Annex 2. Heat in UK buildings today

This Annex supports the analysis of the main report, looking at the current use of heat in buildings. It analyses the relevant characteristics of main subsectors in terms of associated emissions and energy use as well the current policy environment and gaps to meet the carbon budgets.

This annex is structured in four sections:

1. Overview

2. Residential buildings

3. Non-residential buildings

4. Current policy and gaps

1. Overview

Emissions from fossil-based heating systems and stoves were 85 $MtCO_2e$ in 2015, or 17% of the UK total:

- These are mainly from homes, which make up three quarters (64 $MtCO_2e$) of direct emissions (i.e. fossil-based, rather than electric).
- Non-residential buildings account for the remaining quarter of direct emissions, split into 13 $MtCO_2e$ from commercial buildings and 9 $MtCO_2e$ from public buildings.

Buildings are also the largest consumer of electricity, using around 204 TWh (67%) of electricity in 2015 and accounting for indirect emissions of 76 $MtCO_2e$.

Progress in direct emission reduction has been limited, with an average 1% annual reduction between 2009 and 2014. This has been mainly due to the lack of progress in non-residential buildings, although progress in insulating homes has also stalled since 2012.[1]

There has been a similar trend reduction in electricity consumption, with an annual average 1% reduction between 2009 and 2014. In particular, while residential buildings electricity consumption has reduced by around 1.5% per year, non-residential electricity consumption has not changed since 2009.

2. Residential buildings

The UK housing stock is one of the oldest and worst insulated in Europe,[2] with only around 15% of existing stock built since 1990. Most homes are expected to still be in place in 2050.

Out of the total 64 $MtCO_2e$ of direct emissions of residential sector, we identified potential for cost-effective (i.e. at a cost less than the Government's published carbon values, reaching £78/tCO_2e in 2030) emission reduction of 9-10 $MtCO_2e$ by 2030 in our fifth carbon budget advice, with further 5-6 $MtCO_2e$ required to be on track to the 2050 target.[3] These savings are

[1] For details see Table 3.2 in CCC (2016) *Progress Report to Parliament* at https://documents.theccc.org.uk/wp-content/uploads/2016/06/2016-CCC-Progress-Report.pdf
[2] Buildings Performance Institute Europe (2011) *Europe's Buildings Under the Microscope,* available at http://bpie.eu/publication/europes-buildings-under-the-microscope/
[3] See notes to Table A2.1 for an explanation of the ranges.

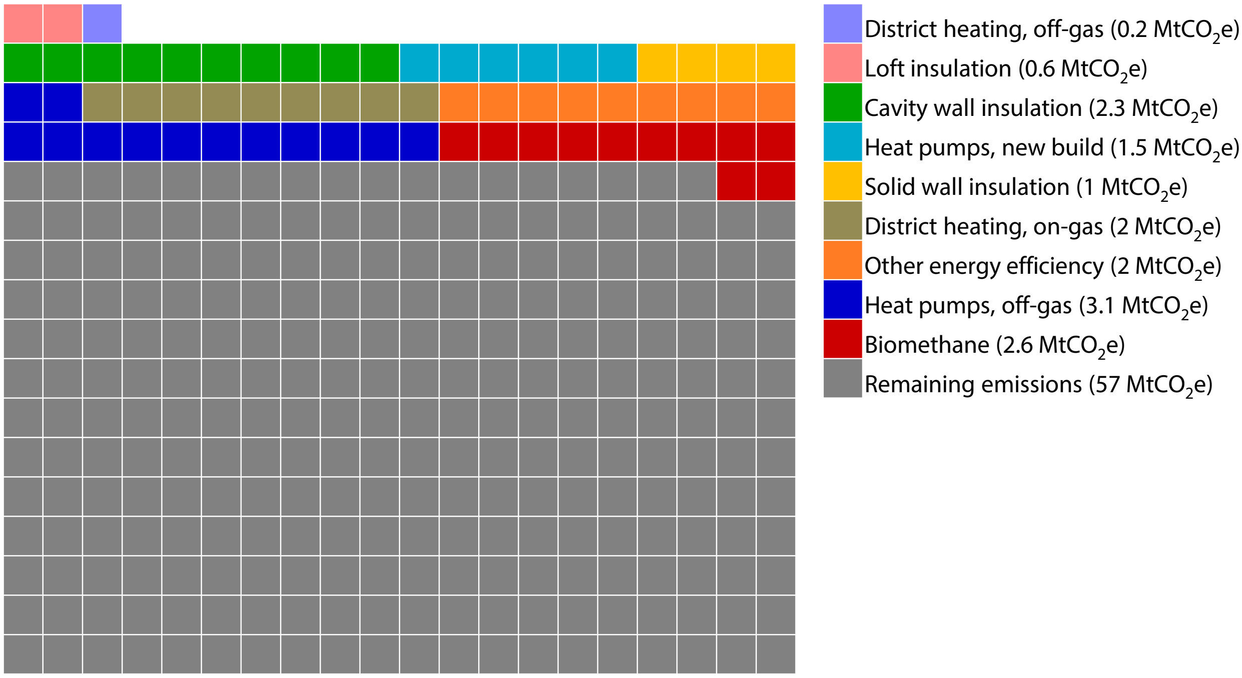
made up of energy efficiency and switching to heat pumps, low-carbon district heating or low-carbon gas (Table A2.1 and Figure A2.1).

Table A2.1. Emission reduction potential in 2030 to meet the fifth carbon budget

Abatement option	**Emission savings in 2030**	
	$MtCO_2e$	**Of which cost-effective**
Energy efficiency improvements	6	4
Heat pumps and biomass boilers in off-gas homes and heat pumps in new build homes	4	3-4*
Low-carbon heat networks in on-gas homes, including new build homes	2	2
Total emission reduction in residential buildings	13	9-10*

Source: CCC analysis.
Notes: Totals may not sum due to rounding.
*Of the 4 Mt CO_2e from heat pumps and biomass in homes by 2030, 1.5 Mt CO_2e of savings are from installing 1.1 heat pumps in new homes. We included this uptake in our Central scenario in order to develop supply-chains and keep open the option of rolling out heat pumps more extensively through the stock to 2050. When we calculate cost-effectiveness of these heat pumps in new homes, we assume that they are connected to the gas grid if not installing a heat pump. If we include the cost of connecting to the gas mains which were not previously factored in to the fifth carbon budget analysis (based on table 2.1 of the main report), then around 1 Mt of the 1.5 Mt is cost-effective to 2030. The lower end of the range is based on the initial fifth carbon budget assessment.
There is a further 2 Mt CO_2e abatement from injecting biomethane into the gas grid.

Figure A2.1. Direct abatement in residential buildings in 2030 to meet the fifth carbon budget ($MtCO_2e$)



Source: CCC analysis.

The detailed residential buildings segmentation in the following section is based on analysis using the National Household Model, unless referenced otherwise. This model uses a number of 2012 and 2010 GB housing datasets together with an energy calculator modelled on 2009 SAP. Results have, where possible, been updated to reflect recent developments and are calibrated to 2015 emissions, but may not align to other sources of published statistics.[4] All figures unless otherwise stated are given for England, Scotland and Wales, but do not include Northern Ireland estimates.

The majority of residential buildings (85% or 23 million) are currently connected to the gas grid, using a boiler and wet-based central heating system. The remaining 15% of homes (4 million) are not connected to the gas grid, using either oil or liquid petroleum gas (LPG) as their main heating fuel or electric heating.

These 'off-gas' homes make up a greater share of heating emissions (23%) due to the higher carbon intensity of oil and LPG - and electricity currently - compared to gas. Most electric heating is used in off-gas homes (77%) with the remainder used as 'top-up' heating.

Apart from the fuel used, other buildings' characteristics are important in determining the amount of energy used, and resulting emissions, such as the heating system efficiency, type of wall or loft insulation, or the building age:

- Homes on gas tend to a have higher proportion of condensing boilers, implying a higher efficiency of heating. In particular, around 60% of on-gas homes have condensing boilers compared to under a third of off-gas homes with boilers.

[4] The outputs are based on the stock of homes in England, Wales and Scotland which were existing in 2012, and do not include around 500,000 additional dwellings created since 2012.

- Over two thirds of homes have cavity walls, the remainder being solid wall. While 69% of homes with cavity walls are insulated, only 8% of solid wall homes have wall insulation.[5]
- There is technical potential to top-up the level of loft insulation in up to a third of homes with lofts and thus reduce the amount of energy use.[6]
- UK buildings are some of the oldest in Europe, with an average on-gas home being built around 1950 and off-gas home in the 1930s.

These characteristics underline the importance of further energy efficiency improvements to reduce the size of energy demand and to make the housing stock suitable for low-carbon heating systems.

In addition, energy efficiency improvements can be a cost-effective way of reducing the number of households in fuel poverty, especially in the off-gas sector. Of around 2.4m households in fuel poverty in 2014 in England:[7]

- Around 2 million households are on-gas (i.e. a tenth of on-gas households).
- Around 0.4 million households are off-gas (i.e. 15% of off-gas households).The higher proportion in fuel poverty is mainly due to the fact that these households face higher fuel costs compared to on-gas homes.

The energy performance of dwellings is measured using the Standard Assessment Procedure (SAP) to generate Energy Performance Certificate (EPC) ratings. EPC ratings are split into A-G bands, with A delivering the highest performance and G the lowest, based on the fuel-cost metric of £/kWh/m^2. According to this method, around 72% of the housing stock is above the E rating, but with 50% of the total rated in category D.[8] However, EPC ratings are directly affected by the costs of different fuels, so they link more closely to economic efficiency than energy efficiency of a dwelling (Box A2.1):

- For on-gas homes, more than 76% of homes are within the A-D bands and only 2% within the F-G group, as the fuel cost of gas is relatively lower than fuel costs off the gas grid.
- For off-gas grid homes, 48% of the stock is within the A-D bands and 24% of homes are within the two lowest bands (Figure A2.2).

- However, if reported on an energy efficiency basis (i.e. kWh of heating per m^2), the off-gas homes perform better than on-gas homes for each SAP band, using on average less heating than on-gas homes. [9]

[5] Based on government insulation statistics for Great Britain. Available online at: https://www.gov.uk/government/collections/household-energy-efficiency-national-statistics
[6] Based on government insulation statistics for Great Britain. Available online at: https://www.gov.uk/government/collections/household-energy-efficiency-national-statistics
[7] Based on the low income high cost definition, government fuel poverty statistics. Available online at: https://www.gov.uk/government/collections/fuel-poverty-statistics
[8] Based on the SAP-2009 survey data.
[9] The estimated average floor area does not differ significantly between on-gas (113m^2) and off-gas homes (116 m^2), implying that the average heating energy is broadly similar across the sectors.

Box A2.1. Standard Assessment Procedure, policy application and other metrics

The Standard Assessment Procedure is the methodology used by the Government to assess and compare the energy and environmental performance of dwellings. It was developed by the Building Research Establishment (BRE) in 1992 and is based on the BRE Domestic Energy Model (BREDEM) which calculates the energy consumption of dwellings.

SAP works by calculating a dwelling's energy consumption at a defined level of comfort and services provision. The assessment is based on standardised assumptions to enable direct comparison of dwelling performance. As a result, it can estimate the fuel costs or emissions of CO_2 per dwelling.

SAP quantifies a dwelling's performance in terms of energy use per unit floor area (kWh/m^2), a fuel-cost-based energy efficiency rating (the SAP rating, in £/kWh/m^2) and emissions of CO_2 (the Environmental Impact (EI) rating, in CO_2/m^2). Consequently, while the SAP rating is mostly suitable for fuel poverty related issues, the EI rating captures the variation in carbon intensity of heating fuels.

SAP ratings have become mandatory for new buildings since 1995 and from 2007 all buildings sold or leased need to have the Energy Performance Certificate (EPC) which is based on the reduced SAP (RdSAP) methodology. The EPC reports both the SAP rating and the EI rating on a scale from A (highest) to G (lowest) and the estimated running costs of the building by used service.

SAP and RdSAP are currently used across many policy areas, including the private rented regulations, in fuel poor related policies, to derive the EPC bands, to calculate deemed heat demand under the residential Renewable Heat Incentive, as a requirement to receive standard Feed-in-Tariff and in building regulations on new build and leases.

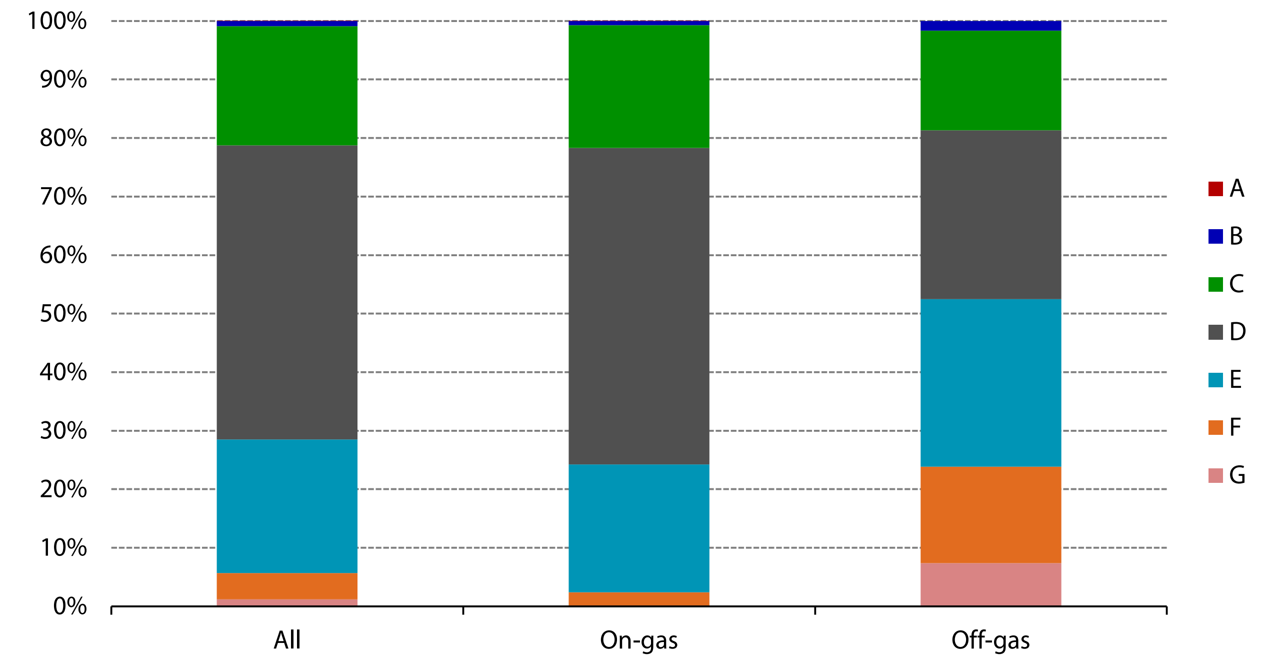
There are potential issues with applying the SAP in some of these policies. For instance, the private-rented regulation requires landlords to have a SAP rating of E or above from 2018 but it is not certain that this will result in genuine energy efficiency improvements since the rating could be achieved by switching to a cheaper heating fuel (i.e. from electric heating to gas where there are gas mains in the locality). The same applies to the feed-in-tariffs requirement of having a minimum rating of D or above. Because of its short-term focus, the SAP fuel-cost approach also encourages the installation of solar PV rather than focusing on energy efficiency and low-carbon heat (Kelly et al, 2012).

Based on the English Housing Survey 2012, the average SAP 2009 score of homes with heat pumps is around 65, or high D rating, which is consistently above ratings seen for off-gas homes (Figure A2.2). However, the on-gas homes with condensing boilers show on average the same or higher rating, disincentivising the switch to heat pumps. If reported on heating energy intensity (i.e. kWh of heating used per m^2), heat pumps would be shown to be typically outperforming any other heating system.

Overall, the SAP rating is more likely to be an appropriate tool for the fuel poverty targets, with other metrics more suitable for energy efficiency (such as kWh/m^2 or efficiency of the heating system) and emission reduction (including metrics like gCO_2/m^2 of delivered heating).

Source: Kelly et al. (2012) *Building performance evaluation and certification in the UK: is SAP fit for purpose?*

Figure A2.**2.** SAP ratings for Great Britain housing stock in 2012 surveys



Source: National Household Model.
Notes: The SAP ratings are consistent with the SAP 2009 methodology.

There are various low-carbon heat options for the residential sector that may have a role in meeting the fifth carbon budget and the 2050 target, including electric heat pumps, connecting to low-carbon heat networks or converting on-gas homes to hydrogen. There is substantial overlap in technical suitability across the housing stock:[10]

- Out of 23 million on-gas homes, most if not all are theoretically suitable for hydrogen, and a large proportion could be fitted with heat pumps.[11] Around 3 million homes might also be viable for economically efficient heat networks based on the spatial analysis of heat demand and supply in our high deployment scenario for the fifth carbon budget analysis.[12]

[10] We applied different technical potential assumptions across the heating technologies as part of the fifth carbon budget advice. For heat pumps, space requirements are a limiting factor and we assume 10% of flats cannot have air source heat pumps. Ground-source heat pumps and heat pumps with storage require more space, further reducing their technical feasibility. The suitability for heat networks is based on our fifth carbon budget 'Max scenario', with around 3.5 million homes connected to district heating in 2050. The split to on-gas and off-gas homes connected to heat networks is then determined by the relevant proportion of homes situated in urban heat dense areas. Last, we assume that all on-gas homes could be technically suitable for hydrogen conversion but none of the off-gas homes.
[11] Installing heat pumps in homes would require further insulation and upgrading heating systems in a significant proportion of gas-heated homes. In the main report, we put the number currently suitable for heat pumps at around ten million (although loft top-up will be required in some cases), with a further ten million or more homes which could be made suitable for heat pumps with insulation (solid wall, with some remaining loft and cavities) and heating system upgrades (Chapter 2).
[12] Based on the fifth carbon budget 'Max scenario' equivalent to 111 TWh of heat by 2050 from heat networks under spatial modelling by Element Energy for the fifth carbon budget advice, factoring in both heat demand density and local availability of heat sources. This is available at https://www.theccc.org.uk/publication/element-energy-for-ccc-research-on-district-heating-and-local-approaches-to-heat-decarbonisation/. The scenario used a number of

- Out of 4 million off-gas homes, almost 3 million homes could be suitable for heat pumps and around 0.5 million homes might also be technically suitable for connection to a heat network.[13]

Based on technical suitability alone, therefore, there are various ways in which the decarbonisation of on-gas homes could play out, whereas the off-gas sector is likely to require a significant deployment of heat pumps, with a more limited role for biomass due to scarcity of bioenergy resources. All the three low-carbon heat technologies currently face significant barriers to uptake (Box A2.2).

Box A2.2. Barriers to uptake of low-carbon heat

All low-carbon technologies currently need to overcome significant barriers to uptake to meet the fifth carbon budget. The research for the Fourth Carbon Budget Review identified the main barriers for heat pumps uptake as:

- **Economic:** Lifetime costs are usually higher than for gas boilers with heat pumps facing high upfront cost that consumers may not be able to cover.
- **Behavioural:** The level of awareness and confidence in heat pumps is lower as they are not a mainstream heating technology; they can also take up more space than conventional systems; hidden costs, like time spent on the research or hassle with the installation can reduce the uptake.
- **Technical:** The suitability of buildings may limit the uptake further as heat pumps require energy efficient homes, an additional area for heat emitters and often hot water storage too; they also need to comply with limits on noise and require optimal installation and operation to deliver heating comfort. There are also regulatory barriers, such as the constant carbon intensity of electricity in SAP assessment.
- **Supply-side:** The supply chain is currently likely to be constrained in its ability to grow fast enough, especially because of the lack of trained installers. The interdependencies in the industry may further limit its potential to grow.

Heat networks currently face many cross-cutting barriers for a substantial roll-out by 2030. The research underpinning the fifth carbon budget advice found the following problems:

- **Market failures:** The lack of carbon pricing of heating means the positive externality of carbon savings is not reflected in the price of heating and results in less than optimal uptake. Further, heat networks are natural monopolies, facing high fixed costs, which means that it is more efficient to have one supplier for a given location but the lack of competition may result in poor customer service. Last, the use of waste heat faces information barrier as it is currently difficult for investors to gain information on the availability of waste heat from a given source (e.g. power stations).
- **Consumer:** The awareness of district heat is low or lacking enough consumers' interest. There may also be lack of trust, perceived poor quality of service or hassle of connecting to the network.
- **Demand uncertainty:** District heating is highly capital-intensive and it is likely to be more viable with sufficient level of demand secured.
- **Institutional:** There may be issues with the adequacy of local authority resources or general level

stretching assumptions, including higher incentives, strong zoning policy and high allocation of biomass to heat networks. Other studies have in the past highlighted a greater technical suitability for heat networks (up to 40% of heat - roughly double) but have typically not undertaken the same level of spatial analysis of both supply and demand.

[13] The overlap between the two is unknown.

Box A2.2. Barriers to uptake of low-carbon heat

of skills and knowledge within the sector.

- **Policy:** These barriers range from conflicting policies with different aims, to unexpected shifts in policies as well as restrictive planning policies which can all reduce the level of investment.

In respect of hydrogen, the fifth carbon budget research showed that the technology faces a number of significant barriers, with the following recognised as particularly relevant to the buildings sector:

- **Public perception:** Negative public perception of hydrogen safety would affect users' acceptance.
- **Technical:** The conversion to hydrogen would require repurposing of the natural gas distribution networks as well as the conversion of all connected appliances. The purity of hydrogen that could be delivered through the network to the end user is still uncertain and needs assessing.
- **Financing:** Substantial use of hydrogen would require a suitable funding mechanism through which the local authorities would fund their conversion schemes.
- **Policy:** The policy would need to require compulsory conversion to hydrogen with sufficient assurance to the appliances market that the hydrogen will be rolled out.

Source: Frontier Economics and Element Energy (2013) *Pathways to high penetration of heat pumps;* Frontier Economics (2015) *Research on district heating and local approaches to heat decarbonisation, Annex 1: Overcoming barriers to district heating*; E4tech (2015) *Scenarios for deployment of hydrogen in meeting carbon budgets.*

2.1 Off-gas residential buildings

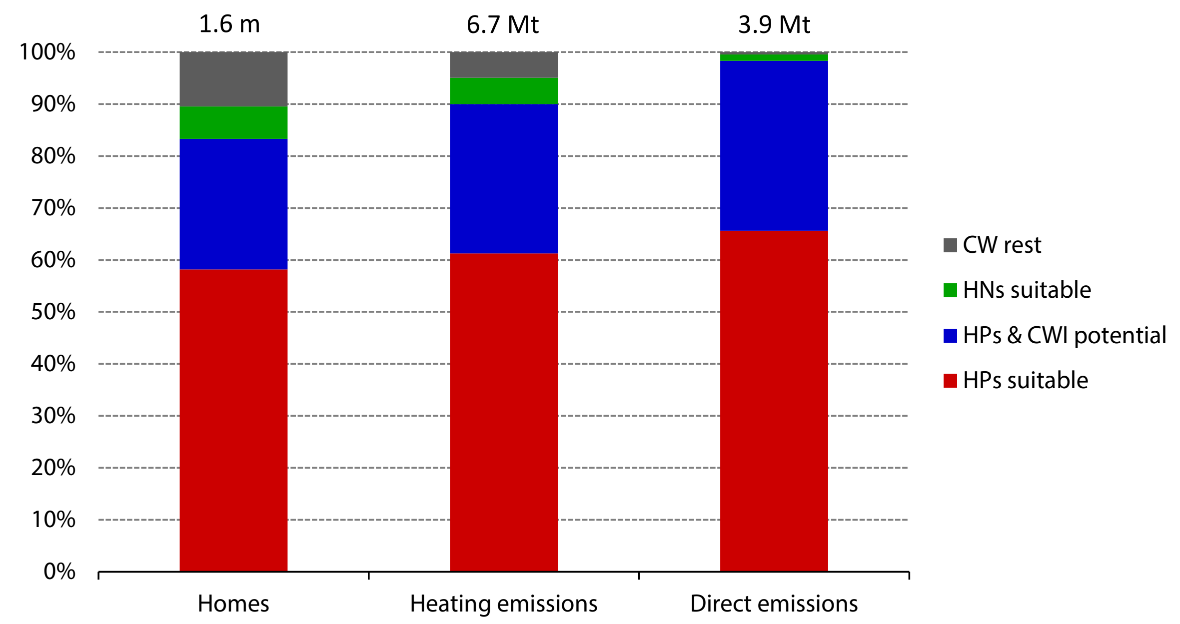
For off-gas grid residential buildings, 17 $MtCO_2e$ of total heating emissions (i.e. direct and indirect emissions) come mainly from owner-occupied homes. A large proportion is from using oil-based heating in rural areas and electric storage heaters in urban areas:

- Out of a total 9 $MtCO_2e$ of direct emissions in off-gas homes, oil and LPG-heated homes are responsible for 8 $MtCO_2e$. These are mainly owner-occupied buildings situated in rural and suburban areas.
- For indirect emissions, amounting to the remaining 8 $MtCO_2e$, owner occupied homes are again the main source of emissions, followed by the private-rented sector homes and social housing. The majority are situated in urban and suburban areas due to use of electric storage heaters.

Not including Northern Ireland, there are around 1.6 million owner-occupied homes off the gas grid with cavity-walls, contributing 4 $MtCO_2e$ of direct emissions and largely technically suitable for heat pumps. The remaining 0.7 million owner-occupied off-gas homes are solid wall properties with a high proportion of direct emissions (4 $MtCO_2e$), but currently less technically suitable for heat pumps due to much lower levels of insulation (Figure A2.3 and A2.4):

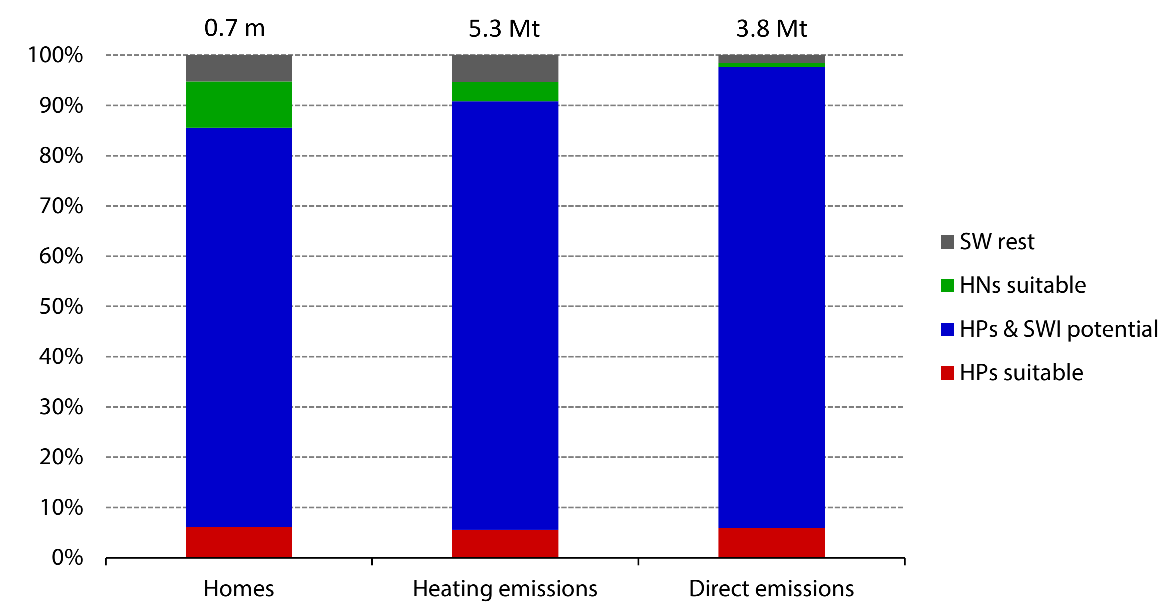
- Around one million have cavity wall insulation which helps ensure they are suitable for heat pumps. An additional 400,000 homes could have cavity walls insulated.
- Only 40,000 solid wall properties have solid wall insulation. A further 0.5 million could be made more suitable for heat pumps with insulation, but this would be more challenging than for cavity wall homes.

Figure A2.3. Off-gas owner occupied homes with cavity walls



Source: CCC analysis.
Notes: CW = cavity wall, HN = heat network, HP = heat pump, CWI = cavity wall insulation
Some loft-top up is likely to be required. Estimates of remaining insulation potential are modelled and are lower than published statistics.

Figure A2.4. Off-gas owner occupied homes with solid walls



Source: CCC analysis.
Notes: CW = cavity wall, HN = heat network, HP = heat pump, CWI = cavity wall insulation
Some loft-top up is likely to be required. Estimates of remaining insulation potential are modelled and are lower than published statistics.

Private rented homes (1.1m) are the source of around 4 $MtCO_2e$ emissions from heating, three quarters from electrical heating. They are generally less technically suitable for heat pumps due to their location in urban areas, but more suitable on average for low-carbon heat networks:

- Around 300,000 homes have cavity wall insulation to a level required for fitting a heat pump. There is further potential to insulate around 150,000 homes to make them heat pump ready. More than 100,000 homes are situated in urban areas and are more likely to be suitable for low-carbon heat networks.
- Only around 30,000 solid wall homes are currently insulated to a level which is suitable for heat pumps (notwithstanding any other improvements including loft top-up insulation which may be required). This could increase to more than 200,000 if properly insulated. Around 80,000 are in areas which are likely to be suitable for heat networks.

Our central trajectory for meeting the fifth carbon budget included around 1.2 million heat pumps in the off-gas sector and 0.1 million homes on low-carbon heat networks, as well as an additional 0.7 million cost-effective solid wall insulations and 0.5 million cavity wall insulations installed by 2030 (Figure A2.5).

2.2 On-gas residential buildings

The 23 million homes on gas account for around 77% of total UK heating emissions (57 $MtCO_2e$), split to 54 Mt of direct emissions from natural gas heating, and a remaining 2 $MtCO_2e$ of indirect emissions, as some households top up their gas heating with electrical heating. These buildings predominantly use gas boilers as their main heating system, while around 60% have a more efficient condensing boiler installed.

In our lowest cost path to meet the fifth carbon budget, we expect only a limited uptake of heat pumps on the gas grid by 2030 as heat pumps are generally not cost-effective displacing low-cost gas heating to 2030, even when including a carbon price (Box A2.2). This section therefore focuses mainly on the potential of on-gas homes with respect to heat networks connection and energy efficiency potential.

In relation to energy efficiency, there is technical, and often cost-effective, potential in areas like cavity wall insulation and loft insulation top-ups (Table A2.1). Whilst the majority of solid wall homes do not have insulation in place, there are areas where it could be cost-effective or could help tackle fuel poverty:

- Around 4.7 million on-gas cavity wall homes have technical potential for cavity wall insulation (around 3.6 million in easy-to-treat and 1.1 million in hard-to treat homes).
- 6.4 million on-gas solid wall homes could have either internal or external insulation installed. Although solid wall insulation is relatively costly, it will be needed to prepare for the 2050 target and to reduce fuel poverty.

We commissioned Element Energy to undertake a detailed analysis of the cost-effective potential of low-carbon heat networks in the UK by 2050.[14] Based on the detailed modelling, we consider around 3 million on-gas homes, generally in areas of high heat demand density, to be technically suitable for heat networks. This is equal to around 50% of all dwellings on gas in

[14] Element Energy (2015) *Research on district heating and local approaches to heat decarbonisation.* Available at https://www.theccc.org.uk/publication/element-energy-for-ccc-research-on-district-heating-and-local-approaches-to-heat-decarbonisation/

dense urban areas. In our cost-effective path to meeting the fifth carbon budget, around 1.3 million additional on-gas homes could be connected to low-carbon heat networks by 2030.

Figure A2.5 summarises the existing buildings in terms of associated heating emissions, technical suitability to different low-carbon options and the size of cost-effective abatement by 2030.

Figure A2.5. Cost-effective abatement and suitable stock for existing residential buildings to 2030

Emissions and 5CB central scenario uptake	***Suitability***

Heat in existing residential buildings

27 million homes

64 $MtCO_2e$ direct emissions

10 $MtCO_2e$ indirect emissions

13 $MtCO_2e$ of direct abatement in 2030 (including bioenergy)

On-gas homes

85% of buildings

86% of direct emissions

23% of indirect emissions

7 $MtCO_2e$ of mainly cost-effective direct abatement: 1.3m homes on heat networks, additional 2.5 m homes with loft top-ups, 2.3m with CWI and 1m homes with SWI

- **Heat networks**
  ~3m homes suitable
- **Energy efficiency measures**
  4.7m to CWI and 6.4m to SWI

Off-gas homes

15% of buildings

14% of direct emissions

77% of indirect emissions

6 $MtCO_2e$ of cost-effective abatement with 1.2m heat pumps and 0.1m homes on heat networks as well as further 0.7m of SWI homes, 0.5m of CWI homes and 0.5m loft top-ups by 2030

- **Suitable for heat pumps**
  Owner occupied: 1.0m
  Private-rented sector: 0.2m
  Social housing: 0.3m
- **Needs CWI to be suitable for heat pumps**
  Owner occupied: 0.4m
  Private-rented sector: 0.2m
  Social housing: 0.1m
- **Needs SWI to be suitable for heat pumps**
  Owner occupied: 0.5m
  Private-rented sector: 0.2m
  Social housing: <0.1m
- **Heat networks**
  ~0.5m suitable

Source: CCC analysis.
Notes: CWI = cavity wall insulation, SWI = solid wall insulation. Direct emissions come from burning fossil fuels, indirect are emissions from production of electricity distributed through the national grid. Estimates of heat pump suitability are subject to any other improvements needed to the building fabric (beyond wall insulation) and heating systems.

2.3 New-build and demolitions

Under current projections, we expect more than 4 million new-build homes by 2030 and 8 million by 2050 with resulting emissions from heating under existing standards:

- The average annual rate of new build is expected to be in the range of 150,000 to 350,000 homes a year between now and 2035 and between 150,000 and 200,000 from 2035 to 2050.[15] This compares to a rate of between 120,000 and 210,000 homes a year in the period 2000 to 2011 in England.[16]
- This would result in more than 50 $MtCO_2e$ of direct emissions from heating between 2016 and 2030 (or 3.5 $MtCO_2e$ per year on average) under the current standards which do not preclude new gas boilers.
- Demolition rates have been steadily decreasing. Nevertheless, there were only around 11,000 dwelling demolitions in England in 2014-15 representing 0.05% of the total residential stock.[17]

It is more straightforward and cost-effective to introduce energy efficiency and low-carbon heating in new homes rather than retrofit. While the energy efficiency standards for new homes have increased substantially over the recent years, low-carbon heating sources are not required in new homes.

2.4 Other analytics on heating

Successful policy interventions need to take into account socio-economic factors that determine the decision-making around heating system installation and replacement. These range from the typical lifetime of heating systems to frequency of home improvements or typical length of residency:

- Typical replacement rates for gas and off-gas boilers as well as storage heaters are between 10 to 15 years. We assume slightly longer lifetime of between 15 to 20 years for heat pumps.
- Almost 50% of all residents typically live in their homes for more than 10 years. In particular, more than 60% of owner occupiers stay for more than 10 years, compared to around 45% of social renters and only 8% of private renters.[18]
- Home improvement planning applications have been increasing since 2008, reaching more than 400,000 applications in 2015. These are heavily weighted to London and southern regions of the UK. For example, almost 100,000 applications were submitted in London only, a rise of almost 50% since 2012.[19]

Homeowners undertaking major renovations are likely to be an area where energy efficiency measures could be more effectively targeted:

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[15] This is based on government household projections and ONS population projections.
[16] DCLG, table 118 Annual net additional dwellings.
[17] DCLG (2015) *Live tables on net supply of housing*. Available at: https://www.gov.uk/government/statistical-data-sets/live-tables-on-net-supply-of-housing
[18] DCLG dataset:*Length of residence of household reference person by tenure, 2013-14*
[19] Barbour ABI (2016) *Home improvers of Great Britain 2016*.

- Efficiency measures are rarely done alone and are three times more likely as part of amenity renovations.[20] In particular, heating systems and wall insulation measures are most likely to be done together with amenity measures.
- The most important features of attractive efficiency and amenity renovations for homeowners are lower upfront cost, reliable contractors, less disruption and less hassle.[21]

This suggests that policies requiring long-term financing (e.g. purchase loans or annual payments) are likely to be most effective for the owner-occupied segment, where there is potential to sell energy efficiency and low-carbon heating as a part of home improvement rather than as low cost energy.

More generally, there is evidence that households typically do not think about heating, associated emissions, or what heating system they use, as long as it is delivering the expected level of comfort and it is considered financially affordable:

- Approximately a third of households are not interested in heat at all, with a further third wanting to engage with heating their homes but lacking the ability to do so effectively, and the remaining third being more effective consumers. Of those interested, around half focuses on comfort levels while the other half is mainly concerned about the cost.[22]
- Most commonly raised criteria for heating systems are the size of fuel bills, effectiveness of the heating system to heat the whole home to the comfort temperature level, ability to provide hot water on demand, and the ease with which the system can be operated.
- Heating system replacements are most often prompted by the existing heating system breaking down (30%). Non-emergency situations are also common, either because the heating system would stop working soon (14%), needed too many repairs (14%) or as part of renovation (13%).
- When replacing the heating system, many homeowners prefer to choose a more recent model of their current system without considering alternatives and with low awareness of low-carbon heat options. Typically advice will be obtained from either a boiler serviceman (42%), friends with technical knowledge (24%) or their energy supplier or a builder (14% each).[23]

Based on users' satisfaction with current heating systems, low-carbon heating is more likely to be accepted in off-gas homes rather than on-gas homes:

- Off-gas grid homeowners tend to be less satisfied with their heating system than people with gas heating. In particular, homeowners in urban areas and using electric heating systems are less satisfied with the service provided on the basis that it is hard to regulate with high running costs. In rural off gas grid properties (i.e. mainly using LPG or oil as the main heating fuel), there seems to be relatively higher level of satisfaction with their current system although some users regard their systems to be more expensive and ineffective compared to gas.[24]

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[20] Amenity renovations are defined as major structural changes to the home beyond refurbishing, redecorating or other minor improvements. Consequently, they may affect the home's energy efficiency.
[21] UKERC (2013) *Understanding Homeowners' Renovation Decisions: Finding of the VERD Project*.
[22] ETI Smart Systems and Heat (2015) *Consumer Challenges for low carbon heat*
[23] Ipsos MORI and Energy Savings Trust for DECC (2013) *Homeowners' willingness to take up more efficient heating systems*.
[24] Ipsos MORI and Energy Savings Trust for DECC (2013).

- Gas heating users are most likely to feel that their heating system meets their needs in terms of being effective, easy to use and allowing flexible hot water demand. Consequently, 90% of on gas grid respondents would choose a gas boiler for future installation.[25]

There is, however, some evidence showing that, if properly carried out, moving from off-gas heating systems to low-carbon options can deliver significant increase in customers' satisfaction:

- Under the Energy Saving Trust heat pump field trials, the majority of interviewed participants were satisfied with space heating supplied by their heat pump and would recommend them because of the efficiency and lower running costs.[26] In addition, users tend to be substantially more satisfied with the controllability of heat pumps compared to storage heaters.[27] More recently, the RHI evaluation showed that the more experience the users had with their new system the more satisfied they tended to be.[28]
- On heat networks, a recent case study showed a substantial change in the level of satisfaction when replacing storage heaters. Specifically, 70% of tenants and 95% of homeowners felt satisfied with their new heating system compared to 27% and 38%, respectively when using the storage heaters. Some householders, however, have been critical of a lack of clear visibility between heat use and cost, indicating the importance of transparent charging structure and a business model adjustable to the needs of the residents.[29]

This evidence shows the importance of socio-economic factors, and consumer needs in particular, in understanding effective means of emissions reduction in residential buildings.

3. Non-residential buildings

There are 1.8 million non-residential buildings in the UK. The non-residential sector covers a wide range of building types from offices to supermarkets, hospitals, restaurants and industrial factories.

Out of the total 22 $MtCO_2e$[30] of direct emissions in the non-residential sector, we identified a potential for mainly cost-effective emission reduction of 10 $MtCO_2e$ by 2030 in our fifth carbon budget advice, split by energy efficiency and low-carbon heat options such as heat networks, heat pumps and biomass boilers (Table A2.2).

Given the diverse range of building structures and purposes in the non-residential sector, there is less understanding of the use of energy for heating, and the suitability of energy efficiency and low-carbon heat alternatives compared to residential buildings. However, there is new data that is emerging through the Building Energy Efficiency Survey (BEES) about the use of energy within non-residential buildings (Box A2.3).

This section is focused on energy used in the buildings, and specifically the energy used for heating within a building. Low and high temperature process heat used to produce industrial goods is not considered here. However, the energy used for these processes and potential

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[25] Ipsos MORI and Energy Savings Trust for DECC (2013) *Homeowners' willingness to take up more efficient heating systems*.
[26] Energy Saving Trust (2013) *The heat is on: Heat pump field trials - Phase 2*
[27] National Energy Action (2014) *Heat pump trials in a range of Bedfordshire off-gas properties*
[28] DECC (2016) *Census of Owner-Occupier applicants to the Domestic RHI: Waves 1 to 12*
[29] SSE (2016) *Reducing costs, improving comfort and lowering carbon emissions.* The SSE case study is based on *Heat and the City* research available at http://www.heatandthecity.org.uk/resources/documents/wyndford_estate
[30] 2015 estimate from CCC (2016) *2016 Progress report to Parliament*, available at: www.theccc.org.uk

abatement in eight of the most heat intensive industrial sectors were considered fully in the BEIS commissioned *Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050* and our advice on the fifth carbon budget.[31]

Table A2.2. 5th carbon budget - non-residential central scenario to 2030

Measure	Uptake (TWh)	Direct abatement ($MtCO_2e$)	Electricity savings (TWh)
Heat pumps	18.5	1	9
Heat networks	27.5	3.5	-1
Biomass boilers	2.5	0.5	2
Energy efficiency	-	5	20.5
Total abatement		**10**	

Source: CCC (2015) *Sectoral scenarios for the fifth carbon budget – Technical report*, available at www.theccc.org.uk.
Notes: There are around 0.1 $MtCO_2e$ additional emissions from methane and N_2O in 2030. Numbers are rounded to the nearest half unit.

3.1 Energy use in non-residential buildings

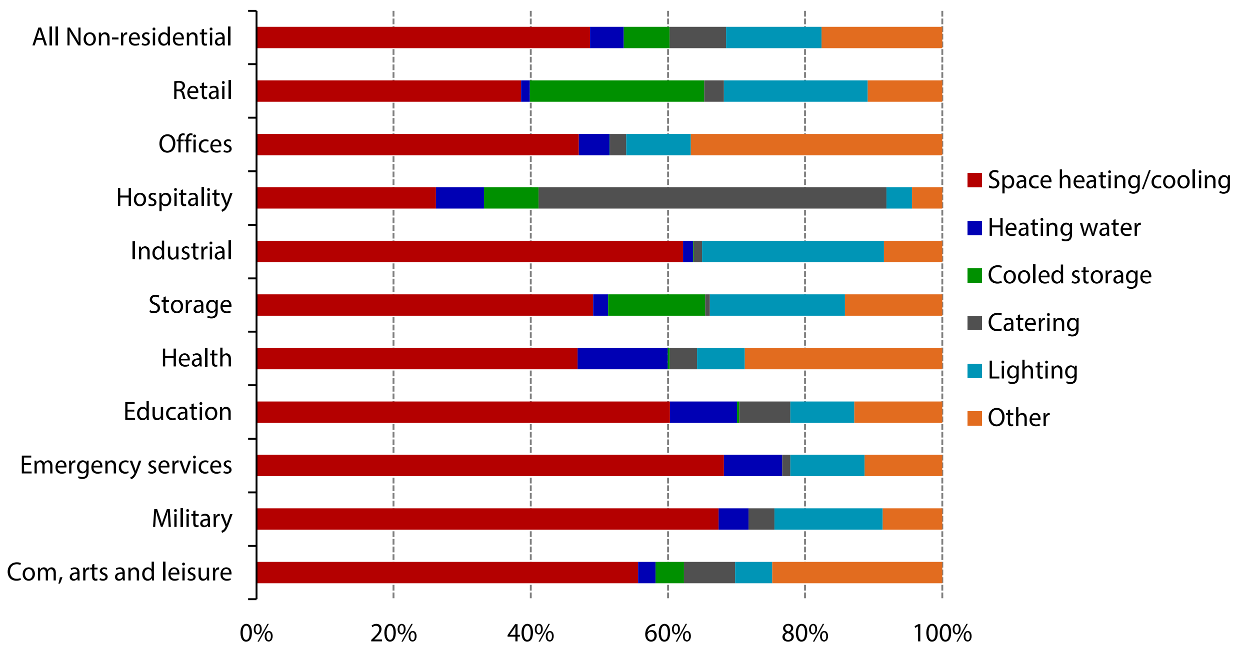
Energy used in non-residential buildings is mainly for some form of heating or cooling of the premises. Most of the energy used for heating/cooling uses natural gas, implying in most cases access to the national gas grid.

- Around half of non-residential building energy consumption is for some form of heating/cooling (Figure A2.6).
- Around half of energy consumption for space heating occurs in the commercial sector with the rest in the public and industrial sectors (Figure A2.7a).
- Regardless of the sector, space heating is the dominant use of energy for heating purposes. Two thirds of space heating uses natural gas, suggesting that the other third may not be connected to the gas grid. Natural gas is also the main energy source for heating water and catering (Figure A2.7b).

In our cost-effective path to meet the fifth carbon budget, by 2030 all off-gas heating sales are replaced by heat pumps. The higher cost of heat pumps replacing gas boilers mean that gas boiler sales are displaced from 2029 in public buildings and 2030 in commercial properties.

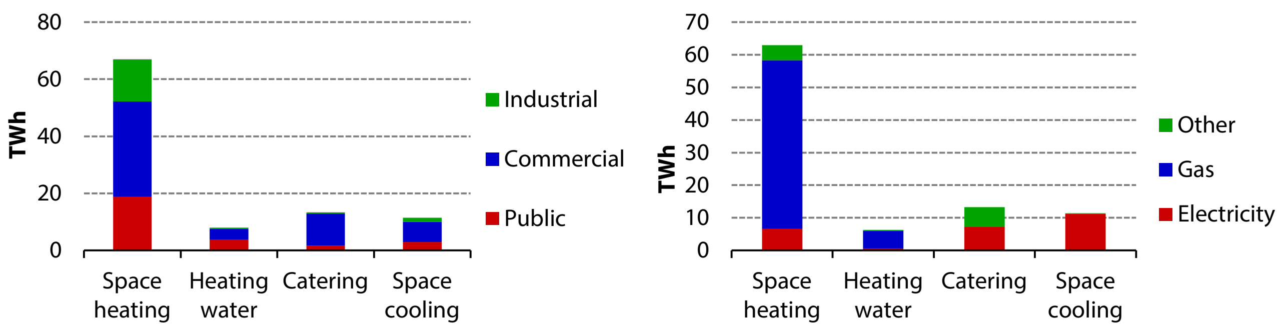
[31] BEIS (2015) *Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050*, available at www.gov.uk, and CCC (2015), *The fifth carbon budget – The next step towards a low-carbon economy,* available at www.theccc.org.uk.

Figure A2.6. Non-residential building energy consumption by purpose used



Source: BEIS Building Energy Efficiency Survey 2014-15.
Notes: 'Space heating/cooling' includes space heating, cooling, humidification and fans. 'Other' includes ICT equipment, small power and other. Com = community.

Figure A2.7(a/b). Non-residential building heating /cooling energy consumption by sector and energy source



Source: BEIS Building Energy Efficiency Survey 2014-15.
Notes: 'Other' includes solid fossil fuel and bioenergy. 'Space cooling' includes cooling, humidification and fans.

Box A2.3. Building Energy Efficiency Survey (BEES)

The Building Energy Efficiency Survey (BEES) was set up by BEIS to improve and update the evidence of how energy is used, and an assessment of the abatement opportunities for all non-residential premises across England and Wales.

This project was led by Verco, working in partnership with GfK NOP, who collected data on non-residential buildings and energy use through 3,690 telephone surveys and 214 site surveys during 2014-2015.

The non-residential building stock is split into ten sectors and 38 sub-sectors, each of which were analysed separately. The survey covered energy use of over 90% of the floor area of non-residential buildings across these sectors. The main exclusions from the scope of BEES were industrial process uses within industrial premises and premises which were dedicated data centres.

The results provide a snapshot in time of the use of energy and heat within the non-residential sector, and characteristics of the organisations and buildings, which is valuable in understanding energy consumption today, and gives indications on abatement potential.

Source: BEIS Building Energy Efficiency Survey 2014-15.

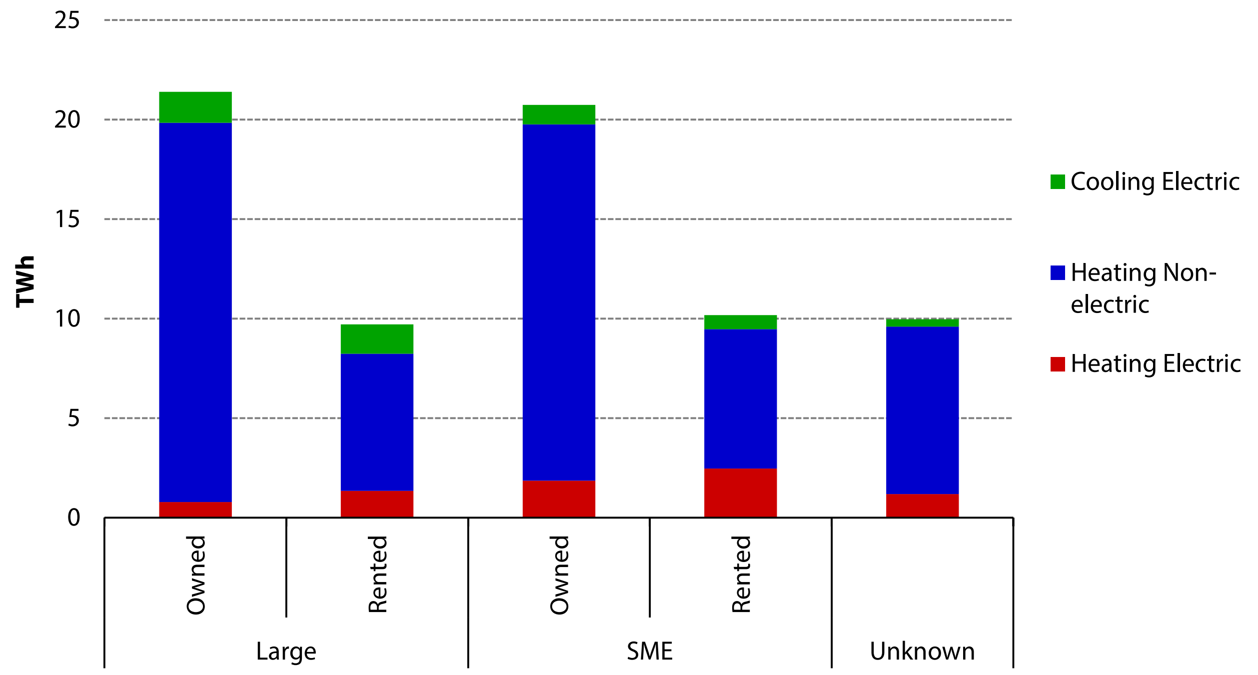
3.2 Organisation and building ownership

Low-carbon heat and energy efficiency uptake will be affected by the size of the organisation (small and medium-sized enterprises, SMEs, may face additional capital constraints), and tenure of the building (tenant organisations have limited control over improvements to the building):

- The BEES data suggests that a little over half of energy consumption for heating/cooling is used by SMEs (Figure A2.8). A number of policies are aimed at incentivising energy efficiency in large organisations (EU Emission Trading System, Climate Change Agreements, CRC Scheme), whereas, especially in England there are relatively few policies focused on SMEs.
- Two thirds of heating/cooling energy consumption is in buildings that are owned by the resident organisation. This leaves a third in buildings rented to non-residential tenants, where policy will need to be directed at landlords to make material differences to the buildings.

Given the greater barriers incentivising uptake of low-carbon heat and energy efficiency in rented buildings and the lack of policy to focus on SMEs, there is a real gap in the policy framework for cost-effective uptake in the non-residential building sector.

Figure A2.8. Non-residential building heating/cooling energy consumption by organisation size and building tenure



Source: BEIS Building Energy Efficiency Survey 2014-15.
Notes: 'Cooling' includes cooling, humidification and fans.

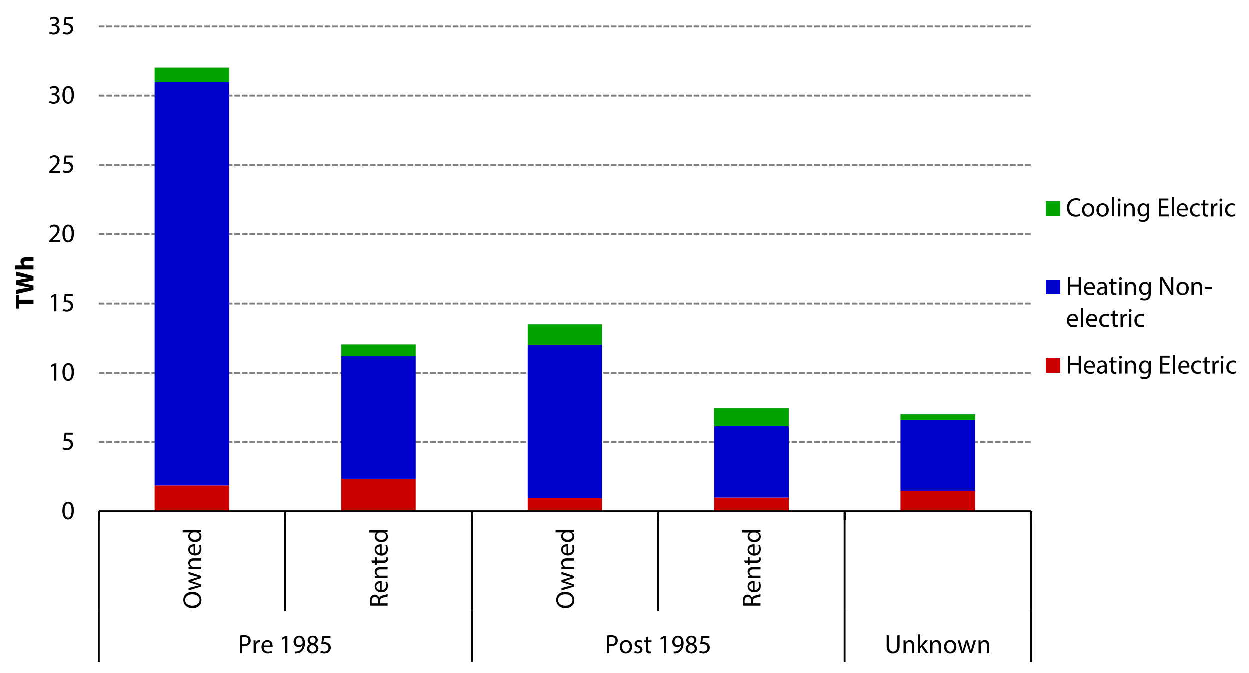
3.3 Building characteristics

Potential for uptake low-carbon options is affected by the characteristics of buildings - for instance age and therefore energy efficiency building standards, and the existence of mechanical ventilation which indicates suitability for centralised heat pump systems:

- The Building Act 1984 brought 'part L' regulations (conservation of fuel and power) to new building standards. Almost two thirds of heating/cooling energy consumption is in pre-1985 buildings, and these are mainly owned by their resident organisation (Figure A2.9). Private Sector Regulations provide an opportunity to improve the rented building stock as tenancies change; however, owner-occupiers will need incentives to upgrade their building stock.
- Projections suggest that 40% of commercial floor space will be air-conditioned by 2020, in comparison to only 10% in 1994.[32] Evidence from BEES show how larger organisations are more likely to have a central ventilation system and mechanical cooling system across a larger proportion of their floor space, suggesting greater suitability for centralised heat pump installations (Figure A2.10 and Figure A2.11).

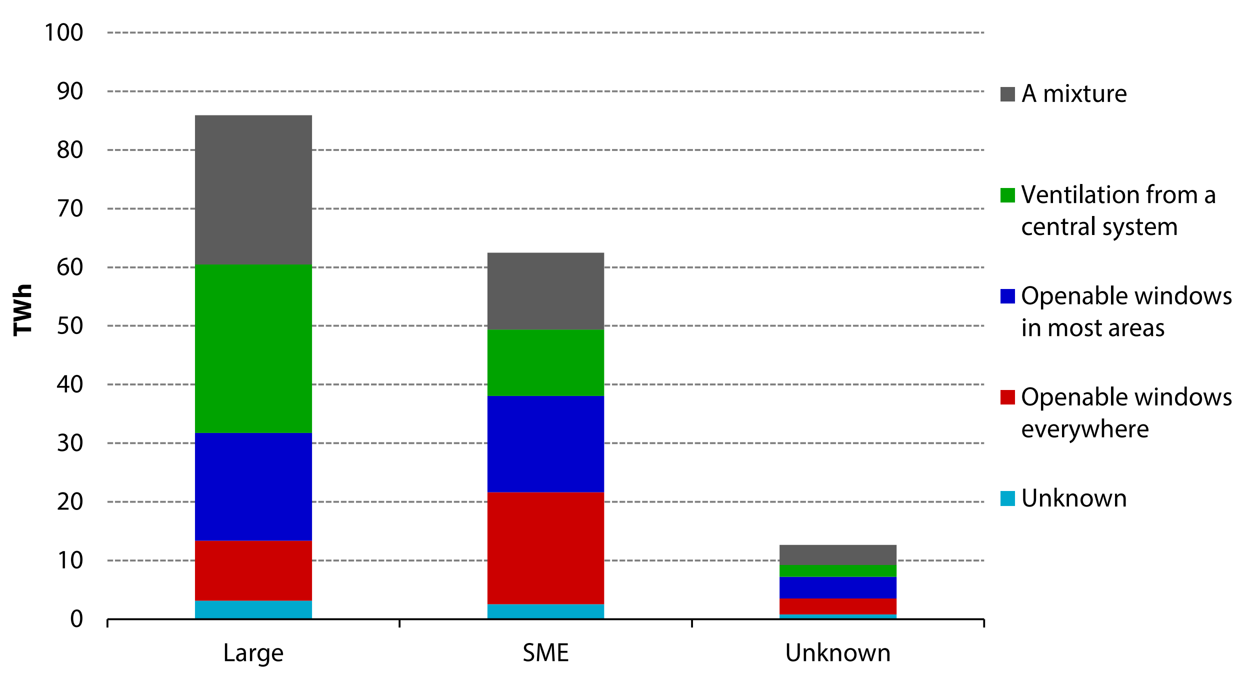
[32] BEIS (2013) *'The Future of Heating: Meeting the challenge'*, available at www.gov.uk.

Figure A2.9. Non-residential building heating/cooling energy consumption by tenure and age of building



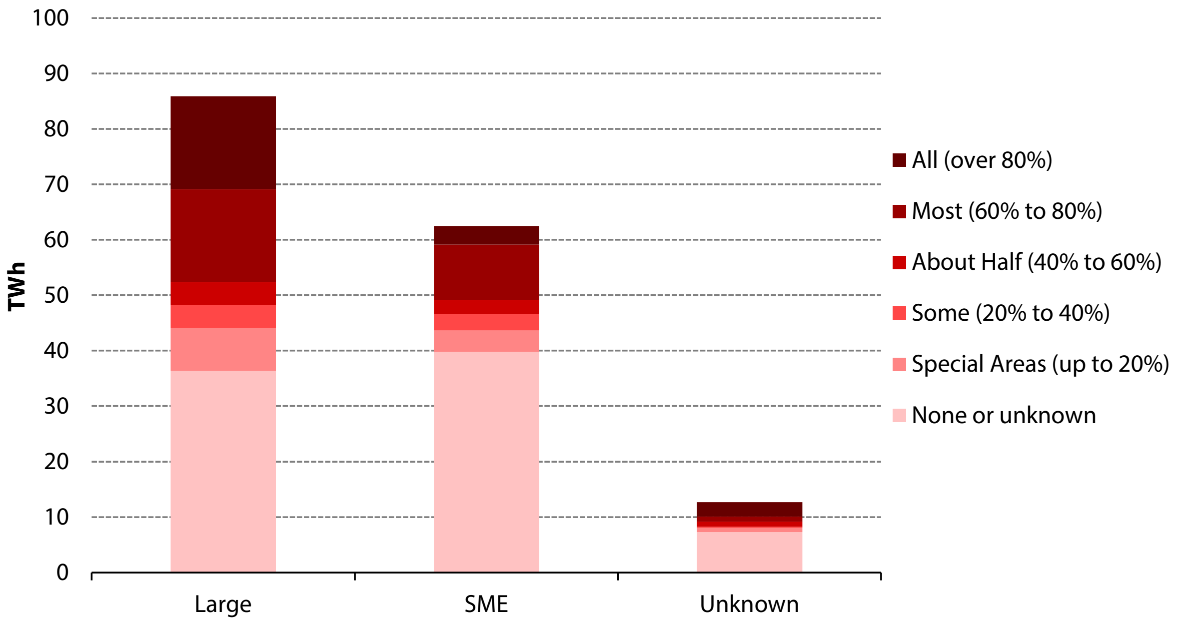
Source: BEIS Building Energy Efficiency Survey 2014-15.
Notes: 'Cooling' includes cooling, humidification and fans.

Figure A2.10. Non-residential building energy consumption by type of ventilation in building



Source: BEIS Building Energy Efficiency Survey 2014-15.

Figure A2.11. Non-residential building energy consumption by % of floor space with mechanical cooling



Source: BEIS Building Energy Efficiency Survey 2014-15.

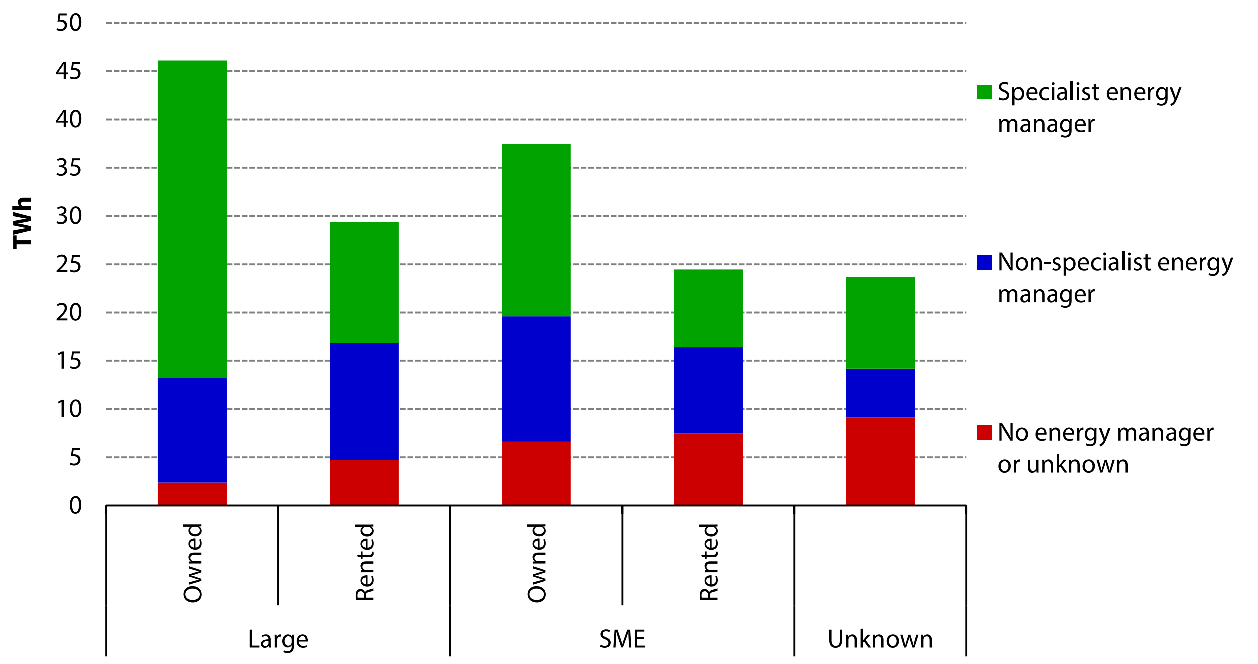
3.4 Building management and comfort

Organisations with a specified energy manager or policy which actively seeks reductions in energy consumption are likely to give salience to potential opportunities.

- Half of energy consumed in non-residential buildings is within organisations that have a specialist energy manager, but a fifth do not have anyone actively managing energy consumption or do not know if there is one. A greater proportion of owner-occupied buildings have specialist energy managers than tenanted ones, and similarly larger organisations are more likely to have a specialist manager (Figure A2.12).
- Over half of energy consumed in non-residential buildings is in organisations that are actively pursuing new ways to manage energy. However, this is more likely for larger organisations (around 70% of energy is associated with active energy policy), than in SMEs where it is not seen as a priority (Figure A2.13). Almost half of energy consumed is thought to be managed well or very well (Figure A2.14a).
- Around half of non-residential building energy consumption is in premises where the temperature for workers is not optimal through the year. This highlights the additional potential wider benefit of comfort from investment or better management of heat systems or energy efficiency in buildings (Figure A2.14b).

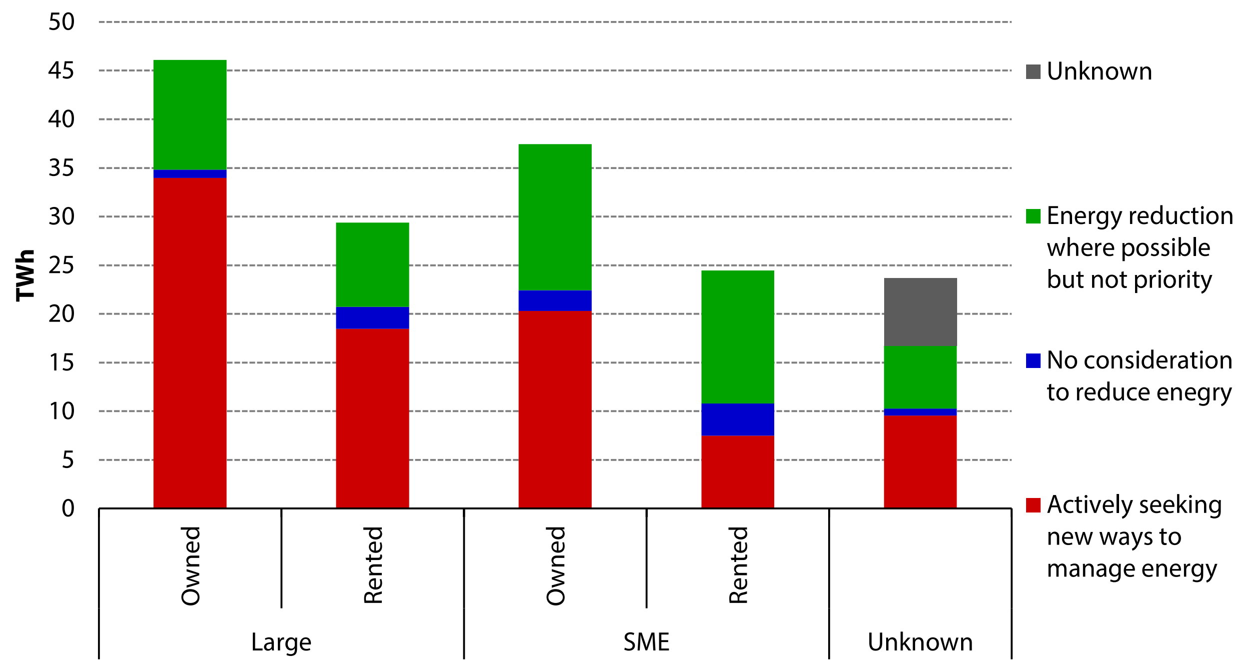
Raising the profile of heat and general energy management is key for improvement opportunities to be salient in organisation decision making. There will be challenges in targeting organisations where there is no energy manager or where energy reduction is not seen as a priority.

Figure A2.12. Non-residential building energy consumption by organisational energy manager personnel



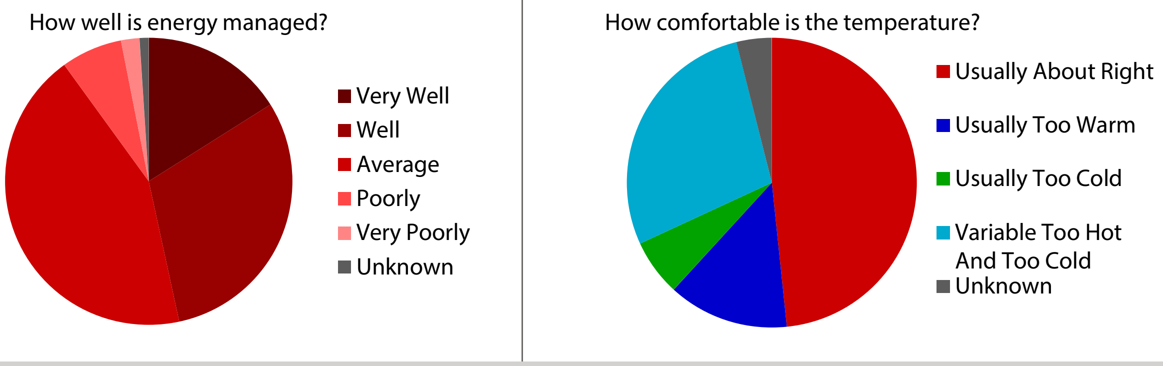
Source: BEIS Building Energy Efficiency Survey 2014-15.

Figure A2.13. Non-residential building energy use by organisational energy management policy



Source: BEIS Building Energy Efficiency Survey 2014-15.

Figure A2.14(a/b). Non-residential building energy consumption by organisational energy management and temperature comfort



Source: BEIS Building Energy Efficiency Survey 2014-15.

4. Current policy and gaps

Responsibility for heat decarbonisation policy is shared between the UK Government and Devolved Administrations, creating a patchwork of incentives and policy. Whilst the Renewable Heat Incentive, the main subsidy scheme, is available GB-wide (and replicated in Northern Ireland), heat policy is otherwise largely devolved to the Scottish Government, and partly devolved to the Welsh and Northern Irish Assemblies:

- The Scottish Government set out plans and targets for energy efficiency and heat decarbonisation along with a set of policies in RPP2. There are a number of funding schemes available for both residential and non-residential buildings. More recently the Scottish Government has published a Heat Policy Statement which sets out its approach to working towards decarbonising the heat system and which has designated energy efficiency as a National Infrastructure Priority. The Scottish Government have set separate buildings regulations, whilst the Heat Networks Partnership and Scottish Heat Map provide support to local authorities.
- The Welsh Assembly has oversight over energy efficiency spending, though not of other areas such as heat networks policy. The decarbonisation agenda is being taken forward under the Well-being of Future Generations Act, which takes a holistic view of development needs across sustainability, poverty alleviation, equal opportunities and diversity, and the Environment Act, which requires the setting of emission reduction targets and development of plans to meet these.
- In Northern Ireland, the NIRHI is the subsidy scheme for heat. It has now closed to new applications due to budgets being exhausted. There are no other support mechanisms available.

This variation in terms of policy coverage and approaches provides opportunities for trialling different approaches and for knowledge-sharing, but runs the risk of mixed outcomes, particularly where there are major policy gaps.

The direction for heat policy has been set out at a UK-level by DECC in the 2013 Heat Strategy, which followed on from the 2012 Strategic Framework for low carbon heat. This set out a direction of travel to 2050, with a focus on developing low-carbon heat supply-chains. The strategy is one of supporting heat networks in urban, heat dense areas, together with heat pumps and biomass in buildings not connected to the gas grid. The 2013 strategy also set out a role for gas transitional technologies such as gas heat pumps and hybrid heat pumps (combining an electric heat pump with a small top-up gas boiler) through the 2020s and 2030s, based on evidence of the system benefits for managing electricity peak loads, and possible consumer preferences for systems which more closely resemble gas boilers:

- The DECC 2013 Heat Strategy is useful in its framing of the problem and in identifying the policy and research priorities.
    - It led to the creation of a specialist Heat Networks Delivery Unit in DECC, which has been supporting Local Authorities to develop feasibility studies with £14m funding spent in the first six funding rounds. In its most recent incarnation as the Heat Networks Implementation Partnership, it is overseeing £320 million of capital funding for low-carbon heat networks over the next five years, with the aims of establishing a self-sustaining market. They have also worked with industry to develop technical standards and launch the Heat Trust in response to the gap on consumer protection.
    - It set the direction of travel for heat-intensive industry decarbonisation with the £1m industrial roadmaps work.
    - It set in train a range of analytical programmes, including on the role of hydrogen for heat, on non-residential buildings energy use, together with whole system modelling and funding for advanced heat storage demonstrators.
- Areas for further work include further linking up of energy efficiency and heat policy in order to maximise decision-making opportunities, together with more detailed policy approaches to support heat pump supply-chains, support SMEs and develop a long-term process for decarbonising the building stock.

The direction for UK energy efficiency was set out by DECC in the Energy Efficiency Strategy (2013). Residential energy efficiency improvements were to be delivered through the Energy Company Obligation (ECO), the Green Deal, the roll out of smart meters and product standards:

- Supplier obligations have been the main mechanism for improving residential energy efficiency with a series of obligations in place since 1994. The scale of obligations grew through to CERT/CESP which were in place from 2008-12 and are widely seen as a good example of delivering energy efficiency. ECO has shown reduced performance with annual rates of cavity wall and loft insulation in 2013-2015 down 60% and 90% respectively on annual rates in 2008-2012.
- From April 2017 ECO will transition to a new lower cost supplier obligation set to run for 5 years. This will be increasingly focused towards delivering efficiency improvements to fuel poor households, with limits on how far boiler replacements can contribute and a declining (and perhaps non-existent from 2018) role for low-cost abatement in non-fuel poor homes. The smaller scale of the obligation and its refocusing from carbon reduction towards fuel poverty means the energy efficiency savings delivered under the obligation are likely to continue to decline.
- The Green Deal failed to generate sufficient demand from households and its funding was stopped in July 2015 amid concerns over industry standards and value for money.

This leaves a significant gap in policy to encourage energy efficiency improvements in households that are not fuel poor. This also undermines the private-rented sector regulations which set a minimum standard of energy efficiency for rental properties, but is now without a delivery mechanism.

Building regulations set out minimum standards for construction including heat loss, ventilation and air tightness. Since 2006, there has been a progressive tightening of energy efficiency standards for new buildings, although this has stalled since 2013 with the Government rolling back on 2016 Zero Carbon standards.

Commercial and public buildings policies have developed overtime, with the Government experimenting with a range of taxes, trading schemes and voluntary agreements.

- Buildings which are part of large energy using sites (such as some factories) or with energy centres above 20 MW (including [some hospitals]) fall under the EU Emissions Trading System, and pay a carbon price.
- The 2008 Climate Change Act allowed for the introduction of trading schemes. The CRC Energy Efficiency Scheme was established in 2011 as part of this framework, capturing energy-consuming buildings and organisations below the EU ETS threshold but above a 6 GWh/yr threshold (roughly equivalent to a £500,000 energy bill). Simplifications to the scheme removed the trading and performance league table elements, leaving in place the carbon pricing, now equivalent to a carbon tax (and arguably just duplicating the existing Climate Change Levy energy taxes). In 2016, the Government announced that from 2018 the CRC scheme will be replaced by an increased level of CCL.
- Energy audits are required for all organisations above 250 employees, but only once every four years, and with no reporting requirement. Government is currently putting together proposals for strengthening the scheme, to replace the reporting elements under the CRC.
- The only bespoke policy for the UK public sector is the low-cost Salix finance for energy efficiency projects. It is otherwise covered by thin patchwork of sectoral schemes and finance which vary in terms strength and effectiveness.
- There are no UK-wide programmes in place to support SMEs, in contrast to countries such as Germany, where small businesses receive support from the central KfW bank for energy efficiency projects. Resource Efficient Scotland provides a model of business support combined with soft loans, which could be replicated if the evidence supports it.

Overall, progress in buildings has been patchy since 2012 - small incremental improvements, where they have been made, do not constitute a coherent plan for meeting carbon budgets.

In the 2016 Progress Report, we highlighted the need for a more comprehensive approach which addresses the behavioural barriers for different segments (i.e. new-build, private and social landlords, owner-occupiers, households and businesses) in a way that is attractive enough to deliver sustained uptake of energy efficiency, heat pumps and district heating at levels far above today's.

The following Progress Report recommendations look ahead to the Government's Emissions Reduction Plan (Table A2.4). They are the starting point for this report.

Table A2.3. Buildings recommendations for the Government's emission reduction plan		
Buildings emissions to fall by around 22% between 2015 and 2030, and create options to allow near-zero emissions by 2050. This will require:	**New policy**	**Stronger implementation**
Clear, consistent and credible policies to drive deployment of heat pumps and district heating, including: • Immediate action to address the upfront cost and information barriers that exist with the Renewable Heat Incentive. • A policy package for sustained low-carbon heat roll-out at higher rates, tackling key segments, addressing barriers and linking support with energy efficiency policy, fuel poverty policy and infrastructure decisions. This must make low-carbon heating visible, cost-competitive and attractive in a timely manner for households. • New policies to support SMEs in England to install cost-effective low-carbon heating.	✗	
Standards to ensure new-build properties are highly energy efficient and use low-carbon heating systems by default. On energy efficiency these should result in new buildings having low energy consumption without leading to overheating.	✗	
A stronger policy framework to drive residential energy efficiency improvement by addressing gaps and strengthening existing policies, including: • A comprehensive set of incentives to drive energy efficiency improvements in able-to-pay households. The policy package should address behavioural factors as well as financial barriers and provide a clear long-term signal to the supply chain. • Strong policy, backed by increased funding, to improve energy efficiency in fuel-poor households, contributing to meeting carbon budgets and fuel poverty targets. • Ensure the private-rented sector regulations are amended or have a new mechanism, in the absence of the Green Deal, to deliver required improvements in efficiency.	✗	✗
More progress on improving the energy efficiency of non-residential buildings: • A consolidated reporting mechanism for commercial and public buildings. This must strengthen incentives without increasing administrative burden. • New emissions reduction targets in place for Central Government and additional support for the public estate, for example, through targets and information. • New policies to support SMEs in England to install cost-effective energy efficiency measures.	✗	✗

Table A2.3. Buildings recommendations for the Government's emission reduction plan		
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Notes: The emissions reduction to 2030 is based on temperature-adjusted emissions in 2015.		