Chapter 3: Reducing emissions from buildings

Introduction and key messages

In 2012, direct buildings emissions (mainly from the use of gas for heating) accounted for 37% of UK greenhouse gas emissions (91 $MtCO_2$). Buildings also were responsible for 67% of electricity consumption and related (i.e. indirect) emissions.

In our 2010 advice on the fourth carbon budget, we suggested that the cost-effective path to the 2050 target involved direct emission reductions in buildings of 36% by 2025 and 53% by 2030 from 2007 levels. Measures to achieve these reductions included increased home insulation (in particular solid wall insulation), widespread deployment of heat pumps in both residential and non-residential sectors, as well as bioenergy and district heating from low-carbon sources. In addition, we identified significant potential for reducing electricity consumption (and hence indirect emissions) through more efficient appliances and lighting. Most of these measures were cost-effective compared to our carbon price assumptions, with some less immediately cost-effective measures required to prepare for meeting the statutory 2050 target.

In this chapter, we set out new evidence on buildings emissions and abatement options. We then update our assessment of what is feasible and desirable over the next two decades. Changes in the evidence base include: new data on the performance of insulation measures, revised estimates of uptake of a range of energy efficiency measures, new research on barriers to heat pump uptake, new evidence on the feasibility of district heating, as well as updated emissions projections from DECC.

Our updated analysis suggests a lower emissions reduction on the cost-effective path than our 2010 advice (28% by 2025 and 35% by 2030).

- Carbon savings from some home energy efficiency options, in particular insulation measures are lower than we previously assumed, reflecting new evidence on energy use in homes and energy performance of solid walls. Overall, we have revised down the annual direct emissions abatement from residential energy efficiency in our cost-effective path by 22% to around 7 $MtCO_2$ in 2030.
- There is limited new evidence on abatement potential from non-residential buildings. However, improved approaches to projecting emissions imply lower reductions to 2030 than we previously assumed. Additionally, new EU regulations for improving the efficiency of electric appliances and lighting are expected to deliver a further 3% (4 TWh) electricity savings in non-residential buildings 2030, with some increased direct emissions to replace waste heat output.

- New evidence on the capital costs, performance and durability of heat pumps suggests that they are less cost-effective in the 2020s than we previously assumed. We have therefore revised downwards our estimates of heat pump uptake across buildings, including 3 million fewer heat pumps in homes by 2030 (down from 7 to 4 million). This would reduce abatement from heat pumps from 31 $MtCO_2$ to 14 $MtCO_2$ in 2030.
- We have assumed increased uptake of district heating to 2030, from 2 to 6% of heat demand, reflecting policy developments in DECC and new analysis (including from National Grid). This would imply building up heat networks consistent with the 40% potential for meeting heat demand identified in our 2050 analysis.
- Compared to a path with no progress during the 2020s, the measures in our updated scenario offer a saving of around £30 billion in present value terms under central case assumptions for fossil fuel and carbon prices.

We set out the analysis underpinning these conclusions in five sections:

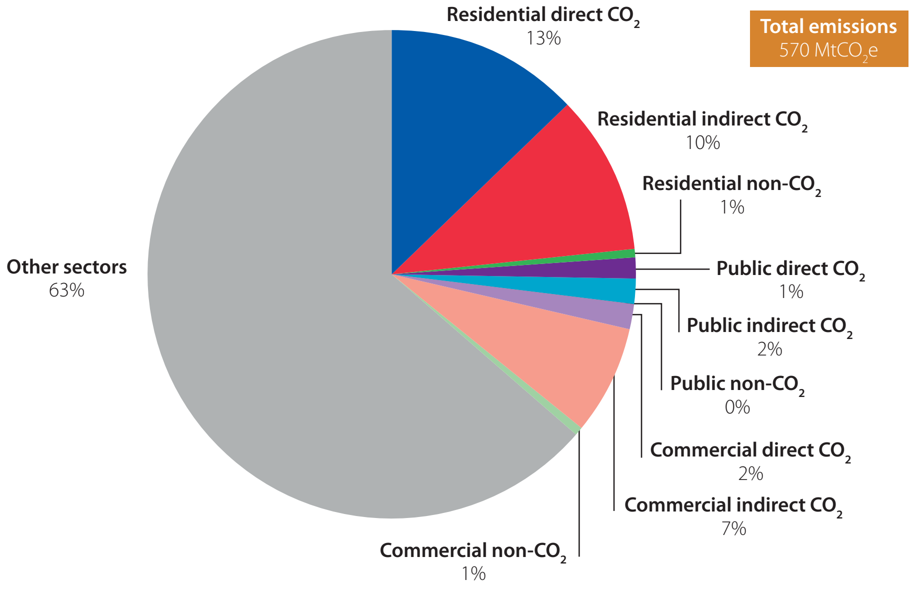
1. Current emissions
2. Projected emissions before abatement action
3. Updated evidence on abatement options and costs
4. Projected emissions with abatement – an updated assessment for the 2020s
5. Benefits of delivering the measures in the fourth carbon budget

1. Current emissions

Overall buildings emissions accounted for 37% of total UK greenhouse gas emissions in 2012 (Figure 3.1). Direct CO_2 emissions from buildings were 91 $MtCO_2$ in 2012. Buildings were also responsible for 67% (212 TWh) of electricity consumption and associated CO_2 emissions (111 $MtCO_2$):

- The residential sector accounted for 66% of overall buildings CO_2 emissions (134 $MtCO_2$), 55% of which were direct emissions (mainly from gas).
- Non-residential emissions from the commercial and public sector accounted for 26% and 8% of buildings emissions respectively. 82% of commercial sector emissions and 57% of public sector emissions were electricity-related.
- Overall buildings CO_2 emissions have fallen by 8% since 2008 but have shown year-to-year fluctuations due to economic and temperature effects.
- Heating (in particular gas) accounted for over 80% of direct buildings emissions.

Figure 3.1: GHG Emissions from buildings in the context of total UK emissions (2012)



Source: NAEI (2013), DECC (2013), Energy Trends, March 2013, DECC (2012) DUKES; CCC calculations.
Notes: 2012 emission estimates are provisional. Commercial sector and non-CO_2 are based on CCC estimates.

There is considerable scope for reducing emissions from the buildings sector through energy efficiency and decarbonising heat. In the residential sector, a large number of energy efficiency measures have been installed since we published the fourth carbon budget in 2010, although there has been a slow-down in 2013 due to policy changes. In the non-residential sector emissions have been fairly flat, with not much sign of significant energy efficiency improvement.

We now consider the latest evidence on projected emissions (section 2) and options to reduce these (section 3), before setting out a new updated assessment of abatement options to 2030 in section 4.

2. Projected emissions before abatement action

The starting point for our new assessment is DECC's updated emissions projections (UEP). The UEP 2013 'baseline scenario' projects emissions to 2030 without the effects of policies that have been implemented since the 2007 Energy White Paper (i.e. pre-first carbon budget). The scenario allows for economic growth, demographics and changing fossil fuel prices. In 2010, we used the DECC model to provide a similar baseline run for our reference projection.

Since our original fourth carbon budget advice, assumptions for key drivers of buildings energy demand have changed (see chapter 1). For residential buildings emissions, demographic assumptions are particularly relevant:

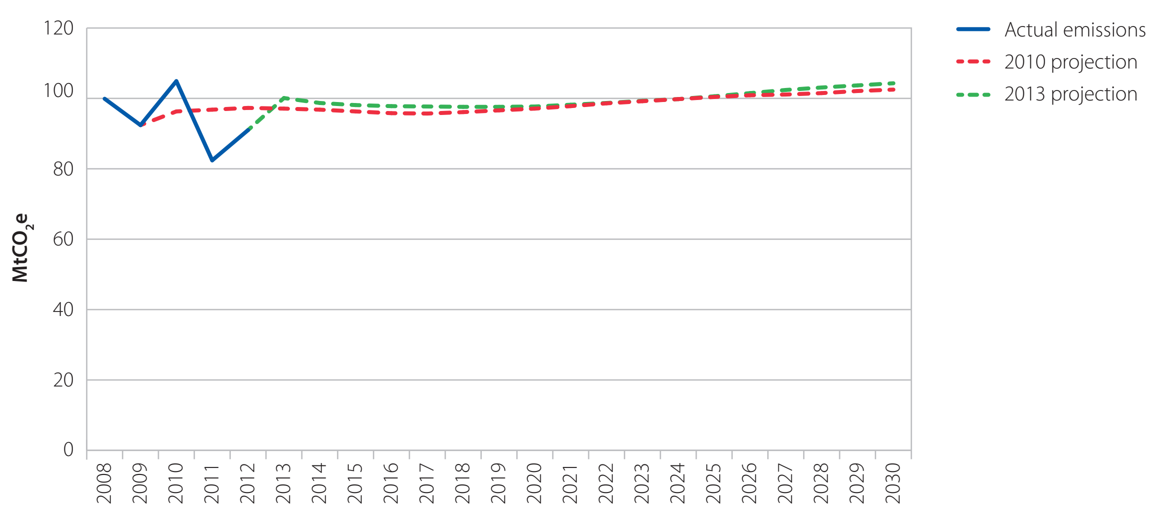
- UEP 2013 uses adjusted population numbers, in line with updated population growth projections. This projects the number of households to increase to 32 million in 2030.
- The size of households is also relevant for emissions – there is a trend towards smaller households which on a per capita basis use more energy.

Direct emissions from the buildings sector in 2030 in UEP 2013 are almost identical to our 2010 reference projection (104 $MtCO_2$ vs 102 $MtCO_2$, Figure 3.2). However, there are some significant changes in the component sub-sectors, as well as to electricity demand (and therefore indirect emissions):

- For residential buildings, baseline emissions are now expected to be almost 13% higher in the fourth carbon budget period compared to our assumption in 2010. The main reason for this higher baseline is a revision in the demand equations for residential gas demand. We have therefore scaled up direct abatement accordingly (Figure 3.3).
- Commercial and public sector emissions are expected to be lower (16 $MtCO_2$ instead of 26 $MtCO_2$ in 2030), primarily reflecting improvements to the estimation of public sector demand equations. In contrast, electricity demand in these sectors is now projected to grow by 31% to 2030, where previously it was forecast to remain flat.

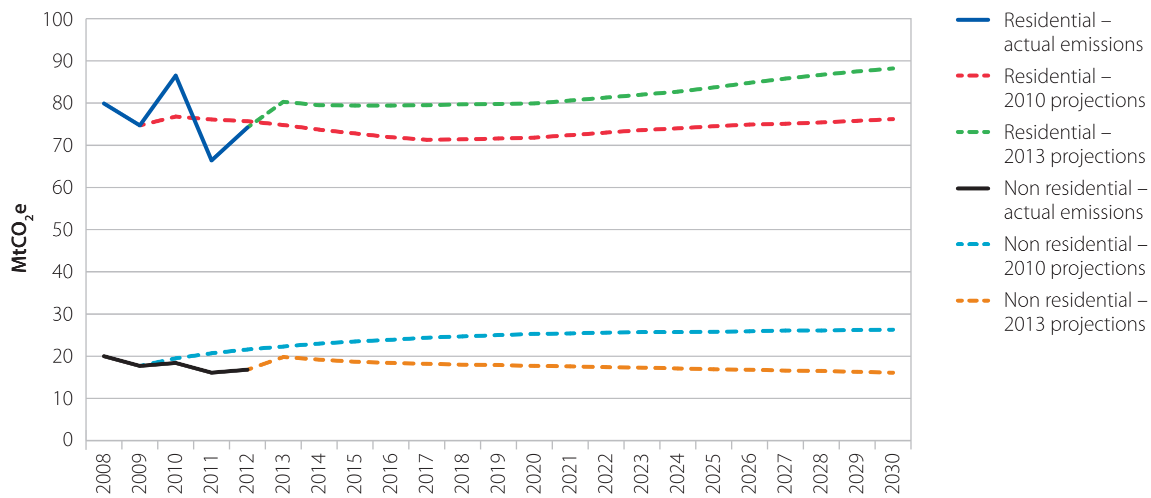
While the new UEP baseline projects an increase in direct buildings emissions of around 10% by 2030 (compared to 2012), policies to which the Government is already committed, as well as further options, will reduce emissions below this level. We now turn to these options.

Figure 3.2: Buildings: baseline projections of direct emissions (2010 and 2013)



Source: DECC (2013).
Notes: Direct emissions only.

Figure 3.3: Residential and non-residential buildings: baseline projections of direct emissions (2010 and 2030)



Source: DECC (2013).
Notes: Direct emissions only.

3. Updated evidence on abatement options and costs

In our advice on the fourth carbon budget (2010), we set out detailed assessments of the options for reducing emissions from buildings. Since then, new evidence on residential energy efficiency measures has allowed us to reassess costs and abatement potential. We have also carried out new analysis on heat pumps and reviewed recent evidence on district heating. For the non-residential sector, the evidence base continues to be less developed, with limited new evidence since 2010.

Residential energy efficiency

Energy efficiency improvements in homes are important for emissions savings and (in the case of building fabric measures) making homes suitable for heat pumps. They also help improve energy affordability and address fuel poverty. Better insulation also offers health benefits associated with warmer homes. Furthermore, electricity efficiency measures reduce the need for additional power capacity. Options include:

- Building fabric insulation measures such as loft insulation, cavity wall insulation and solid wall insulation.
- Other measures to improve heating and hot water energy efficiency such as efficient boilers, heating controls (e.g. room thermostats and thermostatic radiator valves) and hot water cylinder jackets.
- Highly efficient electrical appliances and lighting.
- Behavioural measures such as turning off lights or turning down thermostats.
- Zero carbon new-built homes which are highly energy efficient and meet the remaining heat and electricity needs from renewable sources.

The evidence on abatement potential and costs of energy efficiency measures has continued to develop since our original 2010 advice on the fourth carbon budget (Box 3.1 and Box 3.2). We therefore commissioned Element Energy and the Energy Saving Trust (EST) to review the latest evidence and inform the update of our assessment of the costs and feasibility of measures[1].

Box 3.1: Residential energy efficiency: policy changes and new evidence

The analysis underpinning our recommended carbon budgets to 2027 was undertaken in 2008/09 (for the first three carbon budgets) and 2010 for the fourth carbon budget. Since then there have been significant changes in Government policies, as well as developments in the evidence base for key measures.

Policy changes

In 2010, the Government dropped the target to insulate all lofts and cavities 'where practicable' by 2015. This change has implications for meeting our current indicator trajectories in which we assumed that 10.5m under-insulated lofts and 8m unfilled cavity walls would be insulated between 2008 and 2015.

In addition, in 2013 a major change in energy efficiency policy took place with the introduction of the Green Deal and the Energy Company Obligation (ECO). Initially, this meant the removal of subsidies for easy-to-treat cavity and loft insulation, except for low-income and vulnerable households. DECC's 2012 impact assessment[2] suggested that as a result, only 2.3 million cavity walls would be insulated between 2013 and 2020. This falls far short of the available potential and our indicator trajectories which suggest that 8 million cavity walls should be insulated by 2015.

However, in December 2013, the Government announced some changes to the scheme, including a widening of the carbon obligation of the scheme to fund easy-to-treat cavity walls and lofts. The implications of these changes on future numbers of installations are not yet clear.

New evidence on energy use and energy performance

The National Energy Efficiency Data framework (NEED) was established by DECC to improve the understanding of energy use and energy efficiency in the residential sector. It found that energy use in homes based on actual meter point data and the level of savings from installing energy efficiency measures differed to that predicted by the theoretical BRE Domestic Energy Model (BREDEM) using SAP[3].

Evidence from NEED (e.g. typical savings from cavity wall insulation and condensing boilers are less than predicted) fed into the development of DECC's in-use factors for the purposes of the Green Deal and ECO (Box 3.2).

Further evidence is being collected by DECC that will provide a better understanding of the gap between actual energy use and predicted energy use in the model. These include:

- The English Housing Survey Energy Follow-Up Survey (EFUS, to be published at the end of 2013) will show that the average number of hours that a house is typically heated and the length of the heating season are less than predicted in the model. In addition, the average temperature setting is below the assumed level of 21.3 degrees C for the living room and 20.3 degrees for other rooms. Combined these factors imply that less energy is being used in the average house than had previously been assumed.
- A two year project launched earlier this year by DECC and BRE will look to improve the understanding of heat losses from solid wall properties. Smaller field trials to date have found that the thermal performance of uninsulated solid wall homes, as measured by the u-value, is better than previously assumed. The level of energy savings that can be achieved by installing solid wall insulation is therefore less.

New cavity wall categorisation

Since our 2010 report, DECC has categorised cavity walls as being either easy-to-treat (standard) or hard-to-treat (unconventional). Standard cavity walls tend to be constructed of brick-brick or brick-block with a cavity of more than 50mm wide. This means insulation can be achieved easily and without additional cost. However, hard-to-treat cavity walls are generally more expensive and difficult to fill due to a variety of physical reasons, which can include narrowness of the cavity (e.g. less than 50mm wide), and the frame being made of timber or steel.

Despite having higher costs, the energy saving potential from treating an unconventional cavity wall can be as high as an easy-to-treat wall and therefore insulation is still recommended. The main exception are walls that contain a narrow cavity, where energy savings potential are considered to be low.

1 Frontier Economics and Element Energy (2013) Pathways to high penetration of heat pumps, report prepared for the Committee on Climate Change. Available online http://www.theccc.org.uk/publication/fourth-carbon-budget-review
2 DECC (2012) Final stage impact assessment for the Green Deal and Energy Company Obligation. Can be accessed on www.gov.uk
3 Standard Assessment Procedure (SAP) is used by DECC to assess and compare the energy and environmental performance of dwellings.

Box 3.1: Residential energy efficiency: policy changes and new evidence

New cost data

Our trajectories for insulation measures are based on 2008 data for installation costs. More recent DECC data has higher costs in general and more granularity (e.g. costs for cavity wall are split between easy-to-treat (£376) and hard-to-treat (£1,620), whereas we previously only estimated a single cost for cavity wall insulation of £380 which took no account of the ease of treatment.

The combination of adjusted savings, in-use factors and new cost data has a major impact on the cost-effectiveness of insulation measures (in particular solid wall insulation) which has reduced carbon savings compared to our previous assumptions.

Box 3.2: Reduction ('in-use') factors

Reduction factors were introduced by DECC to bring SAP savings in line with NEED values for a number of measures.

In our previous analysis of energy efficiency measures, we only accounted for a 15% comfort taking reduction factor for the main insulation measures (e.g. solid wall, cavity wall, loft and floor insulation). This took account of evidence at the time that savings were in practice lower than the modelling suggested.

Following a critical evaluation of DECC's in-use factors by Element Energy and the EST, our assessment of the abatement potential for this report incorporates further in-use factors. The in-use factors are split between three elements that contribute to an overall reduction factor per measure (Table B3.1):

- *In-use factor:* accounts for the physical underperformance or systematic difference between the theoretical model of building energy demand and in-situ performance. This factor is applicable to a cross section of measures.
- *Comfort factor:* takes into account the underperformance of a measure which is attributed to the rebound effect, whereby householders for example may decide to increase the temperature in their home following the installation of loft insulation. This factor is applicable to fabric insulation measures only.
- *Inaccessibility:* applicable to solid wall, cavity wall, and loft insulation only. Reduced energy savings reflect the loss of performance by not being able to treat the whole surface area (e.g. architectural features on the façade of a house may prevent the whole wall being externally insulated).

DECC is planning to review the in-use factors each year with the intention of updating the values based on new research and evidence (e.g. heating hours and savings from solid wall insulation).

Table B3.1: In-use factors for main residential energy efficiency measures

Measure	In-use	Comfort	Inaccessibility	Total reduction factor
Solid wall	33%	15%	10%	**49%**
Cavity wall	35%	15%	10%	**50%**
Loft insulation	35%	15%	10%	**50%**
Heating controls	50%	0	0	**50%**
Double glazing	15%	15%	0	**28%**
Floor insulation	15%	15%	0	**28%**
Condensing boiler	25%	0	0	**25%**
Hot water tank insulation	15%	0	0	**15%**

Source: DECC
Notes: As the savings are multiplied by each of the factors, the separate factors do not add up to the total reduction factor. For more information see Element Energy & Energy Saving Trust (2013).

The review concluded that the technical potential to implement measures is similar to the level we previously assumed, but that these measures could be more expensive to install and deliver less emissions reduction than previously expected:

- **Insulation.**
  - *Cavity wall insulation*. We estimate a technical potential of around 4.6 million cavity walls left to insulate that would deliver high carbon savings. This technical potential is split between 1.6 million cavity walls that are categorised as easy-to-treat, and the remaining 2.9 million as hard-to-treat. If all these cavity walls were insulated by 2023, carbon saving in our updated assessment would reach 2.0 $MtCO_2$ by 2030, which is unchanged from our 2010 fourth carbon budget advice.
  - *Loft insulation*. Over 10.3 million easy-to-treat lofts remain to be insulated, which we estimate could deliver annual savings of 0.7 $MtCO_2$ by 2030, down from 1 $MtCO_2$ in our 2010 advice. Over 80% of the savings are derived from insulating lofts that are currently filled to between 50mm-125mm only.
  - *Solid wall insulation:* In our 2010 advice, we assumed a high uptake of solid wall insulation through the 2020s reaching 3.5m by 2030. We assumed this would deliver annual savings of 4.9 $MtCO_2$ by 2030. However, our updated analysis indicates that based on the same level of uptake, annual savings potential would decline to 2.5 $MtCO_2$ by 2030.
- **Other energy efficiency measures.** Our new analysis reinforces our previous assumptions on the level of cost-effective abatement from other energy efficiency measures, after allowing for replacement of waste heat from inefficient electrical appliances. These measures include floor insulation, improved glazing, installation and use of heating controls and some households choosing to turn their thermostats down by one degree (Box 3.3).
- **Zero Carbon Homes:** Since our 2010 report, the Government has decided to limit the definition of Zero Carbon Homes to regulated energy use only (i.e. heating and fixed lighting) and has proposed off-site 'allowable' solutions. Savings potential by 2030 is now 1.1 $MtCO_2$, up from our 2010 estimate of 0.7 $MtCO_2$.

Box 3.3: Summary carbon savings from other energy efficiency measures

In addition to insulation measures, the review by Element Energy and the EST reassessed a number of different energy efficiency measures previously included in our analysis, such as lights and appliances. It also assessed the potential for new measures such as reduced flow showers, and for behavioural change measures:

- **Other heating energy efficiency measures.** Despite a 50% reduction in carbon savings per measure based on the latest evidence, a more ambitious level of uptake for heating controls in our updated assessment delivers 1.4 $MtCO_2$ by 2030 compared to less than 1 $MtCO_2$ from our previous estimate. This reflects the high number of households that still continue to lack basic heating controls. The costs of installing heating controls can be reduced at point of boiler replacement.
- **Lighting.** We now have a better disaggregation of the types of efficient lighting that could be installed, either by switching from incandescent lamps to compact fluorescents or from halogens to LEDs. While more efficient lighting offers considerable savings in electricity-related emissions, there is an increase in direct emissions to 1.2 $MtCO_2$ by 2030 compared to 0.4 $MtCO_2$ previously due to the heat replacement effect[4].
- **Appliances.** Driven by end of lifetime replacements and tightening EU energy efficiency standards, we also expect a high uptake of efficient cold and wet energy efficient appliances (e.g. fridges and dishwashers) over the same period. This will provide significant electricity saving but would increase direct emissions to 0.7 $MtCO_2$ in 2030. We assume an ambitious uptake of the most energy efficient televisions (A+++ energy rating) by the mid-2020s. As these will be 90% more efficient than the current stock, heat related emissions are estimated to increase to 0.8 $MtCO_2$ by 2030. We also assume further increases (to a total of 3.2 $MtCO_2$) from other appliances (e.g. computers and various electrical gadgets).
- **Behavioural change.** By 2030, we estimate direct emission savings of 2 $MtCO_2$ from turning down the heating by one degree centigrade, down from our 2010 estimate of 3 $MtCO_{2.}$
- **New measures.** Based on new evidence, we also have included abatement from an additional measure. Reduced flow showers, which is a hot water efficiency measure, could save 0.9 $MtCO_2$ by 2030. Currently, hot water demand accounts for 6% of CO_2 emissions and reduced flow showers are a very cost-effective measure at -£172 t/CO_2.

Annual direct emissions savings from all the residential energy efficiency measures considered for this report could save 7.2 $MtCO_2$ by 2030. This represents a 22% reduction (equivalent to 2.1 $MtCO_2$) from what we previously estimated in 2010 (Table B3.2). In addition, electricity-related measures would provide electricity demand savings of around 14 TWh by 2030.

Table B3.2: Summary of direct carbon savings by 2030 ($MtCO_2$)

Measure	Old 2010 estimates	Revised 2013 estimates
Solid wall insulation	4.9	**2.5**
Cavity wall and loft insulation	3.0	2.7
Other fabric measures	0.4	0.7
Heating controls	0.1	1.4
Heating 1 degree centigrade decrease	3.1	2.0
Lighting	-0.4	-1.2
Cold & wet appliances	-0.2	-0.7
Electrical products (e.g. computers, televisions, other appliances)	-2.2	-3.2
Other measures	0.6	3.0
Total	**9.3**	**7.2**

Source: CCC modelling

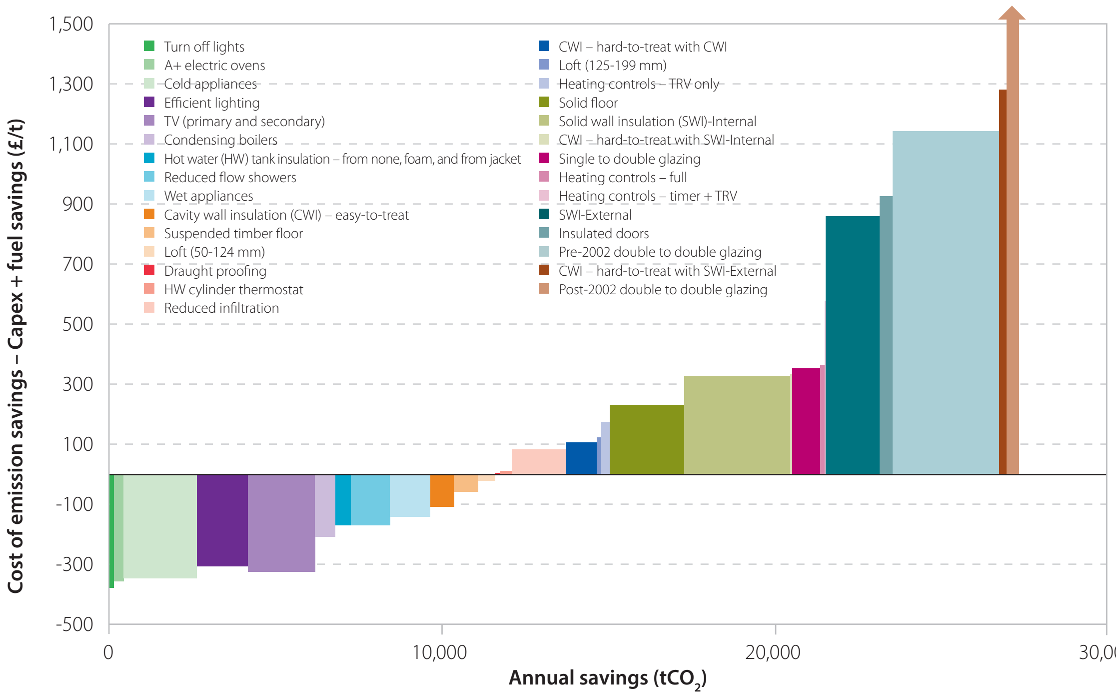
4 As appliances become more efficient, they produce less waste heat. We assume this needs to be compensated for with a small amount of additional heating.

The reduction of estimated energy/carbon savings for some measures combined with updated data on the costs of measures also implies an increase in the cost per tonne of abatement:

- **Solid wall insulation.** The reduced level of carbon savings per unit of insulation combined with higher costs estimates (e.g. cost estimates for external insulation range £3,600-8,400) have sharply increased the average cost of carbon abatement from the fourth carbon budget estimate of £18/tCO_2 to a range of £88 to £2,000/tCO_2 for external insulation and -£70 to £890/tCO_2 for internal insulation. Solid wall insulation is found to be most cost-effective if applied to large electrically-heated homes, and least cost-effective for small homes heated by gas or district heating. We recognise however that in practice the costs of installing solid wall insulation can be much lower if done in conjunction with general home renovation works. For example, fixed costs for external solid wall insulation will be less if the scaffolding is already in place for other works (e.g. a loft conversion).
- **Cavity wall insulation.** Easy-to-treat cavity walls continue to remain cost-effective, saving -£100/ tCO_2. Harder-to-treat cavities all have positive costs, ranging between £106-£1,290/ tCO_2, which reflects the different method that can be used to treat a house with a cavity wall, with the most expensive being the installation of an external solid wall should the cavity prove unsuitable to fill.
- **Loft insulation.** Topping-up lofts with existing low levels of insulation (50-125mm) remains cost-effective, saving -£22/tCO_2. Reduced savings are obtained from topping-up lofts with more insulation already in place (125-199mm) makes them less cost-effective (£123/tCO_2).

In addition to easy-to-treat cavity wall insulation and loft insulation, other cost-saving measures include efficient appliances, lighting, and reduced flow showers (Figure 3.4).

Figure 3.4: Marginal abatement cost curve for residential energy efficiency measures, technical potential



Source: Element Energy & Energy Saving Trust (2013).
Notes: Includes in-use factors.

There is a question over whether more expensive measures should be targeted by low-carbon policies. However, it is important to consider their role in abating fuel poverty (e.g. fuel poverty is more prevalent in solid wall homes), as well as health benefits (section 5). We will return to this question in our 2014 progress report. In the meantime, we include a sensitivity where we assume a lower uptake of more expensive solid wall and hard-to-treat cavity wall insulation measures (section 4).

Non-residential energy efficiency

There is significant variation in energy usage profiles across non-residential buildings due to differences in buildings type, size and use. As noted in our previous reports, the evidence base for abatement potential in the non-residential sector needs to be strengthened and efforts are underway by Government to address this (Box 3.4).

Our fourth carbon budget abatement scenario assumed the uptake of all carbon abatement measures to 2020 that are cost-effective relative to the carbon price, including efficient lights and appliances, heating controls and energy management measures. No further savings were identified in the 2020s.

Overall, our evidence review suggests this is broadly the right level but we have also identified some small additional electricity savings from appliances to 2030 as a result of the new EU regulations on product standards. These are expected to deliver a further 3% of electricity savings in 2030 (4 TWh higher than our original estimate of 5 TWh of savings).

These savings, together with the decarbonisation of the power sector, could lead emissions from public and commercial buildings to be close to zero by 2030.

Box 3.4: Non-domestic evidence gathering project in DECC

DECC are undertaking a major new evidence-gathering project in order to address the lack of evidence on the energy demand and carbon abatement potential of non-domestic buildings.

- The aims are to build a bottom-up dataset of energy end usage and abatement potential, and to review barriers to energy efficiency.
- The project will take a sectoral approach, using a combination of telephone and online surveys, site audits and buildings energy modelling to supplement the existing data from energy bills and building information from the Valuations Office Agency.
- First results will be delivered in 2014, starting with the public sector and the project will complete in early 2015.

As a result, we expect to have improved estimates of abatement potential in our future analysis (e.g. for the fifth carbon budget report).

Source: DECC, 2013.

Low-carbon heat

Low-carbon heat has a critical role to play in meeting the 2050 target, given the need to reduce the emissions from heat to very low levels in 2050. Our previous analysis identified a mix of cost-effective technologies in the 2020s, including heat pumps, bioenergy and district heating. Heat pumps in particular made up a significant portion of abatement in our 2010 analysis – around 70% of all low-carbon heat abatement in 2030 – with just under 7 million heat pumps in homes. However, we also recognised the existence of significant barriers to uptake.

Since 2010, there is new evidence – on heat pump uptake, transitional technologies such as hybrid heat pumps and district heating – which has implications for the fourth carbon budget period. We have therefore carried out new analysis to update our assessment of the feasibility and desirability of heat pumps to 2030.

We set out the results of our new analysis in two parts:

a) Heat pumps

b) Other low-carbon options – bioenergy and district heating

a) Heat pumps

Since we provided our advice on the fourth carbon budget in 2010, the uptake of heat pumps has been slower than expected, although support has also been more limited than we assumed:

- Total sales have remained below 30,000 per year, mainly consisting of air source heat pumps, and in recent years, often installed in social housing.
- Government support for the sector has had limited impact. The domestic Renewable Heat Incentive (RHI) scheme has been postponed to 2014, while the interim Renewable Heat Premium Payment has only delivered a few thousand heat pump installations since 2011. Heat pump tariffs in the non-domestic scheme were initially set too low to drive uptake.

Given the changed circumstances, we commissioned Frontier Economics and Element Energy to review the feasibility of our heat pump assumptions. This identified new evidence on additional costs, lower performance and lower durability of Air Source Heat Pumps (ASHPs) which affects our estimates of the cost-effectiveness of heat pumps (Box 3.5).

We have updated our previous modelling to reflect this new evidence. Lifetime assumptions in particular have a major impact on uptake numbers. Since substantial uncertainty remains, our approach has been to consider the range of impacts on cost-effectiveness:

- Assuming that ASHPs last on average 15 years would suggest cost-effective uptake of around 2 million heat pumps in homes in 2030.
- Increasing the lifetime to 20 years increases cost-effective uptake to 6 million heat pumps in 2030.
- Reflecting this uncertainty, we have adopted a central estimate of 4 million heat pumps in homes in 2030.
- For non-residential buildings, numbers of installations are more difficult to estimate as there is a huge variation of heat demand between buildings. We assume an overall contribution of around 30% of non-residential heat demand (27 TWh), down from 62 TWh previously.

Box 3.5: New evidence on the cost-effectiveness of heat pumps

The study by Frontier Economics and Element Energy identified higher financial barriers than we previously assumed, as a result of higher capital costs, lower performance and shorter lifetimes.

Capital costs

New capital cost data is available from a number of sources, with relatively good agreement between sources:

- The study compared the assumptions used for Phase II of the RHI (AEA, 2012) with costs collected by the Sweett Group for DECC (2013)[5] and estimates supplied through the stakeholder consultation.
- Based on the review, it recommended using ASHP cost data from the RHI Phase II study, and Ground Source Heat Pumps (GSHP) cost data supplied during a stakeholder consultation, including the cost for upgrading heat emitters.
  - The review suggested including additional capital costs of £275/kW (typically over £1,000 per heat pump) from the need to upgrade heat emitters, as heat pumps perform better at lower flow temperatures.
- The advantage of these costs are that they provide a clear breakdown between costs attributed to the heat pump, and the costs to refurbishment of the heating distribution system, and compare closely to those reported in the Sweett Group report. We have therefore reflected the new data in our estimates.

In the residential sector, this corresponds to total installation costs of £5,000 – £15,000 for ASHPs and £8,000 – £23,000 for GSHPs, compared to £6,000 – £10,000 for ASHPs and £9,000 – £17,000 for GSHPs in our previous assumptions.

Consultation with industry stakeholders and experts found that they generally consider the opportunity for reducing equipment costs limited, with no significant economies of scale expected to result from growth of the heat pump industry. Some learning is expected to bring down installation costs, equivalent to 10% of the installed cost by 2030. For GSHPs, communal ground arrays and more widespread drilling rigs could help bring down costs, but there is limited evidence on this to date.

Heat pump performance

Energy efficiency is one of the main factors determining the cost-effectiveness of heat pumps, as it leads to the running cost savings which offset the higher capital costs relative to conventional heating technologies:

- The efficiency of heat pumps – referred to as the Seasonal Performance Factor (SPF)[6]– is calculated as the ratio of heat output to electricity input. It typically ranges in the region of 2-3 for residential ASHPs and up to around 4 for GSHPs without solar recharge (i.e. producing heat equivalent to four times the amount of electricity consumed).
- As the electricity required for heat pumps is more expensive than gas, in the absence of policy intervention, operating cost savings would depend on achieving a level of performance of typically 3.5 or higher where replacing a gas boiler.

Heat pumps efficiency is not expected to improve dramatically over time. The Energy Saving Trust (EST) recently published the second phase results of its heat pumps field trials, where it measured the impact of targeted improvements to the first round of installations. These indicate that there is some potential for improvement in heat pump performance, but that it is likely to remain low compared to some other EU countries, partly due to the low UK housing stock efficiency.

We have therefore limited the improvements to an increase of up to 1 in the SPF, over a 10 year period.

Durability of ASHPs

The evidence on the lifetime of heat pumps is weak. Lifetime estimates for ASHPs are commonly in the range of 15 to 20 years. This suggests that our previous assumption of 20 years for all heat pumps was a high end estimate in the case of ASHPs.

These assumptions are only partially offset by lower supply-side constraints compared to our previous estimates.

Source: Frontier Economics and Element Energy (2013) Pathways to high penetration of heat pumps, and Energy Saving Trust and DECC (2013) Detailed analysis from the second phase of the Energy Saving Trust's heat pump field trial.

5 Sweett Group for DECC (2013), Research on the costs and performance of heating and cooling technologies, Final report. Available on the gov.uk website.

6 The term Coefficient of Performance (COP) is also used. This is a term used by the manufacturer and indicates design performance, whereas SPF refers to the seasonal average, or what is achieved in practice.

Taken together, this evidence suggests cost-effective uptake to 2030 of 4 million heat pumps in homes, and 27 TWh in non-residential buildings.

We had not previously considered hybrid heat pumps (i.e. a heat pump combined with a gas boiler) but new evidence suggests that they could play a role as transitional technologies in the medium term:

- Their advantages include fewer barriers to installation, but carbon savings would be lower.
- The level of uptake of hybrid heat pumps is highly uncertain, with significant variations between different uptake model estimates.

We have therefore not explicitly included hybrid heat pumps in our assessment. Whilst an assumption that all electric heat pumps are replaced with hybrid heat pumps would lead to lower levels of abatement, we consider that this would be within the range explored in our low sensitivities (Box 3.6).

Even at the scaled-down uptake numbers, significant financial and non-financial barriers remain which make this a challenging area for carbon policies:

- Financial barriers – primarily the high upfront costs relative to conventional heating technologies.
- Non-financial barriers – including consumer confidence and awareness, the suitability of the housing stock and a lack of installer capacity.

However, the Frontier Economics and Element Energy study suggests these can largely be addressed by a set of cost-effective policy options. We will return to these in our 2014 progress report.

Box 3.6: Hybrid heat pumps

The term hybrid heat pump is commonly used to refer to an electric heat pump combined with a gas boiler. These can either operate in tandem, or the gas boiler can be used as a top-up for the coldest days in the year. An alternative product is the gas absorption heat pump, which runs off natural gas as opposed to electricity. Hybrid heat pumps are typically less efficient than electric heat pumps, achieving SPFs of around 1.5 (or 150%), compared to typically around 2-3 for ASHPs (Box 3.5)

Recent analysis by National Grid and DECC[7] has suggested that these technologies could play an important role in the transition to decarbonisation, with high uptake of hybrid or gas absorption heat pumps in the 2020s and 2030s. These would then be phased out in the 2040s with the rising carbon price.

Some uptake is likely under the Renewable Heat Incentive (RHI), as the heat output qualifies for RHI payments on the portion of the output that comes from the heat pump, subject to metering.

We asked Frontier Economics and Element Energy to look at the impact of including hybrid heat pumps in our cost-effective path. The headline conclusions were:

- There are some advantages to hybrid heat pumps as a transitional technology (including the practicality of top-up gas, fewer barriers to installation, higher acceptability to consumers, and lower peak load electricity demand).
- The benefits of gas absorption heat pumps are less clear – these are only around 150% efficient, with lower carbon savings and therefore do not hold the same long-term decarbonisation potential relative to gas boilers. Whilst there are some products on the market in Europe, for example in Germany, there are none so far in the UK.
- Consumer uptake modelling suggests we could see uptake of several million under a range of policies. These would be partly replacing other uptake of ASHPs, and partly additional.

Other evidence suggests a range of potential uptake scenarios:

- Modelling by DECC and National Grid suggests that uptake to 2030 may be dominated by either hybrid heat pumps or gas absorption heat pumps, with different models favouring either one or the other technology.

Our approach has been not to include hybrid or gas heat pumps in our assessment. However, assuming a hybrid heat pump involves using a gas boiler to meet around 25% of heat demand during the coldest days of the year, the reduction in abatement from substituting all electric heat pumps in our scenario for hybrids would be within the range bounded our low sensitivity of 2.5 million heat pumps in 2030 (see section 4).

Source: Frontier Economics and Element Energy, 2013.

b) Other low-carbon options – district heating and bioenergy

District heating

We have raised our assumptions about the level of district heating deployment by 2030 to 6% of heat demand (30 TWh/year), based on a combination of low-carbon sources and natural gas combined heat and power (CHP). This is within the range of our previous high scenario of 8% (40 TWh).

- In our fourth carbon budget advice, we assumed deployment of 10 TWh/year, out of a total estimated potential of 90 TWh/year. Since 2010, the evidence base on the potential for district heating to contribute to low-carbon heat supply has been strengthened.

7 Esme and Resom modelling results presented in DECC (2013) The Future of Heating: Meeting the challenge.

- In 2012, we commissioned AEA and Element Energy to look at scenarios for low-carbon heat to 2050 for our report on the 2050 Target[8], published alongside our advice on whether international aviation and shipping should be included in the budgets. This identified greater potential for district heating deployment, at 160 TWh/year by 2050, and showed that a mix of district heat and heat pumps would have similar emissions and overall cost to a scenario with very high level of heat pump uptake.
- DECC's 2013 heat strategy (The Future of Heating) has also identified a greater role for district heating, delivering heat from a range of low-carbon sources including a potentially important contribution from larger-scale heat pumps.

In order to keep in play this greater cost-effective potential for long-term deployment, we assume that it is necessary by 2030 to reach a greater level of roll-out than we had previously envisaged. Whilst this would include some gas CHP in the near-term, this is likely to be phased out over time with a rising carbon price.

Bioenergy

In our 2011 Bioenergy Review, we found that the role for bioenergy in heating buildings is likely to be relatively limited in the longer term, given heat pumps as alternative low-carbon options. Our assessment suggests that broadly the same level of bioenergy in buildings remains sensible (around 8.5 $MtCO_2$ in 2030).

Given limits to the global supply of sustainable bioenergy, it is important that bioenergy is used in an optimal fashion. For heat, Combined Heat and Power (CHP) using local waste or bioenergy and supplying district heating, and bioenergy boilers using local bioenergy in rural homes are likely to provide the best options.

4. Projected emissions with abatement – an updated assessment for the 2020s

In our 2010 advice, we presented an abatement scenario involving measures that were likely to be economically-sensible in a carbon-constrained world. This was our best estimate of the cost-effective path to the 2050 target, and included measures that were cost-effective against the projected carbon prices or were considered important on the path to the 2050 target. For 2030, it included for example the insulation of all technically-feasible lofts and cavity walls, as well as 3.5 million solid walls, a range of energy efficiency measures in non-residential buildings and 37% of heat demand met by low-carbon heat sources, including 6.8 million heat pumps in homes. We expected these measures to reduce direct buildings emissions to 62 $MtCO_2$ in 2025 and 46 $MtCO_2$ in 2030.

8 CCC (2012) The 2050 target – achieving an 80% reduction including emissions from international aviation and shipping. Available online at http://www.theccc.org.uk/publication/international-aviation-shipping-review/

Outlook to 2020

The starting point for our analysis was a projection for emissions in 2020, building in measures which the Government is aiming to deliver, or has committed to deliver. Since many of the policies for 2020 are already in place, this is very similar to DECC's 'Reference' projection in UEP. We have updated our projection based on new evidence since our original advice. The main changes are:

- We have adjusted the energy and carbon savings for a range of residential energy measures, in accordance with the new evidence presented in section 3.
- We have scaled abatement from energy efficiency measures in residential and non-residential buildings, in line with DECC's latest energy demand projections.

As a result, we now assume emissions from buildings will be 80 $MtCO_2$ in 2020. This would be a 12% reduction on 2012 levels but is 9 Mt higher than we assumed in our 2010 fourth budget advice.

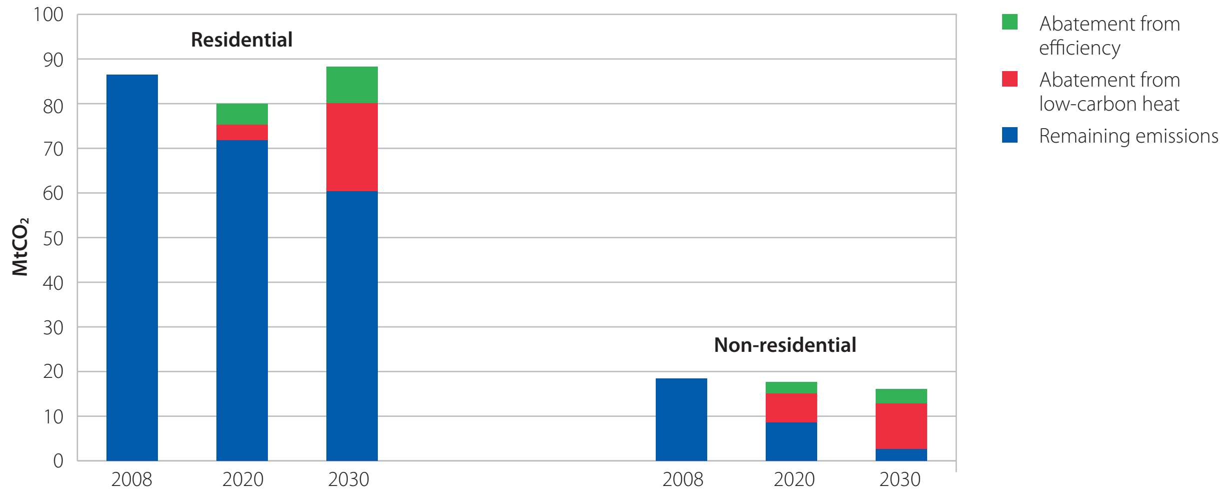
The path from 2020 to 2030

We have updated our assessment for building sector emissions to reflect the new evidence on the effectiveness of energy efficiency measures in the residential sector, on low-carbon heat and on emissions projections:

- **Residential energy efficiency**. Given our new evidence on reduced energy savings, we now assume that wall and loft insulation reduce direct annual emissions from residential buildings by 5% (previously 8%) compared to the baseline without abatement measures by 2030. As in our original fourth carbon budget advice, we assume that other energy efficiency and behavioural measures (e.g. other fabric measures, turning down thermostats by one degree centigrade and zero-carbon homes) reduce emissions by a further 2% against the baseline.
- **Low-carbon heat**. We have revised our assumptions about heat pump uptake down from 7 million installations in 2030 (meeting 143 TWh of heat demand) to 4 million (72 TWh). This is partly offset by an assumed increase in penetration of district heating (up from 2% (10 TWh) to 6% (30 TWh) in 2030.
- **Emissions projections**. We adopt the latest DECC baseline projection, implying an increase in residential direct emissions of 16% in 2030 relative to our previous assumptions, while for non-residential buildings, we assume a reduction in 2030 by 39% compared to our 2010 advice.

Together, these changes mean that we now assume that direct emissions from buildings reduce to 70 $MtCO_2$ in 2025 (down 32% on 1990) and 64 $MtCO_2$ in 2030 (down 38% on 1990, Figure 3.5).

Figure 3.5: Updated scenario for direct emissions abatement in buildings (2010, 2020 and 2030)



Source: CCC modelling.
Notes: Direct emissions only.

We now assume that emissions over the whole fourth budget period that are 50 Mt higher than we originally assumed (and 18 $MtCO_2$ higher in 2030, Figure 3.6). This reflects our more prudent assumptions over heat pump uptake and the effectiveness of insulation measures in use, with no material impact from DECC's new emissions projections, which are – across all buildings – relatively unchanged from those in 2010.

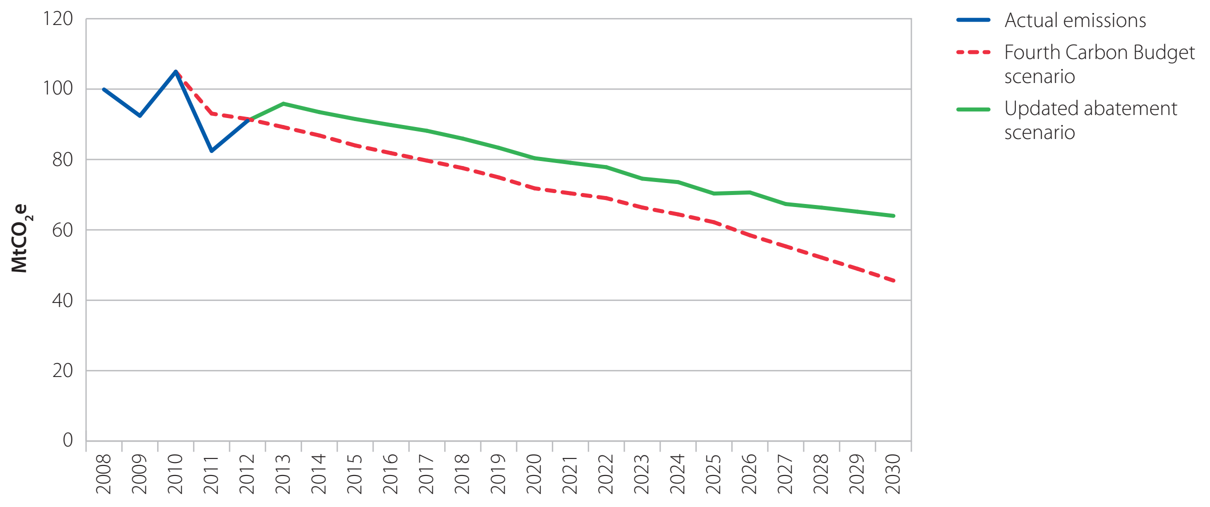
Preparing for 2050

Beyond 2030, this scenario would keep open the option of reducing emissions to a very low level in 2050:

- There is further potential for fabric energy efficiency in the residential sector, with insulation of many of the remaining 4 million or so solid wall properties, as well as potentially additional insulation measures to some of the lower efficiency cavity-walled stock.
- Further efficiency improvements in the commercial sector are possible, linked to refurbishment opportunities.
- Further roll-out of heat pumps and low-carbon district heating to all sectors would be possible as a result of supply-chain development in the 2020s.

By 2050, we assume that these measures could reduce buildings emissions close to zero carbon.

Figure 3.6: Updated abatement scenario for buildings to 2030



Source: CCC modelling.
Notes: Direct emissions only.

Sensitivities and flexibilities

While the measures included in our updated analysis are all feasible and in most cases cost-effective, deliverability will be challenging, especially in the residential sector where uptake in millions of households is required. Some of the measures are potentially high hassle (e.g. internal solid wall insulation) or provide a different kind of service from the incumbent technology (e.g. heat pumps). Furthermore, as outlined in section 3, some measures (in particular solid wall insulation and some cavity wall insulation) are now less cost-effective than we previously assumed.

In view of these uptake challenges, we have considered various sensitivities around key measures:

- **Lower uptake of solid wall insulation.** If we assume that uptake reaches 1 million[9] by 2022 and is flat out to 2030, direct abatement over the fourth carbon budget period would decline by 6 $MtCO_2$ to 3 $MtCO_2$.
- **Lower uptake of cavity wall insulation.** If uptake is focused on the most cost-effective cavity walls only (e.g. easy-to-treat and low-cost hard-to-treat), up to 2 $MtCO_2$ of direct abatement from the more expensive hard-to-treat cavities would be lost during the fourth carbon budget.

9 The level assumed by DECC's 2012 Green Deal/ECO Impact Assessment.

- **Lower deployment of heat pumps.** We have considered a case where uptake in the residential sector rises to only 2.5 million by 2030 (under 1 million in 2025). This is based on the minimum level of uptake required to keep open the option of decarbonising heat to 2050 with heat pumps as the main technology[10]. In the public and commercial sectors, we consider lower uptake consistent with lower ambition to 2020 under the RHI. Altogether, this is equivalent to 24 Mt CO_2 less abatement between 2023 and 2027.
- **Turning down the thermostat.** There is considerable uncertainty over whether it will be possible to realise savings from turning down thermostats. This reflects several uncertainties: it is unclear what internal temperature is assumed in DECC's projections; some households have already turned down temperatures and may have limited scope to do so again (e.g. 2011 EST survey found that 60% of households claimed to have done this), and consumer behaviour is inherently uncertain. We therefore consider a sensitivity where no further households turn down their thermostats, which would increase annual direct emissions by 2 $MtCO_2$ by 2030.

As set out in chapter 1, the fourth carbon budget has some flexibility to accommodate these sensitivities. Lower delivery in some areas could be offset by increased delivery elsewhere. Additionally, our overall assessment of the cost-effective path is that this would reduce emissions by more than required under the legislated budget, so that some under-delivery can be accommodated.

5. Benefits of delivering the measures in the fourth carbon budget

The majority of measures in our analysis are lower cost than the expected carbon price and/or are required to prepare for 2050. A delay in their deployment would therefore increase costs. We have quantified the costs for such a delay:

- Overall, the benefits of the fourth carbon budget buildings abatement versus a ten-year delay are around £31 billion. This includes benefits of £35 billion from low-carbon heat, offset slightly by a cost of £4 billion from energy efficiency where we assume some uptake of insulation measures which are not cost-effective in the 2020s.
  - Significant abatement from low-carbon heat is cost-effective in the 2020s compared to our central scenario for carbon prices (see Chapter 1). In the case of heat pumps, the costs range from negative abatement costs where these are replacing oil boilers or electric heating, to higher abatement costs where they replace gas boilers of around £50/tCO_2. The cost data is weaker for district heating, and we therefore assume abatement costs are zero, on the basis that our analysis to 2050 shows that levelised district heating costs are close to the levelised costs of heat from a gas boiler (not including the carbon cost).

10 As calculated by Frontier Economics for CCC (2013) Pathways to high penetration of heat pumps. The critical path scenario developed in this study considered the minimum level of uptake given supply and demand constraints to keep in play a 2050 decarbonisation scenario with a high heat pump component. It implies additional costs as it is below the cost-effective level of uptake. Failing to achieve this critical path uptake could imply further costs from boiler scrappage in order to meet the 2050 target.

– Based on average solid wall insulation costs (e.g. £859/tCO_2 for external insulation and £329/tCO_2 for internal insulation) solid wall insulation is not cost-effective in 2030 and does not offer a saving relative to delayed action. However, they are important for the roll-out of heat pumps and for addressing social factors (e.g. fuel poverty). The costs and benefits of the measures are set out in table 3.1.

- The benefits would be larger in a world of high fossil fuel or carbon prices. Even in a world of low fossil fuel prices or carbon prices, the benefits would outweigh the costs (see table 3.2). Aiming for the cost-effective path is therefore a low-regrets strategy.

Table 3.1: Abatement costs of measures and importance to 2050

Measure	**Cost per tonne CO_2 in 2025 (weighted average)**	Importance to 2050
Residential buildings, energy efficiency – mainly solid wall insulation	£686	Thermal insulation measures are critical for preparing buildings for low-carbon heating measures such as heat pumps. In residential buildings, the average abatement costs for insulation measures are higher through the 2020s than in the previous years as they consist of more expensive measures such as solid wall insulation.
Non-residential buildings, energy efficiency	Negative	
Low-carbon heat	£17	Decarbonising heat in buildings to 2050 requires building up capacity and supply-chains through the 2020s, particularly in the case of heat pumps and district heating. Abatement costs for low-carbon heating technologies mostly decrease throughout the 2020s with learning.
of which heat pumps	c. £0	Take up of at least 2.5 million heat pumps in homes by 2030 keeps open the option of high heat pump deployment to 2050.
of which district heating	£0	Building up capacity to 30 TWh in 2030 keeps in play a high penetration to 2050, of up to 160 TWh/year.

Notes: Abatement costs are calculated for measures taken up in the 2020s.

Table 3.2: Value of buildings abatement – cost sensitivities

Central	**Low carbon prices**	**High carbon prices**	**Low fossil fuel prices**	High fossil fuel prices
£30 billion	£15 billion	£50 billion	£20 billion	£45 billion

Source: CCC modelling. Rounded to the nearest 5 billion.

Residential energy efficiency measures also have important benefits beyond carbon saving – they increase affordability, reduce fuel poverty and can have health benefits:

- **Affordability:** Home energy bills are expected to increase by around £150 between now and 2030 due to low-carbon measures and the rising carbon price. Energy efficiency measures can help to offset these increases (see chapter 4 of the Advice Report for more detail).
- **Fuel poverty:** Depending on the definition used, there up to 4.5 million fuel poor households in the UK. Fuel poverty is particularly prevalent in the devolved administrations. The 2012 Hills Review on Fuel Poverty has argued that energy efficiency measures are the most effective way of dealing with fuel poverty (see chapter 4 of the Advice Report).
- **Health benefits:** Even where affordability is not an issue, better insulated homes (e.g. less condensation) can have benefits for people with health conditions such as asthma. For example, research for DECC suggests that the value of the health saving per measure installed amounts to £969 for cavity wall insulation and £742 for solid wall insulation.

It is therefore appropriate to aim to deliver significant abatement in buildings, as included in our updated assessment. This will require policy strengthening to ensure that incentives for investment are in place and that barriers to deployment are addressed. We will consider policy in more detail in our 2014 progress report to Parliament, as part of our review of progress over the first budget period.