Chapter 5: Reducing emissions from buildings and industry through the 2020s

Introduction and key messages

Emissions from buildings currently account for 36% of total UK GHG emissions, while emissions from industry make up for 35% of the total. Our previous analysis suggests that there is scope for a 35% reduction in buildings emissions and a 16% cut in industry emissions by 2020, primarily through energy efficiency improvement and increased deployment of renewable heat. In this chapter we consider scope for further cuts in buildings and industry emissions through the 2020s.

The key messages in the chapter are:

• There is scope for emissions reductions by 2030 (relative to 2007) of 74% in buildings and 48% in industry.
  – The potential for cutting direct (i.e. heat related) emissions from buildings is mainly through increased home insulation (in particular solid wall insulation), widespread deployment of heat pumps in residential and non-residential sectors, and district heating using waste heat from low carbon generation.
  – There is also potential for reducing indirect (i.e. electricity related) emissions from buildings through energy efficient appliances and lighting.
  – There is considerable scope for cutting industry emissions through the burning of biomass and biogas rather than fossil fuels, the use of CCS technology and further abatement options in energy intensive industries. There may also be significant opportunities for emissions reductions through product substitution and materials efficiency. These should be considered further given the need for further industry emissions reductions over and above what we have identified to ensure that the 2050 target remains attainable.

• We estimate the cost of cutting buildings and industry emissions to be around £1.4bn (<0.1% of GDP) in 2030 in our Medium Abatement scenario, with a range of -£2.5bn to £5.3bn for sensitivities on technology costs and fossil fuel prices.

• To ensure that the potential we have identified remains an option for the 2020s, it is important now to proceed with major energy efficiency improvements of the housing stock, to develop markets for renewable heat, to demonstrate industry Carbon Capture and Storage (CCS), and to further assess the scope for district heating using waste heat from low carbon power generation.

We set out the analysis that underpins these messages in four sections:

1. The entry point: buildings and industry emissions in the first three budgets
2. Emissions reductions in buildings through the 2020s
3. Emissions reductions in industry
4. Implications for the first three budget periods
The entry point: buildings and industry emissions in the first three budgets

Emission trends from buildings and industry

Emissions from buildings and industry currently account for more than two-thirds of total GHG emissions in the UK (Figure 5.1):

- The residential sector accounts for 23% of total UK GHG emissions.
  - Residential CO₂ emissions comprise 56% direct emissions (i.e. non-electricity related, mainly due to heat) and 44% indirect emissions (i.e. electricity use for lighting, appliances, etc.).
  - Residential emissions fell by 6% between 1990 and 2008. This was driven mainly by falling indirect emissions in the 1990s as a result of the switch from coal to gas-fired power generation (Figure 5.2).
  - More recently, residential emissions fell by 5% between 2004 and 2008. Although there was a small increase in 2008, residential emissions fell by 5% in 2009, due mainly to rising fuel prices and the recession.

- The non-residential sector accounts for 12% of total UK GHG emissions.
  - Within this sector, commercial buildings account for 9% of total UK GHG emissions, with the remainder from public buildings. Commercial buildings CO₂ emissions are largely (around 80%) indirect, with public sector emissions equally split between direct and indirect emissions.
  - Commercial sector emissions have remained broadly flat since 1990, with the impact of falling carbon intensity in electricity generation offset by increased electricity consumption (Figure 5.2). The recession appears to have had a major impact on this sector with a reduction of approximately 19% estimated in 2009.
  - In the public sector, emissions have fallen by 30% since 1990 but have stayed broadly flat in recent years.

- Industry emissions account for around 35% of total UK GHG emissions and comprise around two-thirds direct emissions, with the remainder indirect. Energy intensive industries covered by the EU Emissions Trading System (ETS) accounts for around two-thirds of total industry emissions.
  - Industry CO₂ emissions fell by around 20% between 1990 and 2008 due to fuel switching and industrial restructuring, with large reductions in the mid to late 1990s (Figure 5.3).
  - In the five year period before the recession, industry emissions fell by 7%. As a result of the recession, emissions fell by 5% in 2008 and 11% in 2009.
Feasible emissions reduction potential. Our assessment of feasible emissions reduction reflected a judgment on the extent to which new policy approaches could be introduced to address barriers to action. A number of new approaches are now being taken forward by the Government in the form of the Green Deal, the Renewable Heat Incentive (RHI), and the Carbon Reduction Commitment (CRC) energy efficiency scheme.

Our Extended Ambition scenario, which forms the basis for our Interim target, assumes that effective new policies are introduced and result in buildings emissions reductions of 37 MtCO₂ in 2020 and industry emissions reductions of 12 MtCO₂ in 2020. However, even with these significant reductions over the next decade, very deep cuts are required in subsequent years given the 2050 economy wide target and the limited range for reducing emissions in some sectors (Figure 5.4).

Residential buildings. We assume that new policies successfully address barriers to action and deliver significant energy efficiency improvements in the UK housing stock, including the insulation of 90% of lofts and cavity walls, as well as 2 million solid walls (from a total of nearly 8 million) by 2020. We also assume that 13 million boilers are replaced with new efficient boilers and that substantial increases in appliance efficiency are achieved. In total this could result in a 2020 emissions reduction of 17 MtCO₂ in the residential sector.

Scope for reducing buildings and industry emissions to 2020

Our previous analysis identified significant opportunities for reducing emissions from buildings and industry over the next decade through energy efficiency improvement and deployment of renewable heat. We developed scenarios for feasible emissions reductions based on a three step approach:

- **Technical emissions reduction potential.** We assessed the quantity and cost of emissions reduction potential from a range of energy efficiency improvements (e.g. insulation, efficient appliances and motors), low carbon heat technologies and behaviour change measures (e.g. turning down thermostats).

- **Barriers to unlocking technical potential.** The fact that there remains significant potential for implementation of cost saving measures suggests the presence of barriers to action. We reviewed a range of barriers (lack of information, transaction costs, etc.) and means for addressing these (i.e. through new policy approaches).
- **Non-residential buildings.** We assume that most cost effective emissions reductions (energy efficiency improvement, better energy management, etc.) are achieved through a combination of the CRC and new policy approaches (e.g. for small and medium sized enterprises (SMEs)). In 2020, we assume emissions reductions from non-residential buildings of 9 MtCO$_2$.

- **Industry.** We assume that around 90% of cost effective industry emissions reductions from short pay-back energy efficiency improvements are achieved, due to incentives provided under the EU ETS and Climate Change Agreements. Alongside new policies to strengthen incentives for smaller firms this could result in an emissions reduction from industry of 6 MtCO$_2$ by 2020. We regard this as a lower bound given that existing emissions reduction models (e.g. ENUSIM) do not include the full range of abatement options for industry.

- **Renewable heat.** We assume that the RHI is introduced and results in a 12% penetration of renewable heat in 2020 and 17 MtCO$_2$ emissions reductions, mainly through the deployment of biomass boilers and heat pumps. Recent announcements in the 2010 Spending Review cut the funding for the RHI by 20%. Final proposals will be published at the end of 2010 and we will look at the implications for carbon savings in the period to 2020 in our renewable energy review, to be published in spring 2011.

### Buildings and industry emissions reference projection for the 2020s

The Extended Ambition scenario defines the starting point for our 2020s scenarios (see Section 2.3 for buildings and 3.3 for industry). We also incorporate the Extended Ambition scenario in a reference emissions projection for the 2020s, but assume that there is no additional abatement effort beyond 2020. Therefore emissions in the reference projection grow in line with GDP growth, population growth, and household formation (see Chapter 3 for assumptions on key variables underpinning reference projections across all sectors). This results in a 7% increase in buildings emissions and a 4% rise in industry emissions between 2020 and 2030 (Figure 5.5 and 5.6).

We now consider options to offset this projected emissions growth, and develop scenarios for emissions abatement through the 2020s, which include options that we assess to be both feasible and cost-effective.
2. Emissions reductions in buildings through the 2020s

Given a buildings emissions share of more than one third of total emissions in 2020 (on an end-use basis), it will be important to cut emissions further through the 2020s in order to meet carbon budgets. We now consider the scope for reducing emissions through energy efficiency improvement and renewable heat deployment, and then combine both sets of options in our scenarios for buildings emissions to 2030.

2.1. Energy efficiency improvement

(i) Residential sector – household and emissions growth to 2030

The context for residential buildings emissions in the 2020s is one where there is projected, if highly uncertain, growth of around seven million households relative to current levels. Projected household growth is due to a growing population and demographic change:

- Official projections suggest that the UK population will grow from current levels of around 62 million to 66 million in 2020 and to 71 million by 2030.
- Household size is projected to fall from the current level of 2.3 people to 2.1 people by 2030 due to an increasing number of single person households.
- The combination of these effects would increase the number of households from the current level of 26 million to around 33 million by 2030 (i.e. a 30% increase).

Therefore the rising population and increasing number of households could increase buildings emissions by up to 20 MtCO2, if new household energy consumption was to mirror that of current new build homes (2.8 tCO2 per household, excluding transport).

(ii) Residential fabric improvements through the 2020s

Some of this potential emissions growth is likely to be offset through new build properties achieving zero carbon standards, as envisaged under current policies in England and the devolved administrations (Box 5.1). However, even with a high rate of construction, zero carbon homes are unlikely to account for more than around 10% of the total housing stock by 2030, with the implication that existing houses will still account for at least 90% of the total stock in 2030. Accelerated replacement of the existing stock, while reducing operational emissions compared to older houses, would have to take account of the issue of embodied carbon (Box 5.1).

Box 5.1: Zero carbon homes and embodied carbon

Zero carbon homes

From 2016, new homes in England will have to be built to level 6 of the Code of Sustainable Homes, as ‘zero carbon homes’. The exact definition of ‘zero carbon’ is yet to be decided but it is likely to require high energy efficiency standards (with energy demand for space heating expected to be around 40 kWh/m², compared to an average of around 200 kWh/m² in the existing stock), as well as on-site or off-site renewable energy generation for all building-related energy demand (e.g. lighting, ventilation). The devolved administrations are also introducing zero carbon building standards. By 2030, we can thus expect a stock of new homes built to zero carbon standards of around 2-3 million, primarily driven by the demand for extra dwellings.

Embodied carbon

Improving the energy efficiency of existing homes to levels similar to those found in new-build homes is difficult and expensive. This raises the question over whether replacement of the housing stock should be accelerated. However, accelerated replacement of the existing stock does not necessarily make sense from a carbon perspective:

- A typical new 2 bed home built with traditional materials (brick, concrete foundations etc) embodies around 80 tCO2.
- The carbon payback time (through lower operational CO2 emissions) is several decades, and is thus likely to only be a solution for the least efficient buildings where refurbishment is prohibitively expensive.
- One possibility, which should be considered further, is to build new houses with natural building materials that sequester carbon (e.g. wood, hemp and straw). For example, the Stadthaus block of flats in London, the world’s tallest timber residential building, has been estimated to store almost 700 t CO2. In addition, its construction has avoided 450 tCO2 compared to using a typical reinforced concrete frame.

Given that our Extended Ambition scenario includes the widespread take-up of loft and cavity wall insulation, there should be little left to do on these measures in the 2020s. The focus at this time should therefore shift to measures where there is limited implementation envisaged in the period to 2020, and where abundant cost-effective potential remains. The greatest opportunity is for internal and external wall insulation, primarily in solid-walled houses:

- Even if 2 million solid wall houses are insulated in the period to 2020, as envisaged in our Extended Ambition scenario, this will leave a further 6 million houses that could be insulated through the 2020s and beyond.
- The heat demand reduction associated with further widespread solid wall insulation in the 2020s is around 13TWh, or 3% of total residential demand for heat in 2030 (Figure 5.7).
- Solid wall insulation is cost-effective, with a cost per tonne of CO2 abated of around £18/CO2. It will become increasingly attractive assuming that heat is subject to a carbon price, and that the latter rises through the 2020s.
- Solid wall insulation is necessary to support deployment of heat pumps (see section 2.2 (i) below).

While solid wall insulation provides the greatest potential for energy efficiency improvement in the 2020s, there is likely to be scope for savings from other building fabric measures such as underfloor insulation and energy efficient glazing and other building fabric measures, resulting in further scope for emissions reductions up to 11 MtCO2 (Figure 5.8).
Our Medium Abatement scenario for energy demand and emissions from buildings includes a high take-up of solid wall insulation (i.e. total 3.5 million by 2030), while the High Abatement scenario includes further solid wall insulation take-up (a total of 5.7 million by 2030) and also includes these additional measures (e.g. floor insulation and energy efficient glazing).

### (iii) Residential sector – energy efficiency improvement in appliances and lighting

Residential demand for electricity currently accounts for approximately 40% of total electricity demand, having increased by around 34% since 1990 despite major improvements in appliance energy efficiency. Increased demand is primarily due to the growth in ownership of household and electronic appliances, which account for two-thirds of household electricity consumption.

There is a significant difference between the energy consumption of the least and most efficient appliances (e.g. the most efficient A++ rated fridge-freezer currently on the market consumes 85% less energy than a similar sized A rated fridge-freezer). With lifecycle costs of more efficient appliances lower than those of less efficient appliances, this provides a significant opportunity for cost-effective emission reduction.

We reflect this opportunity in our Extended Ambition scenario, where we assume emissions reductions of approximately 5 MtCO₂ by 2020 as the share of more efficient appliances in the stock increases. Beyond 2020, there is scope for further efficiency improvement given the time taken for turnover of the appliance stock (e.g. 15 years for fridge-freezers, 12 years for washing machines and driers) and expected technology improvements.

Given the underlying economics, we assume that there is widespread take-up of the most efficient appliances through the 2020s, together with the scope for electricity demand reduction from more efficient lighting in households (Box 5.2). We reflect this in our modelling of the power sector in Chapter 4. Our analysis suggests that if primarily efficient appliances and lighting systems were purchased in the 2020s, this would result in electricity demand reduction of around 10 TWh (around 3% of total UK electricity demand in 2030) between 2020 and 2030.

### (iv) Energy efficiency improvement in non-residential buildings

Our Extended Ambition scenario for non-residential buildings includes the uptake of all cost effective measures in companies and organisations covered by the CRC by 2017. Additionally, we assume that cost-effective and more practical measures such as energy management are taken up elsewhere in the non-residential sector by 2020. This could be accelerated by the setting of minimum energy performance ratings for buildings.
There is some evidence that further abatement potential is likely to be available beyond 2020. For example, recent analysis by the Carbon Trust suggests that there is scope for further energy efficiency improvements to deliver a reduction of 2 MtCO₂ by 2030, with savings equally split between measures that are cost effective (non-fabric measures such as timers and programmable thermostats) and measures that are more costly (such as major building fabric upgrades where costs are driven by the labour intensive nature of the installation).

However, as noted in our previous reports, the evidence base for abatement potential in the non-residential sector is weak due to data and model limitations. Therefore, we have been cautious in our scenarios and assumed no further uptake of heating related energy efficiency measures in the 2020s beyond those included in the reference scenario, whilst recognising that more may be possible. For non-heat electricity demand (lighting, refrigeration, computing etc) we have assumed that continuing efficiency improvements deliver a further reduction of 5 TWh by 2030, (5% of non-residential electricity demand in 2030). This has been reflected in our electricity demand scenarios (Chapter 3).

2.2 Deployment of low carbon heat technologies

A large proportion of the energy consumed in homes (around 80%) and the commercial and public sector (56%) is currently used for space and hot water heating, mainly from gas. Reducing emissions from heat, through a combination of energy efficiency improvements and heat decarbonisation, will therefore play an important role in achieving carbon budgets. The 12% renewable heat penetration we assume in our Extended Ambition scenario leaves and heat decarbonisation, will therefore play an important role in achieving carbon budgets.

We now consider these options from both technical and economic perspectives, drawing on analysis that we commissioned from NERA and AEA (Box 5.3) and use this as the basis of our scenarios for emissions from buildings through the 2020s (section 2.3).

Box 5.3: NERA/AEA low carbon heat model

Our scenarios for the uptake of low carbon heat are underpinned by a detailed cost-effectiveness model, developed by NERA and AEA. This model has drawn upon and extended the evidence base used for previous low carbon heat work for DECC and the CCC that looked at the period to 2020. Technology assumptions and input data have been extended to 2030, and additional technologies have been incorporated to reflect possible future developments (e.g. synthetic biogas from the gasification of biomass, and heat pumps with heat storage that can shift electricity load profiles).

The model calculates uptake by considering the cost effectiveness of low carbon heat technologies relative to a conventional electric heating system such as storage heaters or immersion heating. The level of uptake in each year depends upon a complex interaction of factors including the size of the heat market, the ability of industry to deploy low carbon heat and a range of suitability constraints discussed in Box 5.7.

The sensitivity of the results was tested by varying many of the key input parameters, including technology performance and cost, levels of building insulation and energy efficiency, availability of biomass resource, fuel prices and discount rates. The results of these sensitivities are reflected in our uptake scenarios.

We set out our analysis in three parts:

(i) Heat pumps
(ii) Bioenergy
(iii) Combined heat and power (CHP) and district heating

(i) Heat pumps

Heat pumps use electricity to extract heat from the surrounding environment and transmit this for space and hot water heating. One unit of electricity from heat pumps can generate between 2.5 and 4.5 units of heat (Box 5.4), compared to less than one unit of heat via conventional electric heating systems such as storage heaters or immersion heating.

Box 5.4: Performance of heat pumps

The performance of heat pumps is described in terms of its Coefficient of Performance (COP), or the amount of heat the heat pump produces compared to the total amount of electricity needed to run it. The higher the COP, the lower the electrical energy required to deliver a given amount of heat, and therefore the better the performance.

For this analysis, it has been assumed that COPs start from current levels of 2.0 to 2.5. They are projected to increase towards an eventual plateau in the 2020s, with space heating COPs in the range 3.5-5.5 (up to 4.5 in residential applications and 5.5 in non-residential).

The performance of heat pumps depend on a range of factors, including type of heat pump, building insulation levels, type of heating system and weather conditions:

• GSHPs have slightly higher COPs as ground temperature is less variable than air temperature.
• We have assumed higher COPs in new houses built to high insulation standards and able to make use of lower temperature underfloor heating or low temperature radiators. For older properties, we have assumed the use of higher temperature radiators, with COPs correlated to insulation levels.
• The COP of a heat pump varies according to the magnitude of the temperature difference between the heat source and the heat load. The COP is calculated as the weighted average of reported seasonal performance factors, but during spells of cold weather COPs can decrease significantly.

The Energy Saving Trust (EST) recently published the results of the first large scale trial of heat pumps at 83 sites in the UK: A key finding was that heat pump performance can vary considerably between installations, and is particularly sensitive to installation and commissioning practices and customer behaviour.

In the trials, GSHPs had a mid range of around 2.3-2.5, with the highest figures above 3. The mid range of COPs for ASHPs was around 2.2, with the highest figures over 3.

The results of the EST field trial have important implications for the roll out of heat pumps in the UK:

• In general, well installed and operated heat pumps are a suitable technology for reducing emissions in the UK.
• Given the sensitivity of performance to design and commissioning, there is a requirement for improved training for installers.
• Many customers expressed difficulty understanding the instructions, and this underlines the importance of improved information provision and technical support.

Box 5.5: Low carbon heat model inputs

The low carbon heat model is underpinned by a detailed cost-effectiveness model, developed by NERA and AEA. This model has drawn upon and extended the evidence base used for previous low carbon heat work for DECC and the CCC that looked at the period to 2020. Technology assumptions and input data have been extended to 2030, and additional technologies have been incorporated to reflect possible future developments (e.g. synthetic biogas from the gasification of biomass, and heat pumps with heat storage that can shift electricity load profiles). The model calculates uptake by considering the cost effectiveness of low carbon heat technologies relative to a conventional electric heating system such as storage heaters or immersion heating. The level of uptake in each year depends upon a complex interaction of factors including the size of the heat market, the ability of industry to deploy low carbon heat and a range of suitability constraints discussed in Box 5.7.

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The sensitivity of the results was tested by varying many of the key input parameters, including technology performance and cost, levels of building insulation and energy efficiency, availability of biomass resource, fuel prices and discount rates. The results of these sensitivities are reflected in our uptake scenarios.
Reflecting this major efficiency advantage, and the fact that significantly increased deployment of conventional electric heating would require prohibitively high build rates of low carbon power generation, our analysis is focused on heat pumps. However, we recognise that there may be niche applications for conventional electric heating in 2030, for example in highly energy efficient houses with a low heat demand or where there are space constraints.

**Potential applications**

We have assessed three types of heat pumps:

- **Air Source Heat Pumps (ASHPs)** can be used in buildings with vent or wet (i.e. radiator or underfloor heating based) heating systems. ASHPs work well with vent heating systems, and can work in reverse to provide air conditioning, which has led to increasing uptake rates in the commercial sector. In the residential sector, where heating systems are predominantly wet, ASHPs can replace conventional boilers depending on the energy performance of the building (i.e. ASHPs are best suited to modern houses with loft and cavity wall insulation and double glazing).

- **Ground Source Heat Pumps (GSHPs)** will work with the same types of buildings as ASHPs. The key consideration here is outdoor space, with a GSHP requiring a large enough area to locate ground loops. Bore hole applications are an alternative option but are more expensive. GSHP are not subject to the fluctuations in outdoor temperatures in the same way as ASHPs and can thus potentially provide slightly higher COPs, especially in residential applications.

- **Heat pumps with storage** are able to recharge during off-peak periods (e.g. overnight), thereby making use of spare low carbon power generation capacity. However, with current storage options (i.e. large hot water tanks) these units are limited to installation in larger premises only.

While there is currently limited deployment of heat pumps in the UK, these are a relatively mature technology and are widely used in other countries (e.g. both in France and Sweden heat pump sales exceeded 100,000 units in 2009, while in the UK less than 15,000 were sold). Early experience in the UK has suggested the presence of deployment barriers which need to be addressed in the near term to support more widespread uptake (Box 5.4).

**Emissions reductions and economics**

Emissions reductions from heat pumps depend on operating efficiency and whether the electricity consumed is generated from fossil fuels or low carbon sources:

- **Operating efficiency.** This depends on outdoor temperatures, whether heat pumps are used for hot water in addition to heating (Box 5.5), and whether (wet) heating systems are radiator or underfloor based. Energy demand reductions in households for heat pumps vary by up to 35% depending on assumptions about operating efficiency.

- **Power generation source.** At current grid intensities, carbon savings for heat pumps compared to gas boilers are not significant. However in the future, emissions savings of up to 100% are available if the marginal source of power generation is low carbon. The cost effectiveness of heat pumps in reducing emissions depends primarily on four factors:

  - **Heat pump costs.** In the residential sector, the current cost of an ASHP is around £6,000-£10,000 and £9,000-£17,000 for a GSHP, with NERA/AEA’s analysis suggesting scope for cost reductions of around 30% by 2030 (Box 5.6).

  - **Efficiency of heat pumps:** Efficiency of heat pumps can vary by around 100%, see above (Box 5.4).

  - **Heat source replaced:** The economics of heat pumps are currently most favourable when displacing (carbon intense) oil boilers, although going forward there is also scope for cost effective displacement of gas boilers.

  - **Power generation source:** This impacts the cost effectiveness of heat pumps both because it determines the level of abatement and because the cost of abatement depends on the technology used for power generation.

**Box 5.5: Hot water**

At present heating hot water accounts for 6% of the UK’s CO2 emissions. Conventional heating equipment such as gas boilers provide both heat and hot water. In the 2030s, the following will be important:

- If a renewable system is providing hot water as well as space heating, the provision of hot water can lower system efficiencies, therefore making running costs higher.

- Our analysis has assumed that heat pumps can heat hot water with a COP of around 2. In summer, it is assumed that the heat pumps are supplemented by an immersion heater in the domestic sector, which has an efficiency of around 1.

- By 2030, nearly 50% of the additional electricity demand from heat is used for heating water, and this is higher in the domestic sector. The implications of this for the power sector are explored in chapter 3.

- The options for reducing hot water use have not been specifically addressed in this analysis. However, various options exist:
  - On the supply side, more efficient water heating and storage systems and hot water recovery systems.
  - On the demand side, efficient taps and shower heads and behavioural change measures (e.g. shorter showers).

- Hot water will make up a significant proportion of energy demand in highly efficient new homes. To meet zero carbon standards, from 2016 this demand will have to be met from renewable sources.
We estimate that the combination of these factors give a weighted average cost of heat pumps from £18 per tonne of CO₂ abated (i.e. heat pumps reduce costs) for ASHP to £7 for GSHP.

Box 5.6: Cost of low-carbon heat technologies

NERA and AEA developed detailed estimates of technical cost characteristics associated with each of the low carbon heat technologies. These characteristics varied across different customer types according to building type, location, use of the heat load, etc.

The following quantities were estimated, building upon a previous database compiled for DECC:

- Capital costs, including equipment costs, installation costs, auxiliary works, etc.
- Fixed operational costs, chiefly maintenance costs
- Lifetime
- Thermal efficiency and seasonally adjusted coefficient of performance
- Load factor
- Representative size
- Costs of low-carbon heat in the non-residential sector are generally lower due to returns to scale.

- The capital costs of each technology fall in the following ranges:

<table>
<thead>
<tr>
<th>Technology</th>
<th>Domestic (£/kW)</th>
<th>Non-domestic (£/kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASHP</td>
<td>625 – 2,150</td>
<td>568 – 635</td>
</tr>
<tr>
<td>GSHP</td>
<td>1,003 – 2,768</td>
<td>521 – 1,627</td>
</tr>
<tr>
<td>ASHP with storage</td>
<td>1,010 – 2,650</td>
<td>636 – 1,101</td>
</tr>
<tr>
<td>GSHP with storage</td>
<td>1,145 – 2,169</td>
<td>568 – 1,960</td>
</tr>
<tr>
<td>Biomass boilers</td>
<td>344 – 686</td>
<td>286 – 683</td>
</tr>
<tr>
<td>Solar Thermal</td>
<td>1,682</td>
<td>1,359</td>
</tr>
<tr>
<td>Biogas</td>
<td>1,014 – 2,500</td>
<td></td>
</tr>
<tr>
<td>CHP</td>
<td>N/A</td>
<td>592 – 1,223</td>
</tr>
<tr>
<td>District Heating</td>
<td>111-592</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Box 5.6: Costs of low-carbon heat technologies

- Costs per tonne of carbon vary between different demand segments (e.g. one of the lowest cost applications for biomass boilers is in rural off-grid properties, while the highest cost GSHPs with storage are in new build detached properties replacing gas, Figure B5.6).

- These costs are then projected to 2030, based on assumptions about likely cost reductions, (38% for heat pumps, 32% for biomass and 44% for solar thermal).

- As these cost assumptions are uncertain and are a key driver of results, this forms a part of the sensitivity analysis in our low and high scenarios.

- Capital and operating costs are calculated on a levelised basis over the equipment lifetime, using additional assumptions about fuel prices and discount rates. Costs per tonne of carbon vary as shown in Figure B5.6.

- We have also included barriers to low-carbon heat to account for costs that may not be fully reflected in the cost or performance characteristics of technologies. These barriers ultimately split into two categories:
  - Suitability constraints: these barriers are central to the selection of the correct renewable heat technologies. For example, if adequate space for locating ground loops for a GSHP is not available in a particular household, then this technology is not suitable.
  - Quantifiable barrier costs: These are factors that do not necessarily make a technology unsuitable, but may increase the burden associated with installing and operating a low-carbon heat technology in a particular location. Some of the most important barrier costs include the risk of reduced performance or comfort, disruption to production, hassle or time costs, value of space given up for equipment or fuel stores, nuisance factors such as noise.

These factors were included in our analysis via a preliminary suitability assessment of each renewable heat technology, across each building type and heat use.

These factors were included in our analysis via a sensitivity in the estimation of private costs, and in uptake in our low scenario. This drew from work conducted by Enviros on the barriers to renewable heat forms the basis of the estimation of these costs.
(ii) Bioenergy
Within bioenergy, we distinguish between biomass and biogas, and now consider each in turn.

Biomass
There is a range of potential uses of biomass to produce heat, including biomass boilers in residential and non-residential buildings, CHP for community and larger scale district heating (see Section 2(iii) below) and process heat for industry (see Section 3 below).

The key issues here are the level of sustainable biomass that is available, and where this is best used (e.g. across different heat options, and between heat, transport and power). Burning of biomass also has associated air quality considerations, particularly in dense urban areas.

- We have developed three scenarios for available biomass based on global scenarios published by the IEA (Box 5.7).
- The range in these scenarios is from 50 – 200 TWh annually.
- The high end of the range would exhaust UK capacity for domestic biomass production as estimated by E4Tech.

The economics of biomass heating depends on up-front costs, ongoing biomass costs and emissions savings versus alternatives (gas, oil, etc.). Based on this set of considerations, we estimate an average cost for biomass of around £18 t CO₂ abated in 2030.

Given the economics, and the fact that air quality impacts (Box 5.8) are easier to address in larger scale biomass boilers, the results of our modelling show that cost-effective use of biomass is limited in residential and non-residential buildings, with the bulk of use in the industrial sector. We reflect this in our scenarios for industry decarbonisation (see Section 3 below).

Box 5.7: Biomass resource availability and energy intensity
Given the uncertainty surrounding resource availability for bioenergy, scenarios were constructed based on existing projections of resource availability. Our approach differs slightly between biomass and biogas.

In biomass, we considered both a UK share of global bioenergy use in the IEA’s Blue Map scenario (Energy Technology Perspectives 2010), and estimates of the UK’s indigenous biomass resource:

- From the IEA Blue Map scenario, we estimate that approximately 320 TWh of primary bioenergy is available for the UK in 2030 (pro-rated according to total energy consumption). This total includes approximately 60 TWh of biofuels (130 TWh on a primary energy basis), leaving 190 TWh for heat and power.
- From the E4Tech supply curves for DECC (2009, central Renewable Energy Strategy scenario), the total UK resource of solid biomass is around 200 TWh in 2030.

The extent to which this resource is available for heat depends upon the resource made available to the power sector, and to transport. The following figures were used to define the upper bound for our scenarios of resource availability in heat:

- High: 200 TWh, all of the UK’s resource dedicated to heat
- Medium: 100 TWh, half of the UK’s resource dedicated to heat
- Low: 50 TWh, a quarter of the resource dedicated to heat

The Medium Abatement scenario gives total bioenergy use consistent with the IEA BLUE Map.

Biogas feedstock availability is highly uncertain, as it depends upon the availability of food waste, which in turn depends upon diets, recycling rates, and the success of efforts to reduce waste.

- In developing our scenarios, biogas feedstock availability was based on estimates of available waste streams, agricultural residues and energy crops. These estimates drew from the trends in availability observed to date (WRAP, 2009). AEA/NERA extended this analysis of trends out to 2030 based on a range of reports that have estimated the likely pathways for biogas feedstock over the medium term (WRAP, 2008, NNFCC, 2009, Defra, 2005 and 2009).
- This resulted in a total technical potential of feedstock availability of around 20 TWh in 2030. Around 20 TWh of solid biomass from the biomass scenarios described above is also assumed to contribute as a feedstock for gasification into biogas.
- A nominal amount of biogas feedstock is also required in the power sector, where it is assumed that the level of biogas specified in the Renewable Energy Action Plan is taken up. This amount does not compromise the ability to roll out biogas in heat as we assume that it can be constituted from other feedstocks than are used in heat (e.g. through a greater use of energy crops).

In the modelling of biomass and biogas uptake we have assumed the following:

- The value of the lifecycle emissions of biomass is drawn from analysis by AEA for the Environment Agency, as approximately half the emissions intensity of gas.
- The emissions intensity of biogas is assumed to be zero, on the basis that different feedstocks have different lifecycle emissions intensities, some of which could reasonably be assumed to be zero (or even negative, e.g. food waste). Other feedstocks, such as energy crops, would have a positive emission intensity but given the low levels of energy crops used in these scenarios a zero value is considered reasonable. However, in calculating resulting emissions savings, we have assumed the emissions intensity of biomass to be zero in line with carbon budget accounting and the national emissions inventory.

Biogas

Biogas can be used to produce high grade heat, and can therefore be used as a substitute for fossil fuels in residential, non-residential and industrial sectors, either through grid injection or use in CHP plants or in industrial boilers. It is primarily produced by the anaerobic digestion of waste streams, and predominantly from agricultural and food waste. In addition, biogas can be produced from dedicated crops or a combination of waste (e.g. slurry) and crops. Solid biomass can also be gasified but the development and deployment of such systems is still at an early stage.

Biogas is a relatively low cost form of renewable heat, requiring upfront plant costs which are offset by marginal costs of production that are lower than conventional gas. The analysis that we have commissioned from NERA suggests that the balance of these two cost impacts is such that the net abatement cost of biogas is around £56/tCO₂ (Box 5.6).

Given its cost effectiveness, the key issue for deployment of biogas in the 2020s is its availability. The NERA analysis suggests that there is likely to be sufficient biogas available from anaerobic digestion to generate up to 10% of total heat, which is within the range suggested by other studies. In addition, there may be scope to double this through the production of biogas from biomass gasification. However, this is more uncertain, given the need for technology development to unlock biomass gasification, and questions over whether this would be the best use of biomass.
• **Low carbon generation CHP.** Our power sector scenarios in Chapter 4 assume that around 30 GW of thermal low carbon power capacity (nuclear and CCS) could be added to the system in the period between 2020 and 2030. There is the possibility that this could be designed to allow off-take into district heating networks of heat that would otherwise be wasted (accounting for up to 55% of total energy input). The costs of incorporating CHP technology in low carbon power stations is relatively small relative to the potential lifetime heat demand, reflected in an abatement cost of -£238/tCO₂. Heat off-take from nuclear plants for district heating and industry applications is already common place in a number of countries (e.g. Russia, Czech Republic, Switzerland). However, while some low carbon power generation may be located close to heat loads (e.g. CCS in Teesside), nuclear power stations tend to be remotely located, suggesting additional costs of linking to heat demand (see below).

In summary, there may be near term opportunities for investment in conventional gas CHP as a cost effective means for reducing emissions. Beyond the near term, cost-effective emissions reductions would be available from CHP using low carbon power generation, subject to the costs of investing in infrastructure and transporting heat to demand centres.

**District heating costs**

Heat is typically supplied into district heating networks from CHP plants or from large-scale district heating boilers. Networks can be large (e.g. city-wide) but there are also smaller community networks. In the UK, district heating only supplies 1% of heat, while in Denmark and Sweden the share is around 50%. Currently, most district heating networks are primarily based on heat produced by fossil fuelled plant, although there are examples of low carbon district heating systems (e.g. in Sweden, where 70% of district heating comes from mixed low carbon sources including biomass, geothermal, municipal waste and solar thermal).

To utilise heat from low carbon power generation, it would be necessary to transport this from the power station to the source of heat demand. Given that low carbon power stations will typically be located in coastal areas, this would require transport from power stations to urban areas (where demand is sufficiently dense to potentially justify network investment), and local distribution:

• **Transport from power stations to urban areas.** District heat can be economically transported several tens of kilometres, depending on the pipeline cost, the pipeline energy loss, the density of the urban heat load and the cost of alternative heat provision. Well insulated pipes can reduce transmission losses but add to the cost. For example in the Czech Republic a 40km heat pipeline from the Dukovany nuclear plant is currently being assessed.

• **Local distribution.** Data on existing district heating projects shows that the levelised cost of installing a network can be high, at around £22/MWh. The capital cost of large scale district heating schemes is around £1,500/kW, and the operating cost around £15/kW per year. District heating networks can typically have a life up to 50 years, and cost effectiveness of the network relies on a demand for heat throughout this period (we assume 4,000 hours per year). Local distribution of heat also leads to some losses, which typically are around 10% of total heat supplied.

Adding transport and distribution costs to the costs of fitting CHP technology to low carbon generation suggests a total cost of around -£110/tCO₂ abated, which is attractive relative to the cost of heat pumps (i.e. from -£18 to £7/tCO₂).

**Our approach to district heating**

There is a high degree of uncertainty around the technical and economic aspects of district heating based on low carbon CHP, due to the site specific considerations such as the availability of a low carbon heat source near heat loads. However, our preliminary analysis suggests that this may be a promising option, and one that should be explored further. It could for example help to reduce emissions from the section of the building stock which is particularly difficult to treat (e.g. urban conservation areas with a large proportion of solid walled buildings). Also, as stated above for CHP, the use of waste heat from power stations and industry makes the use of energy in these applications more efficient.

However, and given current uncertainties, we adopt a cautious approach whereby our buildings scenarios include relatively low penetration rates for district heating in 2030 (e.g. in our Medium Abatement scenario, district heating accounts for up to 10% of heat demand in 10 cities with high heat density by 2030 – see Section 2.3). Importantly, our analysis suggests that the cost-effective level of roll out from district heating may be in excess of these levels, but non-financial barriers (e.g. lack of certainty about number of customers) to implementation currently constrain investment. Further work is required to determine both the optimal role of district heating in contributing to carbon budgets and ways of overcoming non-financial barriers to implementation.

**Buildings emissions scenarios**

**Scenarios for energy efficiency improvements to reduce heat emissions**

Our scenarios for buildings model a range of energy efficiency improvements in the residential and non-residential sectors.

• **In the residential sector,** we model three energy efficiency scenarios, centred around the roll-out of solid wall insulation. Our low efficiency scenario assumes no further take up of solid wall insulation beyond our Extended Ambition scenario (i.e. 2.3 million by 2022), with a total of 3.5 million by 2030 in our medium scenario, rising to 5.7 million in our high scenario.
• In the non-residential sector, our scenarios assume continuing savings from energy efficiency measures installed during the first three budget periods, as well as from new buildings during the 2020s. Due to the weak evidence base (see section 2.1 (iv)) we have assumed no further uptake of energy efficiency measures in the existing stock through the 2020s.

Scenarios for low carbon heat deployment

In developing scenarios for low carbon heat, we have used a model developed for us by NERA/AEA (see box 5.3 above). The model considers the full set of options for low carbon heat and selects those that are cost effective relative to a carbon price projection. We have developed three scenarios for low carbon heat deployment based on different assumptions around suitability, cost and efficiency (Table 5.1, Figures 5.9 and 5.10):

• **Low Abatement scenario.** The low scenario includes limited departure from the reference scenario, with low levels of heat pump, biomass and biogas penetration, together with some district heating. It reflects low levels of energy efficiency improvement, limited suitability and high costs (including hidden costs).

• **Medium Abatement scenario.** The medium scenario includes significantly increased heat pump penetration, together with some further biomass deployment. It is consistent with the wider uptake of energy efficiency measures and hence building stock suitability, technology innovation to reduce costs, and the potential to reduce hidden costs.

• **High Abatement scenario.** There is further penetration of both heat pumps and district heating in our high scenario, based on faster district heating network roll-out and further energy efficiency improvements.

**Table 5.1: Penetration of Low Carbon Heat Technologies**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Heat Pumps</th>
<th>% of total heat demand (in 2030)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Abatement scenario</td>
<td>78</td>
<td>13%</td>
</tr>
<tr>
<td>Biogas</td>
<td>20</td>
<td>3%</td>
</tr>
<tr>
<td>Biomass</td>
<td>7</td>
<td>1%</td>
</tr>
<tr>
<td>District Heating</td>
<td>10</td>
<td>2%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>115</strong></td>
<td><strong>19%</strong></td>
</tr>
<tr>
<td>Medium Abatement scenario</td>
<td>143</td>
<td>24%</td>
</tr>
<tr>
<td>Biogas</td>
<td>20</td>
<td>4%</td>
</tr>
<tr>
<td>Biomass</td>
<td>13</td>
<td>2%</td>
</tr>
<tr>
<td>District Heating</td>
<td>10</td>
<td>2%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>186</strong></td>
<td><strong>32%</strong></td>
</tr>
<tr>
<td>High Abatement scenario</td>
<td>154</td>
<td>26%</td>
</tr>
<tr>
<td>Biogas</td>
<td>35</td>
<td>6%</td>
</tr>
<tr>
<td>Biomass</td>
<td>17</td>
<td>3%</td>
</tr>
<tr>
<td>District Heating</td>
<td>40</td>
<td>7%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>246</strong></td>
<td><strong>42%</strong></td>
</tr>
</tbody>
</table>

Our scenarios for low carbon heat technologies are therefore dominated by heat pumps (e.g. these account for around 70% of emissions reduction potential in our Medium Abatement scenario, see figure 5.9 and 5.10). Limited use of biomass and biogas in buildings reflects the fact that there is scope for cost effective application in industry (see Section 3). Limited penetration of district heating in our scenarios is a cautious approach reflecting current uncertainties over technical and economic aspects of this option.
Total abatement potential from buildings

The sum of direct emissions abatement potential from the range of measures – energy efficiency improvement and deployment of low carbon heat – is up to 57 MtCO₂ in 2030 (Figure 5.11). With maximum implementation of measures, buildings CO₂ emissions would account for a share of around 18% in total emissions in 2030, compared to 35% currently (i.e. buildings emissions reductions would move at a faster pace than the economy as a whole). The carbon intensity of the buildings sector falls considerably (Figure 5.12). We include the full range of scenarios for buildings emissions in our economy wide assessment (Chapter 3).

Path from 2030 to 2050

Options for further reductions after 2030 for the buildings sector include:

- Further improvements in fabric energy efficiency in the residential sector, with insulation of many of the remaining four or so million 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, linked to refurbishment opportunities.
- Further roll-out of heat pumps and low carbon district heating to all sectors.
- By 2050, we expect the buildings sector to be highly energy efficient and most heating requirements to be met by low carbon sources. This will ensure that the buildings sector is zero carbon or close to zero carbon as required to meet the economy wide 2050 target and given limited scope for reducing emissions in some sectors (Figure 5.13).
Table 5.2: Cost ranges of Medium Abatement scenario

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Costs (£bn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium</td>
<td>£1.2</td>
</tr>
<tr>
<td>Medium – high fossil fuel prices</td>
<td>-£1.1</td>
</tr>
<tr>
<td>Medium – low fossil fuel prices</td>
<td>£3.9</td>
</tr>
<tr>
<td>Medium – high capital costs</td>
<td>£2.2</td>
</tr>
<tr>
<td>Medium – low capital costs</td>
<td>-£0.1</td>
</tr>
</tbody>
</table>

Scenario costs – private basis

However, when considering the implementation of options, it is important to recognise that households and businesses will not use this social discount rate:

- Households may attach more weight to upfront costs than future benefits.
- A related point is that future benefits may be over-discounted where there are uncertainties around technology performance.
- Even when attaching appropriate weight to the future versus the present, finance may not be available at the social discount rate (e.g. due to household credit risk).
- At the corporate level, required returns for projects are typically higher than the social discount rate, which can result in a lack of priority for investments to reduce emissions, especially where they compete for capital with other investments that have higher returns.

In order to reflect divergence between social and private costs, we have modelled sensitivities based on a 10% discount rate:

- The cost of solid wall insulation in a medium gas price scenario rises from £41m to £93m at a 10% discount rate.
- The cost of low carbon heat technologies in a medium gas price scenario rises from £1.2bn to £4.8bn at a 10% discount rate.

The fact that costs rise significantly with higher discount rates does not suggest that these options are not viable in terms of meeting the fourth carbon budget. Rather, it suggests that policy approaches are required to bring private discount rates closer to social discount rates. Policies may include providing better information about future benefits, raising the profile of emissions reducing measures on the corporate agenda, and development of specific financial instruments that extend finance at social discount rates on the basis of appropriate financial security packages (e.g. energy efficiency financing through a Green Investment Bank). Given such policies, and with some residual hidden costs (e.g. space loss due to solid wall insulation), the range of options in our scenarios appear to be economically viable.
3. Emissions reductions in industry

Our Extended Ambition scenario includes industry emissions reductions in the period to 2020 through a range of measures including switching to less carbon intense fossil fuels, and increased penetration of biomass and biogas under the RHI. Emissions in 2020 under this scenario are around 157 MtCO₂ (i.e. 30% of total UK GHG emissions), with energy intensive industries accounting for around 50% of this total (Figure 5.14).

In the absence of any further measures beyond the Extended Ambition scenario, industry emissions could account for almost all of total allowed UK emissions in 2050. It is therefore important that industry emissions are further reduced, both to meet carbon budgets through the 2020s and in the context of the 2050 target, where there is a very limited envelope for all emissions including industry emissions. This section focuses on opportunities for further abatement across the 2020s.

In understanding options for reducing emissions, we first develop a reference emissions projection for the 2020s. This reflects changes in GDP, fuel prices and industry specific factors (e.g. planned changes in regulation of refineries), and results in emissions of approximately 150 MtCO₂ in 2030.

We then disaggregate the reference projection in 2030 to highlight options for emissions reductions:

- The majority of direct emissions in industry in the reference projection come from the combustion of fuels (68 MtCO₂, Figure 5.15):
  - A significant portion of this is used to generate heat (47 MtCO₂), including space heating (7 MtCO₂ considered in section 2 above) and low and high grade heat for industrial applications (40 MtCO₂). Typically low grade heat is used in non-energy intensive industries, raising the possibility, for example, that these could switch to use of electricity or biomass. Energy intensive industries (such as iron and steel) typically require high grade heat, suggesting that switching to biomass, biogas and CCS may be the most promising options.
  - The remainder of combustion (around 22 MtCO₂) is comprised predominantly of drying and separation (this includes drying materials using air flow/ventilation, rather than heat) and a range of other smaller uses.
- Process emissions are projected to make up a further 16 MtCO₂, which arise from chemical reactions within industry (e.g. the calcination of limestone in the production of cement).
- Emissions from the use of electricity are projected in the reference case to constitute around 28 MtCO₂ of emissions by 2030, mainly for running motors and electric heating. This is a substantial reduction on 2008 levels (52 MtCO₂), primarily due to decarbonisation of the power sector.
- In addition to the above, 36 MtCO₂ are projected in the reference case to come from refineries and other energy supply, which are categorised separately from the rest of industry to highlight that these industries produce fuels for downstream combustion, which is detailed below. These emissions could be reduced both through the optimisation of refineries and declining demand for fuels due to the decarbonisation of the economy (e.g. transport sector).
Opportunities for abatement during the 2020s

We now consider in more detail the following options for reducing emissions through the 2020s:

- Conventional energy efficiency
- Renewable space heating
- Use of biomass
- Use of biogas
- CHP
- CCS
- Further options within carbon-intensive industry

Owing to the limited availability of low carbon generation to 2030 (see chapter 6), we do not assess the potential for widespread application of electricity within industry (e.g. electrolysis for steel making industry). However, electrification in industry may provide an additional abatement opportunity beyond 2030.

Conventional energy efficiency

Our analysis of emissions reductions in industry has previously focused on cost-effective, short pay-back options for abatement such as improvements to the efficiency of motors (which we refer to here as conventional energy efficiency). As outlined in our 2010 Progress Report to Parliament, the evidence base for assessing emissions reductions from conventional energy efficiency requires strengthening:

- Analysis relies predominantly on the “ENUSIM” model, which under-represents the opportunities for fuel switching and longer payback options within industry
- The accuracy of the data underpinning ENUSIM is reliant on the often limited ability and/or willingness (given commercial considerations) of industry to provide information regarding abatement opportunities.

Reflecting these shortcomings, we have not identified any further abatement from energy efficiency in industry during the 2020s.

Renewable space heating

The 7 MtCO₂ emissions from space heating in industry in 2030 can be reduced through the use of the low carbon heat technologies discussed in section 2. Using a combination of heat pumps, biomass, biogas, our analysis suggests that around 4 MtCO₂ of abatement is cost effective in the 2020s relative to a carbon price of £70 per tonne of carbon abated. This is additional to the 1 MtCO₂ that is cost-effective in 2020.

Use of biomass

Our Medium Abatement scenario suggests that biomass could be used to meet around 55% of industrial heat demand in 2030.

- The biomass resource for heat is 100 TWh in our medium biomass scenario.
- Projections of heat loads in industry suggest that there will be approximately 180 TWh of industrial heat load in 2030. Of this, 140 TWh is suitable for biomass use (many applications are unsuitable due to gas quality constraints e.g. clean burning fuels are required for ceramic kilns).

Our analysis suggests that the cost of biomass in industry is around £18/tCO₂ abated relative to heat from gas boilers. Based on this, biomass is a cost-effective option for reducing around 39 TWh (22%) of industrial heat demand by 2030 when compared with a carbon price of £70/tonne, resulting in around 13 MtCO₂ emissions savings.

Use of biogas

Our Medium Abatement scenario suggests that around 20% of industrial heat demand in 2030 could be met with biogas, with around half of this from anaerobic digestion and half from gasification of biomass:

- The biogas resource from anaerobic digestion could account for up to 20 TWh of industrial heat demand in 2030. A further 18 TWh of additional biogas is available through the gasification of biomass.
- Heat from biogas is suitable for the majority of industrial heat demand and for applications which require a high quality of gas (where biomass may be unsuitable). This suggests that biogas could provide 20% of industrial heat demand in 2030, additional to that provided by biomass.

As set out in section 2.2 (ii) above, biogas is a relatively cost-effective renewable heat option, with a cost of around £56/tCO₂ abated. Based on this, biogas is a cost-effective option for reducing around 6 TWh (around 5%) of industrial heat demand by 2030 at a carbon price of £70/tCO₂.

CHP

As outlined in section 2.2 (iii) above, given the need to decarbonise both power and heat on the path to meeting the 2050 target, the role for natural gas CHP generation is limited in the 2020s.

The analysis carried out for us by NERA/AEA suggests that costs of biomass CHP are relatively high compared to biomass boilers. In our Medium Abatement scenario, almost all of the available resource is thus taken up either directly in biomass boilers, or through gasification of this resource to make biogas.
There may be potential for use of heat networks to supply industrial heat demand, particularly where industrial heat loads are co-located with a heat source (e.g. CHP and/or waste heat sources). There may also be further scope for using industrial waste heat in district heating networks to supply heat to homes and businesses. As indicated above, further work to explore this option is required to estimate costs and delivery risks. However, our initial analysis indicated that this may be a low cost form of emissions abatement.

CCS

Carbon Capture and Storage (CCS) technology is most frequently discussed in the context of power generation, and specifically coal-fired power generation. In Chapter 6, we set out the role for CCS applied to both coal and gas-fired generation and suggest that both applications are likely to be important and should be demonstrated in the period to 2020.

As with power generation, there are currently no examples of scale application in industry. However, it is likely that this technology will be feasible in energy intensive industries including iron and steel, industrial CHP, refining, cement and chemicals.

We commissioned analysis from Element Energy to assess the viability of CCS in industry. With the caveat that this is highly uncertain given the current stage of technology development, their analysis suggests that CCS could be both widely applicable in energy intensive industries and cost effective:

- CCS could reduce emissions from energy intensive industry by 5 MtCO₂ in 2030 and 37 MtCO₂ in 2050.
- The associated abatement costs are within projected carbon prices over the period to 2030.

Given the need to reduce industry emissions, the potential of CCS and the limited potential from other options, particularly in the energy intensive sectors, industry CCS should be demonstrated in the period to 2020. This would lay the foundations for deep cuts in industry emissions in the period to 2030 and beyond.

Further options within carbon-intensive industry

Several recent reports (e.g. IEA Energy Technology Perspectives) have identified a number of future technologies and approaches in carbon-intensive industry which may result in substantial opportunities for abatement. We commissioned analysis from AEA to assess the feasibility and cost effectiveness of a wide range of future technologies within the six most carbon intensive industries in the UK, accounting for nearly half of industrial emissions as projected by the DECC energy model.

Assessing further abatement opportunities in the industrial sector is particularly challenging due to:

- Uncertainties surrounding the future shape of industry and demand for products, including what proportion of this demand will be met by manufacturing in the UK.
- Uncertainty surrounding the options for reducing industry emissions, and in particular accurate costs and abatement potential of these options.
- Deployment of these technologies is highly dependent on non-financial and/or site specific practical considerations. For example, options that involve significant new infrastructure may have to be installed simultaneously with the refurbishment cycles of existing plant.

Given these challenges, a bottom-up approach to calculating industrial abatement was adopted, employing the knowledge of key sector experts to identify opportunities for abatement in each of the sectors considered.

Iron and steel

Emissions from the production of steel in the UK arise primarily through process emissions in the blast furnace (the smelting process that turns iron ore into pig iron) and through primary steelmaking (which removes the carbon content from pig iron to create steel). Approximately 25% of steel output in the UK is through an alternative steel production route – electric arc furnaces – which uses electricity and is therefore responsible for indirect emissions.

Although a wide range of options was considered for this sector, only a small number was deemed capable of delivering substantial cost effective abatement by 2030. Most significantly, increased recycling of steel could deliver around 5 MtCO₂ at a cost of -£22/tCO₂, although there is some uncertainty surrounding this option.

Further abatement was provided through improvements to the blast furnace (e.g. use of fuel injection, neural networks to improve productivity) and improvements to the electric arc furnace (e.g. continuous strip production, continuous charging).

The ability to increase the use of scrap steel is limited by the level of impurities within scrap, and much of the high quality scrap is already reused. Further work is required to refine the estimates used within this study.

Cement

Emissions in the cement sector arise both from energy use (around 30% of emissions, through firing of cement kilns) and from processes (around 70%, primarily through the calcination of limestone).

Further abatement in the cement sector can be principally achieved through the use of clinker substitutes. The use of these substitutes reduces the energy required for calcinations and the emissions from the clinkering reaction. Clinker substitutes could contribute around 1.5 MtCO₂ of abatement by 2030, at a cost of -£34/tCO₂.

We also considered the potential of other cement substitutes, such as low carbon cement. However, given the early stage of development of these alternatives, we assume that these are unlikely to play a major role until after 2030.
Refrigeration and other energy supply

Refrigeration produce emissions from a range of different operations, including heat, and the flaring of waste products. Refrigeration and other energy supply (e.g. collieries, offshore oil and gas) are distinct from other industry sectors in that they produce fuels for downstream consumption. Fuels produced by refineries are used predominantly in the transport sector, but also within industry and in the residential sector (Figure 5.16). This implies that changes in fuel consumption from abatement opportunities in other sectors (e.g. due to a switch from petrol cars to electric cars, see Chapter 4) may reduce the emissions from refineries and reduce what potential for abatement is available, although there is uncertainty surrounding how the sector might respond to a reduction in domestic fuel demand.

Within the upstream emissions from refineries, there is significant scope for emissions abatement in the UK by bringing them up to the standard of the best performing plant in the Benelux and Scandinavian countries. The energy efficiency of refineries may be improved through a number of measures that can optimise operation (e.g. through the elimination of flaring). There is around 3.5 MtCO₂ of abatement available in 2030 from the implementation of these measures across many of the refineries in the UK, at an average cost of £96/tCO₂.

A number of barriers are present that make these cost-effective opportunities difficult to realise:

- A number of substantial changes are likely in the refining industry to 2030 and the net impact on emissions is highly uncertain (e.g. declining throughput from refineries and potential closures, regulation and potential future requirements at the EU level and increasing demand for diesel aviation fuel).

The vertical integration of oil companies means that there is a lot of competition for capital investment across the whole supply chain for petroleum products. In the current environment of low margins on refining operations, oil companies may find better investment opportunities in other parts of the petroleum products supply chain.

Chemicals, food and drink, glass

There are several low cost opportunities for abatement in these sectors which could be rolled out by 2030, together contributing around 1 MtCO₂ of abatement by 2030:

- In the chemicals sector many low cost opportunities exist, including for example the replacement of distillation with less energy intensive membrane processes.
- In food and drink, options including more efficient heating and cooling (e.g. through heat recovery) and the use of membranes for concentrating/purifying liquids.
- In the glass sector, the abatement opportunities are mainly focused on reducing emissions from the melting process in the glass furnace.
Scenarios for reducing industry emissions

As with our buildings scenarios, our starting point in developing industry scenarios is a reference projection. This projection assumes a level of direct industry emissions commensurate with our Extended Ambition scenario for 2020 (i.e. 117 MtCO₂), and that this grows in line with GDP such that emissions in 2030 are around 121 MtCO₂.

Our emission reduction scenarios then net off emission reductions from the options that we have considered above, selecting a level of uptake that is cost-effective relative to a carbon price of £70/t in 2030 (Figure 5.17):

- Low abatement. The low scenario represents a low level of uptake of biomass, no deployment of CCS prior to 2030, and a less optimistic level of uptake within the carbon intensive industries (reflecting a high degree of constraints on deployment e.g. lower availability of scrap metal of sufficient quality for recycling)
  - Biomass, biogas, CHP, heat pumps = 8 MtCO₂
  - Carbon intensive sectors = 7 MtCO₂

- Medium abatement. The medium scenario represents further availability of biomass, together with options from CCS that are both cost-effective and could be deployed based on the refurbishment rate of major industrial plant. Further options are included in the energy intense sectors reflecting a lower degree of constraints on deployment (e.g. higher availability of scrap metal for recycling).
  - Biomass, biogas, CHP, heat pumps = 14 MtCO₂
  - CCS = 5 MtCO₂
  - Carbon intensive sectors = 12 MtCO₂

- High abatement. The high scenario reflects a higher availability of biomass, more deployment of gasification technologies which increases the availability of biogas, a higher deployment of CCS and an even lower degree of constraints on deployment for options in the carbon intensive sectors.
  - Biomass, biogas, CHP, heat pumps = 17 MtCO₂
  - CCS = 20 MtCO₂
  - Carbon intensive sectors = 18 MtCO₂

In total for the Medium Abatement scenario, these options offer potential direct emissions reductions of 31 MtCO₂ during the 2020s, which would result in direct industry emissions of 90 MtCO₂ in 2030 (Figure 5.18). The associated cost would be of the order of up to £0.1bn (<0.1% of GDP, with the bulk of this cost accounted for by CCS and to a lesser extent biomass).

Therefore, while there is a great deal of uncertainty over the scope for industry emissions reductions, both as regards levels of sustainable biomass and biogas and applicability/cost of CCS, there are plausible scenarios where significant emissions reductions are available at affordable cost through the 2020s. We reflect these scenarios in our economy wide scenarios and recommendations in Chapter 3.

Path from 2030 to 2050

The main options for further reductions after 2030 include increased roll-out of CCS and increased penetration of bioenergy:

- CCS: Analysis for the CCC by Element Energy projected the potential contribution from the contribution from the roll-out of CCS to be 37 MtCO₂ in 2050 (32 MtCO₂ additional to that assumed in our Medium scenario).
- Biomass: In our scenarios, biomass is distributed across space heating and industrial applications according to where it is most cost-effective. However, after 2030 further electrification of space heating suggests that this resource could be shifted to industrial applications. Similarly, electrification of heat could lead to more biogas resource being made available, which could also be shifted to the industrial heat sector. A combination of these options could lead to a further 17 MtCO₂ abatement of direct emissions.
4. Implications for the first three budgets

To deliver the emissions reductions required from buildings and industry which we have outlined in this chapter, there are a number of implications for action in the first three budgets:

- **Energy efficiency improvement.** The path for heat decarbonisation reinforces the need for ambitious energy efficiency improvement in the period to 2020 and beyond. Improved building stock energy efficiency enables the large-scale deployment of heat pumps and reduces emissions from those buildings which will continue to be served by fossil-fuelled heating. Therefore it is important that new policy approaches currently under development (e.g. the Green Deal for the residential and non-residential sectors and the new supplier obligation) are finalised and implemented. These need to deliver significant emission reductions, especially from solid-walled houses.

- **Renewable heat deployment.** Given the potentially high levels of renewable heat deployment needed in the 2020s, it will be important to make progress in this area in the period to 2020 (i.e. high levels of deployment in the 2020s are not plausible unless there is significant progress over the next decade). The RHI is key here, and based on the analysis in this chapter, it should be focused on delivering heat pumps (prioritising off-grid and commercial sector deployment), biomass and biogas in order to lay the foundations for required heat decarbonisation in the 2020s.

- **Fuel poverty mitigation.** Both energy efficiency and renewable heat deployment can help to reduce the incidence of fuel poverty in the face of rising energy and carbon prices. Therefore, the Government needs to fund specific programmes targeted at implementing these measures in vulnerable households (e.g. through the future supplier obligation and additional Government funded programmes), see Chapter 8.

- **Power market reform.** We propose in Chapter 6 that current electricity market arrangements should be reformed, and that a quantity instrument be introduced to provide confidence about the level of low carbon generation capacity that will come onto the system in the 2020s. The level of heat pump deployment in the 2020s, together with the level of electric car penetration (Chapter 4) will have crucial implications for the appropriate quantity of low carbon generation investment through the 2020s.

- **Industry CCS.** This is a promising technology in an area which accounts for a significant proportion of total emissions and where emissions reductions will be required to meet carbon budgets in the 2020s and beyond. The challenge now is to demonstrate industry CCS in tandem with demonstration of this technology on coal and gas-fired power stations.
5. Key findings

The UK’s total emissions coming from buildings and industry.

Energy consumed in homes for space and water heating.

Leaky solid walled houses should be properly insulated by 2030, that’s about half of the total.

Number of homes which could be heated by low carbon heat by 2030.

Heat pumps can be up to 4 times more efficient in generating heat from electricity when compared to conventional electric heating systems.

By 2050, we expect the buildings sector to be zero carbon in order to meet the 80% target.

There is scope for reducing industry emissions by almost half between now and 2030.

- **R&D.** Further technology research and development is needed including:
  - Advanced insulation materials
  - Biomass gasification & CHP
  - Heat pump COPs

There are also three areas that we have identified where further evidence is required:

- **Biomass.** This is a potentially important option for decarbonisation of industry, but with uncertainties over available sustainable supply. Further evidence is required on likely sustainable biomass availability through the 2020s and beyond. The Committee will report on this as part of a broader review of bioenergy, to be published before the end of 2011.

- **District heating.** The possibility of using waste heat from low carbon power generation is attractive but uncertain. Further evidence is required on technical and economic aspects of heat generation, transport, distribution and heat demand in order to better understand the extent to which this is likely to provide a viable option for deployment in the 2020s.

- **Industry.** The evidence base for abatement potential within industry needs strengthening. This includes both the sectors we have covered in this report and additional sectors (e.g. the construction sector), as well as non-heat related combustion (e.g. drying and separation). In addition, there may be scope for abatement through reducing demand in industry (e.g. light-weighting of steel products) and reduction in consumption by end consumers, although further data on this is required.