Too Hot to Handle?

How to decarbonise domestic heating

Richard Howard and Zoe Bengherbi

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Contents

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Glossary of terms

Term	Definition
Anaerobic Digestion (AD)	A biological process where organic matter is processed in the absence of oxygen to produce biomethane.
BEIS	The Department for Business, Energy and Industrial Strategy. Formed in 2016 through the merger of the Department of Energy and Climate Change, and the Department for Business, Innovation and Skills.
Biomethane	Biomethane is a naturally occurring gas that is produced from organic material and has similar characteristics to natural gas. http://www.biomethane.org.uk/
Biopropane	A substitute for LPG which is produced from biomass rather than crude oil.
BioSNG	A Synthetic Natural Gas produced using a Gasification process.
Calorific Value	A measure of the ratio of energy to volume of a gas, measured in megajoules per cubic metre (MJ/m^3).
CCC	The Committee on Climate Change: an independent body established under the Climate Change Act to advise the UK Government on reducing greenhouse gas emissions.
CCS	Carbon Capture and Storage: a process by which the CO_2 produced in the combustion of fossil fuels is captured, transported to a storage location and permanently isolated from the atmosphere.
CHP	Combined heat and power: A system whereby fuel is combusted to generate both heat and electricity simultaneously as part of one process.
Condensing Boiler	A water heater which achieves high efficiency by condensing water vapour in the exhaust gases and so recovering its latent heat of vaporisation, which would otherwise have been wasted.
CO_2	Carbon Dioxide (CO_2) is the main greenhouse gas and the vast majority of CO_2 emissions come from the burning of fossil fuels such as coal, gas and oil.
CO_2e	Carbon Dioxide equivalent: A term used to account for the "basket" of greenhouse gasses and their relative effect on climate change compared to carbon dioxide.
DECC	Department of Energy and Climate Change: a former UK government department (see BEIS above).
Emissions Intensity	A measure of the average greenhouse gas emissions per unit of energy used to provide heating, measured in gCO_2/kWh.
FGHR	Flue Gas Heat Recovery: a system which recovers waste heat from the flue of a gas boiler using a heat exchanger, thus improving the efficiency of the boiler.
Gasification	A gasification process converts organic material at high temperatures into a gaseous form which can then be refined to produce methane. The end product is often referred to as Synthetic Natural Gas (SNG) or BioSNG.
gCO_2/kWh	Grams of carbon dioxide equivalent emissions per kilowatt hour of energy used or produced. A measure of "carbon intensity" of a fuel.
Heat Network	A communal form of heating whereby heat is generated in a centralised location and piped to users (in the form of steam or hot water) where it can be used for space heating or water heating purposes.
Heat Pump	A central heating system that actively pumps heat into a building using a reverse refrigeration process. This heat can be sourced either from the ambient air (an Air Source Heat Pump), the ground (Ground Source Heat Pump) or a water source such as a stream or lake (Water Source Heat Pump). Heat pumps can be powered either by electricity or gas.
kWh	Kilowatt Hour: a unit of energy approximately equal to 0.0341 therms. One Megawatt hour (MWh) equals 1000 kWh, one Gigawatt hour (GWh) equals 1000MWh, and one Terawatt hour (TWh) equals 1000 GWh.
LPG	Liquified Petroleum Gas: a liquid hydrocarbon fuel used for heating
$MtCO_2$	One Million metric tonnes of carbon dioxide equivalent greenhouse gas emissions
Ofgem	Office of Gas and Electricity Markets: the independent economic regulator for gas and electricity markets and networks, and a non-ministerial Government department.
SPF	Seasonal Performance Factor. A metric used to describe the efficiency of a heat pump over a typical season.

Executive Summary

Context

This report considers how we should heat our homes in the future if we are to meet the UK's carbon targets in an affordable manner. The UK has set ambitious goals under the Climate Change Act to achieve an 80% reduction in annual greenhouse gas emissions by 2050, compared to 1990 levels.[1] Significant progress has already being made to decarbonise electricity generation, with total power sector emissions having halved since 1990 as a result of the shift from coal to gas generation and the growth in renewables.[2]

The UK faces far greater challenges in decarbonising the way we heat our homes and other buildings. A total of £32 billion a year is spent in the UK heating homes and other buildings, accounting for nearly half of all energy consumed and one third of total greenhouse gas emissions.[3, 4] However despite its significance, heat remains the "Cinderella" of energy and climate policy, having been largely overlooked in favour of the other main energy sectors: power and transport.

Looking at domestic heating specifically, our analysis shows that greenhouse gas emissions have fallen by 20% since 1990 – far less than the reduction seen in the power sector.[5] Gas and electricity prices have increased sharply since around 2004, encouraging households to improve the efficiency of their homes and heating systems, but this improvement has been partly offset by a 20% increase in the number of households since 1990. Gas remains by far the most common form of heating in UK homes – present in more than 80% of homes.

In recent years the Government has developed a number of strategies and policies to decarbonise heating, but they have failed to deliver a sufficient reduction in emissions. The UK is significantly off track to achieving the 4th and 5th carbon budgets which cover the period to 2032, and the lack of progress to decarbonise heating could make or break the UK's carbon plans.

This report provides an assessment of the Government's current heat strategy, which was developed by the Department of Energy and Climate Change (DECC) in 2012 and 2013. Our analysis identifies significant weaknesses with the Government's approach, particularly the focus of the strategy on electric heat pumps, which as discussed below represents an extremely costly way to decarbonise heating. The Government's strategy has been contested by the energy industry, academics and commentators, who suggest that it would be very expensive and challenging to achieve in practice. As a result there is a huge degree of uncertainty about how we should decarbonise domestic heating.[6]

Our report calls for Government to develop a new heat strategy, based on a more balanced set of priorities and technologies – incorporating substantial improvements in energy efficiency, more efficient gas appliances, greener forms of gas, and alternative heat technologies. This approach could deliver an 80%+ reduction in emissions by 2050, but in a way which involves substantially less cost to the consumer than the approach proposed by Government.

1 The target is defined in terms of UK territorial emissions i.e. those produced within the UK's borders.

2 CCC (2016) *Meeting Carbon Budgets – 2016 Progress Report to Parliament*

3 DECC (2013) *The Future of Heating: Meeting the challenge*

4 DECC (2014) *2014 UK Greenhouse Gas Emissions, Provisional Figures*

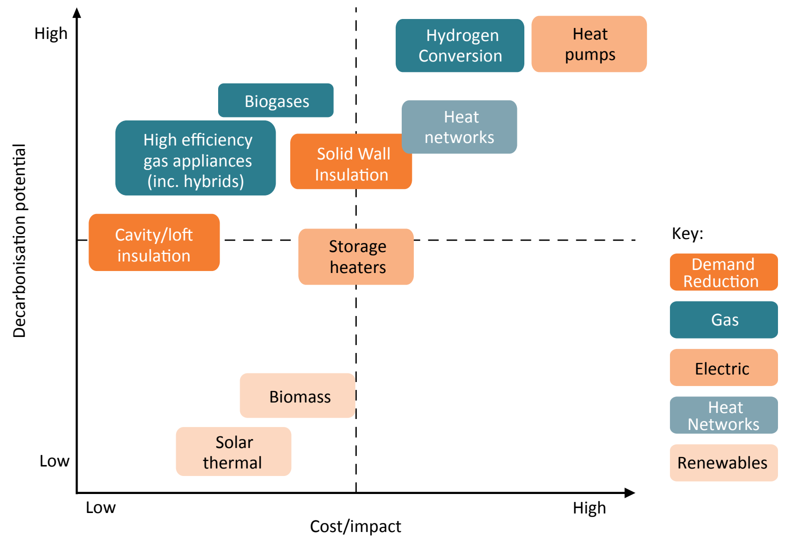
5 On a weather-corrected basis, including direct and indirect emissions.

6 For example see: Chaudry et al. (2014) *Uncertainties in decarbonising heat in the UK*

Assessment of future heating options

This report provides an assessment of a wide range of heat technologies – namely gas, electric, heat networks, and renewables – as well as considering the potential to reduce heat demand by improving efficiency (demand reduction). Each of these options and sub-options is considered in turn based on its decarbonisation potential, as well as the consequences for consumers (i.e. capital and running costs, disruption to the home, and performance issues), and network and supply issues (i.e. the investment in infrastructure required to meet heat demand, particularly at peak times). Figure ES1 provides an overall summary of our assessment.

Figure ES1: Assessment of future heating technologies



Our analysis suggests that **demand reduction** could play a significant role in decarbonising heat, reducing overall domestic heat demand by up to 20% between now and 2050 (despite further growth in the number of households). There is still significant potential to roll out **loft and cavity wall insulation and heating controls,** which are cheap and relatively straightforward to install. Although in order to make significant savings, it will be necessary also to pursue more extensive efficiency measures such as **solid wall insulation** in older properties, which involves significant cost and disruption to the home. Overall, we suggest that the early prioritisation of energy efficiency improvement should be a more central part of the Government's approach to decarbonising heat, as this is beneficial regardless of which heat technologies we use in the future.

There are also a number of technologies which could help to **decarbonise gas use.** Gas is by far the most common form of heating at present, and the emissions associated with gas use will need to be addressed in order to decarbonise heating more generally. There is still significant potential to improve the **efficiency of gas boilers**.[7] The UK has already seen a significant improvement in boiler efficiency with the roll-out of condensing boilers, which have been mandatory for new installations since 2005. However there were still 11 million low-efficiency non-condensing boilers in place in UK homes in 2012, which ought to be upgraded as a matter of priority. Moreover, a number of new technologies such as

7 Defined here as the average heat output delivered per unit of fuel used.

Flue Gas Heat Recovery, Gas Driven Heat Pumps, and Micro Combined Heat and Power have the potential to substantially increase boiler efficiencies beyond the current level. **Hybrid gas/electric heat pumps** could also play a significant role in the future. These systems are capable of switching between gas and electricity, depending on which fuel is cheaper at the time, and crucially, can switch to gas during times of peak demand thus avoiding the network issues associated with electric heat pumps.

In addition, there is potential to decarbonise gas through the use of greener gases such as **biomethane and biopropane**, which can be produced from waste and organic matter. This gas can be used as a drop-in replacement for natural gas, either by injection it into the gas grid or as a substitute for LPG in off-gas grid homes. Switching to such greener gases does not require any changes to gas appliances or networks and therefore offers a cost-effective route to substantially decarbonise gas use. However there are uncertainties about the amount of green gas available.

A more significant transformation could be achieved by **converting the gas grid to run on hydrogen** instead of natural gas, which would achieve an estimated 73% reduction in greenhouse gas emissions. Converting the grid to run on hydrogen would require gas boilers and cookers to be changed in every home, as well as the construction of new infrastructure to produce hydrogen and store the CO_2 produced as part of the process. This could be very costly: a recent study calculated that converting the city of Leeds to run on hydrogen instead of natural gas would involve an upfront cost of £2 billion and annual costs of £139 million.[8] If these costs are scaled up to all 23 million UK homes on the gas grid, this implies a capital cost in the order of £180 billion and ongoing cost of £12 billion per year. The same study suggested that the cost of hydrogen delivered to consumers would be nearly double the retail price of gas. Hydrogen conversion is an interesting option, but further work is required to assess its feasibility and cost-effectiveness.

Next we have considered the potential for **electric heat pumps** – which extract heat from the air or ground and "pump" this into the home. The Government's heat strategy suggests that heat pumps could provide more than 80% of domestic heating by 2050. Assuming that the electricity system is decarbonised, then this provides a route to almost completely decarbonise heating. However our analysis suggests that it would be very costly and challenging to deliver such a large number of heat pumps. We estimate that the cost of installing heat pumps in 80% of homes to be in the region of £200 billion. In addition, an investment of around £100 billion would be required to expand and upgrade the power system to cater for the additional demand for electricity. Switching 80% of homes to heat pumps would require an additional 105GWs of electricity generation capacity (an increase of 175% above current peak power demand) as well as significant investment to reinforce the power distribution network. Overall our view is that there are significant obstacles to achieving the Government's current strategy of shifting the majority of domestic heating to electric heat pumps. Heat pumps could play a role in decarbonising heat, but not to the extent suggested in the DECC heat strategy.

The Government's heat strategy suggests that by 2050 around 15% of homes will be heated by **heat networks** (a collective form of heating whereby heat

8 H21 Consortium (2016) *Leeds City Gate*

is generated centrally and piped into homes). Heat networks are common in European countries such as Germany, Denmark and Sweden, but are relatively rare in the UK accounting for just 1% of UK households. Deploying heat networks is challenging due to the high capital costs and risks associated with development. However, our analysis suggests that the Government's aspiration for 10–15%+ of heat to be provided by heat networks by 2050 is possible provided there is policy support in place. The challenge for policymakers is how to create a regulatory framework which reduces the cost and risk to heat network developers, whilst also enhancing the level of consumer protection for heat network customers.

Finally, we have also considered small-scale renewable heating solutions such as **solar thermal and biomass.** Our analysis suggests that these could play a minor role in decarbonising heat. Solar thermal is inevitably limited by the mismatch between solar radiation and heat demand, and can only realistically meet a proportion of heating requirements. Biomass boilers, which burn logs, wood chips or pellets, are limited by the availability of sustainable bio-resource, the cost of installations, and concerns over the impact on air quality. These options are unlikely to be economic for homes already connected to the gas grid.

Decarbonising heat at lower cost

Building on the above analysis, we have developed two alternative scenarios or approaches to decarbonise domestic heating. These scenarios have been designed to achieve a significant reduction in carbon emissions, whilst minimising as far as possible the cost and consequences to consumers, and the investment required in energy infrastructure such as networks.

Our first scenario shows that an 80% reduction in carbon emissions from domestic heating could be achieved through a combination of:

- A substantial improvement in the thermal performance of the UK's housing stock, through improvements in insulation, which could reduce annual heat demand from around 360 TWh to around 303 TWh by 2050.
- An increase in boiler efficiency, with inefficient non-condensing boilers replaced with condensing boilers and high efficiency gas technologies such as Gas Driven Heat Pumps.
- A reduction in the carbon intensity of gas through the use of greener gases such as biomethane and biopropane (or conversion of parts of the gas grid to hydrogen).
- Shifting a significant number of homes to electric heat pumps (although to a far lesser extent than the DECC heat strategy) and heat networks.

In this scenario, the number of households using gas boilers remains broadly flat to 2050. However, maintaining this level of gas use relies on achieving significant improvements in thermal efficiency, the widespread use of more efficient gas appliances (including gas/electric hybrids) and the use of "greener gases" to partly decarbonise gas use. It also requires the power system and heat networks to be largely decarbonised by 2050 – which is a significant challenge.

Achieving such a reduction in emissions should not be considered "easy" and would require significant and sustained Government intervention over the next 30+ years. However, this scenario goes with the grain of consumer preferences and minimises cost to the consumer, and in our view is therefore far more likely to be achieved than the Government's current heat strategy.

Figure ES2: Scenario 1 – Mix of heating appliances

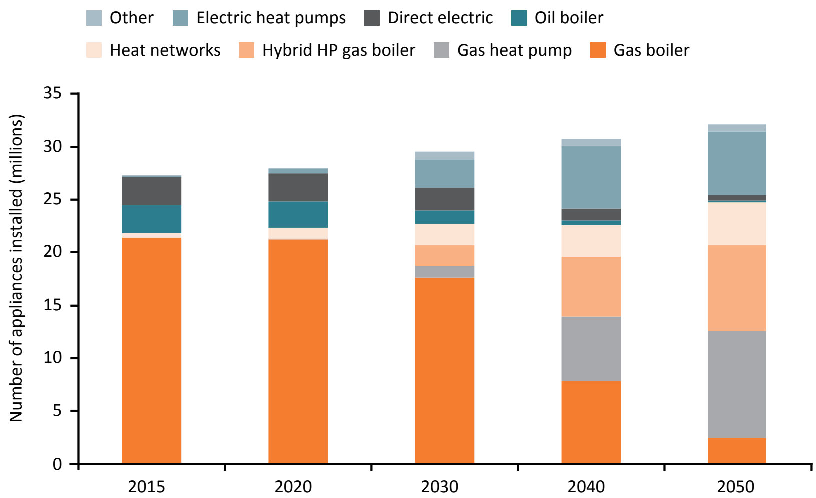
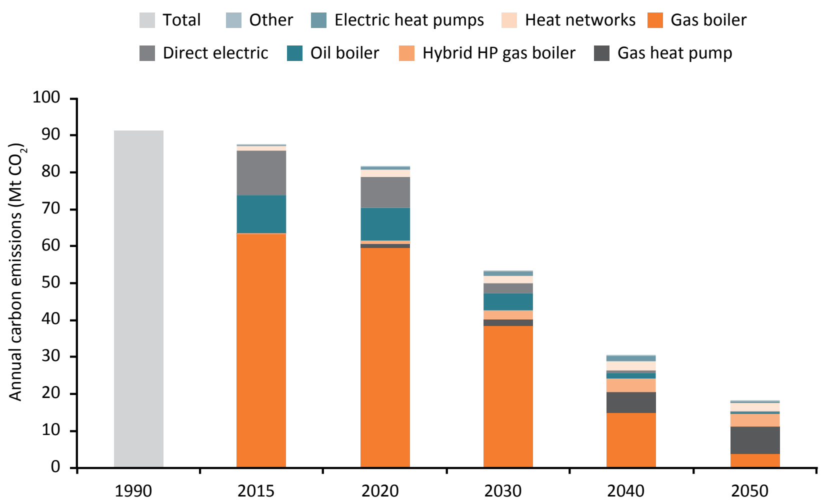


Figure ES3: Scenario 1 – Annual emissions from domestic heating (excluding cooking)



If the Government wishes to pursue a more ambitious reduction in heat-related emissions then this could be achieved either through an expansion in the use of electric heat pumps and heat networks, or through the conversion of the gas grid to run on hydrogen. However, all of these options present far greater challenges in terms of the impact on consumers, networks and supply-side considerations. It is clear from our analysis that targeting a 90% reduction in heat-related emissions would be considerably more expensive and challenging to deliver than an 80% reduction, and is likely to require a very different set of technology solutions.

Policy recommendations

Decarbonising the way we heat our homes and buildings is essential to delivering the UK's carbon targets. Our analysis suggests that limited progress is being made to decarbonise heat, and that the Government's current heat strategy is unrealistic. We recommend that the new Department for Business, Energy and Industrial Strategy (BEIS) **develops a new strategy and approach to decarbonising heat,** either as a standalone strategy or as part of the forthcoming Carbon Plan. This strategy should be based on the following broad principles:

- **Make a long term commitment:** Decarbonising heat will involve transformational changes to our heating systems and related infrastructure. In order to deliver this, Government will need to set out a coherent and achievable long term vision, backed up with sustained policy intervention and considerable cross-party support. Whilst long-term commitment is needed, the strategy should also **pursue "quick wins"** which can deliver significant emissions reduction in the short to medium term (e.g. to 2030) – for example by improving the efficiency of homes and boilers.
- **Pursue a more balanced approach:** one of the criticisms of the current heat strategy is that it focuses far too heavily on particular technologies such as electric heat pumps. Our analysis suggests that a more balanced approach combining energy efficiency, more efficient gas appliances, greener forms of gas, and alternative heat technologies could deliver an 80% reduction in emissions by 2050, whilst minimising costs to the consumer.
- **Put consumers back at the heart of the heat strategy:** The new heat strategy needs to be more consumer-friendly – working with the grain of consumer preferences, and minimising the costs and burdens placed on consumers as far as possible.
- **Avoid picking winners:** Government should avoid setting technology specific targets and "picking winners" and instead create a set of market conditions which encourage the most cost effective routes to decarbonise heating. To that end, we recommend that the (technology-specific) 2020 Renewable Energy and Renewable Heat targets should be scrapped.
- **Use carbon pricing to encourage lower carbon solutions:** Carbon prices can be used to create a market signal for the adoption of lower carbon technologies. At present the effective carbon tax on heating fuels such as gas and heating oil is negative, whilst the levies placed on electricity bills are increasing as power is being decarbonised. This could be corrected through changes to the taxes and levies on domestic heating fuels to better reflect their carbon content. For example, Government could increase the VAT levied on carbon intensive fuels such as gas, heating oil and solid fuel (from 5% to the standard rate of 20%) and use the additional revenue raised to reduce or remove the levy costs placed on electricity bills. This would increase the unit cost of more carbon-intensive fuels in order to discourage their use, whilst avoiding an increase in overall energy bills.
- **Integrate heat, energy efficiency and fuel poverty:** Improving energy efficiency is amongst the most cost-effective routes to decarbonise heat, and offers co-benefits such as reducing fuel poverty. But there is insufficient policy focus on improving energy efficiency, and installation rates have plummeted

in recent years. The new strategy should go further to integrate heat, energy efficiency and fuel poverty policies.

- **A national strategy with a localist approach:** The decarbonisation of heat will require a mix of technologies, rather than "one size fits all" solutions, and the best course of action will vary by location and over time. This raises questions about governance and the extent to which the outcome will be guided by Central Government, Ofgem, Local Authorities, or Utility companies. One solution, as recommended in a recent Policy Exchange report,[9] would be to create an Independent System Operator to advise on future network and system requirements.
- **Tackle technology and system challenges:** The decarbonisation of heat could significantly alter patterns of electricity and gas usage, and therefore presents significant challenges for the operation of these systems. It is clear from our analysis that the availability of storage is key to the deployment of alternative heat technologies such as electric heat pumps and heat networks. Changes to regulations and market arrangements will need to be made in order to encourage the rollout of storage and demand flexibility. There are also significant technological and innovation challenges associated with new and emerging heat technologies. We recommend that Government focuses more research funding on developing and piloting heat and energy efficiency technologies.

Our report also makes a number of detailed technology and policy-specific recommendations as follows:

Driving improvements in energy efficiency

- Make energy efficiency a national infrastructure priority (HM Treasury, BEIS)
- Tighten energy efficiency standards for new build homes, and for existing private rented properties (DCLG, BEIS)
- Link the stamp duty system to energy performance in order to "nudge" households to upgrade the efficiency of their home (HM Treasury and BEIS)
- Expand funding for fuel poverty energy efficiency schemes (BEIS)

Greening gas use

- Raise minimum efficiency standards for all newly fitted boilers (DCLG)
- Provide a financial incentive for the adoption of high efficiency gas appliances (such as gas driven heat pumps) under a reformed Renewable Heat Incentive (BEIS)
- Encourage an expansion in biomethane injection into the gas grid – for example the availability of feedstock could be increased by requiring Local Authorities to offer separate collection of food waste (BEIS and Defra)
- Support the development of new technologies which convert "black bag" residual waste into synthetic bio-gas (BEIS and Defra)
- Review gas standards to facilitate the injection of greener gases into the grid, with appropriate safeguards to protect consumer interests and ensure safety (BEIS, Ofgem)
- Conduct further work, including research and small scale pilots, to investigate the cost, feasibility and consumer acceptance of converting the gas grid to hydrogen (BEIS and Ofgem)

9 Howard, R. (2015) *Governing Power*. Policy Exchange

Reforming the renewable heat incentive

- Reform the Renewable Heat Incentive into a Low Carbon Heat Incentive focused on the most cost effective decarbonisation technologies, including non-renewable technologies (BEIS)
- Cap the subsidy available to any technology under the RHI in order to improve the value for money of the scheme. We propose a cap of 10p/kWh under the domestic RHI, equivalent to 5p/kWh under the non-domestic RHI (BEIS)

Scaling up heat networks

- Expand Ofgem's remit to include the regulation of heat networks (BEIS and Ofgem)
- Create a bespoke regulatory regime for heat networks including a lower risk financing model and greater protections for consumers (Ofgem)
- Extend the remit of the Heat Networks Delivery Unit to support projects through to financial close (BEIS)
- Catalyse investment in heat networks, using the £320 million Heat Networks Investment Project fund to de-risk projects by providing demand guarantees, and grants to "future proof" heat networks for future expansion (BEIS)
- Give heat network developers the same wayleave and access rights as other statutory utilities such as electricity, gas and water companies (Ofgem, DCLG, BEIS)

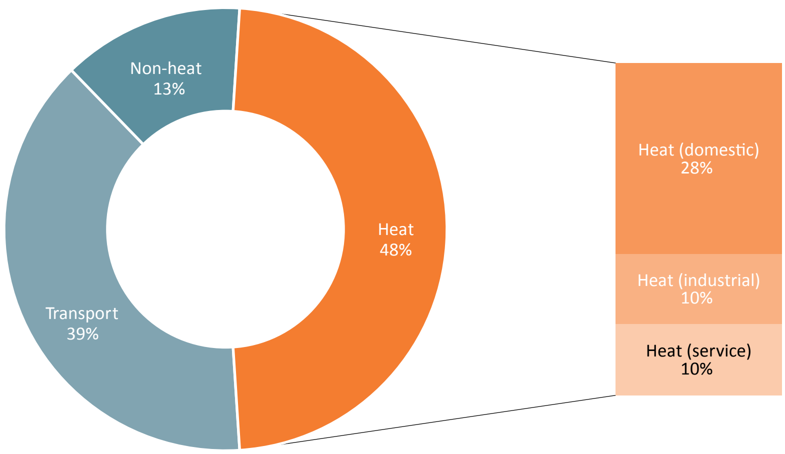
1
Introduction

This Chapter provides context to the report, identifying how we heat our homes at present, and the targets the UK has set to decarbonise heat in the future.

Current status of domestic heating in the UK

Heating is a major component of the UK's overall energy system. Space heating, water heating and cooking in homes and businesses accounts for just under half (48%) of all energy used in the UK, and one third of total UK greenhouse gas emissions. The majority of heating takes place in homes, with domestic heating accounting for nearly 60% of total heat and 28% of total energy used in the UK (Figure 1.1).[10]

Figure 1.1: Energy consumption by end use and sector, 2013[11]



Gas is by far the most common form of heating in UK homes. Out of the 27 million households in the UK, about 23 million (84%) have a gas boiler, usually providing both space heating and hot water.[12] Gas is also commonly used for cooking, with 61% of hobs and 30% of ovens using gas, the remainder mainly being electric.[13] Overall, gas meets 77% of domestic heating needs once space heating, water heating and cooking are combined (Figure 1.2). Aside from gas, the other main fuels used to provide heat in homes are electricity (8.6%), oil (7.5%), biofuels such as wood (4.6%), and solid fuels such as coal.[14] Around 1% of homes in the UK are connected to heat networks or communal heating systems, where heat is sold directly to end consumers.[15]

10 DECC (2015) *Energy Consumption in the UK, 2013 data*

11 Ibid.

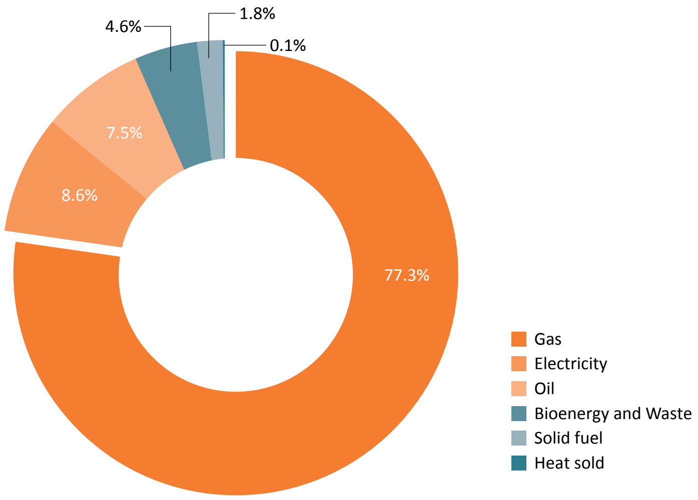
12 Ibid.

13 BRE (2013) *Energy Follow-up survey 2011: Report 9: Domestic appliances, cooking and cooling equipment.* DECC. 2011 data.

14 DECC (2013) *UK housing energy fact file*

15 DECC (2013) *The Future of Heating: Meeting the challenge*

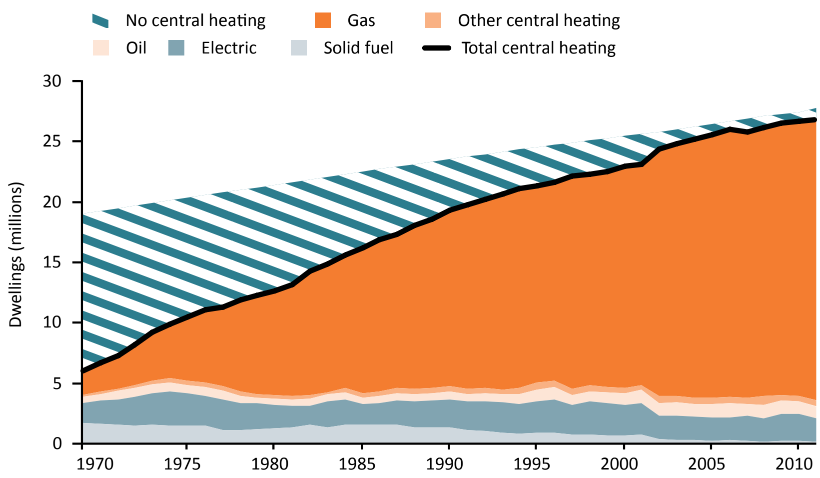
Figure 1.2: Fuels used in domestic heating, 2013



Source: DECC ECUK, 2015[16]

The way we heat our homes has changed dramatically over the last few decades. In 1970, only around one third of homes had central heating (32%) and it was more commonplace to have a standalone coal or wood fire or an electric bar heater. With the discovery of natural gas in the North Sea in the 1960s, gas central heating was rolled out to large numbers of homes during the 1970s and 1980s, reaching 60% of the housing stock by 1990. By contrast, the use of solid fuels has steadily declined. Gas remains the heating technology of choice due to the level of heating and comfort it provides, the low capital and running cost compared to other technologies, and the fact that most households are familiar with gas heating systems.[17] Indeed, the UK is the largest market for domestic gas boilers in Europe with around 1.6 million units sold annually.[18]

Figure 1.3: Installed central heating by type, 1970–2012



Source: DECC ECUK, 2015[19]

16 DECC (2015) *Energy Consumption in the UK 2015.* 2013 data

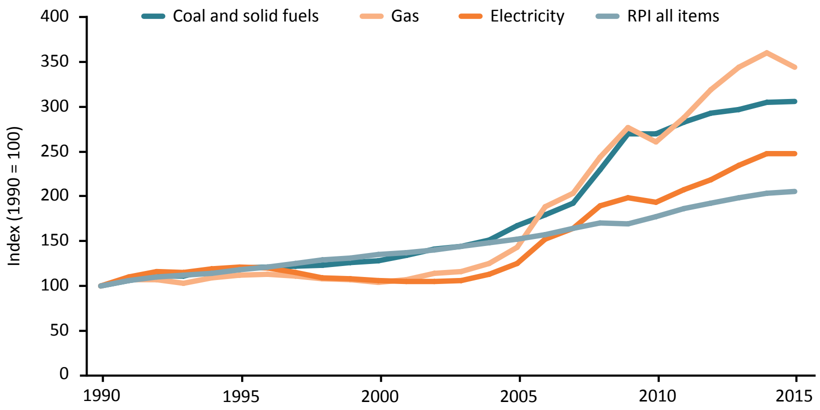
17 Hoggett, R. et al (2011) *Heat in Homes: customer choice on fuel and technologies*

18 Source: Energy and Utilities Alliance

19 DECC (2015) *Energy Consumption in the UK 2015.* 2013 data

The cost of heating fuels has changed markedly over time (Figure 1.4). The retail price of electricity and gas fell significantly in the late 1990s due to the privatisation of the energy industry, coupled with the UK becoming a net exporter of gas. However, the price of electricity and gas rose sharply from around 2004 onwards as the UK become a net importer of gas, just as global energy prices were increasing. As discussed in our previous report, *The Customer is Always Right*, this was compounded by a growth in energy policy and network costs, which added around £120 to the average household energy bill over the period 2009–14 (and now make up 29% of the average dual fuel bill). Overall, gas and electricity prices vastly outstripped inflation over the last decade, increasing by an average of 9.2% and 7.1% per annum respectively, compared to average retail inflation of 3.0%.

Figure 1.4: Price of fuels used for heating



Source: ONS

The way we heat our homes in the UK is very different to what is found in other European countries. For example, gas is far more common in the UK (84% of homes), than in France (46%) or Germany (49%).[20] France has far more electric heating (29%) than in the UK owing partly to its substantial fleet of nuclear power stations.[21] Several other Northern European countries have developed significant heat networks, for example heat networks serve around 60% of households in Denmark (and up to 90% in urban areas[22]), 14% of households in Germany, but only 1% of households in the UK.

Energy efficiency and fuel poverty

The efficiency of our homes has a significant bearing on our heating needs. Significant improvements have been made in the energy performance of the UK's housing stock in recent years, as discussed in our recent report *Efficient Energy Policy*.[23] Since 1990 the average UK home went from an Energy Performance Rating of "E" to a rating of "D" (on a scale of A to G).[24] According to our analysis there has been a 10% reduction in the amount of energy used to provide heating *per household* since 1990. This reduction in energy use has been achieved despite the fact that we now heat our homes to a much higher standard of warmth – the internal temperature in UK homes increase from an average of 13.9°c during the 1980s, to 17.3°c in 2013.[25]

20 http://www.observatoire-electricite.fr/Comparaison-des-situations

21 Ibid.

22 Element Energy (2015) *Research on district heating and local approaches to heat decarbonisation*. CCC

23 Howard, R. (2016*) Efficient Energy Policy, How to encourage improvements in domestic energy efficiency*. Policy Exchange

24 DECC (2015) *Energy Consumption in the UK, 2015*. 2013 data

25 Ibid.

Yet there is potential to improve the efficiency of the UK housing stock further. The UK's housing stock is amongst the least energy efficient in Europe, ranking 11th out of 15 countries in a recent study.[26] The two key aspects of efficiency from a heat perspective are the thermal performance of the fabric of homes (e.g. the insulation and air-tightness of walls, floors, and ceilings/roofs), and the efficiency of heating systems.

Significant improvements in thermal performance have been made by installing loft and cavity wall insulation in a large number of UK homes. However, around a third of homes which have a loft still do not meet minimum standards of insulation (i.e. at least 125mm depth of insulation), and a quarter of homes with cavity walls still lack cavity wall insulation. In addition there are around 8 million properties in the UK with solid walls (typically housing built prior to 1945) which are much more difficult and costly to insulate.[27] Building Regulations are an important tool to drive improvements in the thermal efficiency. Successive amendments to Building Regulations have already delivered a 44% improvement in the efficiency of new dwellings since 2002.[28] However the Government abandoned a previous target for all new homes built from 2016 onwards to be "Zero Carbon", due to fears that this could reduce the rate of housebuilding (see further discussion of this in Chapter 5).[29]

Improvements are also being made in terms of the efficiency of heating systems, but again there is significant room for improvement. The efficiency of heating systems is regulated through UK Building Regulations, as well as European legislation such as the Energy Labelling and Ecodesign regulations. Since 2005 it has been a requirement of Building Regulations that all newly installed boilers must be "condensing boilers" which achieve efficiencies of around 90%, compared to efficiencies of 70% or lower for the non-condensing boilers that were previously available.[30] The higher efficiency can lead to significant cost savings: the Energy Saving Trust estimates that switching to a new boiler with appropriate controls could save a household up to £570 per year on their energy bill.[31] Condensing boilers now make up around half of all boilers installed in the UK, but according to DECC there are up to 11.5 million non-condensing boilers still in use, and of these about five million are believed to be highly inefficient (i.e. an efficiency of less than 70%). DECC forecasts that despite replacement of boilers over time, there could still be around one million non-condensing boilers in use in 2030.[32]

The poor state of the UK housing stock not only increases energy use and emissions, but also has serious consequences in terms of fuel poverty. The UK ranks very poorly compared to other European countries in terms of the rate of fuel poverty and affordability of heating.[33] As documented in our recent report, *Warmer Homes*, there were around 2.3 million households in fuel poverty in England in 2012, making up over 10% of all households.[34] The health effects of people living in cold homes are severe, costing the NHS about £1.3 billion per year[35] and contributing to "Excess Winter Deaths" (of which there were 44,000 in 2014–15).[36]

The Government has published a fuel poverty strategy for England which sets an ambition for "as many fuel poor homes as reasonably practicable to achieve a Band C energy efficiency standard by 2030". The main policy aimed at delivering this objective is the Energy Company Obligation (ECO) which provides free energy efficiency measures mainly to fuel poor households. Since its inception in 2013, ECO has been cut back significantly in order to reduce costs. The Government has

26 ACE (2015) *The Cold Man of Europe*. Energy Bill Revolution

27 DECC (2015) Domestic Green Deal, Energy Company Obligation and Insulation Levels in Great Britain, Detailed Report, September 2015

28 Defined here in terms of the energy use per square metre of floorspace.

29 The Guardian (2015) *UK scraps zero carbon homes plan*. 10th July 2015

30 Boiler efficiency refers to the relationship between its heat output and fuel input.

31 http://www.energysavingtrust.org.uk/domestic/replacing-my-boiler

32 DECC (2013) *The Future of Heating: Meeting the challenge*

33 ACE (2015) *The Cold Man of Europe*. Energy Bill Revolution

34 Howard, R. (2015) *Warmer Homes: Improving fuel poverty and energy efficiency policy in the UK*. Policy Exchange

35 http://www.energybillrevolution.org/fuel-poverty/

36 ONS (2015) *Excess Winter Mortality in England and Wales : 2014/15 (Provisional)*

committed to a replacement scheme which will commence in 2018 for a period of five years. In line with our previous recommendations, the new scheme will focus exclusively on supporting fuel poor households. However, the annual budget of the scheme (£640m) is well short of the funding required to achieve the Government's stated fuel poverty target by 2030 (an estimated £1.2 billion per year to 2030).[37]

The Government launched the "Green Deal" mechanism in 2012–13 to stimulate energy efficiency investment by "able to pay" households. The scheme failed to live up to expectations, providing energy efficiency loans to just 14,000 households[38] against an original ambition for it to support "millions of homes and businesses".[39] As discussed in our previous report, *The Customer is Always Right*, this was due to the fact that the scheme was overly complex, and the loan rate was unattractive to many households. A highly critical report on the Green Deal by the Public Accounts Committee concluded that "*the Government rushed into the Green Deal without proper consideration… about its weaknesses…. resulting in truly dismal take-up.*"[40]

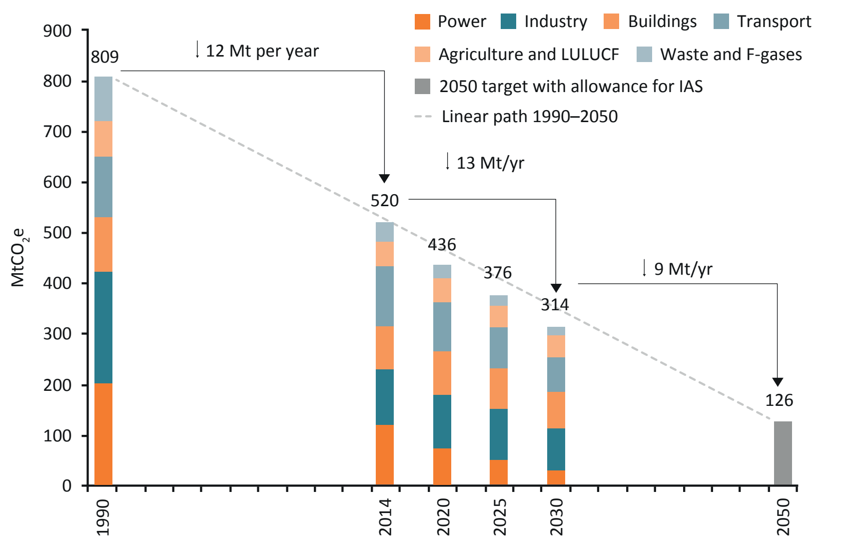
Overall, the cuts to ECO and cancellation of the Green Deal have led to a dramatic fall in the number of energy efficiency measures installed, from more than 850,000 measures in 2011–12 to around 170,000 in 2015–16 (a decline of 80%).[41]

Decarbonisation objectives

The UK Government is committed to substantially reducing carbon emissions in order to mitigate the harmful effects of climate change. Under the Climate Change Act (2008) the UK has committed to reducing annual greenhouse gas emissions by at least 80% by 2050, compared to 1990 levels. This is a unilateral commitment, with strong cross-party support, and as such is unaffected by the recent vote to leave the European Union.

In order to ensure regular progress is achieved, the Climate Change Act requires the Government to set legally binding interim targets, each covering a five-year period. The Government recently agreed the fifth carbon budget, covering the period to 2032. The Committee on Climate Change's (CCC) latest progress report (2016) shows that the UK is currently on track to deliver the emissions

Figure 1.5: Emission trajectory to 2050[42]



37 Howard, R. (2015) *Warmer Homes*. Policy Exchange

38 NAO (2016) *Green Deal and Energy Company Obligation*

39 DECC (2010) *The Green Deal: A summary of the Government's proposals*

40 http://www.parliament.uk/business/committees/committees-a-z/commons-select/public-accounts-committee/news-parliament-2015/household-energy-efficieny-schemes-report-published-16-17/

41 ACE (2015) *Left out in the cold*. Energy Bill Revolution

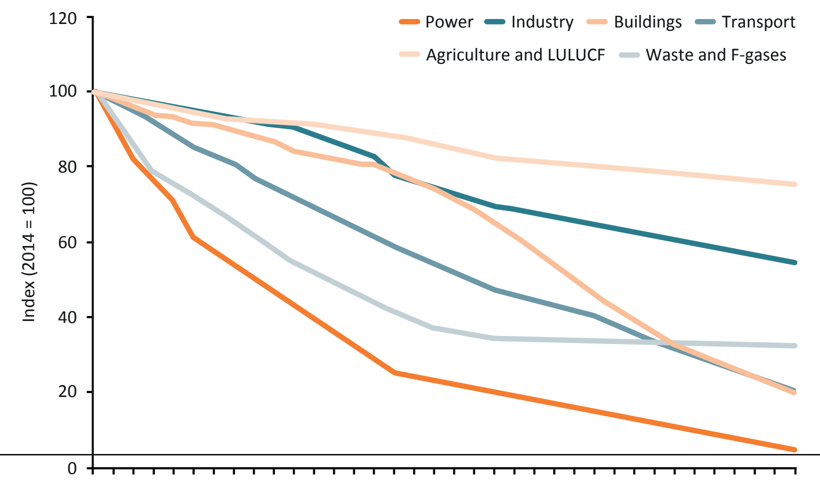
42 CCC (2015) *Sectoral scenarios for the Fifth Carbon Budget*

reductions set out in the first three carbon budget periods to 2022, but based on current policies would miss the fourth and fifth carbon budgets by a wide margin.[43] CCC projections show the scale of emissions reductions required for the UK to achieve the Climate Change Act targets to 2050 (Figure 1.5).[44] Total emissions have already fallen by 36% since 1990, but will need to fall by a further 75% between now and 2050 in order to achieve the 2050 emissions target (after making an allowance for International Aviation and Shipping, IAS).

Emissions reductions are not expected to be delivered evenly across sectors of the economy or over time. The CCC suggests that emissions reductions can be made more easily in the power sector and in buildings and transport, whilst it is more difficult to reduce emissions from agriculture and industry (Figure 1.6).[45] Emissions from the power sector have already fallen by 50% since 1990, as a result of the shift from coal to gas generation and the growth of renewables.[46] Indeed, almost all of the reduction in emissions over the last three years has been in the power sector, with very little progress across the rest of the economy.

The CCC and DECC have estimated that emissions associated with buildings (including heating and lighting) will have to fall to close to zero by 2050 in order to meet the overall carbon reduction target. This is a hugely ambitious, and made all the more difficult by the fact that the UK has a very slow replacement rate of buildings. It is estimated that around 80% of the buildings that will exist in 2050 already exist today,[47] many of which are poorly insulated. The CCC's sectoral plan suggests that power, transport, and waste can be largely decarbonised by 2030, whilst reductions in other sectors will come later. Their analysis suggests that emissions related to energy use in buildings need to fall by 25% between 2015 and 2030, with much steeper reductions thereafter (Figure 1.6).[48]

Figure 1.6: Emissions trajectory by sector to 2050[49]



It is difficult to assess the UK's progress to date in reducing emissions related to domestic heating, since there is no official Government data which tracks this specifically. The CCC produces data on total emissions related to *buildings*, including the split between domestic and non-domestic buildings and the split between "direct emissions" associated with the combustion of gas, oil and solid fuels (e.g. coal, wood), and "indirect emissions" associated with electricity used in buildings. However, since some electricity is used for heating and cooking, this

43 CCC (2016) *Meeting carbon budgets – 2016 progress report to parliament*

44 CCC (2015) *Sectoral scenarios for the Fifth Carbon Budget*

45 Ibid.

46 CCC (2016) *Meeting Carbon Budgets – 2016 Progress Report to Parliament*

47 IEA (2013) *Transition to Sustainable Buildings*

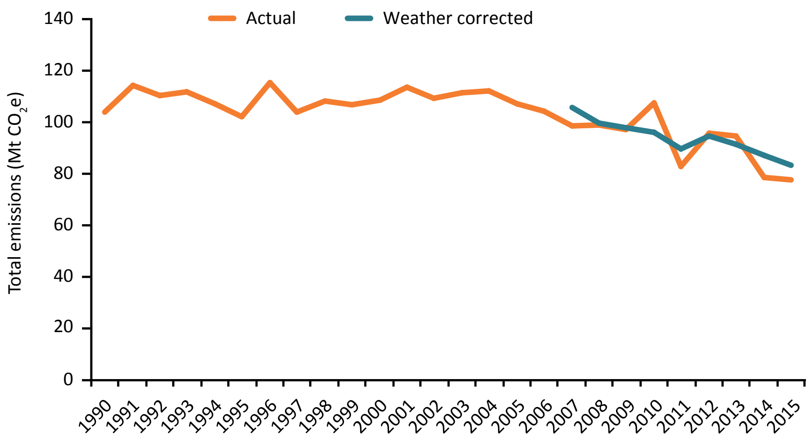
48 CCC (2015) *Sectoral scenarios for the Fifth Carbon Budget*

49 Ibid.

provides only a partial picture of emissions related to heat.

In the absence of official data, Policy Exchange has combined a number of datasets to assess the total carbon emissions associated with domestic heating (including cooking) and how this has changed since 1990. Our analysis suggests that there has been a 25% reduction in the total emissions related to domestic heating between 1990 and 2015. Much of this reduction has been achieved since 2005 due to the combination of Government policies and the sharp increase in retail energy prices (see Figure 1.4). On a "weather corrected" basis (i.e. normalising for the effects of weather in any given year) our analysis shows that there has been a 20% reduction in domestic heat related emissions. This is far less than the 50% reduction in emissions seen in the power system over the same period.[50]

Figure 1.7: Change in emissions from domestic heating (including cooking), 1990–2015



The reduction in emissions can be broken down into a number of components. Our analysis shows that comparing 1990 to 2013 (the latest year for which detailed data is available):

- Overall there has been an 8% reduction in emissions, or 14% if weather corrected (i.e. 2013 was a relatively cold year).
- The number of households in the UK increased by 20% from 22.6 million in 1990 to around 27 million in 2013. All else being equal this would have resulted in an equivalent increase in heat-related emissions.
- There was a 10% reduction in the amount of energy used for heating *per household*, due to the combination of energy efficiency improvements and other factors such as the increase in gas prices.
- Combining these factors, there has been an 8% *increase* in the total energy used to provide heating across all households since 1990. The use of gas, oil and electricity for heating has increased, whilst the direct use of solid fuels such as coal has declined.
- The average carbon-intensity of energy used to provide heating declined by around 15% since 1990.This is due to a significant shift from the use of coal in the home to lower-carbon alternatives such as gas and biomass, and a reduction in the carbon-intensity of electricity.

50 CCC (2016) *Meeting Carbon Budgets – 2016 Progress Report to Parliament*

Renewable energy target

In addition to carbon targets, the UK has also set a target under the EU Renewable Energy Directive (2009) for at least 15% of all energy consumed by 2020 to be provided by renewable sources. Although an EU-wide policy, it is up to Member States to decide how this will be achieved across the energy sector. The UK's National Renewable Energy Action Plan estimated that the UK would need to source 30% of electricity and 12% of heat from renewable sources in order to comply with the overall 15% target by 2020.[51]

The latest figures show that the UK is largely on track to meet its overall renewables target, with 7% of energy coming from renewables in 2014 against an interim target of 5.4%.[52] The UK is ahead of its interim targets for renewable electricity, and renewable heating, but is making very limited progress on renewable transport (with 3.2% coming from renewables in 2014 compared to an interim target of 5.3%).

Following the EU referendum there has been considerable debate about the future of EU-derived policies such as the Renewable Energy Directive. The renewables target has been transposed into UK law and remains in place at least for the time being. However it remains to be seen whether such EU-derived targets will remain in force longer-term, and this depends in part on the nature of the relationship between the UK and EU more broadly. In the event that the UK remains part of the European Economic Area, then many energy and environmental policies would continue to apply, whereas if the UK agrees a looser trade agreement with the EU then such obligations would fall away.

Policy Exchange has consistently argued that the renewable energy target should be scrapped, on the basis that it has pushed the Government to pursue a more limited set of decarbonisation options and increased the cost of decarbonisation.[53] Instead we argue that the Government should take a technology-neutral view, pursuing the lowest cost routes to decarbonisation. (See Chapter 5 for further discussion.)

Domestic heat policies

The main financial mechanism in place to promote the decarbonisation of heat is the **Renewable Heat Incentive (RHI)**. It provides subsidy payments to consumers to install renewable heat technologies such as biomass, heat pumps, and solar thermal heating. Subsidy payments are available for 7 years from the point of installation for domestic installations (20 years for the non-domestic RHI) with the tariffs set technology by technology. The non-domestic RHI scheme was introduced in November 2011, and the domestic RHI scheme for households followed in April 2014. Its stated purpose is to incentivise the deployment of renewable heat technologies, and to develop a market and supply chain for renewable heat to support future deployment. To date the focus of the domestic RHI has been on biomass boilers (which have received 56% of RHI subsidy payments) and air source heat pumps (which account for 45% of total RHI installations).

Based on these figures, the domestic RHI scheme has had a very limited impact to date, representing less than 0.2% of the heating market (in terms of number of households or total heat provided). Moreover, the carbon savings achieved under the RHI have been relatively expensive. Previous analysis by Policy Exchange has shown that the domestic RHI has provided an average tariff of around £120/MWh, compared to a cost of around £30/MWh or less for energy

51 National Renewable Energy Action Plan for the United Kingdom, under Article 4 of the Renewable Energy Directive 2009/28/EC

52 DECC (2016) Third Progress Report on the Promotion and Use of Energy from Renewable Sources for the UK

53 See our reports *2020 Hindsight* (2011), *Going Going Gone* (2013), and *The Customer is Always Right* (2015).

Table 1.1: Summary of domestic RHI installations to April 2016[54]

Technologies	Biomass	Air Source Heat Pump	Ground Source Heat Pump	Solar Thermal	Total
Accreditations	11,612	22,161	7,047	7,662	48,482
%	24%	45%	15%	17%	
Heat Generated (MWh)	468,480	232,198	129,090	14,500	844,268
%	55%	28%	15%	2%	
Payments (£ million)	£53.7	£15.8	£23.9	£2.6	£96.0
%	56%	16%	25%	3%	

efficiency schemes or mature renewables technologies under the new Contract for Difference scheme.[55] There are also a number of tensions between the RHI and other Government policies. For example, the effect of the RHI is to move households towards renewable heating, regardless of whether their previous heat source was gas, oil, electric, or an alternative fuel source. This runs counter to Ofgem's Fuel Poor Network Extension Scheme which aims to connect vulnerable households to the gas grid in order to reduce their heating costs. In other words, Government policies are simultaneously moving some households on to the gas network, and other households off gas heating towards renewables.

The Government announced in autumn 2015 that the RHI would be extended to 2020–21 in order to deliver the European renewable heat target. The annual budget will increase to £1.15 billion by 2020–21. Whilst a significant increase in scale, this is only expected to deliver renewable heat technologies to an extra 500,000 homes, or around 2% of UK households. Overall, the RHI has resulted in limited progress in the deployment of renewable heat technologies, and the current model is too costly to support mass deployment.

Chapter summary

- Nearly half (48%) of all energy consumed in the UK is used to provide heating.
- Domestic heating accounts for 28% of total energy used in the UK.
- Gas is the dominant form of heating, with gas boilers found in over 80% of UK homes. The remaining homes are heated using electric heating, heating oil, renewables (mainly biomass), or solid fuels such as coal.
- Gas prices have increased at more than three times the general rate of inflation since 2005.
- The UK has set an ambitious target under the Climate Change Act to reduce carbon emissions by 80% by 2050 (compared to 1990 levels) which will require a substantial reduction in emissions related to buildings and heating.
- There has been a 20% reduction in carbon emissions associated with domestic heating since 1990, despite a 20% increased in the number of UK households over the same period.
- The Renewable Heat Incentive has had a very limited impact to date, with accredited installations representing less than 0.2% of UK households.
- Despite some improvement, the UK's housing stock is amongst the least energy in Europe, and 10% of households in England are in fuel poverty.

54 DECC (2016) *Non-Domestic RHI and domestic RHI monthly deployment data: April 2016*

55 Howard, R. (2015) *The Customer is Always Right*. Policy Exchange

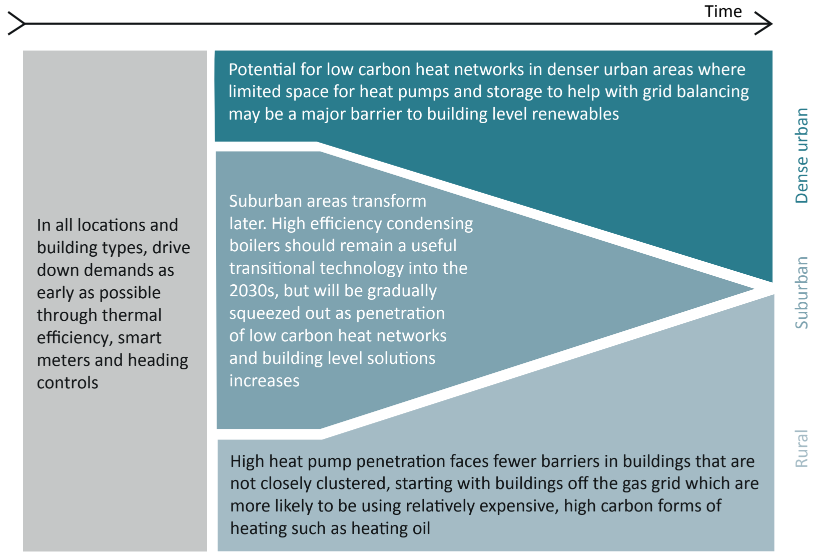
2
Review of the DECC Heat Strategy

This Chapter of the report provides a summary and critique of the Government's latest heat strategy, which was first produced by DECC in 2012 and subsequently revised in 2013. It summarises the strengths and weaknesses of the proposed approach. In particular we highlight the challenge of how to meet the substantial peaks in heat demand which occur during winter months, and argue that this has not been adequately considered. Finally, the Chapter also sets out alternate options to decarbonise heat (so-called "pathways") which have been suggested in previous studies.

DECC's Heat Strategy

DECC produced a "strategic framework" for low carbon heat in the UK in 2012, which set out a vision where heat is almost completely decarbonised by 2050 (Figure 2.1). It suggests that gas boilers will need to be completely phased out in the future (although it is not specific about when this would happen). Instead, the strategy suggests that heat will be provided mainly by heat networks in dense urban areas, and by heat pumps in rural areas (these technologies are described in detail in Chapter 3). DECC estimated in a separate study[56] that 14% of dwellings could be connected to a heat network, which suggests that the remaining 86% of homes would eventually need to be heated via a heat pump. The strategy suggests

Figure 2.1: 2012 DECC Heat Strategy[60]



56 DECC (2013) *The Future of Heating: Meeting the challenge*

57 DECC (2012) *Strategic Framework for Low Carbon Heat in the UK: Summary of responses*

58 Energy UK (2012) *Energy UK response to the Heat Strategy*

59 REA (2012) *REA response to 'The Future of Heating: A strategic framework for low carbon heat in the UK'*

that the focus of policy in the 2010s should be to improve energy efficiency, laying the foundation for the mass rollout of low carbon technologies in the 2020s and 2030s. However, as has already been discussed, the rate of improvement in energy efficiency during this decade is slowing, and is arguably already below that envisaged in the 2012 DECC heat strategy.

DECC conducted a consultation on the 2012 heat strategy[57] in which stakeholders highlighted a number of significant concerns, as follows:

- **Picking winners:** stakeholders felt that the strategy placed too much emphasis on particular technologies such as electric heat pumps. Energy UK suggested that Government should provide "fair and transparent support for all technologies" and that "lock-in to a particular energy delivery path should be avoided."[58] The Renewable Energy Association commented that "Government does not have a good track record on picking winners" and should instead pursue "a more balanced strategy [which] values diversity and options".[59] The UK Energy Research Centre (UKERC) commented that "the performance and acceptability of heat pumps in a wide range of UK homes remains unproven" and that "a more diversified approach to meeting residential heating goals might be justified."[61] Many respondents felt that the strategy appeared to rule out other opportunities too early (such as biomethane) and placed insufficient emphasis on energy efficiency. The Royal Academy of Engineering, IET and CIBSE emphasised the role of energy efficiency in decarbonising heat, and encouraged greater connection between the heat strategy and energy efficiency.[62]
- **Meeting peak demand:** stakeholders felt that insufficient consideration had been given to how to meet peak demand levels during the winter, in particular if there is a significant shift from gas to electric heating in the future (this is explored further below). For example, Eyre (2011) commented that the most ambitious scenarios for electrification of heating are "at best, extremely difficult, and, more likely, infeasible."[63] Related to this, stakeholders felt that more consideration should be given to the storage potential of each type of heating.
- **Infrastructure and network challenges:** stakeholders expressed uncertainty about the suggested pace and scale of electricity decarbonisation required to shift to electric heating. In particular there was a concern about the significant cost of the infrastructure required to cope with the additional load on the power system, such as additional generation capacity and upgrades to power networks (this is quantified in Chapter 3).
- **Cost and consumer issues:** respondents suggested that consumer issues could be a major obstacle to the decarbonisation of heat. For example, respondents highlighted the high cost to consumers of installing new heat technologies, and generally low consumer awareness and acceptance of new heating technologies. Hoggett (2011) commented that the large-scale switch to heat pumps suggested by Government is "not underpinned by an economic analysis of the likely impact on households… nor by an evaluation of the likely role of customer preference and choice."[64] Energy UK suggested that "government should … support solutions that are cost-effective, deliverable and acceptable to consumers."[65]

60 DECC (2012) *Strategic framework for low-carbon heat in the UK*

61 UKERC (2014) *UK Energy Strategies Under Uncertainty: Uncertainties in Energy Demand in Residential Heating*

62 Engineering the Future (2012) *The Future of Heating: A strategic framework for low carbon heat in the UK*

63 Eyre, N. (2011) *Efficiency, demand reduction or electrification? ECEEE Summer Study*

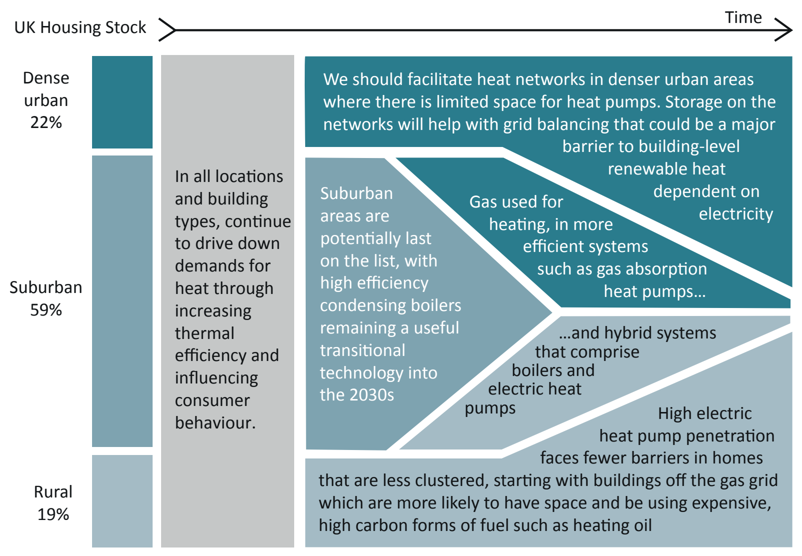
64 Hoggett, R. Ward, J. and Mitchell, C. (2011) *Heat in Homes: customer choice on fuel and technologies.* Scotia Gas Networks.

65 Energy UK (2012) *Energy UK response to the Heat Strategy*

- **Supply chain issues:** the consultation also flagged concerns regarding the performance and quality of installation of new heat technologies (electric heat pumps in particular) and the capacity of the supply chain to scale-up to meet the levels of deployment envisaged in the heat strategy.

Following this, DECC released a revised strategy document in 2013, *The Future of Heating: Meeting the Challenge*. This provided an update on the Government's thinking, based on feedback on the 2012 strategy as well as more detailed modelling and projections for the mix of heating technologies in the future.[66] The overall foundations of the strategy remained broadly the same, with a focus on the mass deployment of heat pumps, together with heat networks in urban areas. But the 2013 strategy began to recognise the challenges associated with meeting peak levels of heating demand. On this basis, DECC suggested a more significant role for gas as a "bridging" technology, for example through the use of Gas Heat Pumps and hybrid gas/electric systems (these technologies are discussed further in Chapter 3).

Figure 2.2: 2013 DECC Heat Strategy[67]



DECC commissioned modelling of the potential contribution of each technology to meet future heating requirements (Figure 2.3). This suggested that electric heat pumps would dominate the market by 2050, meeting around 85% of total domestic heat demand, with the remainder coming from heat networks (10%) and gas boilers (less than 5%). The strategy suggested that conventional gas boilers would need to start being phased out from 2015 onwards, and be completely phased out from UK homes by 2030. It also suggested significant take-up of hybrid gas boilers during the 2010s and 2020s, but with these boilers then phased out from 2030 onwards.

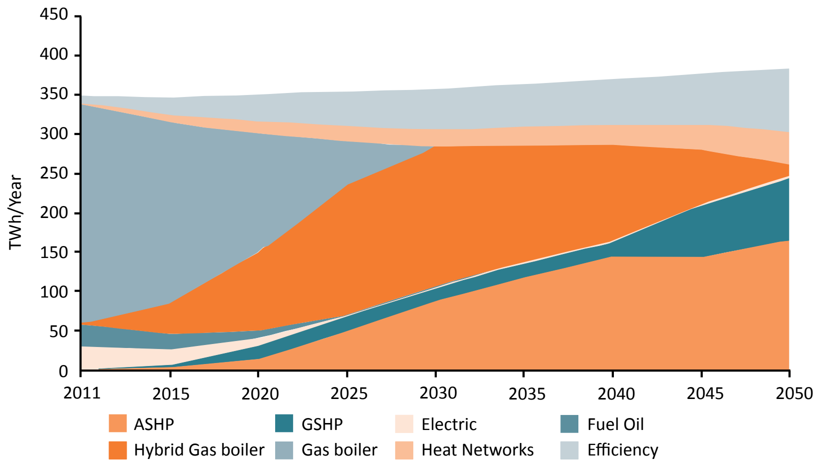
It should be stressed that this modelling is in stark contrast to what is actually taking place. Conventional boilers remain the heating type of choice with around 1.6 million boilers sold per year,[68] whilst sales of heat pumps and hybrids remain very limited. In other words, the current heat strategy is far from being delivered by current policies.

66 DECC (2013) *The Future of Heating: Meeting the challenge*

67 Ibid.

68 Source: Energy and Utilities Alliance

Figure 2.3: Output of heat technologies to 2050[69]



As part of this project, Policy Exchange consulted with a large number of companies and organisations across the energy industry. Our discussions with these stakeholders reinforced the impression that the 2012 and 2013 DECC heat strategies would be extremely costly and impractical to deliver, and that they had been poorly received by industry. The central criticisms raised by stakeholders were consistent with those raised as part of the consultation on the 2012 DECC heat strategy. Stakeholders suggested that DECC had moderated its view on electric heating slightly in the 2013 strategy, but it still placed too much emphasis on the electrification of heating. In Chapter 3, we investigate the costs associated with delivering electric heat pumps and other lower carbon heat technologies in more detail.

The challenge of meeting peak heat demand

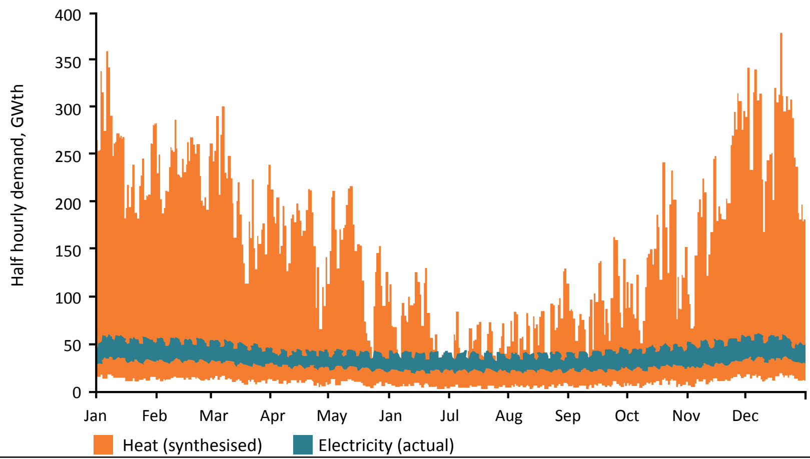
Arguably the biggest challenge associated with decarbonising heat is how to cater for the significant fluctuations in the demand for heat on an hourly, daily, seasonal and annual basis. The demand for heating is highly variable, tending to peak on the coldest days of the year, with both a morning and evening peak. Heat demand also varies significantly year to year depending on winter temperatures, and gas networks are currently required to plan on the basis of peak demands in a 1-in-20 winter.

Figure 2.4 shows a modelled profile for heat demand on a half hourly basis for all sectors (red line) compared to the actual profile of electricity demand (grey line). The data relates to 2010, which was a relatively cold year. As shown, the demand for heat varies massively across the year, reaching peaks of up to 380 GWs, or around 6.5 times the peak demand for electricity (60GWs).[70] Heat demand drops to relatively low levels during the summer months, when it primarily relates to water heating rather than space heating.

69 DECC (2013) *The Future of Heating: Meeting the challenge*

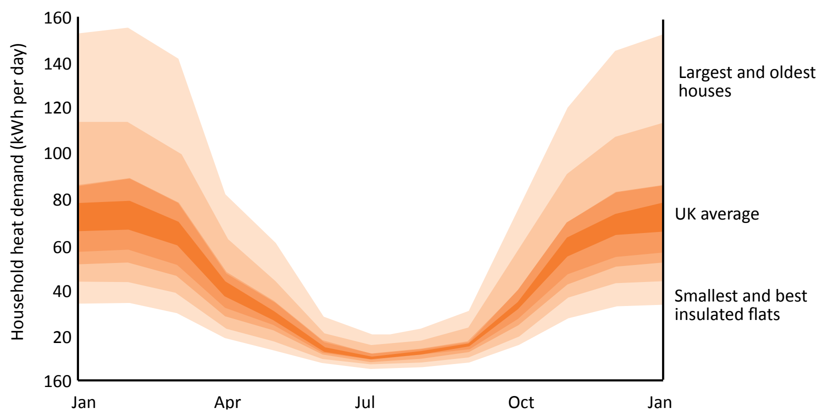
70 Sansom, R. (2014) *Decarbonising Low Grade Heat for a Low Carbon Future.* Imperial College

Figure 2.4: Annual heat and electricity demand profile for 2010[71]



The seasonal pattern of demand is repeated if we focus only on heat demand in homes. Research suggests that the average heat demand on a winter's day is around seven times that on a summer's day, with the largest and oldest houses requiring the greatest amounts of heat overall (Figure 2.5).

Figure 2.5 Heat demand for different household types throughout the year in the UK[72]



These peaks in heat demand are manageable at present due to the capability of the gas system to store energy and then quickly convert this into heat as required. Recent research suggests that the gas network is capable of storing 50,000 GWhs of energy at any time, which is equivalent to about 7% of the total gas used for heating per year.[73] By contrast, the electricity system is currently only capable of storing 27 GWhs of energy, which equates to less than 0.01% of the total electricity used per year. Moreover, the same study suggests that the cost of storing electricity is at least 2,000 times more expensive than gas (on a £/MWh basis).

This raises some serious questions about how heating requirements can be met if and when the UK moves away from gas towards alternatives such as electric heating. In our view Government needs to give far greater consideration to the

71 Sansom, R. (2014) *Decarbonising Low Grade Heat for a Low Carbon Future*. Imperial College.

72 Dodds et al. (2015) *Hydrogen and fuel cell technologies for heating: A review;* Carbon Trust (2007) *Micro-CHP accelerator: interim report*

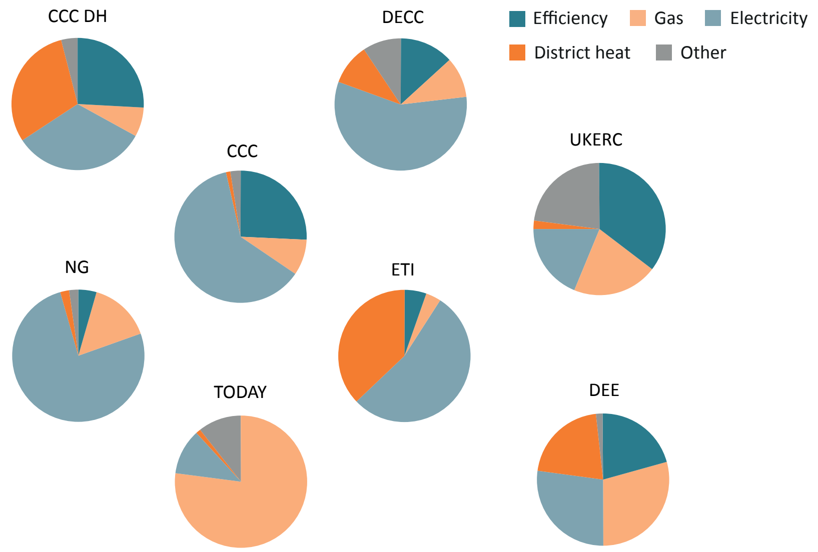
73 MacLean, K. et al (2016) *Managing Heat System Decarbonisation*

variability of heat demand, how this can be met in the future, and the system implications of switching to alternative heating technologies.

Alternative "Pathways" for Heat

Alongside the DECC heat strategy, several independent research studies have considered the future of domestic heating in the UK, suggesting a number of alternative options or so-called "pathways" for heat. These studies have come to a wide range of conclusions about the possible contribution of different heating technologies, leading to great uncertainties about the future of domestic heating. A report by Carbon Connect (2014)[74] summarised a number of key studies (Figure 2.6). As shown, there is considerable divergence between the studies about the contribution from different heating technologies in the future.

Figure 2.6: Heat output by 2050 (and output displaced by retrofit energy efficiency)



Most of the studies foresee electricity playing a greater role in providing heat in 2050 than it does currently, but to wildly varying degrees. For example, National Grid predicts that electricity will provide around 80% of domestic heating in 2050, while UKERC predict it will be only around 20%. There are significant network and system challenges associated with meeting peak heat demand, which have been considered in some but not all of the studies mentioned. Generally, the studies that considered this question suggest that electrifying heat would require significant investment in power generation and power network reinforcement, making it a relatively expensive option.

All of the "pathway" studies suggest a significant reduction in the use of gas for domestic heating by 2050, compared to the status quo, but again to very different extents. The studies by UKERC and Delta-ee suggest gas could still meet up to 30% of heating needs in 2050, whilst other studies suggest a much smaller contribution, typically less than 10%. Some of the studies (in particular the report by Delta-ee) also consider the possibility to lower the carbon intensity of gas, for example by injecting biomethane into the gas grid (this is explored further in Chapter 3).

74 Carbon Connect (2014) *Pathways for Heat: Low Carbon Heat for Buildings*

There is also considerable divergence in views on the potential of district heating (or "heat networks") with studies predicting that it could meet anywhere from close to zero to up to 35% of heating needs in 2050. Finally, the studies also suggest that overall heat requirements could be reduced through improvements in energy efficiency, although again the contribution from energy efficiency varies significantly from around 5% in the study by National Grid, to as much as 35% in the study by UKERC.

Since the Carbon Connect report was published in 2014 a number of new studies have considered the future of heat in the UK. A recent report by Imperial College London[75] identified the costs and impacts associated with electric heat pumps, district heating, and conversion of the gas grid to use hydrogen (all of which are explored further in Chapter 3). The Imperial study does not propose a particular mix of technologies, but does point out the significant challenges associated with all of the main options to decarbonise heat. KPMG also recently produced a report on the future of gas for the Energy Networks Association.[76] This assesses four different scenarios – including scenarios focused on electrification, greener gases, renewables, and a diversified scenario. Their analysis suggests that the lowest cost option would be to continue the use of gas heating at current levels, but decarbonise gas use through the conversion of the gas network to hydrogen and biomethane.

Overall, there is considerable uncertainty about the future direction of domestic heating in the UK. There are many different and divergent views on the prospects for individual technologies, and the DECC strategy has been highly contested. Chaudry et al (2014) argue that the debate about the decarbonisation of heat is "plagued with uncertainty", due to uncertainties about the deployment, performance and costs of key heat technologies, the level of decarbonisation possible, and the likely impact of policy interventions. They conclude that this presents "a great challenge to policymakers to make sound strategic decisions about the future."

The following chapter of this report considers the main technology options in more detail, and then in Chapter 4 this analysis is used as the basis to develop alternative scenarios for the future of heat.

Chapter summary

- The Government's heat strategy envisages a future where domestic heating is largely decarbonised by 2050. The strategy suggests that heat pumps will provide around 85% of domestic heating, with heat networks also playing an important role, and gas heating largely phased out by 2050.
- This view has been criticised by industry and academics as being unrealistic and expensive to deliver in practice.
- Heat demand is highly variable over the course of the year. This raises a significant challenge in how to decarbonise heat, particularly if the UK moves away from using gas towards other heat technologies such as electric heat pumps.
- A number of studies have identified alternative "pathways" for heat – with a wide range of different views on the contribution which will be made by gas, heat pumps, heat networks, and renewable heating, as well as energy efficiency.
- Overall there is considerable uncertainty about how heating can and should be decarbonised, creating issues for policymakers and industry.

75 MacLean, K. et al (2016) *Managing Heat System Decarbonisation: Comparing the impacts and costs of transitions in heat infrastructure*

76 KPMG (2016) *2050 Energy Scenarios*. Energy Networks Association

3

Future Heat Technologies

This Chapter of the report provides a review of the different technologies and options which could be pursued to decarbonise heating. We consider five technology groupings in turn, as follows:

- **Demand Reduction** – measures to improve the thermal efficiency of homes and reduce heat demand, such as insulation and heating controls;
- **Gas heating** – including high efficiency boiler technologies, as well as the use of "greener gases" such as biogases and hydrogen for heating;
- **Electric heating** – including direct electric heating and heat pumps;
- **Heat networks** – heating solutions provided at building, community or district level;
- **Small scale renewables** – such as biomass and solar water heating.

We look at each of these technology groups in turn, considering the following factors:

- **decarbonisation potential** – the potential for the technology to reduce heat demand and/or carbon emissions;
- **network cost/impact** – the challenges and costs associated with delivering network infrastructure to support the use of each technology, in particular the challenge of meeting "peak demand";
- **supply cost/impact** – the challenge in sourcing sufficient resource to meet demand (e.g. low carbon electricity, green gas, or biomass);
- **consumer cost/impact** – factors which may limit consumer support for the technology, such as the upfront cost, level of disruption involved inside and outside the home, and quality and performance issues.

Demand Reduction

Improving energy efficiency and reducing the demand for heat can make a significant contribution towards the decarbonisation of heating. As discussed in Chapter 1, the UK has already made progress in improving energy efficiency, but there is significant potential to improve efficiency further. Improving energy efficiency not only limits the overall energy required to heat our homes, but will also help by reducing peak demand on the coldest days of the year, and improving the performance of heating systems (in particular heat pumps, which do not perform well in inefficient homes). The CCC has said that "heat decarbonisation will have to go hand in hand with improvements in energy efficiency."[77]

77 CCC (2015) *Sectoral Scenarios for the Fifth Carbon Budget*

Reducing heat demand – What are the options?

There are a number of options available to reduce heat demand from homes, each with their own set of challenges and opportunities:

1. Improving insulation in existing homes
2. Improving heating controls
3. Minimising heat demand in new homes

Improving insulation in existing homes

The rate of housebuilding and replacement of homes is relatively low in the UK, and it is estimated that around 80% of the buildings that will exist in 2050 in the UK are already in existence.[78] Improving the thermal efficiency of the existing housing stock can make a significant contribution to reducing overall heat demand and associated carbon emissions. Older homes tend to be less efficient than new homes: households living in properties built prior to 1945 consume on average around 20% more gas than those living in properties built since 2000.[79]

The UK building stock has already undergone some significant improvements, with more than 70% of all buildings with a loft, and 73% of all buildings with a cavity wall having been insulated as at 2015. However, this still leaves another 5 million lofts and 1.3 million homes with cavity walls which are still uninsulated or have the potential to be insulated further.[80] Insulating these properties could yield energy savings of approximately 13 TWh/year.[81] Measures such as loft and cavity wall insulation are considered to be cost-effective, with a typical payback period of around 2 years for insulating an uninsulated loft, 3 years for cavity wall insulation, and 10–15 years for top up insulation.[82] Therefore, an area of focus for policymakers should be to deliver these savings in "easy to treat" properties by 2030 at the latest.

However, a bigger challenge is how to improve the efficiency of "hard to treat" properties (typically built prior to 1945) which have solid walls and cannot have cavity wall insulation fitted. Improving the efficiency of these properties requires more substantial work to fit either internal or external insulation (which is then covered by render or cladding). This can be expensive, with external wall insulation costing £8,000–£22,000, and internal insulation costing £4,000–£13,000, depending on the property type.[83] The payback period for Solid Wall Insulation is generally very long at 20 years or more. The installation process can also be quite disruptive – for example fitting internal wall insulation involves redecoration and also reduces the size of rooms. It is estimated that insulating "hard to treat" properties could deliver approximately 56 TWh/year of additional energy savings.[84] These more expensive measures will eventually have to be tackled as well if total heating demand is to reduce instead of increasing in the future.

Improving heating controls

The second option is to use heating controls to optimise the operation of heating systems and reduce unnecessary over-heating wherever possible. There are several types of controls that can be fitted relatively easily and cheaply in order to reduce heat usage. Simple room thermostats and programmers are the most basic option at a cost of around £100. More advanced options include thermostatic or

78 UKGBC (2008) *Low carbon existing homes*

79 DECC (2015) *Energy Consumption in the UK, 2015*

80 Ibid.

81 Element Energy/EST (2013) *Review of potential for carbon savings from residential energy efficiency*. Note that this refers to the theoretical potential of these measures, as the report states that more research is required in order to assess whether the difference between real and calculated energy savings. "In-use" factors assumed by DECC would lead to all but the easiest insulation measures (easy-to-treat cavities and loft insulation <12.5cm) to become non-cost-effective.

82 Source: Energy Savings Trust

83 Ibid.

84 Element Energy/EST (2013) *Review of potential for carbon savings from residential energy efficiency.*

programmable radiator valves, which can make sure that every room is only heated when it needs to be, and only to the required temperature. Data and information from smart meters and smart home solutions could in future be used to optimise heating systems and further drive down demand. DECC suggests that only 49% of households have a full set of heating controls (a timer, room thermostat and thermostatic radiator valves) leaving significant potential for improvement.[85]

Analysis by Element Energy and the Energy Saving Trust suggests that the roll-out of better heating controls to all homes could save up to 1.2 $MtCO_2$ per year, which would be equivalent to reducing annual heat demand by 5.7 TWh (or around 2%).[86] More recent research suggests that advanced zonal controls could reduce gas use by 12% compared to conventional controls.[87] Separately, the Energy Saving Trust has estimated that installing controls can reduce heating bills by £75–150 per year in a typical three bed semi-detached home.[88]

> "It is essential that new homes are built to the highest possible standards of energy efficiency, in order to minimise heating demand and associated emissions"

The savings achievable through better controls are closely linked to consumer behaviour: research suggests that households need to understand their heating systems properly in order to maximise savings, and conversely that theoretical energy savings can often be undermined by consumer behaviour.[89] As the late Professor David MacKay put it: "the most important smart component in a building with smart heating is the occupant."[90]

Minimising heat demand in new homes

The UK population continues to increase, and with that comes an increase in the number of homes and demand for heating. Government projections suggest that the number of households in the UK could grow from around 27 million today to around 31 million by 2030 and 35 million by 2050 (an overall increase of 30%).[91] This implies that 8 million new homes will need to be built between now and 2050 (not including the demolition and replacement of existing homes which would increase this figure further).

It is essential that these new homes are built to the highest possible standards of energy efficiency, in order to minimise heating demand and associated emissions. Building Regulations have been successively tightened in recent years, with new homes built since 2013 required to achieve a 44% energy efficiency improvement compared to homes built in 2002. However, as discussed in Chapter 1, the Government recently abandoned a prior target that all new homes should be "Zero Carbon" from 2016 onwards, which would have resulted in a significant further improvement. The EU Energy Performance of Buildings Directive requires that all new buildings are "nearly zero energy" from 2020, but at present it is unclear whether or how the UK Government intends to achieve this goal. Analysis shows that the additional cost of meeting the Zero Carbon Homes standard would be around £4,100–£4,700 for a semi-detached property, but that this would reduce energy bills by £330 per year.[92] The bulk of this cost relates to the installation of on-site low or zero carbon heating technologies, with the additional cost of improving thermal efficiency being negligible for most housing types.

85 DECC (2014) *How heating controls affect domestic energy demand: a rapid evidence assessment*

86 Element Energy/EST (2013) *Review of potential for carbon savings from residential energy*

87 Beizaee, A. et al (2015) 'Measuring the potential of zonal space heating controls to reduce energy use in UK homes: The case of un-furbished 1930s dwellings', *Energy and Buildings*, Vol 92 pp 29-44

88 Source: Energy Savings Trust

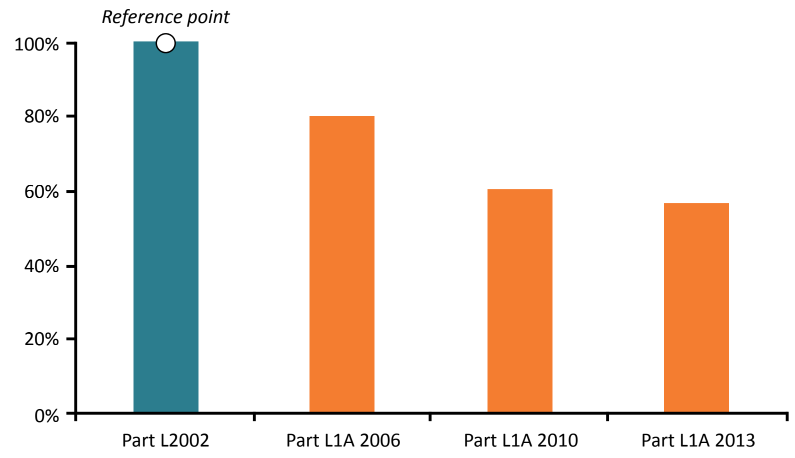
89 DECC (2014) *How heating controls affect domestic energy demand: a rapid evidence assessment*

90 MacKay, D. (2008) *Sustainable energy without the hot air*

91 ONS (2015) Population Projections (October 2015) and DCLG (2015) Household Forecasts (February 2015). Household trend prolongation to 2050 by Delta-ee.

92 Zero Carbon Hub (2014) Cost analysis: Meeting the zero carbon standard. Comparison is between a zero carbon home compared to a home built to 2013 PartL1A standard.

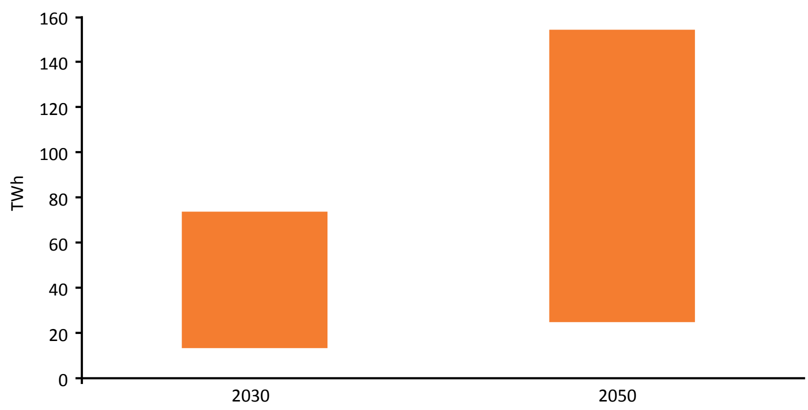
Figure 3.1: CO_2 emissions reductions required under Building Regulations Part L 1A



Overall decarbonisation potential

A number of studies have estimated the overall reduction in heat demand which could be possible in the future. These studies show a very wide range of results, with an estimated reduction in heat across the total building stock (e.g. including non-residential buildings) of 13–74 TWh by 2030 (2–13% of total heat demand) and 25–154 TWh in 2050 (5–35%).[93]

Figure 3.2: Demand reduction potential in the UK building stock



Studies which have looked only at the domestic sector suggest a demand reduction potential of 40–95 TWh per year by 2050, equivalent to 10–25% of total heat demand.[94] The most recent studies suggest that the residual heat demand from UK homes (i.e. after efficiency measures have been implemented) will be between 303–367 TWh in 2050, compared to 368 TWh today.[95] In other words, it is suggested that heat demand will reduce by up to 65TWh (18%) by 2050 despite further growth in population and housing numbers.

93 As summarised in Carbon Connect (2014) *Pathways for Heat: Low Carbon Heat for Buildings*

94 For example: Baringa Redpoint (2012) *Pathways for Decarbonising Heat: Report for National Grid*

95 For example: DECC (2013) *The Future of Heating: Meeting the challenge – Evidence Annex*; Element Energy (2015) *Research on district heating and local approaches to heat decarbonisation.*

There is scope to improve the energy demand in buildings even further by installing technologies such as heat recovery ventilation (where incoming fresh air is warmed using warm air extracted from the home), and waste water heat recovery systems (which recycle heat from drain water from showers and dishwashers etc). More research is required to establish the potential for such measures, which will not be applicable to all homes.

Summary

- Improving energy efficiency should be a core component of the Government's approach to decarbonising heat: it will be beneficial regardless of which heat technologies are used in the future, and contribute to wider objectives such as reducing fuel poverty.
- There is significant potential to reduce heat demand from existing homes through relatively easy to fit measures such as loft and cavity wall insulation and better heating controls. These measures should be tackled as soon as possible.
- There is even greater potential to reduce demand through more extensive measures, such as fitting insulation to solid walled properties, but this is far more costly and can result in disruption to the home.
- Efficiency savings at household level will be offset somewhat by the continued growth in the number of households, which is expected to increase by 30% between now and 2050.
- New homes will need to be built to the highest efficiency standards in order to minimise the resulting increase in heat demand.
- Overall, studies suggest that overall domestic heat demand could be reduced by up to 18% by 2050 (from 368 TWhs per year now to 303 TWhs by 2050).

Gas

As discussed in Chapter 1, natural gas is by far the most widely used and accepted fuel source for heating, used in over 80% of UK homes.[96] Gas heating has wide consumer acceptance, as demonstrated in recent studies by the Energy Technologies Institute and UKERC.[97] Natural gas currently offers households an affordable heating solution, and even if there was an increase in gas prices it would likely remain the most affordable heating solution for households already connected to the gas grid. Gas also plays a crucial role in the UK energy system with its capability to deal with large swings in heat demand, as discussed in Chapter 2.

However, the significant emissions associated with gas combustion have led policymakers and researchers to question the long-term use of gas for heating, and this has become a central challenge to the achievement of the UK's long-term carbon targets. DECC's heat strategy[98] (central scenario) suggests a reduction in the use of gas for heating of approximately 90% by 2050. In this scenario, natural gas remains the main domestic heating fuel until 2030, but with conventional gas boilers being replaced with more efficient hybrid gas/electric boilers from 2015 onwards. Thereafter, DECC's heat strategy envisages that the use of natural gas would reduce substantially over the period 2030–2050, with gas boilers being replaced with electric heat pumps and heat networks (these technologies are explored in later sections below). A range of other studies suggest that gas use will decline by 10–50% by 2030, and by 75–95% by 2050 (see Figure 2.6).

96 DECC (2015) *Energy Consumption in the UK, 2015*

97 ETI (2015) *Smart Systems and Heat: Consumer challenges for low carbon heat*; UKERC (2013) *Transforming the UK Energy System – Public Values, Attitudes and Acceptability*

98 DECC (2013) *The Future of Heating: Meeting the challenge*

However, there are options to decarbonise the way we use gas such that it could potentially continue to play a role in providing heat, for example:

- Improving the efficiency of gas appliances;
- Moving towards hybrid gas/electric forms of heating;
- Decarbonising gas by replacing it (either partially or fully) with "greener gases" such as biomethane, biopropane, or hydrogen.

High efficiency gas appliances

One way to reduce the carbon emissions associated with gas heating is simply to improve the efficiency of gas boilers and burn less gas. As discussed in Chapter 1, the UK has already made significant progress in improving boiler efficiencies, in large part due to changes to Building Regulations in 2005 which mandated the use of efficient condensing boilers (which extract useful heat from boiler exhaust gases). DECC analysis shows that changes to Building Regulations (including boiler regulations) have been amongst the most impactful energy efficiency policies to date.[99] However, according to DECC there are still up to 11.5 million non-condensing boilers used in the UK, and of these about five million are believed to be highly inefficient (i.e. an efficiency of less than 70%). **A significant reduction in heating-related emissions could be achieved simply by completing the rollout of condensing boilers across the UK.**

There are also a number of more advanced technologies which could increase efficiency levels beyond that of a standard condensing boiler. These technologies perform well, although costs will remain high while sales volumes are low.

The first is **Flue Gas Heat Recovery** (FGHR) systems which recover additional heat from the boiler exhaust using a heat exchanger. FGHR systems can reduce gas use and carbon emissions by up to 5%.[100] These efficiency gains are relatively small but could be achieved at a relatively low cost of around £300–500 per boiler. Some boiler manufacturers have already adopted FGHR technology in their products in order to make further efficiency improvements.

The second technology is **Gas Driven Heat Pumps (GDHPs)**, which as with electrically driven heat pumps are able to absorb heat from the air or ground outside the home, and "pump" this into the home using a reverse refrigeration process. Several different types of non–residential GDHPs are available on the market today and tens of thousands of these units have already been installed across Europe and Asia. The first products for the residential sector were introduced in 2013–14, but were very costly at around £12,000.[101] However several new lower cost systems (costing around £8,000) are currently being brought to the market or will be available within the next five years. Previous analysis by Delta-ee suggests that GDHPs can achieve energy and carbon emission savings of 26–43% compared to today's condensing boilers, and that technology development is expected to increase this saving in the future.[102]

The third is **Micro Combined Heat & Power (Micro-CHP)** systems which burn gas to generate heat and electricity at the same time, either on a residential or communal scale (e.g. to supply a heat network). Residential CHP systems cost around £6,000 or more, and can be up to 36% more efficient than the separate production of heat in a gas boiler and electricity in a gas power plant. They can

99 DECC (2014) *Estimated impacts of energy and climate change policies on energy prices and bills*

100 Based on an efficiency of a gas condensing boiler with passive flue gas heat recovery of 94% compared to a standard gas condensing boiler with an efficiency of 89%.

101 Critoph, R. (2013) *Gas Driven Heat Pumps: Market Potential, Support Measures and Barriers to Development of the UK Market*. DECC.

102 Delta-ee (2014) *RHI Evidence Report: Gas Driven Heat Pumps*. DECC

therefore deliver a substantial reduction in carbon emissions (particularly in the provision of electricity – although the relative carbon savings of Micro-CHP systems will decrease as the power system is decarbonised). Micro-CHP could also play an important role in a decarbonised power system by helping to meet peak power requirements, as usage of these systems will typically coincide with periods of high electricity demand, particularly in winter.

One of the available Micro-CHP technologies is the fuel cell, which produces electricity directly through a chemical reaction between a fuel and an oxidant. Fuel cells can achieve an overall efficiency of 90%+ but are currently much larger and more expensive than conventional boilers (around £24,000, but with potential to fall significantly). They are therefore likely to prove unpopular in homes with limited space and would have to reduce significantly in price in order to become economically attractive.

The final option is **hybrid gas/electric systems** which combine a gas boiler and an electric heat pump. Hybrids are able to switch between the two fuel sources, depending on which one is most efficient or cheapest at a given time. Depending on its size, the heat pump will usually meet between 60–95% of annual heat demand, with the gas boiler meeting the remainder. This means that they offer a route to substantially decarbonise heating as the power grid is decarbonised, but at the same time they can completely switch to the gas boiler during times of peak demand. This is a key advantage of hybrid systems, since it means that they are likely to have far less of an impact on electricity supply and networks than a standalone heat pump (see the section on electric heating below). A typical hybrid installation with a low capacity heat pump costs approximately £6,000–£8,000 today, making it more expensive than a standard gas boiler (around £2,500), but less expensive than an electric heat pump (£8,500–£13,000).

Overall there is potential to achieve a significant increase in the efficiency of gas heating systems, firstly through the replacement of old non-condensing boilers, and secondly through the adoption of more advanced boiler technologies. That said, there is a limit to the level of decarbonisation possible through improvements in boiler efficiency, unless combined with greener sources of gas, and some of the more advanced technologies face cost challenges which would need to be addressed before they will be ready for mass roll-out. It is notable that some of the technologies identified do not have explicit policy support at present – for example gas driven heat pumps are not eligible for support under the Renewable Heat Incentive.

“Overall there is potential to achieve a significant increase in the efficiency of gas heating systems, firstly through the replacement of old non-condensing boilers, and secondly through the adoption of more advanced boiler technologies”

Greener Gases

While gas heating in the UK is currently based on the use of natural gas, there is the opportunity to decarbonise gas use by switching to alternative lower carbon gases including “biogases” and hydrogen, as explored below.

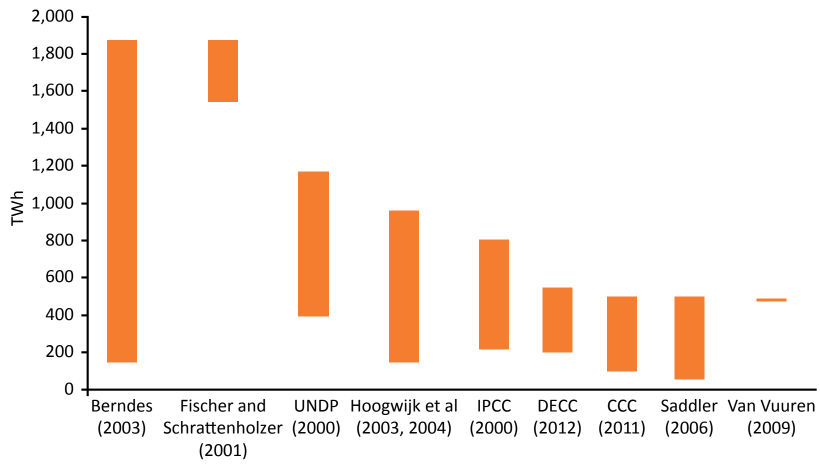
Biogases[103]

A number of gases – referred to as biogas, biomethane, bioSNG,[104] and biopropane – can be produced from sources of organic matter such as organic waste, sewage sludge, agricultural residues (e.g. straw, manure) wood, or energy crops. Processes such as anaerobic digestion and gasification can be used to extract useful gas from these resources, which is considered a renewable and low carbon gas.

Anaerobic Digestion (AD) is a biological process where organic matter is processed in the absence of oxygen to produce biomethane. It has been widely used in the UK for sewage sludge treatment for over 100 years and its use has recently expanded to use other wastes such as food waste, manure, and agricultural residues. Gasification is a process of converting organic material at high temperatures to a gaseous form that can then be further refined to generate methane (the product is often referred to as Synthetic Natural Gas or BioSNG). It has yet to be deployed at a large scale, but both National Grid and DONG Energy are constructing commercial demonstration plants that will use household waste to produce BioSNG, in the hope that this will encourage the roll-out of other gasification facilities in the future. In total there were 50 plants injecting biomethane into the grid as at the end of 2015, in total producing around 2.5TWh of green gas per year.[105] Another 15 plants are expected to be built in 2016. In addition there are 250 facilities which generate biogas and burn this on site to produce power (as at March 2016).[106]

Biomethane has very similar composition to natural gas, and can therefore be used as a direct substitute for natural gas without a need to change or modify boilers or other gas appliances. Biogas has a lower methane content than natural gas, but can be processed in order to upgrade it to biomethane. National Grid has concluded that existing pipelines could be used to deliver biomethane gas to people's homes.[107] A move to substitute natural gas with biomethane could therefore be achieved with minimal investment in the gas network or disruption to consumers, as long as the price of gas could be maintained at a reasonable level.

Figure 3.3: Estimates of overall bio-energy available for the UK in 2050



103 Here we use the term "green gases" to refer to all types of gaseous fuels produced from bioresources. These include, but are not limited to, biogas, biomethane and bioSNG.

104 Bio-substitute natural gas

105 REA (2016) *REVIEW: The Annual Report on the UK Renewable Energy Sector*

106 DECC (2016) *Review of support for Anaerobic Digestion and Micro CHP under the Feed in Tariff Scheme*

107 National Grid (2016) *The future of gas - Supply of renewable gas*

The key question is how much bio-energy would be available in the UK to produce biomethane and biogas, and how much of this could be available for domestic heating, as opposed to other users such as industry. Several studies have assessed the overall availability of sustainable bio-energy to the UK in 2050 across all sectors, including bio-resource sourced within the UK and imports (Figure 3.3).[108] As shown in Figure 3.3, the estimates for total bio-energy vary widely from around 60 TWh per year to almost 2,000 TWh per year. The CCC estimates the range of biomass availability in 2050 to be 100–550 TWh per year, with a central estimate of 140 TWh available domestically, and a further 70 TWh from imports.[109]

The other important question is what share of this should be used in domestic heating. Most studies have assumed that only a small fraction of the available bio-energy would be used in domestic heating, as they have concluded that the best use of this resource would be in energy-intensive industries and transport where decarbonisation is more challenging. For example, the DECC UK bioenergy strategy estimates a total potential of 200–500 TWh per year, of which less than 15% would be available for heating.[110] The most recent research by National Grid concludes that around 80–120 TWh per annum of biomethane could be produced in the UK, mainly from wastes.[111] This is approximately 32% of the overall projected domestic heating demand in 2050 and 30–50% of National grid's projected 2050 overall gas demand. Technological advancements in biomethane production could allow the plausible limit for biomethane production to be increased.[112] In the last five years the gas industry has invested £500 million in renewable gas production and would need to invest an additional £25 billion to reach the full potential.[113] However, even with these investments large uncertainties remain around the availability and sustainability of bio-resource and the share of this available for domestic heating.

In addition to issues around biomass availability, there is also an issue around biomethane quality. Biomethane produced through Anaerobic Digestion typically has a lower energy density than natural gas, and does not therefore meet current gas grid standards. In order to meet these standards, biomethane currently has to be upgraded or "spiked up" by adding 3–5% of more concentrated fuels to it, for example propane derived from fossil fuels, or bio-resources. Scotia Gas Networks is currently undertaking a project to investigate whether gas standards can safely be stretched to accommodate a broader range of gases including biomethane and hydrogen.[114]

Biopropane in Off-Grid Homes

Biopropane is a term commonly used to describe LPG derived from bio-resources such as vegetable oil or animal fats. LPG is currently used as a heating fuel in nearly 200,000 homes across Great Britain.[115] Biopropane can be used as a drop-in replacement for LPG, without the need to change heating appliances, and has carbon emissions of approximately 20% of that of LPG.[116] A number of biopropane production facilities are being developed in Europe, and biopropane will become available to the UK from 2017 onwards.[117] Analysis suggests that biopropane offers a cost-effective route to decarbonising homes off the gas grid compared to other options supported under the RHI, but at present there is no explicit policy support for its use.[118]

108 Assuming that 1.5% of global biomass would be available for the UK in 2050.

109 CCC (2011) *Bioenergy review*.

110 DECC (2012) *UK Bioenergy Strategy*

111 National Grid (2016) *The future of gas - Supply of renewable gas*

112 For example autoclave pretreatment of sewage sludge could increase the biomethane extraction from sewage sludge by up to 45%.

113 National Grid (2016) *The Future of Gas – Supply of Renewable Gas*

114 Source: https://www.sgn.co.uk/Oban/Working-Together/

115 Ofgem (2015) *Insights paper on households with electric and other non-gas heating*

116 Calor (2016) *RHI Consultation Response*

117 DECC (2014) *RHI Evidence Report: Biopropane for Grid Injection*; Calor (2016) *RHI Consultation Response*

118 EUA (2016) *Biopropane for the off-grid sector*

Hydrogen

There is potential for hydrogen to be used for heating as a substitute for natural gas. Hydrogen could either be injected into the gas grid and blended with natural gas, or (parts of) the gas network could be converted to run on pure hydrogen. Switching to hydrogen offers potential as a route to decarbonise heating as well as transport, since the only direct product from burning hydrogen is water. However, there are significant challenges associated with producing the required volume of hydrogen in the first place, as considered below.

Hydrogen was the primarily fuel in the UK gas grid until the switch to natural gas from the 1960s onwards. The gas grid used to be run on "town gas" which contained around 50% hydrogen as well as high amounts of undesirable gasses like carbon monoxide. Town gas was produced from coal and as such was not a low-carbon fuel source. The discovery of North Sea natural gas in the 1960s lead to the decision to transform the grid to natural gas and over a 10-year period more than 40 million gas appliances had to be switched, at a cost of over £3 billion (in today's money).[119]

Research suggests that the current gas network would be capable of handling a blend of up to 10% hydrogen (by volume) without requiring changes to appliances or pipes.[120] However, as hydrogen has approximately one third of the energy density of natural gas, a 10% concentration of (zero-carbon) hydrogen would only result in an emissions reduction of approximately 3.5%. Similar to biomethane, a partial conversion of the gas grid to hydrogen would create issues around metering and billing, since the energy content of hydrogen is lower than that of natural gas.

Converting the gas grid to run on pure hydrogen is a much more complicated and costly process. A major study investigating the technical feasibility and economic viability of hydrogen conversion was completed in July 2016.[121] The report, which used the city of Leeds as a case study, identified the main costs and challenges of hydrogen conversion as follows:

- **Hydrogen production:** the first challenge is how to produce the required volume of hydrogen. Hydrogen is already used in industrial processes such as fertiliser production. However, it has been estimated that replacing natural gas use in the UK entirely with hydrogen would require a 20–35 fold increase in hydrogen production.[122] The Leeds study considered a number of hydrogen production technologies such as electrolysis (in which water is split into hydrogen and oxygen) and Steam Methane Reformation (SMR) by which natural gas is split into hydrogen and carbon dioxide (CO_2). The study concluded that SMR is the only technology capable of economically producing sufficient volumes of hydrogen for use in heating. SMR is a mature technology with around 500 facilities already in operation globally, including one in Teeside.[123]
- **CO_2 storage:** hydrogen produced from an SMR process can only be considered low carbon if the CO_2 by-product is captured and permanently stored. Capturing and storing the CO_2 adds significant complexity and cost to the process, and itself consumes a significant amount of energy. It also means that low carbon hydrogen could only be produced close to a CO_2 storage site. Currently no large scale CO_2 storage projects exist in the UK and the

119 Dodds, R. (2013) *Conversion of the UK gas system to transport hydrogen*. International Journal of Hydrogen Energy.

120 H2FC SUPERGEN (2014) *The role of hydrogen and fuel cells in providing affordable, secure low-carbon heat*

121 H21 Consortium (2016) *Leeds City Gate*

122 H2FC SUPERGEN (2014) *The role of hydrogen and fuel cells in providing affordable, secure low-carbon heat*

123 Ibid

future deployment of the technology is highly uncertain, especially since the Government's decision to cancel its £1 billion Carbon Capture and Storage Commercialisation programme in 2015.

- **Transmission Network and Storage:** a new system would be required to transmit hydrogen from the point of production to the local gas distribution network. The study estimates that this would cost an estimated £230 million for a network serving the city of Leeds. Furthermore, due to the daily and seasonal swings in heat demand (see Chapter 2) there would be a need to build substantial hydrogen storage facilities in order to service demand. The report suggests a figure of £366 million to build two storage facilities to serve Leeds.
- **Distribution Network:** whilst a new standalone hydrogen transmission network would be required, the study finds that the existing gas distribution network in Leeds is largely capable of transporting hydrogen already, and would not require significant investment. The analysis suggests that the distribution network is correctly sized to carry hydrogen (in most of the study area), and that the existing pipe network would be capable of carrying hydrogen safely. This is in large part due to the Iron Mains Replacement Programme, under which significant sums are already being invested to replace steel pipes with polyethylene pipes, which are suitable for transporting hydrogen.
- **Appliance conversion:** finally, there would be costs associated with converting gas appliances (e.g. boilers and cookers) to run on hydrogen. The study estimates these costs to be just over £3,000 per home. There are already a few hydrogen appliances on the market, but appliance manufacturers would need to develop a wider range of products. The conversion process would be carried out on an area by area basis over the summer months, in order to minimize disruption to the consumer. It is thought that a city such as Leeds could be converted in 3 years, with individual consumers disconnected for no longer than a few days.

Overall, the study estimates that costs of converting the gas system in Leeds to run on hydrogen would be significant, with a capital cost of £2.05 billion, and ongoing operational costs of £139 million per year. The report claims that hydrogen conversion would result in "minimal additional cost to consumers", increasing household energy bills by just 1%. However this assumes that the cost of hydrogen conversion in Leeds, which represents just 1% of the UK population, is spread across the entire UK population. The bill impact would be far higher if the cost of converting Leeds was borne by the residents of Leeds, or if a hydrogen network was rolled out nationally. The study itself concludes that a rollout to "major UK cities" would cost in the order of £50 billion. However, if the costs for Leeds are scaled up to the 23 million households which currently use gas for heating, this suggests a much higher capital cost in the order of £180 billion, and an ongoing operational cost of £12 billion. Although crudely calculated, these estimates indicate that a widespread conversion of the gas network to hydrogen would be very costly indeed.

Another way to look at this is in terms of the cost of the hydrogen delivered to consumers. The Leeds City Gate report estimates that the retail cost of hydrogen to consumers would be about 7.6 pence per kWh (not including the cost of converting appliances). To put this in context, the current retail price of gas is around 4 pence per kWh, suggesting that a shift to hydrogen would nearly double heating costs to end consumers.

Whilst the costs of hydrogen conversion are high, it could result in a very significant reduction in carbon emissions. The Leeds report suggests that converting from natural gas to hydrogen would result in a 73% reduction in carbon emissions.[124] However, on this basis the carbon savings appear relatively costly compared to other decarbonisation options, at a cost of £340–400 per tonne of carbon saved.[125]

Overall the Leeds study indicates that converting the gas system to run on hydrogen is technically feasible but potentially very costly. That said, there are still many uncertainties about the cost and practicalities of hydrogen conversion, and the Leeds H21 report suggests a programme of 16 work packages costing £60–80 million to develop the concept further.

Summary

- Gas is the most widely used energy form of heating in the UK, and there are likely to be benefits in terms of consumer acceptability from continuing its use.
- A continued role for gas could help the energy system to cope with large swings in heat demand, in particular to meet winter peak demand.
- Substantial gains in efficiency could be made by replacing inefficient non-condensing boilers, and progressively moving towards advanced boiler technologies such as gas driven heat pumps.
- Hybrid gas/electric systems offer the opportunity to reduce the carbon emissions from heating whilst maintaining a residual role for gas to meet peak heating demands.
- Switching to biomethane or biopropane represents a relatively straightforward way to decarbonise gas use, although there are uncertainties around the availability of biomethane for domestic heating.
- Hydrogen could in theory be used replace natural gas. However, fully converting the gas grid to run on hydrogen would be a very costly and complex process – requiring the replacement of heating appliances, as well as new infrastructure to produce and distribute hydrogen, and capture and store CO_2 from hydrogen production.
- Overall, there is potential to significantly decarbonise gas heating through a combination of more efficient appliances and greener gases.

Electric heating

Electric heating currently meets around 8.6% of the total heat requirement in homes. The most basic form of electric heating is **resistance heaters** which instantaneously convert electricity to heat – such as bar heaters, convection heaters and fan heaters. **Night storage heaters** are similar to resistance heaters, but store up heat when electricity is cheap (e.g. overnight) and then release the heat as required. This means that storage heaters can take advantage of cheaper off-peak electricity tariffs ("Economy 7" or "Economy 10"). Resistance heaters and storage heaters are 100% efficient, in that all of the electricity used is converted to heat, but this is a far lower level of efficiency than an electric heat pump.

124 Scope 1 and 2 emissions, including indirect emissions associated with CO_2 sequestration

125 Based on Scope 1+2 or Scope 1+2+3 emission savings.

Electric heat pumps are a more advanced form of electric heating. They extract low temperature energy from a heat source (the air, ground or a water body) and make it available for heating by "pumping" it up to higher temperatures – effectively like an air conditioning unit or fridge running in reverse. The captured heat can then be used for space heating or water heating in the home, or even in industrial processes. Heat pumps are considered to have efficiencies of over 100% since they capture more energy from the heat source than it takes to drive the heat pump. Heat pump efficiency is strongly dependent on the temperature of the heat source and the required temperature in the house (the flow temperatures of the heating system). The smaller the difference is between these two temperatures, the better the heat pump will perform. Heat pump efficiency is usually denoted by the "Seasonal Performance Factor" (SPF) which is a measure of the average efficiency of the system over the full heating season.

The most important types of electric heat pumps in the UK market are:

- **Air-source heat pumps** – Air-source heat pumps are fitted to the external wall of a house and extract heat from the outside air. They are the lowest cost heat pump option to install, but still cost far more than gas heating systems at around £8,500 for an 8 kW unit. Air source heat pumps are less efficient than ground- or water-source systems, because air is the heat source with the lowest and most variable temperature. Yet, they are still able to reach an SPF of 3 or more in good conditions.
- **Ground-source heat pumps** – Ground-source heat pumps use energy collectors buried in the ground (horizontal collectors) or placed in boreholes (vertical collectors). This makes them more expensive to install than air-source heat pumps, with a typical 8 kW ground-source heat pump costing approximately £12,800 per dwelling. However, ground source heat pumps are more efficient than air-source heat pumps, reaching an SPF of 4 or more (although currently not on a regular basis in the UK, see further discussion below).
- **Water-source heat pumps** – Water-source heat pumps extract energy from water sources such as rivers, ponds, springs, or boreholes, which limits their application to areas close to these water sources. However water source heat pumps are the most efficient type of heat pump currently available (with an SPF of 5 or more, although there is little data available) as water is the heat source with the highest and most stable temperature over the year. Water-source heat pumps cost around the same amount as ground-source heat pumps.
- **Hybrid heat pumps/boilers** – as discussed in the previous section – hybrids are a combination of a heat pump (usually air-source) and a gas boiler. A typical hybrid installation costs between £6,000–8,000 depending on the capacity of the heat pump installed.

Decarbonisation potential

DECC's heat strategy assumes that electric heating will provide over 80% of domestic heat by 2050 (260 TWh) almost entirely from heat pumps.[126] A number of other studies (see Figure 2.6) suggest that electric heating will provide 30–181 TWh of heat in 2030, rising to between 109–404 TWh by 2050 (across domestic and non-domestic sectors). These studies generally see electrification as making

126 Carbon Connect (2014) *Pathways for Heat: Low Carbon Heat for Buildings*

an important contribution to the decarbonisation of heat, although the extent of electrification varies enormously between these studies.

DECC's heat strategy implies that heat pumps would be required in around 27 million of the 35 million homes in the UK in 2050. This translates into an installation rate of almost 800,000 heat pumps installed per year between now and 2050, which is about 45 times the current installation rate.[127] The scale of these numbers underlines the challenge in electrifying heat: the rollout of heat pumps would need to be substantially accelerated in order to deliver the scenarios set out by Government.

In determining the contribution of electric heating to decarbonisation, another important factor to consider is whether the electricity comes from high carbon or low carbon sources, and how this is likely to change in the future. The average "carbon intensity" of UK grid electricity has already declined substantially since 1990 due to the shift from coal to gas and the growth of renewable power generation, declining from 770 gCO_2/kWh in 1990 to 371 gCO_2/kWh in 2015.[128] As it stands, the emissions per kWh are still higher for electricity than gas (at 371 gCO_2/kWh and 184 gCO_2/kWh respectively). This means that replacing a condensing boiler with a direct electric heater would actually *increase* emissions, although moving from gas to an electric heat pump would reduce emissions (Table 3.1). However, looking forward it is expected that the carbon intensity of electricity will fall substantially, such that it falls below that of gas by 2021.[129] This increases the decarbonisation effect of shifting from gas to electric heating, particularly in the case of high efficiency heat pumps.

Table 3.1: Carbon emissions for gas and electric heating technologies

		Gas – condensing boiler	Direct electric	Air source heat pump	Ground source heat pump
Current (2015 data)	Efficiency (ratio between heat output and fuel input)	89%	100%	260%	290%
	Carbon intensity of fuel (grams of CO_2 emitted per kWh)	184	371	371	371
	Emissions per kWh of heat delivered (gCO_2/kWh)	207	371	142	128
Future projection (2021 data)	Efficiency (ratio between heat output and fuel input)	94%[130]	100%	285%	330%
	Carbon intensity of fuel (grams of CO_2 emitted per kWh)	184	180	180	140
	Emissions per kWh of heat delivered (gCO_2/kWh)	196	180	63	55

127 Ofgem (2015) *Domestic Renewable Heat Incentive Quarterly Report, November 2015*

128 CCC (2016) *Meeting carbon budgets: 2016 progress report to parliament*

129 DECC projections show the emissions intensity of electricity falling to 180g CO_2/KWh by 2021, compared to a current emissions intensity of gas of 184g CO_2/KWh.

130 The increased efficiency in 2025 assumes that the gas condensing boiler would be fitted with Passive Flue Gas Heat Recovery

Supply impact

Whilst electric heat pumps can be extremely efficient, they do still require significant power input and place additional demands on the power system. The widespread electrification of heat would thus create challenges in terms of how to meet the additional demand, particularly at peak times. The power market in Great Britain is already relatively tight with low capacity margins, and the Government has had to put in place additional policies such as the Capacity Market in order to ensure there is sufficient capacity to meet peak demand. Electrifying heat would exacerbate these issues by increasing the demand for electricity, in particular during the winter months when heat demand is greatest.

A number of previous studies (identified in Figure 2.6) suggest that heat pumps could require between 36–134 TWh of additional electricity to be generated per year by 2050.[131] This is equivalent to adding 10–40% of current electricity demand, or the annual output from 20 typical gas power stations.[132] DECC's 2013 Heat Strategy suggests that the requirement for electricity generation could be even higher at 278–314 TWh in 2050, based on 80% of domestic heating being converted to heat pumps.[133] This represents a near doubling of total power demand, or the annual output from nearly 50 gas power stations.

However, as discussed in Chapter 2, heat demand is highly variable with very large peaks in demand on cold winter days. Therefore, the impact of electrifying heat on peak power demand levels would be very significant. Baringa,[134] a firm of energy analysts, calculated that meeting 80% of peak domestic heat demand in 2050 with heat pumps would necessitate around 105 GWe of additional electricity supply capacity.[135] This represents an increase of 175% over and above current peak power demand levels,[136] and is equivalent to adding 130 large gas power stations to the grid. The capital cost of building this amount of gas generation capacity would be over £60 billion.[137]

The seasonal pattern of heating demand would mean that the additional capacity required to meet winter peak demand would sit idle for a significant part of the year, undermining the viability (or increasing the cost) of the additional power capacity. The power system would also need to be more flexible than today, as swings in heat demand can reach ±120 GW per hour.[138] There are limits to the ability of conventional forms of generation (including gas) to vary output this quickly.

Overall this suggests that converting a large number of homes to heat pumps could create some significant supply issues. The development of smart technologies such as electricity storage and demand response could play an important role in softening the daily peaks in demand, but cannot cater for the significant seasonal fluctuations in demand. It is clear that it would be very costly to develop a power system capable of serving the high levels of electric heating assumed in the DECC heat strategy. Moreover, the figures presented do not factor in the possible electrification of other sectors such as non-domestic heating or transport (e.g. Electric Vehicles) which would further increase the demand for power. The system challenges of electrifying heat should not be under-estimated, and more research is required before Government commits to a widespread shift to electric heat pumps.

131 Based on an assumed average SPF of 3.

132 Assumes Hinkley Point C at 3.2GWs and Gas CCGT at 820MW capacity, both running at 90% load factor.

133 As above, these figures include demand from other electricity uses.

134 Baringa Red Point (2012). The 34-80% range represents the different levels to which heat is electrified in the different pathways analysed in the Carbon Connect report.

135 This is based on an assumed average peak time COP of the installed heat pumps of 1.4. A higher average peak time COP of 2.0 would reduce this additional demand requirements to 31-73 GWe, showing the importance of improving the installation quality of heat pumps in the UK.

136 National Grid (2016) *Future Energy Scenarios.*

137 Capital cost assumptions taken from: DECC (2013) *Electricity Generation Costs*

138 ETI (2015) *Smart Systems and Heat: Decarbonising Heat for UK Homes*

Network impact

In addition to supply challenges, the electrification of heat would also create significant issues for the power network, in particular the distribution cables which carry power to our homes. Power networks are designed to cater for a maximum level of load. The electrification of heat would create a significant increase in load, triggering the need for significant investments to upgrade and reinforce the power network.

Research by Delta-ee suggests that a rollout of air-source heat pumps and hybrids to 20% of dwellings would require investment in power distribution networks of around £5.5 billion to 2050 nationally.[139] In a high uptake scenario, where 50% of homes dwellings have a heat pump, this would rise to £37 billion nationally.[140] The network cost of rolling out heat pumps to 80%+ of households (as in the DECC heat strategy) would presumably be even higher. In other words, a significant shift to electric heating would necessitate a massive investment in networks, which inevitably would need to be paid for by the consumer. Network costs already represent 22% of the average households energy bill (or around £300 per year[141]) and this would need to increase significantly in the event of such a substantial investment in the power network. Separate research has shown that the cost of network reinforcement to accommodate heat pumps would be approximately four times higher (per dwelling) in rural areas than non-rural areas,[142] challenging the notion that heat pumps are most suitable in rural off-gas grid areas.

As discussed in the previous section, a possible solution would be the continued use of the gas network during peak demand periods, through the use of hybrid gas/electric heat pump systems. Modelling by Delta-ee has shown that deploying hybrid heat pumps instead of standard heat pumps would reduce the cost of power network upgrades by 60% (under the 50% deployment scenario). This would save over £20 billion nationally in network investment to 2050. These results suggest that the use of the gas to meet peak demands from heating should be explored further, especially if there is a potential to decarbonise gas supply through the use of greener gases, as explored above.

Consumer impact

In addition to the network and supply issues raised above, there are significant consumer issues in terms of cost, disruption, consumer awareness, and performance, which would need to be overcome in order to achieve a mass rollout of heat pumps:

- **Costs:** Arguably the biggest issue with heat pumps at present is that they are expensive to install and run. Heat pump systems typically cost between £8,500–£13,000 to install compared to £2,000–3,000 for a condensing gas boiler. The significant upfront cost is a deterrent to most households. Policy Exchange analysis suggests that achieving the level of heat pump deployment suggested in the DECC heat strategy scenario would involve a capital cost of approximately £200 billion for the purchase and installation of heat pumps (even if we assume a significant reduction in installation costs in the future). The economics of heat pumps are undermined further due to the significant difference between gas and electricity prices. Heat pumps are currently around 2.7–3.3 times more efficient than a condensing gas boiler,[143] but this is offset

139 Delta-ee (2016) Managing the future network impact of electrification of heat. Report for ENWL

140 Previous studies identified investment needs between £22 and £26 billion, for example EA Technology (2013) *Smart Grid Forum Work Stream 3 – Analysis of Least Regrets Investments*; and EY (2013) *Assessing the impact of large-scale deployment of heat pumps on electricity distribution network costs*

141 Howard, R. (2015) *The Customer is Always Right*. Policy Exchange

142 EY (2013) *Assessing the impact of large-scale deployment of heat pumps on electricity distribution network costs*

143 Assuming an average SPF factor of 2.44 for an air source heat pump, and 2.92 for a ground source heat pump, based on data from Summerfield et. al. (2016) *DECC RHPP Detailed Analysis Report*. A condensing gas boiler is assumed to have an efficiency of 89%.

by the fact that that current retail electricity prices are around 3.5 times than retail gas price (on a per kWh basis).[144] Recent modelling by Delta-ee shows that under current energy prices, heat pump technologies do not pay back within the expected lifetime of the system against gas or even oil boilers, even with Renewable Heat Incentive subsidies. The recent drop in fossil fuel prices has further increased the challenge of deploying heat pumps in the UK, since energy suppliers have cut retail gas prices but not retail electricity prices.[145] In the future it is expected that the electricity to gas price ratio will increase further to around 4:1 as more energy policy costs are placed on electricity bills.[146] Heat pumps supported under the Renewable Heat Incentive are an expensive decarbonisation option at a cost of £590–880 per tonne of carbon abated.[147]

- **Disruption** – Installing heat pumps in existing homes will often also require the installation of lower temperature distribution systems such as underfloor heating or larger/more efficient radiators, which would involve disruption for the customer. Households may have to carry out renovation or redecoration of the home following the installation of a heat pump, which may be a deterrent to many households.
- **Performance and quality** – another issue with heat pumps is that performance of installations has in many cases been poor. Data from field trials has shown that air-source and ground-source heat pumps installed in the UK are not performing as well as those installed in other European markets. The most recent UK monitoring data showed that the average seasonal performance factor (SPF) was around 2.44 for air-source heat pumps, and 2.92 for ground-source heat pumps.[148] By comparison, German field trials of heat pumps installed in existing buildings in 2006–2009 reached an average SPF of 2.6 for air-source heat pumps (+7% better than the UK) and 3.3 for ground-source heat pumps (+13%). German field trials in new buildings have shown that heat pumps can perform even better, with an average SPF reaching 3.1 for air-source heat pumps, and 4 for ground-source heat pumps.[149] Additional research is required to identify the reasons behind the shortfall in efficiency in the UK, and how to improve performance and installation quality in the future. One possible explanation is that the UK heat pump market remains small, and the supply chain is still under-developed. This may improve as the heat pump market grows in the UK.
- **Consumer acceptance** – Finally, another barrier to the adoption of heat pumps is that consumer awareness of the technology is currently low compared to other options such as gas boilers. A recent report into customer attitudes by the ETI found that, given the choice, 90% of all respondents prefer gas central heating over other options.[150] According to a recent Government evaluation, most UK households who have a heat pump are satisfied with their system, but there is still a significant education challenge to be overcome before this knowledge is transferred into the wider market.

Storage heaters

Storage heaters have been largely overlooked in the debate around the decarbonisation of domestic heat, including in the current DECC heat strategy. Storage heaters avoid some of the network and supply issues associated with heat pumps, since they mainly use power off-peak. Storage heaters are much cheaper

144 DECC (2015) *Energy and Emissions Projections – November 2015*

145 Delta-ee (2015) *Heat Insight Service, Market Forecast Update, Summer 2015*

146 Policy Exchange analysis based on DECC (2015) *Energy and Emissions Projections – November 2015*

147 ADE (2016) *Levelling the playing field: Unlocking heat infrastructure investment*

148 Summerfield et. al. (2016) *DECC RHPP Detailed Analysis Report*

149 Miara (2014) Presentation at the German HP Association's Annual Conference

150 ETI (2015) *Smart Systems and Heat: Consumer challenges for low carbon heat*

to install than heat pumps (at a cost of around £1,500–£3,000 for a 3-bedroom property, compared to £8,000–£13,000 for a heat pump system). However, their running costs are likely to be much higher than a heat pump due to their lower efficiency (100% for a storage heater compared to 250%+ for a heat pump), and are therefore unlikely to be an economic option for properties on the gas grid. Some studies[151] have highlighted the potential of storage heaters but further research is needed to understand whether they could provide a cost-effective complement or alternative to heat pumps.

Summary

- The Government heat strategy assumes that electric heating will be the predominant form of heating by 2050, supplying over 80% of domestic heat. This view has been challenged by industry and academics.
- Installing this many heat pumps would cost in the region of £200 billion, according to our analysis. Heat pumps are costly to install and run compared to gas systems, and installation often results in wider disruption to the home. There have been issues regarding the performance and quality of installation of heat pumps in the UK, relative to other countries.
- A large scale move towards heat pumps would require a significant expansion in power generation capacity to meet peak heating requirement, perhaps as much as 100 GWs. This would be extremely costly, particularly given that the extra power stations would sit idle for much of the year.
- The electrification of heat would also necessitate investment to reinforce the power distribution network, at an estimated cost of £37 billion (assuming that 50% of electric heating is electrified).
- Overall it appears that electric heating could have an important role to play, but not to the extent suggested in the DECC heat strategy.

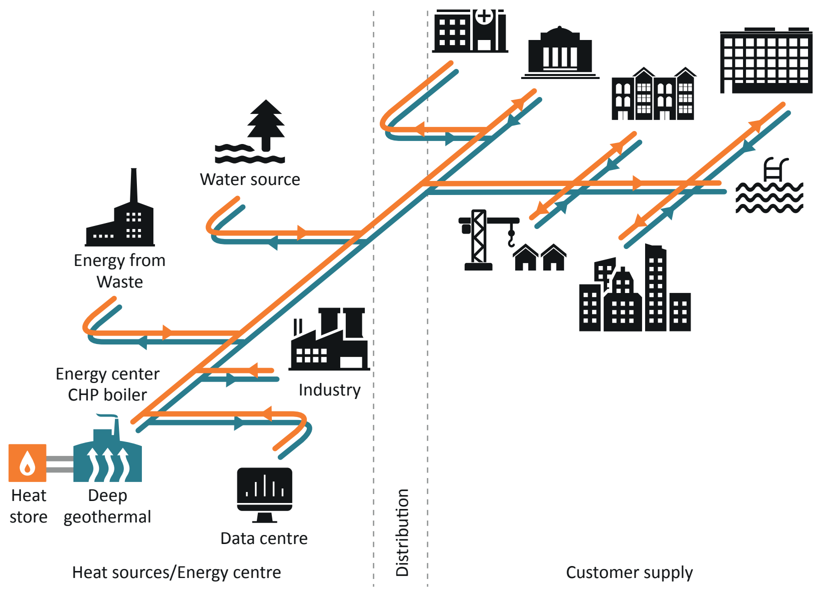
Heat networks

Heat networks (also referred to as "district heating") represent a collective form of heating supply to buildings. A heat network comprises a centralised heat generation unit attached to a network of pipes, which provides heat to individual buildings including residential, commercial and industrial sites. Figure 3.4 provides a schematic illustration of a heat network. Most heat networks in the UK are supplied primarily by a natural gas Combined Heat and Power plant, but heat can also be supplied from biomass, solar thermal, heat pumps, waste heat from an industrial facility, or a combination of heat sources. End-users are connected to the heat network via a heat exchanger so that the working fluids of both networks (generally water or steam) do not mix.

Heat networks are widely deployed in several northern European countries, both as very large city-wide schemes and as clusters of small localised systems. By contrast, heat networks supply fewer than 1% of UK households, with this share remaining fairly static in recent years despite the efforts of many Local Authorities and private sector developers. DECC established a Heat Network Development Unit (HNDU) in 2013, which has supported over 200 heat network projects to date. This programme has been extended with an announcement in November 2015 of £300m of capital support for heat network development (See Chapter 5 for more details).

151 Sansom, R. (2014) *Decarbonising Low Grade Heat for a Low Carbon Future*. Imperial College

Figure 3.4: Example of a heat network[152]

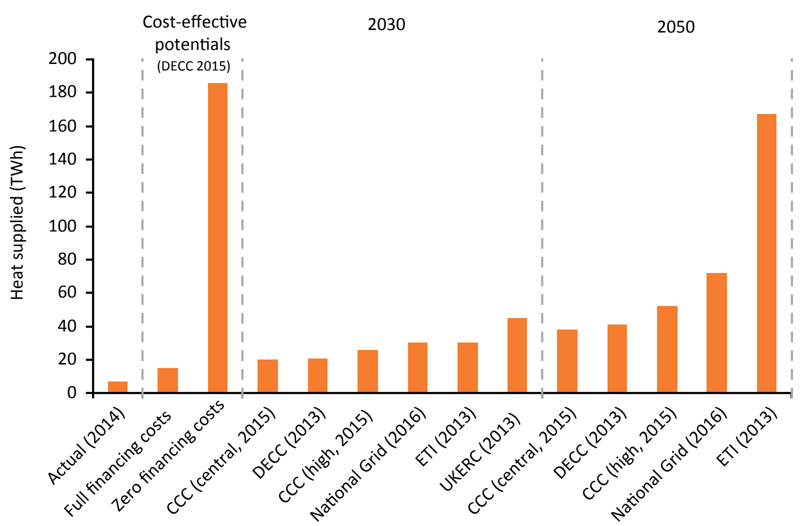


Heat networks offer the opportunity for large scale heat decarbonisation, since multiple energy sources can be connected to the same network, including low carbon sources of heat. However, there are a number of challenges to build low carbon heat networks, as explored below.

Decarbonisation potential

Several studies undertaken in the past five years have estimated the potential for heat networks to supply heat to residential buildings in the UK. The studies suggest that heat networks could meet up to 45TWh of heat demand by 2030 (12% of total), increasing to up to 167 TWh by 2050 (nearly 50% of total) – although there is considerable variation across the studies identified (see Figure 3.5).

Figure 3.5: Potential for residential heat networks in the UK[153]



152 DECC (2015) *Investing in the UK's heat infrastructure: Heat Networks*

153 Sources: DECC (2015) *Assessment of the Costs, Performance, and Characteristics of UK Heat Networks*; Element Energy/CCC (2015) *Research on district heating and local approaches to heat decarbonisation*; Baringa/DECC (2013) *Modelling to Support the Future of Heating: Meeting the Challenge*; National Grid (2016) *Future Energy Scenarios*, Gone Green scenario; ETI (2013) *Smart Systems and Heat: A perspective from the United Kingdom.* UKERC (2013) *The UK energy system in 2050: Comparing Low-Carbon, Resilient Scenarios*

The limit on the potential for heat networks tends to be identified on grounds of cost-effectiveness, and less so on other potential constraints such as energy sources, end user acceptability and issues concerning the connection of end users to heat networks (separate issues which we address below). The cost effectiveness of heat networks is significantly influenced by the capital cost – which varies widely across schemes – as well as the cost of capital to finance this investment. To illustrate this, research for DECC indicates a current cost-effective potential of 15 TWh heat supplied by heat networks in 2050 if heat network developers face the full cost of finance, rising to 186 TWh if Government were to finance the development of heat networks. Whilst it is unlikely that Government would cover the cost of financing heat networks, this analysis shows the important of the cost of finance on the roll out of heat networks.

Most of the other studies indicate that heat networks could realistically provide around 20–30 TWh of heat per year by 2030 and 35–55 TWh by 2050 (with the study by ETI being an outlier). These ranges are further backed up by recent research for the CCC which suggests that heat networks could meet 16% (53 TWh) of final residential heat demand in 2050.[154] The consensus from these studies is that the rollout of heat networks is likely to take place mainly after 2030, in large part due to the many challenges that confront large-scale development of the necessary infrastructure (explored below) and overall development timelines.

As well as the *scale* of heat network deployment, the other key factor which determines the decarbonisation potential of heat networks is the carbon intensity of the heat source. As mentioned above, most existing heat networks in the UK use a gas CHP plant as their fuel source. Whilst this offers a carbon saving of 10–30%, compared to supplying heat from a conventional gas-fired boiler and power from a gas power station, it cannot be considered "low carbon". But an important benefit of heat networks is that they can be fuelled by multiple energy sources, including low carbon sources of heat, which means that they can be progressively decarbonised over time, as illustrated in the following case study.

Box 2: Case study on heat network in cranbrook, Exeter

E.On has developed a district heating network in Cranbrook, near Exeter, which provides heat to 3,500 homes as well as a large industrial park. It currently generates most of its heat from a gas CHP plant, but going forward this will be supplemented by a 2,000 square metre solar thermal array, a high-temperature heat pump powered by solar photovoltaics, and a thermal store. E.On has indicated that heat will be provided exclusively by low carbon sources during the summer months when demand is low, allowing the gas CHP unit to be switched off and the network to run purely on low carbon sources of heat.

That said, there is substantial uncertainty about how heat networks are likely to be supplied in the future, which significantly affects their decarbonisation potential. The studies identified in Figure 3.6 which suggest high usage of heat networks generally assume significant use of waste heat from nuclear or CCS power plants. This depends critically on investment in these power plants taking place, and the co-location of these plants close to residential buildings (such that heat networks can be established). As an illustration, heat networks delivering 50

154 Element Energy (2015) *Research on district heating and local approaches to heat decarbonisation*. CCC

TWh per year of heat would require the waste heat from up to 6GW of power plants. By contrast, the most recent research for CCC assumes the majority of heat (almost 70%) comes from water source heat pumps, which at a cost of £200 per tonne of CO_2 abated, appears to be an expensive way to decarbonise heating. Overall, there are a range of low carbon heat sources which could be used in a heat network, all of which will face technical and economic challenges. Further research is required to better understand the technical, economic, and decarbonisation potential of heat networks.

Network and supply impacts

One of the most commonly cited challenges in developing heat networks is the high capital cost of developing and building the network, and the associated financing costs and risks. To give a sense of scale, Government has identified a pipeline of 280 heat network projects currently being planned, with a total capital cost of £2 billion.[155]

The cost of heat networks is highly situation-dependent: the latest research published by DECC states that buried heat network pipework can cost around £1,000 per metre on average, in a range £422/m to £1,472/m.[156] However, industry figures provided to us during the course of this study indicate an even larger range in costs. This data suggests that heat networks built as part of new housing or industrial developments can cost less than £500/m, while heat networks retrofitted in urban areas can cost between £1,000/m and £10,000/m, depending on location and circumstances. These costs relate to installation of the heat pipework, which represents around half of the total cost of creating a heat network – the other half relating to the cost of the heat generation unit. Time-scales also vary significantly: a new build scheme can deliver 500 metres of heat network per month whereas an urban retrofit heat network might only be built at a rate of around 30 metres per month.

> “One of the most commonly cited challenges in developing heat networks is the high capital cost of developing and building the network”

This very wide range of costs reflects the different scales of networks, and the nature of the installation. Heat networks are likely to be far more challenging to build where retrofitted to existing buildings in urban areas, where there will be other utilities and physical restrictions in place – and much cheaper and easier to build in new-build developments in less congested areas. For example, developers have cited examples where in the course of laying heat network pipework they have discovered unidentified pipework in the ground – which they then need to work around. Unlike other utilities, heat network developers do not have compulsory purchase powers, and can therefore encounter problems obtaining land rights to lay pipework. These issues add cost, delay and risk to heat network schemes.

Heat networks also rely on having sufficient critical mass of heat demand in a given area in order to be viable. Most heat networks in the UK are located in urban areas with a high “density” of heat demand, and large “anchor loads” such as industrial facilities, hospitals, public sector buildings, large multi-tenanted properties, or swimming pools. There are mixed views on the viability of heat networks outside urban areas, in particular due to the low density of heat demand. But there are already some examples of smaller rural and community-

155 DECC (2015) *Investing in the UK's heat infrastructure: Heat Networks*

156 DECC (2015) *Assessment of the Costs, Performance, and Characteristics of UK Heat Networks*

scale projects in the UK and these sorts of schemes are commonplace in other countries such as Denmark. If heat networks can be made to work in rural areas, then they may be an attractive option particularly in off-grid properties where gas heating is unavailable, and hence where the alternative is more expensive forms of heating such as oil.

In order to achieve the higher levels of heat network deployment suggested in the studies above, developers will likely need to pursue developments in urban, sub-urban and rural settings. This will require a more granular understanding of the UK building stock, to identify heat network opportunities. Extending deployment of heat networks from dense urban areas to suburban retrofit schemes will open significantly larger markets, but will require longer networks and lead to higher energy losses. This evolution will also involve increasing the number of connections to private housing and a corresponding requirement to co-ordinate many individual customers.

Whilst there are multiple challenges to deliver heat networks, there are important benefits that heat networks can provide to the wider energy system. By integrating a range of heat sources and thermal storage, heat networks can help to alleviate the peak demand issues highlighted above. There are already examples of large scale heat storage in the UK, such as the Pimlico District Heating system in London which includes a 2,500m^3 thermal store built in the 1950s, with a capacity of about 90 MWh. Having the heat store allows the CHP plant on the system to be optimised to meet heat demand when needed, and also to provide electricity to the grid at times of high demand. Heat networks with storage can therefore be useful in providing a flexible form of supply and alleviating electricity supply challenges. Further research is required to improve the understanding of the costs and benefits of thermal storage in heat networks, in particular the benefits that this could provide to the electricity system.

Consumer impact

There are a number of consumer issues which need to be addressed in order to achieve a mass rollout of heat networks – both in order to facilitate the connection of new customers to heat networks, and to ensure that consumer interests are protected once they switch to heat networks. In order to achieve a large scale roll out of heat networks, they will need to be accepted as a reliable, trusted and cost-effective source of heat. However, at present relatively little is known about what UK consumers generally think about heat networks, and heat networks are largely unregulated, falling outside the scope of the energy regulator Ofgem.

A recent report by *Which?*[157] highlighted some clear challenges around consumer acceptance of heat networks, as follows:

- **Choice:** the commercial model for heat networks requires that a critical mass of customers connect in areas where heat networks are rolled out, and that they don't subsequently switch back to other forms of heating. Heat networks effectively become monopoly suppliers of heat to their customers, with consumers having to commit to long term contracts (typically lasting 15+ years) to purchase heat. This raises a potential concern (for households and policymakers) about whether heat networks are providing a good deal to their customers, particularly since heat suppliers are unregulated. The inability

157 Which? (2015) *Turning up the heat: Getting a fair deal for District Heating users*

to switch suppliers within a heat network goes against the grain of gas and electricity markets, where consumers are being encouraged to switch. Even in Germany, with its long established heat network market, regulators are now beginning to question the monopoly status of heat network suppliers and whether they should be opened up to more competition.

- **Price:** The issue of pricing is closely linked to that of consumer choice. Heat suppliers often offer some form of price guarantee, although this varies by supplier. Consumers need to be confident that they will be paying a fair price in order to agree to switch to a heat network. The report by *Which?* suggests that there is wide variation in the prices charged by heat suppliers, with a range of 5.5–14.9 pence per kWh for heat supplied through a heat network, compared to 9.5–11.6 pence per kWh to install and run a gas boiler. This means that some heat networks are much cheaper than heating a home using gas, whereas others are considerably more expensive than gas.[158] The *Which?* report also highlighted issues around transparency, in that many heat network customers don't understand their bill, and many think that they are being unfairly charged.
- **Consumer protection:** The *Which?* report found that many heat network customers were dissatisfied with their heat network scheme, mainly on grounds of cost and customer service. Related to this, the report highlights the lack of consumer protection for heat network customers, or regulation of heat network businesses, stating that "*district heating customers have no opportunity to switch suppliers or right to redress should the service fail to meet expectations.... At present [consumers] are not only cut off from the gas grid but they are also cut off from effective consumer protection.*"[159]

In line with the *Which?* report, the Citizens Advice Bureau has reported an increase in the number of consumer complaints relating to heat networks over the last 12 to 18 months, in particular focusing on the issues of billing, customer service, and the lack of redress in the heat sector.[160]

In response to these challenges, the Association for Decentralised Energy (ADE, an industry group) established the "Heat Trust" in November 2015. This is a voluntary scheme for heat network operators, which sets standards for customer service and customer protection. CIBSE and the ADE have also developed a "Code of Practice" for heat network operators.[161] This defines minimum and best practice standards for the design, construction and installation, operations and maintenance of the heat network as well as customer obligations. Whilst these are good steps forward to providing some form of consumer protection, they still fall well short of the regulation seen in other parts of the energy industry – not least because these schemes are voluntary. In Chapter 5 we consider how the regulatory regime for heat networks could be strengthened further.

Small scale renewables

An alternative to the large scale heat solutions discussed above is to deploy small scale renewable heating solutions such as biomass or solar thermal in individual homes. Since April 2014 these technologies have been supported by the domestic Renewable Heat Incentive with 11,600 domestic biomass and 7,700 solar thermal systems installed under the scheme to date.[162] Despite the growth in numbers, this still represents a very small proportion of the domestic heat market.

158 Costs calculated for a typical two-bedroom flat built between 2010 and 2016, and include the cost of fuel and installation of heating appliance.

159 Which? (2015) *Turning up the heat: Getting a fair deal for District Heating users*

160 Citizens Advice (2016) *Response to the consultation on the Heat Networks Investment Project*

161 CIBSE / ADE (2015) *CPI Heat Networks: Code of Practice for the UK*

162 DECC (2016) *RHI deployment data: April 2016*

Biomass heating systems

Biomass heating systems can take a number of forms from basic stoves which provide space heating, to boilers which also provide hot water, and CHP systems which provide heat and power. They utilise a range of fuels including logs, pellets or wood-chips. One of the advantages of biomass systems is that they are relatively easy to retrofit to existing properties to replace an existing heating system.

Bioenergy and waste incineration provide around 5% of UK domestic heat demand, but only around 1% of this comes from small scale domestic biomass systems, with the remainder coming from larger scale non-domestic or industrial applications.[163] Almost 60% of biomass systems accredited under the RHI have displaced oil heating – achieving a significant saving in carbon emissions.[164]

Domestic biomass boilers are generally seen as playing a limited role in meeting the UK's domestic heating requirements. For example, in DECC (2010) 2050 *Pathways Analysis*, all 16 of the scenarios presented assume that small scale biomass boilers provide at most 10% of total heat demand in 2050, with most scenarios not featuring small scale biomass at all.[165] The primary reason for this is due to the finite supply of sustainable biomass to the UK. In addition, studies which have considered this have tended to assume that the majority of available biomass will be used in industry (i.e. in larger non-domestic biomass installations) or in heat networks, rather than in small-scale domestic biomass boilers.

However, research suggests that small scale biomass could play a role as a transitional heating technology until 2030.[166] Some scenarios also suggest that local sources of biomass could continue to play a small role in 2050 in off-grid rural homes – particularly those that are difficult to insulate and therefore poorly suited to alternatives such as heat pumps.

There are also a number of barriers to the uptake of biomass from a customer perspective. Biomass boilers are relatively large and also require more attention from the owner for maintenance, cleaning and refuelling. Biomass boilers are also expensive, costing around £10,000 to supply and install (for a domestic boiler). Government has provided significant financial support to biomass in the form of the RHI in order to make biomass an economic option for households. To date biomass systems have received a total of £54 million in payments through the RHI at a cost of around 11.4 pence per kWh – a relatively high level of subsidy. Government recently proposed suggested a 61% cut in the RHI tariff for biomass on grounds of value for money.[167] The cost of installing biomass systems is likely to remain a key issue. Additional concerns around the quality of the biomass fuel (especially moisture content) and uncertainty around future biomass fuel prices reduces the attractiveness of biomass solutions for the customer.

There are also wider sustainability issues to be considered. As noted in our recent study, *Up in the Air*, biomass boilers are a significant contributor to air pollution, emitting Nitrogen Oxides, Particular Matter and Black Carbon. Research has shown that wood burning in biomass stoves is responsible for 7–9% of Particular Matter concentrations in London.[168]

Solar thermal

Heat can also be provided by rooftop solar thermal systems, which use tubes to "collect" solar radiation and store this in a thermal store (water tank) to be used

163 DECC (2015) *Energy Consumption in the UK, 2013 data;* DECC (2016) *RHI deployment data: January 2016*

164 Ibid.

165 DECC (2010) *2050 Pathways Analysis*

166 Baringa-Redpoint (2013) *Modelling to Support the Future of Heating: Meeting the Challenge.* DECC; ETI (2014) *Modelling Low-Carbon Energy System Designs with the ETI ESME Model*

167 DECC (2016) *The Renewable Heat Incentive: A reformed and refocused scheme*

168 Fuller, G. et al (2014) 'Contribution of wood burning to PM10 in London', Atmospheric Environment, 87-94

later for heating. Solar thermal provides zero carbon, renewable heat. It is typically used by households that would otherwise rely on gas or oil for hot water, and therefore can result in significant carbon savings.[169] However, the main drawback of solar thermal versus other technologies is that it usually provides only a part of the heat used in a building, rather than being the sole form of heating. This is due to the inevitable mismatch in timing between solar radiation and space heating demand (e.g. solar thermal produces most heat during the summer while demand is highest in winter). Typically, solar water heating can meet roughly half of annual hot water demand in a home.[170] With a thermal store (a larger and more complex tank that ties into the hot water and space heating systems) it could also meet a small proportion of space heating demand. Solar thermal has to therefore be used in conjunction with another heating system like gas, electric, oil or biomass.

Government recently proposed the removal of financial support to solar thermal under the RHI from 2017.[171] While solar thermal accounts for 17% of installations accredited to date, it provides only 2% of the overall heat generated under the RHI, which has led the Government to question whether to support the technology. Prior to the proposed change in policy, solar thermal received the highest level of subsidy under the RHI. Government has also stated that it considers the technology to be mature with little room for cost reduction. Contrary views do however exist as the Solar Trade Association estimates that the creation of a mass market for solar heating would lead to a 30% cost reduction through economies of scale.[172] However, even with such a reduction in cost solar thermal would still struggle to compete with other more cost-effective heating technologies.

It is also worth noting that there are a number of new solar thermal technologies entering the market. It is now possible to buy hybrid solar photovoltaic thermal panels (known as "solar PV-T") which generate both electricity and heat. At the moment there are only a few hundred solar PV-T installations in the UK. The technology remains relatively expensive and the installation process is more technically demanding than for a standalone solar PV or solar thermal system. Minus 7, a technology company, has also developed a system which is a hybrid between solar thermal, solar photovoltaic, a heat pump and a thermal store.[173] It claims that by integrating a significant thermal store and heat pump, the system can meet hot water and space heating needs, removing the requirement for a backup heating system. This technology is still in the early stages of commercial rollout, and appears to be more suited to larger properties rather than individual dwellings.

Summary

- Small-scale renewable solutions are likely to meet only a small proportion of UK heat requirements.
- There is a limit to the availability of sustainable biomass, and the general consensus is that biomass is better used in industry and large scale applications (such as heat networks) rather than individual homes. Biomass stoves are a contributor to urban air pollution.
- Solar thermal usually acts as only an auxiliary heating system as solar thermal output matches poorly with heat demand. A number of new hybrid solar technologies are coming to the market, but are at an early stage of commercial deployment.

169 DECC (2016) *RHI deployment data: January 2016*

170 Energy savings trust (2011) *Here comes the sun: a field trial of solar water heating systems*

171 DECC (2016) *The Renewable Heat Incentive: A reformed and refocused scheme*

172 Solar Trade Association (2013) *The Scope for Cost Reduction in a Mass Solar Heating Market*

173 See http://www.minus7.co.uk/

Chapter summary

This Chapter of the report provides an assessment of all the main opportunities and technologies to decarbonise domestic heating. Our assessment considers the decarbonisation potential of each option, together with the network, supply, and customer impacts and challenges. Table 3.2 and Figure 3.6 provide a high-level summary of the options against these criteria. As can be seen, the options which are most favourable overall are those associated with demand reduction and decarbonising gas heating – such as improving home insulation and heating controls, switching to high efficiency gas appliances, and greening the gas grid through the use of biomethane. Whilst not without their challenges, these options could deliver significant decarbonisation whilst minimising network, supply and consumer issues.

By contrast, the Government's stated approach, which focuses primarily on a shift to heat pumps, is arguably the most challenging of the options reviewed – in terms of network, supply and consumer cost issues. There is increasing discussion in the energy industry of the possibility of converting the gas to run on hydrogen. Our assessment is that whilst this could potentially deliver significant decarbonisation, it also appears very costly and challenging to deliver. More research is needed to assess the costs and impacts of switching to heat pumps or converting the gas grid to hydrogen before Government commits to either path.

Figure 3.6: High-level assessment of future heat technologies

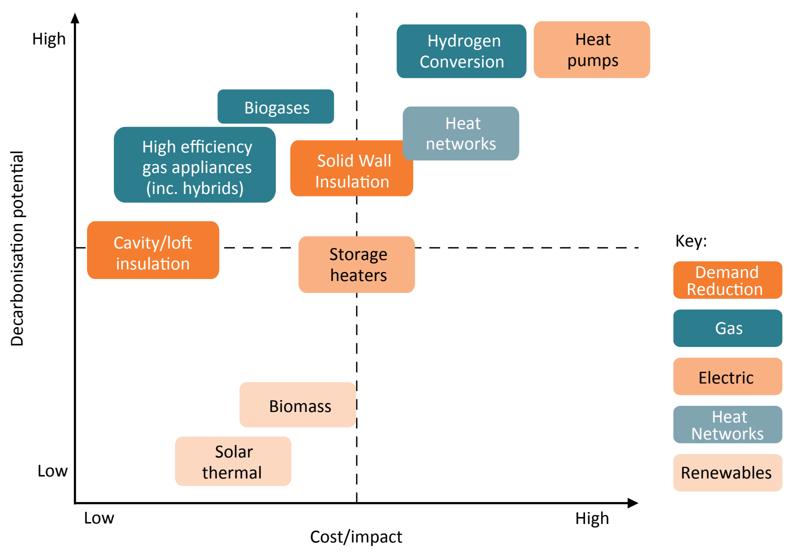


Table 3.2: High-level assessment of future heat technologies

		Decarbonisation potential	Consumer impact (cost, disruption, performance)	Network impact	Supply-side impact
Demand Reduction	Cavity/loft insulation, controls	Medium. Limited by technical potential.	Low – cost effective measures	Low/none	N/a
	Solid wall insulation	Medium/High	High – due to up front cost and disruption	Low/none	Low – scale of supply chain/ availability of skills
Gas	High efficiency appliances (including hybrids)	Medium/High	Low/medium – gas is favoured fuel. Most efficient technologies are costly.	Low – gas still used to meet peak demand	Low/none
	Biogases	Medium/High. Limited by feedstock availability.	Low – gas is favoured fuel type. No disruption to the home.	Low – some challenge associated with biomethane injection	Medium – limited feedstock, cost of production.
	Hydrogen conversion	High	Medium – requires appliances to be replaced. Increase cost of fuel to consumer.	High – costs associated with network conversion and hydrogen storage.	High – cost of producing hydrogen, and requirement for CCS
Electric	Heat pumps	High – but limited by consumer, network and supply impacts	High – high upfront cost, disruption in the home, quality issues.	High – requires significant power network reinforcement.	High – requires significant generation capacity to meet peak demand.
	Storage heaters	Medium – limited by running cost	Medium – low capital cost but high running costs.	Medium – requires some network reinforcement.	Medium – some increase in electricity demand (but less than heat pumps).
Heat Networks		Medium/High. Limited by commercial feasibility & availability of low carbon heat sources.	Medium – issues around consumer choice/protection.	High – requires new network, delivery challenges.	Medium – challenge in supplying low carbon heat into heat networks.
Small scale renewables	Biomass	Low/medium. Limited by availability of sustainable biomass.	Medium – boilers are large and expensive.	Low/none	Medium – limited by availability of feedstock
	Solar thermal	Low. Limited by seasonality.	Medium – requires solar store plus additional heating system.	Low/none	Low/none

4

Decarbonising Heat at Lower Cost

The previous Chapter highlights the challenges associated with each of the options to decarbonise heat. The purpose of this Chapter is to combine these options into a number of different scenarios, which can then be compared against the current DECC heat strategy.

To do this, Policy Exchange commissioned Delta-ee to construct two alternative heat scenarios using Delta's Pathways® Tool. This is a consumer uptake model which demonstrates how the future market for heating systems will react to changes in underlying parameters such as energy and product prices, policy incentives, and installer and consumer attitudes. For further details of the model see Appendix 2. The key outputs from the model are the mix of heating appliances, and the total carbon emissions associated with domestic heating. It should be noted that the analysis is limited to space heating and water heating, but not cooking, and includes both direct emissions and indirect emissions associated with electric heating.

The focus of our approach was to define scenarios which minimise – as far as possible – the cost and impact associated with decarbonising heat, in terms of consumer, network and supply costs. The analysis in Chapter 3 implies that the lowest cost opportunities are to improve efficiency and decarbonise gas use. Figure 4.1 provides a high level characterisation of each of the scenarios developed. Scenario 1 is a "balanced scenario" which achieves a high level of decarbonisation (80% reduction compared to 1990) whilst minimising the cost

Figure 4.1: Summary of scenarios (to 2050)

Scenario 1: 80% emissions reduction	Scenario 2: 90%+ emissions reduction	Scenario 3: DECC Heat Strategy (2013)
• c.80% emissions reduction vs 1990 • Focus on lowest cost/ impact solutions • Strong improvement in energy efficiency • Significant gas use, with higher efficiency appliances & greener gas Moderate uptake of electric heat pumps and heat networks	• c.90% emissions reduction vs 1990 • As Scenario 1, but achieves higher level of decarbonisation • Strong improvement in energy efficiency • Moderate gas use, with higher efficiency appliances & greener gas • Significant uptake of electric heat pumps and heat networks	• c.90% emissions reduction vs 1990 • Moderate efficiency improvement • Gas use largely phased out • Very high uptake of electric heat pumps • High uptake of heat networks

to consumers by maintaining a continued role for gas. Scenario 2 achieves a higher level of decarbonisation in line with that in the DECC heat strategy (90%). This is achieved through a much more ambitious rollout of electric heat pumps and low carbon heat networks, and far less gas use. We have also considered a variant to Scenario 1 which achieves a higher level of decarbonisation through the full conversion of the gas network to run on hydrogen (see Box 1 below).

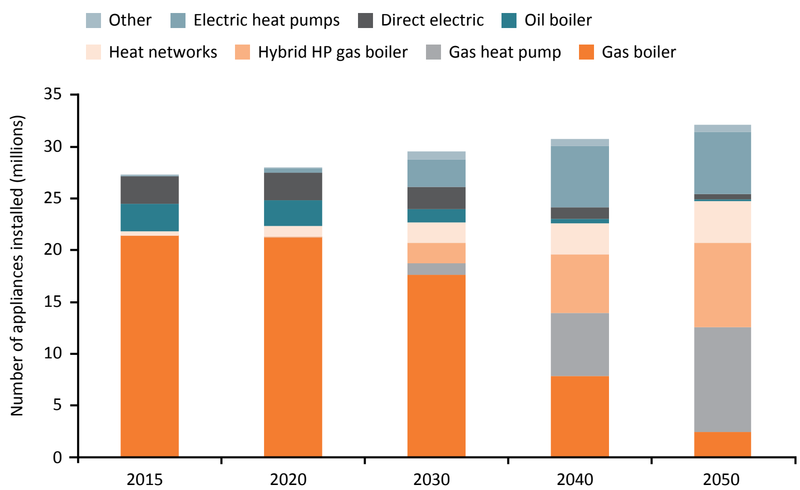
Scenario 1 (80% emissions reduction)

The first scenario aims at reducing greenhouse gas emissions from domestic heating by circa 80% by 2050 compared to 1990 levels. Our modelling indicates that domestic heat related emissions (excluding cooking) were 91.2 $MtCO_2$ in 1990[174] hence this scenario targets emissions of around 18 $MtCO_2$ per year in 2050. The focus of this scenario is to achieve this level of decarbonisation with the minimum impacts on end consumers, networks and systems. This is achieved as follows:

- Delivering a substantial improvement in the thermal performance of the UK's housing stock, through improvements in insulation, with total annual heat demand falling from around 360 TWh to around 303 TWh by 2050.
- Increasing the efficiency of gas use through the replacement of inefficient non-condensing boilers, and the use of high efficiency appliances such as gas driven heat pumps and hybrids.
- Reducing the carbon intensity of the gas grid through the use of greener gases.
- Shifting a component of heat demand to electric heating and to heat networks, both of which will have to be largely decarbonised by 2050.

Figure 4.2 summarises the mix of heating technologies to 2050, in terms of the number of installed heating appliances (note: data tables for both scenarios are provided in Appendix 1). It is assumed that the **overall number of gas appliances remains broadly level**, but that around 18 million households switch from conventional gas boilers to gas heat pumps or hybrid gas/electric systems by 2050. The remaining 2.4 million gas boilers will need to reach high efficiency levels through the use of flue gas heat recovery and more advanced controls.

Figure 4.2: Scenario 1 – Mix of heating appliances



174 Based on DEFRA (2016) *Final UK greenhouse gas emissions statistics 1990-2014;* and data from DECC (2015) *Energy Consumption in the UK*

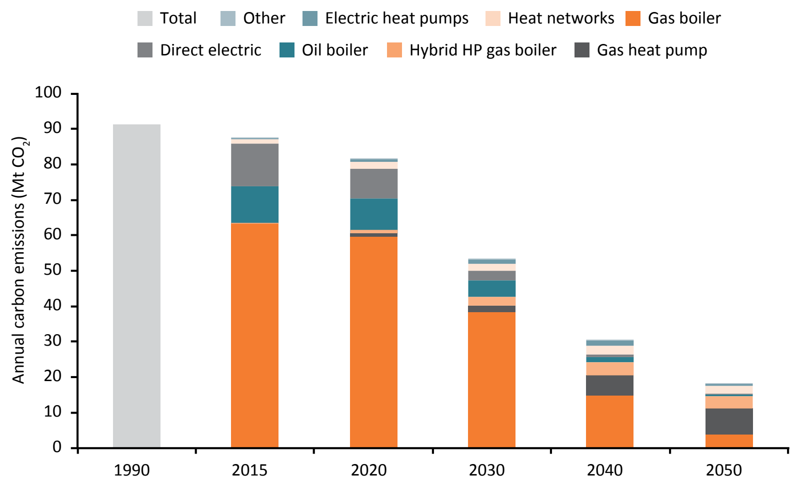
This scenario also assumes a significant roll-out of **electric heat pumps**, albeit to a far lesser extent than the DECC heat strategy, with around 6 million air or water source heat pumps installed by 2050 (2.7 million by 2030). Heat pumps would be focused in particular in new build properties, becoming the default option for new build properties off the gas grid from 2020 onwards.

This scenario has **heat networks** expanding from around 200,000 homes today to around 4 million by 2050 (2 million by 2030). This is assumed to be mainly in zones of high heat density, such as urban areas. This is a relatively modest level compared to the technical potential of heat networks, but nonetheless constitutes a major step change from today. We also assume that the carbon intensity of heat networks falls from over 200g CO_2/kWh today to less than 50 CO_2/kWh in 2050. This will require heat networks to transition from gas being the main source of heat, to incorporate lower carbon sources of heat such as solar thermal, heat pumps, biomass and waste heat.

Compared to the DECC heat strategy, Scenario 1 maintains a far stronger role for gas, and assumes a much lower role for electric heat pumps. This significantly reduces the level of investment required in the electricity sector (i.e. generation capacity and networks) and reduces the impact on consumers. However, in order to decarbonise whilst maintaining this level of gas use, this scenario requires a significant amount of **"green gas"** in the future. The carbon intensity of gas used for domestic heating is assumed to fall from 184 g/kWh today to around 120 g/kWh by 2050. This will require around 40 TWh of decarbonised gas per year, which could either come in the form of biogases or conversion of parts of the grid to hydrogen. As described in Chapter 3, there is uncertainty about the availability of biomethane, whilst hydrogen conversion appears to be a relatively costly option.

Overall this scenario delivers a reduction in emissions of 42% by 2030 and 80% by 2050, compared to 1990 levels (Figure 4.3). The vast majority of residual emissions in 2050 relate to gas use. If Government wished to pursue a more substantial reduction in emissions whilst maintaining a significant role for gas, then one option would be to convert the gas grid to run on hydrogen. This has been considered as a sensitivity to Scenario (see Box 3 below).

Figure 4.3: Scenario 1 – Annual Emissions from Domestic Heating (excluding cooking)



Box 3: Hydrogen conversion

Converting the gas grid to run on hydrogen opens up the possibility of achieving a substantial reduction in emissions whilst still maintaining gas use at relatively high levels. Given some of the uncertainties surrounding hydrogen conversion, we have not modelled this scenario in detail, but have instead considered it as a sensitivity to Scenario 1.

The latest research shows that converting gas heating to hydrogen would result in a carbon saving of 73%.* If we assume the same appliance mix as in Scenario 1, but with all natural gas replaced with hydrogen, this would reduce total emissions from domestic heating to 9.5 $MtCO_2$. This represents a 90% reduction in emissions overall compared to 1990. In other words, the emission saving implied in the DECC heat strategy can be matched whilst maintaining the number of gas appliances at current levels, but only if *all* gas heating is converted to hydrogen. As discussed in Chapter 3, there are significant costs and challenges associated with converting the gas system to run on hydrogen, which would inevitably lead to higher costs to consumers.

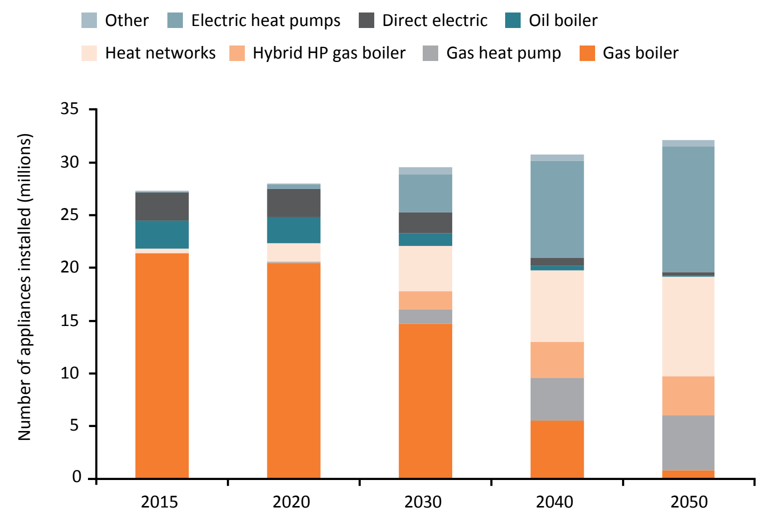
*This figure reflects the reduction in Scope 1+2 emissions, including indirect emissions associated with hydrogen production and CO_2 sequestration.

Scenario 2 (90% emissions reduction)

The second scenario is assumed to achieve a more ambitious 90% reduction in emissions by 2050 (compared to 1990 levels). Delivering such a reduction in carbon emissions would require a far more profound transformation of the way we heat our homes than Scenario 1. We assume that this would be achieved as follows:

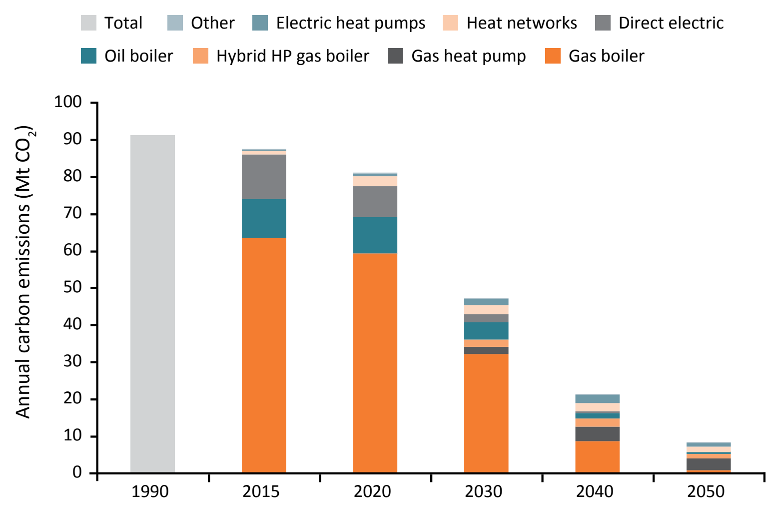
- The scenario assumes a **continued role for gas**, albeit at a far lower level than Scenario 1. It is assumed that the total number of gas appliances halves between now and 2050, and that any remaining gas appliances are either **gas heat pumps or hybrid gas/electric boilers**, with conventional condensing boilers largely phased out over the period 2030 to 2050.
- Significant decarbonisation is achieved through the mass adoption of **electric heat pumps**, with nearly 12 million heat pumps in place by 2050. This is double the number of heat pumps as in Scenario 1 (6 million) but still far fewer than in the current DECC heat strategy (27 million). To achieve this, heat pumps would not only have to be used in off-gas and new build homes, but also increasingly to retrofit existing homes currently supplied by gas. This would require substantial and prolonged policy intervention.
- The scenario also assumes a significant rollout of **heat networks**, with 9 million homes connected to heat networks by 2050. This is more than double the 4 million homes on heat networks in Scenario 1 and at the top end of the feasible range discussed in Chapter 3. In order to achieve this, heat networks would need to be rolled out to areas with lower heat density, thus increasing costs.

Figure 4.4: Scenario 2 – Mix of heating appliances



- Pursuing this Scenario would lead to far greater network and supply challenges than in Scenario 1. The mass roll out of heat pumps in this scenario would require significant investment in the power system (although to a lesser extent than the DECC heat strategy). Heat networks would also need to be almost completely decarbonised, shifting heat sources almost entirely from gas to low carbon alternatives. In this scenario we have assumed that the carbon intensity of heat networks is around 75% less than in Scenario 1 in 2050. Further research will be needed to understand whether heat networks can be decarbonised to this extent.

Figure 4.5: Scenario 2 – Annual Emissions from Domestic Heating (excluding cooking)



This scenario also requires a significant reduction in the carbon intensity of gas. We have assumed that the carbon intensity of gas halves from 184 g/kWh today to 92 g/kWh in 2050, although the much lower gas demand overall means that less decarbonised gas (around 27 TWh per year) is required to reach this level of decarbonisation than in Scenario 1.

Overall this scenario would deliver a reduction in emissions of around 50% by 2030 and 90% by 2050 (Figure 4.5). Compared to Scenario 1, the additional reduction in emissions comes mainly from shifting further from gas towards electric heating and heat networks, as well as by further "greening" of the gas network.

Chapter summary

Our analysis shows that there are several plausible options to deliver a significant reduction in emissions from domestic heating. None of these options can be considered "easy" as all will require significant policy intervention over a long period of time, as well as additional costs to households. Our modelling exercise indicates that the following policies are particularly important to drive deployment of lower carbon heating options:

- Changes to building regulations to require higher standards of insulation and more efficient heating appliances, both for new build properties and when appliances are replaced.
- Financial incentives to support the deployment of lower carbon heat technologies (such as the Renewable Heat Incentive).
- Measures to de-risk heat network projects and drive uptake;
- Mechanisms to rebalance fuel prices to improve the financial case for alternatives to gas. Retail electricity prices are projected to increase faster than gas prices, and this undermines the economics of electric heating options.
- Network planning to ensure that electricity and gas networks are able to cope with changes in demand.
- Policies to support research and development and innovation. The price of alternative heating technologies will need to fall substantially (in real terms) in order to facilitate deployment.
- Policies to ensure high quality installations and performance are also important.

Our analysis suggests that it is possible to achieve an 80% reduction in emissions whilst maintaining a significant role for gas heating. This can only be made possible by significantly improving the efficiency of homes and heating appliances, and reducing the carbon intensity of gas use through the use of "greener gases". In order to deliver an 80% emissions reduction it is also necessary to achieve a significant rollout of heat pumps and heat networks, although to a far lesser extent than in the DECC heat strategy.

Delivering a 90% reduction in emissions implies a much more significant transformation in the way we heat our homes. Our analysis suggests alternative routes to achieving this – either through a mass rollout of heat pumps and heat networks, or through the conversion of the gas network to hydrogen. As discussed in Chapter 3, all of these options are challenging and imply significant cost to consumers. The additional costs of pursuing a 90% reduction in emissions rather than an 80% reduction appear to be very significant, in terms of the cost to consumers and in terms of networks and supply considerations. This challenges the accepted wisdom that the UK should decarbonise domestic heat ahead of other sectors such as industry (see Figure 1.5).

5 Conclusions and Recommendations

The Government needs a new heat strategy

Decarbonising heat is critical to meeting the UK's overall carbon targets. Heat is currently responsible for nearly half of all the energy consumed in the UK[175] and one third of the greenhouse gas emissions, as discussed in Chapter 1.[176]

However, despite its significance, heat remains the "Cinderella" of energy and climate policy. The UK has made progress in decarbonising domestic heating, particularly since around 2005, but to a far lesser extent than the progress made to decarbonise power. Buildings and heating appliances have become more efficient over time, but this improvement has been offset by the growth in the number of people and households in the UK, and the fact that we now keep our homes much warmer than previously. The Government has developed a number of policies to decarbonise heat, but in general there has been insufficient policy focus in this area. The main policy aimed at decarbonising heat, the Renewable Heat Incentive, has had a very limited impact to date and has been relatively expensive compared to other decarbonisation policies.

The current heat strategy, developed by DECC in 2012 and 2013, is generally seen as unrealistic, as discussed in Chapter 2. The strategy suggests that by 2050 domestic heating will be provided predominantly by electric heat pumps, with gas use almost entirely phased out. However, analysis by ourselves and others shows that this approach will be very difficult and expensive to achieve in practice. Deploying such a large number of heat pumps could cost in the order of £300 billion, comprising the cost of installing the heat pumps and investment required to expand and reinforce the power system (see Chapter 3). The current heat strategy fails to adequately consider these costs and the resulting impact on consumers and energy bills. The disparity between electricity and gas prices means that heat pumps are more expensive to run than gas boilers, and uneconomic in the absence of subsidy. Gas boilers remain the heating appliance of choice, and alternatives such as heat pumps are poorly understood or accepted by most households.

Our analysis suggests that there are cheaper and easier ways to decarbonise heat. In Chapter 4 we present two alternative scenarios which take a more balanced path to decarbonise heat, combining improvements in energy efficiency, more efficient gas appliances, greener forms of gas, heat networks, and a more modest rollout of heat pumps. In these scenarios we have sought to minimise the costs and impacts on consumers and networks. It should be stressed that these

175 DECC (2013) *The Future of Heating: Meeting the challenge*

176 DECC (2015) *2014 UK Greenhouse Gas Emissions, Provisional Figures*

alternatives still present many significant challenges, and would require significant Government intervention, but to a lesser degree than the DECC heat strategy.

Overall it is clear that Government needs to develop a new strategy and suite of policies to decarbonise heating. This appears to have been recognised by Government. We understand that officials at BEIS are conducting work which will form part of the Carbon Plan to be published later this year, and that the Committee on Climate Change are also reviewing the Government's approach to heat and energy efficiency. The remainder of this chapter provides a set of recommendations to feed into Government thinking: firstly a set of general principles to follow in developing a new approach to decarbonising heat, and secondly a set of recommendations on how to drive forward particular technologies and opportunities.

Developing a new approach to decarbonising heat

Based on analysis in this and previous Policy Exchange reports, we suggest that the approach to decarbonising heat should follow the following broad principles:

1. Make a long term commitment to decarbonise heat

A consistent message which emerges from the analysis and stakeholders consultations conducted as part of this project is that decarbonising heat will be complex and challenging. The key challenges associated with each of the future heat technologies are set out in Chapter 3. There are no easy options or "silver bullets" to decarbonise heat. Whilst the options suggested in Chapter 4 appear to be more achievable than the DECC heat strategy, they are by no means "easy" to achieve.

The decarbonisation of heat will therefore require significant commitment and investment by Government, industry and consumers. It is a multi-decadal challenge, which will require considerable cross-party support and commitment. Most of the options to decarbonise heat involve substantial infrastructure, such as pipes, wires and generation plants, all of which is highly capital intensive. It is paramount that Government provides as much clarity and certainty as possible about the pace and scale of decarbonisation, in order to reduce risk and the financing costs of these projects.

This can be provided in a number of ways. Government recently legislated to set the Fifth Carbon Budget covering the period to 2032. Government is also required to provide a more detailed Carbon Plan by the end of the year. **The Carbon Plan needs to set clear objectives and parameters for the decarbonisation of heat**, but at the same time allow for future evolution of approach given the uncertainty with some heat technologies. A key factor to resolve is the intended level of decarbonisation of domestic heating compared to other sectors, as this has a very significant impact on the technologies which will need to be pursued. Our analysis suggests that the current target of "near zero carbon" buildings by 2050 would be significantly more expensive to achieve than an 80% reduction in emissions.

2. Put consumers back at the heart of the heat strategy

In our previous report, *The Customer is Always Right*[177] we argued that under the Coalition Government and previous Labour administrations, energy policy became increasingly detached from what consumers and voters want. The report

177 Howard, R. (2015) *The Customer is Always Right*. Policy Exchange

argued that voters identify the cost of living as their number one policy issue, and energy bills as the number one concern in terms of household budgets – but despite this, successive Government policies contributed to a significant increase in energy costs.

In a similar vein, the Government's 2013 heat strategy fails to adequately reflect consumer perspectives. As discussed in Chapters 2 and 3, the focus of the strategy on electric heat pumps represents an expensive solution to decarbonising heat, and is likely to involve significant cost and disruption to households. The current heat strategy envisages that the use of gas will be almost entirely phased out by 2050, despite this being the cheapest, most widespread and accepted form of heating.

Government needs to develop a new heat strategy which is more consumer-friendly, going with the grain of consumer preferences and minimising the cost to consumers. This is consistent with the Government's own commitment, in the 2015 Conservative Manifesto, to cut carbon emissions "as cheaply as possible". The new heat strategy should focus on the options which present the lowest cost and impact to consumers, bearing in mind direct costs (to install and run a heating system), hidden costs (such as the hassle of changing a heating system), and wider system costs.

3. Integrate heat, energy efficiency and fuel poverty.

Improving the energy efficiency of homes and heating appliances is amongst the cheapest ways to reduce carbon emissions. Many efficiency measures offer a quick payback in the form of energy cost savings. As documented previously, improving efficiency can also result in significant "co-benefits" such as improving energy security and reducing the health effects of fuel poverty and living in a cold home.[178]

However, policies concerning heat, energy efficiency and fuel poverty have not been brought forward by Government in an integrated manner. The current heat strategy adopts a fairly conservative approach to the contribution that efficiency can make to decarbonising heat, as shown in Figure 2.6. Support for energy efficiency has been scaled back, with the closure of the Green Deal and cuts to the ECO scheme resulting in a dramatic reduction in the number of energy efficiency improvements over the last five years, as discussed in Chapter 1. This is despite the fact that this is a more cost effective route to decarbonising heat than other policies such as the Renewable Heat Incentive. Despite some recent improvement, the UK housing stock remains amongst the least energy efficient in Europe.

Similarly, there is limited connection between policies concerning fuel poverty and heat. As highlighted in our previous report, *Warmer Homes*, the vast majority of fuel poverty funding addresses the symptoms but not the causes of fuel poverty: only 17% of the £3.2 billion spent on fuel poverty schemes per year is spent on improving energy efficiency, with the rest spent on payments and rebates to reduce energy costs for vulnerable households.[179] The Government is spending less than half of the funding required to achieve its stated fuel poverty target by 2030.

Overall it is clear that the Government needs to rethink its approach, and integrate its thinking concerning heat, energy efficiency, and fuel poverty. The new heat strategy should adopt an approach which seeks to improve efficiency ahead of deploying low carbon heat technologies, where this is cost-effective.

178 Howard, R. (2015) *Warmer Homes*. Policy Exchange

179 Ibid.

4. A national strategy with a localist approach

It is clear from the analysis in this report that the decarbonisation of heat will require a mix of technologies, rather than "one size fits all" solutions. The best course of action will vary by location and over time, depending on the building stock, the location of infrastructure, and the cost and carbon reduction potential of technologies now and in the future.[180] For example, switching to alternative fuels is likely to be prohibitively expensive for properties already connected to the gas grid, at least for the time being. However, progress can be made in these areas by insulating homes, switching to more efficient gas appliances, and switching to greener gases. Off-gas grid properties will require a different set of solutions, with carbon reductions made by shifting away from solid fuel and oil heating towards alternatives such as biopropane, heat pumps, renewables, and heat networks. Heat networks will generally be easier to deploy in new build developments rather than retrofit schemes, and in areas of higher heat density.

UK energy policy is generally determined top-down by national Government, but in the case of heat there is a case for devolution of some decision–making, since solutions will vary by area. This raises significant questions about which organisation(s) will need to lead and support decision making and the delivery of heat infrastructure. This could potentially involve a combination of the following organisations:

- Central Government (BEIS, HM Treasury, DCLG)
- Regulators (Ofgem)
- Network companies (gas, electric, water)
- Local Authorities and Local Enterprise Partnerships
- Community groups
- Major users of heat including industrial, commercial and public sector organisations

Local Authorities and LEPs are becoming more involved in the debate around heat – particularly in the delivery of heat networks where there are strong links to local planning. However, most Local Authorities lack the scale, expertise and financial capital to tackle these issues in their own right. Central Government is supporting the delivery of heat networks through the provision of funding and expertise, and this approach provides a model which could be applied more broadly.

As discussed in Chapter 3, another key challenge to decarbonising heat is how to manage network-related issues. The scenarios outlined in Chapter 4 have very different (and significant) implications for gas, electricity and heat networks. This makes it very challenging for network companies to plan investments and for Ofgem to regulate network companies. The current approach to network regulation is relatively passive in the sense that network companies propose and consult on their investment plans, and Ofgem judges the value for money for consumers. However, the increasingly complex system-interactions between networks suggests the need for a more active role in determining network investment plans. Policy Exchange has previously suggested the creation of an **Independent System Operator**, which could provide guidance on future network requirements and act as a "System Architect" across electricity, gas and heat networks.[181]

180 ETI (2015) *Smart Systems and Heat: Consumer challenges for low carbon heat*

181 Howard, R. (2015) *Governing Power*. Policy Exchange

5. Avoid making technology choices: let the market decide

Previous Policy Exchange reports (*The Customer is Always Right*, and *Going Going Gone*) have argued that the Government should avoid making energy technology choices and instead allows competition and market forces to determine outcomes. As documented in *The Customer is Always Right*, where Government has "picked winners" and determined subsidy levels, this has tended to result in higher costs to consumers than if Government had relied on competition and markets to drive out the cheapest outcomes. For example, under the FIDeR mechanism (Final Investment Decision enabling for Renewables) Government issued a set of contracts without any form of price competition, resulting in an additional cost to consumers of £250–310 million per year which could have been avoided if prices had been set on a competitive basis.

The Government is very far from adopting a market-based and technology-neutral approach to decarbonising heat. The UK has set a technology-specific target for 12% of heat to come from renewable sources by 2020, and has created the Renewable Heat Incentive to deliver this by backing only *renewable* forms of heating – a subset of the technologies available. Government sets the subsidy rates, which offer differentiated levels of support according to the costs and maturity of each technology. The RHI has turned out to be a relatively expensive policy, as discussed in Chapter 1, and is not well suited to deliver the required transformation in heat. **In our view the Government should remove technology specific targets such as the renewable heat target set under the European Renewable Energy Directive.**

Instead, **Government should pursue the lowest cost solutions to decarbonise heat,** and be more open-minded to the range of options available. If energy efficiency measures can be delivered more cost-effectively than renewables, as is suggested by our analysis, then this should surely be a higher priority. Decarbonisation of the gas grid also appears to offer significant decarbonisation potential with limited impact to the consumer, but is largely overlooked by the current heat strategy. Our analysis suggests that the renewable technologies pursued under the RHI (e.g. biomass, solar) will play a relatively modest role.

The Government needs to create a set of market conditions which allows technologies to compete on a level playing field, driving out the lowest cost routes to decarbonisation. A starting point for this would be to ensure that the price of heating fuels reflects their relative carbon intensity, allowing the market to drive out lower carbon solutions rather than higher carbon solutions. This has been achieved in the power sector through the use of carbon taxes such as the European Emissions Trading Scheme and the Carbon Price Floor, which have increased the cost of carbon intensive forms of generation such as coal, and resulted in a switch towards lower carbon alternatives including gas generation.

> "The Government needs to create a set of market conditions which allows technologies to compete on a level playing field"

However, at present the taxes and levies placed on domestic fuels is creating a perverse and distortive set of incentives. VAT is levied at a reduced rate of 5% on gas, solid fuels and heating oil (rather than the prevailing rate of 20% on most other goods and services), which effectively means that the implicit tax on these carbon intensive fuels is negative.[182] At the same time, whilst the carbon intensity of electricity is falling sharply, the taxes and levies placed on electricity bills are increasing over time (including not only carbon taxes, but also the cost of renewable energy subsidies such as the Renewables Obligation and Feed in Tariff). Our previous analysis showed that policy costs already add around £60 to the average household electricity bill (in 2014) and that this could increase by a further £100 by 2020.[183] In other words, the current system of energy taxes and levies is simultaneously providing a tax break for more carbon intensive heating fuels, whilst piling additional costs on to electricity (which by 2021 will become the least carbon intensive domestic fuel, on a per kWh basis).

In order to address this, **Government should consider adjusting taxes and levies on electricity, gas and other heating fuels to better reflect their carbon content.** For example, Government could increase VAT on carbon intensive fuels (gas, heating oil, coal) to the standard rate of 20%. To avoid pushing up overall energy bills, the additional revenue raised could be used to reduce or remove the policy costs levied on electricity (either by moving policy costs into public expenditure, or through bill rebates). These changes would have the effect of increasing the unit cost of more carbon intensive fuels, encouraging improvements in energy efficiency and switching to less carbon intensive fuels, whilst avoiding an increase in energy bills. Increasing taxes on more carbon intensive fuels would also send a strong signal to industry to invest in lower carbon fuels and heating technologies.

6. Combine short term "quick wins" with a long term vision

A key challenge for the new heat strategy will be how to balance short term and long term priorities. The scenarios presented in Chapter 4 suggest a significant transformation in the way we heat our homes will be required, particularly from 2030 onwards. This will require significant investment in new infrastructure across gas, electric and heat networks. Whilst this infrastructure will be delivered over a considerable period of time, some of the key decision points are rapidly approaching. For example, the next round of price controls for electricity and gas networks will be consulted on from 2017 and agreed in 2021.[184] These price controls will determine the level of investment in networks during the 2020s, and it is therefore paramount that these price controls reflect how we are likely to heat our homes from 2030 onwards. This reinforces the need for a **long term vision and commitment to decarbonising heat**, and greater interaction between Central Government, Ofgem and others to create that vision.

At the same time, our analysis suggests that there are "quick wins" which could deliver significant emissions reduction in the short to medium term (e.g. to 2030). The new heat strategy needs to exploit these opportunities where they fit with the long term vision. For example, improving efficiency will be helpful regardless of which heat technologies are chosen in the future, and should therefore be considered a "no regrets" option. Our analysis suggests that there is a role for gas heating even in 2050, hence Government should encourage the switch to lower carbon forms of gas, and the replacement of non-condensing boilers with higher efficiency boilers.

182 Advani, A. et al (2013) *Energy use policies and carbon pricing in the UK*. IFS.

183 Howard, R. (2015) *The Customer is Always Right*. Policy Exchange. Figures in £2014 prices.

184 Note: The price control period for electricity distribution networks is 2023-2031.

7. Tackle technology and system challenges

Decarbonising heat will require Government and industry to tackle some significant technological and system challenges. Many of the technologies described in this report are still relatively immature or just coming to the market, for example heat pumps and hybrid boilers. Our analysis in Chapter 4 suggests that significant reductions in cost and improvements in performance will need to be achieved in order to drive the mass adoption of these technologies. Even more significant challenges remain in areas such as hydrogen conversion. As described in Chapter 3, there are considerable uncertainties regarding the commercial viability of converting the gas grid to use hydrogen, which will need to be explored further before embarking down this path.

Further research, development and deployment of heat and energy efficiency technologies will be required to deliver improvements in performance and cost. However, the UK has historically spent relatively little on energy R&D compared to other similar countries. Since 2010 the UK has spent on average around 0.24% of GDP on energy research, compared to an average of 0.44% across all OECD countries (the UK ranks 21st out of 35 OECD countries by this metric).[185] That said, the UK appears to perform better in terms of the number of clean energy patents registered, ranking 6th amongst OECD countries after Korea, USA, Japan, Germany and France. As part of the last Comprehensive Spending Review, the Government's budget for energy innovation has been doubled from £250 million to £500 million over the course of this parliament. Given the scale of the challenges concerning heat, a significant proportion of this funding should be used to develop and pilot heat and energy efficiency technologies in order to address research challenges and improve understanding.

Another key point which runs through our analysis in this report is the significance of storage as a barrier or enabler to heat technologies. As discussed in Chapter 1, the gas system plays a crucial role at present in storing and delivering large quantities of energy and catering for the seasonal demand for heat. Our analysis suggests that the high cost and impracticality of storing large quantities of electricity could act as a barrier to the deployment of heat pumps. On the other hand, the integration of storage into heat networks is likely to improve their performance. Storage presents challenges both in terms of research and development, and also in terms of commercialisation. A previous Policy Exchange report identified energy storage as one of "Eight Great Technologies" where the UK could become a world leader[186] and £600 million of capital research spending was subsequently allocated to these technologies. Alongside research support, it is also paramount that market arrangements facilitate the deployment of storage, and that there is a "level playing field" between storage and other technologies. Policy Exchange is currently undertaking a project which is exploring the regulatory and commercial barriers to the deployment of storage, which will report shortly.

Driving Improvements in Energy Efficiency

As discussed throughout this report, improving the efficiency of homes could make a significant contribution to decarbonising heat – not only by reducing emissions, but also as a pre-requisite for alternative forms of heating. Improving energy efficiency has been at the centre of several Policy Exchange reports in the past.[187] We previously recommended that **energy efficiency should be considered a Top 40 national**

185 Source: International Energy Agency, RD&D online data service

186 Willets, D. (2013) *Eight Great Technologies*. Policy Exchange

187 Howard, R. (2015) *Warmer Homes*; Howard, R. (2015) *Efficient Energy Policy*

infrastructure priority. This could now be put into practice by **making energy efficiency an area of focus for the new National Infrastructure Commission.**

Given the importance of efficiency to decarbonisation of heat, we suggest that the Government's new heat strategy should set an ambition to raise the **energy efficiency standards of UK homes** – for example that by 2030 UK homes should achieve an *average* energy efficiency rating of Band C, and a minimum efficiency rating of Band D. This will require a number of different interventions and incentives, tailored to different segments of the housing market. Our previous report, *Efficient Energy Policy*, suggested the following two policies as ways to drive investment in energy efficiency by "able to pay" households:

- **Linking the Stamp Duty system to the energy performance of a dwelling** to create an incentive for homebuyers to purchase a more efficient dwelling; and
- **Reforming mortgage affordability tests** to better reflect the energy performance of a dwelling, and to **encourage lenders to offer energy efficiency mortgages.**

In addition, we recommended that Government should strengthen requirements for landlords to improve efficiency by **tightening the Private Rented Sector Energy Efficiency regulations** in the future. Landlords are already required to bring their properties up to a minimum efficiency rating of Band E by 2018. This could be increased to a minimum of Band D in 2025 or 2030 (maintaining the existing exemptions for listed properties and limiting improvements to those that are cost-effective). Industry is largely supportive of this recommendation: the Government consultation on the Private Rented Sector Energy Efficiency Regulations revealed that 88% of respondents agreed a trajectory of standards beyond 2018 should be set as this would provide investment certainty and lower overall installation costs.[188]

In a previous report, *Warmer Homes*, we considered the related issues of energy efficiency and fuel poverty.[189] Our analysis suggested that Government was spending less than half of the amount required to deliver the fuel poverty target for England by 2030. The Government has since announced that the existing ECO scheme will be replaced with a new social obligation from 2018. We welcome the fact that this new scheme will be targeted at fuel poor households. However the budget of the scheme (£640 million per year) is still well short of the amount required to deliver the fuel poverty target (£1.2 billion per year). As suggested previously, the budget for energy efficiency improvement in fuel poor homes could be increased either by **making the Winter Fuel Payment an "opt-in" scheme and reallocating the saving towards energy efficiency**, or by drawing in funds from other sources such as the NHS.[190] Other schemes being considered by Local Authorities to encourage low-income households to invest in energy efficiency include "Care and Repair" loans, and equity release schemes. These options should be explored further.

The above policies should encourage uptake of the remaining low-cost efficiency measures, but it will also be necessary to address "hard to treat" solid wall properties to deliver a more substantial reduction in heat demand. The CCC estimates that 1.5 million properties with solid walls will have to be insulated throughout the 2020s for the UK to meet the 5th carbon budget.[191] However as

188 DECC (2015) *Private Rented Sector Energy Efficiency Regulations (Domestic)*

189 Howard, R. (2015) *Warmer Homes.* Policy Exchange

190 Howard, R. (2015) *Warmer Homes.* Policy Exchange

191 CCC (2015) *Sectoral scenarios for the Fifth Carbon Budget*

discussed in Chapter 3, solid wall insulation can be expensive and disruptive to install. This could be addressed in two ways. Firstly, it has been shown that the cost of solid wall insulation can be reduced by as much as 30% if brought forward on an area or street-by-street basis rather than on the basis of individual houses. Delivering solid wall insulation in schemes of 100 or more homes creates critical mass and reduces the unit cost per dwelling. **The new ECO scheme should continue to deliver solid wall insulation**, potentially including an area-based element to drive more efficient delivery models.

Secondly, companies are now considering more innovative ways to deliver solid wall insulation which reduce cost and the level of disruption. A Dutch organisation called "Energiesprong" has developed a system which uses mass-produced, prefabricated panels clipped onto the outside of the home. This system is far quicker to install than conventional methods of solid wall insulation, taking less than a week to install.[192] Energiesprong has had success with this model particularly with Housing Associations in the Netherlands, where Government has underwritten the required finance, and is looking to roll the approach to social housing providers in the UK.

Finally, it is paramount that **new homes are built to the highest standards of efficiency** in order to mitigate the impact of the growing population on heat demand and related emissions. As discussed in Chapter 1, the Government had previously set a target for all new homes to meet a "Zero Carbon Homes" standard from 2016 onwards, but this requirement was axed in 2015 due to fears that this could hamper the delivery of new housing.[193] The Zero Carbon Homes standard comprised three distinct elements:

1. Fabric energy efficiency – e.g. insulation, air tightness
2. On site low/zero carbon heat and power – e.g. solar, heat pumps, biomass
3. Allowable Solutions – a mechanism to invest in carbon emissions savings off-site in order to "offset" any remaining emissions

In our view, there is merit in reintroducing just the energy efficiency component of the Zero Carbon Homes Standard. This could be achieved by **revising Building Regulations to incorporate tighter energy efficiency standards for new homes.** However as discussed throughout this report, installing on site renewables may not be the most cost effective way to achieve further decarbonisation, and may not be applicable to all homes. House-builders should not be required to install low/zero carbon heat and power (although they may choose to do so). The "Allowable Solutions" element of the Zero Carbon Homes standard is effectively a tax on house-builders, and we suggest that this element of the Zero Carbon Homes standard is not progressed further.

Greening gas use

Contrary to the DECC heat strategy, our analysis suggests that gas could continue to play a role in providing heat, even if the UK wishes to decarbonise heating by 80% or more. However this will require a substantial increase in boiler efficiencies, combined with a shift towards the use of greener gases.

192 EnergieSprong UK (2016) *Briefing January 2016*

193 Harrabin, R. (2015) *Designers create the 'impossible' zero-carbon house*. BBC, 16th July 2015

Higher efficiency gas appliances

Our scenarios analysis, presented in Chapter 4, assumes that by 2030 all conventional boilers will need to achieve efficiencies of 90% or higher, and that around 3 million boilers will need to be changed to gas driven heat pumps or hybrids (Scenario 1). By 2050, all remaining boilers would need to be replaced by gas driven heat pumps or hybrids. Achieving this would require a number of policy interventions as follows:

- Firstly, Government will need to **tighten boiler efficiency standards**. Since 2005, Building Regulations have required all newly fitted boilers to be condensing boilers. We suggest that Government considers tightening these standards further to include a "Boiler plus" requirement, which would make it mandatory to also fit Passive Flue Gas Heat Recovery and/or advanced heating controls – both of which are relatively low cost measures. These technologies should become the norm as early as possible.
- Secondly, national or city-level Government could consider introducing a **Boiler Scrappage Scheme** to accelerate the replacement of non-condensing boilers. As discussed in our recent report on air pollution, *Up in the Air*, this would have considerable co-benefits in reducing both CO_2 and emissions of local pollutants such as Nitrogen Oxides.
- Thirdly, the **Renewable Heat Incentive** should be reformed to incorporate support for high efficiency gas appliances such as gas driven heat pumps (see further discussion below). As discussed in Chapters 3 and 4, these technologies appear to be lower cost (from a consumer and network perspective) than electric heat pumps, but at present are excluded from support under the RHI.

Greener gases

Alongside improvements in efficiency, the future use of gas for heating depends on achieving a switch to greener forms of gas such as biomethane (and biopropane off the gas grid). The scenarios presented in Chapter 4 require 30–40 TWh of green gases for the domestic heating sector alone – a significant increase on the 2 TWh supplied currently.

As set out in Chapter 3, one of the main obstacles to the production of biomethane is the availability of feedstock. This can be addressed as follows:

- There is potential to significantly increase the production of biomethane from food waste (via anaerobic digestion) which would otherwise be sent to landfill and emit greenhouse gases into the atmosphere. Analysis by DECC suggests that food waste is a more cost effective feedstock for anaerobic digestion than other feedstocks such as energy crops.[194] However, policies regarding food waste collection are not harmonised nationally, and more than 40% of Local Authorities in England do not offer separate food waste collection. The REA suggest that only around 12% of food waste generated is currently used for AD – leaving significant untapped potential.[195] In a previous report we argued **that household collection systems should be harmonised** across the country with a requirement for **separate food waste collections** in order to increase the feedstock available for anaerobic digestion.[196] BEIS will need to work jointly with Defra on policies to encourage the use of food waste for AD.

194 DECC (2016) *Consultation Stage IA: The Renewable Heat Incentive: A reformed and refocused scheme*

195 REA (2016) *REA response to Consultation on proposed reforms to the existing Domestic and Non-Domestic Renewable Heat Incentive schemes*

196 Coggins, C. et al (2009) *A Wasted Opportunity?*. Policy Exchange

- Similarly, it is thought that there is potential to increase production of biogas from sewage, agricultural residues, and landfill sites. Ofwat is working on reforms to the sewage treatment sector, which it thinks will encourage water firms to increase biogas production.[197] It is thought that only around 1% of agricultural residues are currently used for AD purposes.[198] Landfill gases could also be used as a low carbon fuel source, but are currently neither allowed for grid injection nor supported by the RHI. Government ran a call for evidence about including landfill gas in the RHI but as yet has not changed its policy.[199]
- Government should also support the development and deployment of gasification and pyrolysis technologies which use "black bag" residual waste to produce bio-SNG. If successful these technologies have the potential to substantially increase the supply of greener gas, using a much larger proportion of the waste stream. The technologies are close to commercialisation but still require further innovation support.
- At present biogas production is eligible for support under the Renewable Heat Incentive, the Small Scale Feed in Tariff, Renewables Obligation and Contract for Difference. Under current conditions the carbon savings from electricity generation outweigh those from injecting biogas into the grid – but this will change as the power system is decarbonised. It could be argued that green gas is more useful when injected into the grid and used to decarbonise heat. **Government needs to provide greater direction on the best use of biogas and design individual policies and financial incentives accordingly.**

Another issue which needs to be addressed relates to **gas standards** which present a significant barrier to biomethane injection at present.[200] Under Ofgem rules, producers have to upgrade biomethane to meet grid standards before it can be injected into the grid to achieve the same "Calorific Value" as natural gas, adding considerable cost and complexity to projects.

Gas standards were developed with large natural gas injection projects in mind, and it could be argued that they are not fit for purpose for smaller scale biomethane projects. Consideration should be given to extending the range of gas standards (known as the WOBBE index) to accommodate a wider range of gases including biomethane and hydrogen. SGN is currently undertaking trials in Oban, Scotland, to establish the safe limits for the chemical composition of grid gas.[201] Government should act on the findings of this research in order to reduce the barriers to the injection of greener gases.

A related issue is that fact that current regulations require gas injection sites to install expensive monitoring devices to measure Calorific Value. This is perceived as a significant barrier to biomethane injection projects. The Energy Network Association recently published a consultation on a number of possible measures to facilitate biomethane injection.[202] Ofgem gave a lukewarm response to the consultation, saying that the options considered did not provide sufficient levels of customer protection, but that it would consider the use of less accurate (and cheaper) monitoring devices.[203] An appropriate balance needs to be found which protects consumer interests but at the same time avoids stifling the growth of the biomethane industry.

Ofgem will also need to reconsider the regulations concerning how consumers are charged for the gas they consume. Gas is charged based on an assumed energy

197 Gosden, E. (2016) *Britain should make more energy from poo, says Ofwat*. The Telegraph 25th May 2016

198 REA (2016) *REA response to Consultation on proposed reforms to the existing Domestic and Non-Domestic Renewable Heat Incentive schemes*

199 DECC (2012) *Renewable Heat Incentive – Call for Evidence: Landfill Gas*

200 UtilityWeek (2015) *Regulation 'burden to biomethane producers', says ENA*

201 Source: https://www.sgn.co.uk/

202 ENA (2015) *Reducing Costs and Removing Barriers for Low-flow Gas Entry Sites: Transforming the Calorific Value (CV) Regime for Small Sites*

203 Ofgem (2016) *Ofgem response to ENA Consultation – Reducing Costs and Removing Barriers for Low Flow Entry Sites*

content, which at the moment is uniform across the gas network. However if biogases are injected into the grid in some areas but not others, then the energy content of mains gas would vary area by area. Billing systems would need to be changed to allow different households to be billed based on the energy-content of the gas they consume. This would also require the gas distribution network to be fitted with sensors to measure the energy-content of gas distributed to households.

In addition, Government should provide support for the use of biopropane in off-gas grid homes, as a low carbon replacement for LPG. We suggested above that Government should tax heating fuels in line with their relative carbon intensity. If adopted, this change may be a sufficient driver to encourage the use of low carbon gases such as biopropane. Alternatively, Government could provide financial support for the use of biopropane under a reformed Renewable Heat Incentive, similar to the existing support provided for biomethane injection. Analysis suggests that a tariff of around 1.85 pence per kWh would be required to support the use of biopropane – which is considerably lower that the subsidies given to other technologies such as Ground Source Heat Pumps (19.51 p/kWh) and Air Source Heat Pumps (7.42 p/kWh).[204]

Hydrogen conversion

Aside from biomethane, another way to decarbonise the gas grid would be to convert it to run on hydrogen. As discussed in Chapter 3, this appears to be a lower cost option than the Government's current strategy of switching to electric heat pumps. Nonetheless, the available evidence suggests that hydrogen conversion is likely to involve significant cost to the consumer, and require substantial investment in new infrastructure.

It is early days in the debate around hydrogen conversion, and there are still significant uncertainties to resolve. It would be prudent for Government and industry to develop this option further, to test the cost, feasibility and consumer acceptance of converting the gas grid to hydrogen. To that end, **we recommend that Government funds further research and pilots into hydrogen conversion** – either as part of the BEIS Innovation budget or the Ofgem Low Carbon Networks Fund. We would encourage Government to focus on small scale pilots first, before contemplating the city-scale project envisaged in the H21 Leeds City Gate report.

Reforming the renewable heat incentive

The Renewable Heat Incentive (RHI) is currently the main policy instrument to support alternative forms of heating. As discussed in Chapter 1, the RHI has had a limited impact on the heat market to date, and has been a relatively expensive policy. In its current form it is not well suited to drive a step change in the decarbonisation of heating. This has to an extent been recognised by Government, who consulted on a package of reforms to the RHI in early 2016. However, in our view these reforms do not go far enough, and we propose that the scheme is further reformed as follows:

Firstly, we recommend that the RHI is expanded into a **Low Carbon Heat Incentive,** covering both renewable and non-renewable technologies. As suggested above, the Government should pursue a technology-neutral strategy to decarbonising heat, focusing on the lowest cost opportunities. The narrow focus of the RHI only

204 EUA (2015) Biopropane for the off-grid sector

on *renewable* forms of heating and delivery of the 2020 Renewable Heat target has led Government to overlook other opportunities to decarbonise heat which could potentially be more cost-effective. The scheme currently does not support high efficiency gas-based technologies such as Gas Driven Heat Pumps – despite these being cheaper and having less impact on networks than electric heat pumps (see Chapter 3 for discussion). Analysis suggests that Gas Driven Heat Pumps would require a tariff of around 3.25 pence per kWh (under the non-domestic RHI) which compares favourably to other technologies (see Table 5.1). Similarly, as discussed above, the RHI currently does not support the use of biopropane as a replacement for LPG, despite the fact that this would require a considerably lower tariff than those available for other heat technologies under the RHI.

Secondly, and related to this, we recommend that the Government improves the value for money of the reformed RHI by **focusing on the lowest cost technologies, and reducing or removing support for more expensive technologies.** At present, support under the RHI is differentiated by technology, with tariffs set to deliver approximately a 12% financial return based on cost and performance data. More expensive technologies such as solar thermal and heat pumps receive the highest level of subsidy, whilst cheaper technologies such as biomass and biomethane injection receive far lower levels of subsidy (see Table 5.1).

Table 5.1: Summary of current and proposed RHI tariffs

Scheme	Technology	Current tariff (effective for new accreditations in the period July–Sept 2016)	Proposed tariffs (effective Spring 2017 onwards)	Equivalent 20 year tariff
Domestic RHI (7 year payments)	Biomass	4.68	4.68	2.43
	Air source heat pump	7.42	7.42–10.00	3.85–5.20
	Ground source heat pump	19.51	19.51	10.14
	Solar thermal	19.51	n/a–support no longer available	
Non-domestic RHI (20 year payments)	Biomass	2.05–5.24	1.80–2.90	1.80–2.90
	Biomethane injection/ combustion	2.06–5.90	2.06–5.90	2.06–5.90
	Ground source heat pump	2.67–8.95	2.67–8.95	2.67–8.95
	Air source heat pump	2.57	2.57	2.57
	Biomass CHP	4.22	1.80–4.22	1.8–4.22
	Geothermal	5.14	5.14	5.14
	Solar thermal	10.28	n/a – support no longer available	

In a recent consultation[205] the Government proposed to withdraw financial support for solar thermal on value for money grounds – a position which we support. However, the consultation also suggests *increasing* the level of subsidy to

205 DECC (2016) *The Renewable Heat Incentive: A reformed and refocused scheme*

Air Source Heat Pumps (under the domestic RHI), whilst reducing support for some more cost-effective technologies under the non-domestic RHI.

The proposed changes, and the design of the RHI, run counter to the notion of technology-neutrality, and the Government's manifesto commitment to cut carbon "as cheaply as possible". We recommend that Government sets an overall cap on the level of support available under the RHI, with this cap reducing over time to encourage further technology innovation. No technologies would be excluded from support per se, but return levels would drop for more expensive technologies. As we argued in a previous report, the Government "needs to overcome its squeamishness about allowing expensive technologies to fail, and substantially narrow the range of subsidies available."[206]

The RHI already has such a "value for money cap" in place, but we would argue that this is set too high. The current cap is set at 10 pence per kWh under the non-domestic RHI (where payments are made for 20 years) which corresponds to a cap of 19.51 p/kWh under the domestic RHI (where payments are only made for 7 years). The cap was originally set at a level equivalent to the amount of direct subsidy to offshore wind – on the basis that offshore wind was seen as the 'marginal' technology required to hit the 2020 Renewable Energy Target. However, even if we accept the basis of the cap, the Government needs to reflect the fact that offshore wind costs have fallen substantially in recent years. Whilst early offshore wind projects received subsidies of up to £100/MWh (or 10 pence per kWh) costs have fallen sharply, and forthcoming projects delivered in the early 2020s will receive a subsidy in the region of £60/MWh,[207] with further reductions expected thereafter. This equates to an equivalent RHI payment of 5.2 p/kWh for a period of 20 years (or 10 p/kWh under the 7 year payment model in the domestic RHI). Setting a tariff cap at this level would limit the subsidy payable to more expensive technologies such as Ground Source Heat Pumps, but at the same time improve the overall value for money of the scheme and free up budget for more cost-effective technologies.

Scaling Up Heat Networks

Heat networks are still relatively uncommon in the UK, providing heat only to around 1% of households. But our analysis suggests that they could play an important role in decarbonising heat, potentially expanding to serve 10–20%+ of households by 2050, and incorporating lower carbon sources of heat. That said, there are some significant challenges which need to be overcome, namely:

- **Financing cost and risk:** Heat networks are highly capital intensive projects. If Government can reduce the risks associated with developing heat networks then this would significantly improve their economic viability (see Figure 3.5) and reduce the cost to consumers.
- **Delivery cost and risks:** Building heat networks can be expensive and time-consuming, particularly when retrofitted to existing urban areas as opposed to new build developments.
- **Insufficient consumer protection and buy-in:** Consumer groups have raised concerns about the lack of consumer redress in the heat networks sector. Equally, there is limited consumer understanding of heat networks at present, which may limit their acceptance and roll-out.

206 Howard, R. (2015) *The Customer is Always Right*. Policy Exchange

207 Assuming the previously announced administrative strike price of £105/MWh for offshore wind projects delivered in 2021.

- **Low carbon heat networks:** At present the majority of heat networks are fueled by gas Combined Heat and Power plants. These offer carbon and efficiency savings versus conventional gas boilers but are by no means "low carbon". In order to maximise the decarbonisation potential of heat networks they will need to incorporate lower carbon sources of heat in the future, but at present there are insufficient incentives for developers to do so.

The current policy and regulatory regime is insufficient to address the above challenges and deliver heat networks at the required scale. The Government has taken a relatively "hands-off" approach to heat networks until relatively recently, and heat networks fall outside the remit of the energy regulator Ofgem. In the absence of formal regulation, the industry has developed its own Code of Practice and consumer protection scheme. Whilst these schemes are a step in the right direction, they remain voluntary and simply do not go far enough in protecting consumer interests. It is inevitable that a more formal system of regulation will be required if heat networks are to scale up to serve millions of customers in the future, as projected in our scenarios. This view is also held by consumer groups such as Citizens Advice, which has argued for the creation of a mandatory consumer protection framework for heat networks.[208]

"The current policy and regulatory regime is insufficient to deliver heat networks at the required scale"

To that end, **we recommend that Government expands Ofgem's remit to include the regulation of heat networks. Ofgem should develop a bespoke regulatory framework for heat networks** which both protects consumer interests and reduces the risks to projects. This could potentially replicate elements of the regulatory system for electricity and gas networks and markets – but it needs to be recognised that heat networks are very different to electricity and gas. For example, electricity and gas sector regulations require the "unbundling" or separation of ownership of network and generation assets; whilst it is normal practice for a heat network operator to be involved in the full value chain of heat generation, networks, and supply to customers. Regulations concerning switching in electricity and gas markets simply will not apply in the case of heat networks, where customers are typically locked in for long periods. However, at the very least Ofgem should create regulations to ensure that customers are treated fairly and charged appropriately, and set minimum standards for customer service and network performance. The regulations need to be proportionate to the scale of heat networks (which are typically orders of magnitude smaller than electricity and gas networks in terms of capital value and number of customers) and carefully designed to avoid stifling the development of the industry.

At the same time, the Government needs to create mechanisms to de-risk and accelerate the delivery of heat network projects. This can be achieved at various stages of the development cycle of planning, financing, construction, and operations. Government is already providing significant support to develop a pipeline of heat network projects. The Heat Network Development Unit, established in 2013, provides grant funding and technical support to heat network schemes led by Local Authorities (which often lack the capacity and expertise to bring forward projects in their own right). To date the HNDU scheme has supported

208 Citizens Advice (2016) *Response to the consultation on the Heat Networks Investment Project*

over 200 projects, and an evaluation of the scheme suggested that it has played a key role in pushing projects through the early stages of development.[209] However, a subsequent report by the ADE identified that many Local Authorities face barriers in taking projects though the final stages of development.[210] They propose extending the remit of the HNDU to support Local Authority led heat network projects through to financial close – a recommendation which we endorse.

Government has also launched a new Heat Network Investment Project (HNIP) with a budget of £320 million to 2020. This aims to kickstart the heat network industry through direct financial support to heat network projects, leveraging around £2 billion in total investment. Government launched a consultation on the project in June 2016. Whilst we welcome the creation of the HNIP, there are several features of the proposals which could be improved, as follows:

- The consultation suggests that the scheme will initially be limited to Local Authority led schemes only. This appears to be an unnecessary constraint which will limit the pool of potential applicants and reduce competition. **We recommend that Government opens up the HNIP scheme to other public bodies (e.g. universities, hospitals) private sector companies, and third sector organisations** involved in the development of heat networks.
- It is suggested that the scheme could provide a mix of grants, soft loans, equity, and guarantees. We recommend that Government considers this carefully, matching the products to the barriers faced by heat network developers. Government cannot and should not provide all of the funding to develop heat networks: they need to become an attractive commercial proposition in order to scale up. In our view, Government should avoid providing subsidised finance at sub-market rates ("soft loans") as this risks creating an industry reliant on subsidy. Local Authorities can already borrow at very low rates in any case.
- One of the biggest barriers identified by heat network developers is that of demand risk: heat network infrastructure must be sized to the number of customers it will serve, but most customers will only sign up once the infrastructure is in place. Government could potentially unlock this barrier through the **provision of demand guarantees or debt guarantees**, which would reduce risk to other commercial investors during the early years of a project's operation. This would significantly expand the pool of investors willing to engage in heat network projects, thereby reducing the overall cost of capital.
- Another issue faced by heat network developers is that of how to scale their network. Heat networks can be rolled out incrementally, but it is best if this is planned from the start. There are instances where relatively small investments up front could "future-proof" the network for further expansion – but developers may still be unwilling to make this investment due to the uncertain payback. **There is potentially a role for Government here to make "anticipatory investments" which facilitate future expansion.**

Aside from the HNIP project, there are potentially other routes for Government to improve the financial attractiveness of heat networks. Other utility networks such as electricity, gas and water are financed through a Regulated Asset Base (RAB) model, underpinned by a predictable and transparent regulatory regime

209 DECC / CAG Consultants (2015) *Evaluation of the Heat Networks Delivery Unit*

210 ADE (2016) *Levelling the playing field: Unlocking heat infrastructure investment*

and price controls. This allows network owners to achieve a very low cost of capital (e.g. a Weighted Average Cost of Capital of around 4–5%) thus minimising costs to the consumer. By contrast, heat networks are perceived to be far more risky investments, with investors typically requiring returns in the range 12–15%.[211] As part of the new regulatory framework proposed above, **Ofgem should investigate whether a Regulated Asset Base model could be applied to heat networks in order to reduce financing costs.** The main challenge with this approach is that unlike electricity and gas networks, which already have a large customer base, the customer base for heat networks is still emerging and uncertain. Under a RAB model, the cost of building a heat network could be passed on to future customers, with Government guaranteeing a certain level of demand (as proposed above).

Finally, Government policies could also help to address some very practical issues concerning the delivery and construction of heat networks. Most utilities, such as electricity, gas and water, are deemed "statutory utilities", which grants them access rights over highways and customer meters, the right of compulsory purchase, and rights to obtain wayleaves (e.g. rights to access a site). Heat networks do not have such rights and therefore have to obtain access rights through negotiation with landowners, which can involve significant cost and complexity.[212] We recommend that as part of the regulatory framework proposed above, **Ofgem considers granting heat networks rights equivalent to other statutory utilities.**

211 DECC (2016) *Heat Networks Investment Project: Capital funding for building heat networks*

212 ADE (2016) *Levelling the playing field: Unlocking heat infrastructure investment*

Appendix 1: Data Tables

Table 1: Scenario 1 – Mix of heating appliances, number of dwellings (Figure 4.2)

	2015	2020	2030	2040	2050
Gas boiler	21,350,000	21,190,000	17,600,000	7,880,000	2,410,000
Gas heat pump	–	50,000	1,160,000	6,070,000	10,150,000
Hybrid HP gas boiler	10,000	90,000	1,950,000	5,600,000	8,170,000
Heat networks	500,000	1,000,000	2,000,000	3,000,000	4,000,000
Oil boiler	2,600,000	2,490,000	1,270,000	440,000	150,000
Direct electric	2,710,000	2,660,000	2,110,000	1,160,000	550,000
Electric heat pumps	90,000	470,000	2,690,000	5,900,000	6,010,000
Other	50,000	90,000	790,000	660,000	680,000
Total	27,310,000	28,030,000	29,570,000	30,710,000	32,120,000

Table 2: Scenario 1 – Annual emissions from domestic heating excluding cooking, $MtCO_2$ (Figure 4.3)

	1990	2015	2020	2030	2040	2050
Gas boiler	–	63.3	60.4	38.5	14.8	3.9
Gas heat pump	–	0.0	0.1	1.7	5.8	7.4
Hybrid HP gas boiler	–	0.0	0.1	2.4	3.6	3.3
Oil boiler	–	10.6	9.8	4.8	1.6	0.6
Direct electric	–	12.1	8.4	2.6	0.7	0.1
Heat networks	–	1.2	1.9	2.0	2.3	2.3
Electric heat pumps	–	0.2	0.6	1.3	1.6	0.5
Other	–	0.0	0.0	0.0	0.0	0.0
Total	91.2	87.4	81.4	53.3	30.3	18.0
Reduction versus 1990		4.2%	10.8%	41.6%	66.8%	80.3%

Table 3: Scenario 2 – Mix of heating appliances, number of dwellings (Figure 4.4)

	2015	2020	2030	2040	2050
Gas boiler	21,350,000	20,450,000	14,680,000	5,490,000	790,000
Gas heat pump	–	50,000	1,380,000	4,080,000	5,290,000
Hybrid HP gas boiler	–	90,000	1,760,000	3,410,000	3,660,000
Heat networks	500,000	1,740,000	4,230,000	6,750,000	9,390,000
Oil boiler	2,600,000	2,490,000	1,270,000	450,000	160,000
Direct electric	2,710,000	2,660,000	1,940,000	790,000	280,000
Electric heat pumps	90,000	470,000	3,570,000	9,130,000	11,900,000
Other	50,000	90,000	740,000	620,000	660,000
Total	27,310,000	28,030,000	29,570,000	30,720,000	32,130,000

Table 4: Scenario 2 – Annual emissions from domestic heating excluding cooking, $MtCO_2$ (Figure 4.5)

	1990	2015	2020	2030	2040	2050
Gas boiler	–	63.5	59.1	32.2	8.7	0.9
Gas heat pump	–	0.0	0.1	1.8	3.8	3.0
Hybrid HP gas boiler	–	0.0	0.1	2.0	2.2	1.3
Oil boiler	–	10.6	9.8	4.6	1.6	0.5
Direct electric	–	12.1	8.4	2.3	0.5	0.1
Heat networks	–	1.0	2.7	2.3	2.1	1.4
Electric heat pumps	–	0.2	0.6	1.7	2.3	0.9
Other	–	0.0	0.0	0.0	0.0	0.0
Total	91.2	87.4	80.9	47.0	21.2	8.1
Reduction versus 1990		4.2%	11.3%	48.4%	76.7%	91.2%

Appendix 2: Delta-ee Pathways Model

The Delta-ee Pathways® Model

This Delta-ee Pathways Model was developed for the UK and other European markets. It segments the housing stock into ~50 segments, and models the performance of different heating appliances in each housing segment. It analyses this competition between technologies in each housing segment, taking into account 'soft' factors as well as economic factors, to determine likely uptake of different heating technologies.

Further information can be obtained from:
http://www.delta-ee.com/research/pathways-service.html