small scale and relatively immature. Most heat networks continue to be powered by fossil gas, and in future – if we're to see them deliver 20% of overall heat demand as some anticipate – we will need to transition them to technology such as large heat pumps or hydrogen. The development of the business models necessary to bring about this change will take time. Given their nature, it will also take time to complete the build out of the infrastructure. It is reasonable for customers in eligible areas to ask if and when they might be connected to a nearby network.

Hydrogen is not going to be available for several years
Hydrogen is not available for home heating at all today, save for small-scale trials, and given the lead times to complete trials, build infrastructure and develop production it is not likely to be available for approximately 10 years.

Furthermore, whilst no-one knows what hydrogen will cost when it is deployed, it is reasonable to believe that it will be more expensive than fossil gas today. It is therefore also reasonable for consumers to not only ask when (and even whether) it will be a realistic option in their area, but also how much it will cost and how it will be paid for.

The answers to these questions are not yet known. This paints a picture of options becoming ready to be deployed at scale at different times in different locations, complicating attempts to find the optimal heating technology mix in each area. This is a challenge for cities and regions aspiring to reach net zero well ahead of 2050, such as London[12] or Manchester.[13]

Buildings are homes and people live in them

When we think about how to address the challenge of decarbonising heat we need to bear in mind that these are not buildings, they are homes. Homes have people living in them who by and large want to exercise choice over how they live their lives and the home improvements they make.

Lifestyles vary from home to home, from those who have multiple homes, those in vulnerable situations, those who are carers, those with large families, those working from home and those in fuel poverty. The transition to low carbon heat may involve asking consumers to voluntarily make changes to the way in which they use their heating system and even configure their homes.

Homes are also personal spaces, and consumers will rightly expect some say over the decisions that affect them. From how future systems work and the level of comfort they provide, to how they impact the aesthetics of their property. It is reasonable to expect **consumers will want the ability to input on low carbon heating technologies available to them**, to ensure they suit their own wants, needs and preferences – rather than passively having a centrally determined option imposed on them.

The familiarity of fossil boilers creates an issue
The challenges this presents are underlined by the benefits current fossil gas systems provide customers with. Boilers can ramp up and down to suit desired comfort levels. They are easy to source and replace, relatively cheap to maintain and run on a fuel that provides the cheapest source of heating and hot water available today.

Additionally, having been present in 22 million homes for over 40 years, they are familiar.

Boilers are also relatively small and quiet to run. In the case of modern combination boilers, they negate the need for additional equipment such as a hot water cylinder. In some homes they have been integrated into spaces designed to store them unobtrusively. Changing them for some low carbon equipment may necessitate changes to a customer's home that they may be reluctant or unable to accept.

> **"Being aware of the personal impact this has on consumers before presenting them with notice of the need for change is important for how we frame engagement."**

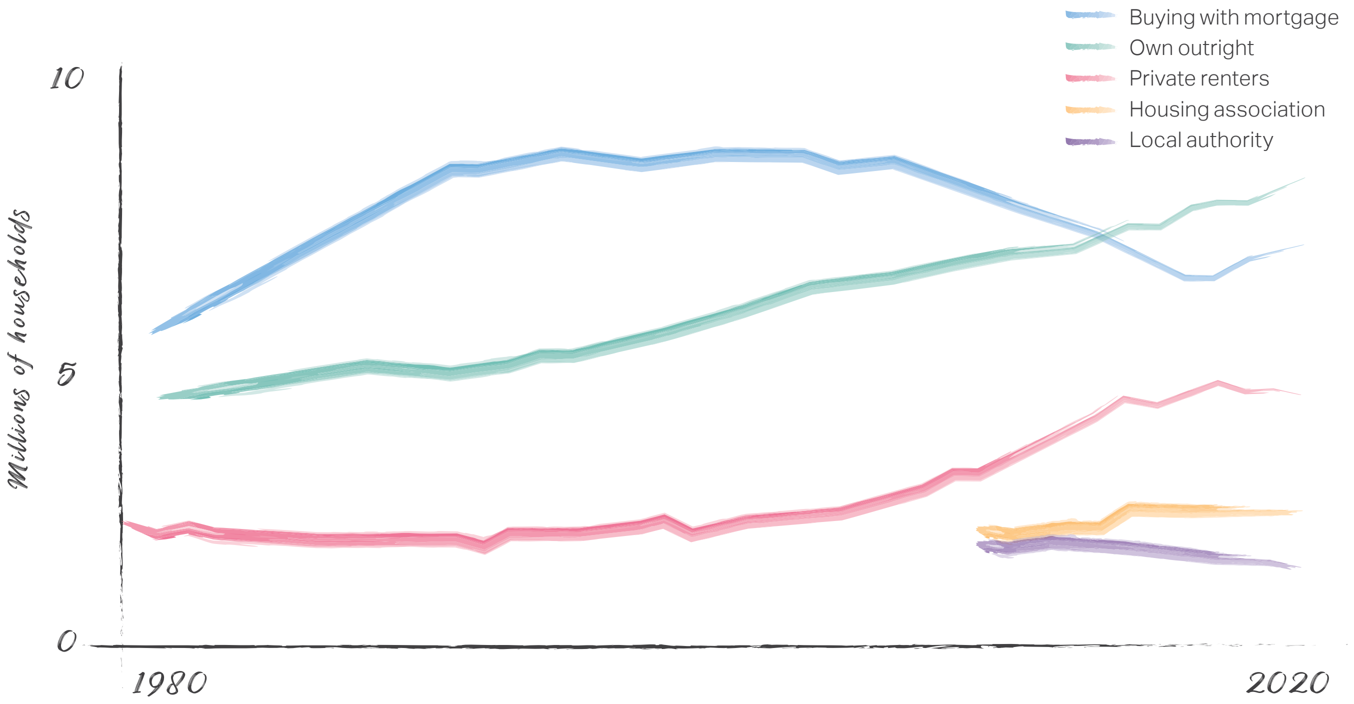
Incentives are specific to whether you are a landlord, tenant or owner occupier

When we speak with consumers, it is apparent there is a difference between the incentives of landlords, tenants and owner occupiers – and that these differences are the key driver of which low carbon investments are made in the home.

Landlords are incentivised to minimise capital investment whereas tenants are incentivised to minimise ongoing running costs. Owner occupiers will tend to take a more balanced view, but in practice give more weight to up-front costs than total lifetime costs. It is therefore important to note that in recent years have seen declines in the number of mortgaged properties and increases in the number of households being rented or owned outright.

Policy needs to account for these different incentives
These differences have implications for the design of the policy that will support the transition to future heat. For example, without strong regulatory intervention or financial incentives targeted at owners as opposed to occupiers **we may not see the level of investment we need in new low carbon heating systems.**

Rising levels of home ownership
Millions of households



English Housing Survey, 2018/19.

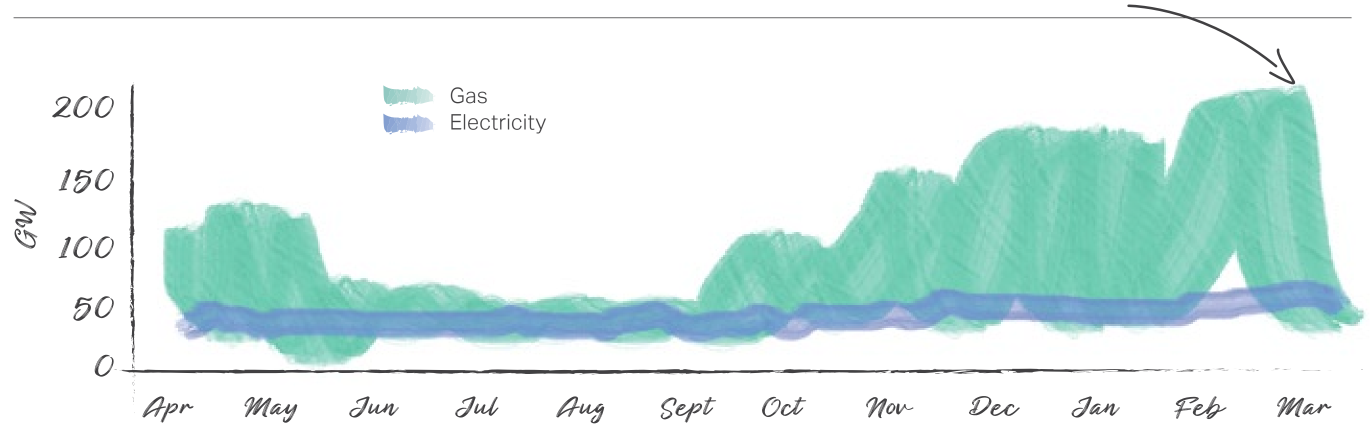
The importance of peak and not average demand

Whilst there is a potential for climate change to lead to milder, wetter, winters in the UK, the energy system still needs to be designed to meet heat demand in even the worst conditions. This requires an assessment of peak heat demand rather than average or total annual demand. In the UK this means designing energy systems that ensure the reliable delivery of heat and power in even the peak demand that would occur in a 'one in twenty year' type event.

The impact of extreme weather
A good example of these extreme events was seen in March 2018 when temperatures were low for a sustained period. Consumers consequently demanded more heat, and gas demand peaked at 214 GW. For context this is more than **four times the peak electricity demand at the same time**. It is also eight times more than average summer gas demand and one and a half times more than average winter gas demand.

Our own experience backs this up. Gas demand on our network can be as much as nine times that needed on a cold winter day as that on warm summer's day. If the comparison is made using hourly gas demand extremes, the multiple rises to 18.

Peak demand
2 April 2017 – 6 March 2018



Recreated with permission from chart produced by UK Energy Research Centre paper 'Challenges for the decarbonisation of heat' (2018).

Peak heat demand does not always correlate with periods of high renewable electricity output
While deploying energy efficiency and demand response measures in the future will reduce the overall amount of heat consumers need during these extreme events, mitigating some of this effect, the future energy system will still need to accommodate significant peaks.

This is complicated by the fact that periods of high heat demand in winter are more likely to correlate with periods of low solar and wind electricity output. In short, **the middle of winter is when we are more likely to see periods of low sunlight and low wind.**

In a future electricity system with high levels of renewable generation, supply may therefore already be tight – even accounting for material growth in flexible power and heat assets such as batteries and demand side response.

This may be less of a concern in a system where hydrogen meets a proportion of heat demand, given the gas network's ability to act as an effective store of energy.

The potential for growing cooling demand
Set against this is the reality that climate change will, on average, result in warmer summers. Combined with the potential improvement in home insulation, the UK may in future face a potential for homes to become overheated at points during the year. While this could be addressed through investment in improved ventilation as the CCC suggest, it should also be noted that heat pumps have the ability to also act in reverse – essentially as air conditioning units. In a scenario where heat pumps are deployed at scale, this would have the effect of increasing summer electricity demand and flattening the peak between seasons.

The way forward

The technical challenges outlined above are not to be underestimated. Each one adds complexity to how we consider how the future of heat decarbonisation will be planned and implemented. For homes, there is a difference between what appears to be technically feasible on paper and what can be achieved in reality.

We need to focus more on the consumer perspective
Cadent believes that consumers have not received the due consideration required for any net zero pathway design to be successful. We need to learn from previous schemes that have fallen short of the plan because of similar generalisations. Very often, too little attention has been paid to ensuring that the process of delivery is specifically aligned with consumer needs in terms of convenience, affordability and process facilitation.

We need to start planning
Similarly, regional and geographical characteristics, the diversity of building stock and tenures create a need for multiple solutions, affecting both gas and electrical infrastructure on a regional and national scale. Given the long lead time for infrastructure investment, **there is a premium on early planning.**

System-wide co-ordination is essential
Finally, choices made by both customers and regions need to be viable both at the individual and system level if we are to ensure that there is a resilient and reliable network. Regional and national co-ordinated planning across supply and demand elements is essential.

What are the future options for consumers?

The low carbon heating technologies that can help us meet this challenge

Approximately 85% of homes in the UK will need to transition to new low carbon heating systems in the next 29 years. Given the average heating system has an asset life of 15 years we have at most two replacement cycles within which to complete this change.

Technologies available today

In formulating a Green Print for Heating we can make use of those technologies already available, specifically resistive electrical heating, heat pumps (both can be combined with a renewable electricity supply contract) and biomass. The speed and scale of take up of these technologies has not yet reached mass adoption and has largely relied on Government incentives – only around 240,000 heat pumps were in operation in the UK at the end of 2019, for example![14]

Technologies available tomorrow

Additional technologies will also be available to us in future. Hydrogen is not currently used for heating or hot water in any homes, beyond those involved in current demonstrations. There are also no commercially available appliances capable of using hydrogen to produce heat or hot water. The development of hydrogen and 'hydrogen-ready' boilers has however progressed under the BEIS Hy4Heat programme,[15] established to test the feasibility of hydrogen as a fuel for the home. Manufacturers such as Worcester Bosch and Baxi have also announced plans to scale production of these – and 'hydrogen-ready' – appliances in the coming years. Gas networks, including Cadent, are leading a range of projects to establish the technical feasibility of delivering hydrogen to homes using the current gas network.

The need for a range of options

So while options exist today, they will change over time. **This is not an excuse for inaction today** – indeed, we cannot afford such luxuries – however it does create the opportunity for an approach that encompasses a range of technologies, each suited to different circumstances. The Government's Ten Point Plan reflects this, emphasising the future role of both heat pumps and hydrogen. Other low carbon heating technologies such as heat networks will also play a role where they can be economically deployed.

In this section we will explore how each of the key technologies work and their suitability for different types of homes.

Key points

85% of homes in the UK will need to transition to new low carbon heating systems in the next 29 years

Given the average heating system has an asset life of 15 years we have at most two replacement cycles within which to complete this change.

Fossil fuel

There are several low carbon heat technologies available to us. The key ones are heat pumps and hydrogen boilers.

Heat pumps

Heat pumps are highly efficient, capable of turning one unit of energy into several units of heat.

Coming soon

Hydrogen boilers are not commercially available yet but will be soon. They are expected to work in much the same way as fossil gas boilers do today.

Combination

Hybrid systems combine these two technologies, using a heat pump for the majority of heating needs and a hydrogen boiler for peaks in demand.

Other heating

Other heating systems will play a role. In particular, heat networks are well suited to areas of dense energy demand such as city centres.

Right solution

The 'right' solution is highly dependent on the characteristics of the individual home. A one size fits all approach will not succeed. We will need each of these technologies if we are to succeed.

Heat pumps

Heat pumps are commercially available to install in UK homes today. There are three main types of heat pump, each drawing heat from a different source: Air Source Heat Pumps (ASHP), Ground Source Heat Pumps (GSHP) and Water Source Heat Pumps (WSHP).

The characteristics of these technologies lend themselves to different situations. ASHPs require less space than GSHPs or WSHPs and so are more suitable for individual and smaller homes. GSHPs require an area of land to draw heat from and so are more suited to larger properties or communal developments. WSHPs need to be sited next to a body of water such as a river and are therefore more suited to city developments. In this section we largely focus on ASHPs given they are expected to form most domestic heat pump installations in future.

Highly efficient, but may involve additional costs

A key advantage of heat pumps is that **they are highly efficient**. For every single unit of energy they use they can produce around three to four units of heat. Whereas a fossil gas boiler would produce heat in the form of hot water that is then distributed around a system of pipes to radiators, a heat pump produces heat in the form of warm water that is then distributed around a system at lower temperatures. This means that in some cases, to reach similar levels of comfort as a fossil gas boiler, a home may either need to install underfloor heating or, in some cases, larger radiators alongside the heat pump.

The heat pump system also requires the use – and therefore sometimes the installation – of an internal hot water tank. These differences can complicate the installation process, potentially creating additional cost and disruption.

The need for energy efficiency

Heat pumps also work best in energy efficient homes and as such may need to be accompanied by simultaneous investment in other upgrades such as insulation. Without supplementary upgrades less energy efficient properties may even need a supplementary heat source for times of peak demand as heat losses can prevent them maintaining target room temperature on their own.

Of course, these energy efficiency installations have wider benefits to the homeowner and the wider energy system. Importantly they will be needed at some point for all inefficient homes – regardless of heating technology. The installation of a heat pump may result in these investments being brought forward to the point when the heating system is changed, however.

Heat pump efficiency will vary through the year…

The efficiency of a heat pump is expressed in terms of a 'coefficient of performance' (CoP) rating, indicating how many units of energy are produced for every unit of energy it uses. In practice, although a single CoP figure is given for each heat pump model, the real-life performance will be within a range depending on how hard the system is made to work – or in other words, depending on the ambient temperature and the target temperature the system is set at. In general, the lower the ambient temperature and the higher the target system temperature, the lower the efficiency of the heat pump.

For example, Viessman suggest their systems can achieve a CoP of 4.5 (that is 450% efficiency, or 4.5 units of energy output for every 1.0 unit of energy input) when the ambient temperature is 7°C. This falls to a CoP of around 2.3 at an ambient temperature of -7°C.[16]

> **"The installation of a heat pump may result in these investments being brought forward to the point when the heating system is changed, however."**

…with lower end of the range correlating with periods of higher heat demand

While such low temperatures are relatively rare in the UK, heat demand will typically inversely correlate with the temperature outside. In other words, as the temperature outside falls, heat demand will rise. This means that, given most heat demand occurs when heat pump conditions are less favourable real-world CoP performance may therefore be somewhere below stated maximums. Importantly this also means that electricity demand from heat pumps will increase per unit of output at times when heating is most needed, for example when it is cold.

The efficiency of various heat pump systems can therefore be better interpreted using a Seasonal Performance Factor (SPF). This represents the average efficiency of the system over the course of an entire year. Under UK conditions this may typically be around 2.5-3.0;[17] levels of efficiency still far ahead of alternative technologies.

When installed correctly heat pumps can provide specific room by room temperature control. Some units also have the advantage of being able to provide air conditioning. Capital costs are dependent on the size of the system, and the extent of any consequential upgrades to the system or building fabric.

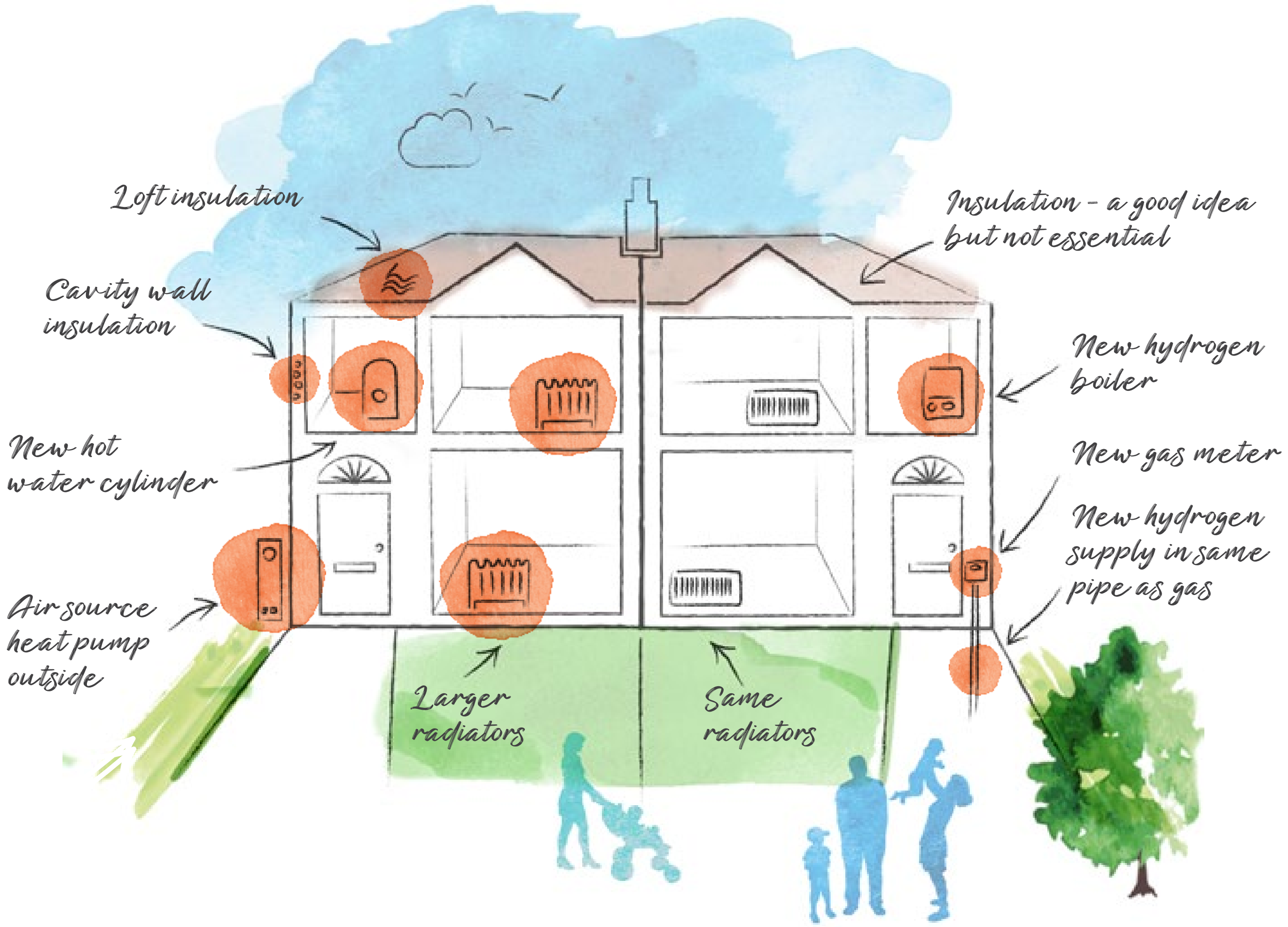
Installing a heat pump in existing homes

Heat pump home

New heat pump cost **£7,250 to £10,000**
Energy efficiency retrofits **£0 to £10,000**
Electricity prices **19p/kwh to 21.5p/kwh**
Electricity only cooking
Time to install **2 to 4 days**

Hydrogen home

New boiler cost **£2,500**
Energy efficiency retrofits not essential
Hydrogen prices **10 to 15 p/kwh**
Can retain hydrogen for cooking new H_2 cooker required
Time to install **1 to 2 days**



Hydrogen boilers

Several appliance manufacturers have already developed hydrogen versions of current domestic fossil gas appliances under the Government's Hy4Heat programme. These include cookers, fires as well as boilers.

Baxi and Worcester Bosch, major manufacturers of fossil gas appliances, have developed prototype boilers that are capable of safely burning fossil gas today and then – following a minor conversion process – pure hydrogen at some point in the future. Several pilot and demonstration hydrogen boiler examples are today in use at trial locations across the country but are not commercially available.

A near like for like replacement on installation
Manufacturers have suggested that when produced at scale they will cost no more than fossil gas boilers do today, approximately £2,750. These boilers work in the same way as current fossil gas boilers and would essentially be a like for like replacement with the existing boiler. There may be other consequential costs. For example, it is likely that switching from fossil gas to hydrogen may require the installation of a new gas meter.

Unlike heat pumps, there will be no need to change the heat distribution system following the installation of a hydrogen boiler, nor any immediate need to improve the energy efficiency of the home. That is not to say that homes converting to hydrogen do not need investment in energy efficiency. Many will. Indeed, doing so will reduce the heat demand and therefore the ongoing running costs of the system.

Instead, the point is that a conversion to hydrogen is not dependent on investment in energy efficiency upgrades and that the investment necessary for these upgrades can occur when the consumer chooses, not when the appliance is installed. A further benefit of the new hydrogen cookers and fires that have been developed **will be safer than those used today** as they will have automatic shut-off valves, something that is not mandated on current appliances.

£2,750

Manufacturers have suggested that when produced at scale hydrogen boilers will cost no more than fossil gas boilers do today, approximately £2,750

Higher fuel costs
However while the cost of these hydrogen appliances is also expected to be largely the same as today, the cost of the hydrogen fuel itself is expected to be higher and, like renewable electricity, will require subsidy to protect the customer as production scales enabling prices to fall.

It is reasonable to assume that while homes installing hydrogen boilers will generally have a significantly lower capital outlay when compared with heat pumps, their annual running costs will typically be higher.

The UK's first homes with boilers, hobs, cookers and fires fuelled entirely by hydrogen have been built in Low Thornley, Gateshead, with funding from the government's Hy4Heat innovation programme, Northern Gas Networks and Cadent. These houses have a three-year lifespan with potential for them to run for longer, up to 10 years. They are intended to showcase the use of hydrogen fuelled applications in a real-world domestic setting, demonstrating the potential of hydrogen energy to help achieve the Government's ambitions to eliminate the UK's contribution to climate change by 2050.

Hybrids

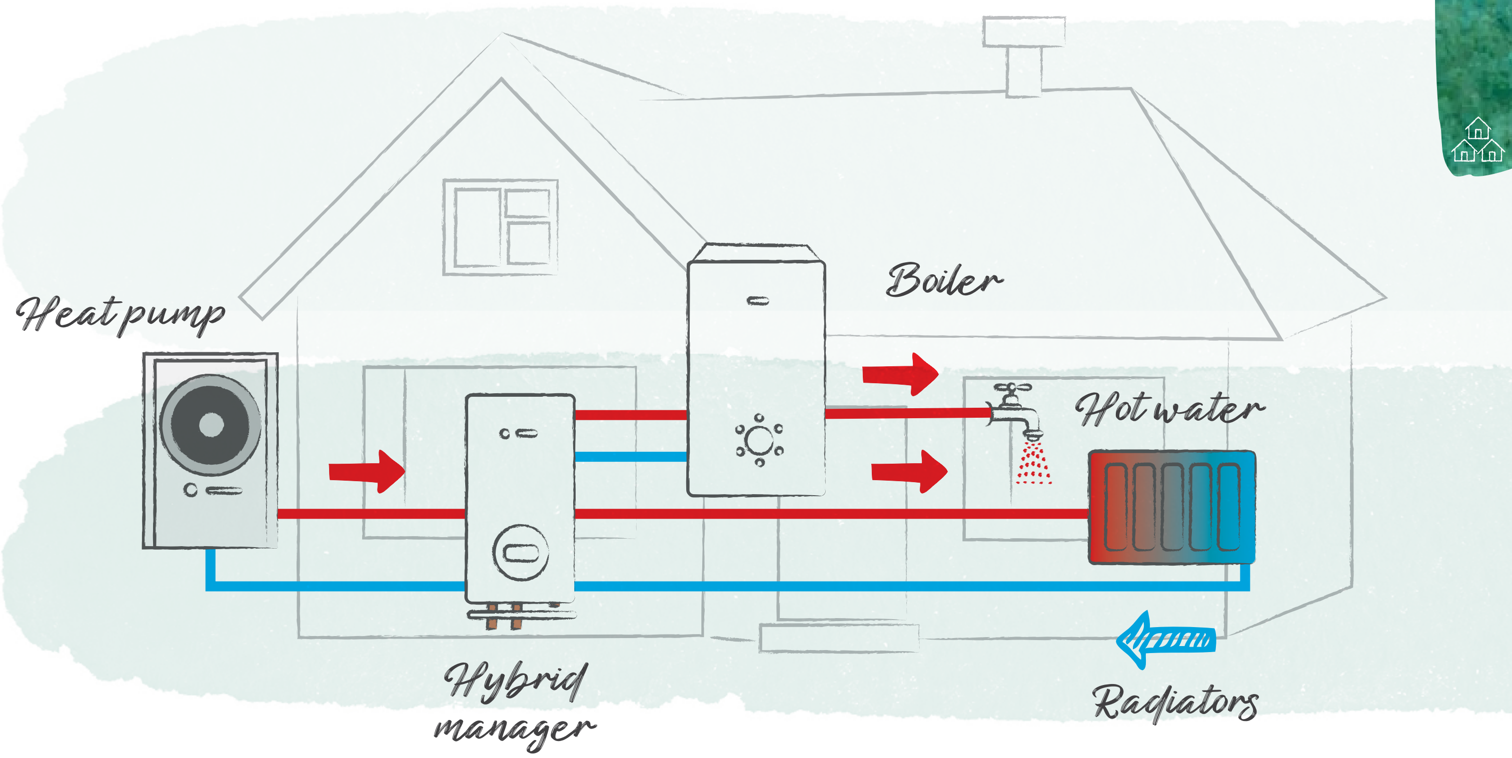
A hybrid heating system combines a smaller ASHP with an alternative heating source – most likely a gas boiler burning either fossil gas (today) or hydrogen (future). This enables a reliable supply of heat to be delivered all year round, with the ASHP element providing a constant source of 'baseload' heat and the gas boiler providing any boost required to meet a peak in demand, for example on the coldest days of winter.

System configuration and use determines efficiency and cost
This is a low carbon solution which delivers emissions savings that vary depending on the overall efficiency of the system, whether it is using the heat pump or the boiler and the source of any gas used.

Hybrid heat pumps can be installed alongside existing gas boilers to provide an immediate reduction in emissions. Furthermore, a hybrid system does not require any internal pipework to be replaced. The existing radiators and pipework can also be retained, though the heat pump itself will require space in addition to the gas boiler.

Hybrid system operation

The system will work in either heat pump or boiler mode depending on the conditions and/or customer choice. Weather compensation control can be added to ensure it operates in the most efficient way.



Other heating systems

Although this report focuses principally on heat pumps and hydrogen – the two technologies most likely to play material roles in the decarbonisation of heat – it is worth noting that there are a number of other technologies which may be relevant in a sub-set of UK homes, either because of their geographical location or because heat pumps are unsuitable for the building and hydrogen is not available in that area.

Resistive heating
These systems pass electrical energy through an element which, through the process of resistance, creates heat. Typical examples include storage heaters, common in many homes heated with electricity today. Given the relatively high price of electricity and their poor efficiency compared to heat pumps, these systems can result in higher running costs than some alternatives. They may however be **suited to well-insulated buildings** in locations without access to green gas and where ASHPs are not appropriate, for example for reasons of space.

If night storage heaters are used to take advantage of cheaper electricity on a two-part tariff overnight, then the quality of evening heating may not be as good as the customer is used to with fossil gas. There has, however, been some innovation in this area – one example being the availability of energy-efficient infrared heating panels in place of conventional electric radiators. These also retain their heat for longer after the heating has been switched off.

Resistive heating however lacks the efficiency of a heat pump, operating instead at an equivalent SPF of 1.0. In effect therefore, it lacks the primary benefit of a heat pump and – because of the necessarily higher renewable capacity and network reinforcement requirements to support demand – has greater downsides.

Heat networks

Heat networks, which for the purposes of this paper include both communal and district heating schemes, have one central energy centre that produces heat and then distributes that heat around the network via a network of insulated pipes. Typically, customer premises have neither a gas boiler nor a heat pump but a Heat Interface Unit (HIU) which enables metering and control of the heat.

Heat networks are particularly suitable in areas of high heat demand density such as city centres, but highly unsuitable to areas of medium to low heat demand density. This materially limits the number of homes that will be able to connect to a heat network in future but provides a real low carbon alternative to those homes located near one. The CCC estimates that heat networks could provide up to 20% of future heat demand.

One advantage of heat networks is that although most energy centres use fossil gas today, the process of converting them to low carbon sources of energy will need to be done only once in order to decarbonise all homes on that network. This can be done by either installing a large heat pump or converting the fossil gas engine to run on green gas.

Heat networks are however natural monopolies and customers would lose access to the competitive retail market. Although studies have found that on average heat network customers pay about the same as customers on the mains gas network, there are examples where customers pay substantially more.[18] Customer research carried out by Which? also highlights a lack of control causing dissatisfaction among some customers, along with concerns over value-for-money and in some cases unreliable heat.[19]

Some of these issues could potentially be mitigated or solved through the introduction of regulation – something that the sector lacks today. This has been accepted by BEIS who are working now to put the market under a statutory regulation framework.[20]

Biomethane

Biomethane is an alternative green gas made from organic matter such as human, agricultural, food or distillery waste. One major advantage of this is that one input for these feedstocks is carbon dioxide, which is then carried over in to any biomethane that is produced. While normally this carbon dioxide will be released when biomethane is burnt, if it can be captured at source biomethane could act as a negative emissions technology. And from a customer point of view, when biomethane is added to the gas grid it becomes invisible, requiring no new appliances or consequential changes to the customer's property.

Biomethane can generally be made in one of two ways – either via anaerobic digestion, the main technology deployed in the UK and elsewhere today, or via thermal gasification. The latter technology can potentially be used in much larger plants but is currently a less developed technology.

The real barrier to biomethane being used at scale for heating is that there is **insufficient supply to satisfy more than a fraction of future UK heating demand** – and given the nature of the feedstock a limited opportunity to increase production. There are approximately 100 biomethane facilities in the UK today, making around 4 TWh of biomethane[21] per annum, equivalent to less than 0.5% of annual fossil gas demand in the UK.

Within the Cadent region alone there are 36 biomethane plants connected to our gas network with another 20 either in planning or being construction. Together they will add a further 4 TWh of biomethane per year into the network. This picture is reflected across the country with the recent extension of the Green Gas Support Scheme. In its central case, BEIS[22] expects an additional 2.4 TWh per year of bio-methane production on average over the period from 2025 to 2046.

36 biomethane plants

Within the Cadent region alone there are 36 biomethane plants connected to our gas network with another 20 either in planning or being construction

In contrast the CCC[23] estimates a biomethane supply potential of 20 TWh per year by 2050, although pathways proposed in their recent Sixth Carbon Budget report suggest upward revisions to these numbers.

In the medium term, biomethane can readily be accommodated in the gas distribution pipeline system alongside hydrogen blended at a rate of up to 20%. In the longer term, however, gas distribution networks converted to carry 100% hydrogen would no longer be able to accommodate any amount of biomethane. Biomethane may therefore make its main longer-term contribution in regions where full hydrogen conversion does not take place, off grid properties unsuitable for electrification and as a transitional fuel for heavy transportation.

> **"In the medium term, biomethane can readily be accommodated in the gas distribution pipeline system alongside hydrogen blended at a rate of up to 20%."**

Technical

Technical suitability

We believe that net zero plans today may have failed to fully assess the feasibility of installing different technologies in different building types. The result is a wide variety of opinions on the addressable market for each technology. For example, the CCC assume that 70%[24] of homes could feasibly take a heat pump. A similar assessment by the EUA puts the number at 46% to 63%.[25]

Whatever the figure, both data sets outline a future energy system **using a balance of technologies** – ASHPs, hybrids and hydrogen. More thorough detail is expected to come from the BEIS Electrification of Heat programme which is installing approximately 750 heat pumps in different types of buildings to assess the achievability and compatibility of such systems with different building types.

46 to 70%

Estimated proportion of homes that can feasibly take a heat pump

What role can hydrogen play?

Production, safety and what conversion might look like

Since it is now clear that we must address all emissions, there is renewed interest in fuels which can provide a viable solution. Hydrogen can be instrumental to this in many areas of the economy – something Government has shown support for by putting hydrogen as one of the key deliverables in their recent Ten Point Plan. This interest is not limited to the UK. More than £200bn is being invested across at least 200 large-scale projects around the world right now as other countries seek to exploit hydrogen's potential as a clean fuel.[26]

Hydrogen doesn't typically exist by itself in nature and must therefore be manufactured using one of a variety of processes. Each process adds cost and, like all energy transformation processes, comes at the cost of some efficiency. Once energy is converted into hydrogen however it can be stored and transported and then turned back into other forms of energy. This makes it **tremendously versatile**, capable of uses in the power, heat and transport sectors.

Despite this potential and the renewed interest in hydrogen, public awareness is generally low. In this section we will therefore lay out the key facts about hydrogen, including how it can be produced and where the industry has got to in terms of demonstrating technical feasibility and safety within the network, homes and businesses.

Technical

Key points

Store and transport

Hydrogen is tremendously versatile, able to be stored and transported and then turned back into other forms of energy. This means it has a range of potential uses across the power, heat and transport sectors.

Certification schemes

It will be important for consumers to have confidence in the low carbon credentials of future hydrogen production. Certification schemes assuring consumers of its low carbon content will be needed.

Future projections

Projections of how much hydrogen we will need vary significantly. Whilst there is agreement that hydrogen will play a role in the future energy mix, it is not yet clear how much of this will be needed to heat homes and businesses.

Safety of hydrogen

Work is underway to demonstrate the safety of hydrogen with projects around the country testing its use under a wide variety of conditions. Findings to date have found no major safety or technical issues.

Plastic gas network

Work that was already underway to replace old iron gas mains with plastic is effectively now making the extensive lower pressure gas network better for carrying hydrogen. 92% of our network will be plastic by 2032.

Heat technology options

Given the uncertainty over the future mix of heat technologies, optionality is important. This means retaining a convertible gas network and progressing all the steps necessary for hydrogen to fulfil the role envisioned in the CCC's Headwinds scenario.

What is hydrogen?

Hydrogen is less well-known than the fossil gases in use today. It is the lightest element in the Periodic Table, known for being a very small molecule with high energy density. At standard temperature and pressure it is a non-toxic, odourless, tasteless and colourless gas. This means that – in the same way as we do with the fossil gas used in homes today – a unique odour would need to be added to it in any future gas network.

It is versatile
Hydrogen's properties mean that it can be usefully applied in a range of use cases. Because it can be either a gas or a liquid it is capable of being stored for long periods of time in either pipes, ships, tankers or even natural underground structures like salt caverns. This means that it is capable of being produced in one season and then used in another.

Once produced it can also be used for several other purposes, such as producing heat, industrial processes, making electricity or powering fuel cells.

Its properties as a long-term, flexible store of energy is valuable in an energy system which is becoming more reliant on intermittent power.

Physical properties create drawbacks
It is important also to note the limitations of hydrogen. The processes to manufacture it today are expensive compared to fossil gases and renewable power. Its properties as a light gas mean that if it is released it dissipates quickly into the atmosphere – a positive – but also that it can pass through some materials over time.

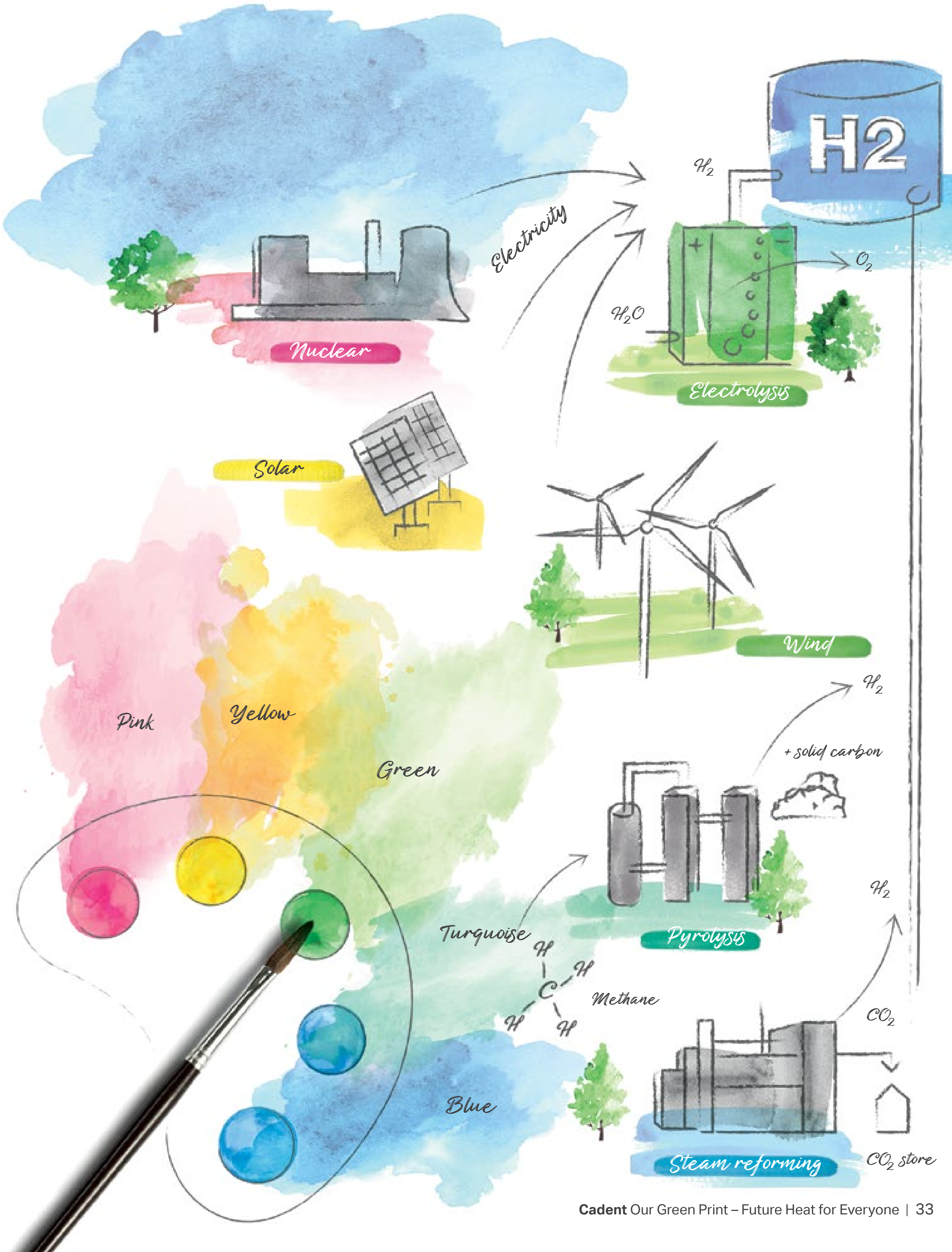
It has a higher energy content than fossil gas but is less dense, meaning that **roughly three times the volume of hydrogen is needed to generate the same amount of energy as fossil gas. Finally, it also combusts differently to fossil gas**. This means that appliances using hydrogen need to be specifically designed to account for this. This means that appliances that use fossil gas today would likely need to be replaced rather than converted.

	Hydrogen	Fossil Gas (Methane)
Chemical formula	H_2	CH_4
Density (kg/m³)	0.0838	0.716
Molecular weight (g/mol)	2.02	16.043
Lower heating value (MJ/kg)	120	50
Higher heating value (MJ/kg)	142	55
Minimum spark ignition energy (mJ)	0.02	0.29
Laminar flame speed (cm/s)	230	42
Flame temperature in air (°C)	2045	1950
Flammability range (%)	4 – 75	5 – 14
Energy per mass (KWH/Kg)	109	13.8
Amount produced globally today (Mtoe)	74Mtoe	3.5 Mtoe (biomethane) 3,986 bcm (natural gas)
Sources	Water, natural gas, coal, biomass, petroleum	Biomass, natural gas, coal, petroleum, livestock emissions, landfill waste, agriculture
Methods of production	Steam Methane Reforming (SMR), Autothermal Reforming (ATR), Electrolysis, Gasification	Hydrogenation of CO_2, Anaerobic Digestion, Gasification
Properties of the gas	Colourless, odourless, tasteless, non-toxic, non-metallic, non-poisonous, invisible flame, low radiant heat, low viscosity, highly combustible, non-corrosive (but can embrittle), most abundant element on earth, lightest molecule in the universe	Colourless, odourless, pale flame, non-toxic, highly flammable, non-corrosive, occurs abundantly in nature, most potent of the greenhouse gases

Low carbon hydrogen production

The colours of hydrogen

Technical



The colours of hydrogen

Cadent supports the UK's 2050 net zero target and believe it will be very important to consumers to have confidence in the low carbon credentials of future hydrogen production methods. **We do not believe continuing to give hydrogen a colour in its description is helpful** in doing that however. Instead it is important that any hydrogen we produce is done to specific carbon standards, backed by a certification schemes that assures consumers of its low carbon content.

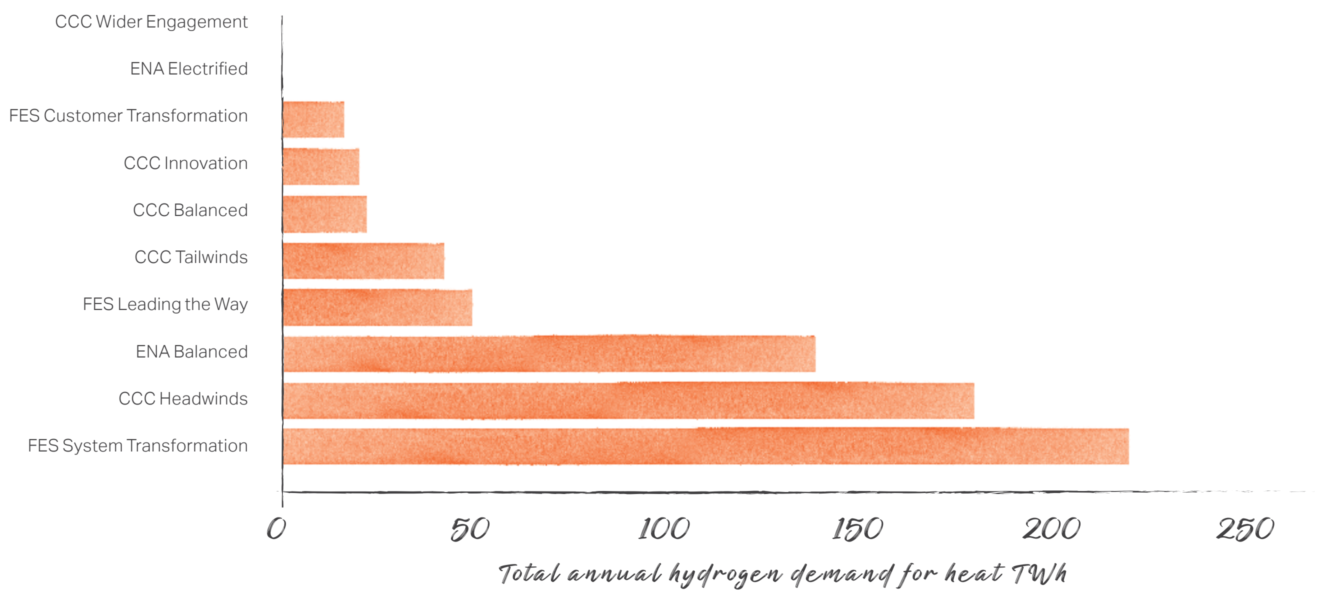
How much hydrogen do we need?
It is becoming more and more likely that **hydrogen will play an important role** in helping us get to net zero in hard to abate sectors such as industry, heavy transport and intermittent power generation. As this paper explores, it is also likely that hydrogen will a role to play in decarbonising home heating.

There have been a range of studies assessing the likely volume of hydrogen we will need for these uses.[27] These studies estimate volume requirements of between 100 TWh and 300 TWh per year, by 2050. National Grid go further and estimate total hydrogen demand of over 500 TWh in one of their three net zero compliant scenarios.[28] To put that in context, it is the equivalent of today's UK annual electricity consumption.

The wide range of estimates on the amount of hydrogen that we might need mean that gas networks like Cadent are planning for a wide range of potential eventualities. Our focus has therefore been on establishing the technical and feasibility aspects of a gas network that can in future enable such use.

Sector	Potential demand in 2050	Comments
Industry	50 – 150 TWh	Hydrogen is the most technically and economically feasible low-carbon feedstock, and source of high-temperature heat, for many industrial processes. This range reflects the potential to also use hydrogen to generate lower temperature heat
Transport	50 – 100 TWh	Hydrogen is expected to have a role in fuelling large vehicles such as HGVs, buses, trains and tankers
Power	50 – 100 TWh	Hydrogen is increasingly seen as a viable low-carbon alternative to fossil gas for peak dispatchable power generation
Buildings	0 – 200 TWh	Hydrogen is one of the leading options for decarbonising heat in buildings, alongside heat pumps and heat networks. the large range here reflects significant uncertainty over hydrogen's role versus the alternatives
Total range	150 TWh – 550 TWh	

Annual hydrogen demand for heating by 2050



Is hydrogen safe?
Hydrogen has many advantages as an energy source, but it also suffers from some negative connotations in the minds of the public. People often associate hydrogen with events such as the Hindenburg disaster and assume it is inherently unsafe – even though they safely use fossil gas today. It is not enough to tell consumers that hydrogen is safe, however. We need to demonstrate that hydrogen for heating will at least **achieve the high safety standards as they have come to expect** from the existing fossil gas network.

Work is underway to demonstrate that hydrogen can do just that, with projects around the country testing hydrogen use under a wide variety of laboratory and real-world conditions. Each of these projects involved the development, submission and approval of initial safety evidence before the trials could commence.

Trials are underway
The first trials to assess the effect of blending hydrogen with fossil gas took place at Keele University[29], and covered the distribution, supply and use of blended hydrogen in residential properties, involving approximately 100 consumers. This trial found no major safety or technical issues. Having satisfied the Health and Safety Executive (HSE) and other authorities of its safety aspects, the next stage will be to proceed with a real-world demonstration of 100% hydrogen in people's homes – something that is now progressing.

This is not the only work underway. Cadent and the wider gas sector are actively leading a broad range of hydrogen-focused projects and programmes, designed to demonstrate safety primarily focused on the following six areas:

- **Home safety:** Is it safe to use in the home?
- **Network safety:** Can it be safely transported in the gas network?
- **Blending:** Can blended hydrogen be used with existing infrastructure and appliances?
- **Household switchover:** How will homes switch over to hydrogen in practice?
- **System operation:** How will gas system operation need to evolve to handle hydrogen?
- **Industrial conversion:** How will industry convert to hydrogen in practice?

The outputs of these projects will be to provide all the technical and safety evidence which the HSE and Government can use to determine whether hydrogen can be considered as a suitable home heating fuel. **The bar for this is rightly high** with conclusive, quantitative evidence needed before the HSE are satisfied that hydrogen is at least as safe as fossil gas.

> "We need to demonstrate that hydrogen for heating will at least achieve the high safety standards as they have come to expect from the existing fossil gas network."

Can we safely blend hydrogen and fossil gas?
Phase One of our HyDeploy project at Keele University, involving approximately 100 consumers, is now complete and has successfully demonstrated how hydrogen blended to 20% by volume with fossil gas in a plastic gas network can operate safely. While this is promising, we will need more complex 'real-world' trials to confirm the safety evidence for blending before it could be rolled out more widely.

Phase Two trials are therefore incorporating a wide variety of pipes and equipment, as well as more customers, including several business and commercial customers. Further research is planned which will follow this with demonstration projects incorporating a broader range of business and commercial customers, running until the end of 2023.

These projects are intended to demonstrate the technical evidence for blending hydrogen at scale from the middle of this decade with the aim of then using the hydrogen production planned in areas of heavy industry such as Aberdeen, Teesside, Humberside and the North West. By way of example, if these demonstration projects are successful, Cadent's HyNet North West project could see more than 500,000 customers in the region receiving blended hydrogen by 2027.

Can hydrogen be safely distributed around a network?
One of the merits of hydrogen in a future energy system is that we can re-use a significant amount of the gas network – a gas network which is already there and that customers have already paid for.

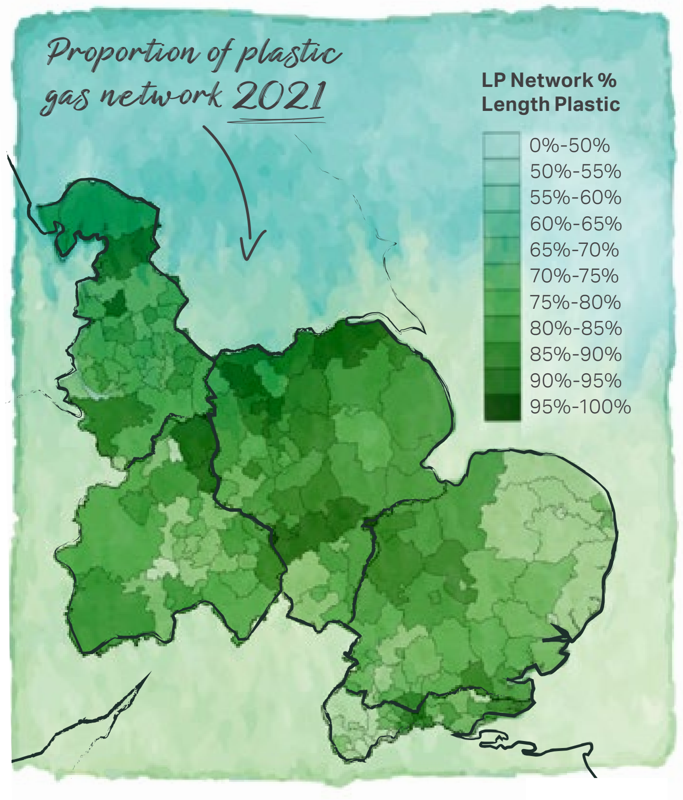
Cadent, like all other gas networks operators, have been replacing old iron mains with new plastic (polyethylene) pipe for the last 40 years. Although the project was originally established to replace ageing cast iron pipework, this work is effectively now making the extensive lower pressure gas network better for carrying hydrogen.

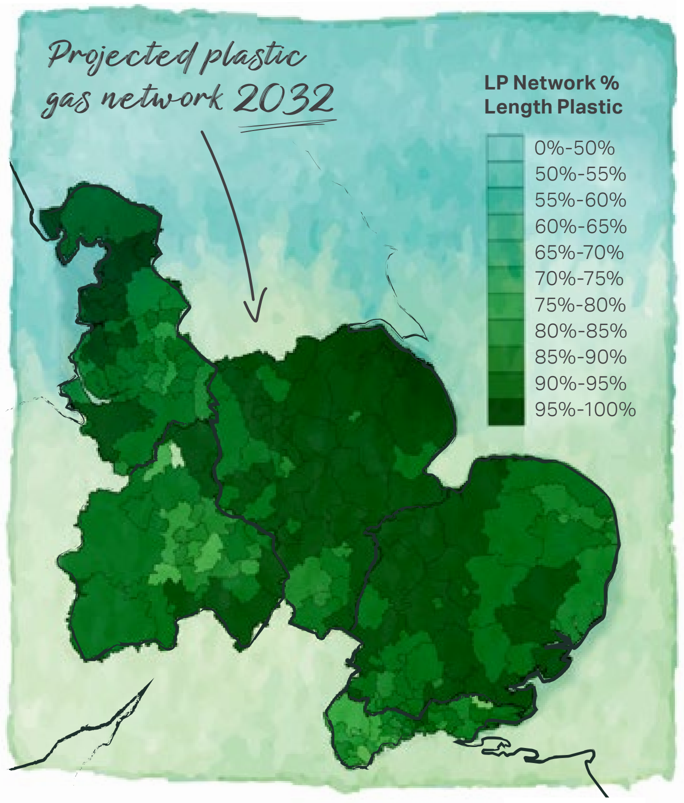
Today approximately 72% of Cadent's overall network has been replaced with plastic. While the proportion converted to date varies by geography, we expect this figure to increase to over 92% by 2032. This is not to say that the gas network needs to be entirely plastic in order to carry hydrogen safely and effectively. Indeed, we are working with the HSE to establish just what mix of materials are compatible with 100% hydrogen across a range of situations.

92% plastic

92% plastic mains by 2032 due to out mains replacement programme

Upgrading the gas network





A network is more than pipes
A network is not just made of pipes, however. There are also assets such as valves and governors that help to safely control the flow of gas. Work is therefore needed to test the compatibility of all these different types of assets and to establish new safe working procedures to operate them both on blends and 100% hydrogen.

We are working closely with colleagues across the industry as part of the H21 project[30] to demonstrate the safety evidence for transporting hydrogen across the gas network right now. This work is detailed, rigorous and in-depth, testing every possible aspect. Phase One has focused on assessing the impacts of any hydrogen leaks and ignition potential from above and below ground assets. Phase Two is currently focusing on establishing new operational procedures for working on hydrogen pipes and assets. Phase Three will be to run a live trial on an existing gas network, starting with around 50 homes in 2022, followed by approximately 600-700 homes in 2023.

Is hydrogen safe to use in the home?
Establishing hydrogen safety in the home has been led by the Department for Business, Energy and Industrial Strategy (BEIS) as part of its Hy4Heat programme.[31] This has so far found that **a comparable safety profile to fossil gas is achievable** if minor mitigatory measures are taken, for example the installation of excess flow valves and flame failure devices on appliances. These mitigations aside, it should be noted that one clear advantage of using hydrogen in the home is that it does not carry the same risk of carbon monoxide poisoning present when burning fossil gas.

The Hy4Heat programme has also provided answers to a number of safety related questions posed at the start of the work, such as will customers be able to see a hydrogen flame (and therefore know if it is burning), will customers be able to smell a hydrogen leak as they can with fossil gas today and will customers have to replace their internal pipework.

500 homes

A series of demonstrations in occupied homes, starting with a small-scale trial of less than 500 homes on a new 100% hydrogen network will be followed by another small-scale project on a repurposed gas network

The impact on the design of consumer appliances
The programme has identified that changing the burner design of cookers and fires eliminates the need for any flame colourant to be added, knowledge which is now being used by manufacturers as they develop hydrogen appliances. The programme has also established that the same odorant used today with fossil gas can be used with hydrogen. Importantly the programme has also demonstrated that hydrogen behaves no differently to fossil gas in internal pipework. In other words, if fossil gas is distributed safely around the home today, hydrogen will be too.

The next steps will be important in developing this safety evidence still further. A series of demonstrations in occupied homes, starting with a small-scale trial of less than 500 homes on a new 100% hydrogen network will be followed by another small-scale project on a repurposed gas network. This will need to be followed by a deployment-scale demonstration showing how the conversion of a whole village or town could occur, involving up to 5,000 homes.

Hydrogen could be coming to you soon
The total of these efforts means that over the coming few years consumers could expect to see a proportion of their gas delivered as hydrogen, without any need to change their appliances or invest in different equipment. It is anticipated that early blends of hydrogen will cost no more than natural gas today, encouraging consumer demand in much the same way that green electricity contracts were sold. Consumers may also come to expect that if their boiler fails during the next decade, they may be able to replace that appliance with a hydrogen-ready equivalent – i.e. a boiler that is able to burn both methane and hydrogen following a simple conversion.

How a conversion to hydrogen might happen

The industry's work on hydrogen to date has largely been focused on the technical and safety aspects of producing and distributing it. However we also need to consider how any transition will happen, where it will happen, when we should start engaging people and how that conversation should be conducted. Importantly, we also need to consider who will be responsible for delivering a town by town transition programme.

Within this, it will be important to ensure that the end-to-end narrative for policy makers shows how it is achievable and will help customers, that customers overall will benefit and that net zero will be achieved in a fair and cost-effective way.

We have not yet articulated how the energy transition will work in the context of hydrogen. In this section we set out what we know today and what we aim to find out through pilots and trials that are in early planning stages. We'll also share a perspective of how hydrogen could be rolled out across the Cadent region, and in what sequence.

Optionality is important
As we discussed in earlier sections, the UK Government has yet to decide just how much hydrogen is required for heating our homes in the future. While there is a general view that electrification will be used wherever appropriate, this is caveated with an acknowledgement that there will be a need for hydrogen and/or hybrid solutions where this is either difficult or uneconomic.

In the CCC's Balanced Scenario there is just 23TWh of hydrogen needed for heat in buildings. However, there isn't sufficiently granular data to yet establish if the majority of this is spread over just the winter months in a wide number of properties as would be needed with hybrids, or in a small number of geographic regions throughout the year as would be required with hydrogen boilers.

The Balanced Pathway implies large scale uptake in heat pumps and energy efficiency retrofits over the next 5 to 10 years. By the time hydrogen is available to deploy at scale we will have good information on the extent to which policy and consumer acceptance has delivered the levels of heat pump and energy efficiency demand that underpin this Pathway. In the meantime, Cadent is working to ensure we have optionality by enabling a network capable of supporting a role for hydrogen.

Setting out 'no regrets' approach
Let's focus on what we do know, and therefore what seems like **a sensible no regrets approach**.

> The future energy system requires hydrogen in order to decarbonise industrial use and there will therefore be hydrogen available in locations **close to industrial clusters** – with the need for hydrogen pipelines and storage nearby.

> There is a merit order of technologies for low carbon home heating and of the options available today electrification is the first option. A regional and national view of the requirements for winter peak and resilience and customer acceptance is required in order to shape and refine this merit order in a world where hydrogen is widely available. It could therefore be likely that a gas grid **is required in most places**.

> The CCC created the Headwinds Pathway to demonstrate what could happen if there was a delay in the proposed roll out of heat-pumps and energy efficiency retrofits. Based on the reasonable observation that UK energy policy has experienced mixed success in delivering intended outcomes that directly affect customers' homes, **it is sensible to retain optionality** and retain a convertible gas network as at least a reasonable option.

> There is a world market developing for hydrogen, with large amounts of money being invested in advancing the technology and bringing costs down. With hydrogen unlikely to be available for heating at scale until at least 2030 it is plausible that the price of hydrogen will be substantially lower by this time. It would be sensible to ensure steps are taken now to **ensure that the UK energy system is set up to make use of hydrogen** should these cost reductions transpire.

> The relative costs of converting and maintaining a gas network for this eventuality **is low in comparison** with other potential contingencies available.

Retaining optionality is therefore a sensible approach. Ensuring we deliver this means making some decisions in the next five years to ensure that the network is ready when needed.

Central to this optionality, based on the CCC's Headwinds Pathway, is enabling a hydrogen network capable of delivering 182 TWh of hydrogen for heat demand by 2050. Planning for this does not imply that it will happen, just that it is plausible enough to prepare for.

How much hydrogen capacity should we plan to build for?
Ensuring there is a resilient and reliable supply of hydrogen is an important selling point for the UK and customers. After all, no one will 'switch' if there is even the possibility that the gas could run out. It will therefore be crucial to ensure that we take the learnings from the development of large volumes of hydrogen production and storage capacity around the planned industrial clusters before town conversions start to happen.

Under the CCC Headwinds Pathway 376 TWh of hydrogen is needed across all use cases by 2050. We estimate that this implies approximately 150 TWh of hydrogen delivered through the network in the Cadent region. When we consider seasonal variability on the volume of gas used year to year, this amount of hydrogen could increase by as much as 20%. While we are not producers of hydrogen, it is important that there is enough hydrogen production capacity either in the UK or through reliable interconnection to meet the demands of consumers. We therefore estimate that optionality would require planning for a hydrogen network capable of delivering between 120 TWh and 180 TWh of hydrogen annually.

It will also be important to create the necessary mechanisms to ensure supply interruptions are minimised and that consumers are protected as a priority. Recent studies[32] have shown the UK has enough on-shore and off-shore storage locations for the volume of hydrogen that could be needed under a Headwinds Pathway. Our estimates, based on extrapolations from the H21 report[33], suggest we might require access to 16 TWh per year of hydrogen storage to meet peak demand in the Cadent region.

"While we are not producers of hydrogen, it is important that there is enough hydrogen production capacity either in the UK or through reliable interconnection to meet the demands of customers."

What do we need to consider as we plan a conversion?
Assuming we need to convert the whole of the existing gas network to hydrogen in order to deliver 120 to 180 TWh per year, we need to map through how a town conversion might happen in practice. In considering how we might deliver a full conversion of our network we will need to consider the following aspects:

> That all homes with a connection to the existing gas network may want the choice of selecting hydrogen as their fuel, even if they may not then select it.
> That we must plan the town conversion to finish earlier than 2050 to ensure that the net zero target and carbon budgets are met.
> That the towns closest to the industrial clusters will receive hydrogen first as hydrogen supplies become available.
> That we must maintain a reliable supply of fossil gas to all homes while managing a transition away from it in adjacent regions.
> That all homes will be offered energy efficient retrofits to reduce the overall demand for energy in the home – regardless of whether their future source of heat is electricity, hydrogen or a combination.
> The low and medium pressure gas pipes will be repurposed for hydrogen, but the intermediate and high-pressure pipes will need to be relayed in order to secure fossil gas supplies for towns while we convert adjacent places.
> The town roll out plan will be synchronised with stepped production and storage increases to ensure there is enough hydrogen for the next stage of the conversion.
> That hydrogen ready appliances will replace new fossil gas only appliances from 2025 to reduce the resource and skills burden on the day of hydrogen conversion.
> That planning for electrical upgrades can happen simultaneously to avoid disruption to the customer.
> That there will likely need to be several conversions happening in tandem to enable national conversion to be delivered.

What might a conversion plan look like?
Based on the previous assumptions, we therefore expect town conversion to be delivered in the following sequential phased approach:

> hydrogen production starts at scale with the industrial clusters;
> short lengths of 100% hydrogen pipelines then start to deliver hydrogen to industrial users within a region;
> storage will be built in parallel to match demand at the scale required. Long-term and short-term stores of hydrogen will be developed in onshore salt caverns and offshore gas fields;
> strategic sections of the existing methane national transmission system will be re-purposed where feasible. Where this is not feasible, a new hydrogen national transmission 'spine' will be built to interconnect different distribution networks, enabling regional conversion and resilience;
> surplus hydrogen from industrial clusters will be blended up to 20% by volume into the current gas grid as a way of providing a stable demand base and immediate decarbonisation benefit; and
> as production and storage is scaled, regional conversion can take place with sections of new transmission main enabling distribution zones of approximately 2.5k properties to be converted at a time.

What is crucial about this planning approach is that it gives a sense of scale and importance to the transition. Decisions around the laying of new mains and hydrogen infrastructure, if they take too long, simply won't enable them to be delivered in time. For example, a plan that delivers full hydrogen conversion would require delivery of the Government's 5GW hydrogen production capacity target by 2030 and well-formed conversion plans from 2025 onwards. This means that early indication of heat policy decisions and specific area plans detailing the role of hydrogen are needed over the next five years.

40 million

Between 1969 and 1977 the UK converted or replaced over 40 million individual gas appliances for over 13 million customers to run on a new fuel – fossil (natural) gas

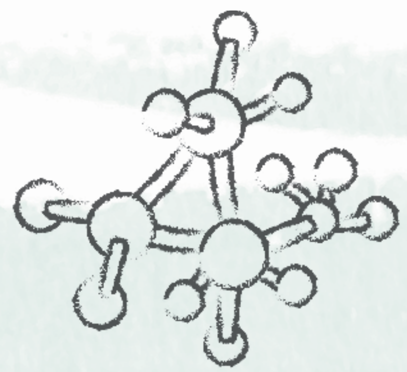
What can we learn from the conversion from town gas?
Until the 1960s, UK fossil gas supplies were manufactured from coal or oil and known as 'town gas'. Then, between 1969 and 1977 the UK converted or replaced over 40 million individual gas appliances for over 13 million customers to run on a new fuel – fossil (natural) gas.

The process was carried out regionally by the twelve area Gas Boards existing at that time, with central co-ordination initially provided by the Gas Council. Regional conversion strategies were determined by the availability of the gas and the relative position of the supply grid.

An emphasis on consumer engagement
Notwithstanding the fact that conversion was offered free of charge, there was initially some customer resistance fuelled by negative media reports. A **public engagement programme** setting out the rationale for the conversion was put together utilising letters, radio talks and video of the conversion works in practice.

A public information campaign supplemented this effort with a leaflet delivered to every home answering key questions. These direct communications started eight months before the conversion of a customer's area and continued right up until the week before in-home work was to be carried out.

Access to people's homes was addressed through the provision of very bold, colourful cards which enabled customers to state when they would be in or where a key would be left. Language barriers within non-English speakers were overcome by publications in foreign languages.



2.3m

By 1971 customers were being converted at a rate of 3,200 per week, and in the peak year 2.3 million households were converted

Impact
By 1971 customers were being converted at a rate of 3,200 per week, and in the peak year 2.3 million households were converted. Fossil gas from the North Sea was cleaner, safer and cheaper than the town gas which preceded it. It contained, for example, far less carbon monoxide. A large-scale move to gas-fired central heating was also facilitated and the total household gas market more than doubled between 1969 and 1977.

There are however important differences to today
Although many would agree that we have done this before and therefore can do it again, there are some significant differences to today that any conversion to green gas in the future will need to take in to account.

The conversion from town gas reduced heat bills and greatly reduced safety risks. Today, the costs of hydrogen are high in comparison to fossil gas. There will need to be a similar compelling customer proposition to the conversion to hydrogen in order to gain public support, and some subsidisation of the cost may be required a for period of time – as has been the case with other technologies such as renewable power.

The energy supply chain is significantly more fragmented today with a larger range of potential interfaces to contend with. This could include shippers, distributers, energy suppliers, appliance manufacturers, meter installers and heating system insurers. **The complexity will add delay and cost.**

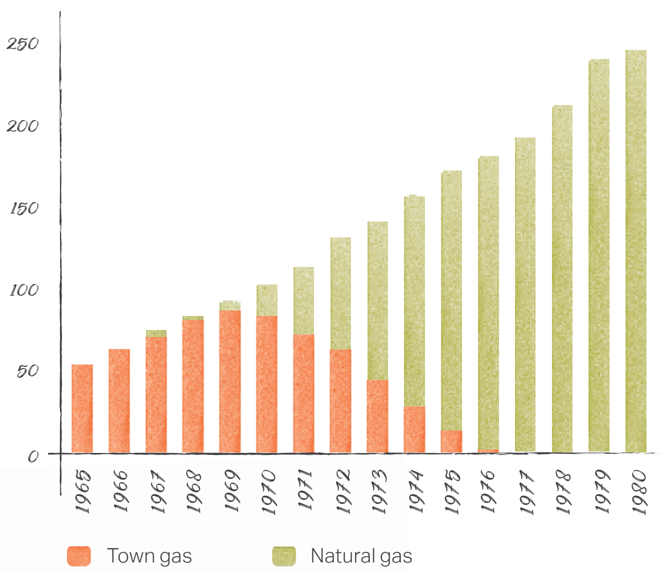
There is a significantly higher population of gas customers today using gas for a wider range of uses. This increases the number of homes potentially requiring a conversion, as well as the number of appliances that would need to be replaced.

Devolution of power to Scotland, Wales, regions and cities means that different geographical areas have far more autonomy than they did at the time of town gas conversion. While this brings important benefits to people across the country, it means any future national programme will greater consideration of how it might be co-ordinated across different areas of authority.

Finally, it is important to note that at the time the public associated town gas with pollution far more clearly than they do today with fossil gas. While there are increasing levels of understanding about climate change and support for actions tackling it, the polluting effects of emissions are far less tangible to the individual than they were in 1969. Consumer engagement on the 'cleaner' aspects of any conversion will need to account for this.

UK household gas consumption 1965–1980

TWh

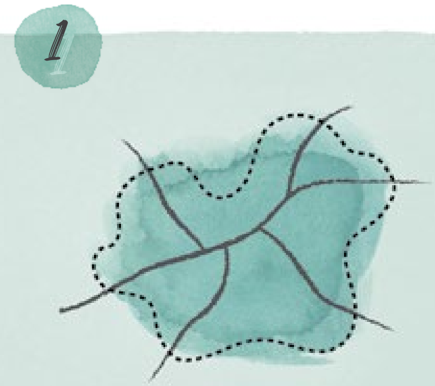


Source: BEIS.

So, what might a hydrogen town conversion look like?

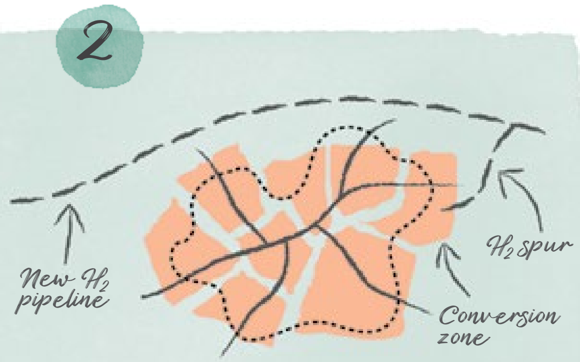
Technical

1



Town to be converted is identified through local planning.

2



Cadent will have planned the route of the new H_2 pipeline and divided the town into conversion zones. Each zone will be connected, whilst the rest stay on fossil gas.

3

We'll talk to homes well ahead of conversion to explain plans, answer questions and discuss options.

4

An engineer will visit to plan your conversion and check for hydrogen-ready appliances and any special circumstances.

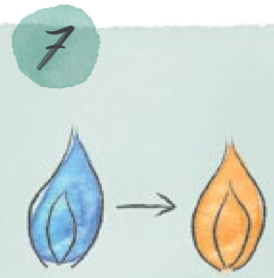
5

Information will be sent advising of the planned conversion period and what to do.

6

Conversion will happen in the summer. Your supply will be isolated and purged. You'll need to be in and we'll provide a gas hob if needed. The day ahead will be explained. Engineers may visit to fit meters and monitors.

7



Your gas flame will change from blue to orange. A follow up care team will be available if any issues, on day or afterwards. New supplier will now bill you for hydrogen.

Section 2

Consumer

Section 2 brings to life consumer wants, needs and expectations – and the implications they create for how we deliver future heat for everyone.

59%
believe fossil gas systems contribute to climate change

32%
proportion of consumers saying they will not change from fossil gas heating systems

c.75%
haven't heard of various low carbon alternatives

What about consumer wants and needs?

Understanding the consumer point of view

The second lens any Green Print needs to consider is that of the consumer, ensuring that we deliver fully considers the impact on both consumers and wider society. Approximately 80% of UK consumers are concerned about climate change according to BEIS, with 51% believing it is either entirely or mainly caused by human activity.[34]

Despite this, consumers are not aware of the impact heating their homes has on carbon emissions and the challenge of net zero. Given there are 22 million homes in the UK today using fossil gas for heat and hot water this is a problem. All these systems will need to be replaced between now and 2050. In doing so we need to be mindful of the scale of the challenge and the level of support that people will need to adapt.

Key points

Climate change

There is growing consumer acceptance both that climate change is real and that it is entirely or mainly caused by human activity.

Alternatives

Yet awareness of the contribution that fossil gas heating systems make and of the low carbon alternatives is low.

Prioritise cost

While sustainability is a growing motivation, consumers are still likely to prioritise cost over it. In the absence of a clear financial incentive for change, engagement is even more important.

Reliability

Consumers also typically prioritise reliability, control and the absence of disruption during any transition.

Trust

Engaging trusted sources of information in the mission, such as tradespeople, will be crucial to success.

Consumer choice

If we are to secure consumer buy-in, ensuring that people feel they have a say will be important. A balance between the need for local area energy plans and consumer choice needs to be found.

The need for consumer engagement

How do we get consumers to want to change? Engaging consumers on the challenge ahead, the need to end fossil gas usage, the alternatives available, their advantages and disadvantages, what the implications are for households and where they can get support to pay for it will be vital. The first step in doing this is understanding what consumer wants, needs and preferences are, what the barriers are to adopting low carbon heating and how we might overcome them.

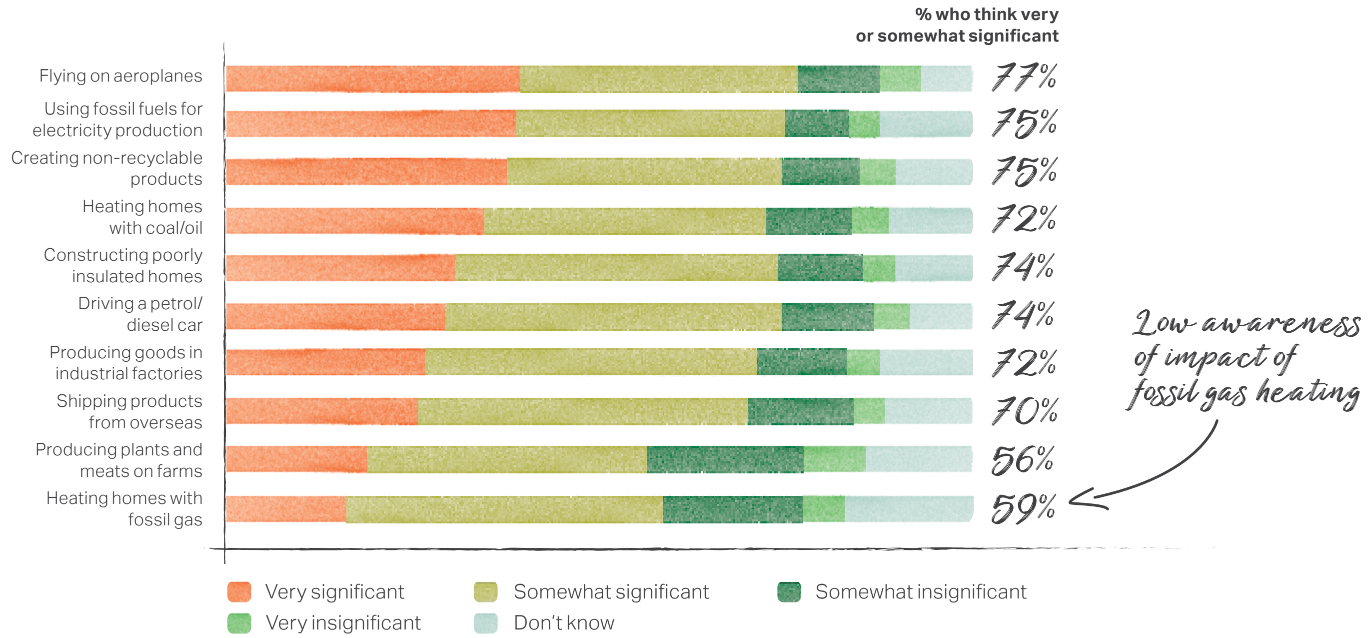
We therefore reviewed existing consumer research literature on the subject to identify key themes[35], and then supplemented this with our own research[36], speaking directly to consumers to understand how they thought about the transition to low carbon energy.

Peoples' awareness of the challenge ahead and the various solutions is low

Whereas flying in an aeroplane, burning coal to generate electricity or failing to recycle are front and centre of peoples' minds when they think about ways in which we contribute to climate change, how we heat our homes does not have the same resonance. There is a disconnect between burning fossil fuels in power stations and burning fossil fuels in homes that needs to be addressed.

Bright Blue's research emphasised this point, finding that although 77% of people agreed that flying on aeroplanes contributed to climate change, **just 59% of people** felt that fossil gas heating systems also contributed.

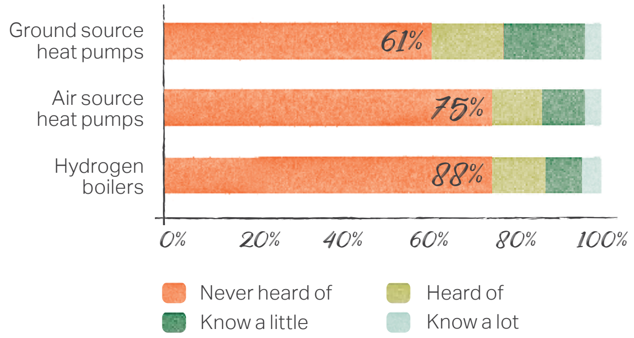
Perceived contribution to climate change



Source: Bright Blue.

The impact of this on peoples' willingness to change is further entrenched by a distinct lack of awareness of and familiarity with alternative low carbon heating solutions. BEIS found that 61% of respondents hadn't heard of ground source heat pumps, 75% hadn't heard of air source heat pumps, 88% and hadn't heard of hydrogen boilers.

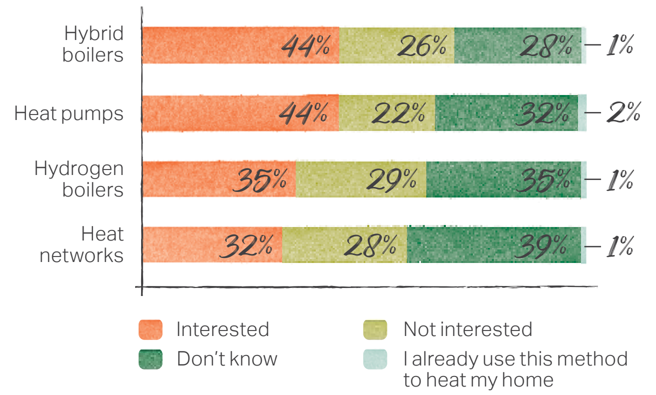
Familiarity with low carbon heat technology



Source: BEIS.

In this context, it is unsurprising that there has been relatively **little interest in the take up of low carbon heating technology** to date – and little sign of that interest increasing in future. Just 44% has 'some interest' in replacing their existing heating system with a low-carbon heat pump or hybrid system when asked by Bright Blue. That number fells to 35% in the case of a hydrogen boiler and 32% in the case of heat networks. A notable number of respondents did not even provide a response.

Interest in low carbon technology



Source: BEIS.

People told us that their interest in switching away from fossil gas boilers to one of these technologies is not high today. While a handful of participants had either done so or were in the process of researching options, their hands were often forced by being 'off the gas grid'. Most people remain relatively unaware of the problems caused by fossil gas boilers, unfamiliar with the low carbon alternatives and were ultimately conditioned to remain on gas.

We therefore wanted to explore what would happen when people were provided with more in-depth information on the climate impact of fossil gas heating systems. When we did this, it revealed a substantial change in thinking. After learning about the contribution fossil gas boilers make to climate change, only 5 out of 45 of our online community respondents agreed with the statement 'I think that people should be able to install and use any heating and hot water system they want to, regardless of environmental impact'. Similarly, 41 out of 45 then agreed with the statement 'I think that heating and hot water systems have a significant impact on sustainability in the UK'.

> **"The one thing I don't like is that I wasn't able to choose this provider because I like to do my own research and make an educated choice. Building off of that, the system wasn't explained a whole lot while moving in so I'm not sure exactly how district heating works other than the entire building uses it."**
>
> North London, 24 years old

Consumer

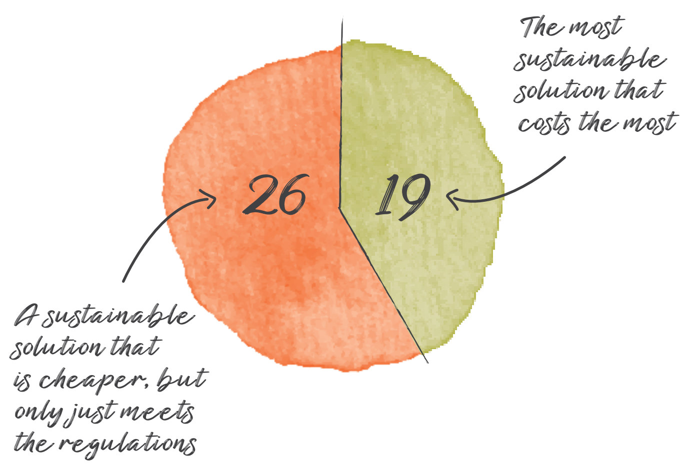
Cost is a greater consideration than sustainability right now

People told us that sustainability is important to them, and this has translated into some day-to-day action for most. For example, 31 out of 45 in the online community said they do their best to make sustainable decisions in their day-to-day life. Only a minority may be at the 'cutting edge' of this, but sustainability is now a consideration for the public in a way that it has never been before.

Notwithstanding this, **sustainability still plays a secondary role to cost** – and usually convenience too. Where being greener corresponded with lower costs, such as in buying a more economical car, consumers consider it a 'no brainer'. If costs are higher however, or a solution is seen as more inconvenient – because for example they have to adapt their behaviour to it – most consumers admitted they would choose the less sustainable option.

Cost is key

Number of votes



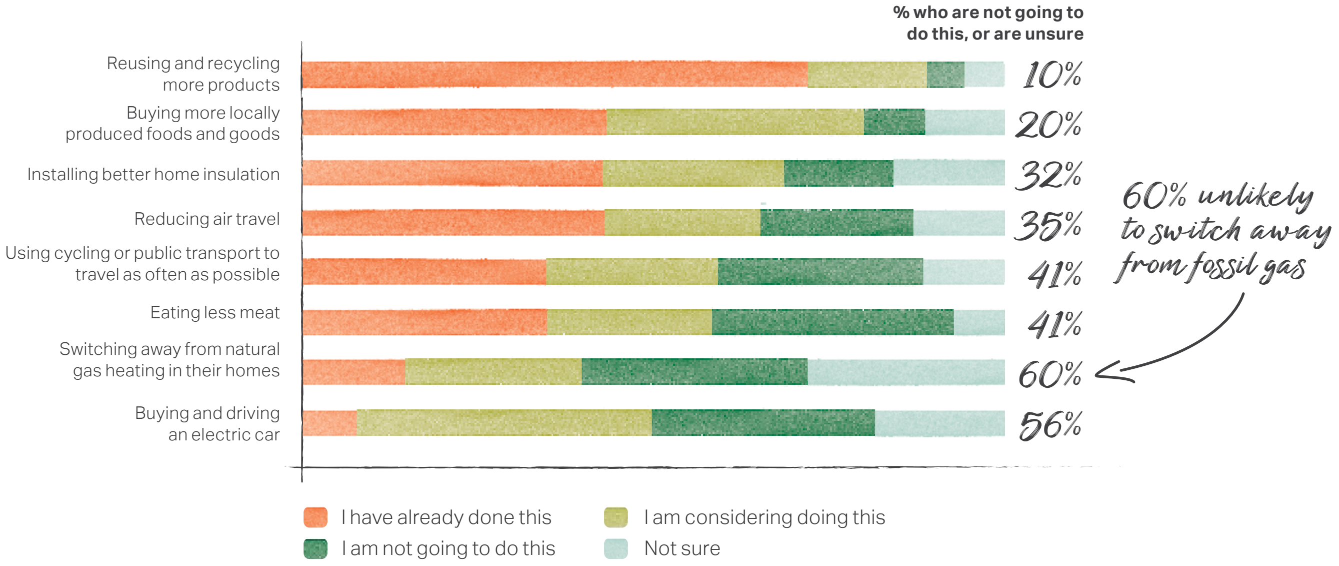
Source: Savanta.

Ofgem's research identified a similar trend, concluding that 'saving money is a key motivator for adopting lower carbon technologies, even among the most 'environmentally conscious'. There is a cohort of consumers who have adopted lower carbon technologies (e.g. electric vehicles) primarily to save money. The environmental benefit is an important, but a secondary consideration'.

We also see this in people's actual purchase decisions. For example, Ofgem found that the most common sustainability behaviours adopted by customers are focused on reducing waste (84% of consumers recycle and 71% are trying to reduce use of single use plastics) as opposed to reducing carbon emissions (5% have an electric or hybrid vehicle and 2% have a heat pump).

Bright Blue echo this, suggesting that although there are high levels of support for taking relatively easy actions such as recycling, there is less support for more costly actions such as replacing a heating system or buying an electric vehicle.

Increased resistance to more costly actions



Reproduced from a graphic created by Bright Blue, with permission.

Fundamentally, while people expect a greener solution will involve a substantial upfront installation cost, they are more willing to accept that if the ongoing running costs will be cheaper than today. Consumers gave us a clear message that cost – and in particular running costs – is the most important factor in their decision making, regardless of whether that system was a new fossil gas boiler or low-carbon alternative. This is an important point when it comes to choices around future heating systems.

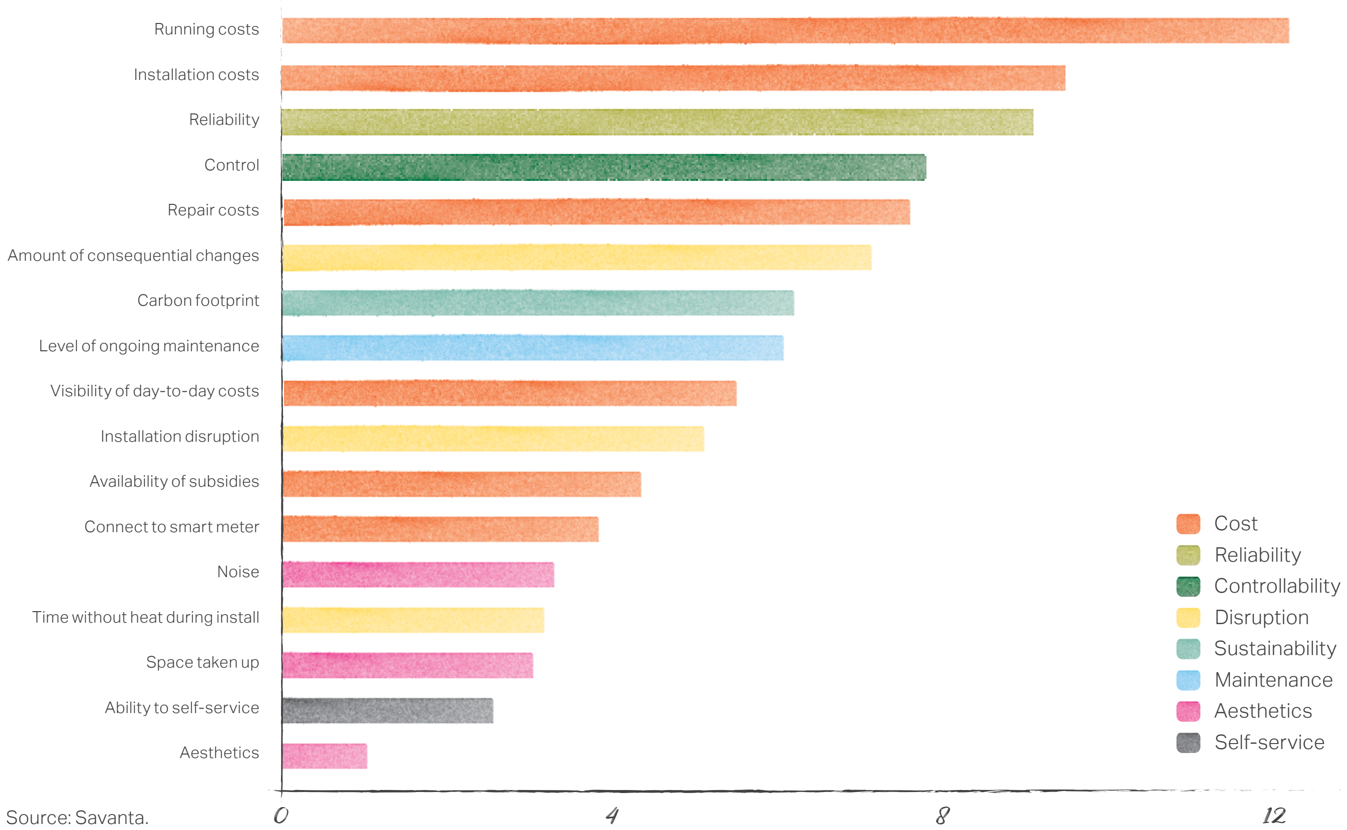
Today, the capital costs of heat pumps are high in comparison to gas boilers, and there is a fear due to the unfamiliarity with the system that it won't perform as planned and result in higher electricity bills as a result.

Similarly, while hydrogen boilers are expected to be low capital costs, the running costs could be high if the hydrogen fuel isn't subsidised in the first instance until production scales and enable hydrogen price reduction.

This creates a serious problem when it comes to the decarbonisation of home heating. Consumers expect 'greener solutions' will involve a substantial upfront installation cost that will be offset by future savings in running costs. All low-carbon heating solutions however are likely to cost more to run than the benchmark today. Furthermore, it is unlikely that we will ever reach a point where consumers will reduce the running costs of their heating system by moving away from fossil gas, without significant subsidy.

In the absence of long-term personal financial benefits, we will need to identify other ways to encourage consumers to take the decision to replace their fossil gas boilers. This must start with a conversation on why a change is needed in the first place, the options available, the practical implications of those options and what financial support will be made available to them and over what period.

Consumer considerations for low carbon heat technology



Source: Savanta.

> **The cost of it. It is an issue with me. I'm a single parent And so, I do have to watch my costs. For me, it's all about how much it's going to cost me monthly. That's my main priority of anything, the cost of it."**
>
> West Midlands, 48 years old

> **I wouldn't go with somebody just because they're greener than the other one. I would go whichever one's cheaper. And that's how I live my life. Being a single parent, it's all about the cheaper option."**
>
> West Midlands, 48 years old

> **I just think expense. I think money. That's all I think, you know. Even though it's not a problem paying for it, but you do go, 'Oh. Got to pay the heating again, yes."**
>
> West Midlands, 41 years old

Consumer

Reliability and control are important considerations

People told us that they consider heating and hot water as a right. These enable people to feel comfortable and safe, especially during the COVID-19 pandemic with people spending more time at home. This was a particularly emotive issue for those in vulnerable situations, including people looking to protect children from the cold, the elderly and those with medical vulnerabilities.

This translated into a need for 'reliability' and 'control', by both feeling warm and heating their homes when they need it and to a temperature that suits them. People told us they felt their circumstances were unique to them and are subject to change, and that their heating and hot water system needs to be responsive to those changes. And while this applied generally, it was a more significant factor for people in fuel poverty.

When National Grid came to a similar conclusion when they looked at this issue, finding that 'over the last few decades, we have grown used to warm and comfortable homes, with heating available instantly and on demand'. Bright Blue went further and found that 'attributes related to control of the system, such as being able to use it at any point (86%), heating up quickly (84%) and ownership (75%), are seen as important'.

"It would just be the reliability to me, I'd want to know that it was definitely going to be reliable and not pack up on us unexpectedly. Having a young family, I just think it is so important that they're able to keep warm and keep clean, you know, it's their right to be like that, so yes, really important."

East of England, 30 years old

"A blanket is fine if you're sat on the sofa but if I couldn't wash in hot water or feel I can walk around my home in relative comfort my lifestyle would change dramatically and stress levels would rise!"

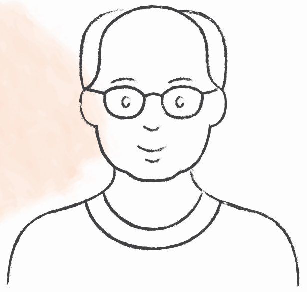
North West, 49 years old

"With the ongoing job insecurity caused by the economic effects of COVID-19 it is likely that our personal finances will be more strained and not less. As such the ongoing running costs and maintenance costs will increase in importance to us as a family. This is also the case for being able to see and control the day to day costs. If money is tighter I will want to take more control of our energy usage and manage it more effectively."

East of England, 40 years old

"I think of heating and hot water as a right and a necessity rather than a luxury. I love the fact that I can decide to have a bath at random times and have the comfort of knowing I will automatically have hot water."

North London, 50 years old



Disruption may be a significant barrier

People told us that when they thought about a future low carbon heating and hot water solution, **their expectation was that it would be similar to a like-for-like switch**, involving minimal disruption and ideally taking under a day and no more than two days. Although this may in part be due to a lack of familiarity with the different low carbon options available to them, people generally expected they would be able to choose a boiler-sized solution that could be housed as it is currently in their property, delivering a similar user-experience.

When we explored which aspects of the transition were important to consumers, they told us that, while minor disruptions were expected, any major disruption would be a barrier, especially if it lasted longer than a couple of days.

This concern was amplified when the system being installed might occupy more space than their current set-up, potentially requiring the additional cost and disruption associated with re-organising or renovating areas such as a kitchen.

The UK Climate Assembly have also called on Government and industry to bear in mind the need to minimise disruption. When disruption was tested by BEIS within some hypothetical transition scenarios, it was also the factor that impacted most on consumer acceptability.

"It's how big the radiators would be and whether I've got to move furniture to accommodate them and that sort of thing... whether we'd need to jiggle furniture about and move the radiators."

West Midlands, 54 years old

Disruption more of a concern for those in smaller properties, or with less disposable income

> I would say the most important factor for me would be no major disruption because when we've had a new boiler installed before it created no end of hassle. Ultimately, it was sorted but it did seem to take a really long time, and now it's just something I associate with hassle."

West Midlands, 46 years old

> I have a specific cupboard that fits the boiler and so if it wouldn't fit in that then I wouldn't do it because there's no other space for it. My flat is really, really small, the kitchen is, like, specifically designed for a really small kitchen and so the boiler is in this tiny cupboard up near the ceiling and yes, it just couldn't go anywhere else."

East of England, 23 years old

Consumers want a say

Consumers notice choice more when they are denied it. Although when someone moves into a home there tends not to be a choice about the heating system they inherit, they generally know they at least have the ability to change to something else in the future if they want to – even if they don't end up doing so. Removing that ability to choose and telling consumers that they will be forced to take a different technology – whatever that may be – is unlikely to land well.

Every home cannot however have a free choice over whether they have a heat pump or hydrogen system. Energy companies need to invest gas and electricity networks well in advance of any future demand in order to make sure their systems are ready and available when needed. This will necessitate the development of energy plans – either local or regional – that will limit choice. **Some curtailment of choice is therefore inevitable.**

From a consumer point of view, the key will therefore be ensuring that they have the ability to engage with the development of local or regional energy plans. The UK Climate Assembly emphasised this, calling for a policy in which 'local authorities and other local organisations are able to choose solutions suited to their local areas, and householders can pick the options best for them'. 94% of the assembly members 'strongly agreed' or 'agreed' that 'people in different parts of the country should be offered different solutions to zero carbon heating'.

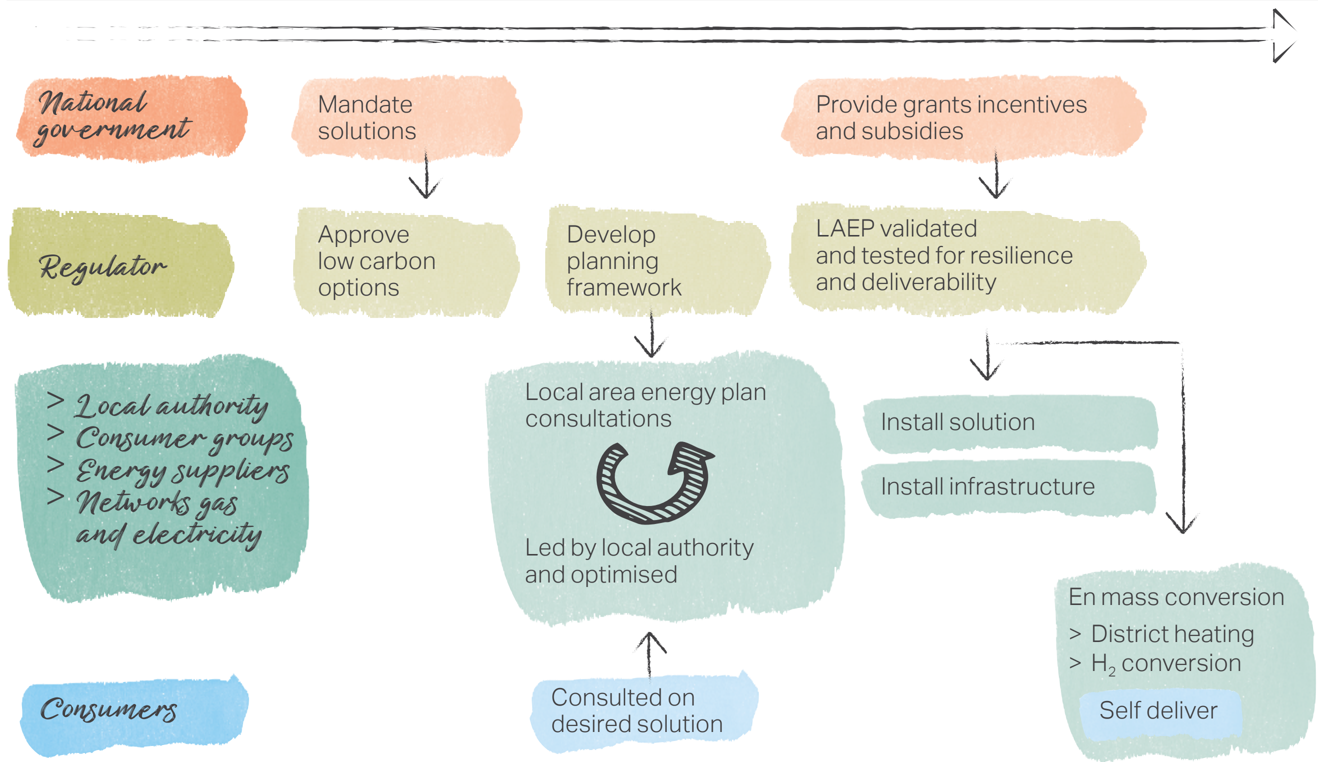
Balancing the need for planning and the need for choice

This finding does not necessarily conflict with the idea of regional or local area energy plans. Government could for example set out a high-level strategy requiring regional and local authorities to decarbonise heat in their areas by 2050. These authorities could then determine a range of technology options that satisfy that obligation in a way in which suits the specific characteristics of that area, and then work with energy companies and consumers alike to deliver it.

People told us that they felt their circumstances were unique to them. This was particularly true for vulnerable groups where heating and hot water can provide both physical and psychological comfort. Those with a medical vulnerability felt that heating helped appease symptoms offered comfort on difficult days. Those with young children regarded the provision of heat as a parental duty.

This belief in unique circumstances translated into a desire to have an input in to any decision over which low-carbon technology they adopted. Unless there was a clear and identifiable benefit to society from the removal of choice, a **'one size fits all' approach would be unlikely to enjoy popular support.**

The ideal journey from the customer perspective



Citizens Advice came to similar conclusions, noting that 'some consumers hate it [a mandate] on principle – they generally did not like the idea of being forced to do something'. They went on to conclude that 'there should be some level of choice. People feel that more than one low carbon option should be available, with options available at different price points to suit people's homes and budgets'.

Bright Blue similarly found that only a minority of people supported a mandate and that there was more support for financial incentives. Specifically they found that 'people marginally prefer policy approaches which use financial incentives to encourage behavioural choices that lead to fewer emissions, rather than laws and regulations that discourage or punish behaviours that lead to more emissions for both individuals (49% and 34% respectively) and businesses (45% and 38% respectively)'.

> We are a family of little income and no savings, so making a decision that would include a large initial outlay is something that really takes a lot of thought and worry if it turns out to be a bad decision."

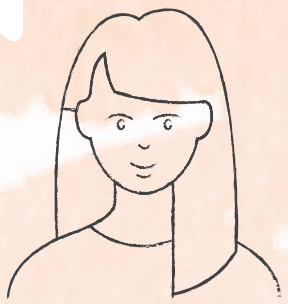
North London, 23 years old

> I live with two other housemates so any new heating and hot water system would have to be a collective decision."

North London, 23 years old

> Space is very important to me because I live in a tiny two bed flat."

East Anglia, 37 years old



Consumer

The vulnerable and fuel poor have specific needs

It is important to realise consumers are not a homogeneous mass but **a collection of individuals** instead, each with their own wants, needs and preferences. Those who find themselves in vulnerable circumstances or in fuel poverty may have specific needs that differ from the rest of the population for example. While these are often translated as a focus on minimising cost, the reality is more nuanced.

Yes, cost is a factor for these consumers. Many stressed the ability to monitor and control daily spending as being more important than the need to minimise costs, however. Many have experienced anxiety at receiving high quarterly or even annual bills and are keen to avoid this occurring again by short-term budgeting and monitoring usage. Their priority is therefore to achieve predictability and controllability of costs.

Those in vulnerable circumstances or fuel poverty often told us of the importance heating and hot water had in providing both physical and psychological comfort. For those with a medical vulnerability, it can appease symptoms and offer comfort on difficult days. Similarly, the absence of heating and hot water would have a greater impact where different vulnerabilities are compounding each other. Vulnerability often translates to more time spent in the home and unique lifestyles such as very frequent handwashing and bathing, emphasising the importance of controllability to this group.

> **"Heating is costly, expensive. But, yes, I mean, it's something you have to have, isn't it, really, it's like a basic need, so even though it is, costly and, you know, if you need to put it on, then you need to do it, don't you, really."**
>
> West Midlands, 51 years old

Consumers want advice from trusted sources

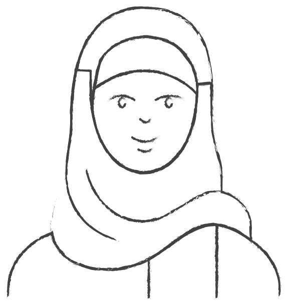
People wanted a choice about the low carbon heat and hot water technology that was installed. However they also knew they lacked the knowledge to make that choice independently, and therefore wanted access to impartial information with which to make that decision.

People told us that they regarded groups like Energy Savings Trust and Citizen's Advice as 'trusted' sources of information. **Local tradespeople were the most trusted of all** however, resulting from a perceived ability to provide impartial advice. People also told us that they wanted local Government and a 'consortium' of companies from the industry to be involved to bring their expertise to bear.

Our findings here contrast with other research in this area. BEIS, for example, concluded that 'non-Governmental organisations were the most commonly selected trusted source, followed by a Government-backed advice service, which in turn was followed by national Government, or a tradesperson or professional'. Instead, people told us that they placed Government below groups such tradespeople. Citizens Advice's finding supported this point, citing 'installers' and 'more knowledgeable personal contacts' as trusted sources of advice.

> **"We have a brilliant friend who is a brilliant plumber, so I would go to him for advice... I trust my plumber and heating engineer 100%! He is absolutely brilliant and came up with cost effective ways for our home before we moved in and went with his recommendation."**
>
> **North West London, 33 years old**

> **"I suffer from an under active thyroid so am often quite cold. We often put the heating on as it makes us nice and comfy. Being cold makes us miserable. There is nothing I like more than having a hot bath at the end of the day."**
>
> **North London, 35 years old**



Homeowners and renters place different weight on these considerations

While the considerations above were generally true for the consumers we spoke to, we found differences in the weighting placed on them depending on whether respondents owned or rented their home. Specifically, we found that:

- **Cost:** Homeowners are more likely to prioritise cost of installation, while renters are more likely to consider visibility and control of day-to-day costs to be more important;
- **Reliability:** Homeowners are more likely to prioritise reliability, while renters are less likely;
- **Controllability:** Renters are more likely to prioritise closely controlling the temperature of their home, while homeowners are less likely; and
- **Disruption:** Not having to make additional changes to the property (e.g. more insulation or larger radiators) is more important to homeowners, and less important to renters.

Ofgem reached similar conclusions, finding that 'for some consumers, the barriers to adoption are related to their circumstances. For example, those renting their homes often feel unable to install low carbon technologies either because they don't want to spend money on something they don't own or because they don't believe the landlord would allow it or wouldn't spend the money on upgrading the property'.

> **"Asking for your landlord to pay two, three or four grand for a new boiler might be stretching the point a bit."**
>
> West Midlands, 52 years old

What does this all tell us?

In the absence of a clear financial incentive to make the transition there is need for effective consumer engagement on the challenge ahead, the options available, the practical implications of each and where people can access the help and support to make the right decision.

This means that a key part of any Green Print needs to start with a clearer articulation of fossil gas being part of the problem, joined with a clear and evidence-based description of the technical and economic characteristics of the key low carbon alternatives – heat pumps, heat networks and hydrogen boilers.

This engagement cannot be rooted in what either Government or the energy industry want people to hear, but rather start from an acknowledgement of what consumers need to hear. And here the research from ourselves and others agree that we need to directly address key issues such as cost, reliability, control and disruption.

Some of these messages will be difficult. The installation of all low-carbon technologies will create disruption for many. All solutions are likely to cost more.

Tradespeople will need to be involved as partners in this process. We will also need to ensure that engagement – and policy design – reflects the differences between the wants and needs of those who own and rent their home.

Planning and co-ordination of decarbonisation will be needed at the regional and local level, but this needs to be balanced with personal choice. This is best achieved by giving consumers a voice in the development of those plans, and by ensuring they can have a 'menu' of options to select from within an area-based framework.

If we fail to get this right, we will fail to gain public support – and that means we will risk failing to make the transition off fossil gas.

Section 3

Economic

Section 3 discusses the economics behind decarbonising home heating, the areas where investment will be needed and how we might deliver all this at best value.

£8bn

per annum estimated additional cost of fully electrified pathway versus balanced pathway

£7.5k

average cost of a heat pump installation today, without any building upgrades

£30-£60/MWh

estimated production cost range for blue hydrogen today

Economic

How much is this going to cost?

Finding the right balance of technologies

The transition will need investment

It is sometimes said that economics is a dismal science – and it is true that economics is often reduced to a financial cost benefit assessment, assuming a 'rational' economic person exists, without full consideration of what economists would call externalities. One such externality in the case of the heating transition is of course the disruption (and effort) caused to people in changing their heating systems.

This is not factored onto the extensive economic modelling that has been done to date – and of course is a subject we touched on earlier. So, in this section while we refer to economics this is very much through a narrow lens, which of course we would argue a Green Print for heat needs to be broader in nature – reflecting the technical and consumer aspects of the change also.

Key points

Economics

The economics of decarbonising home heating is complicated and determining the most economic pathway depends on a small number of key variables, in particular: the cost of energy production; the cost of infrastructure, including the energy networks; the capital and running costs of new equipment in consumers' homes; and the costs of a seasonally resilient system.

Estimated

It is far too early to say in detail what these costs will be. Instead, we can work with a series of estimates which give us a reasonable range of likely costs for different approaches.

Up-front costs

Broadly speaking, a scenario with high heat pump deployment will have higher system and up-front customer costs, but lower running costs. A scenario with high hydrogen boiler deployment will have lower system and up-front customer costs, but higher running costs.

Balanced approach

In the absence of any non-economic factors such as consumer preference, it is possible to construct a scenario where either heat pumps or hydrogen are the primary low carbon solution. Most studies to date find that a balanced approach incorporating both technologies are optimal.

Optimal

Optionality is therefore crucial, deploying heat pumps now where they make sense while progressing development of hydrogen at the same time. This will enable us to adopt the most optimal approach as data becomes more certain.

Learning by doing

This approach also enables 'learning by doing' across a range of technologies that provides essential evidence points to the economic debate.

The economics of decarbonising heat will depend on the nature of the system, or systems, we build to deliver low-carbon heat and hot water to customers. The economic evaluation of the costs to decarbonise heat are complex by nature because they include different energy sources and vectors, infrastructure, in-home technologies and a requirement to deliver cost effectively to consumers to meet all seasonal needs now and in the future.

One thing is certain however: regardless of which technology choices we make, decarbonising heat is going to require significant investment. The CCC estimate that the overall **investment required for homes could be £250bn** between now and 2050.

The investment to support electrification
In general terms, a system largely built on the electrification of heat will require investment in additional renewable electricity production capacity to meet peak winter heat demand, a significant investment in electric network capacity and – at the household level – investment in new heating systems such as heat pumps, plus any associated improvements to heat distribution systems and energy efficiency to make them work effectively. Consumers will also need to pay for the electricity they then use to provide heat and hot water.

The investment to support hydrogen
A system built largely on hydrogen would require either using spare or dedicated renewable capacity to produce hydrogen through new electrolyser assets, and/or the new CCUS infrastructure necessary to produce and store the CO_2 from blue hydrogen. Investments would be required to upgrade to gas network assets and build hydrogen storage, and then install hydrogen appliances and meters in consumers' homes. Consumers will then need to pay for the hydrogen to fuel these appliances.

We are likely to see a mix of technologies
The costs of transitioning to either full electrification or full hydrogen are likely to be prohibitive. This is because both scenarios create extremes which must be paid for, such as managing peak winter demand (electricity) or high levels of new storage infrastructure (hydrogen).

Whilst more work is needed on establishing the relationships of key variables driving the optimal mix, we know enough today to say a more likely scenario will emerge – one where there is **some electrification and some hydrogen**. Calculating the economics of decarbonising heat is therefore a function of what technology mix we will see and the consequential implications of that for required investment in electricity and hydrogen systems. Here, a hybrid system may offer advantages – for example in avoiding some of the extreme costs for decarbonising the hardest to abate properties, or limiting the electrical capacity build out necessary simply to meet 'one in twenty year' peak demand events.

Several studies have already been written examining the costs of different pathways. While direct comparison between the reports is difficult because of differences in their scope and methodology, they are directionally useful in that they compare the economics of different decarbonisation options and highlight where the greatest uncertainties lie.

Previous studies

Element Energy, 2018[37]
In their 'Cost Analysis of Future Heat Infrastructure' report for the National Infrastructure Commission, Element Energy compared pathways focused on heat pumps, electric resistive heating, and a hybrid solution including green gas and hydrogen. They found that all pathways were between £120bn to £300bn more expensive overall than the status quo, with homes in 2050 paying £100 to £300 more per year for their heating.

Element Energy 2018	Electrification Heat Pumps	Electrification Direct	Hybrid with Green Gas	Hydrogen
Achievable level of heat decarbonisation at maximum deployment $MtCO_2$	5 – 10	10 – 15	15 – 20	20 – 25
Additional cost £bn	270	190	210	130
Annualised costs in 2050 Capital £bn	21	5	15	8
Annualised costs in 2050 Opex £bn	19	33	25	28
Uncertainties	Heat pump unit cost, requirement for energy efficiency retrofit, grid reinforcement cost	Electricity fuel cost, grid reinforcement cost, heating system unit cost	Heat pump unit cost, actual emissions reduction strongly dependent on consumer behaviour, potential contribution of green gas	Safety case, in-building retrofit cost, consumer acceptability, readiness and cost of CCS

Full electrification solutions led to an additional peak electricity demand of at least 45 GW, and that the need to distribute this electricity would require major infrastructure upgrades, with an estimated £20bn needed for electricity network reinforcements and over £200bn needed overall for installing energy efficiency measures and heat pumps in consumers' homes.

Their conclusion was that re-purposing the gas grid to deliver low carbon hydrogen was the lowest cost option under most scenarios studied, but that this option also carried the most uncertainty as it relied upon the delivery and scale up of a resilient hydrogen and CCUS infrastructure. Notwithstanding this, the report also highlighted that **a mix of technologies would eventually be needed** with regions having an important role in defining that mix, and that the suitability to individual buildings would likely be the determining factor.

Imperial College, 2018[38]
In 2018 Imperial College, on behalf of the CCC, published their own review of heat decarbonisation pathways. These included pathways focused on low-carbon hydrogen, the electrification of heat supported by low-carbon power generation and a hybrid solution where the bulk of heat demand was electrified with peaks met by hydrogen.

Imperial College explored key challenges and uncertainties including implications for infrastructure investment, and how interactions between systems could increase benefits and the potential trade-offs to be made. Like the Element Energy report, this review assumed the centralised production of blue and green hydrogen as the default technology for hydrogen production. Unlike the previous report though, this review did not include any costs associated with the improvement of energy efficiency of buildings, simply assuming they took place.

Imperial College concluded a full hydrogen pathway was the costliest due to the cost of hydrogen production and storage needed to support this – some £122bn per year. A hybrid pathway including both hydrogen and electricity was the least-cost decarbonisation pathway totaling £88bn per year.

Helpfully Imperial College identified the key variables that pathways were most sensitive too, specifically heat pump efficiency, electricity network investments needed to meet peak winter heat demand, the cost of hydrogen production and storage and the capital cost of heat pumps, home retrofits and hydrogen boilers.

Total system cost	£bn/yr
Electrified	122
Balanced (hybrid)	109

Navigant 2019[39]
Navigant's report for the Energy Networks Association reviewed the differences between the total costs of a largely electrified pathway and a balanced pathway that incorporated hydrogen to optimise and reduce electricity system costs. In contrast to other reports on the topic, Navigant did not solely focus on the decarbonisation of heat but on the wider energy system.

Navigant's conclusion was that **a balanced pathway could save £13bn per year**, largely driven by the differences between capital costs for heat pumps and hydrogen heating in buildings, the necessary reinforcement to the electricity network to meet peak winter heat demand and the additional power generation capacity required in the electrified scenario.

Aurora 2020[40]
Aurora's 'Hydrogen for Net Zero Great Britain' report explored the role of hydrogen in a largely electrified net zero system. This report concluded that although hydrogen related pathways require investment in the production, transmission and distribution of hydrogen, the costs associated with this are more than off-set by the reduced spending on power subsidies, electricity reinforcement and capacity.

In reaching these conclusions, Aurora presented different pathways involving no hydrogen (0 TWh), low volumes of hydrogen (200 TWh a year) and high volumes of hydrogen (500 TWh a year) by 2050. In both the low and high hydrogen scenarios a proportion of hydrogen was used for domestic heating (187 TWh and 280 TWh respectively). Their report highlighted that hydrogen significantly reduces the power sectors requirement for flexibility during the winter months.

Total system cost	£bn/yr
No H_2	455
Low H_2	457
High H_2	464

Aurora did also conclude that the differences in investment in the energy system between scenarios is relatively minor and that small changes in key variables such as carbon prices or technology costs could easily change the cost ranking. The also suggest that with no obviously optimal pathway, the importance of second order benefits such as consumer acceptance and technology exports would be key deciding factors.

The key variables determining the overall cost

These four reports reach different conclusions about the total cost of decarbonising heat, but they agree to greater or lesser extent that there are circumstances where electricity and hydrogen combine to provide the optimal system.

The four reports also agree that while these outcomes have a degree of uncertainty, the optimal mix of electricity and hydrogen will depend on several key variables, in particular:

- > the **cost of energy production** for electricity and hydrogen;
- > the **cost of infrastructure** to support delivery of the required hydrogen and electricity;
- > the **capital costs of home heating technologies**; and
- > the **costs of running home heating technologies.**

Taken together, they imply that hydrogen may have a role in helping decarbonise hard to electrify buildings, reducing winter peak heat demand requirements on the electricity network, acting as a flexible store of excess energy produced by renewable power generation and providing system resilience through the provision of peaking power generation plant.

Electricity and hydrogen systems are set to be intertwined

As we have discussed, the costs of producing the low carbon energy required to provide heat and hot water to our homes in future will not be determined by the cost of fossil gas but the cost of electricity and hydrogen instead. And as these reports highlight, the likelihood is that the overall cost of energy will be determined by a mix of the two.

The calculation here is complex, and not simply a function of the costs of producing hydrogen plus the costs of producing electricity. In a future energy system, electricity and hydrogen systems are likely to be intertwined. The electrolysers used to produce green hydrogen for example will take renewable energy as its feedstock, and the associated cost of that green hydrogen will therefore depend in part on the time of day, the time of year and the other sources of demand on the electricity network at the time. Hydrogen produced from electricity at times of excess renewable supply will therefore be considerably cheaper than that produced during times of excess demand.[41]

The extent to which excess renewables set the cost of green hydrogen production is in part dependent on the extent to which hydrogen is used to meet future heat demand. In a system where hydrogen meets only a small part of demand it may be more feasible to deliver a material share of that from excess renewable generation. If hydrogen plays a far larger role, dedicated renewable generation may be needed for its production, changing the overall cost of the hydrogen produced.

Hydrogen costs will depend on how it is produced

Calculating the cost of any hydrogen used in the mix will also depend on the technology used to produce it. Blue hydrogen costs will be primarily dependent on the capital cost of the steam methane reformation (SMR) plant, the delivered cost of the fossil gas feedstock and the costs of the associated CCUS infrastructure. Current wholesale cost estimates are between £30–£60/MWh[42] with little expectation of significant cost reductions over the next 30 years.

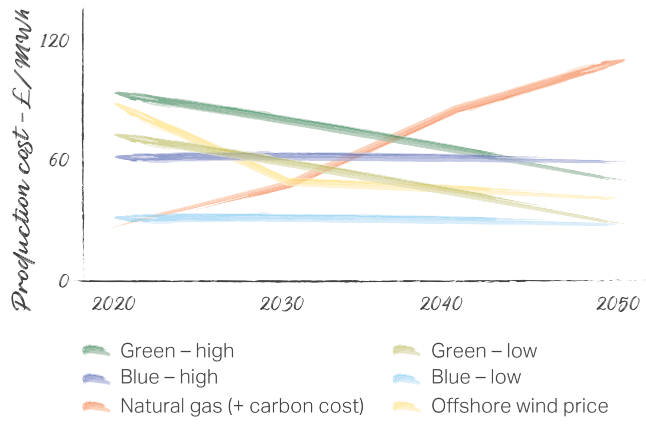
Conversely the costs of any green hydrogen used in the mix will broadly be a function of the capital costs of the electrolysers, any water purification required and the price or cost renewable power used in the process. Today, green hydrogen wholesale costs at scale in the UK are estimated to be £70–£90/MWh, substantially above those of blue hydrogen – but these costs are expected to fall over time.

£30-£50/MWh

Technology innovation, scale benefits and the reducing cost of renewables are expected to see the total wholesale cost of producing green hydrogen in the UK fall to £30-£50/MWh by 2050

This will predominantly be driven by the potential of realising lower electrolyser capital costs as the technology is optimised and scaled. In most assessments technology costs for green hydrogen are assigned similar learning rates and cost reductions to that experienced by the wind sector. Technology innovation, scale benefits and the reducing cost of renewables are expected to see the total wholesale cost of producing green hydrogen in the UK fall to £30-50/MWh[43] by 2050.

Estimated future hydrogen costs



Sources: the CCC, Navigant, Aurora, ENA, ORE Catapult and KPMG.

Green hydrogen is expected to win out over blue

Although the future cost trajectories remain uncertain, many analysts expect green hydrogen could become the cheapest way to produce low carbon hydrogen between 2030 and 2040. It is therefore important to understand that the optimal mix of electricity and hydrogen in providing low carbon heat and hot water – and therefore the overall costs of energy production – could also change over time, driven by (i) reductions in the cost of hydrogen production costs and (ii) shifts in the method of producing hydrogen, from blue to green.

Electricity prices will depend on the future 'merit order'

The cost of any electricity used to produce low carbon heat will be determined by the market, which sets the wholesale price by using a 'merit order' to dictate which producers will deliver electricity to the grid by ranking them in ascending order of price together with the amount generated. This then determines the order in which sources are brought onto the system. The last source of generation brought on to the system to satisfy demand sets the wholesale price paid for all generation – including that supplied for heat.

So while an increasing amount of electricity generation will be met by wind and solar generation producing electricity at very low marginal cost, the overall wholesale price of electricity will continue to be set by the last producer in the merit order. This is generally a gas power station today – something that most analysts believe will continue to be the case even in a future electricity market more heavily dominated by renewable energy.

Projected electricity prices projected to remain much as today

This means that currently wholesale electricity costs are typically in the range of £40/MWh to £60/MWh, with BEIS projections suggesting this may largely continue to be the case moving forward, with the average cost increasing slightly from around £50/MWh today to £60/MWh in 2050.[44]

Within this range however there will be price volatility, and in a system where most heat is electrified – and the amount of intermittent renewable capacity is therefore greater – there **may be higher levels of volatility** than in more balanced systems incorporating hydrogen.

Volatility is important

Price volatility is created by swings in the supply and demand for electricity, and this can happen both within the same day or between seasons. For example, consumers are most likely to demand heat in the morning and evening, periods which coincide with other peaks in demand as the sun goes down and people turn on lights or switch on televisions. In other words, consumers may be demanding heat at precisely the times when existing electricity demand peaks, and when renewable power generation is lower.

Economic

"Some of this volatility could be mitigated by building additional flexibility into the system, either from assets such as batteries or by enabling consumers to shift when they demand electricity."

Some of this volatility could be mitigated by building additional flexibility into the system, either from assets such as batteries or by enabling consumers to shift when they demand electricity. For example, the CCC speculate heat pump consumers will be able to 'pre-heat' their homes during the afternoon, before the evening peak and before any peak in prices. The extent to which same day price volatility impacts the cost of low carbon heat is therefore somewhat dependent not just on the share of electricity in the mix but also the extent to which we can successfully deploy both energy efficiency and flexibility solutions.

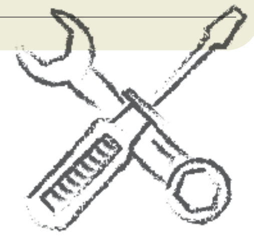
Seasonal volatility is also important as we can expect periods of low solar and low wind generation that last weeks and not days. Such periods are also more likely to occur in the winter months when consumers most need heat.[66] Although flexible assets such as batteries can provide some back-up, and consumers may be able to shift when they consume energy, these are only likely to help for short periods of time, typically no more than a day. Such dark windless periods are therefore likely to lead to higher prices, particularly when they correlate with periods of high heat demand such as in the winter.

This cost spike will be more pronounced in a future system where electricity meets most heat demand, and therefore the amount of intermittent renewable capacity we need is greater. Storing energy as hydrogen to manage these peaks is one option under consideration.

"The overall cost of heat in the future will also be dependent on the costs of moving the energy from where it is produced to where it is consumed, and these costs are likely to be very different depending on the overall share of hydrogen and electricity in the final mix."

As we have already explored, much of the investment needed to make the gas network ready to safely transport hydrogen has already been made. There would however be **material additional investment required** if it is to play a meaningful future role in the decarbonisation of heat. There are several factors that contribute to this.

- **Division of the network:** Equipment such as valves and governors affect how gas moves around the network and converting the network to hydrogen will require more of these to be installed to enable the current network to be divided up into distinct sections, allowing fossil gas to remain in use for some while others are converted to hydrogen. Gas networks will also need to construct new sections of hydrogen transmission pipelines (the larger pipes and pressures) to transport large volumes of hydrogen from the source of production to towns and cities. This is needed to continue to supply fossil gas to consumers while others are converted to hydrogen.
- **Hydrogen storage:** Hydrogen does not compress as readily as fossil gas and so there will be differences in how a future gas network will store energy. The system uses something called 'line pack' today where the network is pressurised overnight to enable peak amounts of gas to be delivered when needed. Line pack will not work in the same way within a hydrogen network and some investment will therefore be needed to develop hydrogen storage capable of ensuring a reliable supply.
- **Maintenance:** The total cost maintaining the gas distribution network in each area is insensitive to the volume going through it. Given expected energy efficiency, the network's capacity to carry energy in the form of hydrogen should be comparable with its capacity to deliver fossil gas today. In other words, the future cost to maintain a hydrogen distribution network should be similar, in real terms, to the cost of fossil gas distribution today.



£8bn

Additional cost per annum of a fully electrified scenario compared to a balanced scenario (Vivid Economics/Imperial College)

The cost of infrastructure
The overall cost of heat in the future will also be dependent on the costs of moving the energy from where it is produced to where it is consumed, and these costs are likely to be very different depending on the overall share of hydrogen and electricity in the final mix. Meeting most future heat demand with hydrogen will mean most of these costs will come from the work needed to develop and re-purpose the existing gas network. Meeting most of that demand with electricity will mean most of these costs will come from the work needed to reinforce the electricity network.

Converting the gas network to handle hydrogen will require significant investment
The precise extent of these costs is not known at this stage but is being established as work progresses. Taken together they are likely to be material, with Element Energy estimating that they could require overall investment of approximately £72bn.[46] A similar conclusion was reached by H21 in their report which suggested investment of £88bn might be required.[47] The extent to which they are greater or less than this estimate depends on the share of hydrogen in the future mix.

Converting the electricity network to accommodate heat pumps is likely to require even more investment
The challenge for gas networks is around the re-purposing of it to transport hydrogen, the challenge with the power networks is one of building the additional capacity required to meet the greater levels of peak demand heat pumps will create.

The precise level of investment required to do this is uncertain at this time, however proposals on this are currently being drawn up by electricity networks. Independent estimates from Element Energy suggest that overall investment of £214bn may be required.[48] Again, the accuracy of this figure will largely depend on the extent to which electricity is used to meet future heat demand, and therefore the amount of network reinforcement that is necessary.

A balanced approach is likely to be the most economical
The single biggest reason that an energy system incorporating hydrogen could have a lower overall system cost versus a fully electrified one is the impact hydrogen has on the system's flexibility and its ability to cope with demand spikes.

One advantage of taking a balanced approach where hydrogen meets some future heat demand is the fact that the UK energy system must deal with large seasonal fluctuations in demand. Peak winter energy demand is around **five times higher than annual average demand**,[49] largely driven by heating on the coldest days. Improvements in home insulation and demand side response will reduce future seasonal variation over time. Nevertheless, winter peaks will remain.

As more and more of the UK's energy needs are met by electricity, for example with the shift to electric vehicles, the UK's peak electricity demand will inevitably increase, regardless of hydrogen's role in the system. This increase will be considerably less in a balanced scenario where hydrogen plays a role in the heating of buildings because of the reduced reliance on electricity to meet peak heating demand.

A recent report by Vivid Economics and Imperial College on the Accelerated Energy System[50] set this out well. In a balanced energy system where hybrid heating solutions incorporating hydrogen boilers alongside electric heat pumps are the dominant solution, system peak electricity demand would increase from 59GW today to 116GW in 2050. Conversely, in a fully electrified system where most buildings are heated using standalone heat pumps, system peak demand could increase from 59GW today to 204GW in 2050, around 75% more than in the balanced scenario.

The additional energy system infrastructure required to deliver this peak could make a fully electrified scenario £8bn more expensive than in a balanced scenario, driven by the additional dispatchable (reserve) power generation capacity needed to meet it, plus the additional reinforcement the electricity distribution network would need in order to cope with this peak demand.

How much will a heat pump cost me?
In a system dominated by electrification of heat, more consumers will rely on air source heat pumps. In analysis submitted to the CCC for the Sixth Carbon Budget Report, Element Energy assume the total cost of an ASHP installation today, i.e. including fittings, installation, controls and labour, is £7,250. These costs are however lower than other industry assessments, including independent advice commissioned by BEIS.[51]

The range of estimates for a heat pump installation that we see today is perhaps in part due to the specific and individual way each heat pump system needs to be designed in each home. **There may also be other consequential costs associated with an installation**, such as the installation of underfloor heating, additional insulation, larger radiators or hot water tanks. These costs will vary substantially based on the circumstances of an individual home. It is therefore difficult to talk about the 'average' cost of a heat pump installation.

The CCC also set out an expectation that today's ASHP unit costs will fall 20% by 2030 and 30% by 2040. It is reasonable to assume some cost reductions over time as the heat pump industry scales up. The levels of cost reductions we will see however – in what is a mature market – are uncertain. The heat pump market is already mature, having been established since 1990, with approximately 15 million units now installed across Europe and with annual sales of 1.6 million in 2020.[52] We consider the extent to which heat pump costs will fall over time is uncertain and unlikely to be this steep.

How much will a hydrogen boiler cost me?
There is more certainty over the expected costs of hydrogen appliances. The recent Hy4Heat programme demonstrated that home conversion is feasible with such appliances, and that these appliances are installable today at no extra cost to the customer beyond the cost of a typical fossil gas boiler.[53]

The cost to consumers at the point of conversion will of course reduce significantly if the consumer has already purchased a hydrogen-ready appliance as part of the normal asset replacement cycle between now and then.

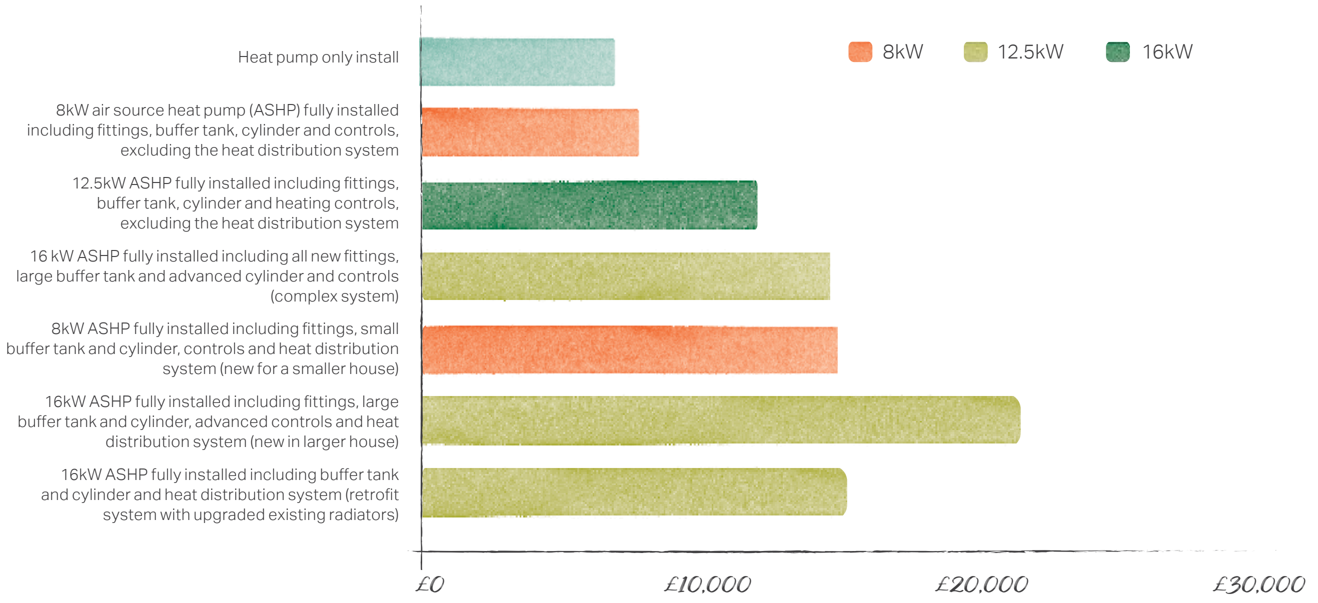
Installing a heat pump may involve other costs…
Because they operate at lower temperatures, heat pumps may additionally require changes to the heat distribution system such as underfloor heating or larger radiators. This may not be required in every case – where the energy efficiency of the home is either already high or is upgraded as part of the heat pump installation process. In the case of a hybrid system it is rarely needed at all. Where it is required however the additional costs could be significant – as much as 50% more than that assumed by the CCC.
Given most boiler replacements are distress purchases today, it is possible that customers switching to heat pumps at point of boiler failure will face the choice of either taking on the additional capital cost of upgrading their system and building fabric at the same time, or tolerate a poorly performing heat pump until such time as they can afford it.

> **"There is no reason why, at similar scale, hydrogen-ready boilers should not reach a similar cost to fossil gas boilers today. The ancillary components, accessories and controls will be identical to those for fossil gas boilers. The property will at some stage require a hydrogen-ready gas meter to be fitted ready for network conversion, however this could be installed on a later date than the boiler. Initially, hydrogen-ready boilers might form a niche market, but a regulatory change mandating their installation would make them a high-volume technology, just as fossil gas boilers are today."**
>
> **Worcester Bosch[54]**

…as there will be with the conversion to hydrogen
A home may typically have several appliances using fossil gas today; including a boiler, cooker and/or fire. These will all need to be replaced with either hydrogen or hydrogen-ready equivalents. While the capital cost of these appliances is expected to be broadly the same as their fossil gas equivalents **it will still mean additional costs for customers.**

Work progressing on the conversion of hydrogen in the home as part of the Hy4Heat project has also identified there may also be a requirement to install an automated shut off valve in the home to protect against the risk of an uncontrolled gas leak. It is also expected that some form of hydrogen sensor may be required to replace the current carbon monoxide sensors found in homes.

Heat pump installation costs



Data in this graphic reproduced with permission from Delta-EE's report 'Cost of installing heating measures in domestic properties' (2018).

Importantly, because of its different characteristics, it is likely that homes converting to hydrogen will need to install a new gas meter. This could in theory be completed with the installation of hydrogen ready meters beforehand, or with a meter exchange at the point of conversion. The solution for this is not yet fully understood but is being assessed as part of the Hy4Heat programme.

The balance of 'other' costs depends on the balance we choose
The total of these 'other' costs at a system level will again depend on the overall mix of electricity and hydrogen in the system. And as suggested above, they will depend on which technology is used where. Decarbonising heat with electricity in homes with high levels of efficiency is likely to lead to lower overall other costs than homes with poor levels of efficiency. It may be that the optimal mix of hydrogen and electricity in the system will in part be determined by the costs on an individual house by house basis.

We also need to think about how much these technologies cost to run
Once the up-front costs have been borne, the customer will need to pay for the ongoing running costs of the new heating system. The key driver of this will be the cost of the fuel itself, maintenance costs being largely similar between the two.

In general terms, although electricity is more expensive per kWh than either fossil gas or hydrogen are expected to be, the fact that heat pumps operate at approximately three times the efficiency of a fossil or hydrogen boiler means that the ongoing running costs of a well-operating heat pump system should be lower.

We need to think about things in terms of lifetime costs
The most economical solution is dependent on the characteristics of each home. This includes an assessment of the size and installed cost of the heating system required, the energy efficiency of the building, the extent of any consequential upgrades and the annual heat demand. For the reasons above hydrogen boilers may be cheaper up front, but then more expensive to run on an ongoing basis. To account for this, **it is necessary to consider cost across the lifetime of a system** – in other words how much it would cost to install and run over a typical 15-year period.

Bringing together the projected capital and running costs for home heating technologies over time from various sources, including the reports cited above, it is possible to construct a range of potential lifetime costs at a household level.

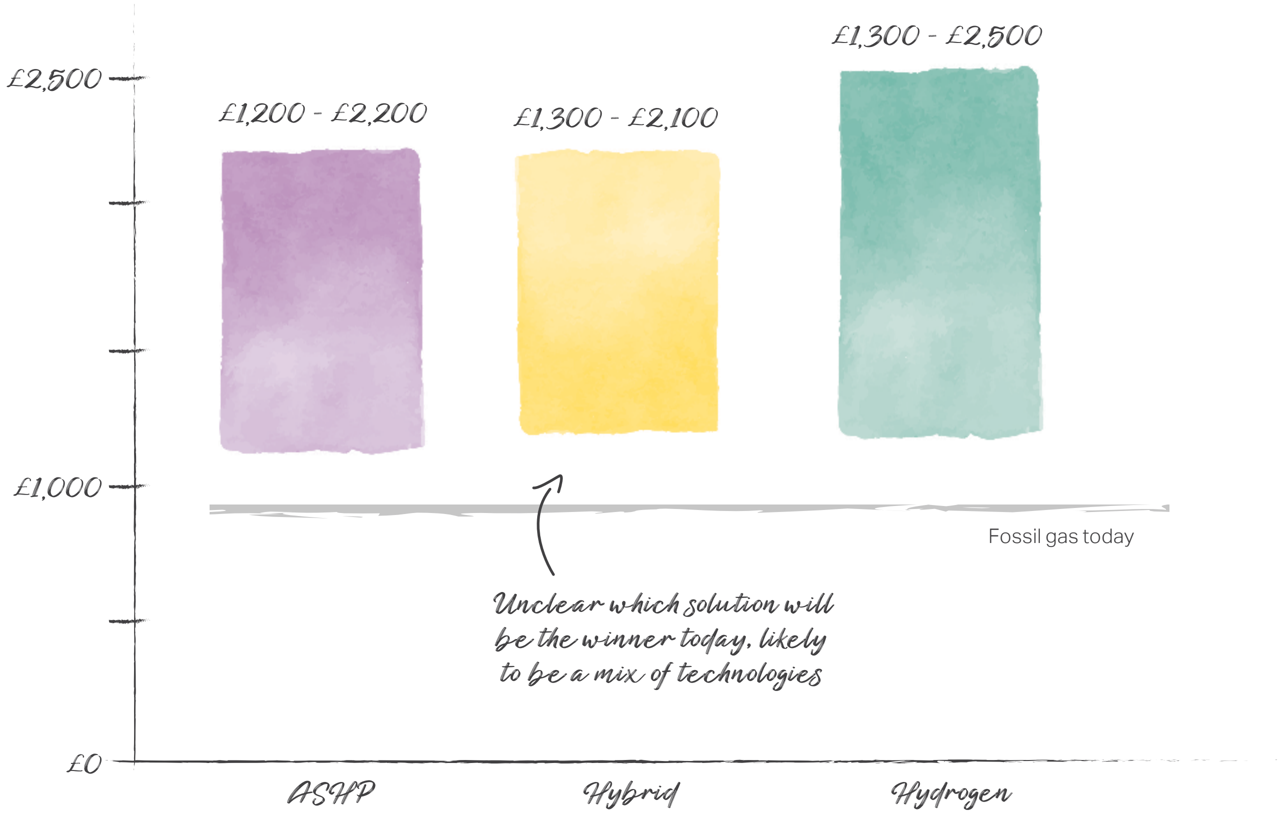
We have done this using projected costs from a variety of sources, to create an estimate of the lifetime cost range for an average home in 2035, using a heat pump, a hybrid system and a hydrogen boiler.

Key assumptions used

	Today's fossil gas boiler	ASHP	Hybrid	Hydrogen
Installation capital costs	£2,750	£5,600 – £7,724	£6,179 – £8,724	£2,850
System efficiency	92%	250% – 348%	216%-294%	80%
Required upgrades/retrofits	£0	£0 – £9,270	£0 – £1,000	£0 – £1,000
Retail energy cost p/kWh	4.5p	19.9p – 21.5p	17.9p – 20.2p	9.8p – 14.8p

Annualised lifetime system costs, including cost of any retrofit

Chart shows the range of potential costs from installing a new low carbon heating technology, along with costs of any retrofit work required, annualised over the lifetime of the system. Source data from review of available literature including the CCC, Element Energy, BEIS, Ofgem, Western Power Distribution, Energy Savings Trust, Delta-EE, Carbon Trust, Citizens Advice Scotland and the Sustainable Energy Association.[55]



This underlines the fact that the lifetime cost of any low carbon heating system is likely to be more expensive than a fossil gas heating system today.

In the best case, such as in a home with good pre-existing levels of energy efficiency, a heat pump is likely to be the best solution. It also shows that this will not be the case for all homes however, and that there will be a significant number of cases where a hydrogen boiler will be the most economical solution.

These calculations are based on an 'average home'. **Actual costs will depend upon the situation in individual properties**. In practice this means that homes with lower annual consumption or high retrofit needs will tend to find hydrogen more suitable given their sensitivity to up-front costs. Homes with higher annual consumption will tend to find heat pumps more attractive given their sensitivity towards ongoing running costs.

Property characteristics such as space, heritage status, size, shape and location will all also contribute to a different cost profile for the transition. Each property will be different, and likely need a solution tailored for it as much as possible. This underlines the findings of others, including the CCC, who have found large differences between technology deployment rates under different pathways.

Maintaining optionality is key
Policy making today should be framed around 'no regret' actions and optionality, keeping open a range of technologies and approaches which could plausibly be part of a preferred long-term low carbon energy mix.

At this stage, it would be unwise for a Green Print to pick a winning low carbon heating technology, whether that be through the mass adoption of electric heat pumps or waiting for hydrogen.

A focus on delivering specific outcomes, for example through a general mandate for low carbon heating solutions, is more likely to be successful that backing single technology approaches.

In that light, the challenge for this decade is to make substantial practical steps that enable all of the serious candidate low carbon home heating technologies for the 2030s and beyond – and test the three factors (technical feasibility, customer preference and economics) in reality. On the evidence presented in this paper, green gas – and especially hydrogen – should certainly be one of those technologies. Anything which cuts off major options such as requiring a move away from conventional gas boilers without providing enabling hydrogen ready equipment or hybrid appliances – would be a backward step.

Low carbon heating – the case for keeping options open

100% Heat Pumps

Pros
> Existing technology
> Highly efficient
> Fit with renewable electricity

Cons
> Not suitable for all homes
> High capital/installation cost
> Highly disruptive in-home impact
> High cost electrification of peak heat – both generation and networks
> Best long term solution for clean peaking/back-up generation is unclear

Balanced Development

> Keep options open
> Level the playing field
> Respect consumer choice
> Recognise diversity – regions and types of housing

100% Hydrogen

Pros
> Ease of transition
> Like-for-like in-home transition
> Use of existing gas networks
> Inter-seasonal storage of hydrogen
> Potential to be lower cost

Cons
> High/uncertain cost of producing clean hydrogen
> Hydrogen-ready boilers still in prototype
> Blue Hydrogen reliance on CCUS (not yet delivered at scale in UK)
> Uneven regional roll-out of hydrogen across UK
> Limited to on-grid properties

Section 4

Our Green Print
Future Heat for Everyone

Section 4 brings together all three elements to form our Green Print for future heat for everyone, setting out the actions we believe can be taken now in order to accelerate progress.

800k homes
the amount we need to decarbonise each year on average, between now and 2050

10GW
the production target we think the UK Government should set

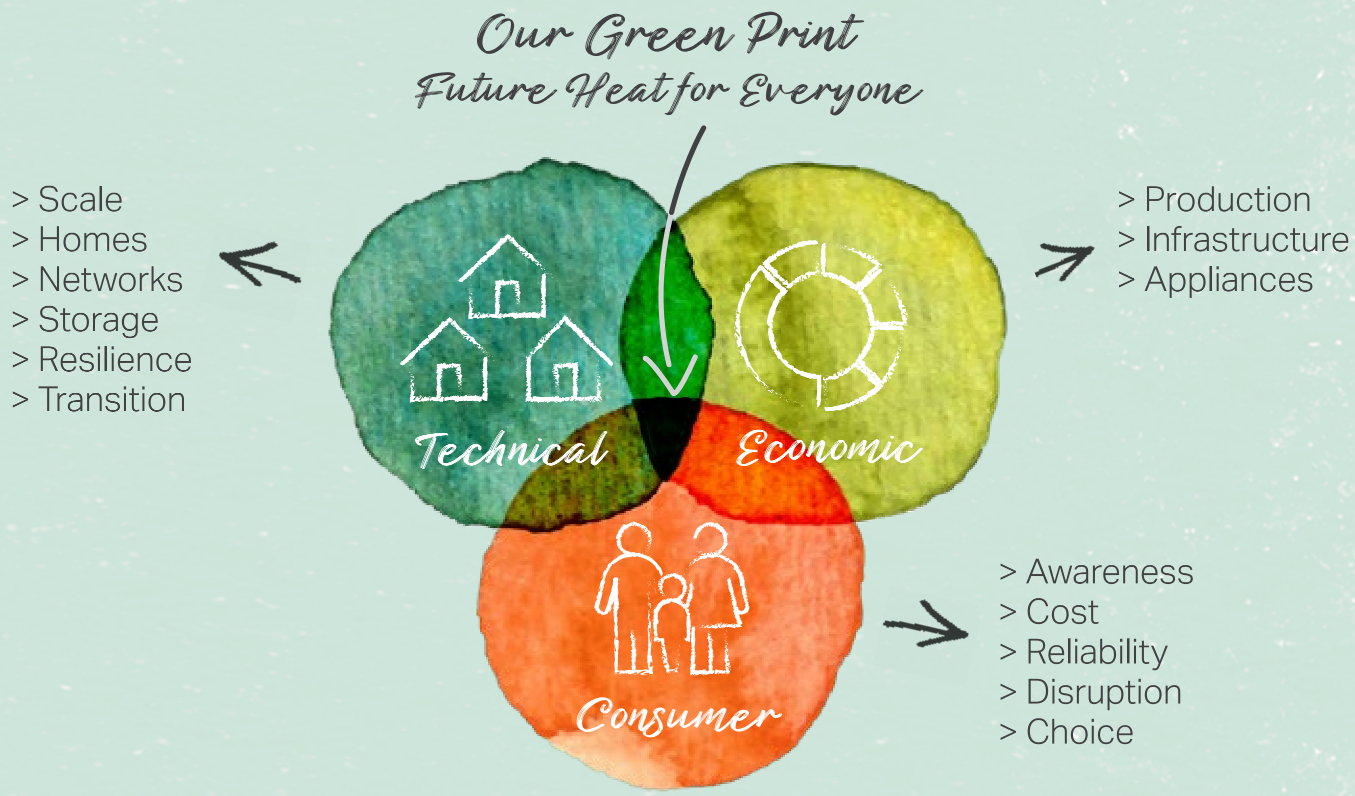
6% saving
the immediate emissions reduction we could realise if we started blending hydrogen

1 in 20
the type of extreme winter event we need our future heat systems to be able to operate within

Our Green Print for future heat

A roadmap for low carbon heating that balances technical, customer and economic components

Stood in 2021, 2050 feels like a long time away. The sheer scale of the task ahead is huge however, equivalent to nearly decarbonising approximately 800,000 homes each and every year between now and then.



Our Green Print – Future Heat for Everyone

Prove the *technical* case by:

1. Demonstrating that hydrogen is safe
2. Enabling the development of a hydrogen economy today
3. Prioritising innovation
4. Injecting pace into the building of infrastructure we know we will need

Ensure *consumer* wants and needs are properly considered by:

5. Ensuring consumers are central to decisions on the future of heat
6. Ending the unnecessary 'format wars'
7. Understanding consumer views on heating and beginning engagement early
8. Being upfront with consumers on how much the transition is going to cost and how it will be paid for

Ensure robust *economic* decisions by:

9. Creating the right incentives to decarbonise heating and deliver net zero
10. Stopping planning in silos
11. Planning for peak demand, not average demand
12. Deepening the understanding of the critical factors in the economics that will determine the energy mix

We need to start now if we are to succeed. This means deploying heat pumps now where appropriate, delivering energy efficiency upgrades, scaling up the heat network sector and investing in demonstration projects and supply chain for hydrogen.

But we are not starting from scratch. We already understand that the energy systems we have today will need to be carefully co-ordinated if we are to deliver the resilient future energy system we need.

The UK continues to be a hot spot for creativity in the technology, engineering solutions and innovation that will be crucial in getting us there. There is also consensus across the political spectrum on the level of ambition that has been set, and on the need to act.

What is now needed is to move beyond ambition and to delivery.

Below we have set out Our Green Print – Future Heat for Everyone – our plan for the actions that we can start to take today, fully considering the technical, consumer and economic aspects, in order to achieve the transition to low carbon heat.

In doing so, we have focused on the role of hydrogen specifically. That is not to say that actions are not needed to accelerate the deployment of heat pumps or heat networks – they are. It is simply to say that others in these sectors are better placed to comment on how implementation there should be accelerated.

The actions we have set out will require work from Government, regulators and the private sector. Cadent stands ready to play its part. We are already investing heavily in this area and are looking to invest more. We also intend to build a broad coalition including Government, Ofgem, networks, shippers, consumers and the wider supply chain to work with us as we deliver the low carbon future we want to see.

Prove the technical case

1. Demonstrating that hydrogen is safe

There is still work to complete to ensure all the safety evidence for hydrogen is completed both in the gas network and in the home. It is therefore important gas networks prioritise work in this space to provide assurance that hydrogen is an effective alternative to fossil gas.

Cadent will: support the completion of the safety evidence to enable a decision on heat policy.

2. Enabling the development of a hydrogen economy today

At the time we write this, the Government's proposed Hydrogen Strategy was still being drafted. We need a Hydrogen Strategy that is ambitious, and effectively sets out how we will move to hydrogen production at scale in a way that really enables costs to come down. In order to do this, the following items must be addressed as a priority if we are to attract the private investment we need:

- **Hydrogen production targets:** Stretching hydrogen production targets are required to demonstrate the intent for hydrogen across industry, transport, power and heat sectors. Through our own involvement with the Hydrogen Taskforce we understand where the significant hydrogen production projects are for the UK. Doubling the existing hydrogen production targets to at least 10 GW by 2030 would help provide this.
- **Hydrogen production business models:** Overcoming the relatively high early stage production costs of hydrogen can be achieved by utilising business models similar to those that saw renewable power production costs fall three-fold in the last 10 years. Electricity customers currently pay for these subsidies through their energy bill. Similar subsidies for the production of hydrogen paid for through the gas bill could have a material impact on the ability of producers to invest and bring costs down.
- **Carbon Capture and Storage (CCS) business models:** Blue hydrogen is likely to feature to some extent – at least in early hydrogen deployment – before the cost of green hydrogen falls to anticipated levels. This will require the development of CCS technology. While the business models that are needed are being developed by industry and Government, this work is also on the critical path for blue hydrogen to play any role and must therefore be delivered.
- **Support for industrial clusters:** The UK only has a small number of heavily energy intensive industrial clusters. These use vast amounts of fossil gas today, emitting huge amounts of carbon in the process. Each of these clusters has developed detailed plans to use a mixture of CCS and hydrogen to decarbonise. Developing policy frameworks which enabling these plans is a necessary step along the journey to net zero and must be delivered as soon as possible. In doing so, we will also provide the starting locations for hydrogen as outlined by the CCC.
- **Blending of hydrogen:** Demonstration projects have shown that blending hydrogen to 20% by volume with fossil gas is achievable and has little or no impact on consumers. Doing so will immediately reduce the carbon emissions of affected UK homes by approximately 6%. It will also demonstrate to consumers how the safe and seamless use of hydrogen can work in their homes, while at the same time enabling industrial cluster sites to commission effectively. Importantly it will create a stable demand centre for scaled production, accelerating the development of supply chains and enabling reductions in the costs of production. Blending requires specific changes to legislation – changes which should be progressed as soon as possible.
- **Mandating hydrogen-ready gas appliances:** On the basis that hydrogen is likely to be required across a range of different buildings in the UK, mandating hydrogen-ready appliances is a sensible no-regrets decision. Doing so would ensure that gas boilers sold could convert to use hydrogen in the future, if the customer chooses not to install a heat pump. Such a mandate could also stimulate innovation, for example around new solutions such as fuel cells. We support the recommendation by the Energy Networks Association (ENA) that hydrogen-ready appliances are mandated from 2025.
- **Underpinning regulatory regime:** A new regulatory regime will be needed to support a hydrogen economy. This would include the necessary primary legislation changes to enable the production and use of hydrogen in the gas network, how the system will operate and the rules and codes that set out the roles and responsibilities of shippers and suppliers.
- **Hydrogen-ready gas networks:** Gas networks have already been investing in an iron mains replacement programme designed to improve safety. Supporting the early completion of this programme would accelerate the hydrogen-readiness of the gas network as well as enabling the skills to be developed to support future town conversions.

3. Prioritising innovation

Achieving our goals will require change across the energy system, requiring innovation across a range of technologies. Mechanisms are needed to bring forward the research and development funding we need to see in order to retail hydrogen as an option.

Equally important, and a key enabler of this, is innovation in both regulation and market design. Without this we are unlikely to see the innovation we need. Regulation today prevents anyone adding hydrogen to the gas network for example.

Ofgem: Review how today's regulatory framework and market design needs to change in order to enable the whole systems innovation we need to see.

Cadent will: Consider what regulatory reforms may be necessary to enable the development of a new hydrogen market, sharing and developing proposals in conjunction with others across the industry.

4. Injecting pace into the building of infrastructure we know we will need

Infrastructure providers have a duty to outline what can be achieved before 2050 and getting started on the delivery of that now. Many national infrastructure projects take many years to develop, and if we start to plan too late we might find that we have lost the opportunity to deliver in time. Supply chains and skills must be developed in parallel to ensure success.

This is as true for hydrogen as it is for heat pumps – both require material investment upstream of the consumer, in production, storage and delivery networks. Government should consider what role they and others need to play in accelerating the planning and development processes.

This will have the added benefit of enabling us to innovate and learn by doing. Real traction comes from large scale projects that enable the sort of learning that can only be done in real life situations. This could include projects such as heat network delivery, hydrogen village or town conversion and scaled hydrogen production.

Prove the technical case continued

Government: ensure that the energy system can deliver the infrastructure changes necessary to support the transition to low carbon heat, for example by accelerating infrastructure investment in the electricity network and creating a hydrogen-ready gas network. Support early large-scale projects that will deliver significant learning by doing opportunity.

Ofgem: Allow feasibility projects to progress to Final Investment Decision before heat policy decisions are set out in detail in order to avoid delays.

Cadent will: develop conversion plans to demonstrate the critical path required for infrastructure decisions relating to the gas network, outlining requirements for skills and supply chain. Bring projects to Final Investment Decision. Ensure the early and effective dissemination of learning across hydrogen innovation and delivery projects.

Ensure consumer wants and needs are properly considered

5. Ensuring consumers are central to decisions on the future of heat

The journey to net zero will mean that we need to design and deliver new heat systems and – for many – change the fabric of homes across the country while being sensitive to the circumstances of individuals. Delivery will mean developing new incentives, mandates and taxes.

There is a wealth of experience in the private sector at designing consumer propositions. Government should explore ways of exploiting this experience in the design of their policy. Our research has highlighted consumers expect Government to mandate the change needed and then allow choice in how that change is delivered on a home by home basis. Consumers know they currently lack the knowledge to make that decision, so they want (a) an approved shortlist of options for them to choose from and (b) access to impartial information with which to make that decision.

Cadent will: continue to develop the necessary consumer insight required to support conversion of consumers away from fossil gas heating systems. This will include a focus on how future hydrogen propositions can be developed with consumers at their heart.

6. Ending the unnecessary 'format wars'

The continuous argument between hydrogen boilers versus heat pumps is unhelpful and gets in the way of a debate about how we deliver both. The truth is that both hydrogen and heat pumps will be needed if we are to decarbonise home heating. They each have limitations that can be resolved with the inclusion of the other. The only question to be settled therefore is the eventual mix of each in the future system.

Given it is unlikely that sufficient certainty will be available in the near term to answer that question, we need to move on from arguing about which will 'win' and instead work together on establishing where each technology will be deployed and how we will help consumers make the transition.

Cadent will: not engage in 'format wars'. Instead we will continue to develop the economic detail on the repurposing of the gas grid to carry future green gases, creating transparency of information. We will support the continued development of economic models that support whole systems approaches, acknowledging where there is a preferred role for other solutions as we develop our future asset strategies.

7. Understanding consumer views on heating and beginning engagement early

Our research highlighted that despite the fact that consumers understand the need to decarbonise in broad terms they often lack a clear understanding of what this means in practice when related to the decarbonisation of heat. Investment in engagement is needed now to ensure that consumers have the information they need to understand the challenge ahead, why it is necessary, the implications for their home heating systems, the options available to them, the pros and cons of each and where they can get help and support with making the transition.

Our research highlighted that a range of parties will need to come together for this to be a success, including Government, local authorities, consumer organisations and the private sector. Work needs to start now on delivering this if the transition to low carbon heat is to be successful.

Government: should explore avenues to increase education of the general public, engaging with the private sector, local authorities and other interest groups to assist in this ambition.

Cadent will: develop education materials on the role of hydrogen in meeting this challenge, setting out both where it can be part of the solution and importantly being clear about where it cannot. We will also work with parties from across the energy sector and society on a coherent and engaging conversation with consumers about the way forward.

8. Being upfront with consumers on how much the transition is going to cost and how it will be paid for

The costs of decarbonising heat are going to be significant regardless of the pathway we choose. Whether it is improving the energy efficiency of homes across the country, installing heat pumps, running hydrogen boilers or investing in the future green gas and power networks needed to distribute low carbon energy, the investment required will be huge and will be ultimately borne by consumers – either directly, through their energy bills or through taxation.

Our research to has shown there is also an expectation that new green technology will be cheaper than current technology – something which although largely true in power today – and will be true in transport tomorrow – is unlikely to be true in heating for the foreseeable future. Incentives may not be enough, as we have learnt from our experience over the last 10 years in encouraging consumers to invest in the energy efficiency of their own homes.

While this suggests an increased burden being met through taxation, this needs to be seen in the context of the worst recession in living memory and public finances acutely stretched by the fight against COVID-19.

We therefore need to assess the costs of decarbonising home heating and start an upfront and straightforward conversation with consumers about what that looks like and how it will be paid for. This will be vital for ensuring we have consent for the decisions we will need to take.

In doing so, we will need to weigh the need to rebalance energy policy costs between electricity and gas bills such that they incentivise the take up of heat pumps with the need to finance the development of the future hydrogen system. Any changes will also need to be carefully designed so that they do not negatively affect levels of fuel poverty.

Government: Consider the full range of system impacts of heating solutions requiring investment prior to the adaptation of the current energy taxation regime. Clearly articulate how the move to net zero will be financed and how this burden will be shared between the energy bill and taxpayers.

Ensure robust economic decisions

9. Creating the right incentives to decarbonise heating and deliver net zero

Industry stands ready to provide the investment necessary for us to reach net zero. In order to unlock this, we need to create a market design and regulatory framework that incentivises them to do so.

With the need to drive long term investment there is a real question over whether the current regulatory framework is 'fit for purpose'. While RPI-X and its RIIO successor have served the energy and other sectors well in driving productive efficiency and in more recent times performance, there is a real question as to whether they will be sufficient moving forwards.

The move towards more 'adaptive' regulation during this RIIO-2 period should give Ofgem more ability to approve investment whether this will be an enduring solution. In order to drive systems thinking there may be a need to consider aligning the price reviews for gas and electricity which are presently out of sync. Other market mechanisms also need to be reviewed, for example those enabling carbon capture and storage, as well as the pricing arrangements needed to enable a future hydrogen market.

Government and Ofgem: Consider the market design and regulatory barriers to investment and identify ways in which market design and regulatory frameworks could be reformed to unlock it.

Ensure robust economic decisions continued

10. Stopping planning in silos

The current regulatory framework governing investment in electricity and gas network infrastructure is not sufficiently joined up. This is most clearly seen in the fact that planning and stakeholder engagement tends to be completed separately by gas and electricity networks. This will hamper our ability to deliver the whole system approach we need in order to decarbonise heating.

Consumers are likely to make choices on their future heating system based on their individual wants, needs and preferences. The sum of these individual choices will require both gas and electricity network operators to coordinate the design of infrastructure to meet these needs in good time. This will require the industry to adopt best practice systems thinking methods.

The seeds of this have already been planted. For example, Cadent has developed positive working relationships with our electricity counterparts. These positive relationships can be leveraged to convert individual network plans into more detailed whole systems plans.

There is also a need for the co-ordination of local area plans for decarbonisation, led by a body that can ensure that we do not deliver a patchwork of easy solutions without considering the impact on the whole system or of the harder to decarbonise buildings. This will underpin choice as well as support future town by town conversion strategies that work for local areas.

Government: Existing work on developing Local Area Energy Plans should continue and be supplemented with work to assess how these can be integrated with wider decarbonisation of heat plans across a whole region.

Ofgem: Consider a review of the regulatory process to enable more effective planning and co-ordination between gas and electricity networks, such as aligning price review processes. Support the development of expertise within the public sector.

Cadent will: continue to develop a town by town hydrogen conversion strategy that illustrates how this might be deployed in every region. We will work with local area planning bodies and other infrastructure providers to provide a full view on whole system resilience.

11. Planning for peak demand, not average demand

Although the goal is to have decarbonised heat well ahead of 2050, the real challenge is to deliver enough low carbon heat to meet the demand in the extreme winter conditions that we experience in the UK every 20 years or so.

Heat demand in these winter periods may be nine times as much as in the summer. Winter periods also coincide with the highest incidence of dark and windless days. The combined impact of these two things could create the single largest challenge to the resilience of the future energy system.

While some forms of energy demand can be shifted to other times of day, for example by shifting when we charge our electric vehicles or power our fridges, demand for heat is more instantaneous and is less easy to shift. Government should consider the consequential impact on price of such extreme events, whether consumers should be protected and through what mechanism.

Government, Ofgem and Cadent: Ensure that winter energy resilience is adequately built into plans for heat decarbonisation.

12. Deepening the understanding of the critical factors in the economics that will determine the energy mix

Hydrogen is not available for homes today, but we have enough information to see that not only will it be an option but that it will be necessary. What we lack is certainty about the extent of the role it will play – something that will depend on how a range of factors change over time. It will be therefore be important to refine the analysis as new information emerges, for example on energy efficiency deployment rates and the pace at which the price of hydrogen falls.

Government: Work with industry to ensure that net zero strategies and plans evolve over time as new information emerges.

Cadent will: share information and analysis on factors relevant to the decarbonisation of heat so that the analysis can be refined as needed. We will work with partners across the energy industry to build and refine analysis over time.

End notes

1. UK Government's Ten Point Plan.
2. The CCC – Sixth Carbon Budget.
3. UK Government's Energy White Paper.
4. All numbers from Digest of UK Energy Statistics.
5. The CCC – Sixth Carbon Budget.
6. English Housing Survey (2018/19).
7. The Guardian.
8. Tado.
9. Ofgem ECO3 reporting.
10. BEIS Smart Meter Statistics in Great Britain (September 2020).
11. As per evidence to the BEIS Select Committee from Ian Rippin, MCS, 9th February 2021 I.
12. Greater London Authority.
13. Manchester Climate Change Agency.
14. Statista.
15. Hy4Heat.
16. Viessmann.
17. Bottom of the range taken from minimum SPF for Domestic Renewable Heat Incentive heat pump installations (Ofgem) and top of the range taken from the assumed SPF used by the CCC in their 6th Carbon Budget modelling for heat pumps in 2020 with a system temperature of 40°c.
18. Competition & Markets Authority – Heat networks market study.
19. Which? – Turning Up The Heat.
20. BEIS – Heat Networks, building a market framework.
21. Digest of UK Energy Statistics.
22. BEIS – Future support for low carbon heat, impact assessment.
23. The CCC – Biomethane technical note (2016).
24. The CCC – Heat in UK Buildings (2016).
25. EUA – Decarbonising heat in buildings (2021).
26. Hydrogen Council.
27. See for example the CCC, ENA and Aurora.
28. National Grid – FES 2020.
29. HyDeploy.
30. H21.
31. Hy4Heat Work Package 7.
32. Mapping geological hydrogen storage capacity and regional heating demands: An applied UK case study.
33. H21 North of England.
34. BEIS – Public Attitudes Tracker (May 2021).
35. Including from BEIS – Transforming Heat, Public Attitudes Research (January 2020); Citizens Advice – Taking the Temperature (August 2020); Leeds Beckett University – Public Perceptions of converting the gas network to hydrogen (April 2020); National Grid – Heating our homes in a net zero future (September 2020); Climate Assembly – The Path to Net Zero (September 2020); Bright Blue – Going Greener – public attitudes to net zero (October 2020); and Ofgem – Consumer opinion about climate change and decarbonisation (October 2020).
36. Research conducted by Savanta on Cadent's behalf. This consisted of a multi-method approach including a survey of 2,043 people across the country, a 5-day online community with a regional and representative group of 45 people to explore viewpoints, opinions and behaviours in a deep and engaging way, and 30 individual 1-2-1 in-depth interviews with people in vulnerable situations, those in fuel poverty, early adopters of new low carbon technology and others to ensure coverage of key audiences and gain a rich understanding of individual circumstances and opinions.
37. Element Energy – Cost Analysis of Future Heat Infrastructure.
38. The CCC – Analysis of alternative UK heat decarbonisation pathways.
39. ENA – Gas decarbonisation pathways.
40. Aurora – Hydrogen for Net Zero Great Britain.
41. By extension, the utilisation rate of any electrolyser is also uncertain – a further key sensitivity for the cost of green hydrogen.
42. Cadent analysis of various sources: CCC, Navigant, Aurora, ENA, ORE Catapult, KPMG.
43. As above.
44. BEIS – Energy and emissions projections.
45. The 'heating season' in the UK is normally considered as October to March.
46. Element Energy – Cost analysis of future heat infrastructure.
47. North of England Report referred to previously. Cost was £15,278m for 3.8 million homes. To calculate the UK cost here were have prorated this cost for 22 million homes.
48. Element Energy – Cost analysis of future heat infrastructure.
49. Cadent written evidence to Parliament.
50. Vivid Economics – Accelerated Electrification and the GB Electricity System.
51. Delta EE – Cost of installing heating measures in domestic properties.
52. Market Data (2020) – European Heat Pump Association.
53. Hydrogen-fired boiler (2021) – Worcester Bosch.
54. Worcester Bosch – Decarbonisation White Paper.
55. Ranges constructed from literature review, including the CCC, Element Energy, BEIS, Ofgem, Western Power Distribution, Energy Savings Trust, Delta-EE, Carbon Trust, Citizens Advice Scotland and the Sustainable Energy Association. Heat demand calculated from central Ofgem estimates today adjusted for assumed 2% energy efficiency improvements each year to 2035. Discount rate of 3.5% applied across all capital costs. Fuels costs are retail, with range of wholesale costs calculated from the reports cited above. Heating systems capitalised over 15 years, building upgrades and retrofits capitalised over 30 years.

Designed and produced by Instinctif Partners **creative.instinctif.com**

Cadent future Your Gas Network

#cadentgreenprint

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July 2021

This report has been produced using recycled paper and a biodegradable matt lamination.