regen
transforming energy

The decarbonisation of heat

A Decade to make a difference paper

WALES&WEST UTILITIES

The Decade to make a difference series

The UK's commitment to net zero carbon requires a transformation in the way in which energy is generated, distributed and consumed. As a key enabler of decarbonisation the energy industry is being asked to rise to the decarbonisation challenge and will need to achieve rapid and dramatic change. The big question is whether the industry, working with its stakeholders, will be able to do this? And if so, what new technologies, policies and business models will be required to enable radical change?

Throughout 2020 Regen will be publishing a series of thought- provoking papers looking at the challenges and solutions that would deliver transformation change across the industry. These will cover the themes of renewable electricity, decarbonisation of heat, low carbon transport, energy efficiency, and the role of cities and regions to reach net zero carbon.

This discussion paper has been researched and produced by Regen, an independent not-for-profit organisation that is committed to the transformation of the UK's energy system. Regen would like to thank our members, and the wide range of industry stakeholders that have provided their expertise and insight to help us develop our thinking. We would also like to thank Wales and West Utilities for supporting the production of this paper. All opinions and views expressed in the paper are Regen's, unless explicitly referenced. We would welcome feedback and comments, and encourage readers to continue to engage with us through our events and membership.

Paper authors:

"Net zero means a radical change in our approach to building and renovating our housing. If we can start to value the multiple benefits of energy efficiency then we have a strong construction sector that will invest to deliver this, benefiting consumers, the economy and reducing the scale of the challenge of decarbonising heat."

Mark Howard, Project Manger, Regen

"Decarbonisation of heat is without doubt the most difficult energy challenge the UK. There are no easy or low cost pathways. It is vital that this coming decade is used to engage with consumers, and build strategic partnerships at a local and regional level that will deliver a heat and energy efficiency revolution."

Johnny Gowdy, Director, Regen

The decarbonisation of heat

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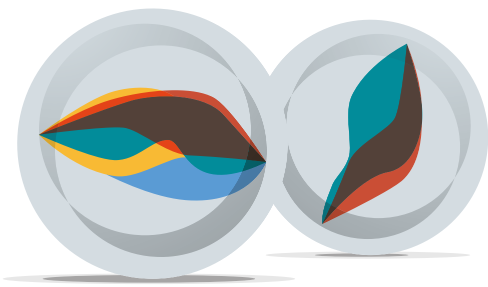


1. Executive Summary

The decarbonisation of heat is the greatest challenge the UK faces in order to become a net zero carbon economy. More than the expansion of renewable electricity generation, or the electric transport revolution, the delivery of low carbon heat must overcome a number of consumer, technological, infrastructure and market barriers. In part, the level of the challenge reflects the importance of heat utility in our homes and across the economy. Easy access to affordable heat has a profound impact in terms of comfort, well-being and productivity, for people and for businesses.

Alongside the challenges, action to decarbonise heat also offers far-reaching opportunities. Not least raising the quality of the UK's building stock, which is amongst the worst in Europe for thermal insulation, to reduce future energy costs and the prevalence of fuel poverty. There is the opportunity to invest in infrastructure for the future as part of a smarter and more integrated energy system, and to develop innovative technologies and fuel uses, that will enable the UK's energy and building industries to expand their supply chains and create new export capabilities.

Progress in the last decade has been difficult. Despite some notable successes at a local and community level, the stop-start nature of incentives, and the delay to wholly embrace low carbon building standards, has failed to rectify the fundamental problem of low consumer engagement, and the absence of a low carbon heat market. It is most telling that at the end of the decade, consumer awareness of low carbon heating seems to be no better, and is by some measures is worse, than it was at the start.

The net zero carbon commitment, and the public response to the climate emergency, has created a renewed urgency. Leadership is needed, at a national and regional level, to push ahead with a range of measures immediately, but strategic action must also be taken to ensure that the fundamental elements are in place that will enable the full decarbonisation of heat well before 2050.

1.1. Getting the fundamentals right – key recommendations for immediate action

This report highlights a number of key policy recommendations and other measures:

1. **Creating a consumer-led market for low carbon heat technologies and services.** Specific recommendations include addressing the current fuel price distortions, and putting in place a universal carbon levy to incentivise decarbonisation, fuel switching and new business models, alongside other market measures to reward carbon reduction and increase the sale and rental value of low carbon buildings.

2. **Adopting zero carbon building standards and embarking on a deeper and wider programme of efficiency and building fabric improvement**, enabling regions, cities, owner-occupiers and businesses to improve building fabric and implement local heat strategies, which will be needed whatever the future heat decarbonisation pathway.

3. **Building consumer trust, and stimulating market demand, by supporting the deployment of technologies and services that offer better, low carbon heating solutions.** Engaging with consumers while continuing to support solutions and exemplar projects that can demonstrate consumer value.

4. **Investing in both technology innovation and new infrastructure that will provide the basis for a heat revolution in the coming decades.** Prioritising heat technology within the UK's industrial strategy and enabling strategic infrastructure investment.
5. **Establishing local partnerships, and governance structures**, between communities, the public sector and the private sector to plan for and lead the heat transformation.
6. **Expanding and sustaining the low carbon supply chain**, including the mass mobilisation and reskilling of heating engineers and service professionals.
7. **Continuing to prioritise consumer protection, and measures to eradicate fuel poverty**, in order to sustain social and political support for change.

1.2. Future pathways - making key strategic decisions

The significance of the net zero carbon commitment, as opposed to an 80% reduction target, is that it has shifted the decarbonisation pathway towards a much more radical and profound energy transformation, under which burning fossil fuels for heating is no longer viable. Within the next five years, key strategic decisions must be made to determine the future decarbonisation pathway for heat.

As the paper highlights, energy efficiency, and the adoption of higher building standards, are a prerequisite no matter what the determined pathway. This should no longer be considered as a strategic decision to be taken, but as a call for immediate action. The question now remains one of tactics and planning to determine how the most effective measures are implemented and financed at a regional, city and local level.

Electrification of heat is the most obvious direct decarbonisation pathway and has the advantage of efficient energy use, alongside a close alignment with the expansion of renewable electricity generation and the electrification of transport. Electrification, however, faces two key challenges:

- The readiness of consumers to adopt new heating technologies that may entail building fabric changes
- Managing the peak energy demand for winter heating.

While the peak load challenge can be mitigated by smarter and more flexible energy solutions to an extent, there will inevitably be a requirement for significant long-term investment in electricity generation and storage assets, and for greater network capacity, especially on the distribution networks. The cost of this investment, how it will be financed and how it is finally reflected through to consumers' and businesses' energy bills, needs to be determined.

Low carbon hydrogen also has potential as a new heating fuel, with the dual advantages of providing the consumer with a heating experience similar to that of natural gas, and the potential to repurpose parts of the existing gas network. The level of global innovation and investment in hydrogen technologies, including the large number of demonstration projects here in the UK, suggests that hydrogen will certainly have a key role to play in our energy future, at least for use in transportation and within industrial clusters.

Whether hydrogen will also become a more ubiquitous heating fuel for homes and businesses will ultimately be determined by the fuel cost. This will in turn be driven by a number of cost factors, including the costs of feedstocks, production process efficiencies, cost of allied carbon capture and storage, the need for inter-seasonal hydrogen storage and peak injection capacity, and upgrades to gas distribution and consumer appliances. Some of those costs may be easily reduced with economies of scale and innovation; hydrogen-ready boilers, for example, are already cost competitive. Current projections, however, suggest that hydrogen costs will remain relatively high for use as a general heating fuel, unless there is radical cost reduction.

For both hydrogen and electrification pathways, decision makers will need to see, and understand, the future cost trajectories within a relatively short period in order to be able to invest in infrastructure and take other steps necessary ahead of a mass roll-out.

A mixed or balanced pathway that involves both electrification and hydrogen delivery, very likely tailored around local and regional factors, could provide some important advantages. Electrification could be developed as a widespread solution for most energy efficient buildings, while hydrogen, produced by electrolysis using cheap summertime electricity, could be used as the basis of inter-seasonal energy balancing, in industrial clusters, in hybrid systems and in discrete urban hydrogen networks. Biomethane may also have an important localised role for "hard to treat" rural properties and rural industries, and in areas of high biomethane production.

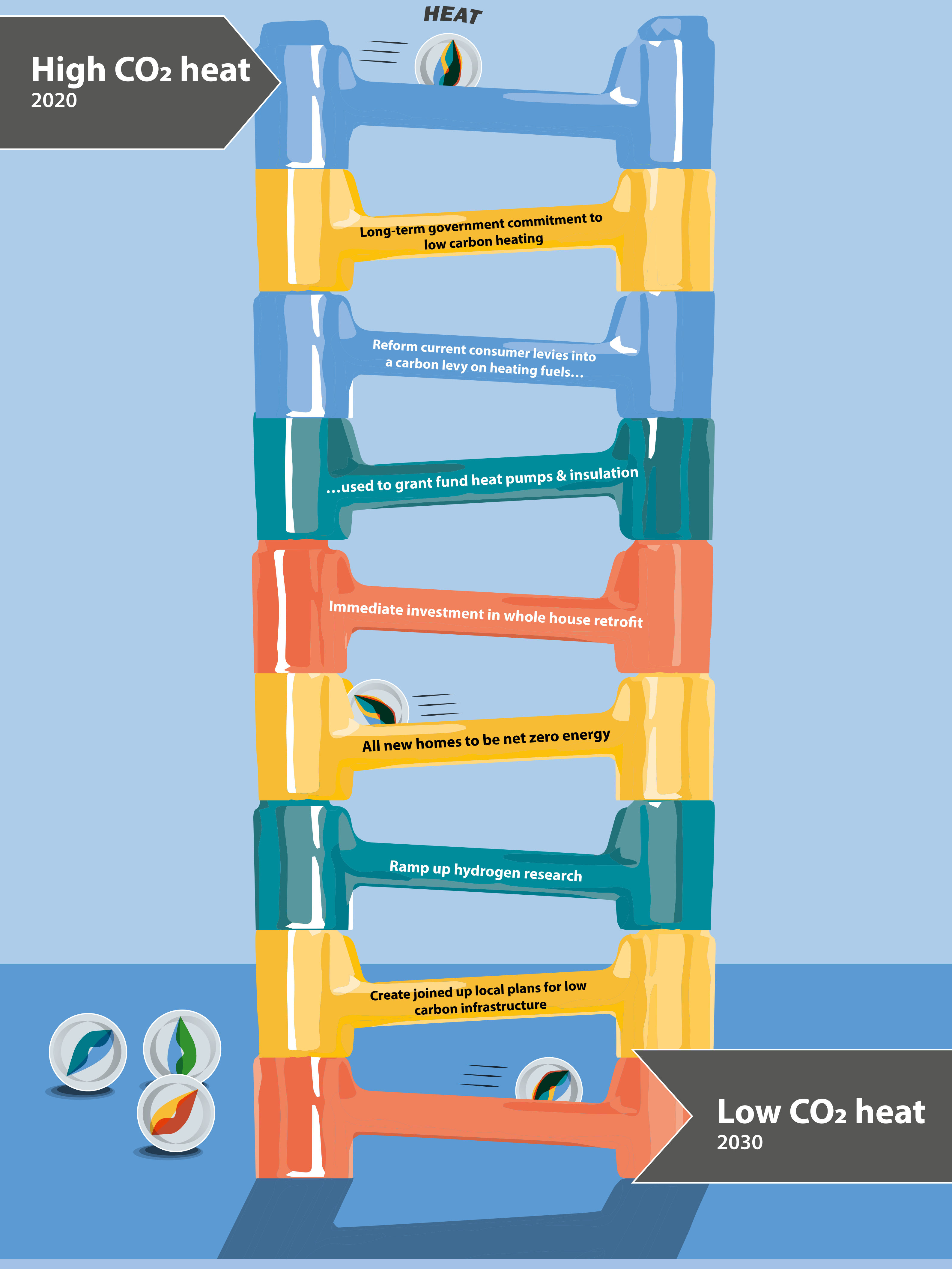
1.3. Harnessing and maintaining public support

The choice of a future heat decarbonisation pathway will have significant and long-lasting implications for consumers and businesses across the UK. A mixed approach will also require decisions to be made at regional and local levels. It is vital, therefore, that pathway decisions are well-made and backed by clear evidence and strong regional support, rather than from ideological positions. Whatever the pathway, the success of heat decarbonisation will ultimately rest with consumers and their willingness to embrace change.

The fact that each of the current potential pathways will require significant infrastructure and technology investment should not be considered an insurmountable barrier, given the imperative to decarbonise and the critical role that heat plays. However, the scale of strategic investment, its timing and associated uncertainty, does point to the need for significant policy intervention and that public finance will be required.

It is critical, therefore, that decisions are not taken in isolation or based solely on a techno-economic assessment. Consultation, engagement, knowledge sharing and ultimately democratic endorsement will be required to ensure that heat transformation is politically and socially sustainable. In this regard cities, regions and communities have a critical role to play to ensure that there is a democratic endorsement of any future heat pathways, and in order to plan for and deliver decarbonisation strategies.

The role of cities, regions and communities is the subject of the next paper in Regen's "Decade to make a difference" series.


High CO_2 heat
2020
HEAT
Long-term government commitment to low carbon heating
Reform current consumer levies into a carbon levy on heating fuels…
…used to grant fund heat pumps & insulation
Immediate investment in whole house retrofit
All new homes to be net zero energy
Ramp up hydrogen research
Create joined up local plans for low carbon infrastructure
Low CO_2 heat
2030

2. The decarbonisation of heat challenge

2.1. Heat and the climate emergency

The last year has seen a massive increase in public awareness and activism to force governments and policy makers to address the climate emergency. The urgency to act, highlighted by striking schoolchildren and wider public protests, has been underlined by the growing evidence that the world is already in a global climate crisis. The record temperatures of the past decade, which have increased the occurrence of wildfires, droughts, melting glaciers and other extreme weather events around the globe, are the clearest sign yet that anthropogenic greenhouse gas emissions are already impacting our planet's climate, and now threaten the environment in which we live.

Recent analysis (2018) by the Intergovernmental Panel on Climate Change (IPCC) warns that significant action must be taken in the next 10 years if we are to avoid catastrophic runaway climate change[1].

One immediate response from policy makers in the UK has been to set a new legally binding national decarbonisation target to achieve a more ambitious reduction of greenhouse gas emissions to net-zero by 2050[2].

'Net zero', along with 'climate emergency', have now entered the common parlance of policy makers and the general public as the UK's response to the challenge of climate change. At a local and regional level as well; devolved governments, cities, local authorities and many other organisations have now declared their own climate emergencies and have committed to achieving a net zero outcome[3].

The reset from an 80% reduction figure to net zero may seem like a modest incremental step but, as we will discuss further in this paper, it requires a far more radical approach to decarbonisation and a much deeper transformation of the UK's energy system. It removes the wriggle room that might have allowed energy sectors to believe they could continue emitting carbon. Instead it allows only minimum emissions that are otherwise impossible to address, that can be balanced or offset by continued active removal of greenhouse gases from the atmosphere.

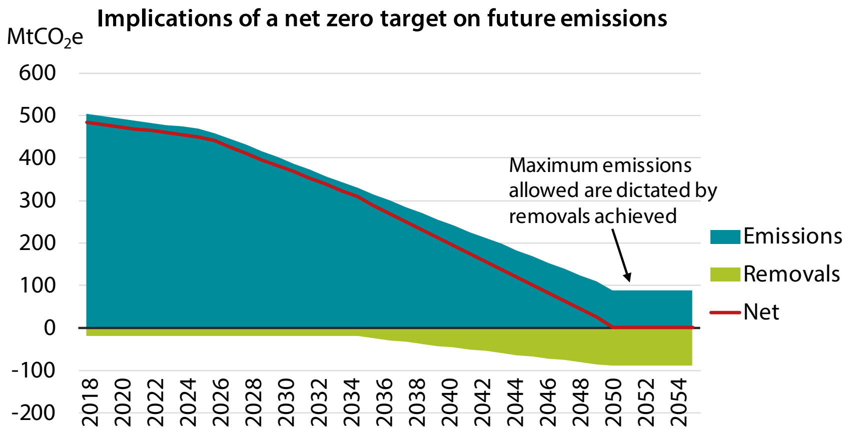


Figure 1. Potential route to net zero 2050, based on CCC further ambition scenario 89 Mt CO_2 removals. Regen analysis based on the CCC Net Zero Technical report, May 2019.

The CCC Further Ambition pathway assumes that 89 $MtCO_2e$/yr. could be offset by removal of carbon through a wide range of measures including negative emission Bioenergy Carbon Capture and Storage (BECCS), tree planting, sequestration and changes in land management.

These measures would however be very challenging and cannot be relied upon to offer a low-cost carbon fix.

Whether CO_2 removal at this scale can be achieved remains uncertain. In the context of heat this means that burning fossil fuels for heat in homes, commercial buildings and almost all industrial processes must be considered as being incompatible with a net zero carbon future. This fact requires a radical redesign of our heating systems and will have far reaching impacts for all consumers.

2.2. Scale of the heat decarbonisation challenge

In the past decade the UK has made significant progress to decarbonise the supply of electricity. The demise of coal fired power stations, and the increase in renewable electricity generation which now contributes around one third of the UK's electricity consumption has resulted in a 45% reduction (to less than 250g CO_2e/kWh) in electricity carbon intensity since 2012[4]. As the generation of renewable electricity continues to increase it is expected that electricity carbon intensity will be as low as 50g CO_2e/kWh by the end of this decade and must be less than 20g CO_2e/kWh at net zero.

Progress to decarbonise heat and transportation has been much slower and is expected to have a far greater impact on the end consumer. In the case of heat, which accounts for over 165 $MtCO_2e$ or 37%[5] of UK greenhouse gas emissions, progress has been especially slow. This puts the UK towards the bottom of the league table of European countries in terms of the proportion of heat sourced from renewable sources, even including the reclassification in 2016 of commercial air-to-air heat pumps usually installed to provide cooling to assume they are also providing low carbon heat.

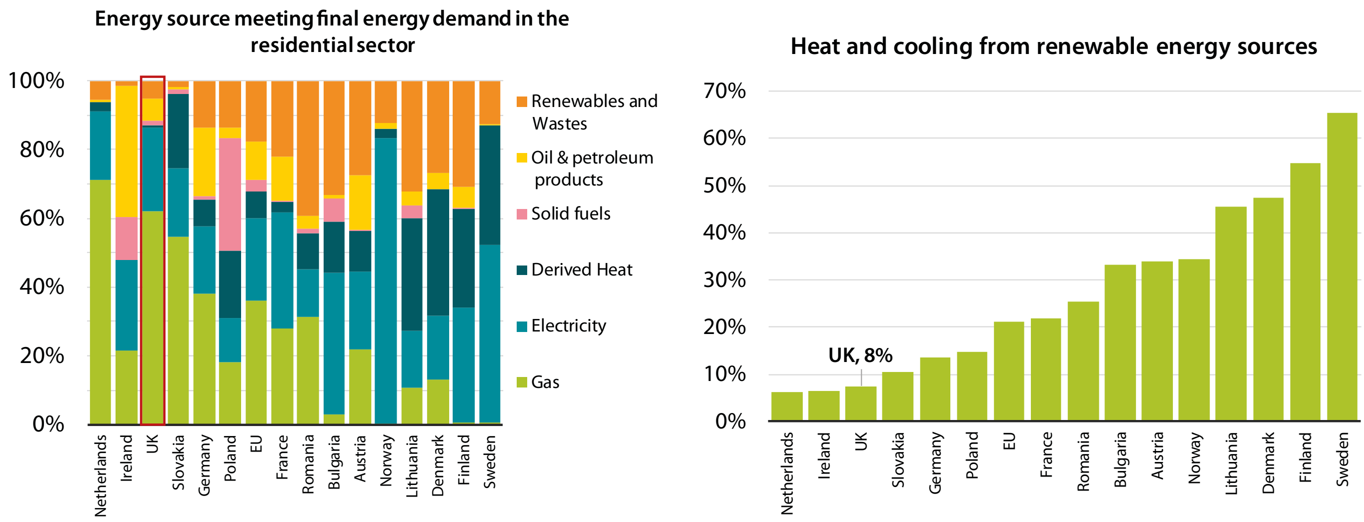


Figure 2. Energy sources and use of renewable heat is highly varied across the EU states. Source: Eurostat Data.

Heat is therefore widely recognised as the most difficult and far reaching decarbonisation challenge. There are some fundamental factors which highlight the scale of the challenge ahead:

- Approximately 75% of heat in domestic and non-domestic buildings in GB is fuelled by natural gas[6], with the majority of this used in our homes
- Around 85%, of the 28 million GB households, are connected to the gas grid[7]
- In addition to delivering relatively cheap heat, the gas networks also meet large daily and seasonal demands. National Grid has forecast that during the winter 2019/20 it will deliver almost 4 times as much energy through its gas transmission network as its electricity transmission network. On a peak day this could be circa 5 TWh, more than five times the energy that the electricity transmission network will supply[8]
- Although UK industrial output has fallen, 38%[5] of heat related emissions are attributable to industrial processes in plants which have been designed around the use of fossil fuels
- Circa 10% of GB households use electricity as their main source of heating, these households are twice as likely to be in fuel poverty[9].

In addition to understanding the scale of the energy challenge it is also important to consider the state of the UK building stock. The current stock is characterised by homes and commercial properties which were poorly built to relatively low thermal efficiency standards. This is partly influenced by the relatively slow turnover and replacement rate for older UK housing. However even in new developments, due to the reluctance of successive governments to adopt ambitious low carbon building standards, the UK continues to build homes and commercial properties which are well below the standard needed to achieve net zero.

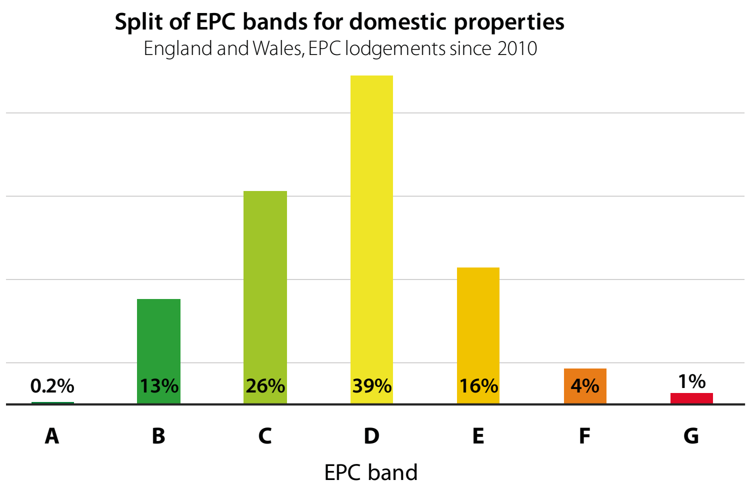


Figure 3. Energy Performance Certificate (EPC) banding in England and Wales based on lodgements since 2010. Note: EPCs are a limited measure of energy efficiency.

Even with an expected uplift in the current rate of new house building, it is expected that most of the current housing stock will still be standing in 2050 and will by then make up 80% of the total stock[10]. This presents a difficult choice between a massive investment programme to retrofit efficiency measures to the fabric of existing buildings, an accelerated programme of building replacement (which will entail higher embedded carbon), or an acceptance of much more expensive heating bills in the future.

What we have

- Low building standards
- An ageing building stock with poor efficiency and high heat demand
- Relatively cheap (per unit) and convenient heat supply via the gas network
- High levels of fuel poverty and low levels of wellbeing
- Industrial processes that are still designed around fossil fuels
- High carbon emissions

What we need

- Highest building standards
- Improved building fabric with lower heat demand
- Affordable, convenient low carbon heat supply
- The eradication of fuel poverty
- A shift in industrial heat demand to low carbon fuels
- Zero carbon emissions

Making a difference:

- **The decarbonisation challenge is also a building challenge. For too long the UK has permitted substandard and inefficient building development.**
- **Change must start now with the adoption of new standards for zero carbon homes and commercial properties.**

2.3. The role of natural gas and the gas network

Following coal and oil, the development of gas fields around the UK continental shelf (UKCS) in the late twentieth century has led to a third fossil fuel boom. At its peak in 2000, the UK produced over 1,260 TWh of natural gas, mainly from UKCS sources in the North and Irish Sea. Since 2004, gas demand has fallen, however natural gas production from the UKCS has fallen further and the UK has become a significant natural gas importer through European pipelines and Liquified Natural Gas (LNG) shipments, mainly from the middle East.

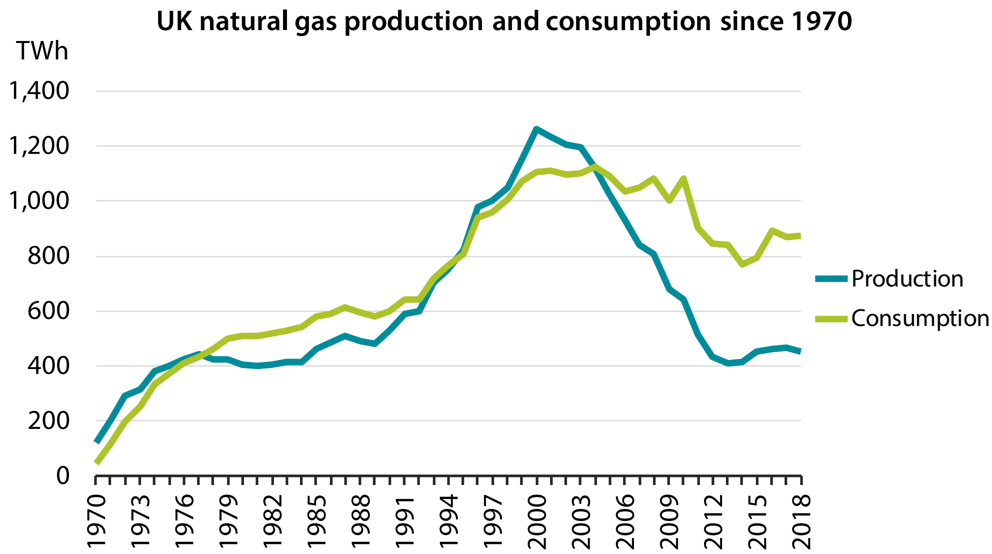


Figure 4. UK natural gas production and consumption since 1970[11].

The availability of cheap and secure natural gas supplies led to a "dash for gas" within the UK energy sector. From 1991 to 2000, thirty four[12] gas fired, Combined Cycle Gas Turbine (CCGT), power stations were built by the newly privatised electricity sector, as gas fired electricity generation rocketed from almost nothing in 1990 to 157 TWh in 2008[13].

The "dash for gas" also saw a significant increase in the amount of gas network infrastructure. The UK now has nearly 7,500 km of high pressure transmission network and over 280,000 km of gas distribution network, which brings over 600 TWh[14] of relatively cheap and accessible fuel energy to 21.5 million UK customers each year. The gas network also addresses the issue of peak demand, providing the ability to store and deliver energy during the peak winter period. Whether and how this infrastructure can be best used in a net zero energy system is one of the key questions that the industry and policy makers now face.

Figure 5. The UK gas grid has nearly 7,500 km of high pressure transmission pipework and 280,000 km of distribution network. © Copyright Peter McDermott and Wales & West Utilities.

In terms of UK carbon emissions, the "dash for gas" has historically had a positive impact since burning gas has a lower carbon intensity than coal or oil. In the power sector, decarbonisation through renewable energy generation and energy efficiency has been supported by the displacement of coal fired power stations with gas fired CCGT, and more recently by less efficient (but more flexible) Open Cycle Gas Turbines (OCGT) and reciprocating engines. As a heating fuel, burning gas through an efficient boiler system has become a relatively low cost means to provide both space heat and hot water, with lower emissions and better air quality than either coal or fuel oil.

Looking ahead however, towards a net zero carbon future, it must be recognised that natural gas is a fossil fuel and a significant source of carbon emissions. At the point of consumption, burning natural gas in a boiler or industrial process releases around 184 grams of CO_2e for every kWh of fuel energy input (the full supply chain and lifecycle emissions of gas are higher[15]).

Burning natural gas will no longer be sustainable as a main, or even as a hybrid, source of heating in a net zero carbon economy.

Making a difference:

- **Burning fossil based natural gas to provide heat in homes, commercial buildings and almost all industrial processes must be considered incompatible with a net zero carbon future.**
- **This requires a radical redesign of our heating systems and will have far reaching impacts for all consumers.**

2.4. Energy cost and the fuel poverty challenge

While energy cost is not the only measure of consumer value (convenience, reliability, ease of use and increasingly carbon emissions are also important), cost is a critical heat decarbonisation challenge. Unfortunately for most UK consumers, cost is often equated with the marginal unit cost of fuel and not the overall cost of energy, or indeed the whole life cost of a heating and energy efficiency solution. The lack of true cost visibility for energy consumers, and in the market generally, is a significant barrier to the low carbon transition.

Heating costs vary greatly depending on the quality of building, heat demands, regional weather and seasonal impacts. It is potentially misleading therefore to focus on average costs; a key success factor for future decarbonisation will be to better understand energy cost drivers and to target consumers facing higher energy bills.

The cost of energy relative to income is important. Depending on which measure is used, between 10% and 13%[16] of households are considered to be living in fuel poverty. In other words, a significant proportion of their low income is spent on energy. In northern areas of the UK the figures are much higher, in Scotland the fuel poverty figure is close to 25%[17]. There is also the worrying issue of hidden fuel poverty affecting people who may have low bills because they simply can't afford to heat their homes.

The high occurrence of fuel poverty has been described as a national shame, leading to an estimated 16,500 excess winter deaths in 2017/18[17]. Whether the root cause of fuel poverty is energy cost, or absolute poverty combined with bad housing, any solution to heat decarbonisation must consider the impact on the fuel poor and vulnerable consumers. Decarbonisation will require radical measures, including energy pricing that reflects the carbon impact of different energy solutions. Such measures will have distributional impacts of different consumer groups and must be taken in the context of a wider package of actions to address fuel poverty, improve energy efficiency and ensure a just transition for all consumers.

To date many of the steps taken to reduce energy costs and address fuel poverty have revolved around the use of natural gas. This includes boiler replacement schemes, and continued investment in gas network expansion under the Fuel Poor Network Extension scheme, which it is forecasted will have supported 97,000 new gas customers to connect to the mains by 2021[18].

The logic to consider natural gas as a solution for fuel poverty is based on the simple cost arithmetic that the per kilowatt hour unit costs of domestic gas, at around 4.17p per kWh, is considerably less than the cost of other fuels including electricity at over 16p per kWh[19]. Off-peak Economy 7 rates are better, but even so it is significant that those heating with electricity are twice as likely to be in fuel poverty compared to gas[9].

As this paper will argue, there are significant price distortions in the energy market which need to be addressed to give a positive signal to create a market for low carbon heat and encourage consumers to switch to low carbon heating and efficiency solution. Nevertheless, whether the low carbon solution is based on electrification or other fuels such as hydrogen, the question of overall solution cost must be addressed.

2.5. People are at the centre of the heat decarbonisation challenge

The discussion about cost and fuel poverty is a reminder that the transformation of heat must be led and embraced by individual consumers. While there is broad support for decarbonisation, no amount of regulation or subsidy will be enough to overcome the barriers to new heat technology adoption unless there is a strong 'pull' and acceptance from householders and businesses to change.

Whereas electricity might be considered a commodity, people don't really care how it is generated as long as it is available, heat technologies are meeting some of our most basic human needs – space heating for comfortable surroundings, hot water for cleanliness and energy to cook food. Consumers will therefore have a more hands-on relationship with their heating systems which are very often part of the fabric of the building in which they live or work. Replacing those heat technologies will require significant consumer agreement and behavioural change, as well as financial investment.

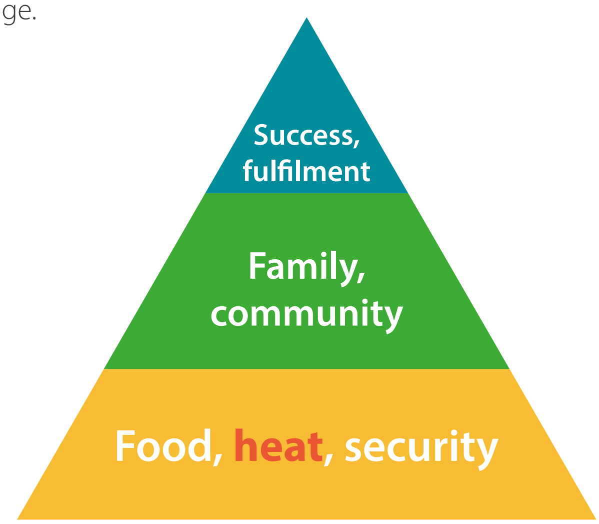


Figure 6. The importance of heat in underpinning our daily lives. Adapted from Maslow's hierarchy of needs.

The climate emergency requires that we change the way in which we provide heat, by both reducing the demand for it and by switching to low carbon sources of energy. Engaging consumers and businesses to raise awareness of the imperative to decarbonise heating is however only the start of a conversation, which must address the question of how this can be achieved in a manner that delivers value to the consumer and ultimately creates a consumer demand for low carbon heat and efficiency solutions.

Making a difference:

- **Decarbonisation of heating must begin by engaging consumers in the decarbonisation challenge and by creating consumer demand for low carbon heating solutions.**
- **Moving the discussion beyond unit costs to consider whole energy and heat solutions is critical.**
- **Reliance on cheap fossil fuels can no longer be considered a solution for fuel poverty.**
- **Transformation at this scale must be accompanied by measures to address fuel poverty, protect vulnerable consumers and ensure a just and fair transition to new heating solutions.**

3. Current heat decarbonisation policies are not working

3.1. Renewable Heat Incentive fails to fire

The government's flagship policy, the Renewable Heat Incentive (RHI), was designed to kick-start the UK towards meeting a target of 12% of heat energy from renewable sources by 2020[20]. By any measure this policy has so far failed to deliver.

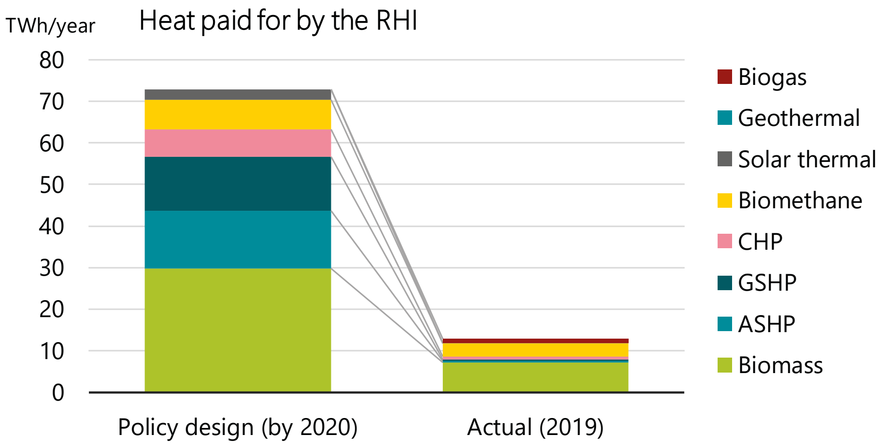


Figure 7. The RHI is only funding ~18% of the heat expected at its inception.

In late 2011, as the RHI was being launched, it was expected to stimulate 'nearly two million installations of renewable heat technology' resulting in circa 73 TWh of additional renewable heat generated per year by 2020[21].

To date only 94,767 installations have been accredited under the scheme and, in 2019, only 12.8 TWh of heat was supported by the scheme[22,23].

The 2019 Department of Business, Energy and Industrial Strategy (BEIS) report, **"Low carbon heat: progress on developing a sustainable market"**[24] which looked at a wide range of success factors and measures of progress in the market for low carbon heat, gives an insight into the broader picture behind the RHI figures.

Positive indicators measured by BEIS show that the renewable heat sector has grown (in terms of turnover and staff) and that supply chain costs are falling, especially for non-domestic renewable heat schemes where there has been some increase in biomass and biomethane production. Overall however, and especially in the domestic heating sector, the adoption of new heating technology has been painfully slow with deployment rates now significantly below their peak in 2014/15[25]. This is particularly true in existing buildings for which only around 56k heat pumps have been accredited under the RHI scheme.

The broader market indicators also show little evidence of progress. Worryingly, the supply chain for heat technology installers has contracted, with 16% fewer Microgeneration Certification Scheme (MCS) accredited installers of heat pumps compared to 2011[26].

Even more significantly public engagement in heat decarbonisation has been in decline with an overall reduction in awareness of low carbon heating technology from a high point of 78% in December 2013, to a five-year low of 57% in December 2019[27].

Falling public awareness is an extraordinary outcome given the massive increase in climate emergency publicity and shifts in attitudes towards renewables, plastics and other environmental issues. Low public engagement, and a weakening supply chain, not only has an impact on the rate of technology adoption but also has a significant impact on the cost of low carbon heat technologies. One heat pump manufacturer told Regen that their "cost to sell" heat pumps was at least double the current manufacturing costs. The cost to sell, to educate, inform and persuade customers, as well as providing system design and post installation support, was high even when working with a relatively well-informed housing association or property developer.

The machinations and complexity of the RHI scheme has itself proved to be an additional barrier and "cost to sell". From that respect a return to a more simplified upfront grant-based approach may be more appropriate for most domestic and smaller non-domestic energy consumers and would be easier to administer.

3.2. Energy efficiency – faltering deployment rates

The UK's other key policy measure, the Energy Companies Obligation (ECO), has sought to establish a market for energy efficiency. However, while many insulation measures have been installed via this mechanism in its early years, the rate of deployment and funding has significantly slowed since early 2014.

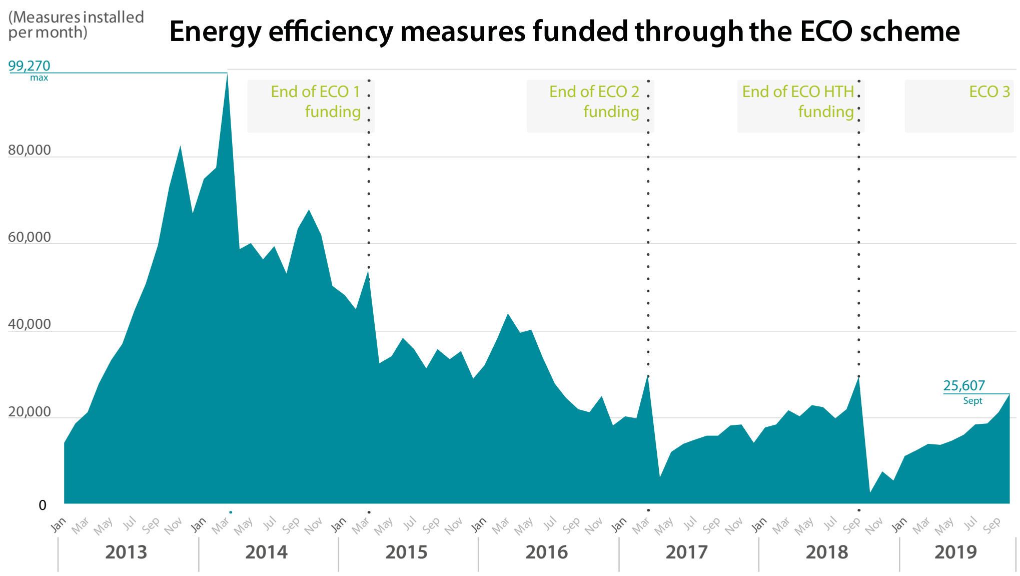


Figure 8. Deployment of measures under each phase of ECO.

Tracking the uneven progress of the ECO scheme provides strong evidence that policies which only address the funding barrier are insufficient to create ongoing demand, or to drive down costs, with the result installations drop as soon as the funding stop[28].

There are some great examples of projects, companies and schemes that have delivered exemplary heating and energy efficiency solutions. Some of these case studies are highlighted in this report. However the stop start nature of ECO funding, and the "peaky" energy efficiency market, has created an uncertain business model for the supply chain, who have been unable to invest in new product and staff skills to improve the standards and quality of what they are able to offer. It has also encouraged the supply chain to focus on the easiest and most profitable measures, and in some cases has led to examples of poor quality work damaging homes[29].

Policy measures have not created a highly skilled supply chain ready to upscale to tackle the massive challenge to retrofit the UK's building stock and, as the easy measures are running out, the supply chain has started to contract.

CASE STUDY

Ramping up the supply chain to deliver at scale - supply chain capability and standards

In the last half century we have seen significant change in our infrastructure; UK households have adopted central heating systems where there were previously none.

Alongside this change a large industry has developed, to the point that approximately 1.5 million gas boilers are replaced each year in the UK[30].

If policy mandated that all gas boiler replacements must instead of a like-for-like swap be a low carbon or low carbon ready alternative (e.g. a hydrogen ready boiler, a heat pump, district heating ready connection), then the conventional domestic gas boiler population could be reduced to zero in just over a decade.

There are over 135,000 registered gas engineers in the UK who could be mobilised to move 1.5 million homes a year onto low carbon heating

To make this change, the number of heating engineers qualified to fit alternatives to fossil fuel boilers will need to increase; the MCS currently lists only 797 businesses accredited to install Air Source Heat Pumps (ASHP)[33].

Gas engineers, easily capable of retraining to deliver these technologies if there is demand, are those best placed to advise a consumer on alternatives (they are also often the most trusted[34]). This industry of engineers must be prepared for another shift in the heating technology they deliver with widespread training on low carbon solutions.

The supply chain is likely to require support for training in the following areas:

- PAS 2035 for construction professionals
- Registered gas engineers to transfer their skills to install and maintain low carbon heating systems
- Revisions of Part L and Part F of the building regulations (for those registered in competent persons schemes).

3.3. Consumers receive mixed messages

At a fundamental level, both the RHI and ECO have struggled from a lack of public engagement and the absence of any underlying imperative for consumers to change their heating technologies. As one heat technology supplier described progress to date, "rolling out the RHI has been like trying to push water up a hill".

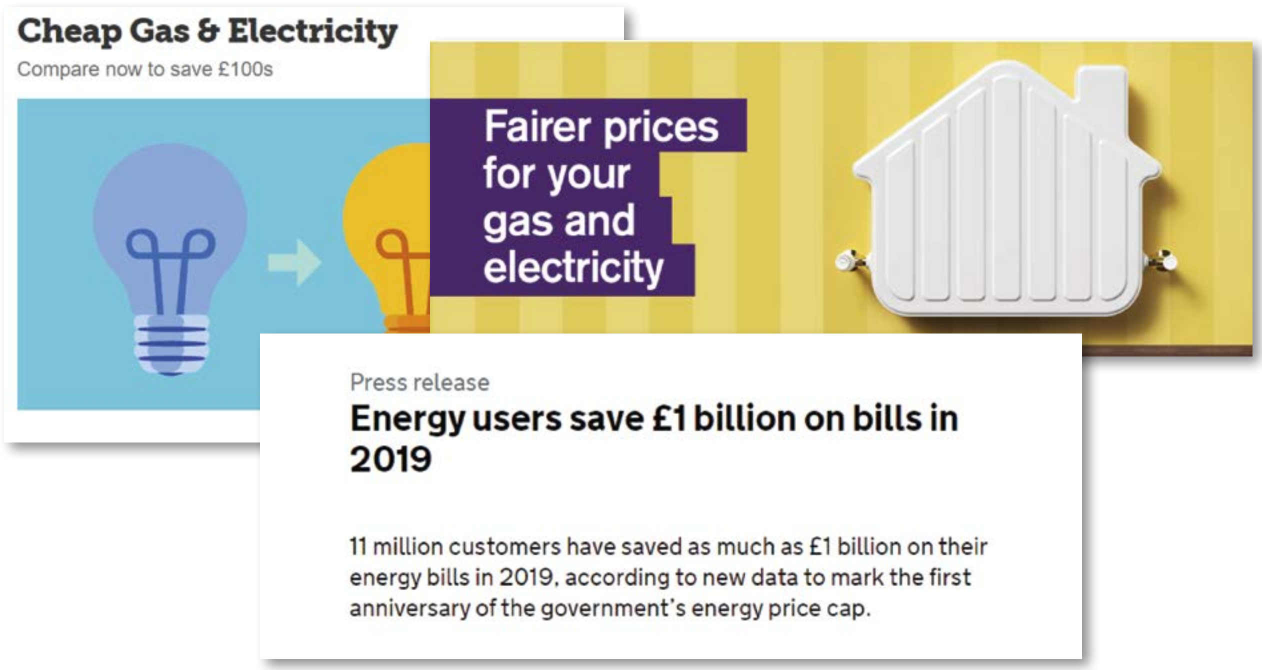
Without a strong pull from consumers wanting to adopt low carbon technology, no subsidy-based scheme will be successful. This applies both to domestic householders and to businesses and commercial heat users. In fairness to BEIS and other policy makers, this weakness in current heat and building policy has now been recognised and it is hoped that the redesign of the RHI will be supported by a relaunch in 2021.

In part the problem is that neither the RHI or ECO has been supported by an allied campaign to promote heat decarbonisation and efficiency. Whilst energy industry professionals might be clear on what 'energy efficiency', 'low carbon' and 'renewable technology' mean, and how each can contribute to decarbonising heat, the average consumer (domestic or commercial) finds the heat technology landscape confusing and opaque.

Even worse, UK consumers have in fact received contradictory and mixed messages.

- **The early focus on gas boiler replacement** and, continued support for gas network expansion to address fuel poverty, has given the message that an efficient gas boiler is still the benchmark
- **Market distortions have skewed consumer choice and policy.** The most significant distortion is that domestic environmental levies sit predominantly on electricity and now make up over 20% of an electricity bill[35], compared to less than 2% of a gas bill, despite both delivering a similar carbon impact per kWh of energy consumed[15]
- **The energy price cap and continued political focus** on energy unit cost has masked the need for efficiency and decarbonisation
- **The EPC scheme**, which should have shined a spotlight on energy efficiency, has largely been ignored by house buyers and renters, and has in any case morphed into a proxy measure of energy unit costs
- **The RHI incentivises generation of heat**, implicitly dis-incentivising its efficient use, and in some cases encourages profligate use of low value heat
- **Energy efficiency has dropped out of the mainstream.** The targeting of ECO measures to low income households may make budgetary sense, but it has failed to engage with the mainstream of householders, landlords and developers who may be in a position to enact measures
- **The delay and lack of clarity around new building standards** has allowed housebuilders and developers to continue to market and sell sub-standard inefficient housing[37]

Energy costs are clearly a very valid consumer issue, which must be addressed as part of the decarbonisation journey, but the overriding focus in the UK on energy unit costs per kWh, which has been encouraged by poor political messaging around price caps[38] and other aspects of the energy market, has masked the need for a broader discussion about longer term efficiency savings, building standards and the need to decarbonise. Instead, the message received is that natural gas is cheap, and all other measures are necessarily expensive. The great irony is that while the UK has comparable energy unit costs with other parts of Europe, our poor quality housing stock and poor insulation means that we will continue to face higher overall energy bills.



3.4. Absence of a wider market stimulus

In combination the RHI, EPCs and energy efficiency measures under ECO have failed to create a market led stimulus for low carbon heating. This problem is systemic of the UK housing and commercial building market, where property owners and rental customers have failed to put a sufficient premium in terms of higher property value, or rental value, on low energy cost and low carbon buildings.

A root cause of the market failure might be the lack of knowledge about unfamiliar, and potentially difficult to understand, technology and the visibility of future energy costs, including the potential cost of carbon. There is also a fundamental barrier that changing heat technology requires at least some degree of up-front investment and incurs a degree of disruption, which can seldom be considered at the point in time of boiler failure, when most people think about replacing their heating system.

Subsidising heating solutions through an incentive scheme like the RHI is one way to stimulate consumer demand but an incentive scheme can only be effective if there is a wider market stimulus. As this paper will discuss, establishing a carbon price and other regulatory measures and incentives that can target the property and rental markets need to be implemented alongside the scheme to create an effective market stimulus package. In the next chapter the paper will discuss how such a market might be created.

Making a difference:

- **Consumer engagement is critical for both commercial and domestic customers with clear and consistent messages aligned with policy measures.**
- **Coherent and long term policies are needed to develop a low carbon heat market and supply chain.**
- **Incentive mechanisms like the RHI or ECO need to be made easy for consumers to adopt and must be supported by a wider market stimulus.**
- **Start immediately with a set of ambitious and unequivocal standards for energy efficiency and new buildings.**

4. Transforming the market for low carbon heat

4.1. Normalising decarbonisation and capturing all benefits

The heating market presents several examples of market failure, and therefore a justification for regulatory measures, incentives and other interventions to support better market outcomes. Carbon and other greenhouse gas emissions are one of several externalities not fully captured within the market price. Others include air pollution, health, well-being and productivity which come from people living and working in clean and efficient homes and workplaces.

Policy actions must normalise decarbonisation within the well-established property and heat markets, enabling not just cost benefits but a range of non-energy benefits to be realised. These benefits include avoiding cold-related deaths[39], improving comfort, wellbeing, and increasing property value[40].

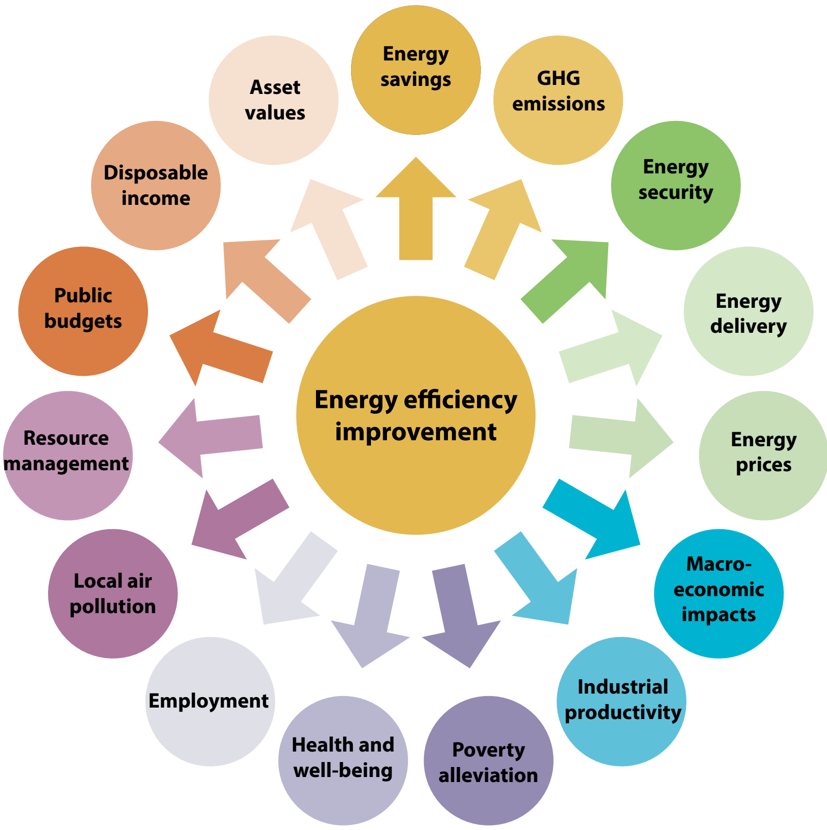


Figure 10. The multiple benefits of energy efficiency. Image courtesy of International Energy Agency (IEA).

Capturing these benefits will require a range of policy interventions, some via financial incentives and subsidies, whilst others may need tighter regulation or a nudge within an existing market to create a positive price signal. It is clear however, from the previous chapter that incentives that try to work against the prevailing market forces are almost certainly bound to fail, or to prove too expensive to be sustainable. Far better to have a package of measures that work together.

As an example, at present, £18 billion is spent annually by UK homeowners on the repair, maintenance and improvement of their buildings[41]. Industry and businesses also spend many billions per year on building upgrades, new plant and equipment. So, there is already a huge market for building and equipment maintenance.

An incentive to consider additional energy efficiency works, or a low carbon heat solution, alongside ongoing property investment, coupled with a knowledgeable builder who can recommend and implement the best measures, would help encourage property owners to look at energy efficiency. Even better, if the works increase the market or rental value of the property. This could be enhanced by mortgage lenders who would offer a better interest rate at the next re-negotiation of the mortgage due to the reduced energy costs and improved market value the work would deliver.

Coupling decarbonisation with changes that consumers want is key, so that the steps to decarbonisation are normalised rather than sitting in the 'too difficult and risky' box.

4.2. Redistributing existing environmental levies – based on a carbon levy

A critical misalignment, or distortion, within the current heat market is the absence of a real and effective carbon price. This is most obvious in the market for domestic heat.

Not only is there an absence of a carbon price, the method of recharging existing domestic environmental levies of around £3.8 billion per year has created a significant distortion that favours higher carbon heating solutions.

- The domestic RHI is funded through general taxation, at a cost of approximately £100m a year.
- Domestic householders also pay an estimated £3.7 billion in environmental and social obligation costs annually, which is used to fund the Feed in Tariff, Contracts for Difference, ECO and other energy efficiency schemes.
- At present environmental levies are almost entirely levied on top of electricity charges and currently make up make a very significant 20.4% of the typical electricity bill compared to only 1.6% of the typical gas bill[42].
- Heating fuels with a higher carbon burden such as Liquified Petroleum Gas (LPG), heating oil and coal are subject to fuel duty (a general taxation) but bear none of the levy specific environmental costs. Heating oil fuel duties are heavily discounted.

This is a market distortion that contributes to the mixed messages delivered to consumers, in this instance that fossil heating fuels continue to be both cheap and acceptable. It also misses a significant opportunity, without increasing the overall consumer energy cost burden, to send a positive price signal to consumers to adopt low carbon heating solutions.

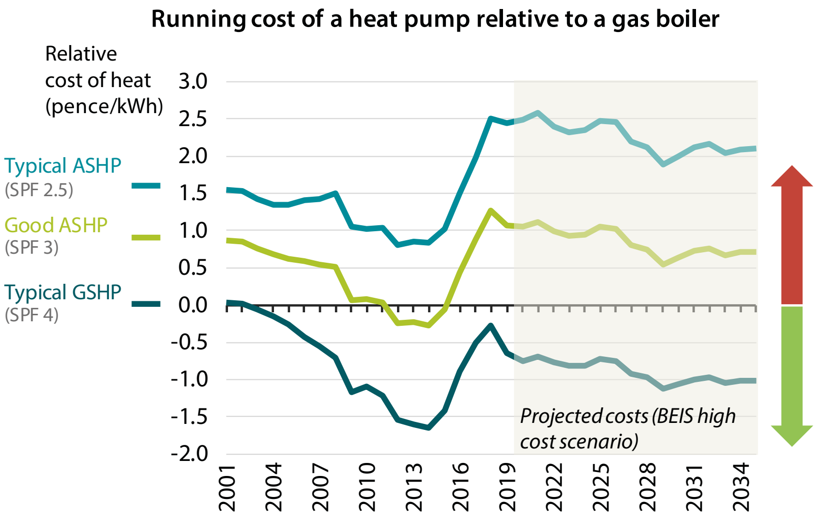


Figure 11. At current fuel prices, only efficient heat pumps systems will offer lower running costs compared to a gas boiler. This would change were pricing to reflect the carbon cost of the energy delivered.

Heat pumps have high capital costs, but due to their efficiency offer the opportunity to make best use of renewable electricity. Current market distortions mean that at present not all heat pumps are able to deliver lower lifetime running costs. This is borne out by analysis of historic and projected domestic energy costs (Figure 11[43]), which show that an efficient ground source heat pump (GSHP), with a high seasonal performance factor (SPF) of 4, has lower running costs than an equivalent gas boiler. Air source heat pumps (ASHP) with a typically lower SPF of between 2.5 and 3, have also struggled to compete with relatively low gas prices. In real world conditions however, this high SPF may not be met.

Removing the environmental levy from energy bills altogether, and adding them to general taxation could be a solution. However, a redistribution of this combined £3.8 billion levy based on the carbon impact of domestic fuels would be a first step in signalling the value of low carbon heat and provide a level playing field for the various low carbon heat technologies, including future green gases, to compete.

4.3. A carbon levy in practice

The concept of putting a direct price on carbon for emissions is already planned or enacted in 57 jurisdictions around the world[44] and is gaining more support in the UK as the most relevant and powerful tool to drive the levels of change required to meet the net zero target.

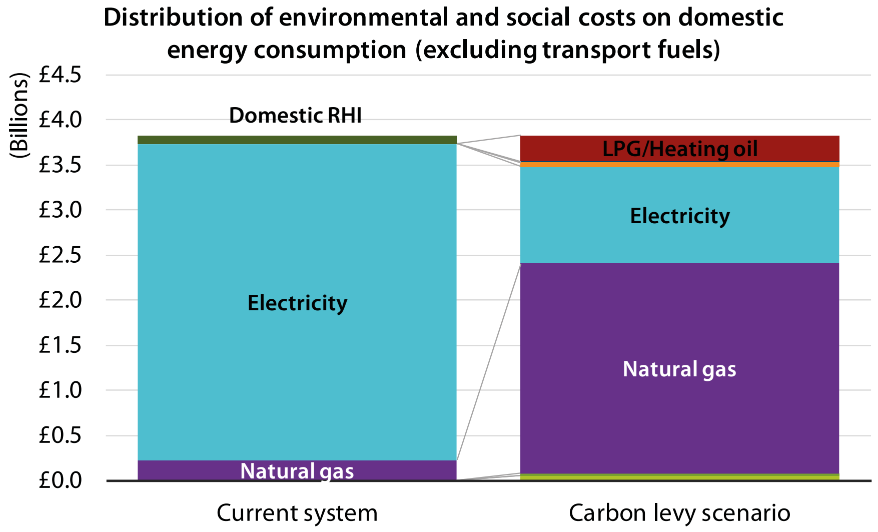
A carbon price levy will not in itself achieve the level of decarbonisation needed but it could be one of the key "making a difference" policies that the UK government could enact to put the UK economy on track to achieve full net zero decarbonisation by 2050. Both the National Grid Future Energy Scenario assumptions[7] and the Committee on Climate Change[46] have identified the use of carbon pricing as an important tool in the climate change armoury. So, some form of universal carbon price levy for heat and other forms of energy seems inevitable, albeit politically challenging, if policy makers are serious about demonstrating climate change leadership and achieving net zero carbon.

"By correcting a well-known market failure, a carbon price sends a powerful signal, steering economic actors towards a low-carbon future. This encourages technological innovation, large-scale infrastructure development, as well as the diffusion of carbon-efficient goods and services."

European Association of Environmental and Resource Economists, 2020

As a starting point, Regen analysis suggests that redistribution of the existing annual environmental levies of £3.8 billion into a carbon levy would result in a domestic carbon levy equal to £36 per tonne of CO_2e. This is a significant figure which would have an immediate impact on the domestic energy market, it is also close to the bottom of the global carbon price range of $40 - $80/t$CO_2$e that the World Bank[47] suggests is required to meet the Paris Agreement climate targets.

A lot more work is required to understand how such a carbon levy would apply in practice and how energy supply market prices may respond. However, in terms of today's average energy duel-fuel bill it would have the effect of reducing electricity bills by approximately 14% per kWh and increasing gas bills by 16% per kWh[48].



Reconfiguring the current £3.8 billion domestic environmental levies into a carbon levy of circa £36 per tonne of CO_2e.

Results in a decrease in electricity costs of approximately 14% per kWh and an increase in gas of 16% per kWh based on current prices.

Figure 12. A potential redesign of the current domestic energy environmental levy into a carbon levy based on relative emissions. Illustrative.

4.4. Market impacts of a domestic fuel carbon levy

The initial step to reconfigure the existing environmental levies into a new carbon levy, without an increase in the overall level of revenue raised, would not be sufficient to overcome all the cost barriers faced by the new heating and energy efficiency technologies, but it would help to reset cost benefit analyses and give a much stronger positive price signal. It may also prove critical for those schemes and technologies that may be on the cusp of viability especially in new developments, mass retrofit programmes and heat networks.

It could also form the basis from which carbon levies could become the main financial incentive once heat technology costs have fallen and subsidies have been removed. One of the key advantages of a carbon levy is that it would be technology neutral and support efficiency measures alongside new low carbon heat technologies.

An obvious immediate impact would be to reduce the cost of electricity vis-à-vis current gas prices, which will encourage the uptake of technologies such as ground and air source heat pumps. The application of the carbon levy could also be used to reinforce other smart energy price signals. For instance, the carbon levy applied to electricity could be flexed depending on the carbon intensity of electricity, encouraging more people to use electricity during times of higher renewable generation nationally or at a regional level.

The carbon levy would also increase the attractiveness of green gases such as biomethane and in the future potentially hydrogen. Increasing the demand for green gas in the energy mix either through blending into the existing gas network or via local energy delivery would jump start the market value and volume of Renewable Gas Guarantees of Origin (RGGOs)[49], or other green gas certificates, as energy suppliers look to source additional green gas within their fuel mix. For the future of hydrogen this will be an essential route to market.

4.5. Consumer impacts and their mitigation

A revenue neutral redistribution of the existing levies would in theory have little or no impact on the average duel fuel consumer since a reduction in electricity bills would be off-set by an increase in gas bills. It would however send a strong ethical signal that carbon emissions have a wider cost and could also send a market signal to expect that carbon costs will rise in the future. Communicating this, and engaging with consumers and energy suppliers, would be critical for the scheme success.

This should not, however, hide the fact that a new carbon levy will have several distributional impacts. The 10% of UK consumers using electricity as their main heating source would see a significant cost reduction. As noted previously these consumers are twice as likely to be in fuel poverty[9]. Consumers using above average amounts of natural gas, or other fossil fuels, for their heating would see a cost increase. This could be viewed as a reasonable redistribution of price incentives if consumers are heavy fuel users but may also impact low income consumers in poor quality housing and if unmitigated could tip them into fuel poverty. It may also adversely impact consumers in the colder north of the UK who already have higher than average heating bills.

Clearly this would have significant social and political consequences which the design of the new carbon levy would have to mitigate. The carbon levy could itself be banded or weighted to mitigate impacts on the fuel poor. This could also be done using complementary measures to improve energy efficiency, address fuel poverty and provide, for example, targeted winter fuel allowances. Applying zero VAT on low carbon heating and energy efficiency would be another obvious fiscal measure.

Making a difference:

- **Remove the existing market distortion and send a stronger carbon price signal by redesigning existing environmental levies into a new domestic carbon levy.**
- **Use the carbon levy to support new heat and efficiency solutions, reducing the need for a subsidy mechanism as technology costs fall.**
- **Clearly communicate the purpose of the carbon levy as part of a wider consumer engagement.**
- **Mitigate the distributional impacts by encouraging greater energy efficiency and protecting fuel poor and vulnerable customers.**
- **Apply zero VAT on all low carbon and energy efficiency measures and technologies.**
- **Coherent and long term policies are needed to develop a low carbon heat market and supply chain.**

4.6. Other market stimulus approaches

There is a very long list of other potential market stimulus measures which could be adopted to complement a carbon levy. Several of these have the objective to increase the market value (property or rental value) of buildings that have a higher degree of energy efficiency and low carbon heating, having the added benefit of increasing the attractiveness of the measures to consumers/homeowners.

Measures could include for example:

- Regulations to require minimum standards of energy efficiency and carbon emissions of rental properties
- Changes to rental bands and price controls which incentivise property owners to improve building fabric efficiencies to reduce energy bills
- Stamp duty or capital gains tax allowances to reward more building efficiency
- VAT relief for all energy efficiency and low carbon technologies and services
- Lenders could be encouraged to allow more favourable mortgage terms to householders (or businesses) with lower emissions and greater efficiency. Already this is beginning to happen[50].

All these market-based approaches could be used to increase the capital or rental value of low carbon homes and commercial properties. For this to be effective, however, we need a clear and reliable measure of building performance and efficiency. Now, this is done through the EPC scheme. As has already been highlighted, the EPC scheme is far from perfect, and has become more a measure of energy running cost rather than carbon, but it is currently the only widely used measure of comparable property efficiency.

Without redesigning the entire EPC framework and starting again, the EPC scheme could be adapted and enhanced. One way to do this would be to place more focus and visibility on the carbon metric within the EPC and weighting this above, or at least alongside, the measure of running costs.

A second reform would be to tie the EPC more explicitly to a decarbonisation plan for the building. Now, most EPCs are obtained as an administrative burden at the point of sale or rental without incentivising real action. It would be far better if the EPC came with a set of building specific recommendations that the homeowner or business could then implement in order to obtain a higher ranked EPC, both to meet future regulatory standards and access to the market incentives.

Decarbonisation plans for a building would need to determine cost effective energy efficiency measures then triage the building based on the complexity of the efficiency measures required – as outlined in PAS2035[51].

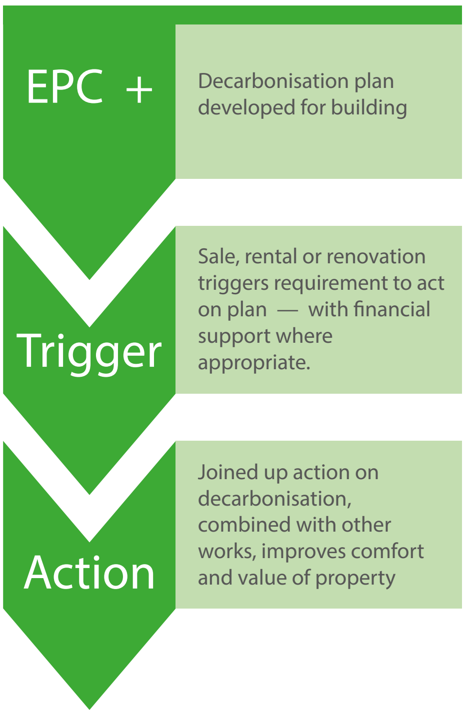


Figure 13. Potential route to bring decarbonisation into the normal building repair, maintenance and improvement cycle.

EPC triggered decarbonisation plans should also be tailored to align with local area energy plans (LAEPs) developed in collaboration between energy networks, local authorities, community and consumer group stakeholders. These could be informed, for example, by a decision tree that would point towards the most appropriate or favourable technology solutions within an energy planning area.

Potential decision tree for a building decarbonisation plan

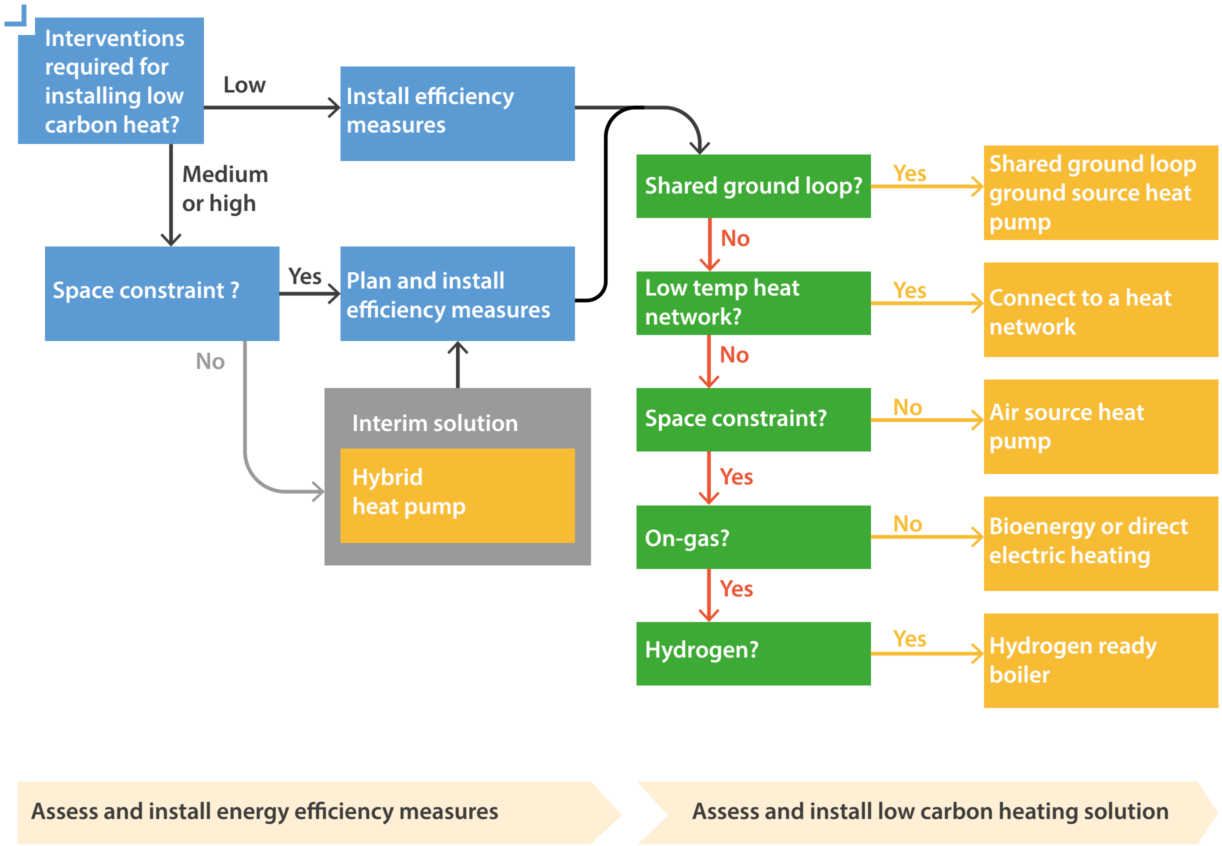


Figure 14. Potential decision tree to identify the optimal decarbonisation route for a building aligned with a LAEP.

Making a difference:

- Set regulatory standards and provide property market incentives to improve building efficiency and reduce emissions.
- Refocus the current EPC scheme towards efficiency and carbon reduction alongside running costs.
- Use the enhanced EPC+ as a trigger to recommend a building decarbonisation plan. Updated building regulations would require stages of this plan to be enacted at key stages such as sale, rental or renovation.

5. Offering the consumer something better

A carbon levy, combined with other regulatory and market incentives will stimulate consumer demand for low carbon heating solution, but it is very clear that providing a strong demand stimulus is only effective if there are solutions available that can meet the consumers' needs in terms of comfort, accessibility, ease-of-use and cost. Put another way, for a consumer centric product that provides a core utility such as heat, no amount of incentives and market sweeteners are going to encourage uptake unless the fundamental product offers a high quality and affordable solution.

Lessons can be learnt from the successful uptake of other technologies. The initial deployment of gas fired central heating, and the recent boiler replacement schemes, have been successful because they combined a strong market pull, subsidised or socialised investment, a good product that people understood and wanted, and a skilled supply chain of trusted[27] heating professionals who could meet demand.

Low carbon heating and energy efficiency products and services are starting from a much weaker position. As has been discussed, consumer engagement and knowledge is low, and the technologies and their long term cost benefit performance can be difficult to understand. Added to that the supporting supply chain is comparatively weak and, in some cases, consumer confidence has already been impacted by poorly designed solutions and business models.

There is an urgency to get on and deliver low carbon heating solutions at scale, in part to catch up on where we should have been in the last decade of slow decarbonisation and also to drive down costs, and quickly get to the point where the market has a momentum to carry itself forward. But it is also essential to maintain consumer confidence and to ensure that the right solutions are deployed in the right place, while maintaining consumer protection.

In the case of heat pumps for example, it is already well recognised that putting a badly sized heat pump system in a poorly insulated property is almost certain to lead to a disappointed customer. On the other hand, there are plenty of opportunities to roll-out and rapidly grow a sustainable heat pump market. This could be done by focusing first on new build properties, off-gas grid properties with expensive heating fuels and deployment alongside energy efficiency measures. Offering early adopting consumers, a better solution, that they will then champion, is essential to build momentum in the market that will eventually help to drive down costs.

New business models associated with 'heat as a service' offers, and with shared heating solutions such as heat networks, must also offer consumers value for money, transparency and a high degree of consumer protection. In the case of heat networks, Ofgem has identified that, alongside measures to encourage investment, there is the need to ensure there is an equivalent consumer protection and regulatory safeguards in place[52]. This is essential to give consumers confidence that they will not become 'trapped' in an inappropriate heating scheme.

5.1. Building a sustainable consumer led market

The good news is that there is now a new wave of innovative solutions, plus new service models, that can deliver affordable low carbon heating and energy efficiency services for UK consumers. Some of these are ready to deploy at scale, especially in the energy efficiency and retrofit market, while others are still at the stage of demonstration trials and exemplar projects.

Speaking with our heat industry and stakeholder groups there is a strong sense that the market for low carbon heat is about to take off. While we have highlighted a few case studies there is not space in this paper to do justice to the wide range of exemplar heat projects that have been, and are being delivered by innovative companies, local authorities, housing associations and community energy groups.

5.2. Zero carbon new homes must pave the way

With an expectation that in the next decade around two and a half million new homes will be built[53], there is a significant opportunity to build energy efficient homes that use low carbon heat. Exemplar zero carbon housing can act as a catalyst to demonstrate the benefits of a modern low carbon home and set the standard to which all properties can be measured. The Stirling Prize winning Goldsmith Street development is a great example of a modern, affordable, low carbon development in which people want to live.

Building regulations that have tightened new-build fabric efficiency standards over recent decades, stalled at delivering zero carbon homes as recently as 2015, but could now take a step forward in the next five years via the Future Homes Standard[54] which is currently under consultation. It is clear that all new homes should built be to the highest standards of energy efficiency and with low carbon heating technologies.

Regen's consultation response[55] called upon the government to implement the highest net zero carbon standards to encourage a building renaissance and avoid the need for costly retrofit in 10 years' time.

The counterargument that efficient homes would cost more to build and would discourage affordable housing does not hold water. Studies and experience have shown that building to these standards over existing building regulations adds less than 10% to build cost[56], and that at the volumes we plan to build new homes in the UK (up to around 250,000 homes a year), this incremental cost would fall rapidly.

A national commitment to decarbonise heat, combined with incentives in the housing market, would increase the market value of a zero carbon homes and overcome developers complaints that additional efficiency measures do not create additional market value.

CASE STUDY

Goldsmith Street, Norwich – Stirling Prize winning housing

Goldsmith Street has been praised by judges of the prestigious Stirling architecture prize as "high-quality architecture in its purest, most environmentally and socially conscious form". The development of just over 100 homes uses high levels of insulation, offering not just low energy costs (expected to be less than £150/year) but also enhanced comfort for occupants. The homes are designed to demand as little energy as possible, utilising waste heat through a mechanical ventilation system and oriented to make the most use of solar gain in the winter, with shading incorporated to minimize this in the summer. Beyond the technical solutions deployed, the architects have placed an emphasis on creating a community centred around green spaces for pedestrians, delivering an improved community feel and 'safe' feel for families with children, resulting in high demand for homes on this development.

5.3. Energy efficiency – warm and comfortable homes for all

Supporting the roll-out of energy efficiency measures for existing homes and businesses is probably the most immediate and effective way to reduce heat carbon emissions and to reduce energy bills for customers.

An energy efficient building has fewer draughts, warmer surfaces and allows for lower temperature radiators or underfloor heating, all of these offer a more comfortable and balanced experience. Capturing these positive benefits is an essential feature of a revised and coherent approach to the decarbonisation of heat. The Committee on Climate Change report *UK housing: Fit for the future?* identifies a broad range of consumer benefits including improving indoor air quality, moisture control and thermal comfort that would reduce the risk of heat and cold related deaths associated with poor quality housing that is estimated to cost the NHS in England £1.4 – 2.0 billion per year.

A challenge for the UK is that many of the easiest measures in the most accessible properties have already been deployed. Of the UK's 29 million homes, just over 14 million have cavity wall insulation and 16.5 million homes have more than the most basic standard of 125mm of loft insulation[57]. While there is scope to encourage householders to continue to implement quick win measures, a more ambitious and holistic approach that address buildings fabric and prepares them for low carbon heating systems is needed.

Many of the currently untreated buildings are those deemed 'hard to treat[58], as they require measures such as solid wall insulation, floor insulation and secondary glazing to improve their efficiency.

New technical approaches, new materials and new ways of funding investment are therefore needed.

With 20% of the housing in England over a century old[63], these measures must also account for the sensitivities of traditional construction techniques to changes in the temperature or permeability of the fabric caused by retrofit measures.

Figure 15. Q-Bots offer a new approach to insulating below floors, opening up an otherwise tiny market that has the scope to deliver significant energy savings in older buildings. Image courtesy of Q-Bots.

CASE STUDY

Energiesprong – buy performance, not equipment

The Energiesprong approach aims to improve the look and feel of a building as well reduce its annual energy demand to net zero. Using off-site construction and delivery at scale, several large contractors are now delivering Energiesprong retrofits, increasing competitiveness and helping costs to tumble.

Figure 16. Insulated façade installed in Nottingham 2017, the first Energiesprong demonstrator in the UK.

In 10 years, a relatively small initial investment is putting low cost, comfortable and net-zero energy homes in reach of a huge retrofit market, lowering emissions and creating new jobs and investment.

Backed by a €50m government fund, in 10 years the approach has built a self-sustaining market that has delivered over 2,000 whole-house retrofits at no net cost to the occupiers, with a further 110,000 homes agreed, including some new build.

In comparison, the UK's Green Deal home improvement fund and cashback scheme cost £170m and resulted in 50,000 homes becoming more energy efficient, but nowhere near net zero energy demand.

Figure 17. 400 flats in Enfield served by a shared ground loop heat pump system. Image courtesy of Kensa Heat Pumps.

5.4. Innovative technical approaches

Shared ground loop heat pumps

Whilst a GSHP offers a higher level of conversion efficiency than an ASHP, the cost of investing in a ground array, as well as physical constraints, can be a barrier.

A solution that has been gaining traction recently is the use of a GSHP connected to a shared ground loop, effectively forming a mini-district heat network that operates at below ambient temperatures, using GSHPs to upgrade the heat to a useable temperature in each property.

This solution allows the capital and maintenance cost of the ground infrastructure (usually several boreholes or a longer ground loop) to be shared across end users, with minimal losses. Shared loop systems, like the recent award-winning Enfield Council housing project[64], can also offer low carbon heating solutions for multi-occupancy buildings.

At present this system has seen most success in social housing where the landlord is able to invest in shared infrastructure. This approach has significant potential in the broader building stock if the appropriate business model can be developed, possibly deployed by infrastructure entities such as the water or gas networks.

Heat networks

Heat networks offer the opportunity to provide low carbon, cost effective heat to homes and businesses, by using a network of pipes that transport heat (rather than fuel) into buildings. Traditionally these networks follow a centralised model that takes heat from an energy centre out to buildings, however many cities are now also looking to a decentralised approach that utilises multiple distributed sources of heat. It is important to note that heat networks are not inherently low carbon and as such is it essential that any new heat networks developed are able to make use of low carbon sources of heat.

Although well-established in many parts of Europe, heat networks are a relatively new technology in the UK, estimated to serve over half a million customers and meet just under 2% of UK heat demand[59].

Heat networks are unlikely to ever be the ubiquitous solution that gas currently is, however in dense urban areas, heat networks could play a significant role in the decarbonisation of heat and should be encouraged. The Committee on Climate Change have suggested that in order to meet the 2050 carbon targets cost effectively 18% of heat could come from heat networks[60]. In recognition of this, as part of its Clean Growth Strategy, the government is currently supporting several local authorities to develop projects. This takes the form of funding for feasibility studies and detailed project design through Heat Network Delivery Unit (HNDU) funding and through £320 million Heat Network Investment Project (HNIP) funding. In February 2020, £30 million of funding from HNIP was allocated to five local authorities and a further £10 million to two private sector projects[61].

To reach the level of deployment required to meet the 18% suggested by CCC, changes in regulation and consumer protection measures will be critical. Currently consumers living in buildings connected to heat networks do not have the same options of changing suppliers as those serviced by gas, meaning they do not have the opportunity to pay less than their supplier offers, or to exit due to poor customer service. Recognising this, BEIS is currently consulting[62] (to close in May 2020) with a view to Ofgem becoming a regulator of heat networks, setting in place consumer protection rules on matters including provision of service, pricing and others. With regards to challenges with building heat networks, the consultation proposes changes to the licensing regime for granting rights and powers for land access and street work rights. The consultation also refers to the need to make all heat networks low carbon, in order for the networks to genuinely contribute to the decarbonisation of heat. Currently only 7% of UK heat networks are fuelled by low carbon heat. One route to decarbonise heat networks would be to take advantage of sources of heat not viable at a fully decentralised level, such as waste heat from industrial and commercial users, re-distributing this to domestic or business users for space heating.

CASE STUDY

Having committed to achieving net zero carbon by 2030, Bristol City Council is an example of a local authority already committed to delivering low carbon heat networks.

The council has taken a city-wide approach and has used planning and designations to ensure the success of the role out of heat networks, through designation of a heat priority area. The council has then carried out a series of HNDU funded master planning and feasibility studies to strategically identify heat network sites, including sites of low carbon energy production and new developments.

Given the 2030 goal, all new heat networks in Bristol are to be fueled by sustainable sources, and the council has used planning requirements to ensure that new developments in these areas are built with the ability to connect to a heat network. Bristol City Council's Core Strategy ensures developers of new buildings will either connect, or provide a low carbon heat solution where this is not possible. A broader programme of stakeholder engagement and education is underway with a view to transitioning existing buildings on to networks.

In order to meet net zero by 2030, Bristol has launched the 'City Leap' initiative, which aims to attract £1bn of investment to transform the city's energy system, creating a cleaner and greener city. City Leap will create a partnership between the council and the business sector to grow its ever-increasing delivery of renewable, smart and low carbon energy projects.

CASE STUDY

Heat Storage Technologies – SunAmp

Energy storage will be a key technology in the future; complementing energy efficiency measures to help mitigate intermittent supplies and manage peak loads on our energy networks. By integrating storage into a heating system, end users can take advantage of lower cost energy when there is a surplus on the national system and store it for their own use at peak times.

Figure 18. Sunamp is able to offer a flexible new approach to storing heat. Image courtesy of Sunamp.

Sunamp has developed super compact, high energy density heat batteries that use patented phase-change material to absorb and release thermal energy during the process of melting and freezing. This technology stores energy from renewable and other sources and releases it as heat to deliver hot water and space heating when required. In a well-insulated building served by a heat pump, Sunamp heat batteries allow the building to time-shift its peak load and take advantage of lower cost off-peak energy.

As well as residential use, the heat batteries have large scale commercial and industrial applications to drive down energy consumption and carbon emissions for heating and cooling.

5.5. New markets and new solutions

Alongside the deployment of new heat technologies, a range of business models and new approaches will be required to deliver energy efficient retrofit and low carbon heating at scale whilst ensuring that consumers benefit from the low carbon transition in a way that is fair and equitable.

A national commitment to decarbonise heat will create a long term market, unlocking investment in skills, manufacturing capability and the research and development of improved products. There is significant potential for growth in the manufacturing sector as digitisation makes the bespoke off-site manufacture of solutions possible; an approach that would allow construction to mimic the automotive sector and deliver improved quality and performance at reduced cost.

New business models will be required in order to deliver a more joined-up and performance led approach to the improvement of our building stock, and to address the key challenge of how to provide funding and finance for building fabric improvements which will necessarily have very long payback periods. Previous attempts to do this through market led solutions like the Green Deal[66] programme have failed because they were not accompanied by a set of joined-up policies and did not overcome the lack of consumer trust and engagement. New approaches are however now being trialled which seek to address these issues through a combination of public/private partnerships and performance driven business models.

This approach has been demonstrated successfully in the Netherlands with the government initiated 'Energiesprong' programme[67] now nascent in the UK with projects in Nottingham[68] and Devon and several other European countries.

There are numerous other examples of the sector exploring new approaches at present such as Retrofit Works and interest in service business models such as 'heat as a service'[69]. Both approaches seek to address issues around performance led delivery and consumer confidence. These could include new roles for surveyors and other construction professionals able to coordinate fabric and technology improvements to deliver holistic solutions.

Retrofit Works – a solution for owner occupiers?

Retrofit Works is a model which addresses concerns about trust and quality assurance in energy efficient retrofit.

This cooperative model uses a central, transparent platform to allow building owners to procure and manage energy efficiency improvements. The work is quality assured and delivered by local, trusted partners and frameworks.

Central to this idea is the training of 'Retrofit Coordinators' who are the main point of contact between the householder, the supply chain and the Retrofit Works scheme. These Coordinators are trained to view properties holistically and provide the sort of advice on energy efficiency improvements on a house by house basis that simply isn't available in most parts of the country.

By providing a managed process using local providers, many consumer concerns around transparency and quality are mitigated.

Many local authorities and community groups are coming together and using the Retrofit Works method and platform to build their own cooperatives, providing a route to market for consumers, as well as bundling in financing and access to benefits.

Heat as a Service

Heat as a Service (HaaS) is used to describe a shift from buying fuel, to buying comfort or warmth. This places responsibility for owning, fuelling, maintaining and operating the heating system into the hands of the supplier, in exchange for improved comfort.

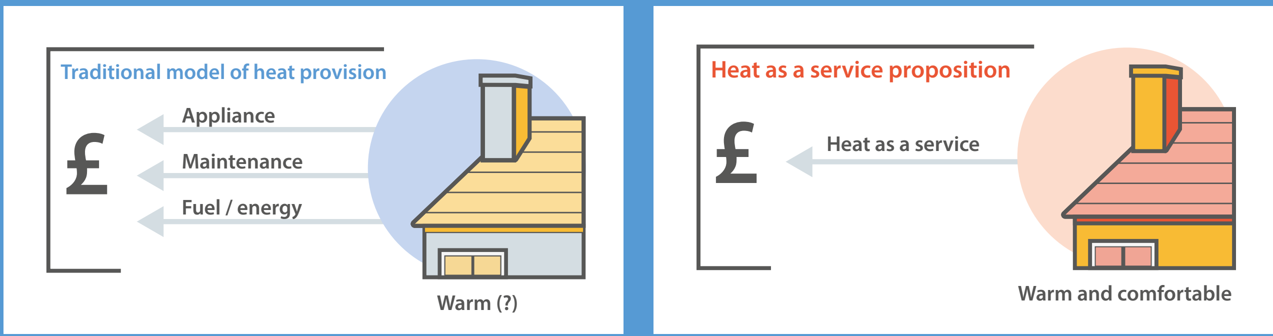


Figure 19. Heat as a Service could offer improved comfort and help to drive decarbonisation

A trusted supplier could be allowed to improve efficiency and install a low carbon heating system, as any associated risk for the end user has been transferred to them.

Whilst HaaS is still an innovative concept being developed and trialled by energy suppliers such as Bristol Energy[70], Energiesprong UK is utilising a similar approach to build a business case for whole house retrofit in social housing[71].

Where a trusted provider is in a position to offer HaaS this could be a successful means of repaying the capital costs of investing in heat decarbonisation solutions.

The design of this support will need to be mindful of the need to deliver change at a rate that ensures quality outcomes are maintained and the sector does not grow too quickly. Sustainable growth of the supply chain is dependent on increasing and maintaining consumer confidence, which can be very easily damaged.

Making a difference:

- **Continue to support the development and roll out of decarbonisation solutions that offer the consumer something better, building a consumer demand for low carbon heat.**

6. Creating a long-term pathway to net zero

6.1. Building local energy partnerships

After a decade of limited progress there is now an urgency to make rapid steps towards heat decarbonisation. The policy measures and actions that have so far been described, including support for the low carbon heat market, new zero carbon building standards, a massive uplift in energy efficiency measures and the rapid roll-out of low carbon heat technologies have the potential to transform how we deliver heat to UK homes and businesses.

However even with an enormous increase in efficiency and low carbon technology deployment, it will not be possible to reach a net zero target within the next decade. Regen's analysis looks at very ambitious decarbonisation scenarios and suggests that for most UK regions, a 40% reduction in heat related carbon emissions compared to current levels, is achievable within a 10 to 15-year period. Achieving this level of reduction would require a step-change in deployment, national policies and a great deal of collaboration and joint investment between regional stakeholders, local government, housing associations and the private sector.

Some UK regions have set a higher level of ambition and are putting themselves at the vanguard of the low carbon transition. The Welsh Government is working with its regional partners, with support from the Welsh Government Energy Service and Regen, to develop regional energy strategies and action plans. Many UK cities and regions have also embarked upon ambitious decarbonisation programmes linked to their climate emergency declarations.

Local decarbonisation leaders demonstrate that the most important thing that cities and regions can do in the next decade is to set out a clear strategy, and to put in place local partnerships, supported by communities, public bodies and businesses, that will sustain the energy transformation.

CASE STUDY

Scotland – Building pathways through local partnerships

The Scottish Government is using its devolved powers to set its own building standards and embark on an ambitious programme of energy efficiency measures and low carbon heat technology projects as part of a wider commitment[72] to reduce emissions by 75% by 2030 and by 90% by 2040, against a 1990 baseline.

To achieve this the Scottish Government has embarked on a number of initiatives including those aimed at householders such as Home Energy Scotland[73], and support for business consumers through 'Resource Efficient Scotland[74]', initiatives to encourage the development of district heat networks[75] and to address fuel poverty and ensure a just transition[76]. Scotland is currently consulting[77] on measures to accelerate energy efficiency deployment in the difficult to owner occupier sector.

The Scottish Government's decarbonisation programme is being supported by strong action at a city and regional level with local authorities drawing up Local Heat and Energy Efficiency Strategies (LHEES)[78].

Glasgow, for example, is working towards making the city carbon neutral, while Dundee has established a citywide sustainable energy climate action partnership to take forward a range of efficiency, fuel poverty and decarbonisation measures which are aligned with Scottish national initiatives.

Scotland's example of holistic thinking, a broad range of initiatives and engagement through local partnerships and the private sector is a blueprint of how decarbonisation pathways can be built.

6.2. Energy efficiency is a critical enabler – whatever the future pathway

There is still a degree of uncertainty around the technology solutions for low carbon heating. It is clear however that whether the solution is based on electrification or hydrogen fuels or heat networks, reducing heat demand and making our buildings more energy efficient is critical. This will not only reduce future energy costs but also peak loads, enabling electricity or hydrogen-based systems to be more affordable.

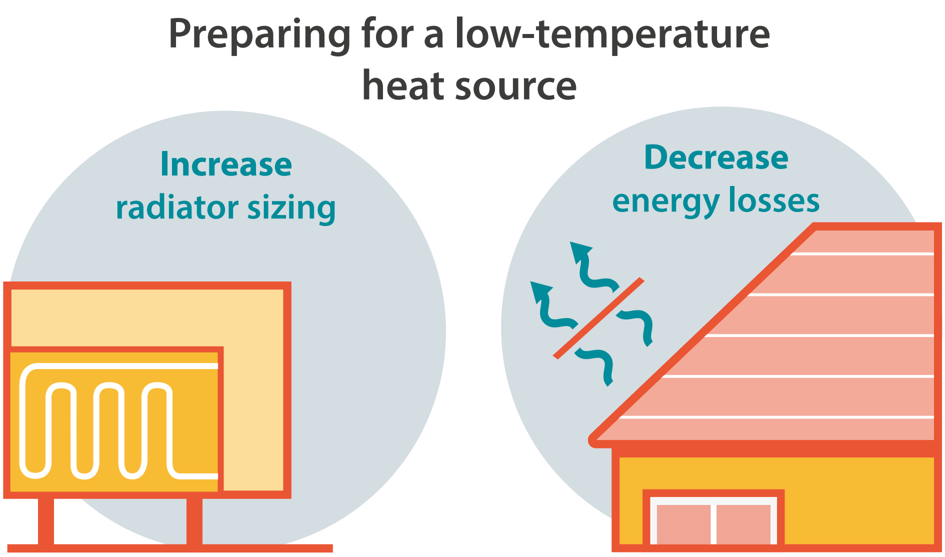


Figure 20. Typical preparations required to prepare a poorly insulated building for a low-temperature heat source.

The numbers of homes and buildings that require energy efficiency measures is significant. Regen's work helping cities and regions to develop their low carbon energy strategy has suggested that, depending on the approach taken, between 30% and 60% of properties could require significant efficiency improvements to achieve an overall 20% reduction in energy demand and annual energy savings of between £350 and £400 per household[79,80]. If replicated nationally that would equate to significant interventions for between 10 and 17 million homes.

Taking a broader view, the English National Housing Survey[81], identifies that 98% of the housing stock could benefit from at least one of the energy efficiency improvements set out by the EPC.

The Committee on Climate Change has flagged that "Energy efficiency retrofit of the 29 million existing homes across the UK should now be a national infrastructure priority". Part of the committee's argument for greater energy efficiency is the potential energy system cost savings which have been estimated at between £0.9 billion and £6.2 billion per year[82], with the highest savings for the electrification pathway.

The CCC has called on the government to deliver a fully-fledged roadmap for heat decarbonisation in 2020 and ensure that Treasury commits to allocating sufficient funding. The CCC's net zero scenario envisages the need for a significant roll-out of energy efficiency measures in new and existing homes including around 6 million cavity walls, 6 million solid walls and 21,000 loft insulation measures[6].

How this programme of works is implemented requires careful planning and a strategic approach. The UK has already suffered from the tendency to support piecemeal measures, cherry picking easy to treat properties to install the lowest cost measures, which make it much harder to finance comprehensive measures at a later date. There is also the difficult question of whether to provide very deep "whole house" solutions for fewer homes, or whether to apply broader measures to bring all homes up to a minimum standard. In some cases it may also be better to replace existing homes with new housing stock.

The appropriate strategy will often depend on very local factors and the state of the local building stock. The process of building fabric improvement therefore needs a high degree of local area planning and engagement. The extent of changes made to a building and its heating services will be dictated by cost and practicalities, for which a coordinated policy approach that recognises all the long term benefits and value flows of energy demand reduction in the long term.

In Scotland, where heat and energy efficiency policy has been devolved, the Scottish Government is now working with local authorities to rolling out the development of Local Heat and Energy Efficiency Strategies, which are intended to provide a more detailed implementation plan for efficiency measures within local areas. Several UK cities are also now developing more detailed heat demand and efficiency maps as part of their local energy plans and beginning to think strategically about the best way to tackle efficiency in both social housing and the owner occupier sectors.

6.3. Technology pathways

While a significant reduction in carbon emissions can be achieved by energy efficiency measures and the accelerated roll-out of current low carbon heat technologies, it is clear that reaching net zero will require a more fundamental change in the way that heat is delivered to homes and businesses.

This quickly raises long term strategic questions about what fuels will be used and the logistical and infrastructure challenge of how those fuels will be manufactured, stored and distributed.

Two main technology pathways have been identified:

- Electrification of heat energy delivery to take advantage of renewable generation and the falling carbon intensity of electricity
- Hydrogen fuelled heating for which fuel could be manufactured using low carbon electricity (by electrolysis to produce 'Green' Hydrogen), or by the reformation of natural gas (using Steam Methane Reformation (SMR) plus Carbon Capture and Storage (CCS) to produce 'Blue' Hydrogen)

There is a degree of uncertainty and debate within the industry and amongst policy makers about the relative merits of electrification versus hydrogen based pathways. In reality both fuel types offer decarbonisation opportunities, but also come with significant challenges in terms of energy cost, infrastructure requirements and potential consumer acceptance issues. There may also be an argument in favour of using both pathways on a regional basis.

In terms of energy costs, the current accepted view is that all pathways will require significant investment and entail some cost increases. The UK's Committee on Climate Change recently concluded that reaching net zero emissions in buildings 'is achievable but remains costly' [83]. The National Infrastructure Commission concluded that, at an overall level, the costs are similar regardless of the energy pathway[84]. A more recent study conducted by Imperial College on behalf of the Committee on Climate Change suggested that a hydrogen heat decarbonisation pathway would be the highest cost pathway towards zero carbon compared to electrification or a hybrid pathway.

It is clear that energy unit cost and energy system costs will remain a critical issue alongside:

- Meeting the peak daily and seasonal load challenge
- Defining a conversion or implementation pathway
- Providing solutions that are acceptable to the consumer.

It is not within the scope of this paper to give an in-depth review and recommendation of the different technology types, but there is an urgency now for policy makers at a national and regional level to make some key strategic decisions which will then enable the necessary investment to be made to support future technology pathways. There is also a need to ensure that the right governance structures are in place to ensure that whatever technology pathways are chosen have strong democratic support and will be able to garner sufficient consumer support to be sustainable.

6.4. Peak load challenge

Both the electrification and hydrogen pathways would have to address the peak load challenge. The existing gas network is able to provide in excess of 400 million cubic metres of gas, or 5 TWh of energy, on a peak winter cold day for heating and also power generation.

It does this by using the energy storage potential of the pressurised gas held within the gas networks (line-pack storage), which is then replaced by gas injection from a variety of sources including interconnectors, gas production fields, LNG and onshore gas storage (Table 1). A typical daily pattern involves depleting line-pack storage during the daytime and evening peak demand periods to be 'topped-up' during lower demand periods and overnight.

UK natural gas sources	Cold winter day delivery 2019/20	
	Million cubic meters gas	TWh
UKCS 'beach landings' from terminals connected to gas production fields	109	1.24
Gas pipeline interconnectors from Europe (Norway, Netherlands and Belgium)	195	2.22
Liquified Natural Gas landings (mainly from Qatar plus some now from the US) and onshore storage (Circa 14 TWh capacity[84])	58	0.66
UK onshore gas storage facilities (~15 TWh capacity[83])	0-92	1.05
Typical cold winter day	~412 +	~5.1 +

Table 1. Gas supplies to meet peak winter days. Adapted from National Grid 2019/20 Winter Outlook.

A key consideration is that while the UK maintains around 12 days of average gas demand (circa 6 days of winter cold day demand) in storage, the daily operation of the gas network is heavily dependent on maintaining line pack gas supplies and pressure through continuous daily supply from gas production fields and European interconnectors.

6.5. Electrification of heat and network investment

The opportunity presented by the electrification of heat is based on the premise that there will be a future abundance of low carbon electricity from a variety of renewable sources, including a high proportion of onshore and offshore wind energy. This pathway foresees a massive increase in renewable energy generation capacity, and a continued reduction in both the levelised cost of electricity generation and the marginal costs of energy.

With abundant and low cost electricity, electrical heating becomes a cheap and affordable option when combined with very efficient buildings and the deployment of efficient heat pump heating systems. A key advantage of an electrified pathway is that it could also support the provision of cooling technologies and be aligned with the electrification of transport.

Norway provides an example of a possible electrification model where over 83% of residential energy demand is met by electricity, almost all from hydro power. As well as the advantage of dispatchable hydro power, it is worth noting that, to support heat electrification and electric vehicles, Norway has also adopted a policy of installing three phase electricity supplies as standard for domestic customers.

The electrification of heat faces three main challenges:

1. The energy network and storage infrastructure needed to meeting the peak energy demands during winter months, and especially during very cold spells
2. The relative cost of electrical heating compared to gas, and retail price distortions (discussed in section 4)
3. Consumer acceptance of a new heating technology that entails a significant change and potential disruption to householders and businesses

Whilst 'resistive' electric heating is relatively cheap to install and maintain, electricity prices would have to be exceptionally low for the straight conversion of electrical power to heat to become a widespread heat solution. Resistive heating may have a role in very efficient and low demand buildings, and as a backup heat source, but as well as the cost issue they would transfer peak loads directly onto the network.

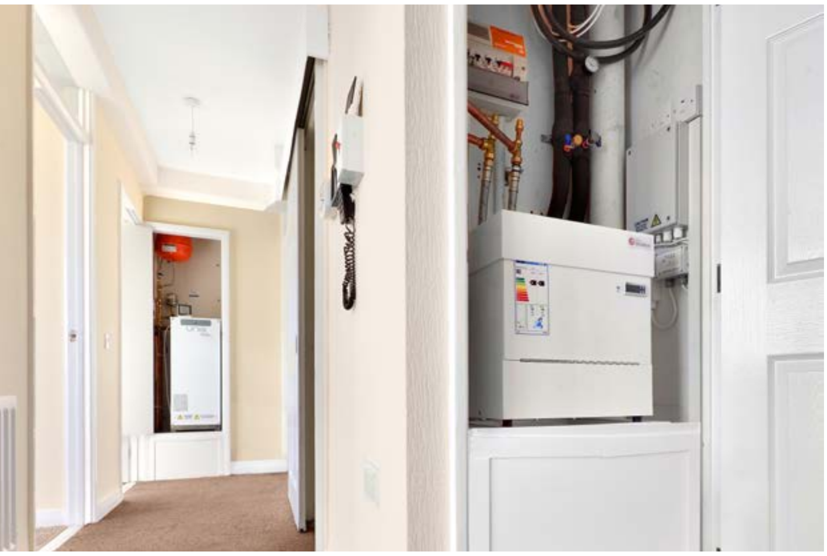


Figure 21. Image courtesy of Kensa Heat Pumps.

Heat pumps (air source, ground source and water source) offer a much more efficient heating solution, with the potential to deliver 2 – 4 kWh of useful heat, harnessed from the heat source, for each 1 kWh of electricity input.

Heat pumps can also be used in conjunction with shared loop systems, and with low temperature heat networks to top-up low grade and/or waste heat.

A key issue however for heat pumps is that their performance efficiency varies and will depend on how the heat pump system is sized, the efficiency of the building, the weather, user behaviour and the ambient temperature of the heat source. During cold spell conditions, air source heat pumps can place a significant load back onto the electricity network. In a worst case scenario heat pumps may perform in a similar manner to resistive heating. Studies have estimated that an ASHP could increase individual household winter peak demand by between 2.5 kW and 5 kW[87]. Varying patters of end user behavior mean that in the event of widespread electrification of heat this load would be diversified across network areas, resulting in a lower 'After Diversity Maximum Demand', in the region of 1.7 kW, to be accounted for by network planners[91].

The network impacts of heat pumps can be mitigated through greater energy efficiency, diversity and flexibility. Ground and water source heat pumps will tend have to lower peak demands, and all systems perform better in well insulated houses. Heat and electricity storage solutions within the building can also reduce peak loads, while consumer behaviour can also be influenced by smart tariffs, to encourage heat demand away from peak load periods, and by incentives to encourage demand side flexibility[88].

We need to understand more about how the widespread deployment of heat pumps will impact the network and how peak loads can be mitigated. It is positive therefore that BEIS is about to support a major new heat pump trial[89]. The widespread roll-out of heat pumps, combined with electric vehicles, will however be expected to increase the need for network investment especially at the low voltage network level.

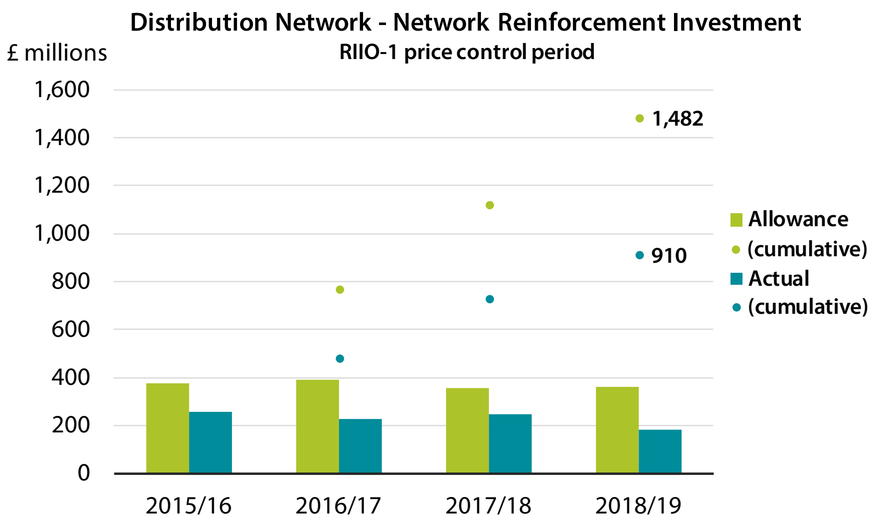


Figure 22. Underspend on electricity distribution network reinforcement allowance.

The situation right now however is that, across most network areas, peak electricity network demand loads have fallen in recent years and so, in the short term, the roll-out of heat pumps will have a limited impact on distribution network investment. In fact, electricity distribution network investment is currently running significantly below its planned budget allowance in the current RIIO price control period (Figure 22[90]). There is therefore a strong argument that networks should be incentivised to use the current underspend to build in future proof resilience for the benefit of future consumers and to enable decarbonisation.

How much heat electrification will cost the electricity networks in terms of investment, above and beyond the refurbishment and reinforcement that will be needed to meet a net zero carbon target, is not clear[92]. An analysis by Capital Economics for Scottish Power Energy Networks[93] has estimated that UK distribution networks may need to invest £48.5 billion in network reinforcement in the period to 2050, an average of £1.6 billion per year, to support renewable generation, electric vehicles and the electrification of heat.

The need for an accelerated approach for electricity distribution network investment to support decarbonisation has been previously analysed by Regen in the ***2019 Energy Networks for the Future*** report. This report highlighted the need for the regulatory model to change to adopt net zero carbon as a key policy goal, allowing networks to make strategic investments to support decarbonisation and to work with regional stakeholders to enable them to achieve their net zero ambitions.

Making a difference:

- Build networks for the future[92] – change the way networks are regulated and governed, to adopting clear decarbonisation goals and allowing networks to collaborate with local and regional partners to make strategic network investments.
- Electrify heat now, in conjunction with energy efficiency and retrofit measures, starting with all new buildings, off-gas grid properties and properties with high energy costs.
- Encourage the development of shared heat source solutions including use of waste heat and shared loop systems.

CASE STUDY

Hybrid heat pumps

Several heat studies, including the Freedom Project[94], have considered the value of hybrid heat pump systems and these now feature as heating technologies within the National Grid Future Energy Scenarios and in the Committee On Climate Change's Further Ambition pathway to net zero. Regen has also included the adoption of hybrid heat pumps within our Distribution Future Energy Scenarios.

A key advantage of a hybrid heat pump system is the ability to switch to a back-up heat source, probably a gas boiler or potentially a bioLPG or biomass fuel in off-gas areas, when the heat pump performance drops below a critical level. This switch could help reduce peak loads on the network, save the consumer money, and may also reduce carbon if done at times when electricity generation has a high carbon intensity. If sized properly, and used well, with appropriate switch control logic, a hybrid system might be expected to revert to the back-up heat source for around 20-30% of heat demand and hot water.

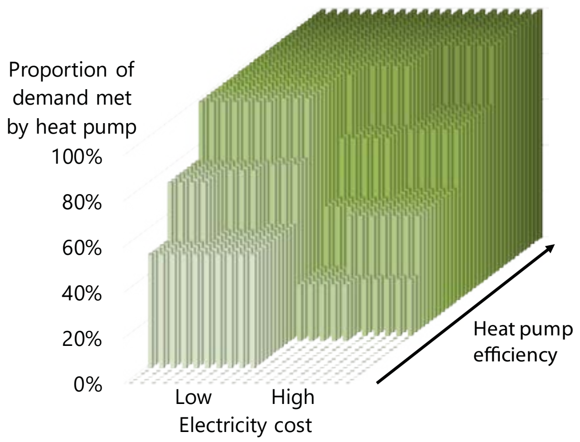


Figure 23. Hybrid heat pumps utilise detailed information to optimise system performance.

The Committee on Climate Change's Further Ambition pathway envisages the extensive roll-out of hybrid heat pump systems in on-gas grid properties in the 2020s as a means to decarbonise to meet interim carbon targets, while retaining the optionality to then later switch either to an electrification solution (full heat pump) or a new hydrogen solution. This would also allow more time to implement energy efficiency measures.

A further potential advantage of a hybrid heat pump approach would be to allow the rapid roll-out of heat pumps, especially in on-gas grid areas, by offering consumers a more easily acceptable transition while retaining a familiar gas boiler backup.

A hybrid heat pump strategy does however come with some risks and potential pitfalls. With the current price differential between gas and electricity there is a risk, and some anecdotal evidence, that consumers may more revert to the back-up heat source, or abandon use of the heat pump altogether if they are perceived to have higher running costs. Under-sized heat pumps, or systems installed in poorly insulated or inappropriate buildings, could reduce consumer confidence in heat pump efficiency, and undermine the wider decarbonisation programme.

Hybrids could therefore have a useful decarbonisation role as a transitional technology but should be deployed where most appropriate.

Hybrid heat systems could also play a important longer term role, to manage peak electricity demand, if the backup fuel can itself be decarbonised. For example by biomethane or hydrogen. This could be through discrete biomethane or hydrogen networks, commercial scale hybrid heat pumps and heat networks.

6.6. Hydrogen opportunities

Hydrogen use in industry and chemical processes is not new, in 2018 global production of mainly "grey hydrogen" from fossil fuels was in excess of 70 million tonnes, for use mainly as ammonia and in refining[95]. With new forms of low carbon production, hydrogen has the potential to be used more widely as a low carbon fuel and could become a key enabler of decarbonisation. Innovation in new forms of hydrogen production, and new applications for hydrogen technology, has received significant global investment, especially in countries like Japan and South Korea.

In the UK there are now a large number of hydrogen based trials and demonstration projects. Some of these are looking at hydrogen production processes, hydrogen as a transport fuel, the creation of hydrogen industrial clusters and also the potential for hydrogen gas networks.

A few notable projects include the Hynet[96] industrial cluster project which spans the north west and north Wales, the H2Wales[97] south Wales hydrogen cluster, the Leeds H21[98] and H2Aberdeen[99] projects, and the Hydeploy hydrogen[100] network trial at Keele University.

Given the formation of a hydrogen task force to drive innovation and technology development[104], as well as the recent £90m funding announcement from the UK Government[101], it seems almost certain that hydrogen will play a significant role in the UK's low carbon economy.

The big question is whether hydrogen's key role will be focused in the areas of transportation and for use in higher value industrial processes where a high quality thermal heat is required; or whether hydrogen will become a low cost and ubiquitous fuel, for widespread use for domestic and commercial heating, in the manner that natural gas is used today. If it did, then hydrogen could become an alternative, or at least a complementary, pathway for heat decarbonisation to electrification.

The answer to that question is not yet clear, but will need to be addressed within the next few years in order for cities, regions and energy networks in the UK to begin to make appropriate investments to support a shift in heat delivery towards electrification and/or hydrogen networks. A critical decision is whether existing gas networks can be repurposed to supply hydrogen, and whether this continues to be done as a nationwide network offering broad coverage, or via a number of discrete hydrogen networks linked to centres of hydrogen manufacturing and storage centres.

Figure 24. Hydrogen pipework under test. Image courtesy of Northern Gas Networks.

Hydrogen as a heat fuel is attractive since it could closely replicate existing heating technologies (boilers) for end consumers. The extent to which hydrogen becomes a widely used heating fuel will however be determined by its delivery cost, which will in turn be determined by the upstream cost of hydrogen production (potentially allied to carbon capture, use and storage (CCUS)), hydrogen storage, and the downstream cost of distribution and of hydrogen appliances.

6.7. Hydrogen manufacturing and storage

Hydrogen is considered a low carbon fuel[102] (Figure 26[103]) because at the point of use (combustion or chemical conversion via fuel cells) the only emission is water. Hydrogen differs from natural gas in several other respects:

- hydrogen has a lower volumetric energy density, it therefore requires more volume, flow or higher pressure to store and deliver the same energy content
- it has smaller molecules and therefore a greater propensity to leak and disperse and is less dense and therefore has a propensity to rise within a storage vessel or in the atmosphere
- it has different combustion properties and is more flammable; safe usage would require modification or replacement of appliances, although boiler manufactures are confident this can be achieved[105]
- it corrodes metals and is therefore not suitable for older iron pipework used in our gas networks and buildings, but would be compatible with the newer polyethylene pipe which is now being installed.

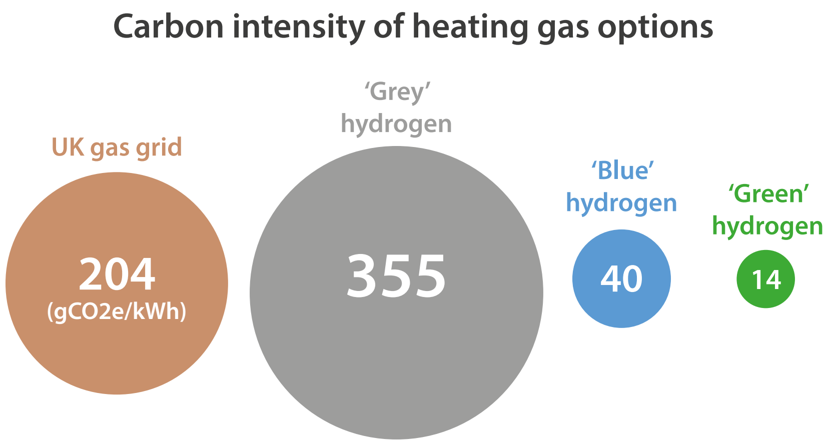


Figure 25. Potential carbon emissions from hydrogen production options and current natural gas in the UK. Current global production of grey hydrogen is responsible for emitting around 830 million tonnes of carbon dioxide per year, equivalent to the CO_2 emissions of the United Kingdom and Indonesia combined.

A key advantage of hydrogen is that it can be manufactured in numerous ways[106]. Two main processes seem to offer the most potential for large scale manufacturing that would potentially provide fuel for heating:

1) Hydrogen produced from natural gas using a form of methane reformation (e.g. Steam Methane Reformation or Autothermal Reformation(ATR)), which must be combined with very efficient CCS to be considered low carbon. Known as **"blue hydrogen"**.

The big opportunity for the UK manufacture of **blue hydrogen** would be to continue to use natural gas from the UKCS, and to convert oil and gas infrastructure such as gas terminals, chemical plants and refineries to produce large scale hydrogen as well as the potential to pump captured carbon back into depleted oil and gas wells.

With today's SMR technology it takes the equivalent of 1.3 to 1.4 kWh of natural gas methane energy to produce 1 kWh equivalent of hydrogen energy. This means there is a very significant energy conversion loss, and higher carbon emissions, to convert methane to hydrogen energy. Adding CCS to the process, using existing technology, implies additional cost and a reduced conversion efficiency.

A number of innovation projects are in progress with the aim to both improve the conversion efficiency and to improve the rate of carbon capture, a good example being project Acorn[108]. CCS efficiency will have to be in excess of 95%[107] for blue hydrogen to be considered compatible with a net zero scenario.

2) Hydrogen produced via electrolysis, using water and electricity. Known as **"green hydrogen"** on the assumption that it will, in future, use abundant low carbon and low cost renewable electricity.

Green hydrogen manufacture via electrolysis also entails a conversion energy loss. Using current processes, it requires around 1.4 kWh of electrical energy to produce 1 kWh equivalent of hydrogen. Hydrogen produced via electrolysis is, however, of higher quality (with fewer impurities) suitable for transport uses. Electrolysis also requires the use of clean water.

The opportunity for the UK manufacture of **green hydrogen** is to manufacture hydrogen using cheap and plentiful electricity if the UK continues to expand its renewable energy capacity, and especially its offshore wind capacity. Green hydrogen manufacturing could be aligned with large scale offshore wind farms, with production facilities along the east coast and Irish Sea. This could coincide with the sites of existing gas terminal, oil refineries and chemical plants.

An alternative would be to locate smaller electrolysis plants, linked to the electricity distribution network and regional renewable energy projects, that are close to industrial clusters in areas such as south Wales. Electrolysis could therefore be aligned with a supply model for hydrogen for industrial clusters and transportation.

Again, there are a significant number of electrolysis projects both in the UK and overseas that are aiming to improve process efficiency, a good example being the Gigastack project[109].

Hydrogen production costs

Both forms of blue and green hydrogen face a significant cost challenge when compared to the current cost of natural gas. Levelised costs of hydrogen manufacturing estimates vary depending on the scale, efficiency and capacity utilisation.

- The IEA report on the Future of Hydrogen has estimated SMR plus CCUS production costs in Europe to be circa $2.32 per kg, roughly equivalent to £0.054 per kWh[95].
- A Navigant Consulting analysis on behalf the Electricity Network Association has assumed that hydrogen production costs will fall to a range of £0.05-0.06 per kWh by 2050 for both hydrogen from reforming of natural gas and electrolysis using dedicated renewables.
- Project Acorn has calculated a projected base case levelised production cost for a 200 MW SMR and CCS plant, offering 98.7% carbon capture efficiency and 75% production efficiency, of £0.076 per kWh[110]. Scaling to a 1,300 MW unit could reduce projected levelised production costs by 15%.

Compared to the current wholesale price of natural gas or an efficient heat pump system, hydrogen production costs would have to fall significantly if hydrogen is to become a widespread heating fuel. Economies of scale, processing efficiencies and falling feedstock costs (natural gas or electricity) would therefore be required.

Hydrogen storage and the peak load challenge

The use of hydrogen for commercial and domestic heat use would also face a peak load challenge. On a like-for-like energy delivery basis the gas network infrastructure, pipes and line-pack storage would need to operate with higher flow rates and volumes. This would require additional capacity, storage and plant investment within the gas distribution networks.

More significantly, the absence of an equivalent daily supply from natural gas interconnectors and production fields, would require an increase in hydrogen manufacturing production capacity and/or a very significant amount of seasonal hydrogen storage to meet peak winter demand. Both approaches would have cost implications in the form of lower production capacity utilisation or increased storage costs. Reducing hydrogen production costs would require very high levels of production plant utilisation. It seems more likely therefore that large scale seasonal storage infrastructure, such as salt caverns, with the capability to support very high injection rates would be required[112].

6.8. Biomethane – a regional and local opportunity

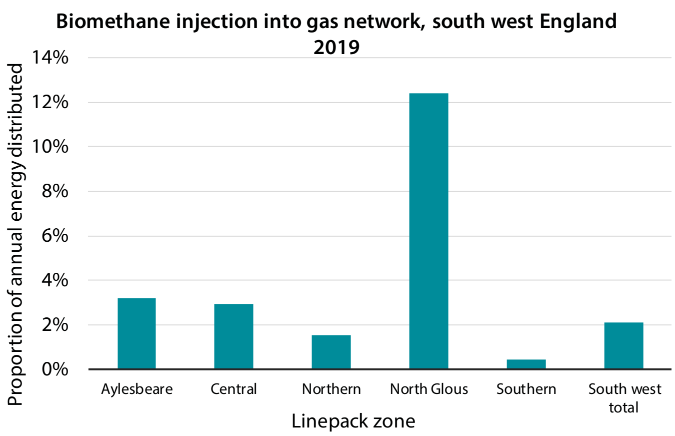
Estimates of potential biomethane[113] production in the UK have varied greatly under a number of different scenarios. A 2017 market review[114] identified a low and high range of between 21 TWh and 124 TWh of annual biomethane production by 2050, with a 55 TWh mid range scenario. This is more conservative than previous studies[115].

Part of the reason for this very broad estimate range is the many types of biomethane feedstocks, their variable commercial viability and the alternative uses to which those resources could be put. This is further complicated by the fact that biomethane can meet energy demand in a number of markets including electricity generation, heat generation, injection into the gas grid and for transport.

In 2018, the UK produced 34.6 TWh[116] of biomethane from landfill, sewage sludge and anaerobic digestion, of which the majority, 28.9 TWh, was used for electricity generation, 4.7 TWh was used for heat. Landfill gas production has been declining since 2010/11 and will continue to do so. Sewage sludge gas production has increased slightly with changing demographics and process improvements. The biggest growth area has been in anaerobic digestion which was used to produce 14.8 TWh of gas in 2018 compared to almost nothing a decade ago.

Gas to grid injection remains a relatively low proportion of biomethane usage, although there has been an increase in network injection which is incentivised under the RHI. In 2018, around 2 TWh was blended into the GB gas distribution network; about 0.4% of the energy delivered.

Biomethane production and the potential for gas to grid injection is not evenly distributed across the UK. The south west of England, for example, which has a higher concentration of agricultural and food processing industries, now has 18 gas injection sites with a combined potential injection flow rate of 16,450 scm/h (standard cubic meters per hour). In 2018, these sites injected 536 GWh into the Wales & West Utilities south west network. Even within network areas there are biomethane injection "hot spots"; North Gloucester[117] currently has the highest mains green gas content in the south west with over 12% of energy content in 2019 (Figure 26).



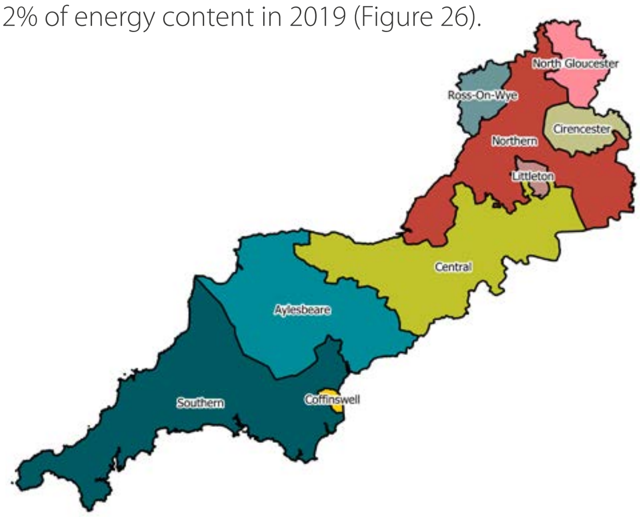


Figure 26. Recent levels of biomethane injection into the gas distribution network (data courtesy of Wales & West Utilities).

Higher levels of biomethane injection in some areas is rapidly reaching the point where network operators need to invest and innovate to ensure that gas quality is maintained and controlled[118].

Biomethane's long term value

Although still a small part of the overall UK energy mix, biomethane is helping to decarbonise the UK energy supply, and is also allowing energy supply companies to begin to offer "green gas" tariffs backed by Renewable Gas Guarantees of Origin. It will also play an important role helping to decarbonise the UK agriculture sector.

As biomethane becomes a more valuable energy resource a more strategic consideration needs to be given to its long term role in a net zero economy. In the short term, low level blending biomethane into the mains network is

Figure 27. Gas storage associated with anaerobic digestion plant. Image courtesy of Spielvogel.

a way to encourage the development of the feedstock supply chain, but in the longer term its significance will be enhanced if its use is planned in a strategic way.

Recognising that biomethane production is likely to be localised in areas close to feedstock supply, and its potential synergy with the agricultural sector, it is important that biomethane production and use are considered as part of local energy strategies and area heat plans.

Consideration also needs to be given to the long-term availability and commercial viability of feedstocks. This means that biomethane production should be an integral part of future land-use planning.

In rural areas, that are off the gas grid, this could mean its best use would be to provide thermal heat for 'hard to treat' properties, possibly as bioLPG linked to hybrid heat pump systems. Biomethane could also become an important fuel for rural industries and transport uses.

Higher concentrations of biomethane production, with inter-seasonal storage, could be used in conjunction with localised green gas networks to support hybrid heating systems and local heat networks.

6.9. Future pathways and difficult decisions

The overriding challenge for full heat decarbonisation is that there are no easy pathways. There are lots of low-regret steps we can take now in respect to new building standards, energy efficiency and by taking a tactical approach to deploying low carbon heat technologies. But getting to a near 90% carbon reduction for heat to achieve a net zero carbon outcome will require significant new infrastructure, and a radical change to the way heat is delivered. It is unlikely that the market will be able to deliver such a transition without strong political leadership at a national and regional level.

The conversion to hydrogen heating would entail less disruption to the end consumer. Hydrogen could be introduced initially by blending into the existing network, allowing manufacturing and storage facilities to be built, leading in time to the complete conversion of regions and city. Such an approach is envisaged by H21 Leeds City Gate project which concluded[119] that it is feasible to convert regions of the existing gas distribution network to a hydrogen gas network and found that on a building level only a change of boiler and perhaps changes to gas supply pipes (to prevent leaks if lead for example) are required.

The biggest challenge for hydrogen however is that, based on current projections, production costs and storage costs are expected to be extremely high. Probably too high without a significant on-going subsidy to offer an affordable solution for most domestic and commercial heat loads, although hydrogen will almost certainly have a role in transportation and in industrial clusters.

Electrification of heat offers a more direct decarbonisation pathway through the incremental roll-out of heat pumps as energy efficiency measures are deployed. Electrification using heat pumps also offers a more efficient use of low carbon electricity, compared to hydrogen electrolysis, and in some circumstances the opportunity to provide cooling. Full electrification would however require a massive increase in electricity generation, storage and network capacity. Electrification would also have to overcome the consumer current reluctance to adopt new heating technologies. As we have seen in the past decade, deploying individual technology solutions to a reluctant consumer is a very slow and expensive way to decarbonise.

A hybrid or balanced strategy could potentially mitigate some of the infrastructure and production cost challenges. The Committee on Climate Change analysis of hydrogen in a Low Carbon Economy[120] identifies a potential pathway where the electrification of heat is widely adopted for most buildings but with hydrogen playing a significant role for industrial processes and for commercial heat demand. Hybrid heat pumps, backed by hydrogen boilers or fuel cell technology could also play a role especially in heat networks and for commercial heat loads. Biomethane could also play its role if used in a strategic way to support rural communities and to provide local area heating solutions.

Given the lack of a clear pathway there is a great risk that the next decade could be wasted with little progress towards heat decarbonisation. At some point in the next 5 years, the UK government and regional leaders will need to make key strategic decisions concerning the future heat decarbonisation pathways at both a national and regional level. Such decisions will have far reaching implications for householders and businesses, and must be taken with a broad political and democratic consensus.

In the meantime making a difference in the next decade means getting the fundamentals right which will enable decarbonisation into the future, as well as demonstrating leadership to push ahead with a range of measures immediately.

1. **Setting new building standards and implementing a mass deployment of energy efficiency measures to improve building fabric, which will help insure consumer against future energy costs, and shrink the peak load infrastructure requirements of any future energy system**
2. **Embarking on a national, and local, programme to inform and equip consumers and businesses to adopt low carbon heating solutions**
3. **Creating the market conditions to support decarbonisation by removing fuel price distortions, incentivising low carbon solutions, increase the market value of low carbon buildings and establishing a carbon levy**
4. **Building up a supply chain of trusted professionals who are able to manufacture, design and install heating solutions. Especially mobilising the UK's current 135,000 heating engineers**
5. **Building city and regional partnerships with local stakeholders, consumers, industry and energy networks to develop and delivery local energy plans**
6. **Incentivising UK industry and businesses to develop and deploy energy efficiency and low carbon technology, and to export that capability**
7. **Empowering and incentivising energy networks to invest for the future, building capacity and capability to manage increased electrification, heat networks and low carbon gases**
8. **Continuing to invest in innovation, particularly heat storage and in hydrogen production which will be required even in a high electrification pathway**
9. **Ensuring that policies and markets protect consumers, address fuel poverty and ensure a just transition for individuals and communities**

In terms of energy usage, heat decarbonisation will have far greater impacts than the growth of renewable electricity or the conversion to electric vehicles. To succeed it must be engage with consumers and offer better solutions that people will really want

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