NEA
Action for Warm Homes

Heat Decarbonisation

Potential impacts on social equity and fuel poverty

Final Report

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National Energy Action (NEA) is the national fuel poverty charity working across England, Wales and Northern Ireland, and with sister charity EAS in Scotland, to ensure that everyone can afford to live in a warm, dry home. In partnership with central and local government, fuel utilities, housing providers, consumer groups and voluntary organisations, we undertake a range of activities to address the causes and treat the symptoms of fuel poverty. Our work encompasses all aspects of fuel poverty, but in particular emphasises the importance of greater investment in domestic energy efficiency.

Foreword

NEA commissioned this report to help stimulate debate on the policy options we must consider as we seek to decarbonise heat alongside delivering fuel poverty strategies across the UK. It helpfully draws out some of the tensions and challenges we face in changing the way in which we heat our homes, and the authors help us to consider the cost implications and distributional impacts of different funding mechanisms.

Already 4 million households struggle to heat their homes at an affordable cost, and we know that making their homes more energy efficient to reduce demand for heat is the most cost effective and sustainable policy. I hope that you find this report a helpful start to the very necessary wider public debates we need to have to ensure we meet our fuel poverty and carbon budget targets though affordable lower carbon heating.

I commend this report to you.

Jenny Saunders OBE DCL
Chief Executive
NEA

Contents

1. Executive summary

1.1 Background

Heat decarbonisation will become an increasingly important area for energy policy to address in the coming years. Since over 90% of today's homes will still be in use in 2050, alongside the development of sensible measures and standards for new buildings, a major retrofit programme will be required. Such a programme could mean decarbonising an average of 20,000 properties each and every week for 20 to 25 years.

Reduced carbon emissions can be achieved through a combination of lowering demand and decarbonising the residual supply. There are a number of potential approaches, all of which could involve significant investment. Due to the variation in geography, housing types and occupancy patterns, as well as the characteristics of the different heat provision options, no single solution can suffice on its own.

All proposed options for heat decarbonisation are likely to be more expensive than the baseline of natural gas. The costs vary considerably for each approach (both in terms of up-front capital and ongoing running charges). Furthermore, there are potentially very different financing and funding models for each solution. Taken together, and unless mitigating measures are introduced, these factors have the potential to aggravate social inequality and increase levels of fuel poverty, so understanding the linkages between the relevant policy areas is of vital importance.

This paper explores the options for delivery of heat decarbonisation by 2050 and how investment could be funded and financed, as well as whether some, or all of the costs could/should be socialised across energy bills and/or taxation. This paper does not attempt to cover all potential variations only to show the order of magnitude of the impacts and what can drive the comparative differences between solutions. Because of the significant difference in costs between households depending on their geography, building type etc., the results should not be used to try to identify "winning" technologies for universal application.

1.2 Scale of the challenge

Heat accounts for over 40% of energy consumption and nearly a quarter of all carbon emissions. Even though end-use heat service requirements may remain at current levels, most future scenarios show a potential for efficiency savings of between 20% and 30% in the demand for space heating by 2050. In contrast, hot water needs are less likely to reduce significantly without major changes to users' approach to cooking, cleaning and bathing.

1.3 Energy efficiency

There are a variety of reasons for investing in energy efficiency which in some circumstances mutually reinforce each other, but in others mean that any investment decision needs to be made in its own right, and on its own merits.

The main drivers for efficiency investment are:

- **fuel poverty –** reduced ongoing running costs and improved comfort levels provide strong justification for investment in energy efficiency measures. Where the up-front capital costs of this can be financed on behalf of the fuel poor, the end result can be justified on the basis of the social policy driver
- **carbon reduction –** if efficiency measures lead to a reduction in demand, this can feed through directly into reduced carbon emissions. At an appropriate cost of carbon this can be justified, although there is a point at which investment in decarbonising supply may become economically more attractive
- **bill savings –** there is a clear level of investment in energy efficiency that can be economically justified for the afford-to-pay sector by a reduction in energy demand and fuel bills.

The paper demonstrates how energy efficiency investment can be cost-effective for a householder, but also that there can be limits to the returns on such investments, especially for the decarbonised heat technology options with higher up-front capital and lower ongoing fuel requirements. This is trelevant for economic and carbon abatement assessment, but does not mean that such investment is not still an effective tool to reduce ongoing fuel costs for those on low incomes, so can nonetheless make sense based on achieving fuel poverty targets and improving the comfort levels in people's homes.

Being clear about the policy objective(s) is important in thinking about the support that may be needed for heat – whether it is transitional or enduring, or whether what is needed is funding or financing. Given that affordability of heat lies at the heart of fuel poverty, with the consequential implications for health and well-being, there is a real imperative to join up thinking on heat and fuel poverty strategies.

1.4 Decarbonising heat supply

There are likely to be at least three main routes to decarbonising heat:

- repurposing the gas grids with low carbon gas, e.g. hydrogen
- electrification with some combination of direct electric heating, storage heaters and heat pumps
- district heating schemes with centralised, low-carbon heat generation.

The paper explores the different challenges and costs associated with each and looks at the different transition paths that may be needed and consequences that could arise. In practice, any solution is likely to involve a mix of some, or all of these. Other technologies such as biomass or solar thermal may play a limited role but are not covered in this report.

All low carbon heat solutions require changes to customers' heating systems in their home and may impact on comfort factors or the responsiveness of the system. This means that end consumer engagement and incentivisation is a much more important consideration than it is in the electricity sector where most changes are made centrally and do not impact directly on consumers.

It is unclear from the current policy debate how far customers will have a choice of different solutions. This will inevitably vary to some extent with the preferred solution. While (as now) customers might still have the option open to them of an electric solution, it is unlikely to be efficient to have competing networks in all areas. This prospect has also led to the idea of zoning where a lead technology might be chosen for each area.

At present, households and businesses are incentivised to change to a low-carbon (renewable) heating system (e.g. through the Renewable Heat Incentive). This means that the process is voluntary and adopted by those who can afford it and for whom the benefits, whether financial or non-financial, outweigh the costs.

The domestic RHI scheme has achieved an installation rate of ca. **10,000 a year**. Looking at the need to achieve the radically higher conversion rate of **20,000 buildings a week** over a 20 - 25-year programme, and to deal with the major infrastructure challenges surrounding the necessary networks, building and appliance investments, it is clear why some suggest a form of regulated or mandated programme of conversion will be required at some point. The extent to which government could mandate a particular solution is a difficult issue, but clearly there are precedents with regulation being successfully used to introduce smokeless fuels and drive the changeover from town gas to natural gas, as well as to specify condensing boilers and energy efficiency standards.

1.5 Potential costs and impacts

Depending on the chosen or available route, the average costs per household could rise by between £200 and £800 per annum, which could accumulate to a difference in cost between £4,000 and £16,000 for the first and last households to convert over a 20-year period, if all costs were recovered through bills rather than taxes. Whatever the roll-out method chosen, the distributional impact of the timing must be addressed.

For district heating the costs are dominated by the need to build new networks, for heat pumps it is primarily the up-front household costs, whereas for hydrogen and storage heating it is the fuel costs, plus some for conversion of appliances. In the modelled examples, the up-front household capital required ranges from £0 to £15,000. This then results in a wide variation in the annual fuel costs ranging from a reduction of £200 to an increase of over £650. Overall, if the network and up-front costs are spread over 20 years, the additional annual costs per household would represent an overall increase of 16% to 65% compared to an efficient natural gas boiler.

To put this into perspective, these cost ranges are actually comparable with the premium that households may currently be paying if they are required to use direct electric heating. A home consuming 10MWh p.a. could currently be paying over £720 p.a. and one consuming 20MWh p.a. could be paying over £1,500 p.a. more than a similar household with natural gas.

These differing cost structures have implications for funding and financing requirements. Financing needs of up to £15,000 could have particularly strong adverse distributional impacts since the availability and cost of any up-front finance can mean lower income households either cannot access the measures or have to pay more for them. Similarly, high ongoing costs can have particularly adverse impacts on fuel poverty.

While cost is important, securing customer acceptance for alternative heat forms requires a deep understanding of the consumer experience of heat and what aspects different customers value (instant control, adequate temperature, reliability and cost) as well as wider considerations around the hassle of conversion, space constraints etc.

1.6 Distributional consequences of current schemes

Looking across the range of regulatory and government schemes in place currently, the paper draws a number of lessons for scheme design that are relevant now but also looking out to 2050. The fairness of a particular approach will depend on a number of factors. For example, there is a need to look at access to the schemes as well as at who pays and who benefits from them.

In current approaches to low-carbon schemes, the benefits have generally flowed to those who are better off. For both the RHI and FiT this reflects the fact that higher income households are more able to afford the up-front costs, and also that their property types and tenure make them more suitable for such initiatives. This is seen as being particularly unfair since it largely benefits those who are better off but is being paid for by consumers at large.

The paper quantifies another consequence of the FiT scheme, in terms of the contribution made to network and policy costs. Specifically, a household that does not receive a FiT now pays £55 p.a. to £90 p.a. more towards these common costs than one which is able to reduce its measured energy consumption from the grid through using its own generation (funded through FiT).

This illustrates an inherent distributional risk in the use of energy levies to achieve social and environmental policy objectives.

1.7 Type of support

The transition to a de-carbonised heat system will require significant investment and is likely to need some substantial element of funding, both to help kick start the market and to address externalities. Targeted help is also likely to be needed for those unable to afford the up-front costs.

International experience has concluded that up front capital support appears more cost effective than ongoing payments in such scenarios. Nevertheless, in the UK, for the design of schemes like the FiT and RHI, there has been a presumption against offering grants in favour of ongoing payments. This decision (driven at least in part by EU State Aid rules) can make the schemes inherently less attractive to those on low incomes. For future schemes, government should revisit its approach.

The consensus view from fuel poverty groups (and others) is that the fairest way to recover the costs of social and environmental schemes is through a means tested route, like taxation, even though there can be other risks associated with tax-funded schemes as they are more subject to the vagaries of political cycles and short term budgeting processes. This is not a reason to favour levies on bills but means that other ways need to be found to give investors longer term confidence in policy.

1.8 Mitigating the impacts on fuel poverty

With the high costs of decarbonisation thought needs to be given to options for mitigating the impacts on fuel poverty. Possible examples are:

- if schemes are funded through bills then thought should be given to the design of the levy, for example to encourage protected block tariffs

- if a carbon price were introduced, the monies raised could be used to mitigate the adverse impacts on fuel poverty from higher fuel and heating costs

- there could be a case for better targeting of the Winter Fuel Payment (currently available above an age threshold regardless of means).

1.9 Other distributional factors

Issues around regional and carbon pricing need to play into long term thinking about how any solution would be implemented:

- if choices are to be constrained in particular geographic areas (reflecting the benefits to the system of high density take-up) then it is important that customers 'forced' onto a particular solution are not disadvantaged compared to others

- if customers are allowed a free choice, then it is important that these choices are not distorted by the costs of subsidies being loaded onto customers of one technology but not another, without a clear rationale.

It is important for the overall acceptability of the decarbonisation programme that the arrangements are seen to be fair.

1.10 Potential impacts on fuel poverty

Quantifying impacts of such complex and long-term changes on fuel poverty is difficult. However, as an indication, the additional total costs from heat decarbonisation, if recovered evenly across 20 years through levies on energy bills, could create an extra 0.6 million to 2.6 million fuel poor households in GB (on the 10% measure).

These are extreme calculations where all costs have been recovered through energy bills, but shows the importance of considering alternative means to fund and finance any investments to avoid such adverse impacts.

With 2.4 million households in fuel poverty in England today, there is already a clear need for action under any decarbonisation scenario given the health and well-being implications of people living in cold homes. Currently customers off the gas grid face the deepest fuel poverty. Given that there are also fewer options for decarbonisation off the gas grid there is a strong case (on a least regrets basis) for moving ahead with decarbonisation of these homes early on, especially where it makes a contribution to alleviating fuel poverty and ensuring a healthy and warm living environment.

2. Background and Introduction

2.1 The challenge of heat decarbonisation

A number of recent reports[1] have concluded that decarbonising heat at scale would need to be well underway by the 2030s and continue beyond 2050 in order to meet the legally binding carbon reduction targets set in the Climate Change Act, let alone to deliver on commitments made in the Paris Agreement to keep global temperature increases well below two degrees Celsius.

Although this may seem a long way off, planning and preparation for decarbonising heat need to be started now in order to pave the way towards reducing carbon emissions for this important sector, in a manner that is equitable, cost-effective and ensures acceptable levels of disruption. This is particularly important in the case of space heating and hot water in domestic and commercial premises, which together are responsible for between a fifth and a quarter of total carbon emissions across all sectors and about two thirds in the heat sector.

Since over 90% of today's homes will still be in use in 2050, alongside the application of sensible measures and standards for new buildings, a major retrofit programme will be required if the carbon performance of about 25 million existing homes is to be improved. Even if spread over a 25-year period, such a programme still means converting an average of 20,000 properties each and every week throughout.

Due to the variation in geography, housing types and occupancy patterns, as well as the characteristics of different heat provision options, no single solution can suffice on its own, so a variety of options will be needed to deal with this diverse range of application environments.

Reduced carbon emissions can be achieved through a combination of lowering demand and decarbonising the residual supply and all of these options could involve significant investment - e.g. in buildings, heat networks or in reinforcement of the electricity grid – as well as in replacement of appliances and heating systems in the home.

2.2 Potential impacts of heat decarbonisation

Much of the debate currently is focussed around the different technology options as well as their overall cost and carbon implications. However, there has been little attention paid to how the infrastructure investment might be financed and funded, or about the implications for social equity and fuel poverty. It has been reported[2] that even before starting, the impact of fuel poverty is so acute that premature mortality related to cold homes is a bigger killer than smoking, lack of exercise or alcohol abuse. The same paper reports that cold homes are estimated to burden the NHS with costs of £1.4 billion per annum, therefore understanding the linkages between the relevant policy areas is of vital importance.

As well as national and international carbon reduction commitments, there is also a legally binding target for the eradication of fuel poverty in England. The Scottish, Welsh and Northern Ireland governments also now have their own approaches to, and targets for the elimination of fuel poverty so, there is a clear focus on the issues across the UK nations even though, since 2011, there is no longer a common approach to the way fuel poverty is measured.

The latest UK Government statistics on fuel poverty levels in England are based on the Low Income High Cost definition. This states that an individual is considered fuel poor where they have required fuel costs that are above average and, if they were to spend that amount, would be left with a residual income below the poverty line. The UK Government estimates that under this measure fuel poverty affects 2.4 million households (over 9 million people) – 10.6% of the total – in England alone.

The levels in other parts of the UK continue to be measured on the basis of the "10% definition", whereby a household is deemed fuel poor if it needs to spend 10% or more of its income on energy bills.

All proposed options for heat decarbonisation are likely to be more expensive than the baseline of natural gas. The costs also vary considerably for each approach (both in terms of up-front capital and ongoing running charges). Furthermore, there are potentially very different financing and funding models for each solution. Taken together, and unless mitigating measures are introduced, these factors have the potential to aggravate social inequality and increase levels of fuel poverty.

On the other hand, highlighting the potential to create positive synergy, the Committee on Climate Change (which has a duty to consider the impacts on fuel poverty in presenting its proposed carbon budgets) has recently concluded that *"If the insulation and low-carbon heat installations required to meet the carbon budgets can be successfully targeted at the fuel poor then around three-quarters can be lifted out of fuel poverty by 2030. However, meeting the Government's goal of improving fuel poor homes to efficiency band C by 2030 would require roughly doubling the funding currently provided under the Energy Company Obligation"*[3].

3. Analysis and research approach

This paper explores the options for delivery of heat decarbonisation by 2050 and how investment could be financed, as well as whether some, or all of the costs could/should be socialised across energy bills and/or taxation. It seeks to answer the following key questions:

What are the extra costs and how should they be paid for – tax and/or levies - and what are the distributional effects and how do these impact on social equity and fuel poverty?

What differences in costs for consumers could arise due to:

- different timescales for roll-out, which could span over 20 - 25 years
- different costs for each solution, housing type and/or location
- different cash-flow requirements (network investment might be paid for up-front by a regulated operator and reclaimed over time in use of system charges; increased running costs may come from a more expensive fuel, e.g. hydrogen; the main costs may lie in consumer appliances and heating systems requiring significant up-front capital outlay from individuals, e.g. heat pumps)
- the interactions with energy efficiency investment.

To do this, the paper:

- summarises the main options/technology solutions that might form a part of the government's heat strategy;
- sets out the range of funding models that are currently used by Ofgem and BEIS where costs need to be socialised, as well as what their strengths and weaknesses are;
- reflects on the unique characteristics of heat and any additional issues/opportunities that they present (e.g. how far individual consumers can still have a choice, the likely role for cities/local authorities/communities).

To illustrate the order of magnitude and significance of the issues, some semi-quantitative analysis has been carried out to:

- estimate the potential range of monetary impacts compared to the status quo
- estimate cost differentials that could arise across time and choice of solution
- identify and explore potential solutions to deal with extra costs and differentials
- estimate and discuss potential impacts on fuel poverty.

In terms of scope, the paper is focussed on UK policy options and looks at the implications for fuel poverty in England, with examples illustrated for Scotland, Wales and Northern Ireland, where appropriate.

The paper is structured as follows:

- Chapter 4 outlines the current situation with regard to heat demand and energy efficiency. · Chapter 5 summarises the options for decarbonisation. · Chapter 6 examines the potential costs and the impacts of funding and financing.
- Chapter 7 summarises the current approach to environmental and social schemes.
- Chapter 8 examines the distributional impacts and fuel poverty implications
- Chapter 9 summarises the conclusions.
- Chapter 10 draws out recommendations/principles for policy-makers to follow, and identifies where further work could be needed.

4. Heat energy demand and efficiency

4.1 Energy for heat

Demand for domestic and commercial space heating and hot water requirements averages out at about 550 TWh p.a. depending on temperature effects - this is about 170% of the total electricity sector.

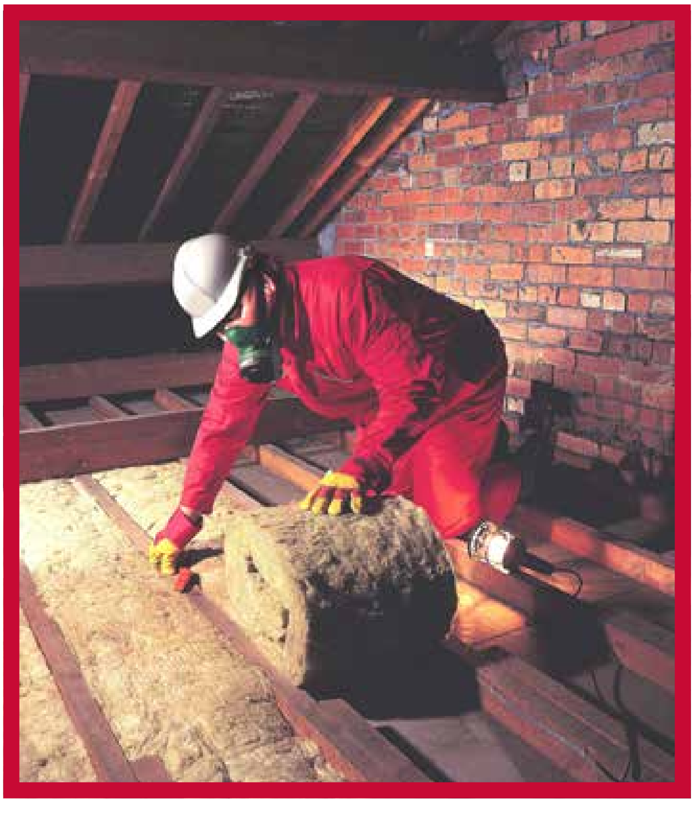
Currently, at least 80% of homes use natural gas for heat. The rest mainly use electricity, oil or biomass. This diversity already leads to significant cost differentials, with electricity being potentially three times as expensive as natural gas for each unit of heat produced (in the absence of heat pump technology or off-peak tariffs). These cost differentials are one reason that fuel poverty is higher in off-gas regions of the country. As a result, fuel poverty reduction programmes often not only seek to make homes more energy efficient but, where possible, to achieve a connection to the gas network.

4.2 The role of demand reduction

Reducing carbon emissions from the heat sector will depend on lower demand levels through improved efficiency of use, as well as on the decarbonisation of heat supply. Most future scenarios show a potential for between 20% and 30% reduction in average space heating demand by 2050. In contrast, hot water needs are less likely to reduce significantly without major changes to users' approach to cooking, cleaning and bathing.

In smaller, well insulated properties, hot water needs could start to dominate the overall demand levels and usage patterns, especially if the trend for instantaneous hot water production, and removal of storage tanks continues. Although an old detached 4-bedroom house might use over 20MWh for space heating and 3MWh (13%) for hot water, a modern 2-bedroomed terraced house might use 3.5MWh for space heating and 2.5MWh (42%) for hot water[4]. In a modern 1-bedroomed flat, hot water can represent more than half of overall heat consumption.

Reductions in heat demand have already been achieved through a combination of improved boiler performance and energy efficiency measures, like insulation and heating controls. For future decarbonisation, efficiency measures, especially improvements to buildings, will be a crucial element in determining not only the residual space heating requirement, but also which heating technologies may be technically feasible. For example, heat pumps cannot operate effectively in draughty buildings with high heat loss.



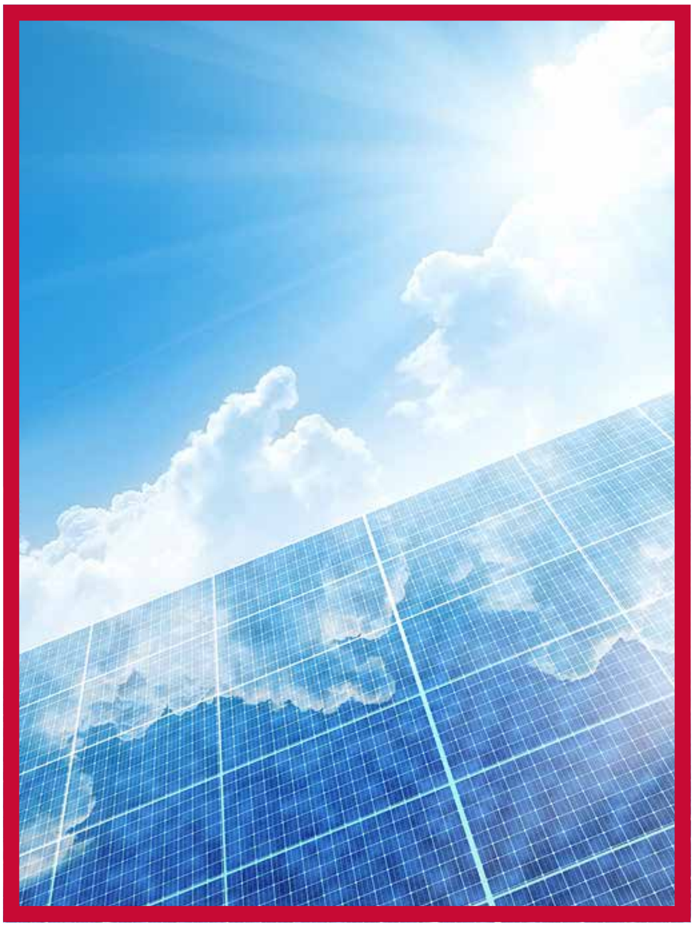
4.3 Differing drivers for energy efficiency investment

There are a variety of reasons for investing in energy efficiency which in some circumstances mutually reinforce each other, but in others mean that any investment decision needs to be made in its own right and on its own merits.

There are many publications and other sources[5] which cover the options and policy for energy efficiency and related demand reduction. This paper does not attempt to recreate the depth of detail provided by them, but looks later in more depth at the impacts and interactions of the following drivers:

4.3.1 Fuel poverty

Where the up-front investment costs do not have to be borne by the fuel poor themselves, any reduction of ongoing fuel usage is a benefit, even when the overall economics may appear unattractive in the absence of this social driver. Nevertheless, this can be a very cost-effective way of tackling fuel poverty, and investments should be implemented on their own merits as part of a continued focus on meeting the 2030 fuel poverty targets. The reasoning becomes even stronger if this can also contribute as a cost-effective step towards heat decarbonisation.



4.3.2 Carbon emissions reduction

Improving energy efficiency can reduce energy demand and thereby have a direct impact on reducing carbon emissions. However, based on the overall cost of carbon, there is an economic balance to be struck between the cost effectiveness of demand reduction and decarbonisation of supply.

4.3.3 Economic benefit

Investing in energy efficiency to reduce consumption levels can save money in its own right. Nevertheless, there are a number of considerations that must be taken into account (more detail in section 6.5):

- there is likely to be an upper limit on the cost effectiveness of the investment and on the pay-back period needed
- there may be a cross-over point where the economics of different heating approaches may be changed by reducing the space heating requirement below a critical level, e.g. the extra capital costs of heat pumps or district heating may not be justified for very efficient new build or retrofitted homes with low space heating requirements
- the approach to energy efficiency investment will vary depending on the relative capital and running costs of different heating solutions, e.g. it is very attractive for approaches with very high running costs, but less economically justifiable to reduce consumption levels for heating technologies that are expensive to install and cheap to run.

4.4 Combined contributions to decarbonisation

So far, the main role of district heating in decarbonisation has been to reduce consumption by improving the efficiency of heat production – it is not fundamentally low or zero carbon if, as is currently the case with most schemes in the UK and Europe, it is fossil-fuel fired. However, with a suitable low carbon source of heat, district heating can contribute to both demand- and supply-side carbon reductions.

This is also true for heat pumps which can reduce demand through the improved efficiency of heat generation, but are only zero or low carbon if the electricity used is sufficiently decarbonised. It is therefore important to study both the demand and supply side options for decarbonisation in order to achieve the best balance and synergies.

5. Options for heat decarbonisation

5.1 Scope

The focus of this section is on the main options for decarbonising the supply of heat in line with potential pathways to full decarbonisation of the sector by 2050. Some approaches have not been considered further in this paper because of their limited potential in the UK and include:

5.1.1 Biomass and biogas

These have so far been the mainstays of renewable heat in the UK and will continue to play an important role in future, including with the potential for synthetic biogas to be created from waste. However, due to competition from other sectors for the limited resource and overall concerns about the sustainability and/or the availability of them as fuel sources at sufficiently large scale, there are limits on the role they can play and hence they have not been considered further here.

5.1.2 Solar thermal

This technology remains relatively expensive and has limited applicability to space heating solutions due to the poor seasonal and daily correlation between solar output and peak demand, so is also not considered further in this paper. However, it could still have an important role in the provision of hot water which as noted later is an area that merits further work.

5.2 Main potential delivery routes

There is a consensus in all the recent reports that the energy for space heating and hot water in 2050 will predominantly be transported and delivered to individual homes and offices by one of three networks:

- gas pipes
- electricity cables
- hot water (or potentially steam) pipes.

Energy will be converted into heat and distributed within the building through appropriate appliances and systems. These three main delivery channels have been explored in detail in the paper by Imperial College[6] and are summarised as follows:

5.2.1 Repurposing the gas grids with hydrogen

As a consequence of the investment in the gas Iron Mains Replacement Programme (IMRP) by the Gas Distribution Networks (GDNs), the repurposing of the local low pressure gas distribution grids for use with hydrogen has become feasible, and could be an attractive option to avoid or reduce disruption from street works or in customer premises, especially for properties in urban and suburban environments, which comprise about 80% of households (in the Imperial College report, this equates to all those on the gas grid).

Hydrogen has the advantage that it can be stored in similar facilities to those used for natural gas – salt caverns, disused gas fields and aquifers, albeit needing about three times the volume (or three times the pressure) due to its lower energy volume density.

Appliances in the home would have to be suitable for use with hydrogen which may mean that existing ones need to be replaced or adapted, as was the case with the conversion from town gas to natural gas in the 1960s and 1970s and, more recently, on the Isle of Man.

It is likely that all sealed-unit boilers will have to be replaced – on-site dismantling of sealed units, combined with making the necessary physical and electronic modifications, then resealing and testing is likely to be very time consuming and may create safety issues that do not arise if a completely new or off-site converted one is installed. Open-flame appliances, such as cookers and fires, may be suitable for on-site burner replacement as long as issues with flame visibility and odorisation can be successfully overcome.

However, the most important precondition for using hydrogen would be the development of large scale, low cost production facilities. This could be by electrolysis of water, although this is currently very expensive (at least four times the wholesale cost of natural gas) and not yet suited to large scale production, or through conversion of natural gas by steam methane reformation (SMR).

This second route is currently less expensive than electrolysis, but still more costly than natural gas (about twice the cost of wholesale natural gas). SMR produces carbon dioxide as a by-product and its use would therefore be very dependent on the availability of Carbon Capture and Storage (CCS), which is not yet commercially or technically proven in the UK, although examples are appearing in other countries[7].

For retrofit, the additional costs of this solution (financing implications[8] shown in brackets) would be:

- residual work on adapting the gas distribution system (up-front capital from the GDNs)
- conversion or replacement of household appliances[9] (up-front capital from either the GDNs or the householder[10])
- higher commodity costs from production and transmission (ongoing cost to the householder).

5.2.2 Electrification

Decarbonising the electricity sector is well under way and a low carbon electricity system could potentially provide considerable future optionality for decarbonising the heat sector once sufficient extra low carbon generating capacity is in place.

However, electricity is more difficult and expensive to store and transport than gas, so consideration must be given at the design stage to storage, demand side management and back-up solutions that will provide low cost, low carbon capacity, capable of dealing with the seasonal variation in space heating requirements, especially as the low carbon electricity system becomes dominated by increasingly inflexible and intermittent technologies.

Electrification with heat pumps

Electrification, using high-efficiency heat pumps, can be a suitable option for new build and in retrofit, particularly for less densely populated environments, and where disruption from electricity system upgrades can be minimised.

However, in-home disruption and up-front cost to the householder could be a significant barrier to their adoption, although this can be kept down by focussing on applications where no major energy efficiency improvements or radiator replacements are required to cope with the lower operating temperatures of a heat pump system.

The electrical effects of installing heat pumps may be particularly significant in the local, low voltage distribution networks and their feeder circuits, since the ability to smooth out their impacts are much more limited than in the higher voltage distribution and transmission systems. Even to accommodate modest penetrations of heat pumps, the Distribution Network Owners (DNOs) could need to upgrade local low voltage and 11kV networks as well as the associated substations. This may well be triggered very early to avoid short term fluctuations in service quality, like flickering, rather than just for reasons of network capacity.

For retrofit, the additional costs of this solution (financing implications shown in brackets) would be:

- upgrading the lower voltage electricity distribution networks (up-front capital from the DNO or the building owner, depending on shallow/deep charges[11] or 3-phase supplies etc.)
- replacement of household appliances and potentially the wet-radiator system (up-front capital from the householder)
- any energy efficiency investment to allow the technology to function (up-front capital from the householder)
- higher unit fuel charge for electricity compared to natural gas (ongoing cost for the householder)
- higher charges when heat needs are greatest due to the introduction of time of use tariffs (ongoing cost for the householder).

Some, or all this extra fuel cost can be offset by lower consumption levels due to the efficiency gains of a heat pump, whereby one unit of electrical energy extracts between one and a half and four times the heat energy from the air, the ground or a suitable water source. Although this reduces the amount of fuel needed, the capital costs must still be recovered, either through a higher fuel price or a fixed charge.

Direct electric heating

There is a point at which the higher capital costs of a heat pump may not justify the lower consumption levels, and where space heating and hot water could be more affordably supplied by direct electric heating, despite the high unit fuel charges. This is likely to be the case for well-insulated properties, particularly flats in high rise buildings, where gas-fired boilers are not available and the space heating requirements are low.

Where this set-up does not already exist and where conversion or retrofit is required, the additional costs of this solution (financing implications shown in brackets) would be:

- upgrading the lower voltage electricity distribution networks (up-front capital from the DNO)
- purchase of simple resistive electric heaters (up-front capital from the householder)
- higher unit fuel charge for electricity compared to natural gas (ongoing cost for the householder)
- higher charges when heat needs are greatest due to the introduction of time of use tariffs (ongoing cost for the householder).

Electric storage heating

There are about 1.7 million households using storage heating to make use of electricity when it is cheapest[12]. The overall running costs using off-peak tariffs are about two thirds of the standard electricity charge (although still double that of gas). The lower running costs must be balanced against the higher capital costs of the storage heaters compared to simple resistive heating systems. The more modern storage heater designs offer much better efficacy, comfort and running costs, but are more expensive to purchase, although still less than heat pumps.

Recognising the increased value that is expected to be attached to flexibility in the electricity system in future there may also be an opportunity to use control over storage heaters to provide ancillary services to the grid, providing an additional revenue stream to help offset costs. Future tariff changes may improve the possible savings from storage heating, but these factors have not been modelled for this paper.

5.2.3 District heating

District heating can supply heat very efficiently and at a low running cost. Although there is currently only restricted choice for low carbon heat generation, having a central production point means that changing the source in the future could be much simpler and more cost effective than changing multiple individual household solutions.

District heating is well suited to areas of mixed use with strong anchor clients, such as municipal buildings, offices and leisure centres. Although most readily installed as part of new developments, district heating can also be suitable for retrofit in less populated areas as part of community energy schemes, as well as for flats in multi-storey buildings. The main challenge is to achieve sufficient customer density so that the high up-front capital costs can be recovered over sufficient users and offset by sufficient fuel savings to keep bills affordable.

The seasonal fluctuations in space heating requirements can be lower in mixed use district heating schemes, and heat storage can be incorporated which is considerably less expensive than electricity storage (one hundredth of the cost), although still considerably more than fuel storage (one hundred times[13]). As in the electricity system, consideration should be given at the design stage to storage, demand side management and back-up solutions.

For retrofit, the additional costs of this solution (financing implications shown in brackets) would be:

- energy centre investment (up-front capital from the developer)
- hot water network investment (up-front capital from the developer)
- conversion/replacement of household appliances (up-front capital from the developer/householder)

Overall heating costs for the householder may be lower in an ideal scheme. This would require a high connection density and the ability to spread the network costs over a long period of time to keep the capital charges low. Due to the efficiencies of district heating, the ongoing energy costs are likely to be lower than for a stand-alone natural gas boiler. However, there is currently no compulsion for households or businesses to connect, so no guarantee that a critical density level is reached and that overall costs will be lower, especially when more expensive, low carbon heat sources rather than natural gas are required.

As with heat pumps, there may be a level of energy efficiency in buildings above which space heating requirements could become too low to justify the capital investment in district heating, despite the ongoing energy savings possible.

District heating networks and service provision are relatively unregulated in comparison to gas and electricity. While there is a voluntary Heat Trust Scheme which provides some consumer protection it cannot cover price and, unlike in gas and electricity, customers will not have a choice of supplier.

Citizens Advice and others have called for additional protection for customers on district heating[14]and there is a wider debate on the potential for regulation to facilitate the development of these networks, as proposed by the Scottish Government. District heating could not only benefit from the introduction of regulation to give consumers better service protection and prevent monopolies exploiting their position. but also from providing operators and developers with statutory powers to aid land purchase and access to wayleaves, as well to lower the cost of capital by treating appropriate networks as regulated assets.

6. Potential cost and funding impacts

The relatively low cost of natural gas has helped to alleviate fuel poverty and to allow many households to keep affordably warm. There is understandably major concern about any moves that might increase heating costs, whether this be for infrastructure investment, policy support or even VAT (currently at the reduced rate of 5%).

All of the proposed heat decarbonisation options are potentially more expensive than the baseline of natural gas. The costs also vary considerably for each approach (both in terms of up-front capital and ongoing running charges) and there are very different financing and funding models for each.

The actual resultant cost and impact on a household will depend on many factors including the amount of energy used, the cost of finance and the number of years over which capital costs are recovered as well as operational factors like distribution losses. In the following sections, some illustrative examples are shown to demonstrate the potential range of impacts that could arise during and after the transition to decarbonised heat solutions. This paper does not attempt to cover all potential variations only to show the order of magnitude of the impacts and what can drive the comparative differences between solutions.

6.1 Roll-out principles

At present, some households and businesses are incentivised to change to a low-carbon (renewable) heating system, primarily through the Renewable Heat Incentive (RHI) mechanism, discussed further in chapter 7. This means that the process is voluntary and adopted by those who can afford it and for whom the benefits, whether financial or non-financial, outweigh the costs. However, the take up rates have been limited and the RHI is capped at a level, which will not even allow the 2020 renewable energy sub-target to be met[15].

The domestic RHI scheme has achieved an installation rate of ca. **10,000 appliances a year**. In order to achieve the radically higher conversion rate of **20,000 buildings a week** over a 20 - 25-year programme, and to deal with the major infrastructure challenges surrounding the necessary networks, building and appliance investments, it is likely that some form of regulated or mandated programme of conversion will be required, dependent on the technology options, as was the case in the national switch-over from town gas to natural gas. Moving away from an entirely voluntary approach creates new issues which are illustrated below and discussed further in section 7.5.

6.2 Who is converted first and last?

The recent ENA/KPMG report[16] made high level estimates for the range of investment which could arise to decarbonise heat supply through a retrofit programme of existing buildings. The costs totalled between £100bn and £320bn, depending on the chosen scenario[17]. These costs are what is needed over and above the status quo for operating and maintaining the current approach to space heating and hot water provision, which is dominated by natural gas.

Calculating the potential impact on space heating and hot water for an individual converted building, the average costs per household could rise by between £250 and £800 per annum, assuming zero interest and discount rates, and that the costs are simply spread evenly over all households and a 20-year period. If these numbers are representative of the potential range, the total difference in up-front capital and/or ongoing fuel costs paid by the first customer to be converted and the last, 20 years later, could accumulate to between £5,000 and £16,000, if all costs were recovered through bills rather than taxes.

If the approach taken were more voluntary, then some other redistributive effects would need to be considered, e.g. those converting early could benefit from higher subsidies and those converting last left to carry a much higher share of stranded asset costs in later years.

This illustrates the significant potential for inequitable distribution of costs based on conversion **timing**. Some of the effects could be mitigated if the costs were covered by tax (as is the case with the current RHI), or if they were socialised in some other equitable manner. As discussed later, unless grants were provided, this would not alter the adverse distributional impacts arising from access to, and cost of capital for any up-front investment needs. Whatever the roll-out method chosen, the distributional impact of the timing must be addressed.

6.3 Which technology is chosen or available?

Taking a more technology specific approach (based roughly on the costs and technology approaches from the Imperial College paper), the graph below shows the average **additional** cost per household[18] for each option compared to existing costs for an efficient condensing boiler using natural gas. The graph shows how these **additional** costs vary for different consumption levels.

Comparisons are made for the following space heating and hot water consumption levels:

- 5MWh per annum – equivalent to a modern one- or two-bed flat
- 10 MWh per annum – equivalent to an old two-bed terrace or modern three-bed semi-detached
- 15 MWh per annum – equivalent to an oldthree-bed semi-detached or large modern detached
- 20 MWh per annum – equivalent to an old four bed detached.

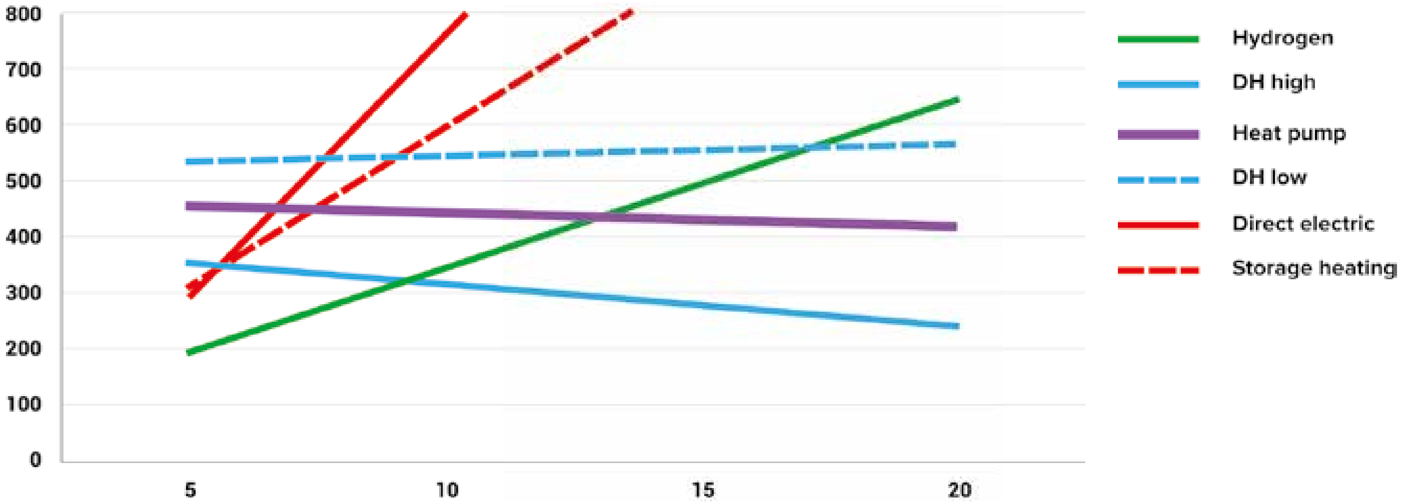
For simplicity and to aid comparison, this assumes that for each solution, including the natural gas baseline, a new heat source is installed. In practice, the gas boiler to be replaced will have some remaining value which would be stranded unless it can be recycled or repurposed.

The calculations also assume that all hot water requirements can be provided by the respective solution[19] and do not consider any change in consumption or costs associated with cooking requirements. If new electric cookers were required and electricity used to run them, then the additional costs could be higher still, even if the equivalent reduction were made to the heat consumption levels.

The calculations spread any upfront costs over 20 years, make an allowance for maintenance but do not incorporate any cost of capital. For electricity and the gas comparator, fuel prices are assumed to remain at current levels.

Clearly all of these assumptions are significant simplifications but, as set out above, are intended to give an indication of the scale of the impacts which is all that makes sense at this stage given the high levels of uncertainty involved. It should also be noted that all figures are averages and there will be significant variations in costs between different households depending on geography, building type etc. which mean that these results should not be used to try to identify "winning" technologies for universal application.

Annual additional costs (£) versus consumption (MWh)



As the chart shows, the ***additional*** costs of the hydrogen, direct electric and storage heating options are primarily driven by the higher cost of fuel, so the solutions become more expensive at higher consumption levels, despite the lower initial capital costs.

In contrast, the ***additional*** costs of the heat pump and district heating solutions are mainly dependent on the capital cost recovery and vary much less with consumption. The high and low district heating ranges represent different levels of customer density. Depending on the balance between capital and fuel costs, the reduced running costs, may be enough to give lower ***additional*** costs at higher levels of usage, as is shown here for the heat pump and high density district heating options modelled.

At low consumption levels, direct electric or storage heating, which require lower up-front capital investment, start to become an economic alternative to heat pumps and district heating despite the higher fuel costs. This could be particularly relevant for recently built flats and other properties with good energy efficiency ratings, as well as for small properties, especially ones off the gas grid and where occupancy rates are low.

6.4 What differences are there for funding and financing?

As indicated above the various decarbonisation options have differing cost structures. This has implications for funding and financing requirements. Financing can have particularly strong adverse distributional impacts since the availability and cost of any up-front finance can mean lower income households either cannot access the measures or have to pay more for them. Similarly, high ongoing costs can have particularly adverse impacts on fuel poverty.

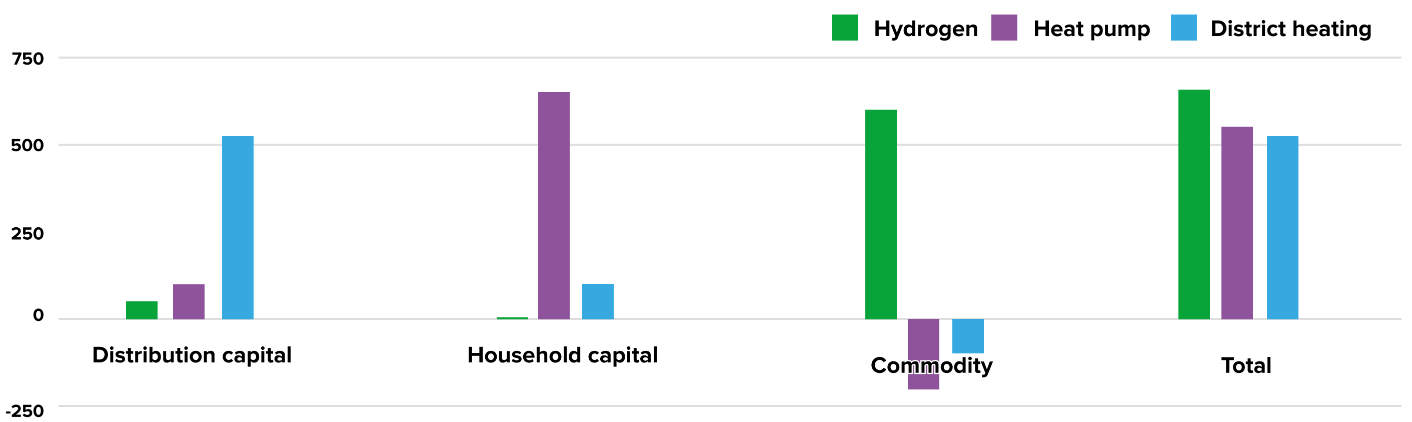
The following graphs show the breakdown of the estimated ***additional*** costs for each of the options at 10MWh and 20MWh annual consumption levels. The graphs are based on the assumptions from the Imperial College report and the costs summarised in the Annex of this paper. Once again, no financing costs have been included in the estimates.

In the hydrogen and storage heating solutions, the biggest cost difference is the increase in ongoing fuel costs. These are so high in the 20MWh p.a. example for storage heating that the solution would not normally be considered at this level and is not shown. With both, some capital investment may be required in the network. For the householder, the capital cost for hydrogen is similar to a new gas boiler. For storage heating the investment by the householder is much more significant than for direct electric heating, especially for larger properties, but still less than for a heat pump.

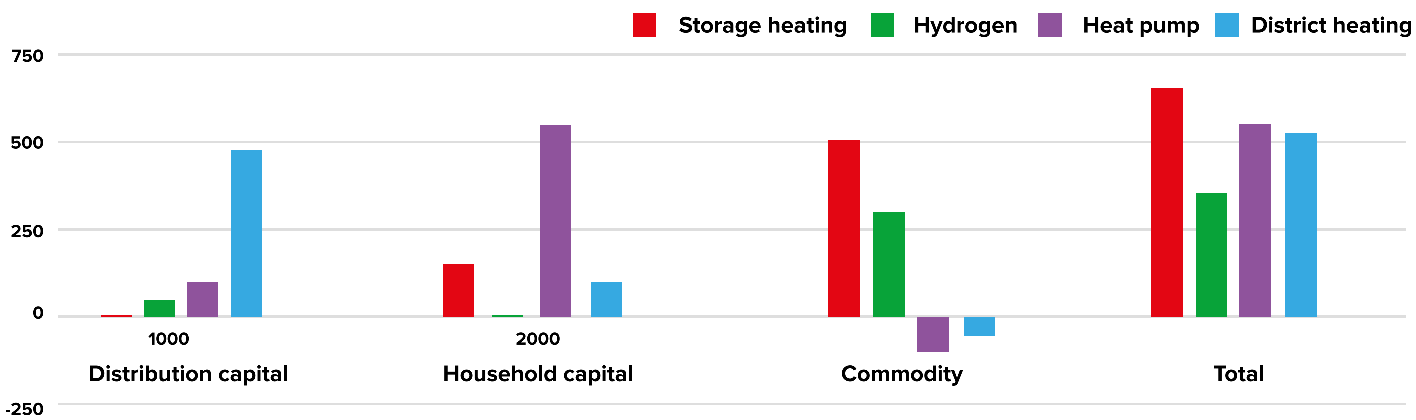
For heat pumps under current arrangements[20], nearly all the capital costs would have to be financed through up-front investment by the householder. This could include 'shallow'[21] network upgrades or the installation of a 3-phase supply as well as the costs of the heat pump, potentially a new radiator system and any energy efficiency measures needed to make the solution technically viable. These costs are shown on an annualised basis and are offset to a degree by the reduced running costs compared to gas.

For district heating under current arrangements, there is likely to be little or no up-front capital investment by the householder, but these costs would still have to be recovered through ongoing heat and fuel charges. The overall impact of fuel charges would be reduced by the efficiency of the solution.

Change in costs (£p.a.) at 10MWh p.a.



Change in costs (£p.a.) at 20MWh p.a.



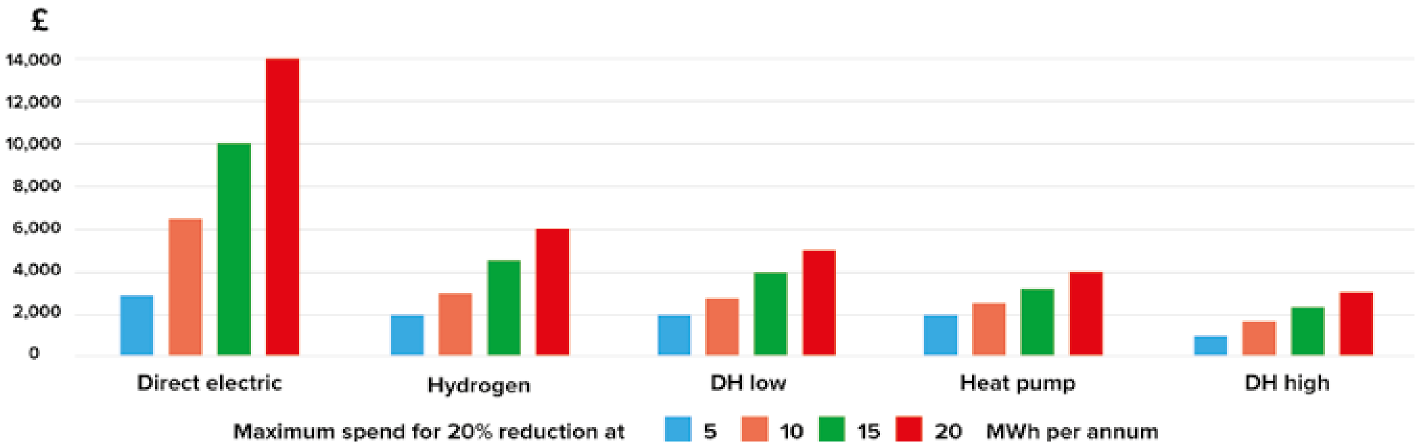
6.5 Impact of energy efficiency on low carbon investment returns

Energy efficiency investment can contribute cost-effectively to decarbonisation by reducing how much energy and associated carbon are produced. Carried out in parallel to heat decarbonisation, it is possible to offset some of the higher costs. However, there is a point above which the additional investment cost to the householder would be more than can be justified by the savings in the cost of heat production. This relationship is covered in more detail in the Energy Efficiency Annex at the end of the paper.

The graph below summarises for each of the technologies across a number of consumption levels the maximum cost-effective investment a householder could make in energy efficiency to achieve a 20% reduction in consumption. The cost-effectiveness of energy efficiency to a householder is greatest when fuel costs are high, but reduces as the proportion of fuel costs to capital costs diminishes.

Although not modelled here, energy efficiency can also have additional system and user benefits if it helps avoid expensive upgrades and related disruptive activities. Once again, it is worth repeating the conclusions from section 4.3 that there may well be other drivers' especially for fuel poverty, that justify higher levels of energy efficiency investment.

Cost-effective energy efficiency investment



6.6 Technology cost summary

The additional annual costs per household calculated by this approach range between £200 and £650 (not including the highest cost electricity examples), an increase over current dual fuel bills (based on natural gas) of 16% to 50%, depending on the chosen option and consumption levels. This compares with the range previously calculated based on the ENA/KPMG report of between £250 and £800 which would represent an increase of 20% to 65%. Clearly this comparison may change in future, depending on how the price for natural gas develops in years to come.

To put this into perspective, these cost ranges are actually comparable with the premium that households may currently be paying if they are required to use direct electric heating. A home consuming 10MWh p.a. could currently be paying over £720 p.a. and one consuming 20MWh p.a. could be paying over £1,500 p.a. more than a similar household with natural gas.

The figures also demonstrate how effective energy efficiency investment can be in some circumstances, but also that there can be limits to the returns on energy efficiency investment, especially for the decarbonisation options with higher up-front capital and lower ongoing fuel requirements. This is relevant for economic and carbon abatement assessment but, as was mentioned earlier, does not mean that such investment does not remain an effective tool to reduce ongoing fuel costs for those on low incomes, so may still make sense based on achieving fuel poverty targets and improving the comfort levels in people's homes.
Based on the economics and not necessarily the carbon emissions, energy efficiency could be prioritised for properties suitable for decarbonisation solutions with low capital requirements and high ongoing fuel consumption, like hydrogen and the electric solutions – or where natural gas is likely to continue to be used for some time. In addition, as was noted earlier, for some buildings, energy efficiency investment may still be needed for heat pumps to ensure that the solution is technically capable of providing space heating to a suitable level of performance.

All of the assumptions for costs used in this comparison are summarised in the Annex at the end of the paper.

7. Current approaches to funding low carbon initiatives

7.1 Overview

When looking at the potential ways that a transition to low carbon heating could be financed and funded there is value in looking at the different models that currently exist in the regulatory and government policy space.

As was clear from the overview of different approaches to delivering low carbon heating the elements of investment that are required can be grouped under three headings:

1. Investment in **individual homes** either to fit a new low carbon heat source (such as a heat pump) or to change/adjust appliances to be able to cope with new forms of gas or a move to district heating;

1. Investment in **monopoly networks** such as district heating systems or upgrades to existing gas networks to accommodate, for example, hydrogen;

1. Investment in **new sources** of heat for district heating or new sources of gas to feed into the networks, which could be **competitively provided**.

1. Subject to the approach taken to decarbonisation there may also be questions about how the costs of the residual gas network are recovered across a decreasing customer base and ultimately how gas networks might be compensated for any **stranded assets**.

It is also important to be clear about the distinction between funding and financing. **Funding** is about who ultimate pays (e.g. through user charges or subsidy). **Financing** is about who provides the capital in the first place – for a return on the investment and in the confident expectation that the capital will eventually be repaid.

Clearly there are a range of ways in which funding and financing could be provided with different approaches having different implications for costs to those on low incomes and in particular those in fuel poverty. As the Frontier Economics work for the Committee on Climate Change[22] highlighted, given that the domestic gas price does not reflect the cost of carbon, there is an economic rationale for some external funding of low carbon heat to encourage customers to adopt sustainable solutions, taking account of externalities. In addition, experience has shown that additional funding can be needed to kick start supply chains or support early learning and innovation. There are also issues about the need to overcome consumer inertia – either to support those who genuinely cannot afford the upfront costs of changeover – or to provide a stronger incentive to those who can afford it but may be reluctant for other reasons.

In broad terms the options for funding any incentives are either levies on industry in some form (who then pass the costs on to consumers through bills) or government funding (through taxation). Clearly there are also questions about the extent of funding and whether it is an explicit subsidy or indirect support through, for example, someone else taking on certain risks or providing low cost loans.

The sections below explore the different approaches that could be taken in each of the areas and draw out the implications in terms of distributional impacts. The specific impacts on the various fuel poverty metrics are considered in chapter 8 below. Clearly there are interlinkages between the different elements of investment required (in particular for district heating) but it is still helpful to look separately at the individual parts of the system given there are different considerations at play.

7.2 In-home investments

Almost all the options being considered for decarbonisation of heat would require investment in the customer's home of the order of £0-£15k. This contrasts with the decarbonisation of electricity where the investment required is in new sources of generation and network capacity, undertaken primarily by the companies concerned. This means that, for heat, in addition to subsidies to address externalities, the issues of incentivising uptake by individual households (ahead of any potential mandate) and questions of affordability of the up-front costs are much more important.

Linked to this it is really important that a greater focus is placed on understanding the consumer experience of heat – and the way that different consumers value different aspects spanning temperature levels, control, ease of use, reliability and price as well as broader factors such as the hassle involved with installation, space requirements and noise concerns. The weighting of different factors will also depend if the change is part of a wider refurbishment or a distressed situation when the current heating breaks down. There are also links with the provision of hot water which are touched on above. While some work has been done in this area by Exeter University[23] and by the Energy Systems Catapult[24] this has just highlighted the scale of the challenge given consumers' current preference for gas fired central heating. While we have seen major changes in the past with, for example the conversion to North Sea gas and the uptake of central heating, these provided consumers with a consistently better or cheaper solution than they had before.

In the same way that effort has been put into expanding the range for electric vehicles to make them more acceptable, research needs to be put into providing consumers with a better, or at least comparable experience from the various heat solutions that are being contemplated. This will be vital to secure consumer support for the decarbonisation programme and to reduce the costs of incentives.

In looking at the different incentivisation options and their impacts it is helpful to break down the different objectives that any support mechanism might be aiming to meet in terms of decarbonisation:

- providing an **enduring incentive to address externalities**. Subsidies may be justified on pure economic grounds where the new technology is more costly and there are externalities that are not reflected in the charges for the current technology. This applies in the case of low carbon heat where current sources (whether gas or oil) do not reflect the cost of carbon[25]. Where there are significant switching costs in terms of hassle for consumers (i.e. a market failure) an incentive may also be needed to encourage customers to act – although arguably the total level of enduring subsidy should not exceed the cost of carbon if the incentive is to be cost effective

- providing a **time limited incentive to help establish the market**. There are arguments early in a product life cycle where government may choose to provide support to help build the supply chain and drive costs down through increasing volumes and standardisation. Where technology is new and customers would be taking on risks in signing up to something unknown (and without the 'kudos' of new technology in other sectors) then again there can be arguments for providing support to encourage early take up and help prove the technology

- providing **financing to help with up-front costs** - but where the cost savings are such as to enable that initial up-front investment to be repaid over time.

In the context of **fuel poverty** there is a clear need for support to directly tackle the problem through improvements to the standards of homes. As noted above, this support can also help in delivering decarbonisation goals. Beyond the imperative of meeting the current fuel poverty target, given that heat decarbonisation policies will lead to higher prices there is a need to consider how to mitigate the impacts for those in fuel poverty. The objectives here can be thought of as:

- ensuring that those in fuel poverty benefit at least proportionately, from any interventions, compared to the population at large

- addressing the distributional impacts where some in fuel poverty benefit from measures and others do not

- providing additional support to all those in fuel poverty to take account of any general increase in prices resulting from the funding of wider programmes.

Looking across the various existing schemes (described in more detail in the Appendix) it is clear that many are targeted at more than one objective, but there are some marked differences e.g. between the Renewable Heat Incentive (where there is a clear externality to be addressed in terms of the cost of carbon) and Green Deal (which was purely a financing scheme to help with up-front costs). Other schemes have evolved over time. For example, the range of energy efficiency schemes (EEC, then CERT/CESP and now ECO) started as a way to try to kick start the market for energy efficiency but, as discussed below, have become gradually more focussed on initiatives that help the fuel poor. The levels of support from Feed-In Tariffs (FITs) have been reduced over time as particular renewable technologies have become established and costs have fallen.

Table: Summary of objectives of current schemes.

	RHI	GREEN DEAL	FIT	ECO
Enduring – market failure/ externality	*		(*)	(*)
Time limited – kick start market	*		*	
Eradicating fuel poverty				(*)
Financing up-front costs		*		

Being clear about the objective is important in thinking about the support that may be needed for heat – whether it is enduring and whether what is needed is funding or financing. Given that affordability of heat lies at the heart of fuel poverty, with the consequential implications for health and well-being, there is a real imperative to join up thinking on the heat strategy and the fuel poverty strategy.

Past and current schemes have had varying degrees of success reflecting the particular challenges of delivering initiatives in customers' homes. Green Deal was notoriously unsuccessful[26], reflecting the fact that it focussed purely on the financing which is not the only (or even the main) barrier to take up of energy efficiency measures - historically suppliers had found it hard to meet their targets for energy efficiency measures in some areas where even full funding of the product was not enough to overcome customer inertia and concerns about practical issues such as the need to clear the loft to install insulation. In contrast the Feed-In Tariff for solar exceeded all expectations perhaps because of the high financial returns[27] and because it provided a visible sign of green credentials (sometimes called "eco bling"). Designing an effective support mechanism thus requires thorough research into the wider consumer drivers – not simply the financial angle.

Aside from clarity around objectives and consumer engagement there are a number of aspects of the design of schemes to support in-home investments (and more broadly) where there are opportunities to reflect on experience to date. These are considered below and cover:

- Who benefits from the scheme? (including questions of grants versus loans or payments)
- Who pays? (ie tax or levies)
- Whether a scheme is cast as an obligation or incentive?

7.2.1 Who benefits?

Reflecting the different objectives there are inevitably distributional issues in terms of who benefits from any scheme aimed at in-home investments.

As noted above the various energy efficiency schemes have been targeted in part at the fuel poor with eligibility criteria or sub-targets to install a proportion of measures in homes in areas of high deprivation[28], for example. This has ensured that low income households and those in fuel poverty do gain some benefit – although the complexity of the fuel poverty definition has made precise targeting difficult[29]. The table below shows the proportion of benefits that have been directed at the fuel poor over time. Legislative changes are now in train to focus ECO more strongly on the fuel poor but the notional spend on the programme has reduced over time from £1.3bn to £640 million leaving a significant shortfall in the spend required to meet the fuel poverty target.

Table: Share of ECO notional spend targeted at fuel poor

	ECO1		ECO2		ECO2T		ECO3			
	2013/14	14/15	15/16	16/17	17/18	18/19a	18/19b	19/20	20/21	21/22
National spend (£m)	1,300	870	870	870	640	320	320	640	640	640
Spend targeted on fuel poor (Affordable Warmth) (£m)	350	310	310	310	450	225	320	640	640	640
Fuel poor proportion (%)	27	36	36	36	54	70	100	100	100	100

Source: NEA paper for the GDNs "In From the Cold" based on The Green Deal and Energy Company Obligation: Government Response (DECC, 2012) and ECO: Help to Heat Consultation Document (DECC, 2016a)

a = to September 2018
b = from October 18

Apart from these schemes that are explicitly targeting the fuel poor, the benefits have tended to flow to those who are better off. For both the RHI and FiT this reflects the fact that better off customers are able to afford the up-front costs, and also that their property types and tenure make them more suitable for such initiatives.

Initiatives to provide financing are aimed at overcoming part of this problem. As well as the failed Green Deal, there are provisions in the FiT scheme to enable third parties to be given rights to part of the income stream in exchange for funding, enabling "rent a roof" type schemes which should also provide some benefit to the householder. This did help drive uptake of FiT schemes among a broader cross section of customers[30], but there are consumer protection issues involved and hence Government in its latest review of the RHI has deferred a decision on allowing third parties (i.e. not the home owner or occupant) to access the scheme.

In the design of schemes like RHI there has been a presumption against offering grants in favour of ongoing payments. This decision (driven at least in part by concerns about EU State Aid rules) makes the schemes inherently less attractive to those on low incomes. Moreover, given that the schemes are effectively designed to ensure a certain level of payback this approach is actually more expensive than providing up front grants. Research[31] looking at international experience has concluded that up front capital support appears more cost effective than ongoing payments. Given that this would also benefit those in, or at risk of fuel poverty, government should revisit its approach.

In its response to the Fuel Poverty Strategy consultation in 2014, the CCC argued that to promote uptake of low carbon heat solutions by off gas grid customers there was a need to ring-fence part of the RHI to provide capital cost support to fuel poor households.

The other factor in scheme design that determines the extent to which those on low incomes can benefit is whether local authority housing or registered social landlords (RSL) are eligible for support. In the early stages of energy efficiency schemes where local authorities could partner with suppliers and provide part funding this provided an easier route for suppliers to sign up customers and helped ensure that those on low incomes did benefit. There was then an effort to narrow the eligibility (justified by the fact that local authority and RSL properties were now the highest standard). Local authorities and RSLs are eligible for FiT and RHI and have helped drive take-up in some areas. In the extension of the ECO scheme to 2018 eligibility for certain measures under the Affordable Warmth strand was extended to social housing in EPC bands E, F or G, and also local authorities are able to nominate certain groups under a "flexible eligibility" arrangement.

While these distributional impacts are of particular importance from a fuel poverty perspective they also have wider ramifications for acceptability of the decarbonisation programme. Considerations of fairness and social equity will be important in how any schemes are seen. Some of the backlash against FITs reflected a sense that the scheme was unfair and largely benefitted those who were better off while being paid for by consumers at large (see page 26).

Example of inequalities from existing low carbon interventions – Feed-in Tariffs

The Feed-in Tariff scheme has successfully encouraged the installation of small scale, low carbon electricity generation technologies through a combination of three different incentives:

- a generation tariff for every unit of energy produced
- an export tariff for energy unused by the generator and exported to the grid (for most domestic schemes, the export is deemed to be 50% of total generation)
- avoided energy costs for the units consumed on site (estimated to be between 25% and 50% of on-site generation, equivalent to £70 - £140 p.a. for a domestic installation).

The total FiT costs in 2015 were about £1.1 billion. These costs were recovered by suppliers from all consumers and spread over 260TWh. This equates to about £4/MWh, so, for an average (non-FiT) household using 3.5MWh of electricity each year, the electricity bill has had to increase by roughly £15p.a. to cover the FiT costs.

However, FiT installations do not pay for the avoided electricity use, and therefore no longer contribute fully to the network and policy costs, normally raised through levies on each unit of electricity billed. About 20% of FiT generation was exported (1.1TWh out of 5.5TWh) and the shortfall for the self-consumption of 4.4TWh must be paid for by other users.

Network and policy costs represent ca. 50% of electricity bills (about £70/MWh) so, due to the avoided electricity use, about £300 million (4.4 million MWh x £70/MWh) is no longer recovered from FiT installations. For this shortfall to be made up, a further £4p.a. must be added to the average household bill.

Overall, bills to non-FiT users will have had to increase by a total of nearly £20p.a or ca. 1.5%. This means that an unintended consequence of the FiT scheme has been to open a gap of £55 to £90p.a. (half of the annual bill savings plus the £20) in the contribution made to network and policy costs between a household receiving a FiT and one that does not. This illustrates an inherent risk from the use of energy levies to achieve social and environmental policy objectives, especially when recovering fixed costs through variable unit charges.

This would not directly impact on fuel poverty if the benefits are available to, and used by the fuel poor. However, in the extreme, if none of the benefits were enjoyed by lower income households, the potential impact could have been to push up to 60,000 more homes into fuel poverty (on the 10% definition) or increase the depth of fuel poverty by up to 1.5%, based on the definitions for England as explained in chapter 8.

Finally, the extent to which it is desirable for those in fuel poverty to be early beneficiaries of any scheme will depend to some extent on the technology. Where the technology is relatively unproven there may be additional risks in rolling it out early to more vulnerable customers. These arguments were worked through on smart metering where the conclusion was that vulnerable customers should not be used as guinea pigs for new technology but equally should not be left behind.

7.2.2 Who pays?

For existing funding schemes, there are essentially two routes – either through industry (and hence ultimately customers) or government (and hence taxpayers). Currently all schemes apart from the RHI are funded through customers' bills – and in most cases through electricity bills.

Historically there was a Warm Front scheme which provided energy efficiency measures and new heating systems in fuel poor homes and was funded through taxation. This ended in 2013 and the intention was that the Affordable Warmth element of ECO would help fill the gap. In Northern Ireland, Scotland and Wales there continue to be government funded schemes to provide heating systems and insulation for those in fuel poverty. England is now the only one of the UK nations which does not have a government funded energy efficiency scheme to sit alongside ECO.

When the RHI was initially being developed back in 2008, the enabling legislation envisaged it being funded through a levy on fossil fuel providers, which would have included gas suppliers and providers of off-grid fuels including bottled gas, oil and coal. However, the conclusion[32] was that there were significant practical problems with this given the fragmented nature of the off-gas grid market. Ultimately the decision was taken to fund the RHI through taxation instead.

Problems with raising money through this wider group of fossil fuel suppliers was also an issue in the Green Deal design. Although Green Deal measures were essentially aimed at reducing heating costs, the need to have a mechanism that could be used to recover money from all customers (including those off the gas grid) meant that Green Deal charges had to be recovered from the electricity bill (removing the obvious link from a customer's perspective between the savings and the charges).

Much has been said and written about the regressive nature of recovering the costs of these schemes through customer bills[33]. The original energy efficiency schemes linked the level of obligation to customer numbers rather than energy used. This encouraged suppliers to reflect these costs in their charges on that basis which was particularly regressive given that on average low income customers have lower usage. The level of the funding is now linked to usage[34] for suppliers with over 250,000 customers on a particular fuel. However, levies on customer bills remain a regressive way of funding such schemes:

- no account is taken of ability to pay as it would be in the tax and benefits system
- low income households typically spend a higher proportion of their income on energy and hence pay a relatively higher proportion of their income on any levy
- there remains an incentive for suppliers to load these costs onto charges for less engaged customers who are more likely to be lower income or vulnerable. The recent CMA report highlighted the disparity in margins that suppliers earn between customers on standard variable tariffs and others. This can be viewed as indirect costs being more heavily loaded onto these customers
- the fact that most subsidies (apart from ECO) are recovered through electricity bills means that those who rely on electric heating, who again are more often low income customers, will be paying disproportionately more. The latest figures from the Committee on Climate Change[35] show that for customers in electrically heated homes 18% of their bill is policy costs as opposed to 9% for the population overall.

As noted above, the consensus view from fuel poverty groups (and others) is that the fairest way to recover the costs of social and environmental schemes is through taxation.

There are also wider affordability issues. Originally, if the expenditure did not form part of the Public-Sector Borrowing Requirement (PSBR), Departments had a relatively free rein over what they did, and funding subsidies through bill levies was a way to achieve this. However, concerns about the overall impact on consumer bills of government schemes led to the introduction in 2011 of the Levy Control Framework which was intended to put a cap on the total costs and encourage government to make trade-offs between different schemes. It also gave

Treasury more control over the expenditure. However, as noted by the NAO in its recent report[36], the scope of the Levy Control Framework had been narrowed so that it only covered decarbonisation schemes meaning that there was no overall view of the impact of government schemes on bills.

In the spring 2017 budget, the chancellor announced that the Levy Control Framework will be replaced with a new set of cost controls which will be set out later this year. With the prospect of increased funding needed to support the decarbonisation of heat it is vital that, if this is being done through customers' bills, then it should be subject to some sort of monitoring or control framework to ensure the total cost is affordable.

From an investor's perspective, there can be alternative risks associated with tax-funded schemes as they are more subject to the vagaries of political cycles - governments cannot commit beyond the 5-year budget cycle and may easily change taxes each year in the Budget. This is not a reason to favour levies but means that other ways need to be found to give investors longer term confidence in policy. The National Infrastructure Commission's National Infrastructure Plan should provide a route to signal longer term intentions around a programme of investment.

Finally, although to date the focus has been on funding by central government the positioning of district heating creates an opportunity for local government financing and funding. Local authorities have the ability to borrow from the Public Works Loan Board at interest rates that reflect government's borrowing costs in the gilt-edged market, i.e. at very low interest rates over much longer periods than commercial companies. In the past, there have also been ideas around discounts on council tax for more energy efficient homes. Currently local authorities are struggling to meet their budgets and hence such funding may be difficult, but their ability to finance investment through low cost borrowing remains strong and their involvement in district heating can bring other benefits in reducing risk as set out below.

7.2.3 Obligations versus incentives

Where funding is provided through suppliers there are two mechanisms that are in use – either an enforceable[37] obligation on suppliers to deliver a certain volume of measures, as with ECO, or a levy that ensures all contribute to the costs of the incentive but with take-up being driven by customers and independent installers (as with the FiT for example). These two mechanisms have different features:

- the obligation effectively sets the number of measures to be delivered, and the cost of delivering them is then effectively set by the market. Historically there have been difficulties assessing the value for money of the energy efficiency schemes set up on this basis, as the costs were born by suppliers and that information was hard to collect. Steps have now been taken to try to improve transparency to address this (including through the introduction of trading of obligations or broker schemes for measures)

- the incentive approach sets the price (level of subsidy) that will be paid for measures but then the volume is set by the market. This is what has led to the problems with the FiT where the volumes and hence the total cost of the scheme exceeded expectations.

Which is the best approach will depend in large part on the objectives to be achieved. The incentives approach would seem to give the best guarantee that any measures represent value for money if the price has been set appropriately, taking account of externalities and the value of learning. As is now the case with the FiT, caps can be set on volumes or degression applied to the tariffs to help manage overall exposure and reduce costs as the product becomes more established.

However, if the imperative is to deliver a certain volume of activity (e.g. a level of decarbonisation) then obligations are more appropriate. The other example where an obligation is used is in relation to smart metering (and the obligation to take all reasonable steps to install a smart meter in all homes and small businesses by 2020). While this is sometimes seen as a "scheme" in the same way as the others discussed above it has a system element attached to it – i.e. certain benefits only come once all customers are on smart meters. Making it an obligation therefore drives achievement of that overall goal. There could be analogies here with for example adjusting appliances to enable different quality of gas to be fed into the system which would need to be done for all customers connected to that network before the gas specification could be changed.

Obligations drive suppliers to deliver them at lowest cost but this may lead to fuel poor customers being left behind if they are more costly to serve. For example, under ECO suppliers are now looking to secure a contribution to the cost of measures which precludes those in fuel poverty, who have the greatest need, from participating.

Bringing in competition is important to deliver greater cost efficiency. This is generally more readily achieved through provision of incentives but can be incorporated into obligations. For example, on the energy efficiency front the use of white certificates and the ability to trade obligations is a way to enable wider participation.

Some local authorities are also arguing for ECO to be recast as a straight levy which they could then bid for to run specific projects (similar to the approach in Northern Ireland[38]), enabling more coordinated delivery of measures. The use of auctions in this way is another route to bring in competition and improve cost efficiency.

Although, to date, obligations have focussed on suppliers, there could be a case for involving gas networks in overseeing any programme of in home change linked to changes in gas specification, for example. The UK is unusual in having its smart meter programme delivered by suppliers which has limited the potential for an area by area approach. The network companies could be better placed to deliver any area based programmes required.

7.3 Monopoly Networks

7.3.1 Gas and Electricity Network investment

In decarbonising heat, investment will also be needed in networks which are natural monopolies and hence in the case of gas and electricity subject to regulation by Ofgem. Where it is clear that additional investment is needed in these existing networks – either in the gas networks to accommodate alternative sources of gas (including hydrogen) or in the electricity networks to accommodate much higher winter peak loads if there is a greater reliance on electrification of heat and heat pumps – then there is already a regulatory framework to deal with that. Customers will pay for that additional investment as part of their bills. For example, the costs of the iron mains replacement programme (which was originally mandated by the HSE on safety grounds but fortuitously also helps make the networks ready for a hydrogen future) are recovered as part of the gas distribution networks price control.

As a part of the RIIO price control framework companies are also subject to certain incentives which can be helpful through the transition to decarbonisation – to encourage trialling of new solutions or to help mitigate some of the impacts for those in fuel poverty. Examples are given in the Appendix. One particular example is the obligation on gas distribution networks to extend their networks to connect additional fuel poor customers (the Fuel Poor Network Extension Scheme). These fuel poor customers do not have to pay for the cost of the network extension (which is borne by customers at large), although they do have to cover the costs of the in-home investment which has limited uptake of the scheme in England (compared to Scotland where funds are available through the Government's energy efficiency programme). A recent report by NEA for the GDNs[39] highlighted the issue and recommended increased funding of the in-home measures to enable what would be efficient additional connections to be delivered by the networks.

Ofgem has recently amended the scheme to allow connections for district heating schemes to be included. However, there are issues around the level of credit that GDNs get for this as it is viewed as a single connection (regardless of the number of fuel poor homes to be connected). Reviewing this going forward would be one way to provide greater support for fuel poor customers connecting to district heating which would be more in line with the future heat strategy than individual gas connections.

More generally it will be important as part of the RIIO2 price controls to have joined up thinking about the implications of heat de-carbonisation for both the gas and electricity networks. For example, assumptions about the level of heat pump penetration will be critical for both. The fact that the timings of the different controls are currently out of step, with RIIO GD2 being determined ahead of when government are likely to confirm the policy direction, creates particular challenges for the process, although the bigger impacts may well not be felt until RIIO3 anyway.

7.3.2 Network charging

There are also wider debates about the approach that should be taken to network charging to support the transition and the implications for different types of customers[40]. As demonstrated in the FiT example above, charging what are essentially fixed costs on the basis of unit rates unfairly benefits those who are able to generate their own electricity. Some sort of standing charge would arguably reflect the value for consumers with their own

generation of maintaining the option of using grid supply if they need to (and has been compared to "insurance"). However, a fixed standing charge would still be regressive (given that typically those on low incomes consume less). Another option – particularly for electricity - is a capacity based charge which would reflect the maximum load that customers use and which is arguably more cost reflective. While less regressive than a standing charge this would be a new form of charge for consumers to understand. In all cases the impacts on consumers depend on how suppliers reflect the network charge structure in their own tariffs.

While not generally included in discussion of options for network charging there is no reason in principle why a specific class of Distribution Use of System Charge (DUoS) could not be created offering lower charges to fuel poor customers as a means of mitigating higher costs. However, there are some practical challenges (e.g. the network companies do not know who is fuel poor) and ultimately customers at large would end up paying for the subsidy as they do now with the Warm Home Discount.

Network charging – and in particular the treatment of fixed and sunk costs - is a complex area on which Ofgem has recently launched a consultation[41]. This focuses on the residual elements of charges for which there is no cost driver (which can account for up to 50% of distribution network costs). Ofgem note the need to take into account issues around fairness and the impacts on vulnerable customers and refer to a paper by MIT which proposes allocating these residual costs on the basis of property charges (as a proxy for wealth) – or potentially even recovering them through taxation. It is vital that Ofgem's work on network charging puts a strong emphasis on the distributional impacts and the implications for fuel poverty. The section below on stranded costs highlights another challenge if the number of customers connected to the gas network reduces over time, with the risk that if lower income customers are left behind they could end up bearing a disproportionate element of the network costs.

A final issue related to network charging is the approach to new connections which, as alluded to above, can result in individual customers bearing significant costs for network reinforcement if they want to install a heat pump. If electrification of heat is to form a significant part of heat decarbonisation strategy – as it almost certainly will in off gas grid rural areas - then there may need to be a review of how connection charges are levied to ensure those costs are recovered on an equitable basis (and that individual customers seeking to connect do not end up bearing a disproportionate cost where reinforcement is required).

7.3.3 The read across to district heating

A related area which presents significant challenges is how to deal with the investment needed in district heating networks. There has been debate as to whether these should be regulated, both to protect consumers and also to provide confidence to investors. The Scottish Government is currently consulting on this question. The issue is also touched on in Ofgem's Future Insights Paper on heat.

The challenge with long term infrastructure investment of this sort is that while investors may be willing to invest, they need to be confident that they will continue to earn sufficient returns over the lifetime of the asset to recoup that investment. The Association for Decentralised Energy (ADE) identifies a range of risks that investors in district heating will be considering – the demand risk (will sufficient customers sign up?) and the risk of stranded assets (if e.g. some new preferable technology comes along). The regulatory model effectively provides a guarantee that appropriate returns will be earned while protecting customers from over charging by the monopoly company.

In the regulatory model these risks are in effect shared across all users of the network. If changes in demand on a particular part of the network mean that investment in it is no longer needed (so it could be viewed as stranded) then it does not matter as the company is able to set its charges so as to allow it to recover its regulatory asset base and to earn a return on that investment.

The challenge for district heating is that as small scale networks the scope for socialising the costs and sharing the risks in this way does not really exist.

A paper by Frontier Economics for the CCC[42] also argued that the administrative effort in running a full-blown price control would be disproportionate for these smaller networks. While that is no doubt true there are lighter touch models that could be used and the complexity of the full-blown price control only arises because of the way that the networks are having to continually evolve to meet new demands and loads linked to their "system" features. A simpler approach could be used for district heating as discussed further below.

Reflecting on the separate questions of financing and funding, and where risks are borne, there are a number of considerations around district heating.

On the question of **funding** for the building of new networks (and the associated energy centres – considered further below), the rationale is similar to that cited above – either to address externalities (i.e. around the cost of carbon and looking at the overall system cost of district heating) or to help with the development of the supply chain and the market.

BEIS has committed £320m through to 2021, funded through taxation, to a Heat Network Investment Partnership to help establish the market on a sustainable basis. The money in terms of grants or loans is expected to draw in £2 billion of additional capital investment. BEIS is also providing practical support to projects in the planning stages through its Heat Networks Delivery Unit.

The expectation is that beyond 2021 district heating should be self-funding.

If additional support were to be provided this could be in the form of support for the in-home investments – or a discount on running costs if the up-front costs are recovered through the bill - as this is most likely to drive connections (itself of benefit to the network investor by reducing demand risk) and could be tailored in terms of eligibility to provide more support to those on low incomes.

In general **financing** seems to be available for these projects through local authorities (see above) or developers – but the ADE do highlight the impact that the risks have on investor appetite. The biggest concern is around managing the demand risk where the support that can be provided – most often by local authorities – is the provision of an "anchor load" that provides a guarantee of some level of initial demand.

The model that has been mooted by the Scottish Government is that a local authority would run a tender for development of a district heating system (including its own "anchor load"). The winner of the tender would be awarded a licence which would provide certain entitlements (including on planning to reduce operational risks and a monopoly right to run heating in that area to reduce stranding risks) but also certain protections for customers including on the level of charges.

To date the focus in district heating has therefore been on ways to reduce (or potentially to reallocate) specific risks rather than to seek wider socialisation of all risks.

As noted above the underlying rationale for regulation of the existing monopoly networks is essentially around consumer protection and ensuring that monopoly providers cannot charge exploitative prices. In Denmark where there is very high penetration of district heating there is a heat regulator and there is a requirement that district heating providers are not for profit which addresses the concern around exploitation[43].

7.3.4 Alternative models – Public Procurement and Competitive Networks

While the Scottish model is described as regulation it is not necessarily that different from a standard/ public procurement/private finance model where the local authority might tender for a project which the bidder would then recover their costs for from charges levied for the use of that infrastructure over the life of the asset, and with charges set out in the contract. The terms of the contract could also specify the need to meet certain consumer protection standards, for example through participation in the Heat Trust.

There are perhaps two core differences between this and the standard network regulation model:

- the first is in terms of who has oversight of and manages the contract. In the public procurement context, the individual local authority would do that. In a regulatory model these skills would effectively be centralised – with the pros and cons that entails

- the second is in terms of whether costs can be socialised across a wider group. In gas and electricity networks costs are currently spread so that all consumers in a given region pay the same network charges although in practice there will inevitably be big differences in the real costs of serving for example rural versus urban customers. There is also the question of what happens when a problem arises and whether any risks can be socialised across a wider group. This would not be an explicit feature in public procurement although local taxpayers will bear certain risks.

Within any framework there are also opportunities for different approaches to be taken to different phases of the project. The higher risk stage of any infrastructure project is the construction phase when there are significant risks of delays or added costs (and hence higher returns are usually required). With established technologies, the operations phase is generally lower risk. Different approaches may therefore be justified for the different phases.

As noted above, network regulation does not have to involve a full-blown price control and Ofgem has evolved its approach to deal with different situations. The most relevant analogies here are the "competitive networks" that are becoming a more common feature in energy regulation, for example:

- for offshore transmission Ofgem runs tenders for the management of the assets once built with the assets then subject to a basic price control;
- interconnectors which are deemed by Ofgem to be in consumers' interests are subject to "cap and floor" regulation, putting bounds on the returns that can be earned;
- independent distribution network operators (who compete to provide connections to new housing estates) are subject to a simple "relative price control".

Further details on these arrangements are provided in the Appendix.

In the first two of these examples there is a sharing of risks with consumers at large which can be justified and managed as these networks form a part of the wider electricity system. For district heating, even as part of a "regulated" model it is not clear that this wider sharing of risks would be viable in so far as the networks remain separate.

The ADE has recently launched a taskforce (involving Ofgem, BEIS, local authorities and consumer representatives) to look at the issues around regulation of district heating looking both at the consumer protection angle and how to make heat networks as attractive an investment as gas and electricity networks, and hence bring down the cost of capital.

There is no rationale for socialising costs through the gas networks unless gas distribution companies were given a formal role in district heating. This would raise potential competition issues given the scope for a wider range of players to become involved in district heating. One potential rationale could be if this enabled gas networks to manage the transition from gas to district heating taking account of the overall system costs. For example, the decision to introduce district heating might most sensibly be considered as an alternative when major investment is needed in the gas network. The question of how to get gas networks to consider such options when planning their networks should be a consideration for the RIIO GD2 price control which kicks off this year.

7.3.5 Stranded assets

This links in with the difficult question of how stranded costs for gas networks should be treated if the heat strategy decided on by government does not include a significant role for gas going forward. While the idea behind the Regulatory Asset Base model is that it guarantees that investments will be repaid and a return earned, there could be limits to this. Ultimately it would not be seen as acceptable (or practical) for a small residual customer base to carry the full costs of the original system.

Similar challenges arise in electricity where the potential for customers to go off grid (using batteries and solar) has prompted a debate about a possible "death spiral" with fixed costs being spread across a progressively smaller customer base driving even more customers away[44].

The goal of regulators is to avoid such a scenario by the way that they set the price control and the charging regime. The answer for gas in RIIO GD1 has been to front load the depreciation profile and to limit investments to those with a relatively shorter payback.

Steps like this help reduce the risk of a small number of customers picking up an increasing share of network charges as households move onto other solutions. Given the risk that those remaining on the gas network could be disproportionately fuel poor it is important that this is addressed.

The wider issues of the risk of stranded assets will no doubt feature heavily in the RIIO GD2 price control. Finding a good solution will be important not only to investors in the gas networks but more broadly. It would be hard to encourage investors into district heating against a backdrop of stranded assets in gas networks.

7.4 Commercial investment in commodity inputs

As well as investment in the networks there is a need for investment in the commodity "inputs" to those networks – whether it is biogas/hydrogen to feed into the gas networks, potential new sources of heat to feed into the heat networks, or additional low carbon sources of electricity generation. Given these are commercial investments the rationale for funding is again whether this is needed to address an externality and/or to help kick start a new market.

In the early stages of the transition, the challenge is to attract new low carbon sources with, where necessary, funding targeted at the commercial providers. Longer term the issues will be around the potentially higher running costs faced by consumers on particular solutions, such as hydrogen.

In electricity, historically, the Renewables Obligation played the role of encouraging large scale renewable generation onto the system with customers (through suppliers) effectively funding a subsidy to renewable generators – either presenting certificates to demonstrate that a proportion of their electricity came from renewable sources or buying themselves out of that obligation (at a pre-set price). This has now been replaced by Contracts for Difference, a mechanism that government hoped would be more cost effective.

7.4.1 Gas sources

Currently the gas that is input into the system is provided by "shippers" (who buy from up-stream providers) and there is a competitive market for different sources. The costs of the investment are reflected in the price of the gas which then feeds through to customers. The system operator (National Grid) arranges for gas on-take and off-take to be kept broadly in balance (although the task is not as complex as in electricity as there is more flexibility with large scale dedicated storage, as well as line-pack[45] in the system providing a temporary store). There is no reason why this model should not still work with new sources of gas – and indeed some levels of biomethane are already being injected into the system.

The non-domestic RHI currently provides an incentive for biomethane injection into the grid, funded through taxation. It might also be possible to design a certificate based scheme for the gas that is fed into the system, requiring a certain proportion to be low carbon. Perhaps inevitably the costs of such a scheme are likely to be funded by gas consumers – but that may be reasonable as a way to start to reflect some element of carbon costs in the system and as preferable to paying for the stranded assets of the gas networks.

Although some injection and blending of hydrogen is possible there are technical limits on how far a blended solution can be taken so, ultimately – if repurposing the gas grid were the chosen policy for 2050 - a shift to 100% hydrogen would need to be mandated and all customers connected to the network would have to use hydrogen. Given the higher commodity costs of hydrogen (discussed above) there will be distributional issues to be addressed and questions of affordability which may require additional funding, at least for those on low incomes.

7.4.2 Sources of heat for heat networks

For heat networks, the sources (whether CHP or industrial waste heat) are currently typically developed as part of the process of building the district heating system. Longer term it is possible that with more interconnected systems there could be the opportunity to connect a range of sources of heat. The heating network operator would then choose what sources to use to optimise the overall system efficiency (as happens now with CHP where there are choices in when to generate etc).

While currently most district heating uses gas CHP, there will need to be a shift in future to low carbon sources that, again, are likely to be more expensive than the natural gas comparator. Currently the non-domestic RHI provides an incentive for low carbon sources connected to district heating. Ultimately, the solution is likely to involve either restrictions or targets for the types of heat sources to be connected to the network being set out in the tender and any subsequent licence/contract. This could work if local authorities themselves had targets they needed to meet (including on e.g. waste disposal).

As set out above, funding through taxation is less regressive than funding through suppliers and hence customers and, for district heating, where there is no natural customer base to socialise costs over, taxation may also be more practical as a way to fund any incentives to decarbonise the heat source, building on the RHI.

7.5 End to end view

7.5.1 Consumer choice?

While the sections above have looked separately at the individual elements of investment required there is a clear need also to look end-to-end at the costs for customers of different potential heating solutions (i.e. covering the in-home costs, network charges and the cost of the fuel/heat itself), in particular in thinking about how the transition might be managed.

It is unclear from the current policy debate how far customers will have a choice of different solutions. This will inevitably vary to some extent with the preferred solution. If a hydrogen network is pursued then clearly consumers on that network cannot choose to continue with natural gas. For some solutions, such as district heating (or hydrogen) there are economies of density where it is desirable for as many customers to connect to

that network as possible. While (as now) customers might still have the option open to them of an electric solution it is unlikely to be efficient to have competing networks in an area. This has led to the idea of zoning where a lead technology might be chosen for that area. For example, the Scottish government consultation floats the idea that subsidies for other solutions might not be available in an area designated to be covered by district heating.

Another model would be to have a hierarchy of measures such as exists now where the RHI is only available once certain insulation measures have been undertaken (where that is possible). Given that the most effective measures will vary by location it is not practical to produce a simple hierarchy at this stage although in most cases cost-effective energy efficiency remains a sensible first step and the development of local area plans may allow local hierarchies to be established.

The extent to which government could mandate a particular solution is a difficult issue but clearly there is a precedent with building regulations being used to drive the uptake of condensing boilers and of energy efficiency standards (notwithstanding that government has pulled back from the zero carbon homes standard). This is likely to be an important driver for new homes and potentially refurbishments where they could, longer term (from 2030 onwards), be used to drive wider change but broader customer acceptance is still likely to be key if a mandatory route is to be pursued.

Issues around relative prices and reflecting the price of carbon need to play into long term thinking about how any solution would be implemented:

- if choices are to be constrained in particular geographic areas (reflecting the benefits to the system of high density take-up) then it is important that customers forced onto a particular solution are not disadvantaged compared to others

- if customers are allowed a free choice, then it is important that these choices are not distorted by the costs of subsidies being loaded onto customers of one technology but not another, without a clear rationale.

7.5.2 Carbon price

As noted above there is an economic argument for reflecting the cost of carbon in some way into the price of gas for domestic consumption. This would ensure that in making choices consumers were taking that cost into account and that in a world where some consumers may be moved early onto low carbon solutions as part of a managed transition they would not be penalised.

However, given the current focus on affordability of energy there is likely to be an understandable reticence to increase the cost of gas to domestic consumers. And from a fuel poverty perspective it would clearly raise very significant concerns. In principal, the funds raised could be used to help address affordability issues for those in fuel poverty but governments have always resisted such hypothecation.

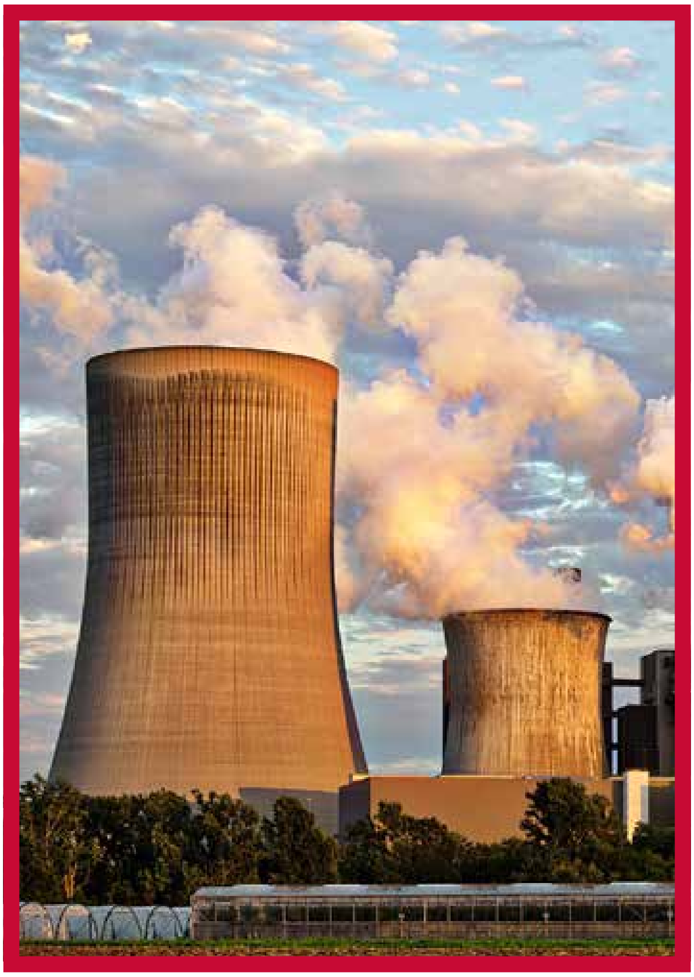
There is therefore merit in considering alternative solutions that would have a similar impact:

- as noted above, a subsidy for low carbon heat would have the same impact as a tax on gas in terms of customers choosing between different solutions (although customers reliant on electricity would, as now, be paying a relatively higher price as the cost of carbon is reflected in the electricity price)

- if ultimately some of the costs of incentives are recovered through a levy on gas bills then that would have a similar effect to a carbon tax (so there is no need for both). One of the challenges here, as was acknowledged when the RHI was potentially to be funded through bills is the difficulty in applying a levy to other forms of fossil fuel
- alternative tariff structures have been proposed in the past as a way of recovering policy costs through bills without penalising the fuel poor. For example, CSE suggested[46] the idea of a protected block tariff where policy costs were only allowed to be recovered on consumption above a certain level. Ofgem in a discussion paper[47] highlighted that this could be achieved by the way any levy obligation was structured – and presented some alternative models
- also as part of discussions around decarbonisation there were suggestions of tradable personal carbon budgets[48] and more recently of obligations on suppliers to reduce demand (and hence carbon)[49]. At the time the idea of personal carbon budgets was seen as a policy ahead of its time but consumer research suggested that it might be more acceptable than carbon taxes. These ideas could be worth exploring further in the context of heat decarbonisation.

If the conclusion is that some sort of carbon tax is important to help in managing the decarbonisation of heat, then there is a question around when such a tax would need to be in place. Until there is a prospect of a sizeable proportion of consumers having viable low carbon alternatives it would seem premature to introduce such a tax. However, it is an option that should be explored longer term as part of any programme for decarbonisation, but with a clear route for mitigating the impacts on fuel poverty.

In looking at options for mitigating the effects of any schemes on fuel poverty there could be a case for revisiting issues such as the better targeting of the Winter Fuel Payment (currently available on an age basis regardless of means) although this has proven to be a politically difficult issue over a long period.



8. Fuel Poverty implications

In broad terms a household is said to be in fuel poverty if it cannot afford to adequately heat its home. Historically in England (and still the case in Wales, Scotland and Northern Ireland) this was defined as being where a household would need to spend more than 10% of its income to achieve an adequate level of heating. In 2011 Professor Hills was asked by the UK government to review the definition for England and a new "low income-high cost" measure has now been introduced.

This section therefore starts with a recap of the various fuel poverty definitions and targets; looks in broad terms at how different policy approaches to de-carbonisation could impact on fuel poverty and finally highlights some areas around the fuel poverty definitions that need to be born in mind in this context.

8.1 Fuel Poverty definitions and targets

8.1.1 The 10% definition

The definition of fuel poverty in the Warm Homes and Energy Conservation Act 2000 is "living on a lower income in a home which cannot be kept warm at reasonable cost". As noted above, historically the measure of fuel poverty was defined to be one where a household would need to spend more than 10% of its income to maintain an adequately heated home.

A critical feature of this definition and of the new definition for England is that the heating costs are modelled, not actual costs, to reflect the fact that low income households may in practice spend a lower proportion because they are under-heating their homes with consequential risks to their health and well-being.

Because the costs are modelled, they rely on a range of assumptions. In terms of what constitutes adequate heating the model assumes:

- for temperature: an adequate level of heating is taken to be 21 degrees in the living room and 18 elsewhere (although in Scotland the level is 23 degrees in the living room)
- for the heating regime: "standard" customers heat their homes for 2 hours in the morning and 7 hours in the late afternoon/evening plus 16 hours at weekends. In addition, allowance is made for elderly people or families with young children who it is assumed heat their homes for 16 hours each day
- number of rooms heated: not all rooms are heated where there is under-occupancy.

Based on detailed modelling by the Building Research Establishment (the BREDEM model) projections are made based on the geographical location, characteristics of the dwelling and the types of insulation in use as to the amount of fuel needed to heat and light the home to the standard above and covering space heating, water heating, lighting and cooking. The model then applies costs for the various fuel types (including for gas and electricity the costs of different payment types) to calculate the modelled cost.

Defining fuel poverty in terms of whether a household needs to spend more than 10% of income to maintain an adequately heated home thus brings in what have always been seen as the three main drivers of fuel poverty – incomes, prices and energy efficiency. This metric and the statutory obligation on government, as far as reasonably practical to eradicate fuel poverty within a given time frame, was instrumental in encouraging some focus on energy efficiency measures in low income homes with fuel poverty numbers initially falling (helped by falling prices). However, by around 2008 with prices starting to rise (in part down to the cost of social and environmental levies) the trend was reversed. It was estimated at that time that each 1% rise in fuel prices pushed an additional 40,000 households into fuel poverty[50]). With projections of continuing fuel price rises and rising numbers in fuel poverty (including many not actually on low incomes) it was acknowledged that the "10%" metric was not always helpful in targeting assistance where it was most needed. instead of more costly, but sustainable energy efficiency measures. This then led to the Hills Review.

8.1.2 The Low Income – High Cost definition (LIHC)

In 2011 Professor John Hills was asked by Government to carry out a review of the definition of fuel poverty in England. His report recommended an approach which made explicit the requirement for homes to be on low income to be considered in fuel poverty as well as having higher than average required heating costs.

In "Fuel Poverty: A Framework for Future Action" Government committed to the use of this approach and in particular to new definitions of fuel poverty[51] (looking separately at the extent and "depth" of fuel poverty) based around:

- calculating the cost of heating the home to the required standard using a version of the BREDEM model as before
- making adjustments to that cost for targeted measures such as the Warm Home Discount
- defining a household as being in fuel poverty if:

    they had required fuel costs that were above the median (average) level; and

    that if they spent that they would be left with a residual income below the poverty line

- the "depth" of fuel poverty (in £s – either measured in aggregate or on average) is then the difference between what is deemed a reasonable heating cost (essentially the median required cost) and the required heating cost for those in fuel poverty.

In DECCs Fuel Poverty Statistics 2016 the latest figures show that in 2014 in England there were 2.38 million households in fuel poverty with an average fuel poverty gap of £371 and an aggregate gap of £882 million.

The Government target on fuel poverty in England, set out in legislation, is for as many fuel poor homes as reasonably practical to be at least band C Fuel Poverty Energy Efficiency Rating (similar to SAP but taking account of rebates as noted above) by 2030.

In 2015 government published its fuel poverty strategy setting out how it intended to meet this obligation. As a part of that, government set some intermediate milestones including that by 2020 as many fuel poor homes as reasonably practical should be at least Fuel Poverty Energy Efficiency Rating Band E. It also said that it would prioritise interventions for those in the deepest fuel poverty.

To help in identifying the most cost effective interventions, BEIS has developed the concept of Fuel Poverty Marginal Alleviation Cost Curves which rank measures taking account of up front, running and hidden costs (such as redecoration) – but not incentives needed to encourage uptake. This shows air and ground source heat pumps in off grid areas as one of the most cost effective interventions.

8.2 Implications of different approaches to decarbonisation

8.2.1 Range of heating solutions

As noted above, over the last decade the take-up of the FiT funded microgeneration and RHI funded heating systems has been lower among low income customers reflecting both the difficulties they might have funding the up-front costs but also the suitability of properties in terms of tenure and outside space etc.

Of the solutions under consideration for heat de-carbonisation heat pumps in particular require outside space and sufficient internal space for a hot water tank which may make that solution unsuitable for many low-income customers (though obviously, there will be some rural customers in particular for whom it could be practical). Looking at those currently in fuel poverty the mix of fuels used shows a very different pattern from the population as a whole which means that they will face different costs in any transition and provides an indication of the potential suitability of different solutions.

In 2014 in England 15.0% of those who were not connected to the gas grid were in fuel poverty compared to 9.9% of those who were connected52. Those using electricity for heating were most likely to be in fuel poverty (over 16%) but those using other fuels (oil, bottled gas etc.) had the greatest average depth of fuel poverty53. Given that one of the principles in the fuel poverty strategy is to prioritise the most severe problems, finding solutions for off gas grid customers on other fuels should be a priority and provides an opportunity to promote increased use of heat pumps in particular.

In addition, the fact that many of those in fuel poverty currently have electric storage heaters provides an opportunity – if the technology could be made more efficient and customer friendly and the storage capability used as part of a flexibility solution reducing costs to consumers – to play a part in a mixed technology solution[54].

The various fuel poverty documents that have been produced do not generally include district heating within the range of likely solutions for fuel poverty, in part at least because they cannot rely on fuel poor customers being sufficiently clustered to justify a district heating system. However, there are schemes being taken forward by local authorities which have fuel poverty as one of the drivers and, as noted above, Ofgem's fuel poor network extensions scheme now covers gas extensions to support district heating for communities previously off the gas grid.

The other issue which has not really been explored to date is the extent to which different heating systems are suitable for different heating regimes. One of the valued features of gas heating is that it is instant response which is important for households who want to quickly heat up the home after coming in. However, this may be less important where an older person is at home all day – although they feel the cold more and hence generally heat to higher temperatures. Heat pumps are allegedly more suitable for providing a steady stream of heat and hence might be more suitable (in terms of that aspect of customer acceptability) for some customers than others. As noted above, the Energy Systems Catapult has done some early work on customer attitudes. Further work – including looking in particular at the experience of those in fuel poverty – is important to help drive thinking in this area.

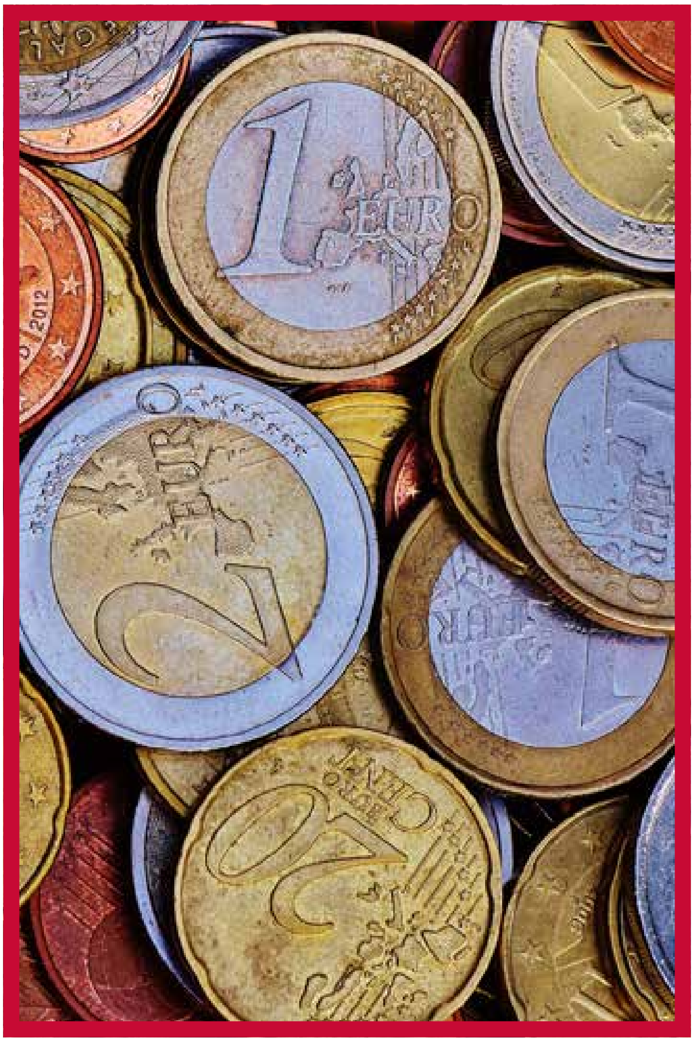
Looking at the targets for fuel poverty which are defined in terms of SAP rating it is also important to understand how a move to different heating technologies can impact on SAP rating. Currently the introduction of a first-time central heating system is one of the measures that is seen as helping lift a household up the SAP ratings. Given limited experience to date of some of the potential low carbon heating solutions the way they are modelled in BREDEM continues to be refined. However, the inclusion of any of these heating measures in a home (apart potentially from 100% hydrogen) could be expected to result in an acceptable SAP rating, given the emphasis is on ongoing running costs, but ignoring the up-front investment required.

8.3 Funding and financing

As indicated above the transition to a de-carbonised heat system will require significant investment and is likely to require some substantial element of funding both to help kick start the market and to address externalities. Targeted support is also likely to be needed to help those unable to afford the up-front costs.

How this support is paid for – whether through taxation or energy bills, and if bills which fuels – will have significant implications for those in fuel poverty.

As noted above, it is widely established that funding through bills is more regressive than funding through taxation. While those on low incomes typically have lower energy use than average this is not universally the case and there is no scope in the billing system – unlike in taxation - to take account of ability to pay (other than by over-laying another scheme such as Warm Home Discount again funded through levies). While there may be arguments for some levies on bills (where these are reflecting true energy system costs or externalities), where there isn't a strong case, equity considerations point to the funding being through taxation.



The implications in terms of fuel poverty of any additional levies to support full decarbonisation is difficult to model given the range of possible scenarios and potential costs. However indicative figures can be calculated on the basis of the following assumptions:

- assuming that any levy is reflected as a proportionate increase in all customers' bills then there would be a negligible impact on the numbers in fuel poverty given it is a relative measure. This is acknowledged in the BEIS Fuel Poverty Statistics 2016 report which says *"For example, if all prices were to rise by 10 per cent for all households, then a household that previously had costs that were five per cent above the median required energy threshold will still have costs that are approximately five per cent above the new median required energy cost – assuming all other factors remain the same. As a result, the fuel poverty status of the household will not change".* In practice the calculation will be a bit more complex as the price impact may vary between the standing charge and unit rates and between tariff types if competition is tougher in some parts of the market than others. Also, there may be some customers where the higher costs push them below the poverty line and hence into fuel poverty. But the effect will be much more muted than under the old definition

- there would however be a marked impact on the average "depth" of fuel poverty where – again assuming a simple proportionate price increase – a 10% increase in prices would result in a 10% increase in the "depth" of fuel poverty. Again, this is acknowledged in the Fuel Poverty Statistics report: "For example, if the median required energy costs are £1,000, then an increase of 10 per cent will result in a rise in the median to £1,100. A household with required energy costs above the median, say £1,500, will see an increase in their energy costs to £1,650. Their fuel poverty gap will therefore increase from £500 to £550," (ie by 10%).

Other factors that are important from a fuel poverty perspective in the design of a support scheme are:

- **which fuel?** If costs are to be recovered through energy bills, then the question of which bill is important. As noted above, currently all levy costs (apart from ECO) are recovered through electricity bills which creates a particular problem for customers who use electricity for heating. Using electricity for heating means that electricity usage will be higher than it otherwise would be and loading additional levies onto the electricity bill would increase relative costs and hence increase numbers in fuel poverty

- any **targeted assistance** or compensation? While the challenge of living in a higher heat cost world will be unwelcome across the population there are clearly customers who are already struggling to heat their homes at current prices and where a significant increase would be untenable. There will therefore be a need for some form of targeted assistance to help with up-front costs for those unable to pay or to mitigate the impacts of other levies among particular groups

- living in the **real world**: In designing Green Deal usage assumptions and energy savings were based on the BREDEM model but, in reality, fuel poor customers would often not have made the assumed level of savings (given they were originally under-heating) and hence would not actually benefit from the "pay as you save" model (especially once high interest rates were added in). Any incentive schemes and modelling needs to take account of the specific needs of those in fuel poverty.

8.4 Link to Fuel Poverty definition and targets

The fuel poverty targets and metrics provide a focus now on tackling the underlying causes of fuel poverty and in particular the need to address energy efficiency in low income homes. However, they need to be treated carefully if they are to be used as a basis for choosing between alternative decarbonisation pathways out to 2050. In particular:

- the use of a relative measure for fuel poverty in England means that general bill increases have a muted effect on the numbers in fuel poverty – the "depth" of fuel poverty captures that effect. In terms of understanding the impacts of heat decarbonisation it will therefore be important to look at the impacts on the "depth" of fuel poverty rather than the numbers in fuel poverty

- SAP targets are helpful while the focus is on energy efficiency and replacing more costly/higher carbon heating with gas central heating. However, for the choice between existing and other low carbon heating solutions SAP will not necessarily drive the best choices for those in fuel poverty given they don't take account of the upfront costs of the different solutions. The FPMACC curve provides a way of capturing the cost effectiveness of different solutions taking account of up-front costs and should be extended over time to include a wider range of low carbon heat solutions.

As noted above the Committee on Climate Change has concluded that *"If the insulation and low-carbon heat installations required to meet the carbon budgets can be successfully targeted at the fuel poor then around three-quarters can be lifted out of fuel poverty by 2030. However, meeting the Government's goal of improving fuel poor homes to efficiency band C by 2030 would require roughly doubling the funding currently provided under the Energy Company Obligation"*[55].

The Committee on Fuel Poverty and the Committee on Climate Change are due shortly to commission a joint study looking at potential win-wins and how best to target schemes to deliver the maximum benefits on decarbonisation and fuel poverty. This will be an important contribution to this debate.

The analysis that underpins the Committee's finding shows that while targeting measures in this way would lift three quarters of households out of fuel poverty there would be a further 400k households who would then move into fuel poverty as a result of the threshold changing. It is also based on the assumption that these measures would be funded through taxation as the RHI is now.

The CSE analysis[56] that was the basis for this statement used detailed bottom up modelling taking account of the types of property and the range of measures identified by the CCC as needed to meet the 4th carbon budget, looking out to 2030. They were able to use this model to explore a range of scenarios for how the measures were targeted and how they were funded as well as looking at the impacts UK wide under both a 10% measure and a LIHC measure. The table below shows the extremes of the scenarios that they considered and highlights the importance of focussing on questions of who pays and who benefits in designing any heat decarbonisation programme.

Table: Impacts on UK fuel poverty in 2030 of different policy approaches

	LIHC Number (m)	LIHC £	10% definition no. (m)
Current	2.86	639	5.6
2030 baseline (no policy costs)	2.95	774	6.3
Perfect targeting on fuel poor, no bill pass through	1.19	330	3.3
No fuel poor benefit Full bill pass through	3.76	1178	8.1

Source: CSE Annex V

As noted above, the challenges of moving to full heat decarbonisation by 2050 will involve even more significant costs and hence it is essential that the potential impacts on those in fuel poverty – and how to mitigate them – are considered alongside the technical options.

8.5 Potential impact on fuel poverty of full decarbonisation

Quantifying impacts of such complex changes on fuel poverty is difficult. However, based on the '10%' definition[57], the additional total costs from heat decarbonisation as shown in chapter 6, if recovered evenly across 20 years through levies on energy bills, could create an extra 0.6 million to 2.6 million fuel poor households in GB. This could also equate to a 16% to 65% increase on today's measure of the depth of fuel poverty in England.

These are extreme calculations where all costs have to be recovered through energy bills, but shows the importance of considering alternative means to fund and finance any investments to avoid such adverse impacts.

9. Conclusions - special features of Heat which impact on policy choices

In the preceding discussion, a number of features of heat were highlighted that had implications for scheme design. These included:

- all low carbon heat solutions require changes to customers' heating systems in their home and may impact on comfort factors or the responsiveness of the system. This means that end consumer engagement and incentivisation is a much more important consideration than it is in the electricity sector where most changes are made centrally and do not impact directly on consumers

- for a variety of reasons - the costs of district heating being highly dependent on uptake levels, or the system requirements for a conversion to 100% hydrogen which mean customers cannot be offered a choice of gas – there will need to be either strong incentivisation, regulation or mandation, if efficient solutions are to be delivered longer term at the scale required

- the optimal solution will be highly dependent on the location and type of property. This points to a greater role for local authorities in strategy development and potentially financing and funding, in particular for district heating

- the very different cost profiles (ie the mix of up front and ongoing costs) associated with the different solutions raises equity concerns – in particular if a mandated approach is followed

- Ofgem regulates gas and electricity but not heat. This means that a consistent approach to network regulation – and coordinated, system level thinking – is currently precluded.

In addition, the different technical options raise different challenges from a fuel poverty perspective:

- for heat pumps the key issue is the need for help with up-front costs. Heat pumps are used in other countries but there is low customer acceptance here and they are not suitable for all homes. The RHI is available (tax funded) but does not help the fuel poor. There will also be a need to consider how the electricity network reinforcement can best be funded as part of the next price control discussions

- for district heating the key issue is around regulation of this new class of monopoly assets. Again, district heating is technically proven but with limited experience to date in the UK. The Heat Networks Development Unit and HNIP (tax funded) are providing necessary early support. Regulation could be a win-win providing consumer protection and risk reduction for the companies. Where local authorities play a leading role, there is scope for them to take account of the fuel poverty impacts

- for repurposing the gas grid there are still huge technical unknowns and the expectation is that any solution will involve both consumer up-front costs and the development of new gas sources. These high costs point to the need for significant mitigating action around fuel poverty, especially in the context where switchover would need to be mandated for those connected to the gas grid. Although some of these costs could be funded through the gas networks/ customer bills, parity with other solutions point to taxation as a more equitable approach here too.

10. Summary of recommendation

10.1 Ensure joined up thinking

The implications of heat decarbonisation on those who struggle to heat their homes is a vital issue given the fundamental importance of heat to them and the scale of costs involved.

There is a need to join up heat and fuel poverty policy to ensure that opportune action can be taken to address the two issues in parallel.

Arrangements need to be in place to monitor and control the bill impact of policies for heat decarbonisation.

10.2 Move now on no regrets "win-win" solutions targeting fuel poverty

Energy efficiency should remain a priority under any scenario (albeit with some limit on what measures are cost effective – which may vary by what the long-term solution is considered to be). This should not be ignored by policy makers and can be progressed now in most cases, especially where it makes a contribution to alleviating fuel poverty and ensuring a healthy and warm living environment. Meeting the EPC fuel poverty target for England is vital both in its own right and as a step towards decarbonisation.

Recognising that those off the gas grid are in deepest fuel poverty and that heat pumps can provide a cost-effective solution for those customers (now and in future) steps should be taken early to promote their uptake where appropriate.

Work is needed to explore the potential for smarter storage heaters which could provide a win-win solution with minimal upheaval for large numbers in fuel poverty today.

10.3 Start positioning for the future

R&D expenditure plus larger scale technology trails should be directed now towards reducing the costs and improving performance of the various technologies.

Further consumer research is needed to build understanding and help design solutions with increased customer acceptability/appeal which will also help reduce the level of any subsidy required. As a part of this there is a need to understand the particular requirements of those in fuel poverty or in vulnerable situations.

Building understanding around use of hot water and options for improving efficiency in that space will be important as this accounts for an increasing proportion of energy use.

Development of local area plans for heat would allow different local factors to be fed into identification of the appropriate mix of solutions in an area, including taking account of fuel poverty.

The idea of regulating heat networks (in a proportionate way) should be further explored.

Building optionality into the system now will help reduce end costs (e.g. design boilers to facilitate switchover)

As more experience is gained of the in-situ costs of different solutions, the FP MAC curve should be updated to include the full range of solutions recognising how this may vary for different housing types, occupancy patterns and demand levels.

10.4 Long term scheme design to mitigate fuel poverty impacts

Funding any subsidies through taxation rather than the energy bill is less regressive and will avoid adverse impacts on the depth of fuel poverty.

Grants to deal with the up-front costs of in-home changes are likely to be more cost effective than ongoing payments and are essential to enable low income households to participate.

Design of any schemes aimed at individual consumers needs careful research to understand the wider customer drivers and impacts. If schemes are to be funded through bills then close attention should be paid to the design of the scheme to minimise the impacts on fuel poverty (for example using a protected block tariff design).

11. Appendix: Examples of the range of approaches to government / regulatory support

Incentives aimed at customers to encourage them to take up measures

Energy Company Obligation (ECO)

The ECO operates on a GB-wide basis and is currently the only domestic energy efficiency delivery mechanism in England. ECO has been in place since 2013 and follows other similar schemes – the Carbon Emissions Reduction Target (CERT) and Community Energy Saving Programme (CESP) which ran in parallel between 2008/9-2012, replacing the Energy Efficiency Commitment (EEC) which ran from 2002-2008. The current phase of ECO is referred to as the ECO transition or ECOt that has been running since April 2017 and will conclude in Sept 2018. The ECOt currently has two key elements:

- the Carbon Emission Reduction Obligation (CERO) which can help fund the installation of insulation and district heat connections. This component of the scheme includes a sub-target for solid wall insulation.

- the Home Heating Cost Reduction Obligation aimed at promoting measures which improve the ability of low income and vulnerable customers to heat their homes (the "affordable warmth" group); again, helping to fund insulation and also providing some limited support for gas boiler repairs and replacements

The obligation takes the form of a licence requirement on obligated energy suppliers (although CESP also used to include large generators). This gives Ofgem the power to take enforcement action if delivery targets are not met. A supplier's inclusion within ECO is based on a supplier's customer numbers, and the level of the obligation is based on domestic customer usage (gas and electricity). As such, the costs for delivery are born by suppliers and hence paid for by customers at large. This has provoked some criticism for being regressive when compared to funding the scheme (or alternatives) out of general taxation. A more specific criticism of the earlier schemes was that by setting the target based on numbers of domestic customers rather than consumption the incentive was for suppliers to reflect it in their charges as effectively part of a standing charge. This further reinforced the regressive nature given that typically (but not exclusively) those on lower incomes use less energy. As highlighted in the main report, the policy response to date has been to focus the overall programme increasingly on those in or at risk of fuel poverty in line with the Fuel Poverty Strategy for England. However, the overall 'notional annual spend' of ECO has also been significantly reduced from the original £1.3bn in 2013 to £640m currently. New Ministers have also yet to confirm if there will be any further delay beyond the transition phase to being fully focused on reducing fuel poverty, with a consultation planned for winter 2017/18.

Domestic Renewable Heat Incentive (RHI)

Provides payments to householders to offset the cost of installing low carbon heating systems in individual homes. It covers solar thermal, air source heat pumps, ground source heat pumps and biomass. It is open to homeowners or landlords but not normally to new build. The tariff in terms of pence/kWh varies between technologies – paid quarterly for seven years. As noted in the body of this report the original intention was for the costs to be recovered through a levy on gas suppliers and providers of fossil fuel for heating but this proved too complex and the costs are recovered through taxation.

Feed-In Tariffs (FiT)

Established in 2010 the scheme requires electricity suppliers to pay people with small scale renewable generation equipment for the electricity they generate. They are paid a fixed price per MWh for all the electricity they generate and an additional sum for any they export. The tariff varies between technologies and there are now caps in the numbers of new installations that can receive support in any period (so that applications join a queue for entry into the scheme). All suppliers above the 250k threshold in terms of customer numbers have to register and make FIT payments – smaller suppliers can do so on a voluntary basis.

Ofgem acts as the manager of these payments ensuring that all electricity suppliers (whether registered as a FIT provider or not) contribute equally to the costs of the scheme – noting in addition that a customer can use a different supplier for his FIT than his energy supply. Suppliers have to contribute to the Ofgem E-Serve FIT Levelisation Fund based on market share of combined domestic and non-domestic usage. Because the costs are linked to electricity usage, homes that have electric heating arguably bear a disproportionate share of these costs while those who generate gain a further benefit from avoiding the costs of this and other schemes, as set out in the main report.

Green Deal

The Green Deal was introduced in 2013 as a means of providing finance for energy efficiency measures with the concept that the costs could then be recovered through the bill (on a "pay as you save" model). As noted in the main body of the report the costs had to be recovered through electricity bills for practical reasons despite the fact that savings would typically be on heating – but combined bills were intended to be lower. A Green Deal Finance Company was set up to provide the loans (at interest rates of around 7%) and suppliers had obligations placed on them to collect the money through the bill and to repay the Green Deal Finance Company.

Although the primary focus was on the provision of finance, arrangements were also made for Green Deal Assessments to be carried out by registered assessors (for a fee which could be waived if they were then given the contract for the work) who would identify what cost effective measures were suitable for the property. The work would then be carried out by registered Green Deal providers. These arrangements were intended to help build understanding and confidence in the sector. In order to try to stimulate demand Government also made available funding for "cash back" and other incentives, funded through taxation.

The scheme was not successful and following the 2015 election the Government abandoned it. The scheme was seen as overly complex, the interest rates were not particularly attractive and there are wider consumer barriers beyond simply financing. In January 2017, the residual Green Deal Finance Company was sold to investors who are exploring whether there are still opportunities, for example in the landlord sector where the ability to have improvements paid for by tenants through electricity bills may still have appeal.

Scotland: HEEPS

Since 2013, the Scottish Government has supported domestic energy efficiency under Home Energy Efficiency Programmes for Scotland (HEEPS) – an umbrella programme made up of a range of initiatives. The two key schemes targeting fuel poor homes are HEEPS: Area Based Schemes (ABS) and HEEPS: Energy Assistance Scheme (EAS), recently rebranded as HEEPS: Warmer Homes Scotland.

Wales: Warm Homes

In Wales, the Welsh Government supports households under Warm Homes, principally comprised of the Nest and Arbed schemes. Through Nest, on average £20 million has been invested annually by the Welsh Government to deliver energy efficiency measures to low income private tenure households living in the worst housing stock.

Network Regulation

Alternative models of network regulation

For the **offshore transmission** links (OFTOs) the current regime involves the offshore generator managing the design and build phase using primarily equity finance but with Ofgem then running a tender for companies to take over the management of the asset on a regulated price cap basis. The experience is that this has allowed projects to be delivered with a much lower cost of capital than for the RIIO price control - reflecting the fact that investors are highly geared, have avoided the construction risk and that in the operational phase risks are borne by consumers at large (if the generator fails to generate) or by the generator.

A similar regime is being proposed for elements of the **onshore transmission** networks that might in future be competitively tendered. There has been debate on the merits of tendering for a full design, build and operate solution – or whether the design is done by the SO and the tender is for just building and/or operating.

For **interconnectors** Ofgem runs what is known as a "cap and floor regime" where, if it can be shown that the interconnector is in consumers' interests the developer is given a licence which guarantees a minimum level of revenue (the floor) but limits the maximum revenue that can be earned (the cap). Again, energy consumers bear the risk of revenue falling short of what is expected.

For connections and small scale **independent networks** there is now a competitive market with developers seeking bids from a range of providers. The independent networks are licensed by Ofgem and are limited in the charges that they can levy by a relative price control that is administratively light touch (setting charges linked to those of the main distribution networks) **incentives on network companies through RIIO**.

Gas connections to fuel poor homes are delivered under Ofgem's **Fuel Poor Network Extension Scheme (FPNES)**. The scheme operates by issuing a 'voucher' to an eligible household to cover the cost of a connecting the property to the gas network. FPNES has been running since 2008 and is committed until at least the end of 2021. Connection targets are set by Ofgem at the start of each price control period. For the current RIIO-GD1 price control mechanism 2013-2021, GDNs have a target of a minimum 91,203 fuel poor connections.

Within RIIO the network companies also have a range of incentives aimed at delivering particular outcomes. Companies are rewarded or penalised for their performance with the costs (or savings) reflected in their allowed revenues and hence network charges. Some of these incentives are relevant to the transition to low carbon heat:

- incentives where companies can bid for additional funding to develop innovations that will support the transition to a low carbon energy system. This funding has been used for example to explore the use of hydrogen in the gas networks
- customer service incentives which give companies rewards for improved customer service and also for innovative approaches to supporting vulnerable customers
- environmental incentives: though there is no financial incentive, companies progress in connecting biomethane is reported and is intended to provide a reputational incentive.

Incentives aimed at market participants to move to low carbon energy sources

Renewable Obligation - RO

Established in 2002, the RO requires energy suppliers to present RO certificates (ROCs) to Ofgem for each MWh of electricity they supply to customers or make up any shortfall through buy-out payments. The government set the buy-out price in legislation. The money received through buy-outs is paid back to suppliers who have certificates. Renewable generators receive ROCs for electricity generated from accredited plant and effectively sell these to suppliers. The RO was the biggest scheme in the Levy Control Framework. The scheme will not be open to new generating capacity from 1 April 2017 but existing plant will still benefit. The cost of the RO is passed on to domestic and non-domestic customers through bills in proportion to energy used.

Contracts for Difference (CfD)

The Contracts for Difference scheme replaces the Renewables Obligation. Contracts are available to new low carbon generation plants and will be between the plant owner and the government owned body (the LCCC) set up to act as the counterparty to the contracts.

The counterparty body pays the generator holding the contract the difference between the prevailing wholesale price and a fixed price (indexed for inflation) agreed at the start of the contract and known as the strike price. If the wholesale price is higher than the strike price then the generator pays the counterparty. The net cost of payments made by the counterparty is then recouped from suppliers who will recover these costs from domestic and non-domestic consumers.

Capacity Market

The Capacity Market is a system for providing payments to new or existing power generators in exchange for guarantees that they will provide electricity generating capacity (which may or may not be called on).

Non-Domestic RHI

The Non-Domestic RHI is open to businesses, public sector and non-profit organisations. It can also be used for groups of individual homes connected for example by district heating. The range of technologies supported covers solid biomass, heat pumps, solar thermal, deep geothermal, biomethane injection, biogas combustion and CHP driven by a renewable heat source. The tariffs vary by technology and regular payments will be made for 20 years, funded from taxation.

Energy Efficiency Annex

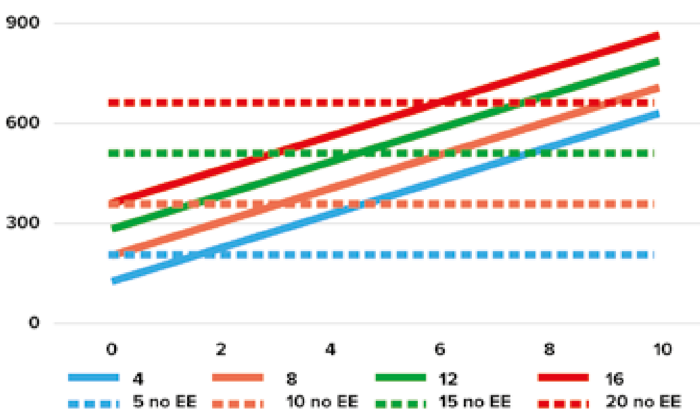
There are likely to be different economic benefits from energy efficiency investment depending on the decarbonisation option, the consumption levels and the cost of energy efficiency. The graphs below illustrate this by comparing, on a separate chart for each decarbonisation option, the change in the ***additional*** costs (on the vertical axis) for each consumption level (represented by the four colours) against different levels of investment costs (along the horizontal axis) ranging between £0 (e.g. behaviour change only) and £10,000 (e.g. for solid wall insulation). In all cases the investment is assumed to achieve a 20% reduction in consumption and a proportionate reduction in the capital costs for heat generation.

These figures are then compared on each chart with the original ***additional*** costs at each consumption level without energy efficiency investment (as shown by the correspondingly coloured dotted lines).

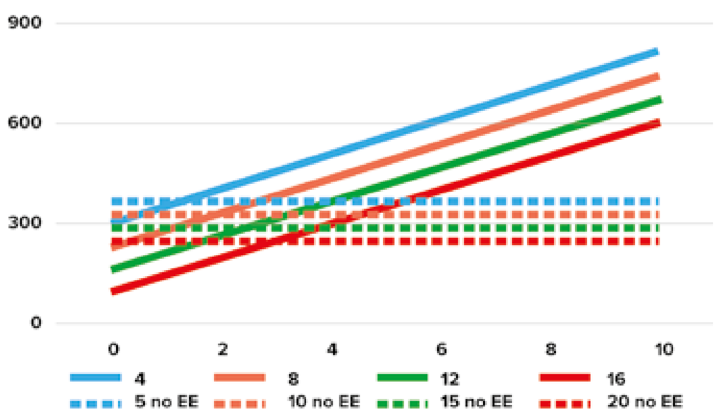
The consumption levels used and shown in the legend reflect the consumption before and after energy efficiency measures – so that without energy efficiency (the dotted lines) consumption levels are 5, 10, 15 and 20 MWh p.a. as above, and with energy efficiency (the solid lines) these are reduced by 20% to 4, 8, 12 and 16 MWh p.a. respectively).

These graphs show very different results across the solutions. If there is no cost in achieving a 20% demand reduction then, not surprisingly, in all cases there is a reduction in the ***additional*** costs from the baseline (the equivalently coloured dotted line). Moving to the right as the cost of achieving the 20% energy efficiency improvement is increased, the results start to vary. In each case the capital costs of decarbonisation must still be recovered, as must the ***additional*** energy efficiency investment, however the fuel cost changes (both increases and decreases) will be less at lower consumption levels. The overall impact on ***additional*** costs therefore varies depending on the relative balance of up-front capital and ongoing fuel costs.

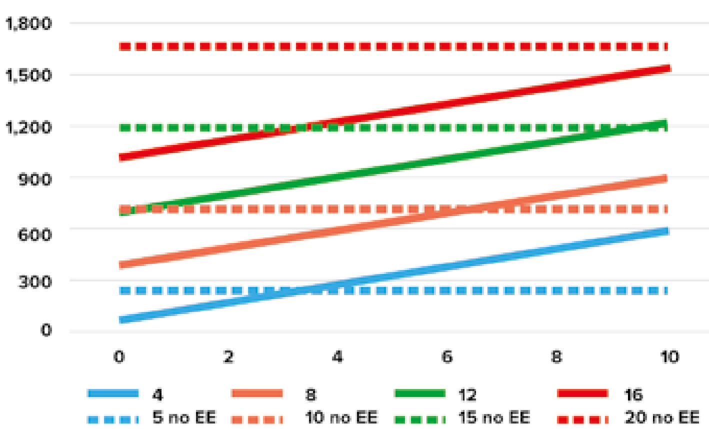
Additional costs versus EE-investment - Hydrogen



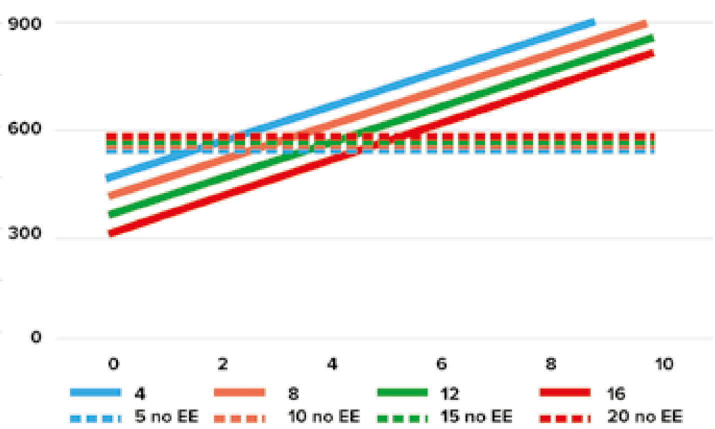
Additional costs versus EE-investment - DH-high



Additional costs versus EE-investment - Direct electric



Additional costs versus EE-investment - DH-low



The results for the various technologies can be summarised as follows:

- for direct electric heating, the overall variation is considerably greater than for the other options due to the very high fuel cost (NB the scale of the vertical cost axis is twice that of the others). If the investment cost is £2,000 the reduction in ***additional*** costs would be economically justified at all consumption levels (i.e. the solid line is below the equivalent dotted line). At the two highest consumption levels, the additional costs are reduced even if £10,000 must be invested to achieve the 20% reduction in consumption

- investment of £2,000 for the 20% improvement also leads to a reduction in the ***additional*** costs for hydrogen at all but the lowest consumption level

- for both hydrogen and direct electric heating, the highest ***additional*** costs arise at the ***highest*** consumption levels since they are dominated by fuel costs

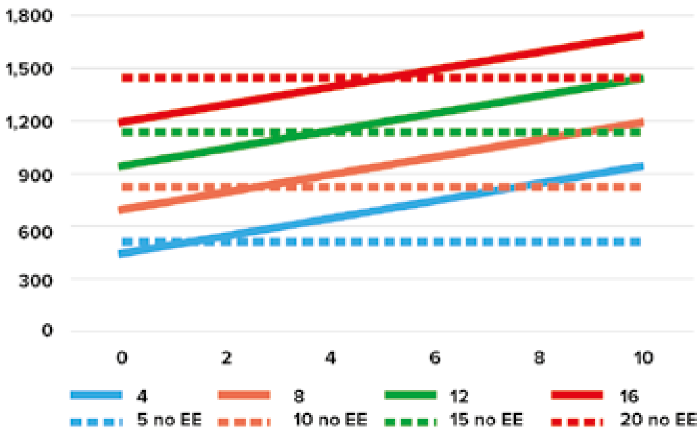
- for district heating (and heat pumps which show very similar results to the high customer density district heating example), the benefits of the energy efficiency investment are much more limited reflecting the lower proportion of fuel costs. For the high-density scheme, modest improvements are only seen at the lower consumption levels and only when the investment needed for the 20% demand reduction is £2,000 or less. In all other cases, the energy efficiency investment leads to higher ***additional*** costs

- in contrast to hydrogen and direct electric heating, for all district heating and heat pump examples, the highest ***additional*** costs arise at the ***lowest*** consumption levels, since capital costs dominate and the compensating fuel savings are less at the lower consumption levels.

For comparison, the graph below shows the results for energy efficiency investment applied to the baseline natural gas.

This shows that at £2,000 the energy efficiency investment reduces the ***total*** costs for all but the lowest consumption level. At higher investment costs, the benefit reduces or disappears for all but the high consumption level, for which £5,000 would be the maximum cost-effective level of investment. Higher levels of investment would only be economically justified if more than 20% savings could be achieved or if there were other benefits as discussed above.

Costs versus EE-investment - Natural gas



Cost Annex

Gas	5	10	15	20
Capital (£)	1,750	2,000	2,250	2,500
Maintenance (£p.a.)	150	150	150	150
Annual fixed costs (£)	238	250	263	275
Fixed costs (£/MWh)	48	25	18	14
Fuel costs (£/MWh)	60	60	60	60
Total costs (£/MWh)	108	85	78	74
Total costs (£p.a.)	538	850	1,163	1,475

Hydrogen	5	10	15	20
Capital (£)	2,750	3,000	3,250	3,500
Maintenance (£p.a.)	150	150	150	150
Annual fixed costs (£)	288	300	313	325
Fixed costs (£/MWh)	58	30	21	16
Fuel costs (£/MWh)	90	90	90	90
Total costs (£/MWh)	148	120	111	106
Total costs (£p.a.)	738	1,200	1,663	2,125

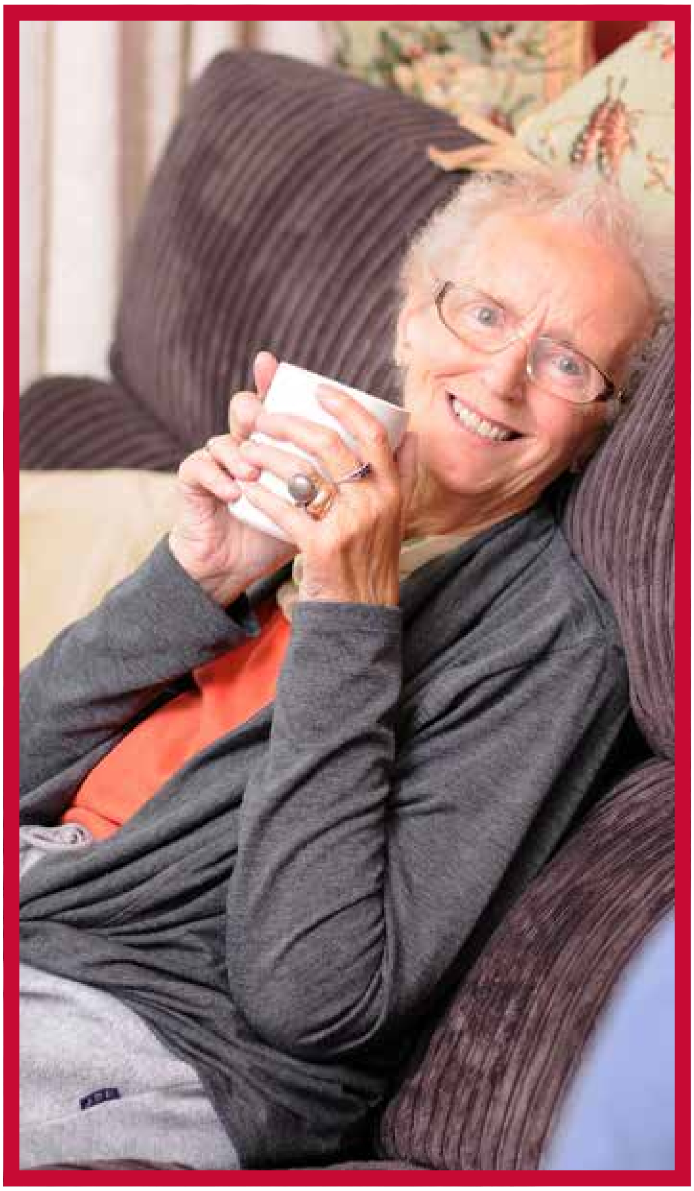
Heat pump	5	10	15	20
Capital (£)	12,000	13,000	14,000	15,000
Maintenance (£p.a.)	150	150	150	150
Annual fixed costs (£)	750	800	850	900
Fixed costs (£/MWh)	150	80	57	45
Fuel costs (£/MWh)	50	50	50	50
Total costs (£/MWh)	200	130	107	95
Total costs (£p.a.)	1,000	1,300	1,600	1,900

Storage heating	5	10	15	20
Capital (£)	4,000	5,000	7,000	9,000
Maintenance (£p.a.)	100	100	100	100
Annual fixed costs (£)	250	350	450	550
Fixed costs (£/MWh)	50	35	30	28
Fuel costs (£/MWh)	110	110	110	110
Total costs (£/MWh)	160	145	140	138
Total costs (£p.a.)	800	1,450	2,100	2,750

District electric	5	10	15	20
Capital (£)	1,200	1,400	1,600	1,800
Maintenance (£p.a.)	0	0	0	0
Annual fixed costs (£)	60	70	80	90
Fixed costs (£/MWh)	12	7	5	5
Fuel costs (£/MWh)	155	155	155	155
Total costs (£/MWh)	167	162	160	160
Total costs (£p.a.)	835	1,620	2,405	3,190

DH high	5	10	15	20
Capital (£)	10,000	10,500	11,000	11,500
Maintenance (£p.a.)	150	150	150	150
Annual fixed costs (£)	650	675	700	725
Fixed costs (£/MWh)	130	68	47	36
Fuel costs (£/MWh)	50	50	50	50
Total costs (£/MWh)	180	118	97	86
Total costs (£p.a.)	900	1,175	1,450	1,725

DH low	5	10	15	20
Capital (£)	12,000	12,500	13,000	13,500
Maintenance (£p.a.)	175	175	175	175
Annual fixed costs (£/MWh)	775	800	825	850
Fixed costs (£/MWh)	155	80	55	43
Fuel costs (£/MWh)	60	60	60	60
Total costs (£/MWh)	215	140	115	103
Total costs (£p.a.)	1,075	1,400	1,725	2,050



End notes

1. e.g. Imperial College, MacLean et al; KPMG/ENA; Northern Gas Networks H21; Policy Exchange
2. Association for the Conservation of Energy (March 2015) Chilled to Death: The Human cost of Cold Homes
3. Committee on Climate Change (March 2017) Energy Prices and Bills – impacts of meeting carbon budgets
4. Sutherland tables
5. e.g. Heat and Energy Efficiency: Making Effective Policy (Committee on Climate Change)
6. See http://www.imperial.ac.uk/media/imperial-college/research-centres-and-groups/icept/Heat-infrastructure-paper.pdf
7. See http://www.ccsassociation.org/why-ccs/ccs-projects/international-projects/
8. This is based on current practice and is not a recommendation for how this should be done going forward, which is explored later in the paper.
9. For this and other solutions it is possible that cooking appliances as well as boilers will be affected
10. For the conversion from town gas these costs were borne by customers who could afford to pay. On the Isle of Man, they were covered by the gas network company
11. Shallow charges cover only the direct impacts of connection; Deep charges include wider system reinforcement
12. Ofgem Insights paper on households with electric and other non-gas heating (Dec 2015)
13. See http://www.svenskfjarrvarme.se/Global/EU-fr%C3%A5gor/Consultation%20Forum%2009092015%20-%20Issue%20Paper%20IV%20-%20Linking%20heating%20and%20cooli.pdf
14. Citizens Advice (January 2016) District Heating Networks
15. See http://provpol.com/wp-content/uploads/2016/04/Renewable-energy-by-2020.pdf
16. See https://www.energynetworks.org/assets/files/gas/futures/KPMG%20Future%20of%20Gas%20Main%20report%20plus%20appendices%20FINAL.pdf
17. Also assuming some limited reduced demand levels compared to today
18. NB Because this chart looks at **additional** costs, over and above natural gas, it is important to note that the **overall** costs will still be higher than natural gas regardless of the relative movements.
19. This is an over-simplification for heat pumps where, over the year, as little as 50% of the hot water may be provided and where direct immersion heating may be required, adding significantly to the cost
20. Under the RHI, although a subsidy is provided, this is through ongoing payments and the householder or business must initially finance this themselves
21. 'shallow' costs cover local upgrades arising from the higher electricity requirements. 'Deep' network upgrade costs for the impact further into the system would be paid for by the DNO and normally recovered from all users through higher network charges.
22. Research on District Heating and local approaches to heat decarbonisation. Annex 1: overcoming barriers to district heating. Frontier Economics (November 2015)
23. Heat in Homes: Customer choice on fuel and technologies. University of Exeter (July 2011)
24. Consumer Challenges for Low Carbon Heat (2016)
25. This is because household gas consumption is not capped under the EU ETS
26. See for example the NAO report on Green Deal and the Energy Company Obligation (April 2016) which notes that 14,000 homes took up Green Deal loans with an estimated additional 35,000 taking action on the back of the assessment. The scheme cost £240m.
27. Around 12% when interest rates were near zero
28. But noting that areas with a high Index of Multiple Deprivation can nonetheless include well off areas
29. The NAO report also picks up on the extent to which ECO is effectively targeted on the fuel poor
30. See Citizens Advice Solar PV Report
31. UKERC Policy Briefing (Nov 16) Review of UK Energy Policy
32. The specific reasons for the shift are not totally clear. See Political Power and the development of the GB renewable heat incentive. Richard Lowes University of Exeter (2016)
33. See for example Centre for Sustainable Energy: Distributional Impacts of Climate Change Policies (2010). The same point has been made by the CCC, IFS, NAO, CFP and FPAG.
34. A review of the suppliers Consolidated Segmental Statements for 2015 shows that how the costs of ECO are allocated between gas and electricity varies between suppliers and hence it cannot simply be assumed that because the obligation is linked to usage suppliers will recover costs on that basis.
35. Committee on Climate Change (March 2017) Energy Prices and Bills Report
36. Controlling the consumer funded costs of energy policies: the Levy Control Framework (Oct 2016)
37. As meeting the obligation is a licence condition, failure to meet it can lead to penalties of up to 10% of turnover.
38. NI Sustainable Energy Programme, see: https://www.uregni.gov.uk/sites/uregni.gov.uk/files/media-files/NISEP_Annual_Report_2014-15_FINAL1104162.pdf
39. NEA – In From The Cold (Feb 2017)
40. See for example the Citizens Advice paper "The Tariff Transition: Considerations for Domestic Distribution Tariff Redesign in GB" (May 2016)
41. Ofgem Targeted Charging Review (March 2017)
42. Research on District Heating and local approaches to heat decarbonisation. Frontier Economics (2015)
43. See https://ens.dk/sites/ens.dk/files/Globalcooperation/regulation_and_planning_of_district_heating_in_denmark.pdf
44. This is a real issue now in Hawaii and is being debated across the US and Australia. See for example Rocky Mountain Institute – the Economics of Grid Defection
45. By changing the operating pressure in the gas networks, additional gas can be added to or removed from the system to help balance supply and demand
46. Distributional impacts of UK climate change policies CSE (2010)
47. Can energy charges encourage energy efficiency? Ofgem discussion paper (July 2009)
48. Personal Carbon Trading - House of Commons Environmental Audit Committee (May 2008)
49. For example, the Average Demand Reduction Obligation raised in Beyond the ECO. CSE (Nov 2014)
50. EFRA Select Committee on Energy Efficiency and Fuel Poverty HC37 2009
51. See Fuel Poverty Methodology handbook BEIS / BRE updated September 2016
52. Source: Fuel Poverty Statistics 2016 BEIS
53. It should be noted that oil prices have dropped markedly recently and hence in the short term oil heating can be the most cost effective
54. VCharge, a company established in the US and now part of OVO, have received funding from the Scottish government's Local Energy Challenge Fund to run projects using this technology in Mull and Orkney. They are now exploring the potential for it to be used more widely in tower blocks for example. SSE has also carried out pilots using Network Innovation Competition (NIC) funding as part of the NINES project.
55. Committee on Climate Change (March 2017) Energy Prices and Bills – impacts of meeting carbon budgets
56. CSE "Fuel poverty implications of carbon budgets to 2030" (2014)
57. Defined as a household spending 10% or more of its income on energy, the old definition used in England and still used in Scotland, Wales and Northern Ireland. Under this definition, it is estimated that each 1% increase in bills leads to an additional 40,000 homes in GB falling under the definition

Action for Warm Homes

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