Next steps for UK heat policy

Committee on Climate Change
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Executive Summary

Heating and hot water for UK buildings make up around 40% of our energy consumption and 20% of our greenhouse gas emissions. It will be necessary to largely eliminate these emissions by around 2050 to meet the targets in the Climate Change Act and to maintain the UK contribution to international action under the Paris Agreement.

Progress to date has stalled. The Government needs a credible new strategy and a much stronger policy framework for buildings decarbonisation over the next three decades. Many of the changes that will reduce emissions will also contribute toward modern, affordable, comfortable homes and workplaces and can be delivered alongside a major expansion in the number of homes.

The key messages in this report are:

- **Government must set out the role of hydrogen for buildings on the gas grid in the next Parliament.** The Government will need to make a set of decisions in the next Parliament and beyond on the best strategy for decarbonising buildings on the gas grid. Specifically, it will have to decide on whether there is a role for hydrogen supplied through existing gas networks (extending the useful life of the gas grid infrastructure) alongside other technologies such as heat pumps.
- **Action is required now to reduce emissions and to prepare for future decisions.** Policy needs significant strengthening now to increase the implementation of low-carbon measures in the next decade:
  - New homes can and should be built to be highly energy efficient and designed for low-carbon heating systems. That will avoid costly retrofit in future and ensure household energy bills are no higher than needed.
  - Energy efficiency should be improved across the existing building stock. This can reduce emissions and energy bills, improve competitiveness and asset values for business, improve health and wellbeing, help tackle fuel poverty and make buildings more suitable for low-carbon heating in future.
  - Deployment of low-carbon heat cannot wait until the 2030s. Low-regret opportunities exist for heat pumps to be installed in homes that are off the gas grid, to install low-carbon heat networks in heat-dense areas (e.g. cities) and to increase volumes of biomethane injection into the gas grid. These opportunities can be taken within funding that has already been agreed provided policy measures are well-targeted and we learn the lessons from previous UK and international experience.
  - Hydrogen pilots can also begin and must be of sufficient scale and diversity to allow us to understand whether this can be a genuine option at large scale. As large-scale hydrogen deployment would require use of carbon capture and storage (CCS), a strategy for CCS deployment remains an urgent priority.
- **The forthcoming Emissions Reduction Plan must incorporate immediate action and prepare for decisions to be made in the next Parliament.** The Government's plan for meeting the fourth and fifth carbon budgets should set clear goals for improving efficiency and rolling out low-carbon heating. The plan should set a timetable of next steps for policy development and ensure that informed decisions can be made in the next Parliament about

the role of hydrogen in heating. We identify a number of policy principles for an effective approach to increase the implementation of low-carbon actions:

– A stable framework and direction of travel, backed up by standards for the emissions performance of buildings that would tighten over time.

– A joined-up approach to energy efficiency and low-carbon heat that works across the building stock, and focuses on real-world performance where possible.

– Simple, highly-visible information and certification alongside installer training to ensure that low-carbon options are understood by consumers and that installers are effective and trusted.

– A well-timed offer to households and SMEs that is aligned to ‘trigger points’, such as house moves, when refurbishment is least disruptive.

– Consistent price signals that clearly encourage affordable, low-carbon choices.

The rest of this summary is in four parts:

i) Actions that should be taken now

ii) Preparing for Government decisions during the next Parliament

iii) Principles that should guide the development of policy

iv) How effective policy can build on the current framework.

(i) Actions that should be taken now

In the next decade, there is a set of measures that are sensible regardless of the longer-term path ("low-regrets" measures). The Government’s Emission Reduction Plan should set clear goals for policy in this area:

- **New-build.** Buildings constructed now should not require retrofit in 15 years' time. Rather, they should be highly energy efficient and designed to accommodate low-carbon heating from the start, meaning that it is possible to optimise the overall system efficiency and comfort at a building level.
- **Energy efficiency improvement to existing buildings.** UK buildings have widely differing levels of energy efficiency. In many cases the gap between the best and poor performing buildings could be reduced substantially by installing insulation or a new boiler, with money saved on fuel sufficient to offset some or all of the upfront cost of the change. Performance reporting in offices reduces costs and adds asset value for tenants and developers. Our scenarios include around a 15% reduction in energy used for heating existing buildings by 2030 through efficiency improvements, requiring insulation of about 7 million walls and lofts in homes, and heating controls and other insulation measures in homes and non-residential buildings.
- **Low-carbon heat networks.** District heating schemes require a certain density of heat demand in order to be economic, which means that they are suited to urban areas, new-build developments and some rural areas. Low-carbon heat sources can include waste heat, large-scale (e.g. water-source) heat pumps, geothermal heat and potentially hydrogen. Current capital funding to 2020 is sufficient to meet the ambition required to 2020, provided

it is deployed effectively. The period to 2020 should be used to develop the policies for delivering a continued expansion through the fourth and fifth carbon budget periods.

- **Heat pumps in buildings not connected to the gas grid.** Heat pumps have faced challenges to date, but remain the leading low-carbon option for buildings not connected to the gas grid. Together with installation in new-build properties, heat pump installation in buildings off the gas grid can help to create the scale needed for supply chains to develop, including developing skills and experience, potentially in advance of accelerated roll-out after 2030. Installation of around 200,000 heat pumps between 2015 and 2020 under our scenarios is consistent with the announced funding to 2020 available under the Renewable Heat Incentive, provided that funding is focused on heat pumps and deployed efficiently, learning lessons from past experience in the UK and elsewhere. Further funding will be needed for deployment in the 2020s.
- **Biomethane.** Injecting biomethane into the gas grid is a means of decarbonising supply without requiring changes from consumers, and provides a route for capture and use of methane emissions from biodegradable wastes. However, its potential is limited to around 5% of gas consumption.

This set of measures can deliver emissions reductions to 2030 consistent with meeting the fourth and fifth carbon budgets. On their own they would still leave a large number of homes and workplaces using heating based on natural gas, and more action will be needed after 2030. The best current understanding about how to achieve the 2050 target at least cost suggests that the decarbonisation of heat for buildings, including those on the gas grid, is essential.

(ii) Preparing for Government decisions during the next Parliament

The main options for the decarbonisation of buildings on the gas grid in the 2030s and 2040s are heat pumps and low-carbon hydrogen. Heat pump deployment could be extended from applications off the gas grid to buildings on the grid. Alternatively, in some regions replacement of natural gas with low-carbon hydrogen may be preferable. To produce low-carbon hydrogen at sufficient scale would require carbon capture and storage to be deployed in the UK.

At present the best balance between hydrogen and heat pumps, alongside heat networks, is unknown. More evidence is required about costs, industry's capacity to deliver and preferences of households and businesses:

- **Heat pumps**. Heat pumps remain a niche option in the UK as previous policies have failed to deliver a significant increase in uptake. However, they are used widely in many other countries (e.g. Sweden and France) and are the primary low-carbon option for most UK buildings off the gas grid. Where they have been installed correctly satisfaction levels are high, even though installations are often disruptive and heat pumps operate in different ways to gas and oil boilers. Low-carbon options to provide electricity for heat pumps are available, although widespread deployment would bring significant challenges for meeting peak demand in winter. Improved building efficiency is an essential part of effective heat pump roll-out.
- **Hydrogen.** A large-scale shift to a hydrogen gas supply is technically feasible for existing gas distribution networks. The difficulty to date in deploying heat pumps more widely means this option merits attention alongside the measures described above for heat pumps. Hydrogen for heating would, in some ways, require less change in behaviour from consumers since hydrogen shares many characteristics with natural gas (e.g. the ability to increase heat supply very responsively). Roll-out would need to be done in a way that

ensures a coherent hydrogen infrastructure that exploits economies of scale, but this could be at a regional rather than national scale.

- A switch to hydrogen would require a switchover programme with some similarities to that for the switch from town gas to natural gas, including replacing gas appliances (e.g. boilers) with hydrogen-compatible ones, but with the need also to put in place hydrogen production facilities. The mechanics of roll-out across large parts of the UK are not yet fully understood and costs are uncertain.
- To produce hydrogen in a low-carbon way at the necessary scale would require carbon capture and storage (CCS) – whilst this is technically well understood, it remains undeveloped. The need for production facilities based on CCS and for large-scale storage of hydrogen may also constrain the areas of the country for which hydrogen is the best option. However, provision of hydrogen and CO_2 infrastructure for industrial clusters, including production of hydrogen with CCS, could provide wider opportunities for decarbonisation (e.g. hydrogen use for heat in industry).

Approaches based on heat pumps, hydrogen and heat networks will only be realised with strong Government leadership at both local and national levels because all of these solutions will require coordination. Most consumers and businesses in a given area would need to deploy the same option in order to keep costs down. If emissions from heating are to be largely eliminated by 2050, a national programme to switch buildings on the gas grid to low-carbon heating would need to begin around 2030, requiring Government decisions on the route forward in the next Parliament.

For hydrogen and heat pump providers to develop their products, innovate and test them ahead of decisions in the next Parliament, the Government will need to offer support in the coming years. Heat pumps require a market of sufficient size to enable increased roll-out between now and 2030. For hydrogen, it will be necessary for CCS to be under active development, together with forward-looking regulations, demonstration projects and innovation support:

- The heat pump market has plateaued at around 20,000 installations per year in recent years. To decarbonise heat supply it would need to run at over 1 million installations a year from the mid-2030s. That gap could be partly closed in the next decade through deployment in new homes, homes off the gas grid and in commercial buildings. Deployment in these areas could also help to overcome issues of technology familiarity that currently constrain take-up, and it provides an opportunity to build a strong supply chain capable of installing effective systems with minimal disruption. Funding that has been allocated through the Renewable Heat Incentive to 2020 is just sufficient to meet this requirement but needs to be properly focused and delivered effectively. Further funding will be needed for deployment in the 2020s.
- Shifting to a hydrogen gas supply, whether regionally or nationally, would require a coordinated Government-led effort to overcome major obstacles. To understand whether this is desirable and how best to proceed, it will be vital to undertake pilots and demonstrations in the next decade. Before a decision to proceed with hydrogen, it would be essential that CCS is under active development in the UK, in order to provide a low-carbon route to producing hydrogen at scale. This should be part of the Government's new strategy on CCS.

- Preparatory action, including R&D and pilots, is required in order to:
  - Test the feasibility of hydrogen for heat and to reassure the public and businesses that fuel switching to hydrogen networks can be done safely, affordably, and with minimal disruption.
  - Improve the understanding of the construction sector, installers and Government about what is required for high-quality heat pump and heat network retrofit across a range of different types of buildings, including interactions with measures to improve fabric efficiency of buildings, and how to standardise and drive down retrofit costs.
  - Improve understanding, across all pathways and as smart controls are rolled out, of how consumers interact with heating systems and appliances, along with how to create consumer-centric products and solutions.

The reforms will require a range of Government and regulatory bodies to act. In the immediate future, it will be important that Ofgem ensures that the next price control review for the gas transmission and distribution networks (for the period from 2021) reflects the wide range of possible pathways for heat supply, including a move rapidly away from fossil fuel use (e.g. under a 'no CCS' pathway) and a shift to hydrogen in the 2030s and 2040s.

(iii) Principles that should guide the development of policy

We identify a number of policy principles that would help the strategy succeed:

- **A stable framework and direction of travel, backed up by evolving standards for the emissions performance of buildings.**
  - Standards should be used to allow competitive markets to develop on a level playing field, including ensuring that low-regret actions are taken up and addressing barriers to implementation (e.g. making sure new buildings are built to be very low-carbon, including low-carbon heating, from the start).
  - Standards for emissions should be tightened over time to reflect the need for continued decarbonisation.
  - The schedule of future standards should be clear to allow businesses and consumers to prepare efficiently and for dynamic markets to emerge.
  - As far as practical, standards should be focused on ends (e.g. reducing carbon emissions) rather than the means (e.g. specific technologies) and should be based on actual rather than modelled performance (e.g. by using data from smart meters).
- **A joined-up approach to energy efficiency and low-carbon heat that works across the building stock, and focuses on real-world performance where possible.**
  - Emissions reductions can be achieved by improving energy efficiency and by shifting to low-carbon fuels. Many of the barriers to action (e.g. disruption from changes, the need to find a trusted installer, financing constraints) are shared across both types of measure. In addition, improved energy efficiency can reduce the cost and improve the suitability of buildings for low-carbon heat options. Renewed policy should therefore seek to take a combined approach.
  - Policy should target distinct groups of householders and businesses. For example: existing subsidies for heat pumps are less attractive for smaller homes given economies of scale; some householders and small businesses will require improved access to low-

cost finance; rented buildings are likely to require different approaches to owner-occupied buildings; more generally, small and medium-sized enterprises (SMEs) are poorly addressed by existing policies.

  - Improving the efficiency of existing heating systems (e.g. by moving to lower flow temperatures) in homes connected to the gas grid through the 2020s can cut bills and emissions, and helps to prepare the stock for widespread roll-out of either heat pumps or hydrogen after 2030.

- **Simple, highly visible information and certification alongside installer training to ensure that low-carbon options are understood by consumers and that installers are effective and trusted.**
  - Awareness of low-carbon heating and energy efficiency options is generally low. In businesses, energy performance is assessed infrequently and often not discussed at senior management or board level, and so has little strategic value or 'salience'. A key policy focus must be improved information (which could be enabled by smart meters), through business performance reporting and building performance labelling that generates value in low-carbon investment.
  - A nationwide training programme is needed to develop high professional standards and skills for implementation of low-carbon choices in the building and heat supply trades. Clearly this would need to be developed in partnership with industry.
  - There is also an opportunity for leadership through public procurement and low-carbon investment, given that the public sector constitutes a third of non-residential heating needs and almost a fifth of heating energy in non-residential leased buildings.
- **A well-timed offer to households and SMEs that is aligned to 'trigger points'.** These include house moves and major renovations, when low-carbon options can be installed with less additional disruption and at lower cost. Trigger points are relevant for effective use of standards, incentives and information. SMEs are responsive to policies built around local business networks and supply chains.
- **Consistent price signals that clearly encourage affordable, low-carbon choices.**
  - While many energy efficiency improvements are already financially attractive, some other measures, including most low-carbon heat options, would not currently be attractive without public subsidy. Consumers will generally only take up these options when sufficiently incentivised to do so, and businesses will only invest and innovate in supplying the market if they are confident that incentives will remain in place.
  - The unattractiveness of some measures in part reflects the current balance of tax and regulatory costs on energy bills: costs of funding low-carbon policies are significantly larger for electricity than gas or oil heating, and the full carbon costs are not reflected in the pricing of heating fuels. In the transition to low-carbon heating, particularly if low-carbon heat is rolled out in different parts of the UK at different times, there will be important questions to be resolved around how to pay for heat decarbonisation.
  - Even where energy efficiency improvements may be financially advantageous, they are often usefully supplemented by additional fiscal incentives to encourage uptake and low-cost loans to enable households and SMEs to cover upfront costs.

(iv) How effective policy can build on the current framework

The existing set of policies is not an effective overall package for decarbonising heating. However, there are positive elements of current programmes that can act as building blocks for a new approach:

- **Standards have been used to drive uptake and development of new markets.** Standards for the energy efficiency of new properties and for boiler efficiency have been progressively tightened over time in line with technology development and in step with the skills of the supply chain. Standards for private-rented properties have already been set out to 2023, but these are in need of a new delivery mechanism given the failure of the Green Deal. Standards should be set further ahead, be extended across the building stock and be backed by tailored delivery mechanisms to ensure compliance.
- **Information provision has been aligned to trigger points.** Energy information for residential buildings is provided at key trigger points of property sale and rental, but this is not translating sufficiently into investment in measures to improve efficiency and there are questions around compliance in the private-rented sector. Energy performance reporting for non-residential organisations and buildings has been rolled out, even if infrequently assessed. For these to be more effective they should be substantially enhanced through a focus on actual performance, more regular reporting, with increased prominence (e.g. board-level, public reporting) and linked to incentives and/or standards for improvement. The smart meter roll-out programme will support a shift towards actual rather than modelled performance for households and SMEs.
- **Significant funding has been allocated.** Funding for low-carbon heating (set under the RHI) is just sufficient to support the increased uptake of heat pumps in our scenarios to 2020 alongside low-regret expansion in the use of biomethane. Achieving greater heat pump uptake is likely to need adjustment of subsidy rates, or a shift towards upfront funding, which could be accommodated within the existing funding pot. Beyond 2020, funding will need to increase in line with the higher required roll-out. Replacing subsidies with electric heating standards to drive heat pump uptake in non-residential properties could release funds for residential heat pumps.
- **The public sector has provided some leadership.** Energy efficiency investments in parts of the public sector have been funded with interest-free loans through Salix Finance. Expansion to central Government and other parts of the public sector would accelerate progress.
- **Some schemes in parts of the UK already demonstrate the principles of good policy design.** Understanding their performance should feed into the development of national policy options. For example:
  - The Home Energy Efficiency Programmes for Scotland (HEEPS) have been delivering improved efficiency in Scotland including through area-based schemes and interest-free loans. A parallel programme is in place to support SMEs. The Scottish Government is going further through the Scottish Energy Efficiency Programme (SEEP), which applies to all buildings and will pilot innovative approaches and multi-year funding certainty for ambitious projects. The Scottish Government has sought to widen the uptake of low-carbon heating by providing low-cost finance.
  - The Arbed scheme in Wales is an excellent demonstration of the broader health, affordability, wellbeing and regeneration benefits of an area-based retrofit programme, as well as improving the appearance and value of the nearly 3,000 properties treated.

There is a good opportunity to build on this success through the implementation of the Wellbeing of Future Generations Act in Wales. Wales also has policies in place to support SMEs to take up insulation and other energy saving measures, through a combination of soft loans and tailored advice.

– The Northern Gas Networks H21 study in Leeds has taken an in-depth look at what would be required to repurpose the city's gas distribution network to hydrogen based on production from natural gas with carbon capture and storage.

The Government's Emission Reduction Plan should set out clear objectives for heating and energy efficiency with a timetable of next steps in policy development to deliver on those objectives. Figure 1 sets out an example of a policy package that can build on existing policies, with a timeline for when we would expect new policies to apply, using a range of different policy instruments and consistent with the principles above.

New policies will need to be developed well in advance. The earlier they are set the more time there will be for the market to prepare. We would expect the Government to refine the policy package based on further detailed analysis, piloting and consultation, and possible development of a White Paper.

The rest of this report is set out in three chapters:

1. The challenge to reduce emissions from heating UK buildings

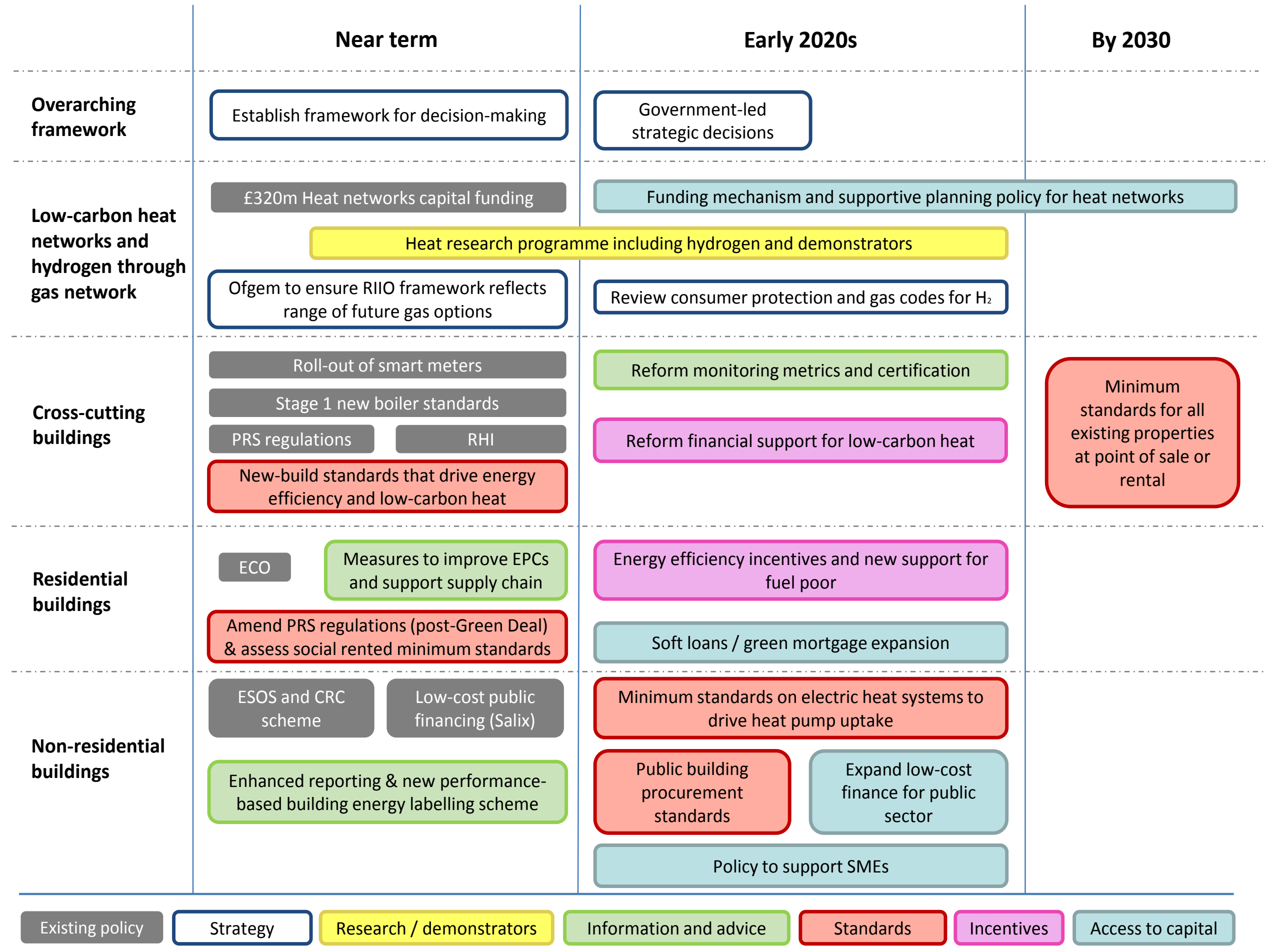
2. Possible low-carbon pathways

3. Policy to drive the transition

It is supported by technical papers setting out the advice received from an academic Advisory Group,[1] assessments of what has worked historically and internationally in driving improvements in energy efficiency and take-up of low-carbon heating, and an analysis of how regulation of the gas grid may need to evolve as the UK's heat supply is decarbonised.

[1] In forming our advice, the Committee have assembled an expert Advisory Group, whose report to the Committee is published alongside this one and summarised in Chapter 3. The group was chaired by Professor Jan Webb (University of Edinburgh) and included Professor Nick Chater (Warwick Business School, CCC), Professor Nick Eyre (University of Oxford) and Professor Robert Lowe (UCL), with contributions from Dr. Peter Mallaburn (UCL).

Figure 1. Example policy package timeline



Notes: A more detailed version is set out in Chapter 3, split into three separate diagrams covering overarching heat policy, residential buildings and non-residential buildings. RIIO is Ofgem's framework for setting price controls for network companies (Revenue = Incentives + Innovation + Outputs); PRS = private-rented sector; H_2 = hydrogen; RHI = Renewable Heat Incentive; ECO = Energy Company Obligation; EPC = Energy Performance Certificate; ESOS = Energy Savings Opportunity Scheme; CRC = CRC Energy Efficiency Scheme (formerly known as the Carbon Reduction Commitment).

Chapter 1: The challenge to reduce emissions from heating UK buildings

Homes and workplaces need to be comfortable to live and work in and affordable to operate. They also need to meet those needs in a lower-carbon way to comply with the UK's climate commitments. An effective strategy to reduce emissions from heating will need to focus on what people and organisations want from building and energy services.

This report considers the options for reducing greenhouse gas emissions from heating buildings in the UK. In the face of uncertainty, the report identifies policy priorities aimed at deploying low-cost and low-regret opportunities while developing other options that are likely to be needed in the long term if the UK is to meet its climate obligations.

This chapter sets out how heating in the UK is currently supplied and the context in terms of how consumers make decisions relating to their heating systems. Chapter 2 identifies possible pathways to decarbonise heating, picking out low-regret measures and decision points for larger changes. Chapter 3 sets out policy considerations for the Government, as part of its wider Emission Reduction Plan for meeting the legislated carbon budgets.

Our key messages in this chapter are:

- Heating and hot water for buildings make up 40% of energy use[2] and 20% of greenhouse gas emissions in the UK.
- These emissions need to be reduced by over 20% by 2030, with a near complete decarbonisation by 2050, as a contribution to the legally-binding targets set by Parliament in the Climate Change Act.
- Achieving those reductions will require a combination of improved energy efficiency and use of low-carbon energy (e.g. waste heat, geothermal heat, electricity, biomethane or hydrogen derived from low-carbon sources). It is not possible now to predict the precise mix that will be preferred by consumers and offer the lowest cost route to reducing emissions to 2050 and beyond.
- People are at the heart of decisions relating to heating. The challenge for policy is to harness consumer choice and to develop markets to deploy the best solutions to reduce emissions.
    - Householders typically want comfortable, attractive, easy to maintain homes, and affordable bills.
    - Commercial investors want improved rental returns on buildings. More generally, businesses want improved productivity and enhanced reputation.
    - Local authorities want new income streams, cost savings and economic regeneration, whilst public services want high-quality, affordable workplaces and community facilities.
    - Social housing providers seek improved rental returns, along with comfortable, high-quality buildings and lower bills for tenants.

This chapter is set out in two parts:

(a) The need for change in the UK's heating systems

(b) Consumer demand and decision-making

[2] On a final energy demand basis - the equivalent figure on a primary energy demand basis is slightly lower.

(a) The need for change in the UK's heating systems

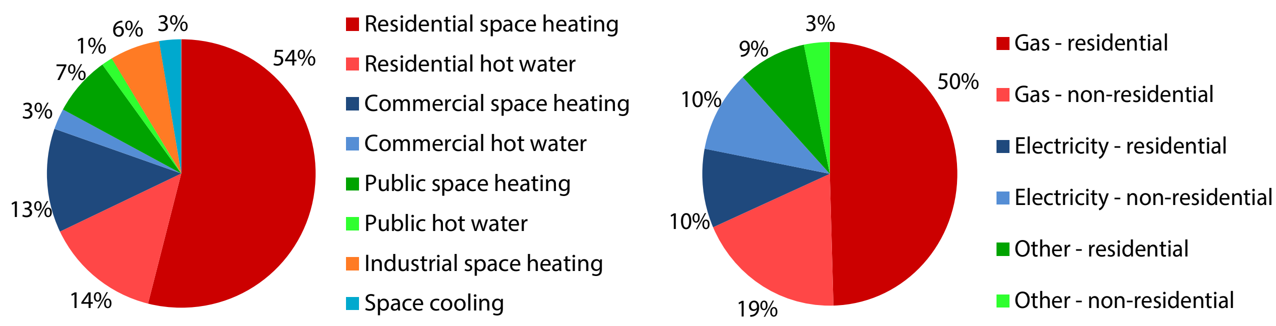
Heating and hot water for UK buildings make up around 40% of our energy consumption, and around 20% of our greenhouse gas emissions. Two thirds of these emissions are from housing, with the rest from commercial, industrial and public premises (Figure 1.1).

Emissions from gas, oil and solid fuel heating fell by a tenth in the years from 2005 to 2012, having been broadly flat before 2005.[3] This fall was a result of improving efficiency of buildings and heating systems, which have more than offset increases in the number of buildings and the average temperature to which they are heated. The roll-out of more efficient condensing boilers has been a strong driver of efficiency improvement in recent years, together with low-cost insulation. Heating emissions have flattened out again since 2013 as progress in rolling out insulation measures has stalled.[4]

A more detailed description of current heat in UK buildings and associated emissions is available in a technical annex to this report.[5]

Cooling (i.e. air-conditioning) is not currently a large source of emissions in the UK. As the climate warms there is potential for this to increase. To the extent that the demand for air-conditioning increases, there will be a need to meet it through low-carbon supply. There are likely to be synergies between reducing emissions from heating, limiting emissions from cooling, and ensuring that buildings are well-suited to a changing climate.[6]

Figure 1.1. UK heating emissions by source and fuel type (2013)



Source: DECC (now BEIS) (2016) *Energy Consumption United Kingdom* (ECUK), CCC analysis
Notes: Total emissions 134 $MtCO_2e$, based on 2013 source and fuel use from ECUK. Electricity emissions from average grid-electricity emission intensity in 2013. Over 90% of space cooling is in commercial premises. Does not include emissions from energy used for cooking which were around 13 $MtCO_2e$. Other energy includes liquid fuels, solid fuels and bioenergy. Percentage figures may not sum to 100% due to rounding.

There is significant potential to reduce emissions by improving the efficiency of buildings and boilers. The Committee's scenarios for the fifth carbon budget suggest these could reduce

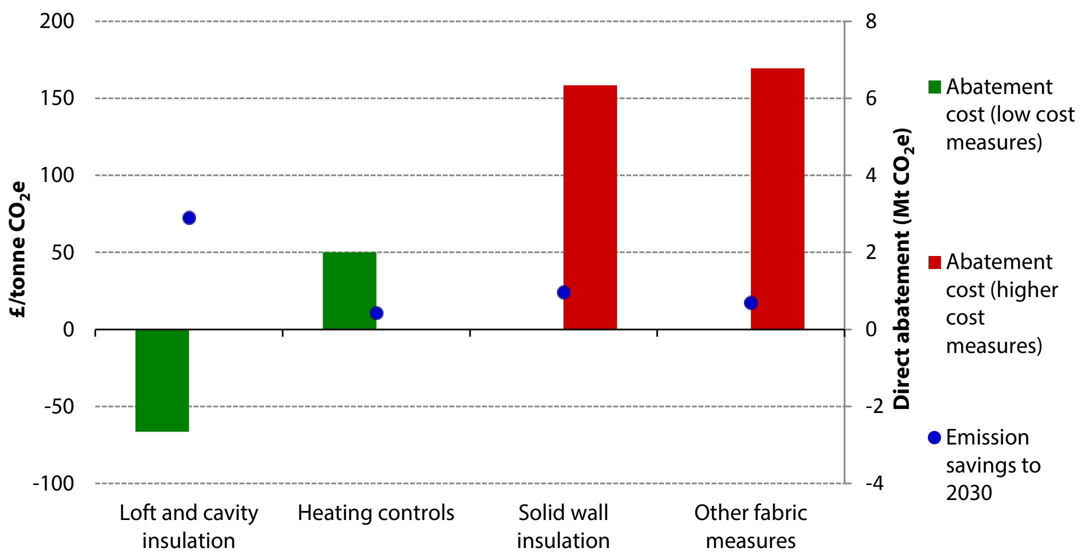
[3] Total direct emissions are used as a proxy here for heating emissions, given that over 95% of buildings fossil fuel consumption is for heating.
[4] On a temperature-adjusted basis, removing the effect of particularly mild or cold winters.
[5] *Annex 2: Heat in UK buildings today*, available online at https://www.theccc.org.uk/publication/next-steps-for-uk-heat-policy/
[6] There are also some trade-offs. For more detailed consideration, see Sansom, R. (2016), *The provision of cooling as part of a smart heating system*, report for the Energy Systems Catapult.

emissions by around 7 $MtCO_2e$ to 2030 at relatively low cost from current levels (Figure 1.2). Further savings of 11 $MtCO_2e$ in electric heating should be realised from decarbonising the UK's power supply and an additional 16 $MtCO_2e$ of abatement from low-carbon heating and demand reduction.

However, greater reductions will almost certainly be needed to meet the UK's commitments to reduce emissions (Box 1.1). Even if success in decarbonising other sectors means that an 80% reduction in overall UK emissions can be achieved with some continued use of gas heating, overall emissions will need to fall further beyond 2050 towards zero.[7] Ultimately this means heat for buildings being very largely based on energy delivered to consumers in non-hydrocarbon form (e.g. electricity, hot water piped through heat networks or hydrogen).

To achieve these further emissions reductions a large-scale shift from gas boilers to low-carbon heating will be required. This is likely to include a combination of heat pumps, low-carbon heat networks, and low-carbon gas (e.g. hydrogen or biomethane) utilising the existing network. For that to be possible by 2050, progress will be needed in the next 15 years to contribute to meeting legislated carbon budgets to 2032 and to prepare for the deeper emissions reductions required thereafter. For example, the Committee's Central scenario to meet the fifth carbon budget, designed to be on track to the 2050 target, involves a reduction in heating emissions of 22% to 2030 relative to 2015.[8]

Figure 1.2. Costs of reducing emissions from heating to 2030



Source: CCC fifth carbon budget analysis.
Notes: Sources of abatement included here are residential only and do not cover all residential abatement (e.g. glazing, behaviour change). Other non-residential low-cost abatement not included here includes Mechanical Ventilation Heat Recovery.

[7] CCC (2016) *UK climate action following the Paris Agreement*, available online at: https://www.theccc.org.uk/publication/uk-action-following-paris/
[8] *Annex 2: Heat in UK buildings today*, available online at https://www.theccc.org.uk/publication/next-steps-for-uk-heat-policy/. This estimate does not include savings of 6 $MtCO_2e$ from boiler efficiency, which are accounted for in the baseline.

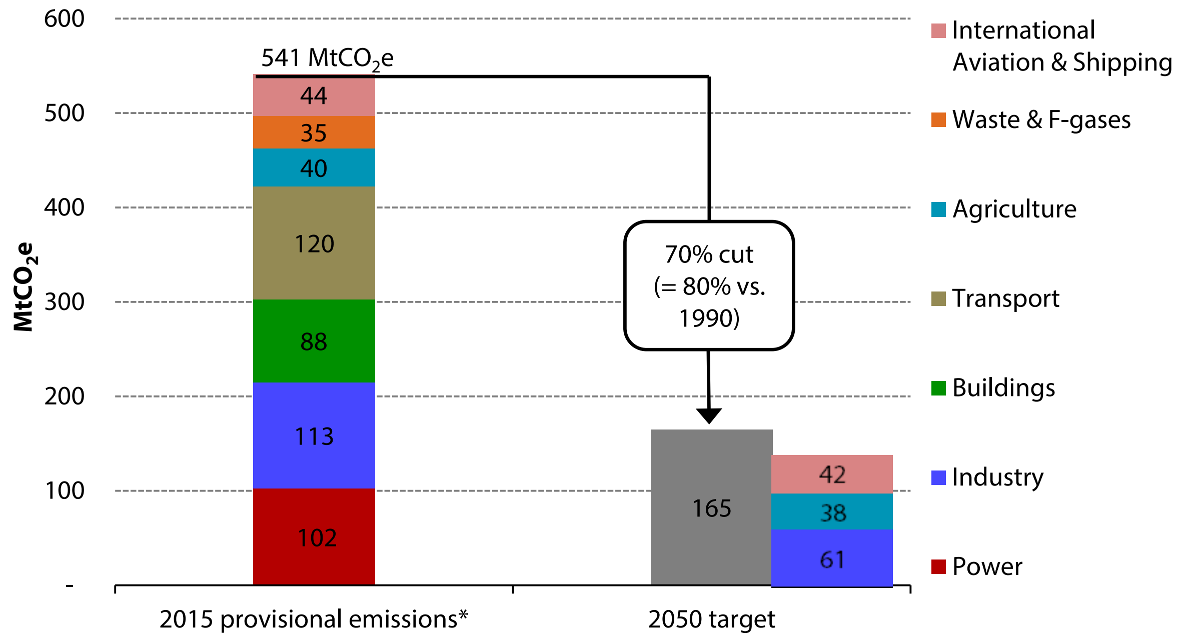
Box 1.1. The need to reduce heating emissions to meet the 2050 target

For the fifth carbon budget advice to Government in 2015, we undertook detailed bottom-up modelling of the costs and potential for decarbonisation of the UK economy by sector to 2050:

- The analysis factored in uncertainty in fuel prices and technology costs, and considered the impact of barriers to uptake on a sector-by-sector basis.
- It also factored in our assessment of the best use of scarce bioenergy sources, based on our 2011 Bioenergy Review (Box 2.6).
- It built on previous scenarios developed for the 2010 *Fourth Carbon Budget*, the 2012 *International Aviation and Shipping Review* (and specifically, the technical annex, *The 2050 target – achieving an 80% reduction including emissions from international aviation and shipping*) and the 2013 *Fourth Carbon Budget Review*.

This shows that meeting the 2050 target requires a near complete decarbonisation of heat. This is because under the central fifth carbon budget scenario to 2050, there are limited cost-effective options for reducing emissions from industry, agriculture and international aviation (Figure B1.1). Remaining emissions from these sectors make up around 140 $MtCO_2e$ of a total 2050 budget of 165 $MtCO_2e$.

Figure B1.1. Hard-to-reduce sectors and the 2050 target



Source: CCC fifth carbon budget analysis.
Notes: 2015 provisional numbers presented here for waste & F-gases and international aviation & shipping are 2014 actual figures. The right hand column shows our assessment of residual emissions in 2050 from International Aviation and Shipping, Agriculture and Industry after cost-effective abatement opportunities have been taken up (our Central scenario).

(b) Consumer demand and decision-making

People care about comfort, cost and ease

Heating emissions result from the burning of fossil fuels (natural gas, heating oil, LPG[9] and coal) to produce heat, which is used to improve the comfort of homes and workplaces. People do not demand these fossil fuels per se – rather, they demand comfortable homes and workplaces, which in most cases are currently achieved by burning gas.

Low-carbon heating systems and energy efficiency improvements will need to be attractive to consumers, either by improving comfort levels or maintaining them while saving money. Consumers must be made better off through the transition.

Consumers also want low-hassle heating systems, both in terms of operation and installation. This creates an immediate barrier to change, since change typically involves some disruption. However, there is no reason for low-carbon heating systems to be any more hassle once installed:

- Biomethane and hydrogen provide virtually identical user experience as natural gas when used in appliances.[10,11]
- Heat pumps and heat networks, when correctly sized and installed, will provide an equivalent level of service to gas heating, albeit with different heating patterns and flow temperatures in the case of heat pumps. They are popular in many European countries.[12] Heat pumps require less servicing than gas boilers.[13]

Innovations in 'smart' energy systems could support low-carbon choices by increasing the focus of people on comfort levels regardless of heating technology and on avoiding energy waste (Box 1.2).

Box 1.2. Smart energy systems

The Government has a manifesto commitment to ensure that every home and business in the country is offered a smart meter, delivered as cost effectively as possible. Smart meters show consumers exactly how much energy they are using and what it is costing, in near-real time. They also send accurate meter readings to energy suppliers, avoiding the need for estimated bills or manual meter readings.

In residential properties the smart metering roll-out obligation requires energy suppliers to take all reasonable steps to replace traditional energy meters with smart meters by the end of 2020. The first stage of the roll-out has involved setting up frameworks to support smart metering, trialling and testing systems and engaging with consumers. By the end of March 2016, 2.9 million smart meters had been installed in residential properties, equivalent to 6% of meters in residential properties. The main roll-out will occur between 2016 and 2020.

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[9] Liquid Petroleum Gas.
[10] In the case of hydrogen, there may be some small differences in the flame quality if used for cooking.
[11] E4tech (2015) *Scenarios for deployment of hydrogen in contributing to meeting carbon budgets*, available online at: https://www.theccc.org.uk/publication/the-fifth-carbon-budget-the-next-step-towards-a-low-carbon-economy/
[12] Hanna R,. Parrish B., Gross R. (2016) *UKERC Technology and Policy Assessment Best practice in heat decarbonisation policy: A review of the international experience of policies to promote the uptake of low-carbon heat supply draft*
[13] Frontier Economics and Element Energy (2013), *Pathways to high penetration of heat pumps,* available online at: https://www.theccc.gov.uk

Box 1.2. Smart energy systems

Research by Citizen's Advice shows that so far users have had high levels of general satisfaction with smart meters, with half of users surveyed giving the maximum satisfaction score. The most popular benefits were the visibility of energy usage and new ways of topping up for pre-payment customers. Around 80% of consumers are viewing their smart-meter data (either through an in home display, app or website) and, of these, 75% are viewing their data weekly or more often. However, while 66% of consumers report savings, the research suggests that some consumers are failing to translate their intention to save energy into action. Smart meters are also highly appealing to around two thirds of consumers without a smart meter, which lays down a challenge to industry to meet these high expectations and ensure that the benefits consumers expect are realised.

Government research also shows the positive experience of consumers and the use of in-house displays. BEIS have been researching effective advice provision and piloted advice provision by installers with a sample of consumers. This has shown the importance of tailored advice and providing consumers with specific actionable strategies. In particular, the pilot showed the following key elements: an engaging evidence-based hook (ideally, estimated financial savings from an independent source); myth-busting information; and guidance to ensure customers know not just what to do, but how to do it.

There are also a number of smart heating-control systems on the market that consumers can buy to allow them to control the heating, hot water supply and lighting in their home remotely via use of an app. These have the potential to enable consumers to use their systems more efficiently by adjusting when their heating is on and may appeal to some households for the extra visibility and ability to control systems via mobile devices.

Sources: DECC (2016) *Smart Meters Quarterly Report to end March 2016, Great Britain*; Citizen's Advice (2016) *Early consumer experiences of smart meters*; DECC (2015) *Smart Metering Implementation Programme: DECC's Policy Conclusions: Early Learning Project and Small-scale Behaviour Trials*; Charlesworth, A., Harrison, M., and Budge, M. (2016) *Energy efficiency advice delivered through the GB smart metering roll-out*

Consumers are happy with low-carbon choices, provided they are well installed

Available evidence suggests that consumers who have switched are happy with improved insulation and low-carbon heating systems, provided these have been well installed. However, poor installations lead to poor consumer experiences:

- Evidence from consumers who have installed heat pumps, biomass boilers and solar thermal under the RHI shows that the majority (80%) were happy with the outcome. Where there were issues with the installation, these were primarily due to disruption caused by installation (14%), unclear information or advice (10%) or problems with installers ('lack of trusted installers', 11%, 'identifying or finding an installer', 9%, 'lack of local installers', 8%).[14]
- The 2015 Which? report on heat networks[15] highlighted cases where the historical lack of standards and consumer protection has led to poor outcomes for households connected to heat networks.[16] However, recent evidence points to improving heat networks experiences,

[14] DECC (2016) *Census of Owner-Occupier applicants to the Domestic RHI: Waves 1 to 12 A research project commissioned as part of the Renewable Heat Incentive Evaluation,* available at www.gov.uk
[15] Which? (2015) *Turning up the heat: Getting a fair deal for District Heating users.*
[16] McCrone, D., Hawkey,D. Tingey, M. and Webb, J. (2014) *Bringing Warmth to Wyndford: Household experiences of new district heating.*

including the Wyndford estate in Glasgow and the majority of London new-build networks. New business models and smart systems have successfully addressed issues of poor-performing schemes.[17]

- High levels of satisfaction for insulation and heating efficiency improvements can be achieved. For example, 87% of participants were satisfied or very satisfied with Northern Ireland's Warm Homes scheme.[18]

Greater take-up of low-carbon heating and insulation will need higher standards to be enforced, particularly during installation. This is likely to require a larger number of skilled installers who will take time to train. Recent policies have begun to address the challenges.[19] A steady ramp-up in the size of the markets for heat pumps and heat networks is likely to support continued high standards across the supply chain as the rate of deployment increases.

Following concerns over quality and the dissatisfaction of some customers, the Government has commissioned the Bonfield Review to assess consumer protection, advice, standards and enforcement for home energy efficiency and renewable energy measures. It will be important that the government acts in response to this to ensure quality and confidence around installation are improved.

Decisions relating to energy efficiency and heating systems are influenced by factors wider than cost and comfort

Decisions around insulation and heating systems are made in the wider context of social norms and decisions around building refurbishment. They are also made at specific times such as when the existing boiler breaks down.

- **Social norms** are critical in shaping behaviour. Awareness of what others are doing can reinforce individuals' underlying motivations. There have been many examples where providing such information has delivered the desired outcomes, for example in encouraging recycling, increasing tax payments and reducing littering. Trials run by the energy company OPower in the US have shown that comparing household energy use to an efficient neighbour can reduce overall energy usage by 2-4%.[20]

- There are often **trigger points** to household decisions to renovate or invest in new heating systems. While some purchases of new heating systems are triggered by the breakdown of a boiler leading to a rushed purchase, wider energy efficiency and heating improvements are likely to be made as part of household renovation considerations. The ultimate influences in these cases are often periods of transition in life patterns, for example when moving home,

[17] In one London-based scheme, unit costs have been driven down from over 7p/kWh to below 4p/kWh.

[18] Northern Ireland government (2014) *Warm Homes early years customer satisfaction survey*, available online at: https://www.northernireland.gov.uk

[19] This includes the Renewable Energy Consumer Code for renewable heat, along with recent consumer protection initiatives for heat network customers, including the launch of the Heat Trust and the CIBSE design guidelines. The new 2014 Metering and Billing regulations should help address issues around transparency in billing. More recently, BEIS are working on the principle of 'no detriment' for all heat networks receiving public support, which will need to demonstrate that there is no decrease in service levels for end-users.

[20] Behavioural Insights Team (2014) *EAST: Four Simple Ways to Apply Behavioural Insights*

retiring or having a child. Evidence suggests that financial incentives are only attractive to households once they are committed to renovating.[21]

- **Household decisions** reflect attitudes towards 'home', different needs and priorities. This highlights the importance of targeting policies to different groups and effectively marketing them to make use of the attributes that appeal most to different types of household.
  - The **meaning of home** goes beyond thinking about a house as just a physical structure. For example, a home can be viewed as a haven and associated with privacy, comfort and identity. Homes can also be seen as a project to further develop or as an area to carry out activities such as cooking and spending time with family.[22]
  - **Consumers have different needs and priorities** including saving on energy bills, improving comfort (for themselves, or other young or elderly family members), the rapid availability of steady hot water, helping the environment, improving health or aesthetics of the relevant equipment.
- **Landlords** are driven by the demands of their current and prospective tenants, regulatory compliance, maintaining the value of their property and tax incentives:
  - **Social landlords** are driven by the social and charitable objectives of providing decent and affordable housing that complies with regulation. These objectives determine their asset-management strategies, including the pursuit of affordable heating. They tend to approach investment in terms of coordinated fleet upgrades (and planned maintenance cycles in the case of heating systems). National energy efficiency targets in Scotland and Wales are enshrined in regulation and are based on Standard Assessment Procedure (SAP) scores, with some voluntary SAP targets in England. Despite some issues around the accuracy of the SAP, it is widely used as a proxy for affordable warmth, making the treatment of renewable heat technology under SAP an important factor in decision-making. [23]
  - There is a 'principal-agent' issue in the **private-rented sector**, where landlords have little incentive to invest in improvements to their property given that the tenant would receive the reward for this through reduced energy bills. Regulations have been introduced to protect tenant rights, for example over safety features of the property and from April 2016 in relation to energy efficiency. However, initial evidence suggests that many landlords are refusing tenant requests for energy efficiency improvements.[24]

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[21] Wilson, C. et al (2015) *Why do homeowners renovate energy efficiently? Contrasting perspectives and implications for policy. Energy Research & Social Science*, 7 (2015) 12–22
[22] Aune, M. (2007) *Energy come home*, *Energy Policy*, 35 (2007) 5457–5465
[23] NatCen, Eunomia and CSE for DECC (2016) *Qualitative research with social housing providers. A research project commissioned as part of the Evaluation of the Renewable Heat Incentive*, available online at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/498798/Qualitative_research_with_social_housing_providers.pdf
[24] Cornwall Energy Daily Bulletin 3rd August 2016 reports a survey by online letting agent PropertyLetByUs that shows 58% of tenants surveyed have had requests for energy efficiency improvements refused.

Business investment decisions are based on perceived strategic importance or 'salience' of the investment

Opportunities to invest in energy efficiency and low-carbon heat may not be taken even though they may be cost-effective under normal investment criteria:[25]

- Part of the problem is that there are many economic, behavioural, technical and financial barriers to investment,[26] including capital constraints, split incentives, imperfect information and perceived risk.[27] A number of existing government policies are focused primarily on overcoming these barriers.[28]
- Recent research shows that these barriers, whilst real in themselves, should be viewed as part of the organisation's overall investment decision-making processes.[29] It is the strategic value or 'salience' of an investment decision that determines whether it goes ahead or not.
- For example energy costs are highly salient for energy-intensive companies with energy bills of 5-25% of turnover. Investing in energy efficiency is therefore a strategic priority. Energy bills lower than 1-2% of turnover are not salient and are therefore not noticed or acted upon.

Non-residential energy efficiency and heat investments can become salient if they enhance the strategic position of the organisation in other ways (Box 1.3):

- Organisations are influenced by a range of non-energy drivers affecting the salience of an investment. These include reputation and risk management, productivity, competitiveness and staff welfare, and vary according to organisation type, size, sector and market.
- Organisations with low energy costs can be encouraged to invest in energy efficiency and heat projects when doing so brings ancillary benefits such as enhanced corporate reputation.

Drivers of salience are complex and varied, but can be influenced. Salience maps are being developed to guide policymakers.

There is a rationale for government to step in with an effective policy framework to overcome consumer inertia

In both homes and workplaces decisions are often taken in the context of poor information about the opportunities to improve efficiency or to change heating system. For some, financial constraints preclude installing systems with high upfront costs, whilst risks associated with change are perceived. Alongside this, the installer workforce is generally unlikely to suggest alternative heating systems, even when people are willing and able to consider them. These barriers (set out in more detail in the technical annex) imply a strong bias in favour of existing heating technologies.

This suggests that a successful strategy to reach high uptake must ensure that low-carbon choices are understood and are attractive, timely and cost-competitive. Ultimately these choices

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[25] Hirst, E., & Brown, M. (1990) *Closing the efficiency gap: barriers to the efficient use of energy*. Resources, Conservation and Recycling, 3(4), 267-281

[26] Sorrell, S. (2011) *Barriers to industrial energy efficiency: a literature review*. UNIDO Working Paper 10

[27] Mallaburn, P. (2016) *A new approach to non-domestic energy efficiency policy: a report for the Committee on Climate Change*, available online at: https://www.theccc.org.uk/publication/next-steps-for-uk-heat-policy/

[28] For example: climate change levy, the Renewable Heat Incentive, CRC scheme, enhanced capital allowances etc.

[29] DECC (2012) *Factors influencing energy behaviours and decision-making in the non-domestic sector*.

should be seen as a social norm. We reflect these factors in Chapter 3, when setting out policy priorities for increasing the rate of progress.

In the next chapter we present the possible pathways to decarbonise heat by 2050, identify what critical government-led decisions will need to be made during the next Parliament and the preparation needed in order to make those decisions. We also highlight 'low-regrets' measures to increase energy efficiency and decarbonise heat that are sensible regardless of which longer-term options are chosen.

Box 1.3. Organisation decision-making processes

There are normally at least three stages of a company's decision-making process:[30]

- The organisation makes decisions on its strategic priorities,
- Based on these decisions, it determines what investments are salient to these priorities and develop these options further for appraisal,
- These investment options are appraised (using Net Present Value or payback tools) for a final decision.

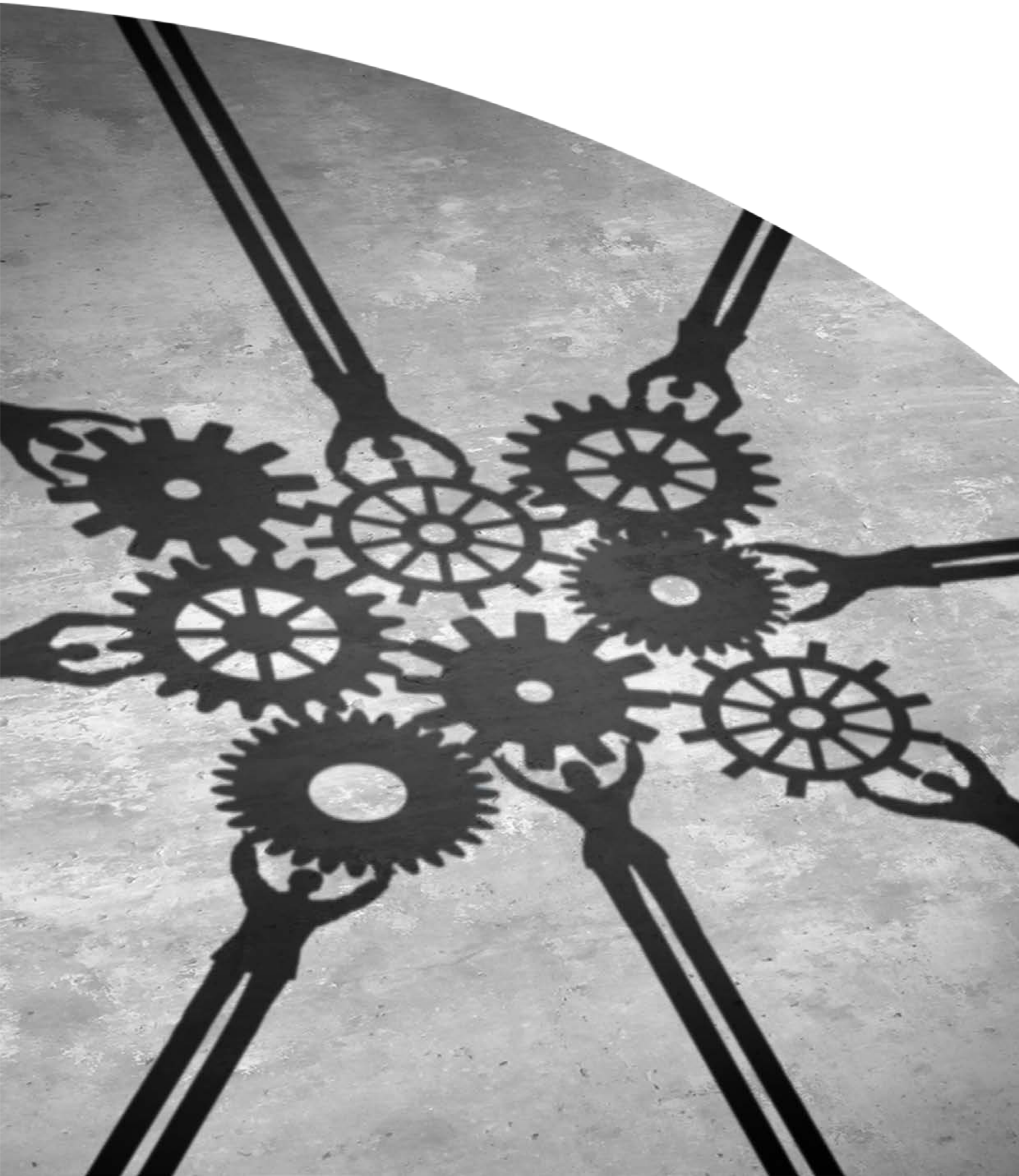
Current policy tends to focus on the last stage in the process, for example by promoting the cost-effectiveness of energy efficiency. However by this stage, energy efficiency may already have dropped off the agenda. This suggests that policy should focus on the whole decision-making process. Research has identified three influences that can bring low-carbon investment forward to an earlier stage in an organisation's decision-making process:

- External drivers raise the profile of an investment if it enhances the organisation’s corporate positioning, for example its reputation with investors or customers, or its competitiveness. These drivers influence mainly larger and outward-facing organisations (e.g. public-sector bodies, publicly-quoted organisations, organisations that tender for public-sector contracts and organisations with a high public profile).
- Internal drivers that help to bridge the gap between energy management and boardroom strategic decisions raise awareness of the opportunities of low-carbon investment through the organisation. Policy may address these drivers, for example by providing technical information to make energy understandable or incentives to connect the energy manager with the Board and senior decision-makers.
- Sectoral drivers such as external relationships with peers, supply chains, government, NGOs and other stakeholders may influence access to information and priorities. These external relationships are particularly useful to influence SMEs, where lack of technical knowledge and management time are particular barriers to progress.

An effective policy framework will influence a range of external, internal and sectoral drivers. Given the diversity of the non-residential sector, its design requires a deep understanding of organisations and their drivers.

[30] Cooremans, E. (2012) *Investment in energy efficiency: do the characteristics of investments matter? Energy Efficiency*, 5: 497-518

Chapter 2:
Possible low-carbon pathways



Chapter 1 identified the need to reduce emissions from UK heating while continuing to meet the demands of consumers for comfortable homes and workplaces with heating systems that are easy and affordable to operate. This chapter sets out the options for meeting that challenge.

Our key messages are:

- **Government must set out the role of hydrogen for buildings on the gas grid in the next Parliament.** The Government will need to make a set of decisions in the next Parliament and beyond on the best strategy for decarbonising buildings on the gas grid. Specifically, it will have to decide on whether there is a role for hydrogen supplied through existing gas networks (extending the useful life of the gas grid infrastructure) alongside other technologies such as heat pumps.
- **Action is required now to reduce emissions and to prepare for future decisions.** Policy needs significant strengthening now to increase the implementation of low-carbon measures in the next decade:
  - New homes can and should be built to be highly energy efficient and designed for low-carbon heating systems. That will avoid costly retrofit in future and ensure household energy bills are no higher than needed.
  - Energy efficiency should be improved across the existing building stock. This can reduce emissions and energy bills, improve competitiveness and asset values for business, improve health and wellbeing, help tackle fuel poverty and make buildings more suitable for low-carbon heating in future.
  - Deployment of low-carbon heat cannot wait until the 2030s. Low-regret opportunities exist for heat pumps to be installed in homes that are off the gas grid, to install low-carbon heat networks in heat-dense areas (e.g. cities) and to increase volumes of biomethane injection into the gas grid. These opportunities can be taken within funding that has already been agreed provided policy measures are well-targeted and we learn the lessons from previous UK and international experience.
  - Hydrogen pilots can also begin and must be of sufficient scale and diversity to allow us to understand whether this can be a genuine option at large scale. As large-scale hydrogen deployment would require use of carbon capture and storage (CCS), a strategy for CCS deployment remains an urgent priority.

Figure 2.1 illustrates the timing of the challenges facing Government:

- During this Parliament the Government must take steps to increase implementation of low-regret measures and avoiding lock-in to suboptimal choices.
- It must also take active steps to develop and to understand the options for decarbonising heat for on-gas properties, ahead of a set of strategic decisions in the next Parliament.
- Roll-out of low-carbon heating across properties on the gas grid must then occur during the 2030s and 2040s.

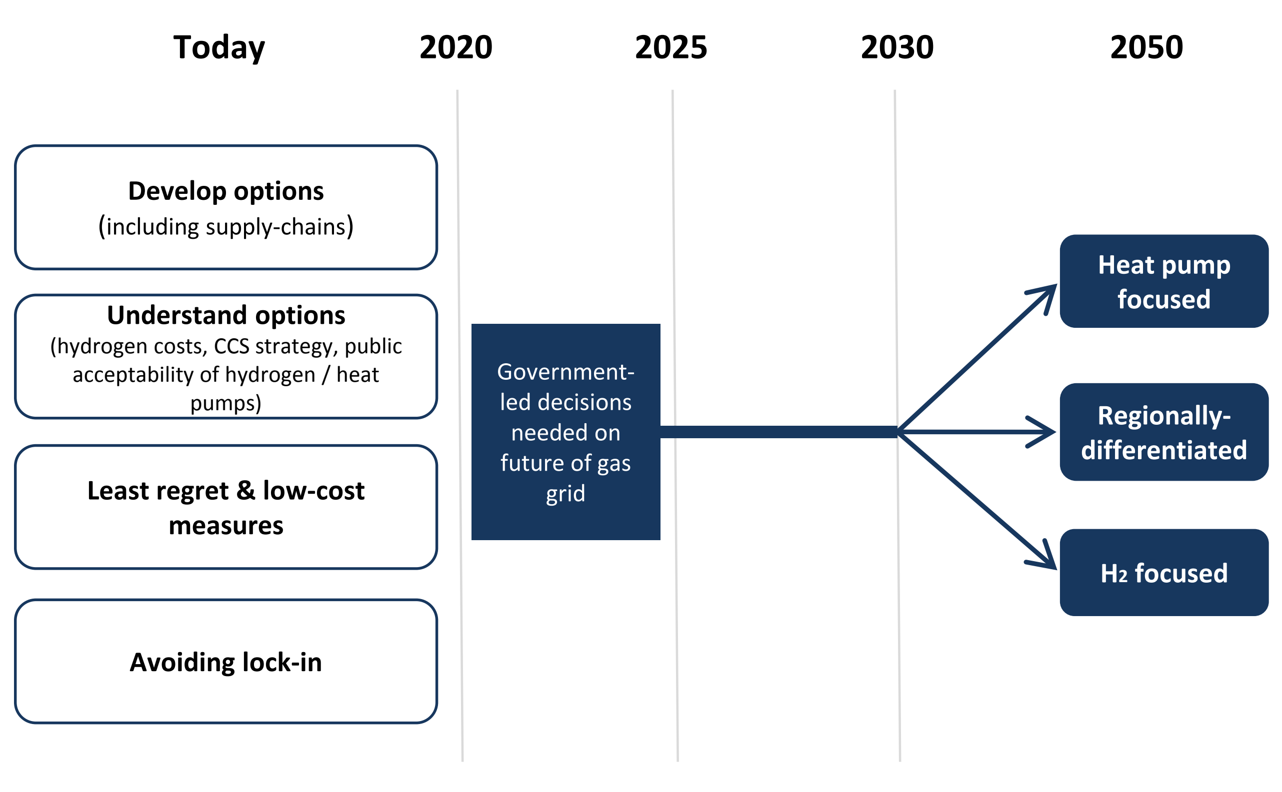
This chapter is set out in three sections:

(a) Opportunities for reducing emissions from heating UK buildings

(b) Decision points

(c) Low-regret measures

Figure 2.1. The need for strategic decisions in the next Parliament regarding the future of the gas grid



(a) Opportunities for reducing emissions from heating UK buildings

There is a set of low-regret measures that make sense in most plausible futures for UK heating with lower carbon emissions. These include improvements to energy efficiency, use of biomethane and some take-up of low-carbon district heating in areas with sufficient density of heat demand. We explore these in more detail in section (c).

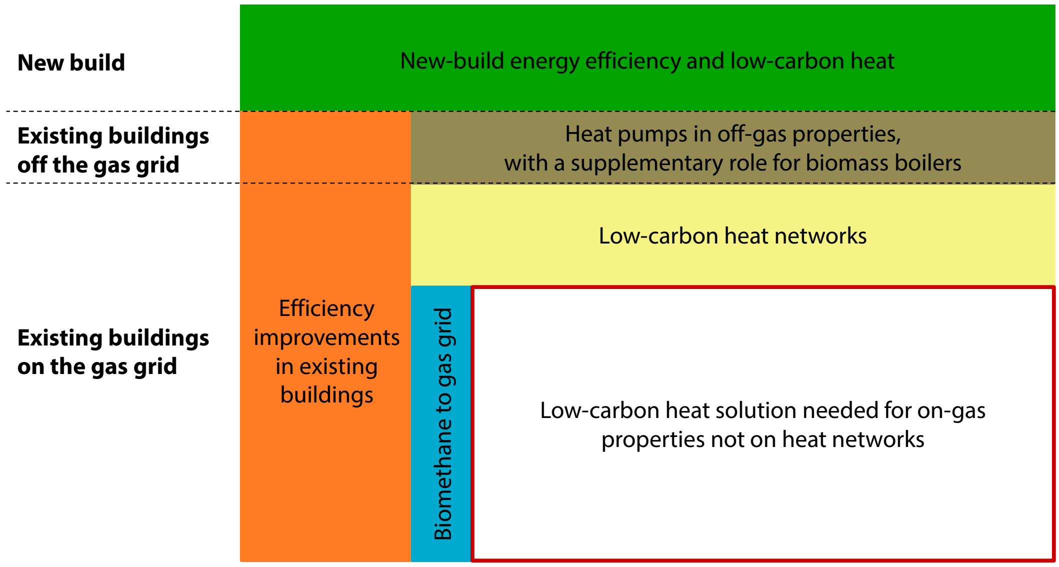
However, there are limits to how far these options can reduce emissions, as they are limited in terms of the carbon-saving potential, by nature of being suitable for a particular section of the building stock, or (as is the case with biomethane) the supply itself is constrained (Figure 2.2):

- **New-build.** Although most of the projected stock to 2050 has already been built,[31] it makes sense for the standards of new buildings to be such that they do not require retrofit in 10-15 years' time. But while this avoids adding to the challenge of buildings decarbonisation, it does not tackle emissions from existing buildings.

[31] In our fifth carbon budget analysis, we use dwelling projections based on estimates worked up with BEIS and Element Energy, using the DCLG household projections and ONS population projections. This suggests at least 80% of homes in 2050 have already been built. The Energy Technologies Institute have a higher estimate of over 90% of homes in 2050 already built, in ETI (2015), *Smart Systems and Heat, Decarbonising Heat for UK homes*.

- **Energy efficiency improvement to existing buildings.** Our scenarios include around a 17% reduction in energy used to heat existing buildings by 2030 through improving efficiency.[32] However, this alone would leave buildings emissions too high in 2050; low-carbon heat will also be needed to meet this lower demand for heating.
- **Low-carbon heat networks.** District heating schemes require a certain density of heat demand in order to make them economic. This means that they are suited to urban areas, new-build developments and some rural areas. So while they can provide an important contribution to decarbonising new and existing buildings, this is limited to around 20% of total building heat demand to 2050 even if deployment challenges can be overcome.[33]
- **Heat pumps in buildings not connected to the gas grid.** Heat pumps have faced challenges to date, but remain the leading low-carbon option for buildings not connected to the gas grid, where the costs, hassle and carbon-intensity of existing heating systems are higher than for gas-connected buildings. Not all buildings will be suitable for heat pumps, although improvements to energy efficiency will substantially increase suitability. For those that cannot be made suitable, use of local sustainable biomass could play a role.
- **Biomethane.** Injecting biomethane into the gas grid is a means of decarbonising supply without requiring changes from consumers, and provides a route for capture and use of methane emissions from biodegradable waste. However, its potential is limited to around 5% of current gas consumption.

Figure 2.2. Low-regrets measures and the remaining challenge for existing buildings on the gas grid



Notes: The sizes of the blocks broadly reflect the scale of emissions reduction, but do not do so precisely. Some potential for heat networks will be in new-build and off the gas grid, rather than all on-grid as presented. Biomass for heat may also play a role in hard-to-insulate rural properties.

[32] This 17% estimate includes savings from boiler efficiency which are included in the baseline in the DECC projections and in the fifth carbon budget analysis. The corresponding estimate excluding boiler efficiency savings is 13%.
[33] CCC (2015) *Sectoral Scenarios for the Fifth Carbon Budget* and Annex 1. This estimate is the potential by 2050.

Beyond those low-regrets options, the key choice is whether and how far to shift heating for on-gas properties outside of heat-dense areas to a low-carbon gas supply (e.g. based on hydrogen produced primarily using carbon capture and storage) or to pursue mass roll-out of heat pumps:

- **Heat pumps**. Although heat pumps have not gone beyond being a niche option in the UK to date, they are extensively used in many other countries (e.g. Sweden and France), and could also be rolled out to buildings connected to the gas grid.
  - This is more challenging than roll-out off the gas grid due to the popularity and low current cost of gas heating.
  - It would require a major change in the heat pump supply chain - over 1 million installations would be needed annually from the mid-2030s, compared to only around 20,000 in 2015. This could only be achieved if progress is made to prepare in the next decade.
  - In the initial stages, roll-out could involve a role for hybrid heat pumps (see section (b) below), especially if roll-out were to start at scale during the 2020s.
  - Heat pumps are currently suitable in around ten million properties on the gas grid (although loft top up will be required in some cases). A further ten million or more could be made suitable through insulation (solid wall, with some remaining cavity wall and loft insulation) and other heating system upgrades.
  - Low-carbon options to provide electricity for heat pumps are available, although widespread deployment would bring significant challenges for electricity system management on both a daily and seasonal basis (Box 2.1).
- **Hydrogen**. Alternatively, existing gas distribution networks could be repurposed to carry hydrogen produced from low-carbon sources. Although there is considerable uncertainty, there is sufficient evidence to warrant serious consideration as an option for heat decarbonisation to 2050 (Box 2.2).
  - A wholesale shift to a hydrogen gas supply is technically feasible and would in some ways be less disruptive to consumers since it shares many characteristics with natural gas (e.g. the ability to increase heat supply very responsively). It could also have spill-over benefits for decarbonising other sectors (e.g. hydrogen could also be used for seasonal power generation, in heavy goods vehicles and for some industrial processes).
  - Producing hydrogen in a low-carbon way at the necessary scale is only likely to be feasible and economic if the bulk of production is from natural gas with carbon capture and storage (CCS). This would require CO_2 transport and storage infrastructure to be available from the outset (i.e. by 2030), although contributions from other low-carbon sources (e.g. electrolysis using low-value low-carbon electricity) could be material. CCS is technically well understood, but remains undeveloped in the UK.
  - The need for production facilities based on CCS and for large-scale storage of hydrogen may also constrain the areas of the country for which hydrogen is the best option. However, provision of hydrogen and CO_2 infrastructure for industrial clusters, including production of hydrogen with CCS, could provide wider opportunities for decarbonisation (e.g. hydrogen use for heat in industry).
  - Our understanding of the mechanics of a widespread roll-out is at an early stage and cost projections are uncertain. It would be important that such a transition should be well

managed and address safety concerns. To understand how best to proceed, it will be vital to undertake pilots and demonstrations in the next decade.

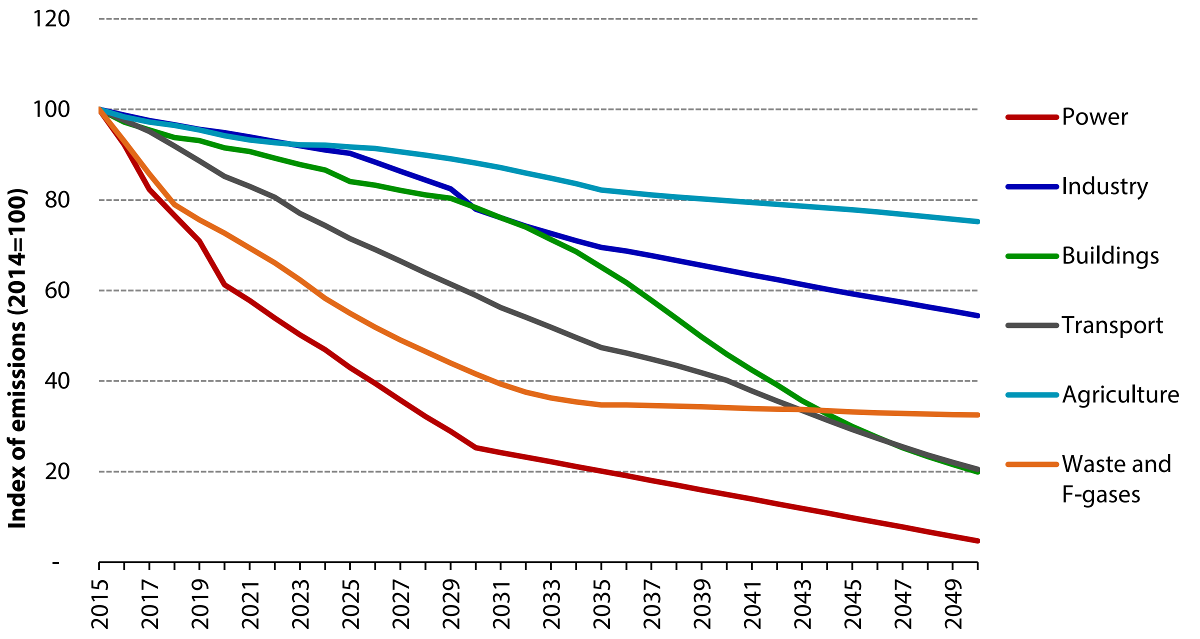
Reflecting the uncertainties, in conjunction with low-regrets measures, our 2015 fifth carbon budget scenarios featured two alternative central scenarios, one with a heat pump focus and one with a hydrogen focus. Our scenarios, which are similar to others that have been published, assumed that deployment of low-carbon heat for gas-connected properties is limited in the next decade, with emissions from buildings reducing later than emissions in other sectors of the economy (Figure 2.3, Box 2.3).

Both heat pumps and hydrogen bring significant challenges, but in order to reduce heating emissions close to zero in the long term, extensive use of at least one of these options will be required. It may require a combination of the two solutions, with each dominating in different regions, interspersed with heat networks. ***It is not possible at this stage to identify either heat pumps or hydrogen as the dominant solution, nor should either be ruled out.***

Given this uncertainty, the period to 2030 should involve take-up of the low-regret measures alongside development of the heat pump and hydrogen options to allow extensive roll-out to properties currently on the gas grid in the 2030s and 2040s. Given that heat pumps are the main option for properties off the gas grid and also have better economics in those buildings, the off-grid segment is the priority area to begin building a heat pump market and supply chain, together with installation in new-build properties (see section c).

These measures to 2030 are important, not only in terms of their contribution to medium-term emissions reduction but also to prepare for an acceleration in the rate of decarbonisation after 2030. Our scenarios suggest a doubling in the rate at which emissions from buildings are reduced, from 1.2 $MtCO_2e$ per annum before 2030 to 2.5 $MtCO_2e$ per annum after 2030. Lesser progress in reducing emissions to 2030, or delay in making the choice for decarbonisation of heat in on-gas buildings, would put at risk the ability to ramp up the rate of emissions reduction sufficiently to make the necessary contribution to meeting the 2050 target.

Figure 2.3. Buildings decarbonise later than other sectors under CCC scenarios



Source: CCC (2015) *Sectoral scenarios for the Fifth Carbon Budget - Technical report.*
Notes: Index based on direct emissions.

Box 2.1. Developing a heat pump market

In the near term, the two segments presenting an opportunity to develop the UK heat pump supply chain are buildings not connected to the gas network, together with new buildings:

- Heat pumps are already cost-effective on a social basis when displacing oil heating or resistive electric heating. Our central scenario to meet the fifth carbon budget includes cost-effective uptake of 1.2 million heat pumps in homes off the gas grid, along with a further 20% of non-residential heating by 2030, with continued roll-out to 2050 in these segments.
- Heat pumps are also cost-effective in new buildings from the mid-2020s. Designed as part of an integrated system in well-insulated buildings, they can perform better and be sized for lower peak heat demand, with commensurately lower capital costs. Hassle costs and barriers to installation are respectively non-existent and much lower. Costs of heat pumps in new properties compare more favourably with gas heating when including the cost of connecting to the gas grid, estimated at £350-1,080 per domestic connection, and higher for some commercial or industrial units (Table 2.1).

There are clear challenges in this scenario, even to 2030. Practical considerations when installing heat pumps include the space requirements, the need to coordinate with energy efficiency upgrades, reinforcing local electricity networks and other related infrastructure:

- Retrofit in homes needs to happen alongside any loft insulation and wall insulation. Many properties will require upgrading heat emitters (either with radiators or underfloor heating) and in the case of homes with electric-heating, installation of wet-based central heating. This implies a more significant programme of work and level of disruption than a typical heating-system replacement.
- Ground-source heat pumps are attractive on the basis of their higher performance relative to air-source systems, but require boreholes where horizontal ground loops cannot be accommodated.

Box 2.1. Developing a heat pump market

Drilling boreholes implies a high upfront cost unless it can be shared across a number of neighbouring households.

- Where local electricity infrastructure needs to be reinforced to accommodate the additional electricity demand, this implies additional network costs and may also lead to disruption from road-excavation works. However, other forms of low-carbon heat also require significant changes to existing infrastructure or development of new networks.

Consumer awareness remains low, with consumers more likely to attach a risk premium to an unfamiliar technology. Heat pumps may also suffer through association with conventional electric heating, which is less popular than other forms of heating due to difficulty of control and high running costs.

Between 2030 and 2050, deployment would need to accelerate rapidly if extending to cover most of the 23 million homes connected to the gas grid. When considered as a replacement for a gas boiler, the challenges are greater:

- Gas heating is typically viewed by consumers as both responsive and low hassle.
- Electricity is around three times the price of gas. As heat pumps are around three times the efficiency of gas boilers, energy bills are likely to be similar after switching. This means that it is not possible to recoup the higher capital costs of the heat pump through reduced energy bills. This issue is likely to persist while carbon costs are not fully reflected in gas prices.

The costs to the electricity system of widespread roll-out of heat pumps are likely to be substantial but can be reduced through a combination of measures, including substantial improvements to energy efficiency, heat storage and demand-side response:

- Imperial College London, as part of a project with Element Energy for the CCC in 2013, modelled a decarbonisation scenario for 2030 including around 7 million heat pumps (compared to around 2.5 million in 2030 under our fifth carbon budget scenario) in a building stock with improved energy efficiency and some heat storage, as well as 8 million electric vehicles.
- The modelling found that the decarbonisation would have investment requirements in local electricity networks over the period to 2030 of £31.4bn, compared with £25.2bn under a 'no climate action' scenario, with demand-side response able to reduce costs further by around £1.7bn.
- In a scenario with uptake of heat pumps clustered in certain areas, the modelling showed lower reinforcement costs, due to fewer upgrades being required to distribution networks, albeit sometimes to a higher capacity.

It is important that the electricity system costs resulting from a very high uptake of heat pumps are investigated in more detail, covering both local network infrastructure and electricity generation. This should include consideration of the range of options to mitigate these costs, including energy efficiency improvements, heat storage, demand-side response, availability of flexible low-carbon generation and whether use of hybrid heat pumps rather than full heat pumps could imply lower costs (Box 2.5).

Source: CCC (2015) *Sectoral Scenarios for the Fifth Carbon Budget*; CCC (2013) *Fourth Carbon Budget Review, Technical Report*; Ipsos Mori and EST for DECC (2012), *Homeowners willingness to take up more efficient heating systems*; Imperial College and Element Energy (2013) *Infrastructure in a low-carbon energy system to 2030: Transmission and distribution*.

Box 2.2. Could the UK convert its gas grid to supply hydrogen by around 2050?

While most options for low-carbon heat entail a move away from use of gas in buildings, and therefore away from use of the gas grid, the existing natural gas low-pressure networks could instead be repurposed to carry hydrogen. This would mean that these assets would continue to be of value to the energy system in the long term, and relatively little change would be required to consumer behaviour. It is not envisaged that the high-pressure network (e.g. transmission) would also be repurposed.

The ongoing Iron Mains Replacement Programme, due to be completed in the early 2030s, is replacing old iron pipes with plastic ones that are suitable for carrying hydrogen. Converting gas networks to hydrogen would require a coordinated switchover of different parts of the grid, including replacing of gas appliances (e.g. boilers) with hydrogen-compatible ones.

In order for hydrogen to make a significant contribution to heat decarbonisation it would need to be produced in bulk from low-carbon sources. Low-carbon hydrogen can be produced through a range of routes, but only CCS can provide large volumes at relatively low cost, as contributions of other sources are limited by resource constraints and/or cost:

- **Steam methane reforming (SMR) with CCS.** Bulk hydrogen production via SMR is a widely used and mature process globally, producing a stream of CO_2 that can be sequestered relatively easily. Available CO_2 storage capacity in the North Sea is estimated at up to 78,000 $MtCO_2$,[34] sufficient to accommodate CO_2 captured from hydrogen production, which could reach 150 $MtCO_2$ per year by 2050 in a high hydrogen scenario (covering transport and industry as well as buildings). Hydrogen production with CCS has been clearly identified as the lowest-cost route to low-carbon hydrogen.[35]
- **Low-carbon electricity.** Near-full conversion of gas distribution grids to hydrogen for heating energy-efficient buildings would imply a demand for hydrogen of around 330 TWh in 2050,[36] even without hydrogen demands from other sectors (e.g. transport). Supplying this from electrolysis would require additional low-carbon generation of around 400 TWh, over and above the 475 TWh required to meet other electricity demands in 2050 (including for transport decarbonisation). This scale of low-carbon capacity would be extremely challenging to achieve. Whilst there is a potentially valuable role for hydrogen production to soak up low-value low-carbon electricity (e.g. at times of low demand and/or high renewable generation), the volumes available via this route at reasonable cost are likely to be relatively small.
- **Bioenergy.** There are a range of routes for hydrogen production from bioenergy. However, given limits to the potential for sustainable bioenergy supply, as well as competing uses elsewhere in the energy system, its contribution is likely to be limited. In the long-term hydrogen production is one option for combining bioenergy with CCS, for negative emissions and to maximise the emissions reduction per tonne of bioenergy resource.

The hydrogen scenario is therefore heavily reliant on CCS development in the UK, although it would still be possible for a substantial fraction of hydrogen supply to come from other low-carbon sources.

Northern Gas Networks have undertaken a study to examine how the low-pressure gas network in Leeds could be converted to 100% hydrogen. Their H21 Leeds City Gate study[37] demonstrates that the existing network has sufficient capacity for conversion to hydrogen. It sets out that this would entail converting the gas grid in stages over three years, with each customer disconnected from the gas grid

[34] ETI (2015) *Strategic UK CCS Storage Appraisal*
[35] LCICG (2014) *Technology Innovation Needs Assessment (TINA) Hydrogen for Transport*, available at https://www.carbontrust.com/media/593904/h2-for-transport-summary-report.pdf
[36] As calculated by CCC, for scenarios analysed by Frontier Economics in their gas grid study (see Box 2.4).
[37] Northern Gas Networks (2016) *H21 Leeds City Gate*

Box 2.2. Could the UK convert its gas grid to supply hydrogen by around 2050?

for less than a week during the summer months. As with the conversion of the gas grid from town gas to natural gas, it would be necessary for technicians to visit each property and replace gas-burning appliances with hydrogen-compatible ones, which would operate in a similar fashion.

The H21 report produced cost estimates for the full switch from natural gas to hydrogen in Leeds, including technical changes to the pipe network, the need for new hydrogen appliances in buildings and hydrogen supply infrastructure, based on hydrogen production (via SMR with CCS). As well as hydrogen production facilities, infrastructure to transport and store the CO_2 is essential, as well as large-scale hydrogen storage in salt caverns, as has been done for some years in the North-East of England. The ETI has mapped potential locations for new salt cavern hydrogen storage.[38] The H21 study estimates that the cost of converting Leeds to hydrogen would be around £290/tCO_2, although with potential for cost reductions applying to later deployment elsewhere. There are considerable uncertainties around the costs of switching gas supplies to hydrogen, not least the costs of CCS.

The H21 study also outlines further work that would need to be undertaken before a decision to convert, including a detailed engineering design study, demonstration of hydrogen appliances (e.g. boilers), development of standards and field trials. It suggests that these could be completed in time for a decision in 2021 to go ahead in Leeds, with conversion starting in 2026 and completing in 2028.

Key uncertainties remain over the prospects for converting gas networks to hydrogen, including its public acceptability and identification of the areas of the country for which it would make sense (i.e. with suitable proximity to geological formations for hydrogen storage and for CO_2 storage), as well as precisely how best to do the roll-out. Further research and feasibility work is required, including engineering studies, trials, siting of hydrogen production and appliance development.

Conversion to hydrogen would have implications for regulation of gas distribution networks. These have been considered in detail in a project by Frontier Economics (Box 2.4) and would raise questions over how to pay for the costs of decarbonisation (e.g. whether customers in an area converted to hydrogen have higher gas bills than those whose network has not yet been converted).

The conversion of gas networks to hydrogen could have wider benefits to decarbonisation of the energy system, as it would provide a widespread low-carbon hydrogen supply infrastructure, greater flexibility in operating the power system and value as a means of storage:

- **Transport.** Given potential roles for hydrogen in transport decarbonisation (e.g. for heavy-duty vehicles), widespread availability of low-carbon hydrogen via pipelines would provide a foundation for the necessary fuelling infrastructure. Should gas networks not be repurposed nationwide, this would need to be supplemented by other hydrogen sources (e.g. electrolysis) elsewhere.
- **Power.** There are various ways in which hydrogen and electricity could be complementary, including combined heat and power (CHP) at a district or building scale, for example based on fuel cells; use of hydrogen turbines to decarbonise peaking generation; and the use of electrolysis to provide balancing services and to store surplus power.

While the option of repurposing gas networks to hydrogen may be viable, further work is required to determine whether and how this should be done. It is important that this detailed work is undertaken over the next few years in order to inform key strategic decisions over how to decarbonise heat supply for on-gas buildings.

[38] ETI (2015) *Hydrogen - The role of hydrogen storage in a clean responsive power system*, available online at: http://www.eti.co.uk/insights/carbon-capture-and-storage-the-role-of-hydrogen-storage-in-a-clean-responsive-power-system/

Box 2.3. Heat scenarios for the Fifth Carbon Budget

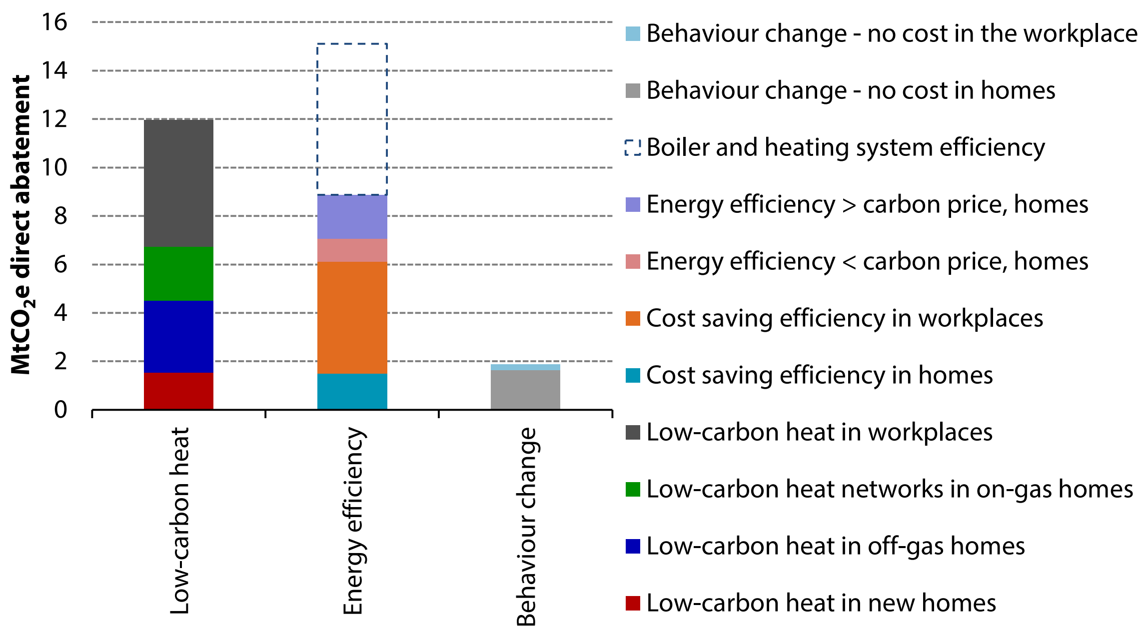
The Central scenario for our advice on the fifth carbon budget involved deploying a mix of energy efficiency, heat pumps, heat networks and biomethane over the period to 2030 (Figure B2.3). It was designed to keep open the option of very extensive roll-out of heat pumps by 2050, while deploying other measures that could reduce carbon at relatively low cost (on average, cost saving across buildings):

- **Residential energy efficiency.** Emission savings from residential energy efficiency are mainly from fabric efficiency improvements, with cavity wall insulation contributing the greatest savings. We assume the majority of remaining loft insulation is delivered in the 2020s and solid wall insulation is installed where cost-effective and in some cases to tackle fuel poverty. Other measures include turning down thermostats by 1 °C, other insulation (such as glazing, floors and hot water tanks) and heating controls.
- **Heat pumps in more cost-effective segments.** To 2030 this ambition could be met by deploying heat pumps in one in four homes off the gas grid and one in five new homes: 2.3 million homes in total, split evenly between the two segments.
- **Low-carbon heat networks.** Around 1 in 20 homes are connected up to low-carbon heat networks by 2030, primarily urban properties such as blocks of flats with communal heating or poorly performing electric heating, together with new developments. In most cases, this has the potential to provide cheaper heating with higher levels of comfort than the alternatives. It is also a safer approach than individual gas boilers for high-rise developments.
- **Non-residential buildings.** In public and commercial buildings, half the abatement is from low-cost energy efficiency, including Mechanical Ventilation Heat Recovery (MVHR). The remaining abatement is from buildings connected to low-carbon heat networks and from buildings off the gas grid switching to heat pumps and biomass boilers.
- **Bioenergy.** To 2030, the Central scenario includes 21 TWh of biomethane injected into the gas grid, equivalent to around 4% of gas piped through the low-pressure network in 2015. Biomass boilers also supply heat to 300,000 homes off the gas grid.

Our assessment is that this is the minimum level of abatement that keeps in play an ambition for full decarbonisation by 2050. Between 2030 and 2050, further roll-out of heat networks and, in particular, heat pumps would be required. Some further energy efficiency would also be required, in order to improve building suitability for low-carbon heating measures. Our Alternative Central scenario features a similar role for energy efficiency, heat networks and biomethane, but sees hydrogen for heat replacing some uptake of heat pumps in buildings on the gas grid.

A 2014 report by Carbon Connect showed that there is relatively good read-across between this and other scenarios from DECC, ETI, UKERC, National Grid and Delta EE. They all feature a combination of energy efficiency, heat pumps and low-carbon heat networks displacing gas (although there is some variation in the respective shares). Other more recent scenario analysis has started to include hydrogen for heat under some pathways (see for example the 2016 KPMG report for ENA).

Figure B2.3. Abatement measures in the Central scenario for the Fifth Carbon Budget



Source: CCC (2015) *Sectoral Scenarios for the Fifth Carbon Budget.*

Sources: CCC (2015) *Sectoral Scenarios for the Fifth Carbon Budget*; Carbon Connect (2014) *Future Heat Series Part 1 Pathways for Heat: Low Carbon Heat for Buildings*, available online at: http://www.policyconnect.org.uk/cc/sites/site_cc/files/carbonconnect_pathwaysforheat_webcopy.pdf; KPMG for the Energy Networks Association (2016) *2050 Energy Scenarios, The UK Gas Networks role in a 2050 whole energy system*, available online at: http://www.energynetworks.org/assets/files/gas/futures/KPMG%20Future%20of%20Gas%20Main%20report%20plus%20appendices%20FINAL.pdf

(b) Decision points

Decisions require strong Government leadership

Approaches based on heat pumps, hydrogen and heat networks will only be realised with strong Government leadership at both local and national levels, because all of these solutions will require coordination. Most consumers and businesses in a given area would need to deploy the same option in order to keep costs down. If emissions from heating are to be largely eliminated by 2050, a national programme to switch buildings on the gas grid to low-carbon heating would need to begin around 2030, requiring Government decisions on the route forward in the next Parliament.

The different options have fundamentally different implications for the future of local gas and electricity networks, but each pathway requires infrastructure development and repurposing to some degree. In the absence of clear choices there is potential for excessive costs relating to suboptimal infrastructure development or overlaps between roll-out of different low-carbon heat solutions in a given area (e.g. supporting heat pumps in areas where low-carbon heat networks are being rolled out):

- **The gas grid**. It is highly likely that any move to repurpose gas networks to hydrogen will require decisions and direction from national government, alongside regional and local planning.
- **The electricity distribution network**. Areas with high uptake of heat pumps are likely to require strengthening of the local electricity grid.[39]
- **Coordination of local efforts**. Should the hydrogen option not be pursued in a given area, choices will be required on a more local basis regarding the strategy for roll-out of district heating or heat pumps. In particular, coordination should avoid multiple conflicting incentives which may undermine efforts to achieve the high connection rates required to make infrastructure-intensive solutions (e.g. heat networks) economic to run. This may involve an important role for local government and elected mayors.

Decisions should be taken in the next Parliament, requiring active preparation in the next decade

There is time before the UK needs to commit to the precise pathway for heat decarbonisation, which allows experimentation over the next decade or so to develop the best strategy. This does not imply a 'wait-and-see' approach, but rather pro-active development and exploration of options and removal of barriers, providing the basis for an informed and evidence-based decision on heat decarbonisation in the mid-2020s.

For heat pumps this will require that a market of sufficient size is developed to enable increased roll-out in future. For hydrogen, there will need to be pilots and demonstrations of sufficient scale to fully understand the potential challenges and how they are best overcome, alongside carbon capture and storage (CCS) development, forward-looking regulations and innovation support:

- There are currently major uncertainties around consumer attitudes to hydrogen, and around how attitudes to heat pumps and heat networks may shift over time as they become more prevalent. Critical to this will be the ability to address issues around poor installation and performance, and current weak levels of consumer protection.
- Before a decision to proceed with hydrogen, it is essential that CCS is under active development in the UK, in order to provide a low-carbon route to producing hydrogen at scale. This should be part of the Government's new strategy on CCS.
- Investment now in R&D and pilot projects is crucial in order to test the feasibility of hydrogen for heat and to reassure the public and businesses that fuel switching to hydrogen networks can be done safely, affordably, and with minimal disruption.
- There is also a need to improve our understanding of what is required for high-quality heat pump and heat network retrofit across a range of key housing types, how to standardise and drive down costs across building retrofit, and the impacts of integrating smart controls on system performance. How consumers interact with heating systems and appliances is a

[39] MacLean, K., Sansom, R., Watson, T., Gross, R. (2016) *Managing heat System Decarbonisation, Comparing the impacts and costs of transition in heat infrastructure*, available at: http://www.imperial.ac.uk/media/imperial-college/research-centres-and-groups/icept/Heat-infrastructure-paper.pdf

central question across all pathways, along with how to create consumer-centric products and solutions.

The new strategy set out in the Government's Emission Reduction Plan needs to build steadily from 2016 to 2030 to a point where the remaining required levels of roll-out of low-carbon heat in the 2030s and 2040s can feasibly be achieved:

- Gas boilers typically have a lifetime of around 15 years, so in order to decarbonise without a significant need for premature scrappage, renewed heating systems will need to be low-carbon from 2035 at the latest. Currently, 1.6m boilers are sold every year, so new supply chains will need to be built up.
- Conversion of a significant proportion of the gas network to hydrogen has been estimated to take at least 20 years, [40] so would need to begin by around 2030 in order for it to be substantially completed by 2050.

This process will require strong Government leadership. In order for large-scale deployment to start in 2030, the Government will need to take clear strategic decisions in the next Parliament, by 2025 at the latest. To ensure this is possible, supply chains for either option will need to be well developed by that point, consumer attitudes must be better understood and familiarity with both heat pumps and hydrogen must be significantly increased.

In the immediate future, Ofgem will need to ensure that the next price control review for the gas transmission and distribution networks reflects the wide range of possible pathways for heat supply. This should include a more rapid move away from fossil fuel use (e.g. in a no-CCS pathway) and a shift to hydrogen in the 2030s and 2040s. That will require consideration of decommissioning costs, and regulatory developments allowing for uncertainty (Box 2.4).

Box 2.4. Frontier gas grid project findings and recommendations

We commissioned Frontier Economics to assess the institutional and regulatory implications of a wide range of future gas grid scenarios consistent with carbon budgets, ahead of the next price control period for the gas transmission and distribution networks (2021-2028). The report is published on the CCC website as supporting evidence to this report.

They considered four scenarios for natural gas and hydrogen demand projections to 2050:

1. The central CCC fifth carbon budget scenario, which sees a continued though reduced role for natural gas in 2050 (around 50% down from 2015).
2. A scenario in which there is a need to go further in reducing buildings emissions by 2050, without hydrogen (e.g. in a 'no CCS' scenario). This sees the greatest reduction in use of the low-pressure distribution networks for transporting gas.
3. A high hydrogen conversion scenario. This could see an increase in the overall volume of gas transported through the network.
4. A regional hydrogen conversion scenario, which is effectively a combination of scenarios 1 and 3.

[40] Northern Gas Networks (2016) *H21 Leeds City Gate*. http://www.northerngasnetworks.co.uk/wp-content/uploads/2016/07/H21-Report-Interactive-PDF-July-2016.pdf; E4tech (2015) *Scenarios for deployment of hydrogen in contributing to meeting carbon budgets*, available online at: https://www.theccc.org.uk/publication/the-fifth-carbon-budget-the-next-step-towards-a-low-carbon-economy/

Box 2.4. Frontier gas grid project findings and recommendations

Frontier established network cost and operational consequences in each scenario. They then used this to model average network tariffs to approximate the impact on consumers; and the value of the Regulated Asset Base (RAB) to 2050, which is indicative of the some of the implications for investors.

An initial stakeholder engagement process highlighted the following insights:

- **Decision-makers**. There is a lack of clear allocation of roles and responsibilities across decision-makers, resulting in a lack of coordination and a potential for distortions between energy vectors. There is also no clear allocation of responsibility or governance framework for localised decision-making.
- **Companies**. The current class of investors (primarily pension funds) are relatively risk-averse. This type of investor is more likely to be resistant to changes that produce greater uncertainty or volatility in returns.
- **Customers**. Achieving customer buy-in is likely to be central to securing ongoing political and regulatory support for decarbonisation. One way to achieve this is to ensure a strong customer voice in decision-making. Customers will also be reluctant to engage with change if it results in unfair outcomes across different customer groups and creates arbitrary winners and losers.

The scenario analysis highlighted the importance of understanding decommissioning costs – particularly in a pathway where CCS technology fails to materialise within the next 15 years. This is also the scenario in which investors face the greatest risk that their investment could be stranded, since there are material increases in the portion of consumer bills made up by network costs (currently around 1p/kWh, or a fifth of the final bill). Hydrogen scenarios will require allocation of roles and responsibilities across market players.

The study highlighted two main sets of recommendations: the first set concerns what needs to be put in place now so that decisions can be made in the 2020s regarding the strategic direction of heating policy (including the role for hydrogen); and the second are a set of low-regrets actions for Ofgem while uncertainty persists, which can be implemented during the upcoming network price control reviews:

- **Key immediate recommendations for policy (2017 to 2020**)

  1. Government, Ofgem and industry need to recognise the (potential) case/need for a mandatory switchover of some form – particularly for hydrogen.

  2. BEIS must develop a consistent decision-making framework to facilitate meeting the longer-term challenges - identifying the role for Government, local authorities, Ofgem, consumers and infrastructure networks. For example, BEIS are likely to be the only body with authority and scope to mandate a hydrogen switchover.

  3. A significant programme of research must be developed to enable informed decisions to be made in the 2020s. In the near future BEIS will need to identify the questions that need to be answered (e.g. to understand better the infrastructure costs associated with a national hydrogen switchover); the appropriate party to answer these questions (e.g. network companies, Ofgem, others in industry); and the source and scale of available research funding.

- **Low-regrets actions for Ofgem while uncertainty persists for the next price control reviews (2018 to 20)**

  1. Ofgem should consider stranding risk and identify a clear approach to allocation of risk.

  2. Introduce appropriate uncertainty mechanisms to the regulatory price control framework that will allow re-openers at relevant trigger points.

Box 2.4. Frontier gas grid project findings and recommendations

3. Instruct Gas Distribution Networks and the National Transmission System to develop a decommissioning strategy and assess decommissioning costs. Ofgem should also develop a straw - man model for regulating these decommissioning costs.

4. Review of the connections regime (e.g. Fuel Poor targets, requirements for Gas Distribution Networks to assess alternatives).

5. Enhanced incentives for stakeholder engagement with Local Authorities and other interested parties in relation to heat networks; as well as for Gas Distribution Networks and National Transmission System to co-ordinate with electricity networks.

Finally, they highlighted the following elements as dependent on the decision around whether to adopt a mandated switchover to hydrogen in areas of the network:

- **If yes:** network codes to be revisited (2025-2030); Ofgem/BEIS need to develop model for regulating hydrogen infrastructure (2025-2030); and geographical coverage of hydrogen switchover needs further consideration (2025-2030).
- **If no:** ongoing evaluation of approach to zoning and co-ordination (2020–2025), along with consideration of the potential for Ofgem to take on the wider role of heat regulator (2025–2030).

Source: Frontier Economics and Aqua Consultants (2016) *Future Regulation of the UK Gas Grid, Impacts and Institutional implications of UK gas grid future scenarios*, available online at: https://www.theccc.org.uk/publication/next-steps-for-uk-heat-policy/

Transitional technologies may have a role

Hybrid heat pumps

In progressing towards a decision from 2025 there may be a role for hybrid heat pumps, which typically combine a smaller electric heat pump with a small back-up gas boiler (Box 2.5). The main benefits of these are that they can reduce medium-term emissions (by over 50% compared to a gas boiler) whilst supporting development of a heat pump market and familiarity with new heating systems:

- Hybrid systems can be installed without upgrading radiators and are more likely to be feasible to install when replacing a broken heating system (i.e. a 'distressed purchase').[41]
- Increased familiarity with heat pumps could potentially lead to greater acceptance of pure heat pumps later on, although there is not yet the evidence to support this.
- It is possible to retrofit them around existing gas boiler systems, delinking installation timescales from boiler replacement cycle – this means that more rapid roll-out could occur, if supply chains allow.

These benefits from a system perspective led to their inclusion in the 2013 DECC Heat Strategy, where they are seen displacing gas boilers through the 2020s and 2030s as a stepping stone to full electrification by 2050.

[41] If a boiler has broken down and needs replacing at short notice.

Deployment of hybrid heat pumps in the 2020s could provide an additional source of abatement to meet the fourth and fifth carbon budgets beyond that in our scenarios, which do not feature any substantive deployment of heat pumps in homes on the gas grid before 2030.

However, the lesser emissions savings from hybrid heat pump systems may be insufficient to meet longer-term emissions targets. A 15-year turnover period for the boiler stock means that there will be an opportunity to replace those deployed in the 2020s and early 2030s with lower-carbon options before 2050.

Trials are underway in Holland to model interactions within town-scale multi-vector energy systems including impacts on electricity grids, usage patterns and interactions with ICT, although these are not yet modelling hybrid heat pumps systems.[42] If pursuing a strategy of developing hybrid heat pump supply-chains, further research including trials would be beneficial in the UK.

Biomass boilers

Biomass boilers are constrained as an abatement option by the limited supply of sustainable biomass. In the long term, heating may not be the best use for achieving the maximum emission saving from the scarce resource (Box 2.6).

If only transitional, and not paving the way for other forms of low-carbon heat, deployment may be counter-productive due to the risk of crowding out other low-carbon options with a long-term role. Deployment of biomass has dropped under the domestic RHI following the cuts in biomass tariffs, but bioenergy continues to dominate in the non-residential scheme where tariffs remain high.[43] Given limited funding available to 2020/21 and the paramount importance of developing heat pump supply-chains, there is a case for further rebalancing support so that biomass boilers become the exception rather than the norm.

Box 2.5. Hybrid heat pumps as transitional technologies

Hybrid heat pumps may come into play as a bridging technology driven by consumer preferences:

- Hybrid heat pumps typically combine an electric system with a small gas boiler which provides back-up on the coldest days of the year, reducing the load on the electricity system at peak times. Making greater use of the gas boiler component could make the experience of having the system more similar to a gas boiler through greater responsiveness, although this comes with a carbon penalty attached.
- It would be important that hybrids are not run predominantly in gas mode. This requires appropriate sizing and installation, together with control systems that provide sufficient comfort (such that users do not need to override them).

While a hybrid system involves having both a gas boiler and a heat pump, the costs are typically similar

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[42] Van Pruissen, O., van der Togt, A., Werkman, E. (2014) *Energy efficiency comparison of a centralized and a multi-agent market based heating system in a field test*, Elsevier; van Pruissen, O., Kamphuis, R. (2011) *High Concentration of Heat pumps in Suburban Areas and Reduction of their Impact on the Electricity Network*; TNO, 'Energy System Integration Facility, Proofing the Energy System Configurations of the Future', https://www.tno.nl/media/6303/energy_system_integration_facility_tno_infoblad.pdf, accessed on 07/10/16

[43] CCC (2016), *Progress Report to Parliament,* available at www.theccc.gov.uk

Box 2.5. Hybrid heat pumps as transitional technologies

or slightly lower than for a pure air-source heat pump solution:

- Current average prices reported by BSRIA of around £4,200 for the electrical unit, implying a total of around £5,600 for the unit including the gas boiler and controls.
- If the system is retrofitted around an existing gas boiler then the capital costs for this part will be avoided.
- This compares to average installed cost estimates from BSRIA of £5,700 for a monobloc air-source heat pump (ASHP), £6,450 for a split system ASHP and £15,600 for a ground-source heat pump (GSHP), broadly in line with our estimates.

The lesser contribution of the heat pump at times of peak heat demand would also reduce the need for strengthening of the electricity grid. However, the emissions saving will also be lower:

- The emissions saving relative to a gas boiler will depend on the proportion of heat that can be delivered by the heat pump, around a 60% saving relative to a gas boiler.
- The figure will depend on the sizing of the heat pump relative to peak demand, and the extent to which there is use of manual override of the heat pump in favour of the boiler.

Overall, hybrid heat pump systems provide useful emission savings versus gas boilers, with relatively small implications for infrastructure investment, building heating systems and consumer behaviour. However, the emissions savings may not be great enough for their widespread deployment to be a sufficient contribution to meeting the 2050 target. They therefore provide a potentially useful interim option to reduce emissions in the 2020s and early 2030s, and may improve prospects for pure heat pump roll-out thereafter.

If the Government sees an important role for these technologies, it will be important to conduct trials before widespread roll-out in order to understand their acceptance by consumers, how this affects their views of pure heat pump solutions and how they would be operated in practice (e.g. the balance between electricity and gas consumption).

Sources: Average installed heat pump costs based on BSRIA (2016) *UK Heat pumps, Report 59122/11*. These electric heat pump costs are broadly comparable to our central estimate of £1000/kW for an ASHP. It is likely the GSHP costs are slightly lower than our central estimate of £2000/kW for a GSHP based on Sweet Group for DECC (2013) (depending on average sizing).

Box 2.6. Best use of biomass

The Committee's 2011 *Bioenergy Review* provided an assessment of the potential roles for bioenergy given lifecycle emissions and other sustainability concerns, and also considered alternative uses for bioenergy feedstocks (e.g. use of wood in construction). It concluded that:

- It will be difficult to meet the overall 2050 emissions target unless bioenergy can account for around 10% of total UK primary energy (compared to the current 2%) and CCS is deployed. This reflects that there are a small number of economic activities where alternatives to hydrocarbons may either not be feasible (e.g. in aviation) or have not yet been identified (e.g. in energy-intensive industry). Scenarios for global land use which take account of required food production suggest that a reasonable UK share of potential sustainable bioenergy supply could extend to around this level (200 TWh of primary energy) in 2050.
- Given limits to the global supply of sustainable bioenergy, it is important that this is used in an

Box 2.6. Best use of biomass

optimal fashion:

  - If CCS is available, it is appropriate to use bioenergy in applications with CCS, making it possible to achieve negative emissions. These applications could include power and/or heat generation, the production of hydrogen, and the production of biofuels for use in aviation and shipping.
  - If CCS is not available, bioenergy use should be skewed towards heat generation in energy-intensive industry, and to biofuels in aviation and shipping, with no appropriate role in power generation or surface transport.
  - In either case, the use of woody biomass in construction (rather than as an energy source) should be a high priority, given that provides carbon storage while reducing the need for carbon-intensive products such as steel and cement.
- It is important that the role of bioenergy in low-carbon strategy reflects realistic estimates of total lifecycle emissions for different types of feedstock, including both direct and indirect land use change impacts.

The two main routes for using biomass in buildings are building-scale biomass boilers and larger biomass boilers or Combined Heat and Power units connected to heat networks.

Burning biomass can lead to air-quality issues arising from emissions of fine particulate matter and nitrogen oxides. These emissions can be mitigated through tail-pipe measures such as filters, scrubbers and catalysts, although the costs are more easily absorbed in the case of larger-scale boilers than smaller units.

This suggests that the two key roles for biomass in buildings are either in relation to heat networks (where other cost-effective options such as waste heat are not readily available, or in a secondary role for smoothing demand peaks) and in more rural areas (particularly properties which are expensive to insulate where heat pumps are less suited).

For the fifth carbon budget analysis, we developed a set of scenarios for biomass use in buildings, based on our updated assessment of the Bioenergy Review and previous sector scenario analysis:

- We include 5-15 TWh of biomass used in building-scale boilers in 2030, and 11-27 TWh including biomass used in heat networks. This is in line with our previous assessment in the 2013 *Fourth Carbon Budget Review*.
- To 2050, we include 13 TWh of local bioenergy sources for use in heat networks in our central scenario, with a high end estimate of 59 TWh.
- A higher level of deployment is possible in the 2020s and 2030s, provided that this does not displace other low-carbon technology and jeopardise the ability to meet the 2050 target. Consideration would then need to be given as to how to transition to other low-carbon heat options in buildings, should this bioenergy be diverted to other uses such as bio-CCS to 2050.

Source: CCC (2011) *Bioenergy Review*. Available at https://www.theccc.org.uk/publication/bioenergy-review/ and CCC (2015) *Sectoral Scenarios for the Fifth Carbon Budget*.

(c) Low-regret measures

Low-regret measures are those actions that support different long-term paths for decarbonising the UK heat sector and often offer low-cost ways to reduce emissions now. Given the need to reduce emissions to meet carbon budgets and to tackle climate change, these actions are sensible under any reasonable future scenario.

As set out at the start of this chapter, low-regret actions include:

(i) Ensuring new buildings are highly carbon-efficient

(ii) Low-cost efficiency improvements

(iii) Heat networks in areas with high heat density

(iv) Heat pumps in buildings off the gas grid

(v) Biomethane injected to the gas grid

(i) Ensuring new buildings are highly carbon-efficient

To meet current housing needs and accommodate a growing population, up to 5 million new homes may need to be built by 2030 and 8 million by 2050 (around a fifth of the housing stock).[44] Generally, it is much cheaper to integrate high-efficiency and low-carbon heating sources into new homes and commercial/public buildings than to retrofit those options to existing buildings:

- Evidence from the Zero Carbon Hub puts the cost of meeting tightened fabric efficiency standards at around £2,000 in 2014 with further reductions possible.[45] These costs were forecast to deliver around 1 $MtCO_2e$ of savings annually, and would be recovered in bill savings in ten years or less. A recent study for the Greater London Authority put the cost of meeting a tighter standard (including onsite renewables) at 1-1.6% of build costs (equivalent to £980-2,700 for a three-bed semi-detached property).[46] Achieving the same level of efficiency is harder and more costly when retrofitting, due to the difficulty in optimising at a building-scale including potential issues with thermal bridging, ventilation and solar gains. This is also true in larger non-residential developments.
- Heat pumps have lower costs and perform better where designed in, and where building standards imply low levels of heat loss. If heat pumps are fitted in 50% of new houses from 2025 and 100% by 2030, then this would amount to cumulative 1.1 million heat pumps in new-build properties by 2030 and up to nearly 8 million by 2050 (dependent on build rates).

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[44] Fifth Carbon Budget projections, developed with BEIS (formerly DECC) and Element Energy, based on DCLG household projections and ONS population projections. There is a gap between the current supply of dwellings and the household projections: the dwelling projections assume that supply increases to address the shortfall, catching up with demand in the mid-2020s.

[45] Sweett Group for Zero Carbon Hub (2014) *Cost Analysis meeting the Zero Carbon Standard*, available online at: http://www.zerocarbonhub.org/sites/default/files/resources/reports/Cost_Analysis-Meeting_the_Zero_Carbon_Standard.pdf

[46] David Lock Associates with Hoare Lea and Gardiner and Theobald, (2015) *Housing Standards Review - Viability Study*

- Building in low-carbon heat from the start in on-gas areas would avoid the cost of connecting to the gas grid, which are estimated at between £350-1,080 per domestic connection, and higher for a large commercial or industrial unit (Table 2.1).
- Even if heat pumps are not included from the start, buildings can be made 'heat pump ready', by installing underfloor heating or larger radiators. These allow lower-temperature systems, which also make gas boilers more efficient.

These arguments are reflected in the decision by the Greater London Authority to introduce the planned Zero Carbon Homes standard in London from October 2016 (Chapter 3). Developers in London are also required to connect to a low-carbon heat network if there is one in the vicinity, and to future-proof new developments for connection at a later stage.[47] This suggests that the industry is largely ready to meet higher standards, although there is likely to be a need for more support for smaller builders.

Table 2.1. Costs of connecting new properties to the gas mains

Connection type	Cost per property
Single property to an existing gas grid (outside London)	£346
Single property to an existing gas grid (London)	£743
Small development of 10 properties	£988
New development of 100 properties	£1,076
Commercial / Industrial estate (20 medium-sized units)	£1,681

Source: Aqua Consultants for CCC, as part of Frontier Economics and Aqua Consultants (2016) *Future Regulation of the UK Gas Grid, Impacts and Institutional implications of UK gas grid future scenarios*, available online at: https://www.theccc.org.uk/publication/next-steps-for-uk-heat-policy/
Notes: In the case of the single property connections, the assumptions are that the property is located within 23 metres of relevant main, that the Domestic Load Connection Allowance is applicable, and that the work is undertaken by a Gas Distribution Network company. In the other cases, the assumptions are that the installation is undertaken by suitably qualified installer, and the final connection by the Gas Distribution Network, and that there is no requirement for network reinforcement.

(ii) Low-cost efficiency improvements

UK buildings have widely differing levels of energy efficiency. Many properties still have opportunities to improve insulation at low cost, for example through top-up loft insulation or cavity wall insulation. Such measures can provide comfort and health benefits, as well as reducing energy bills. There are also opportunities to improve the efficiency of gas central-

[47] This means making an assessment of the future low-carbon heat supply options and ensuring that pipes and other associated infrastructure are sized to account for any future development plans.

heating systems, including by ensuring they run at lower temperatures so as to achieve higher efficiencies with condensing boilers, reducing bills whilst preparing the building stock for heat pumps or hydrogen (Box 2.7):

- Significant progress has been made in improving the thermal performance of homes. Increased energy efficiency improvements, primarily through improvements in boilers and insulation, led to an increase in the mean SAP score of the existing housing stock in England from 53 in 2008 to 60 in 2013.[48] Efficiency improvements from 2004 to 2013 are estimated to save a typical dual-fuel household £165 per year on their energy bill.[49]
- Nevertheless, significant further potential for cost-effective energy efficiency measures remains. There are over 2 million standard cavity walls yet to be insulated and over 4 million standard lofts suitable for top up, both of which are low-cost. While more expensive, solid wall insulation can be cost-effective in some electrically heated homes (Box 2.8).
- Measures to reduce the leakiness of buildings and to increase the efficiency of the heating system are critical for electric heat pumps. They can also serve to insulate consumers from higher prices of hydrogen relative to natural gas.[50]
- Many fuel-poor households are in inefficient homes with high energy bills. Although the cost of improving the efficiency of these homes is sometimes high (e.g. involving expensive solid wall insulation), doing so has an important social objective in tackling fuel poverty and is already targeted by Government policy. This will have spill-over benefits in reducing CO_2 emissions, increasing the proportion of the housing stock suited to heat pumps, and potentially stimulating innovation in solid wall installation (Box 2.9).
- Evidence from our fifth carbon budget analysis suggests there is also significant remaining cost-effective potential for energy efficiency in public and commercial buildings from energy-management measures (such as heating controls), boiler efficiency, insulation and glazing measures.

Box 2.7. Gas heating system efficiencies

Our fifth carbon budget scenarios include an assessment of the potential savings from improvements in gas heating, based on turnover of the boiler stock and the replacement of inefficient gas boilers with new condensing boilers (required by the 2005 boiler regulations). Efficient condensing boilers made up around 60% of the stock in 2014. We estimate abatement potential of 6 $MtCO_2e$ by 2030 by reaching 87% fleet in-situ efficiency across the stock.[51]

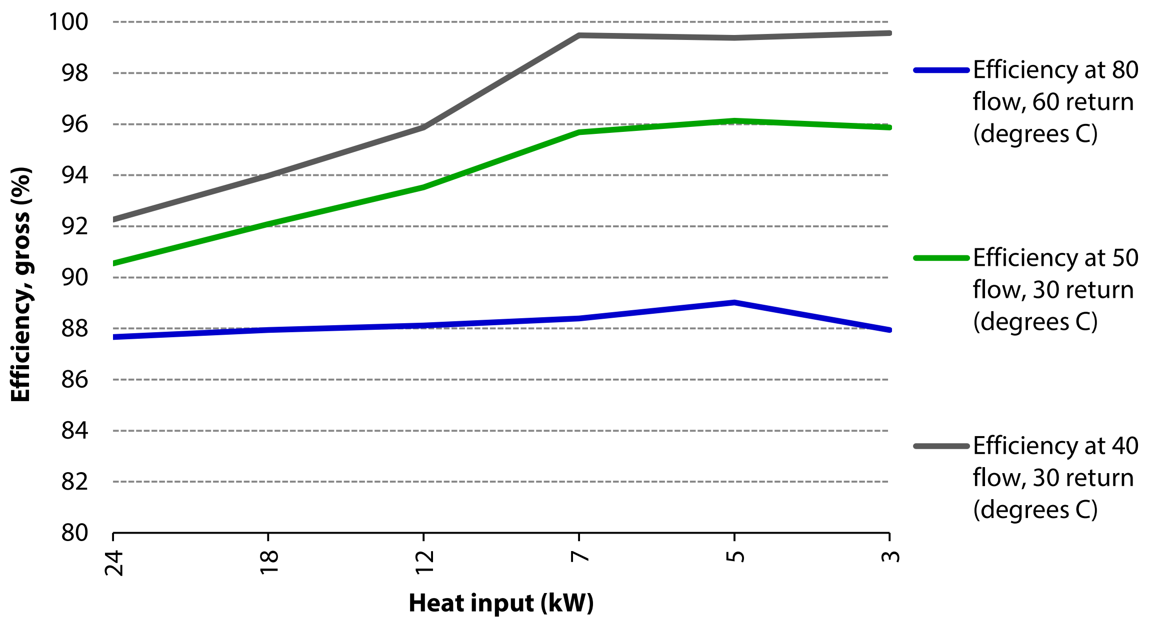
Achieving these emission reductions will occur partly as a function of the continued roll-out of efficient condensing boilers across the stock. Closing any remaining gap in condensing boiler efficiency is likely to mean ensuring that systems are not set to run at too high a temperature (so that 'return' temperatures are no higher than 55°C). It is likely that this is not currently being achieved across the stock, based on conversations with installers.

[48] DCLG (2016) *English housing survey headline report 2014 to 2015*
[49] CCC (2014) *Energy prices and bills – impacts of meeting carbon budgets 2014*
[50] Hydrogen produced from natural gas with CCS will be more expensive than natural gas, given the efficiency penalty when producing hydrogen and the capital costs of hydrogen production and CO_2 infrastructure.
[51] All efficiencies are presented on a higher heating value basis unless otherwise specified.

Box 2.7. Gas heating system efficiencies

- Where radiators are large enough, it may be possible to adjust the flow temperature of boilers to secure lower heating bills immediately. In other cases, heating system upgrades would be needed (larger radiators or underfloor heating).
- Whilst there is an upfront cost to upgrading heating systems (estimated at around £1,000 per household, based on Element Energy for CCC in 2013), this can lead to immediate bill savings of £60/year for a typical dual fuel household if increasing system efficiency by up to 10 percentage points. Further savings can be achieved where homes are sufficiently insulated to sustain lower heating temperatures (Figure B2.7).

Figure B2.7. Condensing boiler efficiency as a function of flow temperature and heat input



Source: Data supplied to CCC by the Energy and Utilities Alliance (EUA).
Notes: Laboratory test results for common UK market condensing boiler model. The efficiency is given for two sets of temperatures - the 'flow' temperature when it is first circulated, and the 'return' temperature to the boiler once it has cooled.

Source: CCC (2015) *Sectoral Scenarios for the Fifth Carbon Budget*, Element Energy (2013) *Pathways to a high penetration of heat pumps, a report for the UK CCC*
Notes: Estimated costs for upgrading heat emitters are based on a cost of £275/kW in Element Energy (2013) for upgrading heat emitters and the hot water cylinder, net of an estimated installed cost of £500 for the hot water cylinder. Estimated bill savings based on a dual-fuel household with annual heating demand of £12 MWh/yr.

Box 2.8. Insulation potential

Cavity walls

Research carried out by the Energy Saving Trust (EST) for BEIS suggests there around 2.3 million standard cavity walls that are currently uninsulated and could be insulated at low cost. They estimate there are also a further 1.3 million uninsulated walls with cavities that are of non-standard construction (e.g. concrete, stone, narrow cavity) and around a further 2.3 million dwellings that have a standard masonry cavity, but have issues that that need special attention (e.g. wall faults, exposure issues or access issues), both of which would be more expensive to insulate.

Forthcoming research by BRE indicates that there could be greater energy savings potential than previously thought from insulating uninsulated and partially insulated cavity walls of dwellings built between 1985 and 2001. Several changes to the building regulations in that period led to uncertainty in the thermal efficiency of these buildings. The research finds that 63% of dwellings failed to meet the target that was introduced in building regulations in 1985. BRE estimate that filling uninsulated and partially insulated cavity walls to the standard assumed for retrofitted walls would pay back within five years.

Lofts

The EST research also shows significant low-cost potential for further loft insulation with at least 4.2 million dwellings with standards lofts that have insulation of less than 125mm thickness. They estimate around a further 2.2 million dwellings with non-standard lofts that could be insulated at higher cost.

Solid walls

BEIS statistics show that the vast majority of solid wall homes, around 7.5 million, do not have insulated walls. This offers considerable potential for energy and emission savings, but the costs can be high and vary across types of properties. Our fifth carbon budget analysis found that in general, large- and medium-sized electrically heated homes are the most cost-effective to insulate, while gas-fuelled homes would not be cost-effective during the fifth carbon budget period on a carbon basis alone.

Source: Energy Saving Trust for BEIS (forthcoming) *Quantification of non-standard cavity walls and lofts in Great Britain*; BRE for BEIS (forthcoming) *Research into performance of, and measures to improve the performance of, UK dwellings with Cavity Wa*lls; BEIS (2016) *Household Energy Efficiency National Statistics.*

Box 2.9. Fuel poverty across the UK

Fuel poverty is a partially devolved issue; each separate administration has their own target. Scotland, Wales and Northern Ireland classify households as fuel-poor if they need to spend more than 10% of their household income on fuel in order to heat their home to a satisfactory standard. Each has a target date for eradicating fuel poverty on this basis.

In England, fuel poverty is measured on the basis of a Low Income High Cost definition, which considers a household to be fuel-poor if their required fuel costs are above the national median and if they were to spend that amount they would be left with a residual income below the official poverty line. The depth of fuel poverty is described as the fuel poverty gap which is the difference between the required fuel costs for each household and the median required fuel costs. England's fuel poverty targets are based around improving the efficiency of homes, in particular improving the energy

Box 2.9. Fuel poverty across the UK

performance of fuel-poor homes up to an EPC band C rating by 2030 as far as practicable.

Fuel poverty and energy efficiency are closely linked. The latest data for England show the incidence of fuel poverty and the size of the fuel poverty gap is significantly higher in properties with EPC ratings E to G than those rated A to C. For example, in 2014 around 30% of households living in G-rated properties were considered fuel-poor compared to only around 2% of those living in properties rated A to C. The majority of fuel-poor households in England live in homes rated D and E, reflecting the greater number of these in the stock than homes rated F and G. Solid wall homes represent 45% of English fuel-poor homes and have a significantly higher fuel poverty gap than fuel-poor cavity wall homes.

The Committee on Fuel Poverty's recent report indicates that there are significant challenges in meeting England's fuel poverty target, with considerable further funding needed. They recommend focusing the future supplier obligation solely on improving the EPC score of fuel-poor homes, improving the targeting of the obligation, seeking cost-effective measures and helping fuel-poor households pay their energy bills while they are awaiting efficiency improvements.

Source: DECC (2016) *Annual fuel poverty statistics report: 2016*; DECC (2016) *Fuel poverty detailed tables: 2014*; Committee on Fuel Poverty (2016) *Committee on Fuel Poverty: A report on initial positions.*

(iii) Heat networks in areas with high heat density

Cost-effective potential for heat networks could account for nearly 10% of heating demand in 2030 (Box 2.10). The level of deployment to 2030 should reflect this potential and the need to keep open the option of a range of higher ambition to 2050.

- Heat networks are particularly well suited to areas of high heat density, including cities, new-build developments and some rural areas. The overall viability of schemes is very sensitive to the level of demand, principally determined by heat density of the area and the proportion of properties connecting to the network.
- They are a key low-carbon solution for commercial and public buildings, which are more concentrated in urban areas and can provide important anchor loads to make schemes economic to run. Whilst the deployment in our scenario represents just under 10% of overall heating demand in 2030, it represents over 25% of non-residential heat demand.
- Low-carbon heat sources can include waste heat (from industrial and power plant, or other sources such as electrical substations or underground railways), large-scale heat pumps (e.g. water- or sewage-source), geothermal, biomass boilers or CHP, and potentially hydrogen.
- It is unlikely that schemes will prove viable or attract support in all the areas assessed as having cost-effective potential in our earlier work, but it makes sense to pursue the option strongly. Government has made £320 million available to 2020 for low-carbon heat networks, although the detail of the scheme is still currently being developed. This could add a few TWh of heat supply by 2020. A reasonable level of ambition would be to go beyond this such that heat networks provide over 40 TWh overall by 2030 (around a tenth of heat demand), in line with our central fifth carbon budget scenario.

The critical path in rolling out heat networks is in laying the hot water distribution pipe infrastructure, rather than in the supply of heat. It makes sense therefore to continue installing networks now based on gas CHP, provided these can be largely switched to low-carbon heat

sources in future (e.g. a potential low-carbon heat source is identified and pipes are sized to accommodate it).

Box 2.10. Heat networks modelling for the fifth carbon budget

We commissioned Element Energy to undertake detailed analysis of the cost-effective potential of low-carbon heat networks in the UK to 2050. The work included a review of district heating, thermal storage and district cooling, along with consideration around the transition over time to both low-carbon and low-temperature heat networks.

The scenarios are based on detailed spatial analysis of supply options, combined with spatial analysis of demand.

On the demand-side, the analysis derived 144 zone archetypes from national heat map data, allowing for variation in heat density, different mixes of residential and non-residential buildings, and building types (solid wall/cavity wall, house/flats).

It considered a range of supply-side technologies, including high-temperature waste heat from power and industrial plant, low-temperature waste heat boosted by heat pumps, gas Combined Heat and Power (CHP), Energy from Waste, and large-scale heat pumps (water-source and sewage-source).

The study highlights a key role for thermal storage, but a more limited role for gas CHP plant.

- Thermal storage can reduce the size of peak load plant, help match supply to demand and manage the network return temperature (improving overall efficiency). The most common form of storage is large hot water tanks; interseasonal storage is expensive unless there is a natural source (such as an aquifer), and it is not expected to play a significant role. Just over 7% of operational schemes in the UK are known to use a thermal store currently – this is expected to increase.
- As the electricity grid decarbonises, the carbon savings from gas CHP diminish, with no additional abatement in new schemes from the end of the 2020s.

Water-source heat pumps contribute around a quarter of the heat in the central scenario in 2030, with further growth potential to 2050. The analysis is based on new water-source heat map data developed by DECC together with the Environment Agency.

Sources: Element Energy, Frontier Economics and Imperial College (2015) *Research on district heating and local approaches to heat decarbonisation*; CCC (2015) *Sectoral Scenarios for the Fifth Carbon Budget.*

(iv) Heat pumps in buildings off the gas grid

Heat pumps have faced challenges to date, but remain the leading low-carbon option for buildings not connected to the gas grid. Heat pumps have a high initial capital cost, but are largely cost-effective in off-gas grid buildings as an alternative to oil or electric heating (i.e. they can reduce carbon emissions at a cost comparable to other options required to meet the UK carbon budgets). There are limited lock-in issues in locations that are remote from the gas network, because heat networks are typically less viable and hydrogen is not an option.

Recognising this cost-effective potential, our central scenario for the fifth carbon budget has 1.1m heat pumps retrofitted in homes to 2030. Such a level of installation, combined with adoption for new build, would develop the supply chain for heat pumps to a point where they could be rolled out across a large proportion of the building stock by 2050, should that be required.

Heat pumps are already cost-effective in electrically heated non-residential buildings and could become the dominant form of heating through the 2020s, particularly for larger offices and commercial premises with cooling loads.

In buildings off the gas grid for which heat pumps are unsuited (e.g. because it is not feasible to improve them to a sufficient standard of energy efficiency), there is likely to be a supplementary role for biomass boilers if sustainable supplies are available.

(v) Biomethane injected to the gas grid

Biomethane injection into the gas grid can be considered 'low-regrets' as it reduces emissions without locking into new network infrastructure. Producing biogas via anaerobic digestion and upgrading it to biomethane for injection into the natural gas network, with no changes required by end-users, can avoid methane emissions from the waste sector and reduce CO_2 from fossil gas consumption.

Biomethane injected in to the gas grid is currently supported under the Renewable Heat Incentive (RHI) at an average of 4.5p/kWh over 20 years.[52] Output has grown to over 2 TWh annually in four years, putting the UK at the forefront of biomethane-to-grid development internationally.[53] Support for biomethane makes up around 40% of committed future expenditure for 2017 under the RHI, at £190m a year to 2020/21.

It is important that anaerobic digestion facilities are based very largely on waste feedstocks. While this limits the size of the resource, it limits competition with food production and the overall lifecycle emissions of biomethane production. Our scenarios for the fifth carbon budget have biomethane injection to the grid of 21 TWh in 2030, as well as small amounts of further biogas use on a distributed basis (e.g. on farms).

For a facility injecting biomethane into a gas network that is to be converted to hydrogen, there would be a range of potential ways that its output could be utilised. For example, it could be reformed to hydrogen on a small scale, with the biogenic CO_2 either released to atmosphere or captured (e.g. as part of carbon capture and utilisation). Alternative uses include liquefying the biomethane and using it in transport for heavy-duty vehicles, as has been done at a landfill gas facility in Surrey since 2008.

Expansion of biomethane production based on waste feedstocks is therefore a low-regrets action over the period to 2030.

Summary

Improved energy efficiency is required under all future pathways and can continue to deliver cost savings to consumers and limit future bill increases. Avoiding lock-in to high carbon infrastructure is a priority for new buildings. In the near term, there is a clear case for continued policy support of heat pumps in off-gas buildings, heat network development and biomethane to grid. Government's role is to provide a clear, long-term direction of travel and to ensure that the growing markets in these areas are stable by minimising levels of policy risk.

Chapter 3 considers the policy options for ensuring these low-regret actions are taken.

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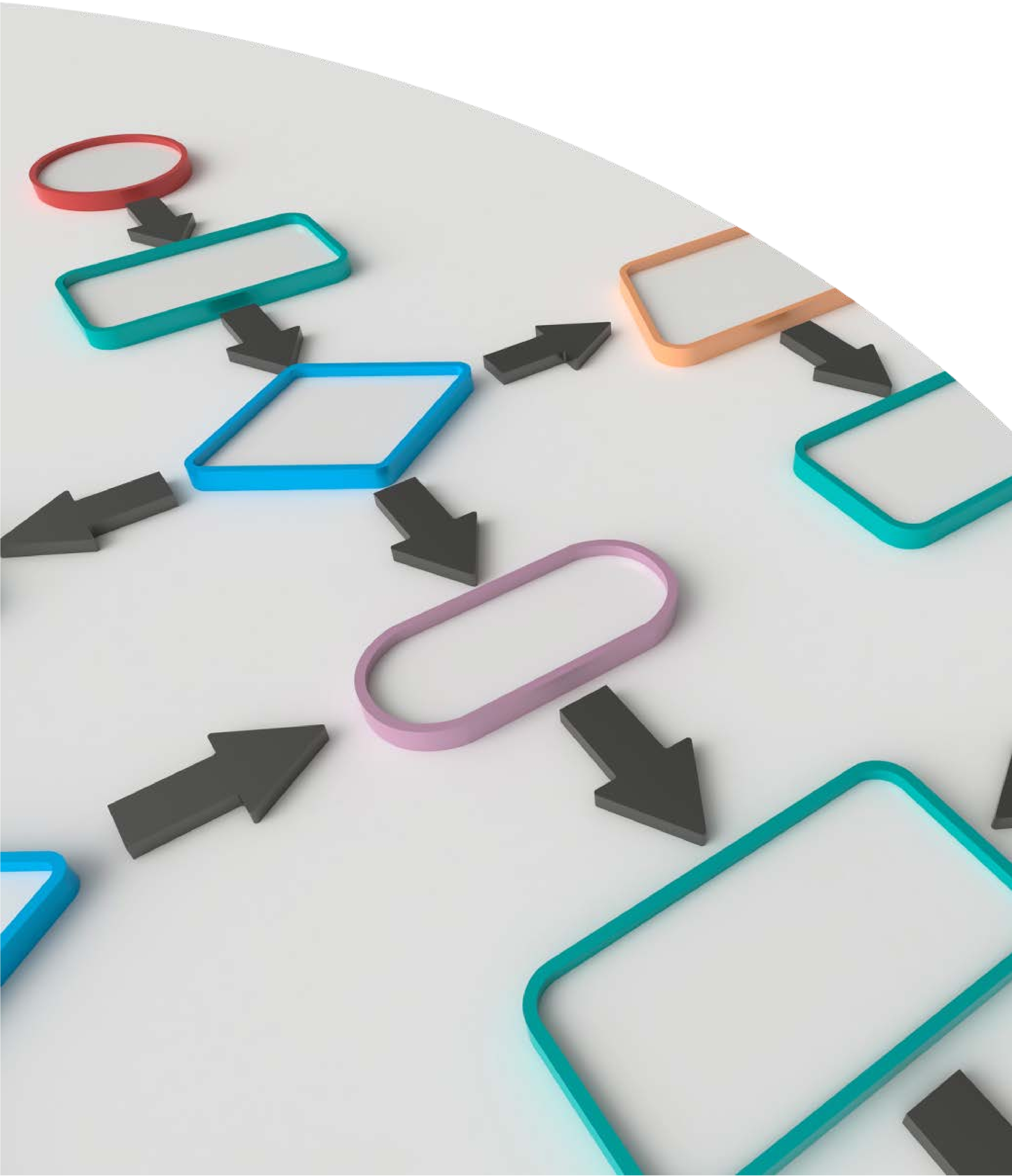
[52] Calculated based on DECC(2016) *RHI Consultation Impact Assessment, The Renewable Heat Incentive: A reformed and refocused scheme*

[53] Some industry estimates now put this close to 3 TWh.

Chapter 3:
Policy to drive the transition



Chapter 2 identified the priorities for an effective heat strategy: preparing for the major decarbonisation required in the 2030s and 2040s, and increasing the implementation of low-regrets measures throughout the next 15 years. In this chapter we consider how effective policy can address each of these areas.

Our key messages are:

- **The forthcoming Emission Reduction Plan must incorporate immediate action and prepare for decisions to be made in the next Parliament.** The Government's plan for meeting the fourth and fifth carbon budgets should set clear goals for improving efficiency and rolling out low-carbon heating. The plan should set a timetable of next steps for policy development and ensure that informed decisions can be made next Parliament about the role of hydrogen in heating.
- Success requires a joined-up approach to energy efficiency and low-carbon heat underpinned by standards that tighten over time, consistent price signals, and a package that is widely understood and attractive to households and businesses.
  - **A stable framework and direction of travel, backed up by evolving standards for the emissions performance of buildings.** Standards should be used to allow competitive markets to develop on a level playing field, including to ensure that low-regret actions are taken and to overcome barriers to implementation (e.g. making sure new buildings are built to be low-carbon from the start). They should be tightened over time, with the expected future direction set out in advance to allow decision-makers to prepare efficiently and for dynamic markets to emerge. As far as practical, they should be focused on ends (e.g. reducing carbon emissions) rather than the means (e.g. specific technologies) and be based on actual rather than modelled performance (e.g. by using data from smart meters).
  - **A joined-up approach to energy efficiency and low-carbon heat that works across the building stock.** Emissions reductions can be achieved by improving energy efficiency and by shifting to low-carbon fuels. Many of the barriers to action (e.g. disruption in making changes, need to find a trusted installer, financing constraints) are shared across both types of measure, while improved energy efficiency can reduce the cost and improve the suitability of buildings for low-carbon heat options. Renewed policy should therefore seek to take a combined approach. Policy should target distinct groups of householders and businesses, including small and medium-sized enterprises (SMEs), which are poorly addressed by existing policies. Modernising the efficiency of heating systems in homes connected to the gas grid through the 2020s is an important complement to fabric efficiency improvements, and is required to prepare the stock for widespread roll-out of heat pumps and hydrogen from 2030.
  - **Simple, highly-visible information and certification alongside installer training to ensure low-carbon options are understood by consumers and installers are effective and trusted.** Awareness of low-carbon options and their value is generally low. In businesses, energy performance is assessed infrequently and often not discussed at senior management or board level, and so has little strategic value or 'salience'. A key policy focus must be improved information, which could be enabled by smart meters and improved business reporting. A nationwide training programme is needed to develop high professional standards and skills for low-carbon choices in the building and heat-supply trades in partnership with industry. There is also an opportunity for leadership through public procurement and low-carbon investment, given that the public sector

constitutes a third of non-residential heating needs and almost a fifth of heating energy in non-residential leased buildings.

– **A well-timed offer to households and SMEs that is aligned to 'trigger points'.** These include house moves and major renovations, when low-carbon options can be installed with less additional disruption and at lower cost. Trigger points are relevant for effective use of standards, incentives and information. SMEs are responsive to policies built around local business networks and supply chains.

– **Consistent price signals that clearly encourage affordable low-carbon choices**. While many energy efficiency improvements are already financially attractive, some other measures, including most low-carbon heat options, would not currently be attractive without public subsidy. Consumers will generally only take up low-carbon options when sufficiently incentivised to do so, and businesses will only invest and innovate in supplying the market if they are confident that incentives will remain in place. In part this reflects the current balance of tax and regulatory costs on energy bills: costs are significantly larger for electricity than gas or oil heating, and the full carbon costs are not reflected in the pricing of heating fuels. In the transition to low-carbon heating, particularly if low-carbon heat is rolled out in different parts of the UK at different times, there will be important questions to be resolved around how to pay for decarbonisation of heat. Even where energy efficiency improvements may be financially advantageous, they are often usefully supplemented by additional fiscal incentives to encourage uptake and low-cost loans to enable households and SMEs to cover upfront costs.

In considering options to develop existing policy we first consider the existing evidence on policies that have worked effectively in the UK and internationally to deliver improvements to energy efficiency and shifts in heating systems. We also consider the wider objectives and constraints on policy. The chapter structure reflects that approach:

(a) 'What works?'

(b) The broader policy context

(c) Current policy and policy gaps

(d) Options for strengthening policy

In forming our advice, the Committee have assembled an expert advisory group, whose report to the Committee is published alongside this one and summarised in section (d). The group was chaired by Professor Jan Webb (University of Edinburgh) and included Professor Nick Chater (Warwick Business School, CCC), Professor Nick Eyre (University of Oxford) and Professor Robert Lowe (UCL). The group's role included reviewing three What Works policy reviews: one on non-residential buildings energy efficiency policy by Dr. Peter Mallaburn (University College London), one on low-carbon heat policy by the UKERC Technology and Policy Assessment team at Imperial College London and one on residential energy efficiency policy by the Committee secretariat. They also reviewed a Frontier Economics study for the Committee on the future of the gas grid and research by the Committee secretariat on market segmentation and possible future pathways. All this work is summarised below and published at www.theccc.org.uk.

(a) 'What works?'

Residential consumers – what do we know about effective policy-making?

Effective policies are ones that target decision-making opportunities, gain consumer trust, are timely, low-hassle, easily communicable, backed up by a strong marketing strategy and deliver high-quality installations (Chapter 1). These lessons are supported by best practice from UK and international policy-making, as set out in Annex 3,[54] the Imperial College paper on low-carbon heat policy and the UCL paper on non-residential buildings energy efficiency.[55]

Internationally a range of policies have been effective at encouraging consumers, particularly home-owners, to install measures that reduce energy consumption (Annex 3). These underline the importance of consistency and long-term commitment, and the value of packages of mutually-reinforcing policies:

- **High-quality information and advice** are needed to support decision-makers in the face of a number of information failures. For example, there can be issues with incomplete or asymmetric information, uncertainty, hidden costs and high transaction costs including the search for knowledge. Information programmes have had varying results, but information provision is often a relatively cheap intervention and is able to facilitate and reinforce other policies:
  - Energy certificates and labels can be effective with most studies showing a premium in rents or sale value for more-efficient buildings. However, the results are less positive for residential buildings than for commercial buildings where there is a more rational decision-making process. Government-backed certificates with credibility and stability have a greater impact than informal or private information provision.[56]
  - Feedback programmes have been seen to reduce energy consumption by 1-5%.[57] They can be very low cost and make use of social pressure (e.g. comparing bills to neighbours). The frequency and persistence of feedback are important, which is in line with the function of smart meters, which have the potential to reduce energy use by up to 15%, although at higher cost.[58]
  - Energy audits are able to provide personalised information, but the empirical results of such schemes are less promising.[59]
- **Taxes** on energy or CO_2 provide price signals to consumers to adopt more energy-efficient technologies or behaviours. Taxes are complementary to other policies, reinforcing their

[54] *Annex 3 - Best practice in residential energy efficiency policy: A review of international experience*, available online at: https://www.theccc.org.uk/publication/next-steps-for-uk-heat-policy/
[55] Hanna R,. Parrish B., Gross R. (2016) *UKERC Technology and Policy Assessment Best practice in heat decarbonisation policy: A review of the international experience of policies to promote the uptake of low-carbon heat supply draft*; Mallaburn, P. (2016) *A new approach to non-domestic energy efficiency policy: a report for the Committee on Climate Change*. Both available online at https://www.theccc.org.uk/publication/next-steps-for-uk-heat-policy/
[56] Ramos, A. et al (2015) *The role of information for energy efficiency in the residential sector. Energy Economics 52* (2015) S17–S29
[57] UKERC (2015) *Energy Efficiency Evaluation: The evidence for real energy savings from energy efficiency programmes in the household sector*
[58] Ramos et al (2015)
[59] Ramos et al (2015)

impact[60] and can help in setting social norms. Some of the countries with the best energy efficiency performance, such as Denmark and Germany, have very high energy taxes. [61]

- **Incentives** such as grants, tax incentives, supplier obligations and feed-in tariffs encourage households to take up measures by lowering the costs faced by consumers. In theory subsidies have a stronger role to play in cases where an investment is socially desirable but not attractive to a household because it will not pay back quickly, and they have a clear role in supporting fuel-poor households for equity reasons. Incentives are often also used in a wider range of cases to support uptake especially when technologies are new. Over the longer term there may be budgetary pressure to transfer towards measures providing more access to capital.
  - Supplier obligations have a strong record in delivering installations and are widely used across Europe. The obligations in place in the UK in the period 2008 to 2012 delivered annual savings of around 1.1% of final energy consumption in the household sector,[62] but have since had their level of ambition reduced.
  - Grant schemes, such as Ireland's Better Energy Homes, can be cost-effective and can generate significant benefits beyond energy savings (e.g. Warm Up New Zealand has generated considerable health benefits).[63] However, their cost-effectiveness can be reduced by paying for measures that households would have installed without the scheme.
  - Tax rebates on energy efficiency works have been available in several countries and can deliver significant improvements, but are often taken up by higher earners and their cost effectiveness can be affected by the benefit being received by households who would anyway have paid for measures in the absence of the scheme, as has been the case with France's Crédit d'impôt développement durable (CIDD).[64]
- **Measures improving access to capital,** such as low-cost loans and preferential-rate mortgages, have an important role in facilitating energy efficiency improvements that have large upfront costs and for households that have limited access to funds. There are several examples of such schemes delivering substantial energy savings (e.g. apartments using KredEx loans in Estonia are estimated to save 39% in energy consumption, and homes built or refurbished to the top standard in Japan's Flat 35 mortgage scheme use only a third of the energy of average Japanese homes).[65] Providing access to capital is most appropriate where the measures are desirable to consumers either because the energy savings will quickly offset the cost, or due to other policy (e.g. subsidy or standards). However, a lack of financing

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[60] Rosenow, J. et al (2016) *Energy efficiency and the policy mix*, Building Research & Information, 44:5-6, 562-574

[61] Eurostat (2016) *Energy price statistics.* http://ec.europa.eu/eurostat/statistics-explained/index.php/Energy_price_statistics. For example, in Denmark 69% of the final price of electricity and 57% of the price of natural gas for household consumers is taxation.

[62] Ricardo AEA for ClimateXChange (2015) *A Comparative Review of Housing Energy Efficiency Interventions,* http://www.climatexchange.org.uk/reducing-emissions/comparative-review-housing-energy-efficiency-interventions/

[63] Grimes, A. et al for the New Zealand Ministry of Economic Development (2012) *Cost Benefit Analysis of the Warm Up New Zealand: Heat Smart Programme*

[64] Nauleau, M. (2014) *Free-riding on tax credits for home insulation in France: An Econometric assessment using panel data*. Energy Economics, 46 (2014) 78–92.

[65] Association for the Conservation of Energy (ACE) for the World Energy Council (WEC) (2013) *Financing energy efficiency in buildings: an international review of best practice and innovation*, http://www.eceee.org/all-news/press/2013/2013-10-22/WEC-EEC-Final

is seldom the primary reason that energy efficiency projects do not go ahead. Financing is only useful once the product has been sold.[66] Many of the loan schemes are combined with a level of subsidy to make the investments more attractive, for example a share of German KfW loans is not repayable.

- **Standards** are often essential for shifting social norms within an accelerated timeframe. These usually work by removing the least efficient products from sale. They work best where the standards are easily measurable and enforceable and expected to be ramped up over time. Standards provide stability and can produce reliable outcomes without a high cost to government. The 2005 regulations mandating condensing boilers provide an example of strong, well-implemented UK legislation in this field. In this case, a clear commitment was made by government, industry was involved in developing the policy, with significant investment in training in the two years leading up to the introduction, and there were clear criteria for testing compliance.

No single type of intervention is superior. Much of the effectiveness of a policy depends on its design, implementation and context. One of the most important success factors is providing a long-term stable policy framework to gain consumer trust and provide the supply chain with sufficient certainty to grow and innovate. Building on experience of what works includes learning from behavioural research relating to, for example, tailored messaging and targeted trigger points (Box 3.1).

Box 3.1. Policies that work with the grain of people's behaviour

Targeting trigger points. Policies tend to be more effective when targeting trigger points, such as when households are moving home or considering renovation, since these are times when households are considering their options and are already likely to be exposed to a level of disruption. Some countries such as Denmark and Sweden require high levels of efficiency on extensions to a home and require certain upgrades to be made to the existing structure at the same time. Japan's Flat 35 scheme provides preferential-rate mortgages to households willing to buy a more energy-efficient property.

Effective communication and marketing are essential to making the policy known and appealing to the public. Communication is best when conveying a simple message, targeted in terms of the messages that matter most to the group on whom the policy is focused and ideally with one source of information providing a harmonised message and streamlined approach across schemes. Many countries have an agency that provides this function. For example, New Zealand's Energy Efficiency and Conservation Authority has been successful in communicating its programmes through its dedicated ENERGYWISE website. This has a high brand recognition and has used TV and leaflets displayed in a range of service providers and retailers to create visibility. It has been based on a long-term strategy changing the focus of the messaging over time and has tapped into household's desires to improve comfort and health. Experience in other countries shows that businesses are well placed to take a lead on marketing, for example where retail banks are the interface with consumers such as in schemes in Germany and Japan.

Gaining and maintaining consumer trust is important in making sustained progress. There is an important role for trusted intermediaries, for example energy agencies, to make programmes well aligned and to manage the quality of delivery by setting high design standards and ensuring consumer protection. There is also a strong need for a skilled supply chain. Providing the industry with enough

[66] Borgeson, M. (2014) *The Limits of Financing for Energy Efficiency*. Lawrence Berkley National Laboratory, http://escholarship.org/uc/item/10b8d9zs

Box 3.1. Policies that work with the grain of people's behaviour

clarity on policy to train its workforce is key, as are suitable minimum training requirements and rigorous accreditation. For example, Germany has developed a supply chain of trusted, highly qualified engineers over years of stable policy.

Source: ACE for WEC (2013) *Financing energy efficiency in buildings: an international review of best practice and innovation;* AEA Ricardo for ClimateXChange (2015) *A Comparative Review of Housing Energy Efficiency Interventions.*

Linking low-carbon heat and energy efficiency

Consumers generally think about warmth and comfort in the home rather than energy efficiency or renewable heat. Furthermore, there are benefits to combining interventions on energy efficiency and renewable heat: disruption to the householder can be minimised by making changes at the same time, and renewable heat systems (e.g. heat pumps) are generally more effective and cheaper in well-insulated properties.

Policy should reflect this by bundling low-carbon heat and energy efficiency together to reflect consumer decision-making, and designing solutions for the whole home rather than trying to optimise individual parts. This has proved effective in other markets:

- Good examples of **integrated policy packages** include the German KfW programme where higher levels of incentives are awarded for combining energy efficiency and low-carbon heat, or the French 0% finance scheme for a package of low-carbon retrofit measures (building envelope and heating system, with a minimum element of energy efficiency).
- The **whole-house retrofit** approach is another example of how this can work in practice. The leading example is the Dutch Energiesprong social housing retrofit programme which has driven down the intervention time from several weeks to several days, together with dramatic unit-cost improvements.[67] This also shows the benefits of undertaking measures in one go rather than in multiple separate occasions.[68]

Decarbonising heating substantively where there is an incumbent natural gas grid has not yet been undertaken. Early significant deployment of heat pumps and heat networks in leading European markets took place as a response to the oil crises in the 1970s. Nevertheless, Germany and Italy have over 20 million natural gas customers and have also sold half a million or a million heat pumps respectively from 2005 to 2013. In market-leading European countries, heat pump deployment has been driven by a stable combination of information campaigns, technical standards and fiscal incentives (Box 3.2). There is evidence that upfront subsidies are more effective than ongoing payments for supporting consumers to install capital-intensive low-carbon heating such as heat pumps:

- The lesson from a number of other European heat pump markets in the 1980s and 1990s is that success depends on having standards in place for manufacturing, installation and

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[67] Webb, J., *Heat and Energy Efficiency: Making Effective Policy Advisory Group Report, A report for the UK Committee on Climate Change, a*vailable online at: https://www.theccc.org.uk/publication/next-steps-for-uk-heat-policy/
[68] The Committee also made this point in the 2015 response to the fuel poverty strategy consultation, available online at: https://www.theccc.org.uk/publication/letter-fuel-poverty-strategy-consultation-response/

maintenance which are strong enough to maintain the reputation of the heat pump industry. For example, an initial surge in the German heat pump market following the introduction of a tax credit scheme saw a crash in the mid-1980s, attributed variously to lower fossil fuel prices, poor installations, a lack of maintenance and low installer experience. Enhancing the reputation of the industry through standards and regulations subsequently helped address this and improve consumer awareness and confidence.[69]

- Uptake of the domestic Renewable Heat Incentive (RHI) feed-in tariff in the UK to date has been very low. To the extent that there has been take-up, this has been predominantly from wealthier households with access to capital, achieving returns of over 10% (in real terms) for larger properties.[70] Most international subsidies have an upfront element,[71] and the Scottish Government has put in place social finance to help widen the uptake to less-wealthy households.

Upgrading the building stock by 2030 and rolling out low-carbon heating widely post-2030 imply major changes, which are unlikely to be delivered by the market without a strong Government role. Lessons from international policy-making suggest that clearly demarcated roles and leadership at all levels of Government can improve policy outcomes:

- Central Government provides the long-term policy vision, targets, legislation and finance, together with the main overarching decisions. Good examples include the German KfW programme and finance, and the French Fonds Chaleur programme, set up to meet the respective renewable heat targets of 15.5% by 2020 and 38% by 2025.
- Regional and local Government is uniquely placed to join up and support the chain of decision-makers (e.g. householders, social landlords, installers and suppliers). Local area-based schemes such as Arbed in Wales illustrate how visible benefits can help support uptake, whilst the Kirklees Warmzone programme and the Stroud District Council Target 2050 Homes project are examples of where zoning of incentives were well supported by advice, and in the case of Stroud, a local list of trusted installers and 'one-stop shop' communication.[72] A 2015 Frontier Economics review of best practice in tackling barriers to uptake of low-carbon measures highlighted other best practice including the benefits of face-to-face contact over letter drops, Street Champions and engaging parents through schools.[73]

[69] Hanna R., Parrish B., Gross R. (2016) *UKERC Technology and Policy Assessment Best practice in heat decarbonisation policy: A review of the international experience of policies to promote the uptake of low-carbon heat supply draft.*
[70] DECC (2016) *RHI Consultation Impact Assessment, The Renewable Heat Incentive: A reformed and refocused scheme*
[71] IEA (2016) *Medium-term Renewable Energy Market Report*, Heat Chapter, draft version.
[72] Frontier Economics (2015) *Research on district heating and local approaches to heat decarbonisation Annex 1: Overcoming barriers to district heating.*
[73] Frontier Economics (2015)

Box 3.2. What Works in low-carbon heat policy

The 2016 UKERC review of What Works in Heat policy, published as supporting research to this report, assesses best practice in international policy support for heat pumps and heat networks. It stresses the importance of contextual factors (ownership structures, degree of liberalisation, energy prices) along with historical context. The review highlights a number of important lessons, including the role of policy stability, and a policy package that combines finance with information, regulation and standards, a supportive planning and regulatory framework:

- **Policy stability** promotes industry, consumer and, in the case of district heating, local authority confidence. Where it comes to heat networks, perceived policy stability means banks in Iceland and Denmark compete to loan to district heating projects. In the UK, short-term and abruptly-changing policies relating to heat network development have created uncertainty and perceived risks for local government and the commercial sector. Similarly, heat pump deployment in Denmark has been adversely affected in the past by varying political support for the environmental agenda, opposition to electric heating, or a lack of recognition of heat pumps as a legitimate form of renewable energy.
- A range of **incentives, taxation and subsidies** have proved successful in different markets. Fossil fuel or carbon taxation has been successful in building stable low-carbon heat markets in Sweden and Denmark. Subsidies for replacing oil and electric heating can also be effective in stimulating demand both for heat pumps and heat networks. Investment grants appear to be particularly important for heat networks where energy markets have been liberalised (and where district heating markets are less developed).
- **Information, regulation and standards** are each key to policy effectiveness. In Switzerland and Germany, policies to increase technical standards, promote heat pumps and implement information campaigns have been successfully deployed in combination with subsidies to stimulate the widespread take-up of heat pumps. In the case of heat pumps, the success of public subsidy support and promotion depends upon technical standards being established in the first place. In this regard, the setting up of national heat pump associations and test centres to monitor heat pump performance have been instrumental for increasing quality assurance. For heat networks, price regulation may also play a role in reassuring consumers.
- **Planning and regulatory frameworks** are helpful for giving heat network developers confidence that they will secure a high enough percentage of the local heat market to justify the initial capital expenditure in liberalised energy markets. Strong planning policy is a feature of most large-scale heat network development (e.g. Denmark, Sweden and London). Zoning has been introduced in Denmark, supported by mandatory connection to heat or natural gas networks, and banning of heat pumps in collective supply areas, while subsidisation of heat pumps has been increased outside collective supply areas.

Source: Hanna R., Parrish B., Gross R. (2016) *UKERC Technology and Policy Assessment Best practice in heat decarbonisation policy: A review of the international experience of policies to promote the uptake of low-carbon heat supply draft.*

Infrastructure and heat networks planning - What Works

Supply and demand for heat is by nature more specific to local areas than electricity production and consumption, due to the relative difficulty in transporting heat over long distances. This has implications for the mix and nature of low-carbon heat solutions, and for planning and governance frameworks. Lead times for major infrastructure require detailed long-term planning (including CCS infrastructure where relevant). For energy infrastructure, long-term national

planning relies on regional spatial planning together with coordination, support, capacity-building and public engagement at a local level:

- In the case of heat network development, a supportive planning and regulatory framework is critical for underpinning the business case, combined with an attractive and stable financial framework. Learning from the large increase in Austrian community biomass district heat between 1979 and 2013 also points to the role of regional and local government knowledge brokerage and capacity-building.[74]
- Coordination and support at a local level can also provide a natural forum for public engagement, which is vital for securing a local mandate for infrastructure and can help avoid costs and delay. Alternative successful models of public engagement involve setting up a national body, as in the case of the French Commission nationale du débat public:
  – A 2015 report by Green Alliance makes the case that there is no space for the public to participate in strategic, place-based discussions about where infrastructure should go; the different ways in which needs could be met; and the trade-offs that such choices will involve. Whilst engagement should be appropriately scaled (according to the recognised spectrum: inform; consult; involve; collaborate; empower), the current limited consultation of technical documents falls short of meaningful and extensive public engagement.[75]
  – The French national commission for public debate (CNDP) was set up in 1995 based on a system developed in Quebec, Canada. The process is triggered for all large infrastructure projects above a given threshold. After four months of public debate, where each of the participants is given equal support in drawing up its arguments and participating in the debates, the CNDP produces a synthesis report. The developer then decides whether to push ahead with the scheme or not, with around a third of cases since 2009 being dropped or extensively modified.
  – This issue will need to be tackled head-on in undertaking a significant shift away from natural gas heating, particularly if pressing forward with any hydrogen conversion project.[76]

Trials and demonstrators have an important role to play in improving our understanding of technical and governance best practice and can at the same time help in engaging consumers and understanding the impacts of consumer behaviour on the system.[77]

Businesses and the public sector – what do we know about effective policy-making?

A wide variety of energy efficiency policies and measures are being used around the world. Many of these policies have been in use for over 40 years and include improving information

[74] Johnson, V. and Geels, F. (2016) *Research Briefing 01 Supporting Diffusion of Low-Energy Systems, Paper by the Centre on Innovation and Energy Demand*. Available online at: http://cied.ac.uk/files/file.php?name=3525-cied-policy-briefing-01-heat.pdf&site=440

[75] Green Alliance (2015) *Opening up infrastructure planning, The need for better public engagement,* available online at: http://www.green-alliance.org.uk/resources/Infrastructure_planning.pdf

[76] Frontier Economics and Aqua Consultants (2016) *Future Regulation of the UK Gas Grid, Impacts and Institutional implications of UK gas grid future scenarios*, available online at: https://www.theccc.org.uk/publication/next-steps-for-uk-heat-policy/. See Box 2.4.

[77] Notable examples include the Swiss heat pump trials running since 1994 (the main trials ran between 1994 and 2003).

through monitoring and reporting of performance, regulating technical standards and developing voluntary agreements, financing for capital-constrained SMEs and supporting market change with public procurement leadership (Box 3.3).

Research on why certain policies are effective has emphasised that more attention should be spent not on 'what' is implemented, but 'how' polices are implemented, specifically 'how' they focus their influence on an organisation's decision-making processes. The analysis of decision making in Chapter 1 showed that energy efficiency investments are more likely to happen when they are salient (i.e. of strategic importance) to the organisation, and that salience is influenced by a combination of internal, external and sectoral drivers.

A simple policy of energy performance reporting, for example, can be a particularly effective approach if implemented to exploit each driver of salience:

- The UK government's review of the CRC scheme found that Board sign-off of an energy performance report raised internal visibility of energy efficiency across the organisation and connected senior management with the energy and facilities management teams.[78] The result was a much higher likelihood that the company would conduct energy audits, install energy management systems and give approval for energy efficiency investments.
- External reporting or 'public disclosure' relies on drivers such as competitiveness, reputation and compliance risk. Many studies have shown that organisations will take action if it boosts their reputation (e.g. retailers and publicly quoted companies), offsets a bad reputation (e.g. sensitive sectors such as energy extraction) or helps tendering companies comply with government procurement rules.[79]
- Reporting of performance among peers or benchmarked against industry standards can be a strong driver for improvement when combined with sector or supply-chain networks, or collective voluntary agreements.

Another clear lesson to be drawn from international evidence is that success depends not just on which policies and measures are used, but how they are used together. This is not a new insight – the need for joined-up policies has been known for some time.[80]

Recent experience of salience shows that this means more than simply joining policies together. They must be co-ordinated to maintain the salience of low-carbon investment through the organisation and decision-making process, carefully tailored to fit the needs of the organisation and the market it operates within.

Two international case studies illustrate how policy sequencing and development of a complementary package has worked:

- For commercial and public buildings the Australian NABERS scheme uses actual performance labelling to allow tenants to choose energy-efficient offices for reputational and cost-saving benefits. The induced demand for energy-efficient properties raises asset value and certainty for investors. Carefully designed, with industry closely involved, this collaborative approach began as a voluntary scheme. It was then widened to include more property types and

[78] DECC (2015) *CRC Energy Efficiency Scheme evaluation*, available at www.gov.uk.
[79] DECC (2012) *Factors influencing energy behaviours and decision-making in the non-domestic sector*, available at www.gov.uk.
[80] Sovacool, B. (2009) *The importance of comprehensiveness in renewable electricity and energy efficiency policy, Energy Policy 37*, 1529-1541.

supported with government procurement initiatives. This policy sequencing created market confidence in the building labelling brand, allowing the government to gradually regulate roll-out and accelerate the impact of the policy over time. Offices compliant with the Building Energy Efficiency Disclosure (BEED) Act 2010, which includes a NABERS assessment, have experienced a 12% reduction in CO_2 emissions on average. In addition, a report by the IPD Australian Green Property Index concluded that offices with a high NABERS energy rating achieve higher basic rent, higher net operating income, lower capital expenditure, lower vacancy rate, and longer WALE (weighted average lease expiry).[81]

- For industry, the German energy efficiency network scheme is a series of local business-to-business networks whose members agree to reduce emissions in return for financial incentives from the German bank KfW. The networks differ from more traditional voluntary agreements by deliberately targeting sectoral drivers of salience such as supply-chain mentoring, peer-to-peer benchmarking and locally run advice and finance schemes. This programme of complementary policies provided a broad level of motivation and support. The German pilot scheme delivered energy savings of around 2% per annum.

A more detailed description of these and other case studies are in a supporting paper published alongside this report.[82]

Summary

A comprehensive policy package is needed that sets long-term expectations, drives the necessary change, rewards those that make changes early or go further and supports the most vulnerable. This requires specific policy options to address different segments, aiming to keep on track to 2050 and reveal options where possible, and covering energy efficiency and low-carbon heat together.

Box 3.3. What Works for non-residential buildings policy

A large number of demand-side energy efficiency policies have been used in one form or another since energy efficiency programmes first emerged over 40 years ago:

- **Information, monitoring and reporting:**
  - **Performance labelling for buildings** allows tenants and owners to choose more efficient buildings, encouraging developers to compete for clients willing to pay a premium for efficient buildings. Well executed building labelling has created higher value for efficient buildings and attracted capital for low-carbon investment to go 'beyond code' (e.g. the Australian NABERS and the US Energy Star Buildings programmes).
  - **Energy audits** are formal reviews of energy performance with recommendations for improvement. They are more common in industrial companies and especially SMEs. Audits require the organisation to measure energy consumption and set out options for reducing it. The best researched examples are in the US and Sweden.
  - **Energy management systems (EMS) and standards** set out a range of integrated practices for measuring, reporting, managing and reducing energy use. EMS can be

[81] NABERS Annual Report 2013/14, available at https://www.nabers.gov.au

[82] Mallaburn, P. (2016) *A new approach to non-domestic energy efficiency policy: a report for the Committee on Climate Change*, available online at: https://www.theccc.org.uk/publication/next-steps-for-uk-heat-policy/

Box 3.3. What Works for non-residential buildings policy

informal, such as the US Portfolio Manager for commercial buildings or bespoke programmes for SMEs, or internationally certified such as ISO 50001.[83]

  – **Technical information and advice** is provided by the government so that organisations can get independent information that the market will not provide, for example on the performance and reliability of a technology type, or by benchmarking an organisation's own performance. One of the best examples of an information programme was the UK's Energy Efficiency Best Practice Programme that ran from 1983 to 2001.

- **Regulation and voluntary agreements:**
  – **Technology standards** remove inefficient or encourage efficient buildings, technologies and products. Japan's Top Runner programme is a successful example of an approach based on best practice. The EU eco-design, energy labelling and energy performance of buildings regulations set minimum standards for a range of markets.
  – **Voluntary or Long-Term Agreements** are formal agreements with sectors to reduce emissions over an extended time period. They typically include incentives to help member companies and measures to offset competitive effects. The UK's Climate Change Agreements are a good example of a long-term agreement on energy efficiency, with the Energy Agreements for Sustainable Growth in the Netherlands covering a wider section of the economy.
- **Public procurement** exploits the buying power and influence of public bodies by specifying efficient products or services. Many countries have procurement standards for office buildings and for products and services provided to the government. The Swedish Technology Procurement Groups programme is a good, well-established example.
- **Financial support** has been an important element to enable low-carbon investment to occur where there are higher capital costs involved, specifically for SMEs that are more capital constrained. Financial support takes many forms, including grants and loans, tax breaks and depreciation allowances. Germany has many of the most innovative financial programmes managed by the state bank KfW. Many countries also collect a small levy on energy bills to pay for energy efficiency programmes to apply SOPs to businesses, such as the Energy Efficiency Portfolio Standard schemes run by US State governments and the Danish Energy Efficiency Obligation. The UK version covers residential consumers with the Energy Company Obligation.

Source: Mallaburn, P. (2016) *A new approach to non-domestic energy efficiency policy: a report for the Committee on Climate Change*, available online at: https://www.theccc.org.uk/publication/next-steps-for-uk-heat-policy/

(b) The broader policy context

Effective policy to reduce emissions must be aligned to, and ideally support, broader policy objectives. In many cases, changes that support emissions reductions support these wider objectives and vice-versa, although there can also be some trade-offs that need to be managed (e.g. whilst energy efficiency improvements often cut cost in the long run, low-carbon heating tends to be more expensive):

- **Fuel poverty and energy affordability**. UK nations each measure fuel poverty and there are targets to make significant progress in making heating a home affordable. The Government

[83] Khanna et al (2007) in DECC 2012

has a statutory target in England to ensure that as many fuel-poor homes as is reasonably practicable achieve a minimum EPC rating of C by 2030. It has interim milestones in achieving this for a minimum of an E rating by 2020 and a D rating by 2025. Improvements in the thermal energy efficiency of homes mean that less energy is required to heat them to the same temperature, improving the affordability of heating and reducing fuel poverty.

- **Health and wellbeing**. The government aims to reduce health inequities and protect and improve the nation's physical health, mental health and social wellbeing. The built environment has an important role to play in this since people spend considerable amounts of their time at home and in workplaces or schools. Currently around 24,000 deaths per year are attributed to excess cold.[84] Improvements in the thermal efficiency of buildings and user-friendly heating controls are important for maintaining comfortable levels of heating and reduce mortality and illness. Insulation can also reduce noise disturbance with associated physical and mental health benefits. Holistic design should also consider any potential trade-offs, for example around the need for ventilation, avoidance of moisture and to limit the potential for overheating in summer.[85]
- **House-building.** A number of reviews in recent years have suggested that the UK needs to increase the rate of build of new homes from under 200,000 a year (the lowest since the 1920s) to meet the needs of a growing population.[86]
  - The construction sector is currently geared up to delivering the Zero Carbon Homes standard in London,[87] with no forecast impact on construction rates or land availability.
  - Within the context of a wider set of policies to train small builders and drive up construction rates (including making public land available for new homes), the Government must support and oversee an expansion of new, high-quality homes with lower heating bills, which are fit for future decades.
- **Competitiveness.** Many UK companies compete in global markets. Improvements in energy efficiency reduce energy costs for UK businesses and sensitivity to changes in energy prices. In our 2014 report, *Energy Prices and Bills* we estimated that energy efficiency potential could reduce energy bills by up to 20% by 2020 and there are examples of likely further savings across a range of businesses to 2030.
- **Industrial strategy.** The government, working in partnership with industry, aims to set the long-term direction needed to give business the confidence to invest through supporting sector partnerships, innovation of new technologies and developing skills. In order to decarbonise its building stock, the UK will need a highly skilled workforce that can retrofit a range of heating systems and efficiency measures, and understands the interactions of these

[84] UKGBC (2016) *Health and wellbeing in homes*, http://www.ukgbc.org/resources/publication/uk-gbc-task-group-report-healthy-homes
[85] See Box 3.7.
[86] See for example House of Lords Economic Affairs Committee (2016) *Building more home*, available online at: http://www.publications.parliament.uk/pa/ld201617/ldselect/ldeconaf/20/20.pdf and 2004 Barker Review of Housebuilding. Housebuilding rates based on DCLG live tables on the net supply of housing, available online at: https://www.gov.uk/government/statistical-data-sets/live-tables-on-net-supply-of-housing
[87] Greater London Authority, *Energy Planning - GLA Guidance on preparing energy assessments*, available online at: https://www.london.gov.uk/what-we-do/planning/planning-applications-and-decisions/pre-planning-application-meeting-service-0 (accessed on 08/10/16)

at a building-level. This is a major challenge, but also an opportunity to support large numbers of high-quality jobs.[88]

- **Fiscal sustainability.**
  - The UK is still currently running a fiscal deficit of around 5% of GDP, whilst productivity lags below the other major global economies. At the same time, annual investment into infrastructure (public and private) between 2010/11 and 2013/14 was around 2.75% of GDP, below the 3.5% which the OECD suggest is necessary in developed countries to prevent negative impacts on growth. The OECD, IMF and IFS have all recognised that increased spending on infrastructure could enhance fiscal sustainability in the long run.[89]
  - Future investment in UK infrastructure will need to be low-carbon. Investment in energy efficiency projects across the public estate, such as through a spend-to-save model, can reduce long-term running costs due to lower energy bills.
  - Whilst fiscal support is required to decarbonise buildings, our analysis suggests that it is possible to support the fifth carbon budget residential heat pump and biomethane deployment to 2020 within the existing funding envelope.[90]

In making changes to current policy the Government should seek to make the most of these potential synergies, while minimising and managing any conflicts.

(c) Current policy and policy gaps

The current policy framework is not delivering at the level required to meet carbon budgets and stay on track to the 2050 target. Whilst there are some positive elements, overall it has significant gaps, is complex and does not reflect the international lessons about what works (Box 3.4 summarises key elements of the current policy package). Furthermore, the existing tax and regulatory regime often creates perverse incentives that work against low-carbon changes (Box 3.5). As a result there is a large gap between what current policies can be expected to deliver and what is required by the legislated carbon budgets (Figure 3.1).

Comparing the current policies with our assessment of what is needed (Chapter 2) and what works (section (a) of this chapter) suggests a number of important gaps that ought to be filled and shortcomings that should be addressed:

- Current new-build regulations in England and Wales, and Scotland, all target lower levels of efficiency than comparable standards in other countries (Denmark, Germany).[91] They are not currently designed in a way that drives take up of low-carbon heat or prevents potential overheating in future (Box 3.6).
- Information and certification are currently insufficient to provide salience in organisations, confidence to consumers in low-carbon choices and their installers:

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[88] Cambridge Econometrics (2014) *The economics of climate change policy in the UK*, available online at: http://www.camecon.com/Libraries/Downloadable_Files/WWF_Final_Report_1.sflb.ashx
[89] Zenghelis (2016) *Building 21st century sustainable infrastructure,* available online at: http://www.lse.ac.uk/GranthamInstitute/profile/dimitri-zenghelis/
[90] See Box 3.7.
[91] BPIE (2015) *Nearly zero energy buildings definitions across Europe*, available online at: http://bpie.eu/uploads/lib/document/attachment/128/BPIE_factsheet_nZEB_definitions_across_Europe.pdf

- – Energy performance ratings of private buildings (EPCs) and public buildings (DECs) are valid for up to ten years.[92] This does not provide regular intervals for assessing performance, provides limited information for tenants and little incentive for building owners to invest. The reliability of EPCs has also been questioned, with wide variations in assessments undermining their credibility and their potential to inform consumers.
  - – Energy audits for large businesses are only required every four years (ESOS).[93] The first year of ESOS showed that relatively few organisations indicated the results of the assessment would be discussed with senior management and hardly any have published information from their audit. While the assessments do include suggestions for improvements, there are no perceived reputational benefits of promoting performance, signposting to finance or support mechanisms to make improvements.
- Current policy is insufficient to unlock the full opportunity for low-cost energy efficiency improvement in homes:
  - – Owner-occupiers: there is a gap in policy to incentivise uptake of energy efficiency measures in able-to-pay owner-occupier households. Owner-occupier households who are not in fuel poverty represent 59% of English households.[94]
  - – Private-rented sector: regulations are not binding due to their reliance on the Green Deal, which is no longer funded by government. They also do not apply where an EPC is not in place and according to government statistics only 26% of residential tenants are informed about the energy rating of the property they inhabit.[95]
  - – Social housing: the Decent Homes standard sets criteria around thermal comfort of social-rented homes, but has potential to go further. Tighter standards have been introduced in Scotland and Wales based on minimum SAP scores.
  - – The proposed supplier obligation is unlikely to be sufficient to make the progress in insulating fuel-poor households needed to put England on track to its fuel poverty targets and to make the necessary contribution to carbon budgets.
- There are significant gaps in policy to encourage greater low-carbon investment in existing buildings for non-residential organisations and particularly commercial and public buildings:
  - – The withdrawal of public funding for the Carbon Trust in 2012 means that there is no longer a systematic incentive structure in place to help organisations identify and implement energy efficiency investments. This gap is particularly acute for organisations with little upfront capital for process and plant investments, predominately medium and larger industrial SMEs.
  - – The CRC was originally designed to address several drivers of salience for large, non-energy-intensive public and private organisations. The removal of league tables meant to encourage action through reputational drivers, followed by the CRCs announced closure, leaves a gap. The government's proposals to raise the level of the Climate Change Levy

[92] HM Government website, https://www.gov.uk/buy-sell-your-home/energy-performance-certificates (accessed on 02/10/16) and https://www.gov.uk/check-energy-performance-public-building
[93] Details on ESOS and results of first year can be found at https://www.gov.uk/guidance/energy-savings-opportunity-scheme-esos
[94] DECC (2016) *Fuel poverty detailed tables: 2014*
[95] Warren, A. (2016) *Energy in Buildings & Industry*, July issue

(CCL) will redress some of this, but there is still a gap in reporting, disclosure and board awareness.[96]

  - For public-sector organisations Salix Finance supports capital investment. However large gaps remain, with central Government and some other areas of the public sector unable to make use of Salix loans.
  - The public sector, and central Government departments in particular, could make a valuable contribution to energy efficiency policy by showing leadership. For example, the Government could revisit the commitment made in the 2005 Energy Efficiency Action Plan to only procure the most-efficient office buildings.

- The Renewable Heat Incentive is not sufficient in itself to create a dynamic market for heat pumps:
  - The market for domestic heat pumps has flat-lined in recent years in existing homes at around 9,000 a year, despite the recent decreases in levels of support for domestic biomass.[97] The latest RHI projections aim to reach 16,000 a year by 2021, but there is no evidence of any acceleration in the rate of take up. For air-source heat pumps, this is most likely due to the upfront cost barrier, low awareness, and the fact that the tariffs deliver lower returns for smaller properties.[98] The Government has concluded that the ground-source heat pump tariff does not, on average, yield the targeted returns at the current tariff level, but is constrained by its own value-for-money investment rules.[99]
  - Reversible air-to-air heat pumps are well suited for offices and other buildings with heating and cooling demands and low usage of hot water. These are not supported under the RHI, reflecting concerns around misuse of funds to support cooling, but uptake could be encouraged through other policy mechanisms such as standards.
- While some work has been undertaken to understand how gas distribution networks could be repurposed to hydrogen, this option requires carbon capture and storage (CCS) in order to be feasible, low-carbon and economic. CCS policy is currently unclear in the UK, following the cancellation of the demonstration programme at the 2015 Autumn Statement. The Committee has emphasised the need for Government to urgently develop a strategy to commercialise CCS in the UK, including the separation of support for CO_2 transport and storage infrastructure.[100]

A further set of policy areas have adequate policies and funding in place until 2021, but require policy development now to ensure that successor schemes are in place without an investment-damaging policy hiatus.

- The RHI, to date, has been popular for bioenergy. That includes biomethane, which is on track to match our scenarios to 2020. Further support through the 2020s will be required for continued expansion whilst full carbon costs are not reflected in the price of natural gas.

[96] At Budget 2016 the Government announced that they will consult on a "new simplified energy and carbon reporting framework for introduction by April 2019".
[97] A further 9,000 heat pumps are installed in new and non-residential properties (mainly the former).
[98] DECC(2016) *RHI Consultation Impact Assessment, The Renewable Heat Incentive: A reformed and refocused scheme*
[99] The Government has calculated a value for money cap on the level of subsidies for technologies deployed to meet the 2020 Renewables target. This is based on the cost of deploying offshore wind.
[100] CCC (2016) *A strategic approach to Carbon Capture and Storage, a letter to DECC Secretary of State Amber Rudd, 6th July 2016*, available online at: https://www.theccc.org.uk/wp-content/uploads/2016/07/Letter-to-Rt-Hon-Amber-Rudd-CCS.pdf

There is an option to put the cost of funding biomethane onto gas bills following the power sector model for supply-side decarbonisation.

- Funding of £320m is currently in place to support low-carbon heat networks until 2021. This creates an opportunity to design the successor vehicle to drive major network expansion through the 2020s. Although the funding is likely to fall short of the 10 TWh of heat supplied in 2020 in our central fifth carbon budget scenario, targeting the funds judiciously could help narrow the gap.

We now turn to the options for addressing these gaps and shortcomings. There is considerable flexibility for the Government in determining the policy details, including to reflect the broader context set out in section (b). However, to meet the statutory requirement to prepare policies on track to carbon budgets and the 2050 target it will be necessary to take actions to strengthen policies.

Box 3.4. Current policies to increase energy efficiency and take-up of low-carbon heat

The following policies are currently in place in the UK (unless otherwise designated) and complemented by further devolved administration policies:

- **Energy Performance Certificates (EPCs) and Display Energy Certificates (DECs):** EPCs provide standardised information about a building's modelled energy use, typical costs and ways to reduce energy use, required when buildings are built, rented or sold. Ratings are given from A (most efficient) to G (least efficient) and are valid for ten years. DECs are a similar tool but based on actual rather than modelled performance. They provide a benchmark for how a building is performing relative to other comparable buildings. DECs are required in for public buildings with a floor space over 500 m^2. Commercial buildings can adopt DECs on a voluntary basis.
- **Energy Company Obligation (ECO) (2013-2017):** GB-wide obligation on energy suppliers to improve energy efficiency, reduce fuel poverty and save carbon in homes.
  - There are three sub-obligations: the Carbon Emissions Reduction Obligation (CERO) delivering low-cost carbon savings, the Carbon Savings Community Obligation (CSCO) and Affordable Warmth focusing on fuel-poor households. The costs are recovered through the energy bills of all households.
  - There will be a transitional year in 2017/18 when the Government plans to remove CSCO and increase the share of the Affordable Warmth sub-obligation, along with changes to improve the targeting of the scheme and put more focus on insulation measures. Funding is committed to 2022 for a new obligation, which the government intends to focus primarily on reducing fuel poverty. The level of funding and target number of homes to treat represents a drop in ambition from ECO and its predecessors. Figure B3.4 shows the stagnation in insulation installation when previous obligations where replaced with ECO in 2013.
- **Renewable Heat Incentive (RHI):** Subsidy scheme available to businesses and public bodies (since 2011) and householders (since 2014). It pays a fixed tariff per unit of renewable heat produced for a range of technologies including heat pumps, biomass boilers and solar thermal. Uptake has been limited to bioenergy under the non-residential scheme. Take-up of domestic subsidies has been skewed towards wealthier households with access to capital, which probably reflects the persistence of the upfront cost barrier along with the higher returns in larger properties. Awareness of the scheme remains low.
- **Support for low-carbon heat networks:** In 2013, the UK set up the Government Heat Networks Delivery Unit (housed within DECC), which has supported local authorities to develop feasibility

Box 3.4. Current policies to increase energy efficiency and take-up of low-carbon heat

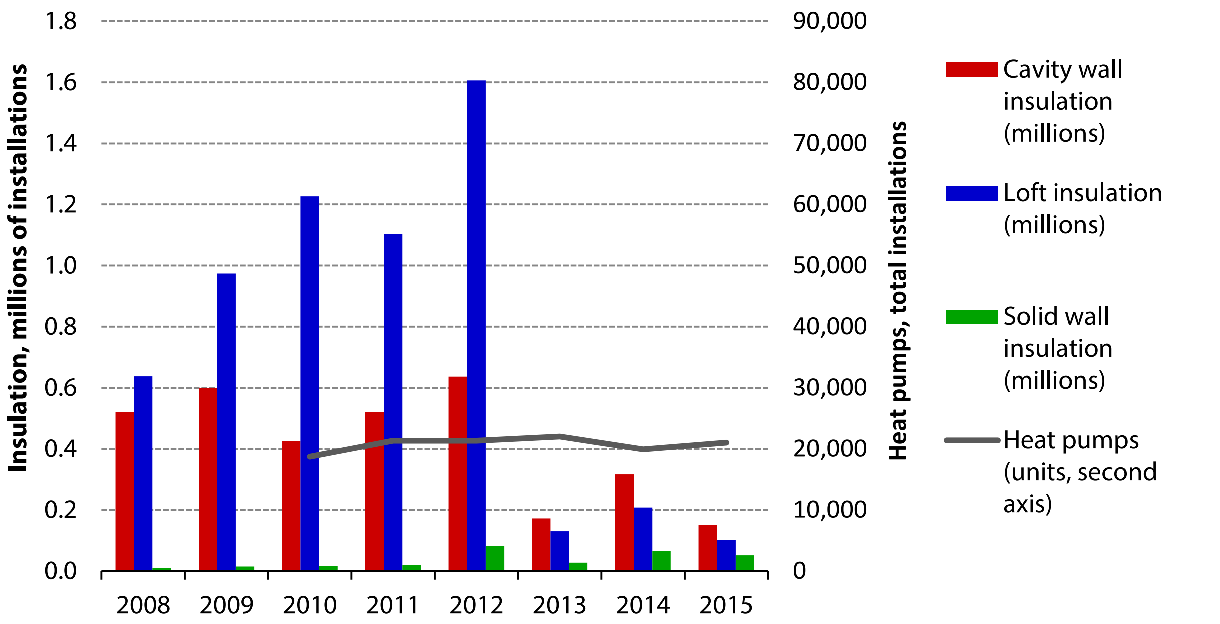
studies with multiple rounds of funding. In 2016, it was renamed the Heat Networks Investment Partnership, with a new remit to design a programme of support with £320 million for capital funding through to 2020. In Scotland, the support role is performed by the Heat Network Partnership, with a target in place for 1.5 TWh and 40,000 homes connected by 2020.

- **Private rented sector regulations** require in England and Wales that:
  - From April 2016 - except in exceptional circumstances - residential private landlords agree to a tenant's request for energy efficiency improvements where Green Deal finance or subsidies are available to pay for them.
  - From April 2018, landlords will need to ensure that their properties reach an EPC rating of at least E, or have installed those improvements that could be funded using available Green Deal finance or subsidies available to pay for them, before granting a tenancy to new or existing tenants.
  - From April 2020, these requirements will apply to all private-rented properties – including occupied properties in the residential sector and from April 2023 in the non-residential sector.

  The Green Deal mechanism underpinning these regulations is no longer being funded by the Government.
- Social-rented sector regulations vary across Great Britain:
  - The **Decent Homes** standards set the minimum energy efficiency requirements in England, based on requiring different levels of insulation dependent upon heating system.
  - **Scotland's Energy Efficiency Standard for Social Housing (EESSH)** and the **Welsh Housing Quality Standard** set tighter standards meaning that by 2020 in the main social properties will have an EPC rating of at least a D.
- Devolved administration policies supplement this:
  - **Home Energy Efficiency Programmes for Scotland (HEEPS)** delivers efficiency improvements in fuel-poor households and provides interest-free loans.
  - **The Nest and Arbed schemes** in Wales have delivered further improvements for fuel-poor homes. The Arbed scheme is an area-based retrofit programme which demonstrates the broader health, affordability, wellbeing and regeneration benefits of energy efficiency, as well as improving the appearance and value of the nearly 3000 properties treated.
  - Fuel poverty and energy efficiency are fully devolved in Northern Ireland.
- There is a significant gap in policy to encourage energy efficiency improvements in owner-occupied households that are not in fuel poverty.

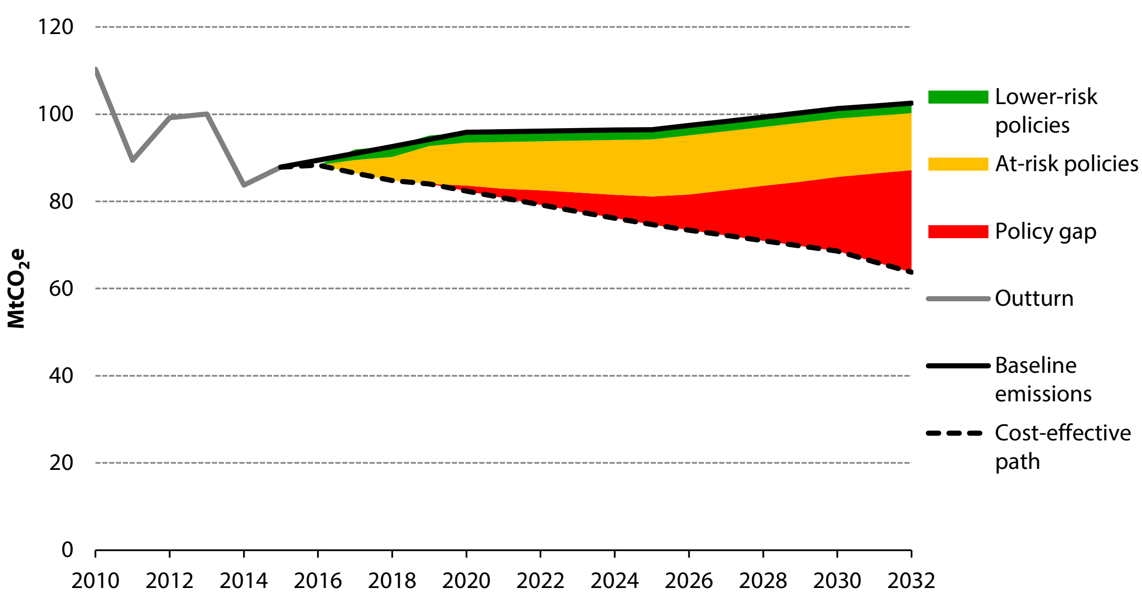
Box 3.4. Current policies to increase energy efficiency and take-up of low-carbon heat

Figure B3.4. Recent poor progress in energy efficiency and low-carbon heating



Source: DECC (2016) *Household Energy Efficiency National Statistics*; DECC various sources for pre-2014; BSRIA (2016) *UK Heat pumps, Report 59122/11;* CCC calculations.

Figure 3.1. The policy gap in reducing emissions from heating buildings



Source: CCC (2016) *Progress Report to Parliament*.
Notes: Based on DECC (2015) *Updated emissions projections*; CCC analysis. The cost-effective pathway includes the 3 $MtCO_2e$ of abatement from biomethane in buildings in 2030, in order to be consistent with DECC's assessment of policy impacts.

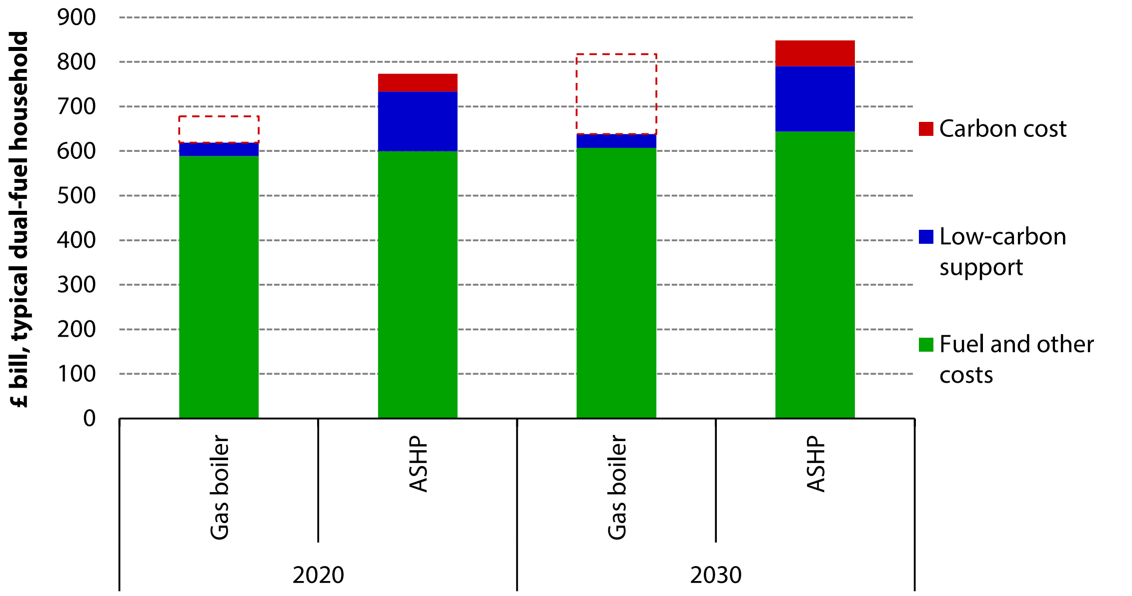
Box 3.5. How current taxes and regulations can work against low-carbon policy

Switching to heat pumps is made more costly by the fact that the carbon costs of gas are not reflected in its price and the distribution of the costs of low-carbon support across fuels:

- Electricity consumption is subject to a carbon price under the EU Emissions Trading System (ETS) and the Carbon Price Floor in the UK, whereas there is no carbon price on gas consumption.
- Both electricity and gas prices include a portion which is support for low-carbon and fuel poverty schemes, at 2.1p/kWh on electricity and 0.2p/kWh on gas. Low-carbon support costs are higher on electricity as they include the costs of decarbonising the power sector (through subsidies such as the Renewables Obligation and Contracts for Difference).

This imbalance means that more subsidy is required to compensate consumers switching to heat pumps (Figure B3.6a).

Figure B3.5a. The lack of carbon pricing on gas penalises low-carbon heat options



Source: CCC calculations.
Notes: ASHP stands for Air-Source Heat Pump.

For businesses, the layering of energy and carbon policies over time has led to a large degree of variation in carbon prices across different organisation and fuel types (Figure B3.6b). This causes distortions in the market through firms' choice of fuels and thus technology, and could lead to potential lock-in of higher-carbon processes.

The implicit carbon prices that result from energy bills, energy taxes and the EU ETS were set out in 2013 in a joint report from the Institute for Fiscal Studies, Esmée Fairbarn Foundation, ESRC and the Centre for Climate Change Economics and Policy:

- The implicit carbon price for electricity is much higher than for gas, due to both upstream (e.g. the EU ETS) and downstream (energy efficiency and fuel poverty) policies.
- Non-energy-intensive medium and large enterprises face the highest implicit carbon prices on

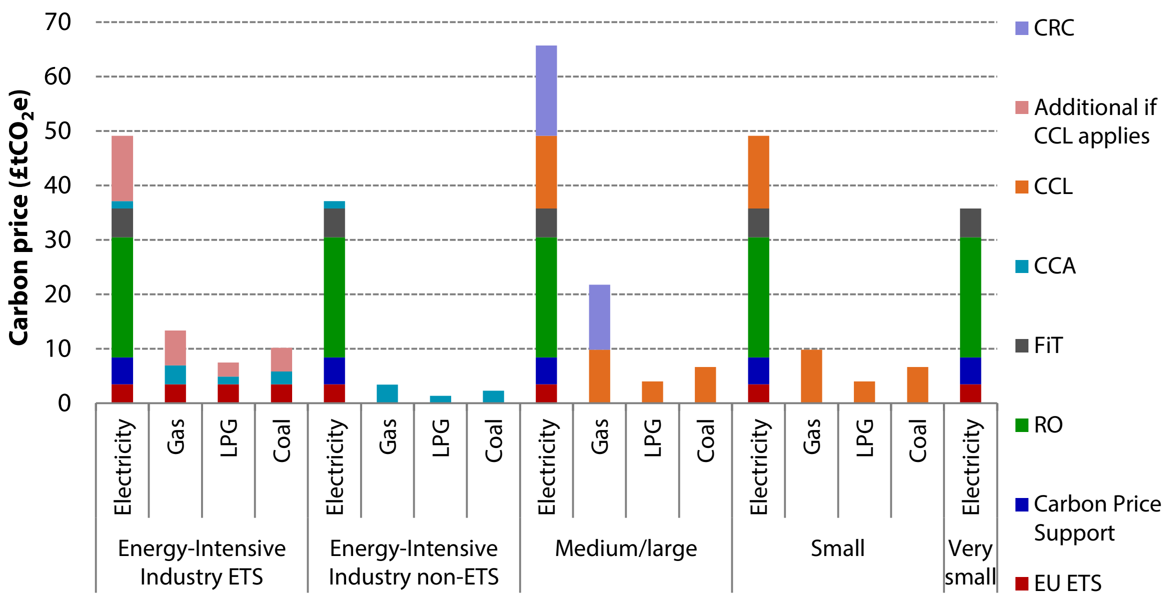
electricity and gas.

- There are no policies imposing a carbon price on gas use by households. Taking account of the reduced rate of VAT paid on household energy consumption (5%, down from the standard 20%) effectively leads to a negative carbon price for gas.

Since this report the government has announced the closure of the CRC scheme, and that the Climate Change Levy (CCL) will be raised to compensate. The CCL levied on electricity and gas energy will also be from rebalanced from the current ratio of 2.9:1 to 1:1 by 2025. This rebalancing will reduce the CCL carbon distortion between electricity and gas, but it will not equalise the CCL between the two fuels on a carbon basis as the power sector continues to decarbonise.

Further movement to carbon-reflective energy prices as electricity decarbonises will incentivise and help heat systems based on low-carbon electricity to displace gas.

Figure B3.5b. Uneven carbon prices for UK business sector, by type and size of business, and by fuel (2013)



Source: Bassi, S., Dechezleprêtre, A., Fankhauser, S. (2013) *Climate change policies and the UK business sector: overview, impacts and suggestions for reform, Policy paper, Centre for Climate Change Economics and Policy, Grantham Research Institute on Climate Change and the Environment*.

Source: CCC (2014) *Energy Prices and Bills,* available online at: https://www.theccc.org.uk/wp-content/uploads/2014/12/Energy-Prices-and-Bills-report-v11-WEB.pdf

Box 3.6. Building new low-carbon homes

New-build standards can and should be designed so that they encourage cost-effective low-carbon heat installation and mitigate the risk of overheating:

- The UK has been developing policies for zero-carbon new homes since 2002, but none of the working proposals to date have been designed in a way which is likely to lead to **low-carbon heat** being installed instead of gas boilers. This is because solar PV and low-carbon heat are treated as substitutes - and solar PV, together with fabric efficiency, is more cost-effective (Sweett, 2014). However, whilst there are other options for decarbonising electricity, heat decarbonisation must occur at the building or local scale. This issues applied to both the zero-carbon homes policy which was abandoned in 2015, and the work to date on the 'nearly-zero energy buildings' requirement under the Energy Performance in Buildings Directive, which will apply to all new buildings from 2020 across the EU member states.
- In building new homes, consideration also needs to be given to risks of **overheating**, which we have assessed in the Adaptation Sub-Committee's progress reports in 2014 and 2015. A significant factor in the increased overheating risks in retrofit buildings is the reduced passive ventilation rate caused from making buildings more air tight (Kovats and Osborn, 2016). Careful attention needs to be put in to design, and full consideration given to options such as passive cooling:
  - Passive cooling strategies include increased energy efficiency of appliances, shading, window upgrades and high-reflectivity roofs. Casual gains from items of electrical equipment and lighting have in many cases reduced.
  - Excess solar gains can be controlled through passive ventilation and solar shading (including recently developed thin film solar control coatings in glazing systems). For example, Mcleod et al. (2013) found that full external shading devices and the glazing to wall ratio on the south-facing façade played a substantial role in reducing the risk of overheating.
  - An element of mechanical ventilation may be needed to prevent excess levels of humidity when buildings are designed to be very airtight. Depending on the building size and occupancy mechanical heat recovery may also be useful.

Sources: Sweett Group (2014) *Cost analysis: Meeting the zero carbon standard;* Kovats, R.S., and Osborn, D., (2016) *UK Climate Change Risk Assessment Evidence Report: Chapter 5, People and the Built Environment*. Contributing authors: Humphrey, K., Thompson, D., Johns. D., Ayres, J., Bates, P., Baylis, M., Bell, S., Church, A., Curtis, S., Davies, M., Depledge, M., Houston, D., Vardoulakis, S., Reynard, N., Watson, J., Mavrogianni, A., Shrubsole, C., Taylor, J., and Whitman, G. Report prepared for the Adaptation Sub-Committee of the Committee on Climate Change, London; McLeod, R. S., Hopfe, C. J., Kwan A.S.K. (2013) *An investigation into future performance and overheating risks in Passivhaus dwellings. Building and Environment*, 70,189-209; Porritt, S., Cropper, P. C., Shao, L. and Goodier, C. I. (2013) *Heat wave adaptations for UK dwellings and development of a retrofit toolkit. International Journal of Disaster Resilience in the Built Environment*, 4(4), 269-286.

(d) Options for strengthening policy

An urgent process of policy renewal is required. New policies will need to be developed well in advance - the earlier they are set the more time there will be for the market to prepare.

We have identified two key challenges: preparing for the major decarbonisation required in the 2030s and 2040s, and increasing the implementation of low-regrets measures throughout the next 15 years. The Government's plan for meeting the fourth and fifth carbon budgets should clearly commit to this policy renewal and set out the timeline the Government intends to follow.

We would expect the Government to refine the policy package based on further detailed analysis, piloting and consultation, and possible development of a White Paper.

We have identified a number of policy principles and priority areas that we would expect to see in the government's new approach to reducing emissions from heating to 2030. These policy priorities take account of the findings of our Advisory Group, which identified specific recommendations for governance and decision-making (Box 3.7).

Success requires a joined-up approach to energy efficiency and low-carbon heat underpinned by standards that tighten over time, consistent price signals, and a package that is widely understood and attractive to households and businesses:

- **A stable framework and direction of travel, backed up by evolving standards for the emissions performance of buildings.**
  - Standards should be used to allow competitive markets to develop on a level playing field, including ensuring that low-regret actions are taken up and addressing barriers to implementation.
  - Standards for emissions should be tightened over time to reflect the need for continued decarbonisation. The schedule of future standards should be clear to allow businesses and consumers to prepare efficiently and for dynamic markets to emerge.
  - As far as practical, standards should be focused on ends (e.g. reducing carbon emissions) rather than the means (e.g. specific technologies) and should be based on actual rather than modelled performance (e.g. by using data from smart meters).
  - A standard on new-build properties that drives high energy efficiency and low-carbon heating system is a clear step to avoid the need to further retrofit buildings in a few years' time. At a minimum, new properties should be future-proofed for future low-carbon heating (i.e. by leaving space for a hot water tank and installing lower-temperature heating systems).
  - Building on the existing approach in the private-rented sector, this could include setting a long-term minimum standard at the point of sale and rental of existing properties based on gCO_2/m^2/year from 2030 with a clear trajectory of how the standard will be tightened over time. A standard when homes are renovated or extended to ensure high efficiency could be well timed and avoid future lock-in if proportionately designed.
  - For non-residential buildings, minimum energy efficiency standards on electric heating systems, in place of feed-in tariff incentives, could drive uptake of heat pumps at lower cost to the taxpayer.
- **A joined-up approach to energy efficiency and low-carbon heat that works across the building stock, and focuses on real-world performance where possible.**
  - Emissions reductions can be achieved by improving energy efficiency and by shifting to low-carbon fuels. Many of the barriers to action (e.g. disruption from changes, the need to find a trusted installer, financing constraints) are shared across both types of measure. In addition, improved energy efficiency can reduce the cost and improve the suitability of buildings for low-carbon heat options. Renewed policy should therefore seek to take a combined approach.
  - Policy should target distinct groups of householders and businesses. For example: existing subsidies for heat pumps are less attractive for smaller homes given economies of scale; some householders and small businesses will require improved access to low-

cost finance; rented buildings are likely to require different approaches to owner-occupied buildings; more generally, small and medium-sized enterprises (SMEs) are poorly addressed by existing policies.

  – Improving the efficiency of existing heating systems (e.g. by moving to lower flow temperatures) in homes connected to the gas grid through the 2020s can cut bills and emissions, and helps to prepare the stock for widespread roll-out of either heat pumps or hydrogen after 2030.

- **Simple, highly visible information and certification alongside installer training to ensure that low-carbon options are understood by consumers and that installers are effective and trusted.**
  – Awareness of low-carbon heating and energy efficiency options is generally low. In businesses, energy performance is assessed infrequently and often not discussed at senior management or board level, and so has little strategic value or 'salience'. A key policy focus must be improved information (which could be enabled by smart meters), through business performance reporting and building performance labelling that generates value in low-carbon investment.
  – A nationwide training programme is needed to develop high professional standards and skills for implementation of low-carbon choices in the building and heat-supply trades. Clearly this would need to be developed in partnership with industry.
  – There is also an opportunity for leadership through public procurement and low-carbon investment, given that the public sector constitutes a third of non-residential heating needs and almost a fifth of heating energy in non-residential leased buildings.[101]
  – The roll-out of smart meters provides an opportunity to increase the visibility and frequency of feedback to households on their energy use. This needs to be backed by effective advice to help households change their consumption.
  – The certification of energy and emission performance of homes needs to be made timely, more reliable and enforced, so that purchase, tenancy and renovation decisions can be well informed, and to underpin the proposed standards.
- **A well-timed offer to households and SMEs that is aligned to 'trigger points'.**
  – Trigger points include house moves and major renovations, when low-carbon options can be installed with less additional disruption and at lower cost. They are relevant for effective use of standards, incentives and information. SMEs are responsive to policies built around local business networks and supply chains.
  – For residential buildings, policy that targets times of change in life patterns can be most effective and need to be designed and communicated to highlight the aspects that appeal most to different consumers (e.g. bill savings, aesthetics of the home). Providing comparative information can also be effective by tapping into people's tendency towards social norms.
  – Given variations across households, a mix of policy is needed. For example, recognising the different incentives for owner-occupiers and landlords, how some incentives will

[101] Based on BEIS Building Energy Efficiency Survey 2014-15.

favour homes of different size or location, and that low-income households will need more support to make changes.

  – For non-residential buildings the framework should be based on a segmented understanding of the sector. The resulting programme of policies will need to be complementary and sequenced effectively to raise the salience of low-carbon opportunities and create investment value.

- **Consistent price signals that clearly encourage affordable, low-carbon choices.**
  – While many energy efficiency improvements are already financially attractive, some other measures, including most low-carbon heat options, would not currently be attractive without public subsidy. Consumers will generally only take up these options when sufficiently incentivised to do so, and businesses will only invest and innovate in supplying the market if they are confident that incentives will remain in place.
  – The unattractiveness of some measures in part reflects the current balance of tax and regulatory costs on energy bills: costs are significantly larger for electricity than gas or oil heating, and the full carbon costs are not reflected in the pricing of heating fuels. In the transition to low-carbon heating, particularly if low-carbon heat is rolled out in different parts of the UK at different times, there will be important questions to be resolved around how to pay for heat decarbonisation.
  – Even where energy efficiency improvements may be financially advantageous, they are often usefully supplemented by additional fiscal incentives to encourage uptake and low-cost loans to enable households and SMEs to cover upfront costs. Fiscal incentives such as a rebalanced stamp duty, or partial subsidy could encourage emission saving improvements that go further and sooner than minimum standards.
  – Funding for low-carbon heating (set under the RHI) is just sufficient to support the increased uptake of heat pumps in our scenarios to 2020 alongside low-regret expansion in the use of biomethane. Achieving higher uptake is likely to require further work on tackling barriers, along with adjustment of subsidy rates, or a shift towards upfront funding, which could also be accommodated within the existing funding pot (Box 3.8).
  – Subsidies (e.g. through a supplier obligation, grants or area-based schemes) will be needed to support fuel-poor households.
  – Better consideration of energy costs in mortgage affordability calculations and the expansion of green mortgages could encourage the purchase of more efficient properties at little cost to government. SMEs and households that are more capital-constrained could use low-cost capital to invest in cost-effective energy efficiency and low-carbon heat opportunities.

As well as supporting implementation of 'low-regrets' measures, policy in the next decade needs to prepare for a Government-led decision on the long-term approach to decarbonising buildings on the gas grid:

- A **process for making decisions on heat infrastructure** through the 2020s should be established, including the roles for different actors and a coherent governance structure.
- A **new strategy** is required that will develop a **CCS infrastructure** and industry in the UK capable of expanding to **large-scale hydrogen production** in the 2030s.

- **Pilots and demonstrations** should be rolled out alongside a programme of research to better understand the challenges of a wider-scale hydrogen switchover. Trials of hybrid systems should be included if Government pursues this option.
- A mechanism for supporting the **continued expansion of low-carbon networks** through the 2020s needs to be developed, including attracting new types of investor and establishing a proportionate regulatory framework.
- Investment into the gas networks between 2021 and 2028 will be determined by Ofgem in the **price control review** which will begin soon leading to a final decision in 2020.[102] BEIS should ensure that the process **reflects the requirements of carbon budgets** by setting out the priorities for Ofgem in Strategy and Policy Statement ahead of Ofgem's 2019 Strategy decision (Box 3.9).
  - This includes identifying an approach to stranding risk, understanding the costs and benefits of decommissioning, introducing uncertainty mechanisms into the price control process and undertaking a series of steps to develop the regulatory approach for hydrogen as that option develops.
  - The price control process should reflect the Government's strategic approach to developing hydrogen, including the key decision points.

In designing its new approach, the Government should build on the positives of the current policy framework, including learning from schemes in parts of the UK already that reflect the principles of good policy design:

- **Standards have been used to drive uptake and development of new markets.** Standards for the energy efficiency of new properties and for boiler efficiency have been progressively tightened over time in line with technology development and in step with the skills of the supply chain. Standards for private-rented properties have already been set out to 2023, but these are in need of a new delivery mechanism given the failure of the Green Deal. Standards should be set further ahead, be extended across the building stock and be backed by tailored delivery mechanisms to ensure compliance.
- **Information provision has been aligned to trigger points.** Energy information for residential buildings is provided at key trigger points of property sale and rental, but this is not translating sufficiently into investment in measures to improve efficiency and there are questions around compliance in the private-rented sector. Energy performance reporting for non-residential organisations and buildings has been rolled out, even if infrequently assessed. For these to be more effective they should be substantially enhanced through a focus on actual performance, more regular reporting, with increased prominence (e.g. board-level, public reporting) and linked to incentives and/or standards for improvement. The smart meter roll-out programme will support a shift towards actual rather than modelled performance for households and SMEs.
- **Significant funding has been allocated to 2020.** Funding for low-carbon heating (set under the RHI) is just sufficient to support the increased uptake of heat pumps in our

[102] The next price control reviews are known as RIIO-GD2 (for gas distribution networks) and RIIO-T2 (for gas transmission). In these price reviews, Ofgem will set network cost allowances and determine the incentive framework for the period running from1 April 2021 to 31 March 2029. Ofgem will launch an important consultation in December 2018 which will set the policy context for the RIIO-GD2 and T2 reviews.

scenarios to 2020 alongside low-regret expansion in the use of biomethane. Achieving greater heat pump uptake is likely to need adjustment of subsidy rates, or a shift towards upfront funding, which could be accommodated within the existing funding pot. Beyond 2020, funding will need to increase in line with the higher required roll-out. Replacing subsidies with electric heating standards to drive heat pump uptake in non-residential properties could release funds for residential heat pumps.

- **The public sector has provided some leadership.** Energy efficiency investments in parts of the public sector have been funded with interest-free loans through Salix Finance. Expansion to central Government and other parts of the public sector would accelerate progress.
- **Some schemes in parts of the UK already demonstrate the principles of good policy design.** Understanding their performance should feed into the development of national policy options. For example:
  - The Home Energy Efficiency Programmes for Scotland (HEEPS) have been delivering improved efficiency in Scotland including through area-based schemes and interest-free loans. A parallel programme is in place to support SMEs. The Scottish Government is going further through the Scottish Energy Efficiency Programme (SEEP), which applies to all buildings and will pilot innovative approaches and multi-year funding certainty for ambitious projects. The Scottish Government has sought to widen the uptake of low-carbon heating by providing low-cost finance.
  - The Arbed scheme in Wales is an excellent demonstration of the broader health, affordability, wellbeing and regeneration benefits of an area-based retrofit programme, as well as improving the appearance and value of the nearly 3,000 properties treated. There is a good opportunity to build on this success through the implementation of the Wellbeing of Future Generations Act in Wales. Wales also has policies in place to support SMEs to take up insulation and other energy saving measures, through a combination of soft loans and tailored advice.
  - The Northern Gas Networks H21 study in Leeds has taken an in-depth look at what would be required to repurpose the city's gas distribution network to hydrogen based on production from natural gas with carbon capture and storage.

These options for strengthening policy are assessed further in *Annex 1: Policy design options*.

Box 3.7. Advisory Group report key messages and recommendations

In forming our advice, the Committee assembled an expert advisory group, whose report to the Committee is published alongside this one. The group was chaired by Professor Jan Webb (University of Edinburgh) and included Professor Nick Chater (Warwick Business School, CCC), Professor Nick Eyre (University of Oxford) and Professor Robert Lowe (UCL). The group's role included reviewing three What Works policy reviews: one on non-residential buildings energy efficiency policy by Dr Peter Mallaburn (University College London), one on low-carbon heat policy by Imperial College and one on residential energy efficiency policy in the Committee secretariat. They also reviewed a Frontier Economics study for the Committee on the future of the gas grid and research by the Committee secretariat on market segmentation and possible future pathways.

The Group raised a concern around the absence of an effective UK governance process for managing the significant changes needed for buildings and all infrastructure networks and technologies:

- They identify an immediate need in this Parliament for further cost-effective action on insulation of existing buildings; incentives and standards to support take up of electric heat pumps; development of urban heat networks; standards and tools for measuring the real energy performance of buildings, and near-zero energy standards for new buildings.
- They also conclude that it is imperative to initiate the post-2020 process for development of whole building retrofit systems, an associated comprehensive programme for workforce professionalisation, a strategy for decision-making about the mix of low-carbon heat supply infrastructures (electricity, heat and repurposed gas networks) and regulation, while avoiding wasteful duplication; and appropriate demonstrators and trials of low-carbon heat systems and low-energy building solutions.

Given the significant technical and supply-chain challenges - and investment requirements - which cut across departmental jurisdictions, levels of government and sectors, the Group recommend use of a White Paper setting out a 'Pathway to a Sustainable, Zero Carbon Building Stock' as the best available means to provide the necessary vision, leadership and long-term policy framework.

The report stresses the critical role of the governance process in assessing cost-optimal investments and allocating risks and responsibilities; the cost-effectiveness of regulatory standards, and the need for a whole-building approach based on measured energy performance. Specific areas of focus include the value of regulatory standards, taking a joined-up approach across low-carbon heat and energy efficiency, developing a strong vision and narrative around heat decarbonisation and creating dynamic markets for low energy and low-carbon heat:

- The Advisory Group report sets out the case for **standards** as a cost-effective means of addressing market failures. They are of particular value in achieving higher standards for energy and carbon performance of existing and new buildings; increasing technical performance standards for electric heat pumps; setting system efficiencies for gas central heating with condensing boilers, and setting technical standards for performance of heat networks. These should be signalled in advance, properly enforced, and where possible focused on ends rather than means, and based on actual rather than modelled performance:
  - For building performance, the Group advocates use of an environmental indicator ($gCO_2/m^2/year$), with a subsidiary energy efficiency indicator (kWh/m^2).
  - To minimise corrupt practice, poor-quality work and distrust by buyers, the Group makes the point that regulation should be enforced through independent assessors, as well as by industry. The Group recommends a unitary system, using local Building Control Officers, as a cost-effective structure.
- The Group supports a case for a **whole-house approach** to be set in train by a new policy framework arguing that the current 'highly segmented' heat and energy efficiency supply chains

Box 3.7. Advisory Group report key messages and recommendations

and trades 'require each individual house owner to be an expert project manager in technical-economic options appraisal, supply-chain assembly, procurement, financing and performance appraisal.'

- The Group states that whole-building retrofit and near-zero energy new build are 'far beyond the capability of the current supply chain', recommending a '**systematic education and up-skilling of the workforce** to create high quality, cost-competitive and professional building trades, including project managers, building services engineers, gas fitters, electricians, and insulation installers.'
  - It argues that this is not only urgent, but will need to continue over a few decades to create the foundations for high performance standards, new industry norms, business models for whole building low-energy solutions, and consumer trust.
  - At the same time, consumers need to be equipped with market intelligence to understand and discriminate between supplier offers. This implies a role for independent institutions to collect and analyse performance data, undertake research, promote best practice, accredit technologies and provide consumer advice.
  - A key part of consistent strategy is a **narrative** or **vision** which conveys the scale of the opportunity and the importance of concerted action. This narrative needs to make low-energy, low-carbon buildings and heat supply a 'high-visibility matter, with a story focusing on 'what people and organisations want' from building and energy services.' The report adds that '[a]rticulating such a narrative requires clarity about the institutions governing policy development and a coordinated division of responsibility between them.'

Source: Webb, J., *Heat and Energy Efficiency: Making Effective Policy Advisory Group Report, A report for the UK Committee on Climate Change*, available online at: https://www.theccc.org.uk/publication/next-steps-for-uk-heat-policy/

Box 3.8. Retargeting the Renewable Heat Incentive

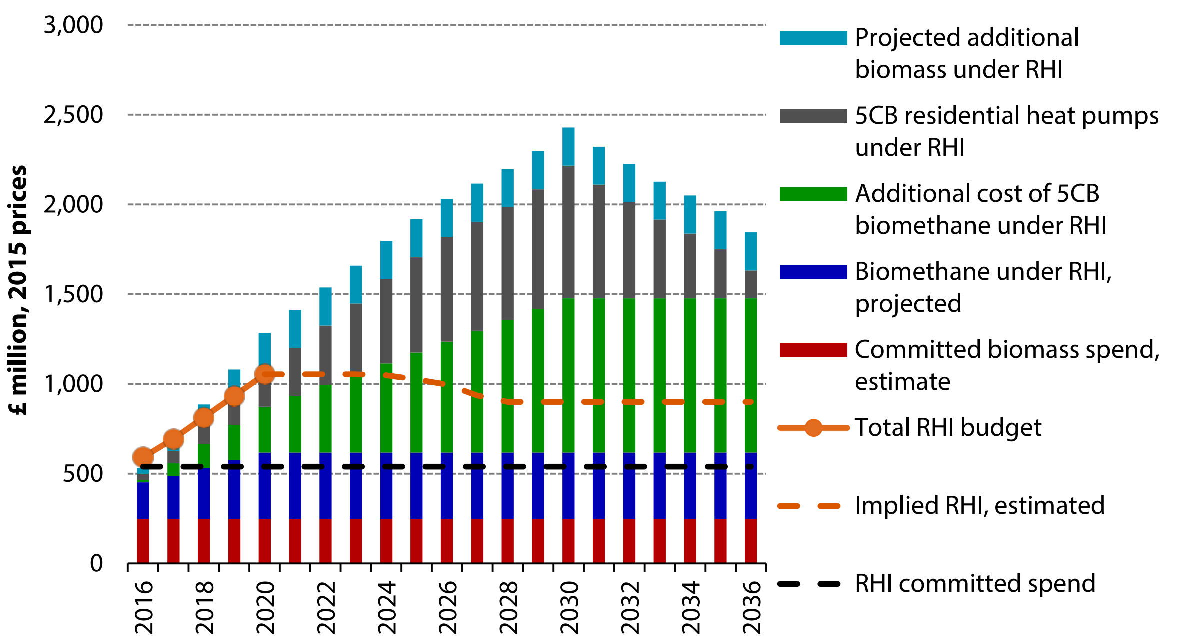
In the 2015 Autumn Spending Review, the Government extended funding for the Renewable Heat Incentive to 2020/21, with investment increasing to £1.15bn by that time. Around £500m/year is committed to continued support of the existing scheme - mostly bioenergy. It is possible to support the residential heat pumps and biomethane deployment to 2020 under our fifth carbon budget central scenario within the existing funding envelope (Figure B3.8a).

Rebalancing residential heat pump subsidies towards upfront payments can reduce the overall subsidy costs and potentially widen scheme access by addressing the upfront cost barrier. This would imply more frontloading of the costs in the first six years of the scheme, but leads to savings over time by reducing the financing costs calculated as part of the tariff rates (B3.8b):

- Supporting deployment of residential heat pumps under our fifth carbon budget Central scenario to 2030 under the current RHI levels has a net present cost to Government of around £5.5bn between now and 2036.
- If shifting instead to a system of upfront grants based on capital cost of the heat pump, net of the cost of an oil boiler, this net present cost reduces to around £4.6bn between now and 2036.

This potential cost saving to Government is calculated on the basis that consumers also retain the fuel-cost savings relative to electric or oil heating. This is a simplification compared to the current RHI design, which may compensate for the fact that the estimates do not include an uplift for hassle costs or a consumer 'risk premium'.

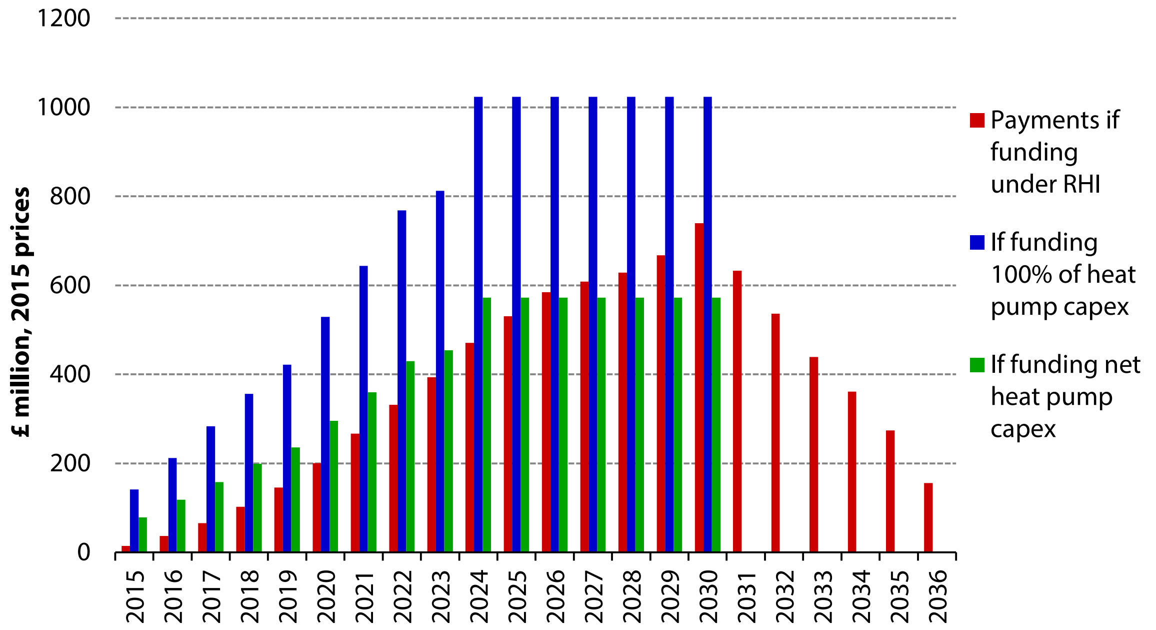
Figure B3.8a. Existing funding to 2020 is sufficient to support heat pumps and biomethane deployment



Source: DECC (2016) *RHI Consultation Impact Assessment, The Renewable Heat Incentive: A reformed and refocused scheme*; CCC analysis.
Notes: RHI is the Renewable Heat Incentive. 5CB is the fifth carbon budget. Non-residential air-to-air heat pumps are not included on the basis that an alternative policy approach is pursued (e.g. standards and low-cost financing). We assume heat pumps supported have an average household demand of 14 MWh/yr and are supported at the current RHI rate of 7.3 p/kWh for air-source heat pumps. Additional biomethane support levels are based on an average support rate of 4.5p/kWh, in line with calculated rates under the 2016 RHI Consultation Impact Assessment.

Box 3.8. Retargeting the Renewable Heat Incentive

Figure B3.8b. Heat pumps support - payments by Government over time if rebalancing towards up-front payments



Source: DECC(2016) *RHI Consultation Impact Assessment, The Renewable Heat Incentive: A reformed and refocused scheme*, CCC analysis.
Notes: RHI is the Renewable Heat Incentive. The oil boiler is picked as the reference replacement technology in line with the basis of the residential air-source heat pump subsidies.

Source: CCC analysis.

Implications and summary

Rolling out low-carbon heat and energy efficiency will require continued support from Government through the 2020s in the absence of regulation and carbon pricing to drive uptake (Table 3.1):

- The current funding to 2020 is enough to roll out necessary low-carbon heat identified in our scenarios, but there is currently no funding for able-to-pay residential energy efficiency.
- We estimate that to meet the additional required rollout of energy efficiency and low-carbon heat through the 2020s will cost £1.5-2.5 billion a year, not including support for the fuel poor.
- Under current Government incentive levels and policy design, this cost is likely to be greater.

Introducing standards earlier in the 2020s can transfer some of this cost to consumers and business, if deemed affordable.

This support is in addition to £1bn funding for energy efficiency measures for fuel-poor households. There will also need to be funding for developing hydrogen pilots at sufficient scale and diversity, and CCS deployment.

We assess the implications for the devolved administrations and for Ofgem in Box 3.9. The devolved administrations have policy levers that should supplement actions that benefit from coordination across the UK (e.g. regulations and decisions related to the gas grid).

In Figures 3.2 to 3.4, we set out an example timeline for policy options that would be consistent with the principles above. However, we would expect the Government to refine these based on more detailed analysis and consultation. The Emission Reduction Plan should set out clear steps, timetable and objectives for heating and energy efficiency. We will assess the Government's response in our next Progress Report to Parliament in June 2017.

Box 3.9. Implications for the devolved administrations and Ofgem

The Government should work with the devolved administrations, Ofgem and other relevant parties in developing its policies for reducing emissions from heating buildings, and ensuring that relevant actors contribute to coordinated action.

The devolved administrations

Scotland, Wales and Northern Ireland have different sets of powers relevant to reducing buildings emissions, and will therefore require different degrees of coordination with the UK Government:

- Scotland has an array of devolved powers, many of which it is already using in order to drive buildings decarbonisation (e.g. on building standards).
- Powers devolved to Wales are much more limited, and it shares the vast majority of its policy framework with England.
- In Northern Ireland, some powers are devolved, although in many cases these have not been used to go beyond UK Government policies.
- Some UK cities, most notably London, also have a considerable range of devolved powers. For example, despite its cancellation nationally, London is continuing to implement the Zero Carbon Homes standard.

Devolved powers provide opportunities for the devolved administrations to go beyond UK-level policy, which can be helpful in driving decarbonisation and in setting an example to other parts of the UK. However, this also makes it essential for action to be coordinated between the parties in control of different policy levers.

There are also clearly some things that are best done at a UK level, such as decisions over regulation and wide-ranging infrastructure decisions (e.g. on hydrogen roll-out).

Ofgem

Ofgem will launch an important consultation in December 2018 which will set the policy context for the RIIO-GD2 and T2 reviews, covering the 2021-2029 period (1 April 2021 to 31 March 2029). It would be beneficial for Ofgem to consider options for regulating decommissioning costs as part of the next gas price control review, including whether to charge individual customers who are disconnecting or to spread the costs over the remaining consumer base:

- Under most future gas scenarios it is likely there will be the need for some decommissioning by 2050, and this could be particularly extensive if CCS is not developed at scale. There is currently material uncertainty in the costs and benefits of decommissioning, including any requirements

Box 3.9. Implications for the devolved administrations and Ofgem

from HSE, limitations from the configuration of existing networks and any potential for repurposing assets.

- Ofgem could address this issue by requiring the gas networks to develop a decommissioning strategy and assessment of the costs and benefits of decommissioning in a scenario in which use of fossil fuels for heating is phased our rapidly (e.g. under a 'no CCS' scenario), as part of the well-justified business plans due in summer 2019.

Along with this, Frontier Economics have highlighted the following considerations (Box 2.4):

- Considering stranding risk and identify a clear approach to allocation of risk.
- Introducing appropriate uncertainty mechanisms to the regulatory price control framework that will allow re-openers at relevant trigger points.
- Instructing Gas Distribution Networks and the National Transmission System to develop a decommissioning strategy and assess the decommissioning costs, with a view to then developing a straw man model for regulating these decommissioning costs.
- Reviewing the connections regime (e.g. Fuel Poor targets, requirements for Gas Distribution Networks to assess alternatives).
- Enhanced incentives for stakeholder engagement with Local Authorities and other interested parties in relation to heat networks; as well as for Gas Distribution Networks and National Transmission System to co-ordinate with electricity networks.

Table 3.1. Estimated high-level funding implications of heat decarbonisation scenarios in the 2020s

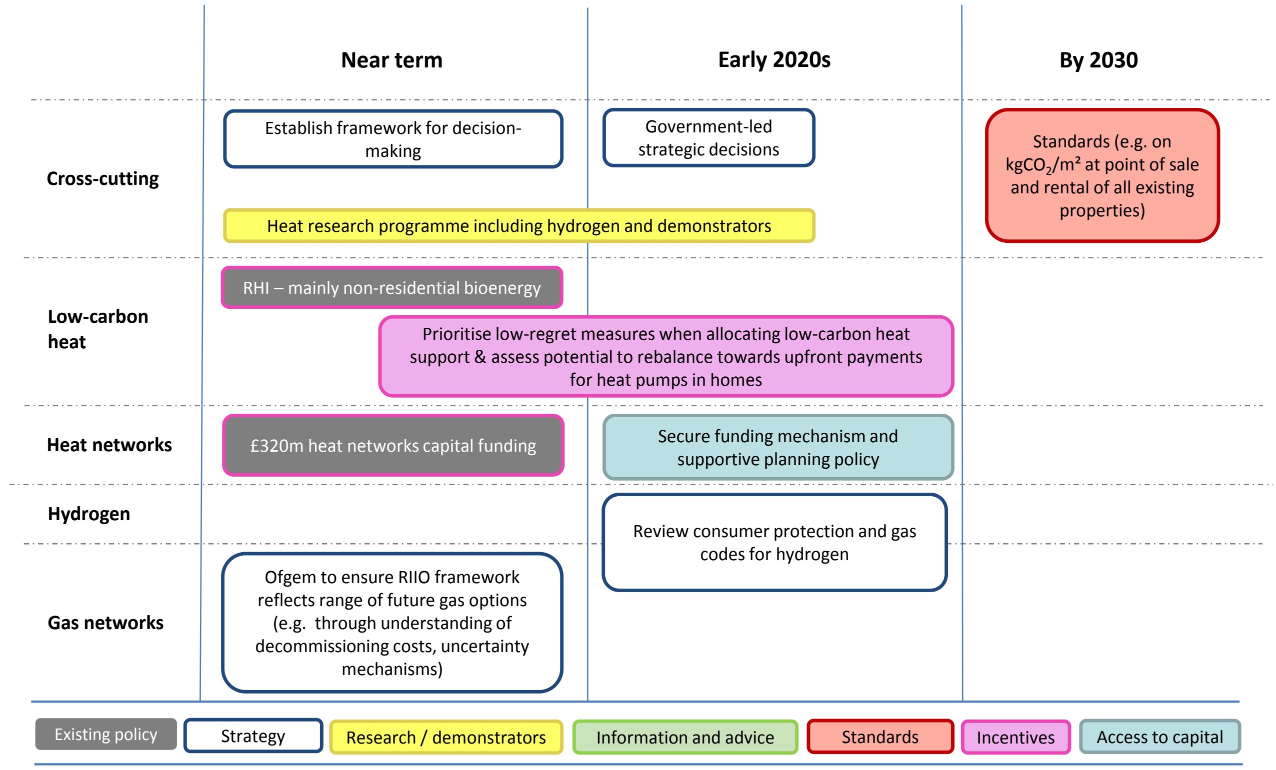
Segment	Current funding pot for 2020	Costs of measures in 2025	Costs under current incentive levels
Biomethane to grid injection	RHI central scenario includes £0.5bn	£0.8bn	£0.9bn
Retrofit residential heat pumps	RHI central scenario includes £0.1bn for all heat pumps	£0.5bn	£0.5bn
Retrofit non-residential heat pumps displacing oil		<£0.1bn	~£0.1bn, plus up to £0.4bn if subsidising heat pumps displacing electric heating
Able-to-pay residential energy efficiency	No funding currently in place	Up to £0.4bn	N/A

Table 3.1. Estimated high-level funding implications of heat decarbonisation scenarios in the 2020s

Segment	Current funding pot for 2020	Costs of measures in 2025	Costs under current incentive levels
Low-carbon heat networks	Pot of £320m capital funding support to 2020	Up to £0.3bn*	Not costed
Fuel poverty			
Fuel-poor energy efficiency	£0.6bn for GB through a supplier obligation	£1.0bn for England's 2025 fuel poverty milestone, and further funding for Wales and Scotland	Not costed

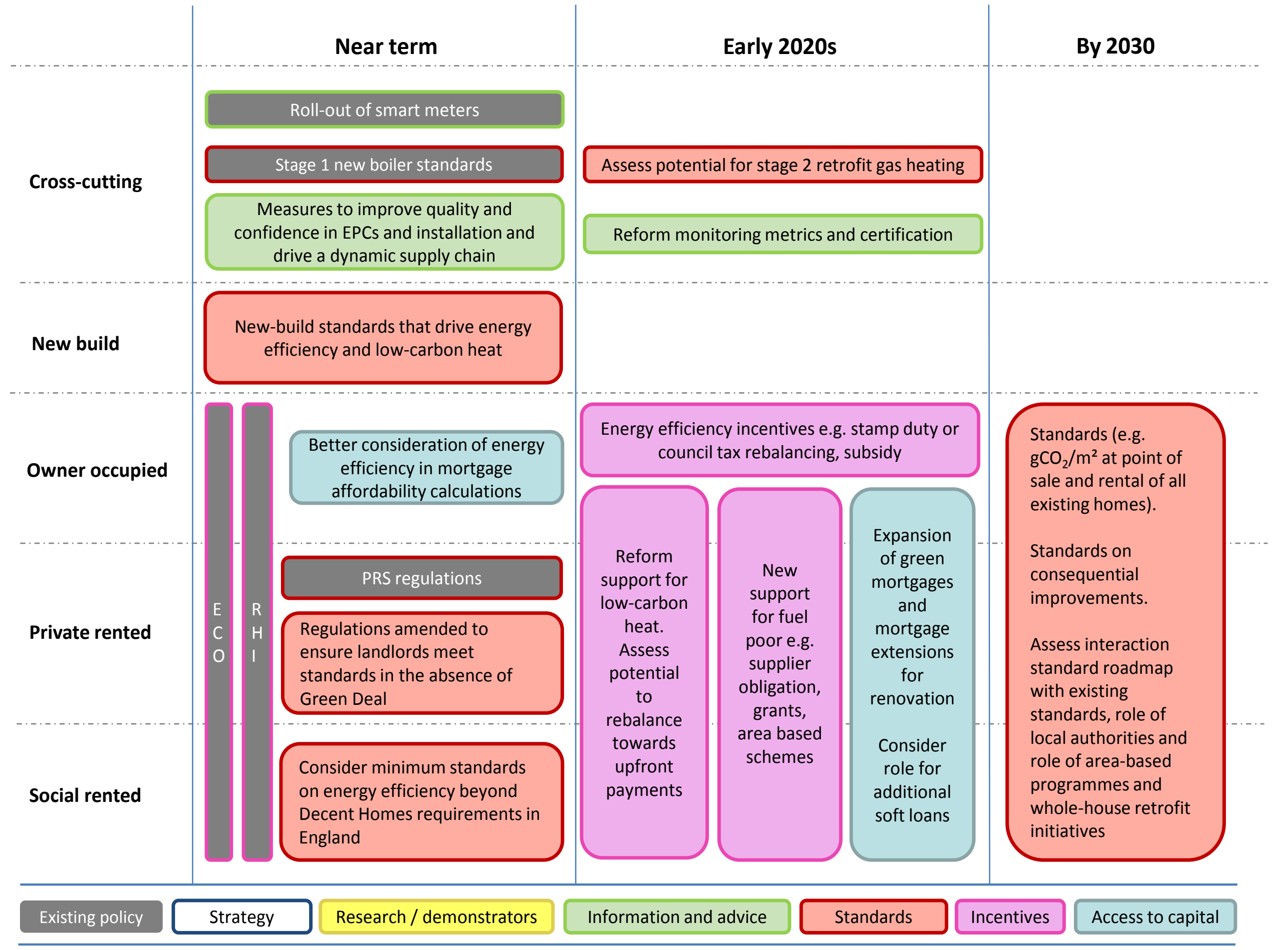
Notes: (1) Numbers are rounded to nearest £0.1 billion.
(2) Cost of measures in 2025 are presented for those measures where there is a net cost after considering energy savings. Net costs are considered on a private basis using retail prices and costs after taxation, apart from in the case of heat networks. Hassle costs and transaction costs are not included. A 3.5% discount rate is applied to energy savings accrued. The cost of capital is assumed to be 7.5% for commercial investments, and 3.5% for households and the public sector.
(3) Biomethane production costs could reduce 10% over next decade based on Carbon Trust (2012) *Technology innovation needs assessment bioenergy report*. We have cautiously assumed that incentives could reduce by an equivalent extent to 2025.
(4) Non-residential heat pumps that displace resistive electric heating are cost-saving, and are therefore not included as a policy cost in the central column under the assumption that standards are introduced rather than a reformed RHI funding model. Funding under current incentives is assessed using the current non-domestic RHI air source heat pump tariffs of 2.57 p/kWh : the range reflects the fact that air-to-air heat pumps (AAHPs) are not currently supported by the scheme. Support levels if extending the scheme to AAHPs are not currently known. (5) Heat networks costs are based on social costs rather than private costs (including a 7.5% commercial cost of capital and 3.5% discount rate). There is potential to look at using Government guarantees in lieu of continued capital grant support to leverage in private finance, which could lead to lower levels of public investment, not quantified here.
(6) Non-residential energy efficiency opportunities identified are largely cost-saving and will involve capital investment of around £8 billion through to 2030.
(7) Able-to-pay energy efficiency: Based on a three bed semi-detached house and the Central fifth carbon budget scenario. The net cost for able-to-pay households is up to £0.4bn in 2025, as households have not been split by fuel poverty in this analysis. The total capital cost in 2025 for measures that are estimated to pay-back on a private basis is £0.7bn (again not split by household type).
(8) Fuel poverty: Current funding estimate does not include income support measures or separate devolved administration programmes. It has only been possible to estimate the cost in 2025 for England. This is based on CSE (2014) *Research on fuel poverty*.

Figure 3.2. Example overarching heat policy timeline



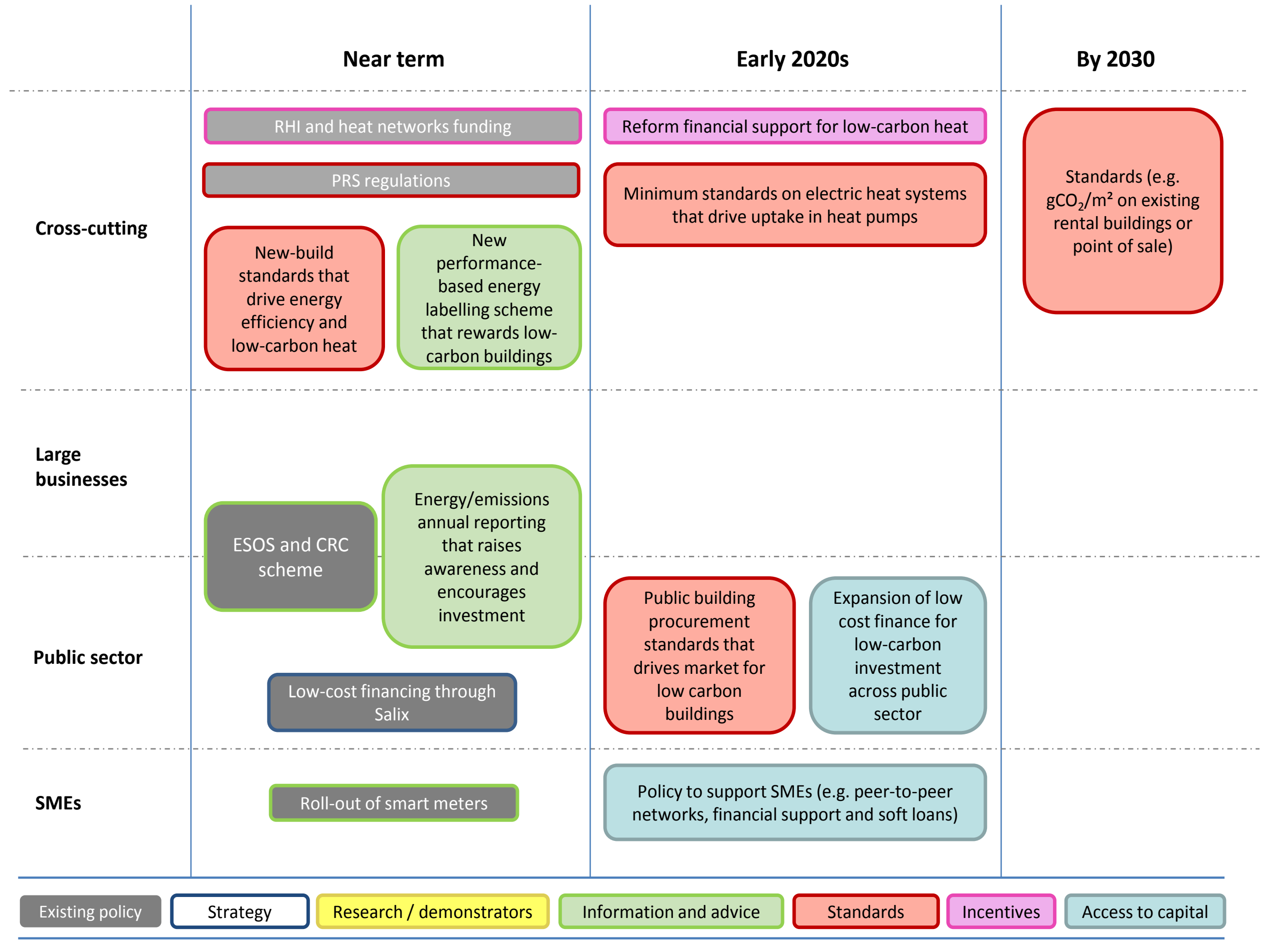
Notes: RIIO is Ofgem's framework for setting price controls for network companies (Revenue = Incentives + Innovation + Outputs); RHI = Renewable Heat Incentive.

Figure 3.3. Example residential buildings policy timeline



Notes: PRS = private-rented sector; RHI = Renewable Heat Incentive; ECO = Energy Company Obligation; EPC = Energy Performance Certificate.

Figure 3.4. Example non-residential buildings policy timeline



Notes: RHI = Renewable Heat Incentive; PRS = private-rented sector; ESOS = Energy Savings Opportunity Scheme; CRC = CRC Energy Efficiency Scheme (formerly known as the Carbon Reduction Commitment).

Annex 1. Policy design options

We explore policy priorities in more detail in the following sections which bring together the policy strands:

(i) Driving energy efficiency improvement in homes and growing the market for low-carbon heating

(ii) Policy for businesses, public and third-sector organisations

(iii) Developing low-carbon heat infrastructure

The suggestions here represent one view of a policy package for meeting carbon budgets, based on the evidence in Chapter 3. They are intended to be explorative rather than prescriptive; to identify the questions to be resolved by policy-makers this Parliament without pre-empting the policy development work underway.

(i) Driving energy efficiency improvement in homes and growing the market for low-carbon heating

By 2030, a high level of energy efficiency needs to be achieved across the stock, combined with around 13% of homes and around half of non-residential heat demand in buildings not connected to gas mains switching over the low-carbon heating. This is likely to require incentives, underpinned by a long-term timetable of standards to drive up levels of efficiency across the board, with more targeted approaches for low-carbon heating deployment. The single most important requirement from a policy package is that it should provide long-term stable direction of travel in order to create the right conditions for securing investment.

Across the housing stock standards could provide a clear trajectory and help in shifting social norms. A mutually reinforcing package could combine these with a fiscal incentive for early adopters, access to low-cost, long-term capital, plus support for fuel-poor households.

- Minimum standards based on annual gCO_2/m^2 would encourage both an improvement in energy efficiency and a movement towards lower-carbon heating systems in a technology-neutral way (Box A1). Such standards could be introduced at the point of sale and rental of homes when financial decisions are being made and when renovation is more likely. This could set a target for 2030 with a clear trajectory of how the standard will be tightened over time, thus providing a clear signal to households and suppliers.
- In the nearer term, consideration should be given to amending the regulations for the private-rented sector so that the intended progress is made. Standards based on SAP have shown to be a useful driver for upgrading social housing in Scotland and Wales (Chapter 1). Consideration should be given to raising the energy efficiency of English social housing beyond the Decent Homes requirements. Minimum standards when properties are being renovated or extended also align to important trigger points and avoid further lock-in.
- Fiscal incentives such as rebalancing stamp duty or council tax to provide a discount to more-efficient homes and a penalty to the least-efficient homes would encourage early adopters and give an incentive to go beyond the minimum standards. This could be done in a fiscally neutral way, or subsidy in various forms could provide an incentive (Box A2).
- Subsidies to support the retrofit of homes of fuel-poor households will be necessary, for example through grants, a supplier obligation or area-based schemes.
- Access to capital, including low-cost finance, will be needed to facilitate home-owners' response to such standards and incentives. Mortgage market developments such as better accounting for energy costs in mortgage affordability calculations, preferential-rate

mortgages for more-efficient homes and green mortgage extensions could help facilitate the purchase of energy-efficient homes and retrofit with little cost to government (Box A3). Consideration should be given to gaps in this provision and the need for government-backed loans or revolving funds, particularly for those not moving home and for low-carbon heat.

Box A1. Designing good standards - issues for policy-makers

Standards should focus on delivering ends rather than means. A standard on a building's heating emissions intensity (e.g. gCO_2/m^2/year) could be met by heating system efficiency, insulation, low-carbon heat or a combination of these.

- A dual standard could be considered that also specifies the minimum thermal efficiency of buildings, reducing the choice set but ensuring that low-cost efficiency improvements are taken up irrespective of heating system to reduce resource pressures e.g. the need to generate additional electricity. This would be important in the private-rented sector, where the landlord pays the capital cost, but the tenant pays the energy bill, especially in the case that resistive electric heating is sufficient to meet the standard.
- The metrics used for future regulations should be considered in the context of the data that will be available, the incentives these generate and compatibility with or refinement of existing metrics. For example, the Environmental Impact rating on Energy Performance Certificates already provides a similar focus on environmental performance, although its emission measurement also includes energy used for lighting, ventilation and is net of energy generated on site; the gCO_2/m^2/year result is transformed into a rating system which may distort the distribution of the underlying data and the rating is currently not heavily focused upon by consumers.
- The implications for households should be considered so that certain groups are not unfairly penalised. For example, there could be a ceiling on the total cost a household is expected to pay, limitations for listed buildings, or a buy-out mechanism where households wishing to sell their property can buy-out at a cost greater than the cost of undertaking the required improvements in case timescales are too short for improvements to be made.[103]

Box A2. Retrofit incentives

A number of incentive schemes to encourage energy efficiency in existing homes have been proposed by a range of groups:

- **Variable stamp duty.** A discount on stamp duty could be applied to purchases of efficient homes offset by a stamp duty premium on low-efficiency homes. This would provide incentives to purchase more efficient properties in a fiscally neutral way. This policy could embed energy efficiency more within the value of property, with home-owners who are not moving also considering improvements to maintain the value of their property.
  - This could be done on the basis of EPC ratings which are required at the point of sale or an alternative metric in the future. It would also be possible to supplement the variable rate of stamp duty with a rebate, for example if buyers of an inefficient home improve its performance within say a year, they could claim the premium back.
  - Stamp duty based policy would address properties as they are sold, and in particular those

[103] Rosenow, J and Sagar, R. for Res Publica (2015) *After the Green Deal: Empowering people and places to improve their homes*, available online at: http://www.respublica.org.uk/wp-content/uploads/2015/09/After-the-Green-Deal.pdf

Box A2. Retrofit incentives

above the stamp duty threshold of £125,000. The point of sale is an effective trigger point, there may be a powerful effect on behaviour due to the perception of being able to 'get one over on the taxman'.[104] The policy would complement regulations applying at the point of sale and mortgage market measures to collectively encourage the purchase of more efficient properties.

- The effect would be limited by the rate of turn-over of the housing stock and the extent to which households respond. Analysis by the UK Green Building Council (UKGBC) suggests that such a reform could lead to 270,000 homes being improved per year.
- In many cases where the house price is not far over the stamp duty threshold the incentive through changes in stamp duty rates would lead to small changes in costs, which relative to the scale of costs in a home purchase may not seem significant. Given the national variation in house prices, the geographical spread of impact would need to be considered.

- **Variable council tax.** A similar process could be applied to council tax, with the main differences being: this would not focus on a trigger point, but would be a more constant reminder and it would affect all homes not just those being sold. This widens its scope for impacting upon a large number of homes, but would be more complex to administer, including the need for energy assessments on all homes, and issues around regional balancing and maintaining revenue-neutrality over time. It could retrospectively penalise those living in inefficient homes, and would need to give consideration to those with low income. The Association for the Conservation of Energy (ACE) and UKGBC have proposed some ways these impacts could be avoided. It would also be possible to trial this by local authority or phase in changes over time.
- A variety of other incentives are available if maintaining revenue neutrality is not crucial, including:
  - **Grants:** funding to cover part of the cost of an energy efficiency measure or package. These have proved effective in a number of countries, but are often focused towards lower-income households given the financial implications. Unless implemented with credibility that they will persist over time they can also create cycles of boom and bust in the supply chain.
  - **Energy efficiency feed-in tariff:** regular payments over time for reducing energy consumption, either based on EPC assessments or on actual performance using smart meter data. This could focus on actual energy use including system performance and behaviour, but would require careful consideration of baseline data and monitoring, and may favour higher-income households who can pay upfront to install measures.
  - **Salary sacrifice scheme:** energy efficiency loans could be provided by employers as a tax-free benefit to employees, such as with the popular Cycle to Work or Childcare Vouchers schemes. This would provide a discount of 20% on the cost of retrofit for basic rate income tax payers. However, this would not be closely tied to properties or decision points, and may favour those working for large companies and higher earners.

Source: UKGBC (2013) *Retrofit incentives: Boosting take-up of energy efficiency measures in domestic properties*; ACE (2011) *Fiscal Incentives – encouraging retrofitting,* http://www.ukace.org/wp-content/uploads/2012/11/Council-tax-proposal-LB-Oct-2011.pdf

[104] UKGBC (2013) *Retrofit incentives: Boosting take-up of energy efficiency measures in domestic properties,* , available online at: http://www.ukgbc.org/campaigns-and-policy/task-groups/retrofit-incentives

Box A3. Mortgage market developments

Under the Mortgage Market Review (MMR), lenders are now required to assess what repayments a customer can afford considering both their income and major expenditures. Many UK lenders take some consideration of energy costs as part of this, but do not consider the energy performance of the building. Improving the consideration of energy costs in mortgage-affordability calculations has the potential to reduce risk for lenders and would enable buyers to borrow more to buy a more-efficient home. There is also potential for preferential-rate mortgages for more-efficient homes given the lower default risk they represent. This is an area where government encouragement, without large cost, could help. A number of organisations are exploring the potential in this area:

- Research by the UKGBC and UCL shows that use of already available data could double the predictive power of modelling fuel costs by lenders. However, while EPC data clearly have a role to play, their analysis finds that EPC ratings are not as good an indicator of fuel costs as they could be. This is attributed to the limited amount of information incorporated in EPC ratings and the lack of attention paid to their accuracy.
- Analysis by the Buildings Research Establishment (BRE) for the Wales Zero/Low Carbon Hub (WZLCH) also shows the impact of better accounting for energy costs. Their research implies the extra disposable income of a household in a more-efficient home could support a typical repayment mortgage of £15,000 more for a home with an EPC rating of a high-B compared to a home with a low-E rating. This would be of a scale that could influence buying decisions.
- Innovate UK are working in partnership with a number of organisations under the LENDERS project to provide better evidence on the relationship between EPCs and fuel costs, and to develop a process to replace existing mortgage-affordability calculations.
- The European Mortgage Federation – European Covered Bond Council (EMF-ECBC) has recently launched a European Energy Efficiency Mortgage initiative which aims to create a standardised "energy efficient mortgage" based on preferential interest rates for energy-efficient homes and/or additional funds for retrofitting homes at the time of purchase. This will bring together input from a group of major banks and mortgage lenders, as well as businesses and organisations from the building and energy industries.

Source: UKGBC and UCL (2015) *The role of energy bill modelling in mortgage affordability calculations*; WZLCH, *EPCs & Mortgages: Demonstrating the link between fuel affordability and mortgage lending*, available online at: http://www.cewales.org.uk/current-programme/energy-performance-certificates-mortgages/; EMF, http://www.hypo.org/Content/default.asp?PageID=421

A major renovation programme to 2030 in **gas-heated homes** could reduce bills, improve comfort levels and prepare the stock for low-carbon heating after 2030. Lower-temperature heating systems can cut emissions and be cheaper, as well as prepare homes for heat pumps post-2030 (enabling more of a 'plug-and-play' installation).[105] In the short-term, this requires upgrading service maintenance standards and protocols for installing condensing gas boilers. The proposed new gas boiler regulations have focused on small incremental efficiency improvements through boiler add-ons such as Flue Gas Heat recovery and heating controls. This paves the way for moving on to wider heating system efficiency in the next stage of the process. It is important that the scope extends to the five million private-rented sector properties. It

[105] This is also useful if converting to hydrogen, due to the likely higher unit prices compared to natural gas (due to the efficiency penalty and cost of CCS) (Chapter 2).

would also be useful to consider the wider requirements of making homes suitable for low-carbon heat, including not removing existing hot water storage in homes (Box A4).

In addition to the stock-wide energy efficiency programme, holistic consideration is needed of **off-gas rural homes**, to deliver heat pumps together with the insulation required to make these effective. Based on evidence in Chapter 3, this suggests:

- A future emissions standard set with considerable lead times at a level that precludes higher-carbon forms of heating, accompanied by near-term incentives and a stable framework of social finance (for example, following the model of the German KfW bank).
- Rebalancing incentives towards upfront costs. This would lead to higher spending upfront, but reduce overall levels of Government spend (Box 3.8, main report). It would help address the regressive nature of RHI subsidies and widen access to the funding pot, whilst also raising the profile of low-carbon heat across the population. In time, this can serve to improve consumer confidence and reduce risk premiums, ensuring greater affordability to the taxpayer and making subsidies go further.
- The UK could learn from approaches that combine finance for heating and efficiency measures, and the unit-cost reductions achieved through Energiesprong whole-house retrofits in the Netherlands, particularly for homes with similar build and features. This model is particularly suited to social landlords.

New-build standards had been planned for 2020 under EU policy. Standards should be introduced this Parliament and set at a level which drives low-carbon heat installation. Unlike the proposed Zero Carbon Homes standard and the 2020 EU standards for new homes, this should not allow solar PV as a substitute for low-carbon heating.

Information and certification improvements are needed to enable households to make informed decisions and have trust in outcomes:

- Smart meter data could be the key to giving householders access to regular benchmarked information on their energy costs, although this will need to be supported by advice on how to make changes. Additional billing information could also play an effective role.
- Improving skills in the supply chain, thorough accreditation and enforcement of standards is crucial in gaining consumer trust and in delivering the maximum potential savings from installations.
- The usefulness of EPCs could be enhanced by tighter checks on validity and would provide better feedback if updated more frequently. In the longer-term monitoring metrics should be reviewed to ensure they best target different policy aims, e.g. emission reduction and fuel poverty reduction, while trying to maintain a manageable process and measurement consumers understand.

There are a number of detailed questions for policy-makers to resolve around detailed policy design:

- The approach to setting standards (metrics, timetable, implementation and linkages with existing energy efficiency and boiler regulations) which will have fundamental implications for how decarbonisation is paid for.
- The role of local authorities and other actors such as Local Enterprise Partnerships
- The role of area-based programmes and whole-house retrofit initiatives.

These should be at the heart of a new strategy (e.g. a White Paper) in this Parliament.

Box A4. Preparing gas-heated homes for heat pumps or hydrogen post-2030

The Government consulted earlier this year on a new set of boiler regulations to build on the 2005 standards. The 2005 standards required all new boilers to be condensing models. As a result, the share of efficient gas and oil condensing boilers has increased from 5% in 2005 to around 60% of the stock in 2014 (BEIS, 2016). The proposed new gas boiler regulations have focused on small incremental efficiency improvements through boiler add-ons such as Flue Gas Heat recovery and heating controls, which can deliver a few percentage increments in efficiency.

More significant efficiency improvements are to be gained from wider heating-system efficiency measures, which enable the boiler flow temperatures to be set lower. Condensing boilers do not work optimally unless the return temperature is set at a maximum of 55 degrees Celsius. In general, lower flow temperatures are more efficient and lead to lower heating bills (Box 2.7, main report). This is particularly true of heat pumps, where heat generation efficiency decreases as a function of the temperature difference between the ambient air and the hot water output.

A range of other options can help improve heating system efficiency, including hydraulic balancing, thermostatic radiator valves, larger radiators or underfloor heating. Hydraulic balancing consists in ensuring that each radiator receives a consistent amount of heat through use of electronic readers or clip-on thermostatic readers on the incoming and outgoing radiator pipes. It can lead to operational savings of 10% or more (SEA, 2016). It is recommended best practice currently and is taught as part of level 3 NVQ Diploma in Domestic Heating (required for all plumbers and installers), and takes between 0.5-4 hours of installer time (SEA, 2016).

There is potential to assess these as part of the next stage of heating system regulations.

Since 1990, consumers have been removing hot water tanks when installing combination boilers, as they are not needed with a combi system. The share of homes with a tank has fallen from 91% in 1990 to under 50% now. This is an issue as building-scale hot water storage is needed for heat pumps. Thermal storage is currently around 100 times cheaper than electrical storage when it comes to in-day storage, and therefore can be a useful option to maintain for system flexibility in the long run.

Sources: BEIS (2016) *Energy Consumption in the UK*; Heating and Hot water Industry Council (2015) *Boiler Plus: The next step in boiler regulations*, draft report by Isaac Occhipinti; Sustainable Energy Association (2016) *Heating System Plus Policy Position Paper;* MacLean, K., Sansom, R., Watson, T., Gross, R. (2016) *Managing heat System Decarbonisation, Comparing the impacts and costs of transition in heat infrastructure*, available online at: http://www.imperial.ac.uk/media/imperial-college/research-centres-and-groups/icept/Heat-infrastructure-paper.pdf

Box A5. Local government, cities, planning and Local Enterprise Partnerships

In Chapter 3, we highlight evidence on the role of local and regional Government in energy planning, knowledge brokerage and capacity-building. This builds on our 2012 report on Local Authorities, where we emphasised the important role councils have in helping the UK meet its carbon targets and preparing for the impacts of climate change. This report also outlined specific opportunities for reducing emissions, highlighting good practice examples from a number of local authorities. The Committee recommended at the time a **statutory duty** and/or **additional funding** to ensure local authorities have stronger incentives to act.

However, there is still **no requirement for local authorities to take action on climate change and funding remains extremely limited**. Where Local Authorities are pushing ahead with low-carbon programmes (such as low-carbon heat networks), this is non-statutory. The evidence shows the considerable ambition of local authorities, particularly in relation to energy efficiency, heat networks and combined heat and power, but they struggle to assemble capacity and resources at the scale necessary to make material impacts (Webb et al, 2016). The same is true of the UK's 39 Local Enterprise Partnerships (LEPs), which are currently incentivised to drive economic development and create local employment, although they remain reliant on the Local Authority for finance and as the official legal entity. The indicators which LEPs are monitored against are in terms of outputs such as new homes and jobs created, rather than low-carbon growth or efficiency savings, meaning that any focus on the opportunities for low-carbon growth (as seen in Leeds) is effectively voluntary.

The **wider devolution agenda** offers some opportunities to improve on this, but these are not currently being widely taken up. Cities can play a vital role by mapping, coordinating and leading the conversation with residents, businesses, services and infrastructure commissioners and operators. Under the first wave of the City Deals agreed in 2012, Birmingham, Bristol, Leeds, Liverpool, Manchester, Newcastle, Nottingham and Sheffield have been given decision-making powers, devolved funding and new financing models in return for drawing up growth plans. This was followed with a second wave agreed in 2013/14 with a further 18 cities and the new devolution deals with Sheffield, Greater Manchester and Leeds in 2014 and early 2015. There is considerable variation in how central low-carbon growth is to the deals, although most of the wave 1 deals include some element of low-carbon energy, energy efficiency or sustainable transport (Green Alliance, 2012).

All public-sector bodies can take a prominent lead in creating a dynamic market by using a high energy efficiency standards in procurement; further improving their own estate; connecting buildings to heat networks and collaborating with other public services to secure heat network economies of scale, and by making prominent public statements about the resulting advantages for facilities, services and public spending (Webb, 2016).

Sources: CCC (2012) *How local authorities can reduce emissions and manage climate risks*; Green Alliance (2012) *Green cities, Using city deals to drive low carbon growth*, available online at: http://www.green-alliance.org.uk/resources/Green%20cities.pdf; Webb, J., Hawkey, D. and Tingey M. (2016) 'Governing cities for sustainable energy: The UK case', *Cities*, doi.org/10.1016/ j.cities.2015.10.014; National Audit Office (2015) *Devolving responsibilities to cities in England: Wave 1 City Deals*, available online at: https://www.nao.org.uk/wp-content/uploads/2015/07/Devolving-responsibilities-to-cities-in-England-Wave-One-City-Deals.pdf; Webb, J., *Heat and Energy Efficiency: Making Effective Policy Advisory Group Report, A report for the UK Committee on Climate Change*, available online at: https://www.theccc.org.uk/publication/next-steps-for-uk-heat-policy/

(ii) Policy for businesses, public and third sector organisations

By 2030, our fifth carbon budget scenario identifies potential for cost-effective energy efficiency improvements and nearly 50 TWh of low-carbon heat uptake in non-residential buildings. Much of this can be realised by private sector investment through developing a dynamic market that creates value in low-carbon buildings and thus encourages capital to follow. To achieve this, the investment opportunities need to become salient to organisations' strategic objectives and reasonable returns established, so as to become a business priority.

International examples suggest that a government policy programme can, if implemented carefully, create a supportive balance of incentives and standards that influence the drivers of salience. ***Policies have been successful due to their complementary design, sequencing and implementation in order to target drivers of action across a diverse range of businesses and public sector organisations.***

Information collection and reporting can raise salience through increasing awareness of low-carbon potential to customers, the board room, and to investors:

- Energy and environmental labelling of buildings that has industry confidence could encourage competition and investment in more energy efficient and lower-carbon buildings. Consideration could be given to how to develop a new performance-based building energy labelling scheme that generates added value for market leaders and frequent enough to continuously move the market forward. Characteristics from the successful Australian NABERS scheme include assessing actual rather than modelled performance, separated between building and tenancy use, and clear identification of low-cost options for improvement.
- Energy and emissions mandatory annual reporting would regularly highlight organisations opportunities for low-carbon investment and strengthen the Energy Savings Opportunity Scheme (ESOS). This can raise the salience of carbon performance internally with Board-level oversight, and externally through reputation with selective public disclosure and promoting best practice performers. Consideration should be given to how the reporting framework could enhance low-carbon investment, while minimising administrative burden.

Private sector buildings make up 70% of non-residential building heating/cooling energy consumption:

- New-build emission standards for buildings to drive energy efficiency and low-carbon heat need to be developed with support from the industry, and ensure heating systems are low-carbon (e.g. heat pumps or connection to a heat network).
- Existing rented buildings make up half of private sector building energy consumption. While promotion of market-leading buildings through actual performance labelling would drive investment to overachieve benchmarks, minimum standards will bring up the bottom end of the sector. All rented premises will need to meet minimum standards from 2023. Building on this with a 2030 gCO_2/m^2/year target for existing buildings at point of sale[106] could create long-term certainty for investors.
- Minimum standards on electric heating systems. Non-residential buildings' consistent space heating/cooling requirements with relatively low hot water needs, mean that reversible air-

[106] i.e. as well at point of lease.

to-air heat pumps uptake through energy efficiency standards may be a lower-cost option to realise potential than financial incentives such as the RHI, particularly in the case of larger organisations which make up around a third of demand. This could release budget resource to incentivise heat pumps in the more challenging residential sector. Within the non-residential sector, electrically heated buildings with mechanical ventilation and cooling systems could present a cheap and relatively straightforward early segment. Consideration is needed, with additional analysis to assess which types of organisations could realise this potential and how to effectively structure standards to increase uptake.

SMEs make up around half of non-residential heating/cooling energy consumption and need additional support through technical knowledge, management and financing of low-carbon investment:

- Networks between peers or within supply chains can help SMEs through exchange of knowledge, mentoring by larger organisations, benchmarking and developing voluntary targets. Germany has demonstrated a successful industry-led programme supported by Government to help with technical knowledge, skills and management constraints.
- Low-cost capital through grants or interest-free loans programme for energy efficiency and low-carbon heat could help SMEs overcome capital constraints to cost-effective investment.

Public sector buildings make up 30% of non-residential building heating/cooling energy consumption and nearly a fifth in the rental sector:

- Market-leading minimum public sector building procurement standards could support a market developing higher performing buildings, encouraged by actual performance building labelling. Public sector leasing could reward the market leading buildings while reducing public sector energy costs and emissions.
- Finance for investing in existing public estate energy efficiency and connection to heat networks. This could be realised by expanding access to interest-free loans through Salix, ensuring accounting rules incentivise investment or devolving finance decisions to the local level to allow borrowing to invest in building infrastructure.

There are a number of detailed questions for policy-makers to resolve around detailed policy design:

- How an acceleration in energy efficiency and low-carbon heat can be part of an industrial strategy for the UK;
- The balance between meeting requirements while minimising costs to business, especially for SMEs; and
- How to increase public sector low-carbon investment while meeting fiscal sustainability constraints.

These should be at the heart of the government's new strategy (e.g. White Paper) in this Parliament.

(iii) Developing low-carbon heat infrastructure

The main requirements for low-carbon heat infrastructure are to prepare for Government-led decisions on the long-term approach to decarbonising buildings on the gas grid. In Chapter 3, we establish that this requires a programme of research and development, including pilots and demonstrations and a new CCS strategy to ensure that hydrogen can be produced economically

at scale in a low-carbon way. It also needs to ensure that gas network investments over the next price control period (2021-2028) reflect the requirements of carbon budgets.

The remaining two priorities are assessed further in the following section:

- Developing a mechanism for supporting the continued expansion of low-carbon networks through the 2020s, including attracting new types of investor and establishing a proportionate level of regulatory framework.
- Establishing the process for making decisions on heat infrastructure through the 2020s, including the roles for different actors and a coherent governance structure.

The continued roll-out of low-carbon heat networks through the 2020s will require a combination of a supportive planning policy framework and a financing framework (e.g. including the use of Government guarantees to de-risk large multi-stage developments). The immediate priority for BEIS is to finalise the details for the £320m funding pot to 2020, both setting out what carbon savings this funding will achieve and providing a longer-term framework into the 2020s. Research undertaken by Frontier Economics to support our advice on the fifth carbon budget in 2015 highlighted a number of policy options for review, including zoning with additional powers for local authorities, removal of competing subsidies, and requirements to connect for new-build and public buildings where cost-effective (Box A5).

At the same time, Government will need to set in train a **process for determining the direction of travel for heat decarbonisation post-2030**. This includes identifying the decisions to be made through the 2020s, a timeline for making those decisions and the role for different stakeholders, including who is ultimately responsible:

- Given the multiple scales at which decisions over heat infrastructure need to be made, this should assess options for developing a balance of central and regional governance to create the mandate for low-carbon heat options at a local and regional scale.
- One of the key questions for policy-makers is to assess options for different delivery-agent models, including the role for cities, Mayors and Local Enterprise Partnerships, energy companies, network operators, ESCOs, and other public authorities. In particular, this should consider the potential for driving down delivery costs through coordinated approaches.

Box A5. Frontier Economics 2015 heat networks study

In 2015, to provide supporting evidence for our recommendations on the fifth carbon budget, we commissioned Frontier Economics to look at barriers to uptake for the roll-out of heat networks, and to consider a set of policies to overcome these barriers. They undertook a combination of stakeholder interviews and a review of existing research, drawing on lessons from other countries with more developed markets for heat.

Their assessment was that policy intervention will be required to overcome a number of barriers, including the lack of carbon pricing, natural monopoly issues and uncertainty of demand. They set out a number of recommendations:

- A financial incentive to investors, which could be replaced by carbon taxation in the longer term.
- Competition policy, to address natural monopoly issues.
- Supportive planning policy, in the form of dedicated zones for heat networks, where other conflicting incentives are not available (e.g. for small domestic heat pumps). This could be combined with a policy of public bodies connecting to heat networks where this is cost-effective.
- A set of 'low-regret' policies including information provision on waste heat and localised approaches to developing consumer trust and awareness.

Source: Element Energy, Frontier Economics and Imperial College (2015) *Research on district heating and local approaches to heat decarbonisation.*

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