The Carbon Plan: Delivering our low carbon future

December 2011

HM Government

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Delivering our low carbon future

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December 2011

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Foreword

Even in these tough times, moving to a low carbon economy is the right thing to do, for our economy, our society and the planet. This plan sets out how Coalition Government policies put us on track to meet our long term commitments. The Green Deal will help cut energy bills, the Green Investment Bank will attract new investment, and our reforms to the electricity market will generate jobs in new low carbon industries. Climate change requires global action; every country needs to play its part. This Carbon Plan shows that the UK is prepared to govern in the long term interests of the country and build a coalition for change.

David Cameron
Prime Minister

Nick Clegg
Deputy Prime Minister

In June 2011, the Coalition Government enshrined in law a new commitment to halve greenhouse gas emissions, on 1990 levels, by the mid-2020s. This Carbon Plan sets out how we will meet this goal in a way that protects consumer bills and helps to attract new investment in low carbon infrastructure, industries and jobs.

By 2020, we will complete the 'easy wins' that have helped emissions to fall by a quarter since 1990. By insulating all remaining cavity walls and lofts, while continuing to roll out more efficient condensing boilers, we will cut the amount consumers spend on heating by around £2 billion a year. Having fallen by a quarter in the last decade, average new car emissions will fall by a further third in the next, as internal combustion engines continue to become more efficient. Emissions from power stations, already down a quarter since 1990, will fall a further 40%, with most existing coal-fired power stations closing.

Over the next decade, we must also prepare for the future. The 2020s will require a change of gear. Technologies that are being demonstrated or deployed on a small scale now will need to move towards mass deployment. By 2030, up to around a half of the heat used in our buildings may come from low carbon technologies such as air- or ground-source heat pumps. Electric or hydrogen fuel cell cars will help to reduce vehicle emissions to less than half today's levels. New low carbon power stations – a mix of carbon capture and storage, renewables and nuclear power – will be built. In the 2020s, we will run a technology race, with the least-cost technologies winning the largest market share. Before then, our aim is to help a range of technologies bring down their costs so they are ready to compete when the starting gun is fired.

The transition to a low carbon economy will require investment. But by insulating our homes better, and driving more fuel efficient cars, we will use less energy, offsetting the funding needed for low carbon energy. By investing in more diverse energy sources, we will be less vulnerable to fossil fuel price spikes. And by investing in industries that suit our geography and skills, such as offshore wind and carbon capture and storage, we will gain a long-term comparative advantage in industries with a big future.

This plan shows that moving to a low carbon economy is practical, achievable and desirable. It will require investment in new ways of generating energy, not a sacrifice in living standards. But turning it into reality will require business, government and the public pulling in the same direction. We face big choices on infrastructure and investment. I hope over the next year this plan can help us to forge a new national consensus on our energy future.

Chris Huhne
Secretary of State for Energy and Climate Change

Executive summary

1. This plan sets out how the UK will achieve decarbonisation within the framework of our energy policy: to make the transition to a low carbon economy while maintaining energy security, and minimising costs to consumers, particularly those in poorer households.

2. Emissions are down by a quarter since 1990.[1] Current policies put the UK on track to cut emissions by over a third, on 1990 levels, by 2020. In the next ten years, we will develop and deploy the technologies that will be needed to halve emissions in the 2020s. This will put the UK on a path towards an 80% reduction by 2050.

3. By moving to a more efficient, low carbon and sustainable economy, the UK will become less reliant on imported fossil fuels and less exposed to higher and more volatile energy prices in the future.

Box 1: The Climate Change Act 2008 and the carbon budget framework

The Climate Change Act established a legally binding target to reduce the UK's greenhouse gas emissions by at least 80% below base year levels by 2050, to be achieved through action at home and abroad.[2] To drive progress and set the UK on a pathway towards this target, the Act introduced a system of carbon budgets which provide legally binding limits on the amount of emissions that may be produced in successive five-year periods, beginning in 2008. The first three carbon budgets were set in law in May 2009 and require emissions to be reduced by at least 34% below base year levels in 2020.

The fourth carbon budget, covering the period 2023–27, was set in law in June 2011 and requires emissions to be reduced by 50% below 1990 levels.[3]

This report sets out the proposals and policies for meeting the first four carbon budgets.

	First carbon budget (2008–12)	Second carbon budget (2013–17)	Third carbon budget (2018–22)	Fourth carbon budget (2023–27)
Carbon budget level (million tonnes carbon dioxide equivalent ($MtCO_2e$))	3,018	2,782	2,544	1,950
Percentage reduction below base year levels	23%	29%	35%	50%

1 This figure includes the effect of emissions trading. UK territorial emissions have fallen by 28% over the same period.

2 The base year is 1990 for carbon dioxide, nitrous oxide and methane, and 1995 for hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.

3 To be reviewed in 2014 in light of EU Emissions Trading System cap.

Progress so far

4. Our past record shows that progress is possible. Between 1990 and 2010 emissions from power stations fell by almost a quarter, as the 'dash for gas' in the 1990s saw large numbers of coal-fired power stations replaced. In the last decade wind and other renewables have grown to the point that they now provide nearly a tenth of UK generating capacity. With nuclear power generating 16% of total UK electricity, a quarter of electricity generation is now low carbon.

5. In buildings, emissions have fallen by 18%, despite the growth in population and housing. Regulation has required the introduction of new, more efficient condensing boilers, saving at least £800 million this year on energy bills. Eleven million homes, 60% of all homes with cavity walls, have been fitted with cavity wall insulation. This will reduce the amount the UK spends on heating in 2011 by £1.3 billion.

6. In transport, emissions are roughly the same as they were in 1990. Emissions rose before 2007 as the economy grew and transport demand increased, but have since fallen due to improvements in new car efficiency, an increased uptake of biofuels and, to a lesser extent, the recent economic downturn.

7. Since 1990 industrial output has grown at an average of 1% a year while emissions have fallen by 46%. Industry has become more energy efficient and the UK's industrial base has shifted towards higher value, more knowledge-intensive sectors.

8. Agricultural emissions have fallen by almost a third, due in part to more efficient farming practices, while the diversion of waste from landfill, as a result of the landfill tax, has cut waste emissions by more than two thirds.

9. Government policies are already helping consumers. Our analysis predicts that average energy bills for domestic consumers will be 7.1% lower in 2020 than they would have been without policy interventions in place.

Vision

10. However, if we are to cut emissions by 80% by 2050, there will have to be major changes in how we use and generate energy. Energy efficiency will have to increase dramatically across all sectors. The oil and gas used to drive cars, heat buildings and power industry will, in large part, need to be replaced by electricity, sustainable bioenergy, or hydrogen. Electricity will need to be decarbonised through renewable and nuclear power, and the use of carbon capture and storage (CCS). The electricity grid will be larger and smarter at balancing demand and supply.

11. But there are some major uncertainties. How far can we reduce demand? Will sustainable biomass be scarce or abundant? To what extent will electrification occur across transport and heating? Will wind, CCS or nuclear be the cheapest method of generating large-scale low carbon electricity? How far can aviation, shipping, industry and agriculture be decarbonised?

12. The sectoral plans in this document seek to steer a course through this uncertainty.

13. **In the next decade**, the UK will complete the installation of proven and cost effective technologies that are worth installing under all future scenarios. All cavity walls and lofts in homes, where practicable, are expected to be insulated by 2020. The fuel efficiency of internal combustion engine cars will improve dramatically, with CO_2 emissions from new cars set to fall by around a third. Many of our existing coal-fired power stations will close, replaced primarily by gas and renewables. More efficient buildings and cars will cut fuel costs. More diverse sources of electricity will improve energy security and reduce exposure to fossil fuel imports and price spikes.

14. The UK is not alone in taking action on energy efficiency. Japan has set a goal of improving its energy consumption efficiency from 2003 levels by at least 30% in 2030. The Swedish Government has proposed an energy efficiency target to reduce energy by 20% between 2008 and 2020.[4]

[4] International Energy Agency (2009) *Implementing Energy Efficiency Policies.*

15. Over the next decade the UK will also prepare for the future by demonstrating and deploying the key technologies needed to decarbonise power, buildings and road transport in the 2020s and beyond. Rather than picking a single winner, this plan sets out how the UK will develop a portfolio of technologies for each sector. This has two virtues. It will reduce the risk of depending on a single technology. And it will generate competition that will drive innovation and cost reduction.

16. In electricity, the three parts to our portfolio are renewable power, nuclear power, and coal- and gas-fired power stations fitted with carbon capture and storage. In transport, ultra-low emission vehicles including fully electric, plug-in hybrid, and fuel cell powered cars are being developed. In buildings, the technologies will include air- or ground-source heat pumps, and using heat from power stations. Both of these are solutions proven by their use in other countries.

17. **During the 2020s**, each of these technologies – low carbon electricity, low carbon cars and low carbon heating – will move towards mass roll-out. We estimate that between 40 and 70 gigawatts (GW) of new low carbon power will need to be deployed by the end of the decade. Emissions for the average new car will need to fall to between 50 and 70 gCO_2/km, compared with 144 gCO_2/km in 2010. Between 21% and 45% of heat supply to our buildings will need to be low carbon by 2030.

18. By developing options now, the UK will not only reduce the costs of deploying these technologies in the 2020s. It will also gain a long-term competitive advantage in sectors that play to our comparative strengths. These include offshore wind, carbon capture and storage, and information services to manage smart grids, heating controls and transport.

19. To 2030 and beyond, emissions from the hard-to-treat sectors – industry, aviation, shipping and agriculture – will need to be tackled. This will require a range of solutions to be tested by at the latest, the 2020s, including: greater energy efficiency; switching from oil and gas to bioenergy or low carbon electricity; and carbon capture and storage for industrial processes.

Sectoral plans

Low carbon buildings

20. In 2009, 37% of UK emissions were produced from heating and powering homes and buildings. By 2050, all buildings will need to have an emissions footprint close to zero. Buildings will need to become better insulated, use more energy-efficient products and obtain their heating from low carbon sources.

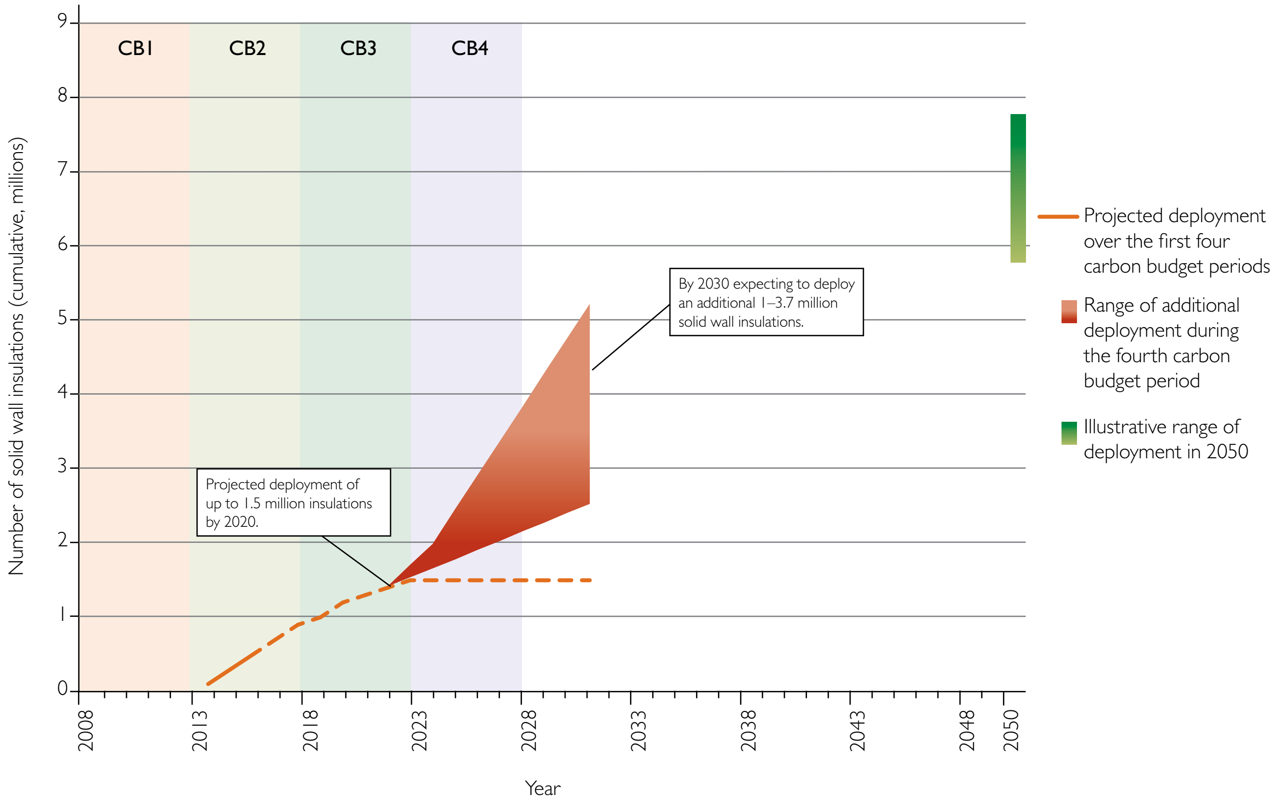
Energy efficiency

21. **Over the next decade**, with trends in installation rates maintained at today's levels, all cavity walls and lofts, where practical, will be insulated. Alongside this, the Government will support up to 1.5 million solid wall insulations and other energy efficiency measures such as double glazing.

22. The Green Deal, launching in 2012, will remove the upfront costs to the consumer of energy efficiency, with the cost being recouped through savings on their energy bills. The Energy Company Obligation will support this effort. It will place a duty on energy companies both to reduce emissions through undertaking solid wall insulation and to tackle fuel poverty by installing central heating systems, replacing boilers, and subsidising cavity wall and loft insulation. In parallel, Smart Meters will be deployed to every home to support consumers in managing their energy and expenditure intelligently. The Government will introduce zero carbon homes standards to cut the energy demand of new homes still further, reducing emissions and fuel bills. Through European energy standards and labelling we will promote the sales of the most efficient electrical appliances and products on the market.

23. **During the 2020s,** deployment of solid wall insulation will increase and installation costs will fall as the supply chain and the skills base become established. Chart 1 shows different levels of ambition for the uptake of solid wall insulation, ranging from 1 million to 3.7 million additional homes insulated by 2030.

Chart 1: Projected deployment of solid wall insulation over the first three carbon budgets, and illustrative range of deployment over the fourth carbon budget period and in 2050



Source: Department of Energy and Climate Change

Low carbon heating

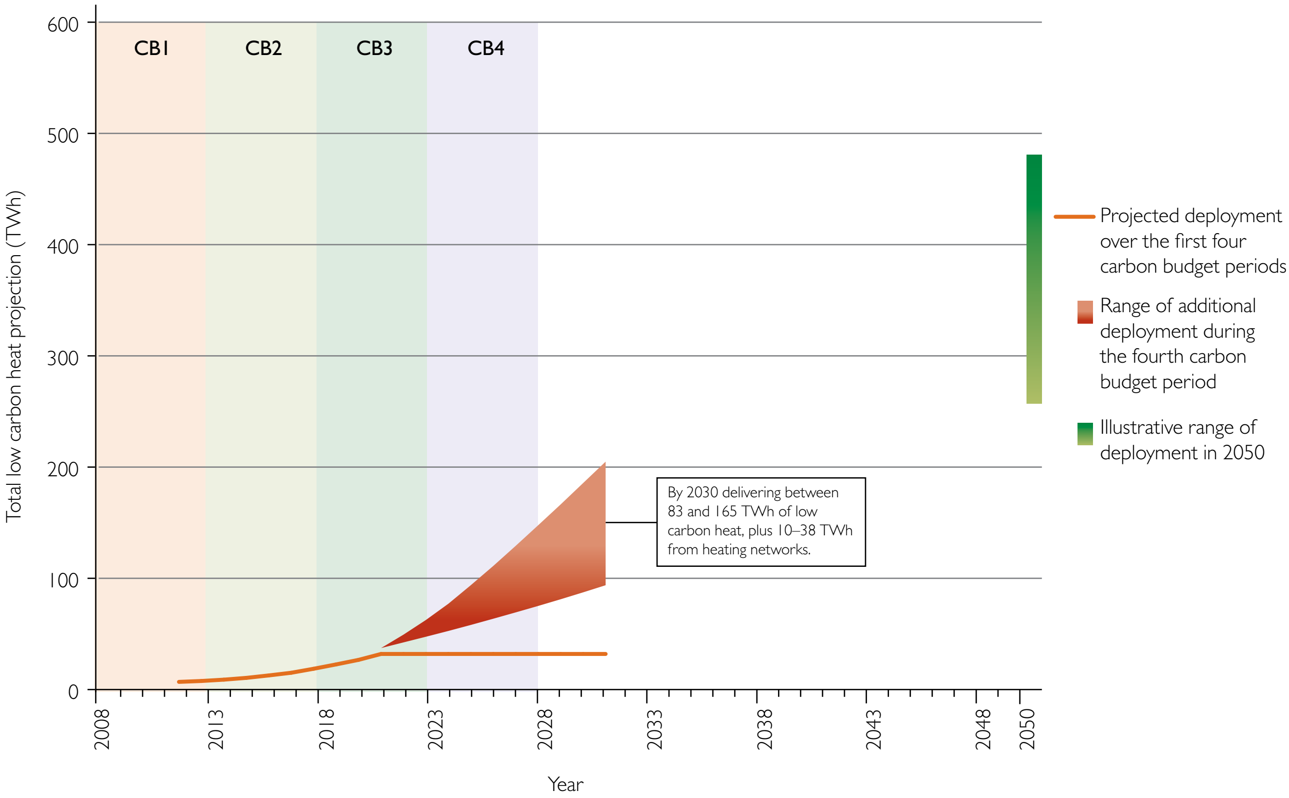
24. Energy efficiency is the immediate priority. But **in this decade** we also need to support ways of heating buildings without emitting carbon. Through the Renewable Heat Incentive (RHI) and Renewable Heat Premium Payment, over 130,000 low carbon heat installations are expected to be carried out by 2020.[5] While we do not expect mass-market deployment of these technologies in this decade, there is an important opportunity to build the market, particularly in off-gas grid homes and in the commercial sector. At the same time the Government will work with local authorities, where appropriate, to lay the foundations for district heating networks, particularly in urban areas with more densely packed demand for heat. This should enable the long-term delivery of heat from low carbon sources.

25. **During the 2020s**, we need to begin the mass deployment of low carbon heat. Technologies such as heat pumps will begin to expand at scale into residential areas, overcoming current barriers such as cost and unfamiliarity, and working with the supply chain to meet consumer demand. At the same time, the heating networks that started in urban areas during this decade will begin to expand to meet demand in surrounding areas, and to compete with low carbon heat technologies in individual buildings, helping to keep costs down.

26. By 2027, based on the scenarios set out in this plan, emissions from buildings should be between 24% and 39% lower than 2009 levels.

[5] This only includes installations as a result of RHI Phase 1.

Chart 2: Projected deployment of low carbon heat in buildings over the first three carbon budgets and illustrative ranges of deployment potential in the fourth carbon budget period and in 2050



Source: Department of Energy and Climate Change

Low carbon transport

27. Domestic transport emissions make up nearly a quarter of UK emissions. By 2050, domestic transport will need to substantially reduce its emissions.

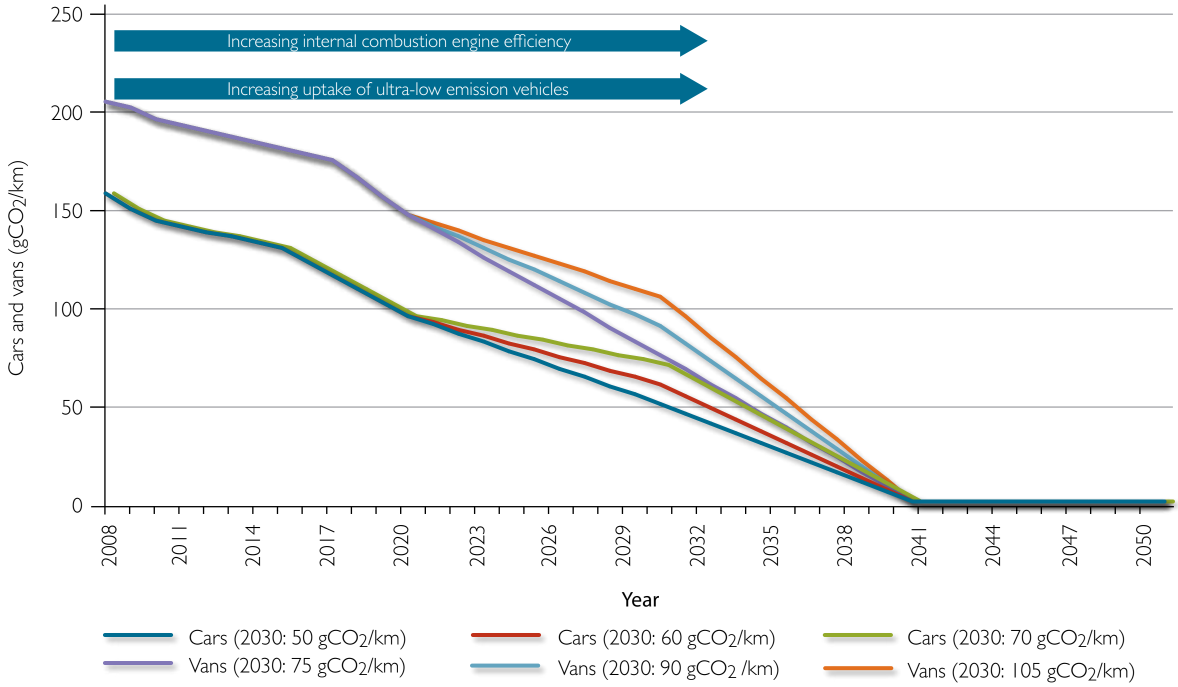
28. **Over the next decade**, average emissions of new cars are set to fall by around a third, primarily through more efficient combustion engines. Sustainable biofuels will also deliver substantial emissions reductions. As deeper cuts are required, vehicles will run on ultra-low emission technologies such as electric batteries, hydrogen fuel cells and plug-in hybrid technology. These vehicles could also help to deliver wider environmental benefits, including improved local air quality and reduced traffic noise.

29. To ensure that these emissions savings are delivered, the Government will continue to work at European Union (EU) level to press for strong EU vehicle emissions standards for 2020 and beyond in order to deliver improvements in conventional vehicle efficiency and give certainty about future markets for ultra-low emission vehicles.

30. To support the growth of the ultra-low emission vehicle market, the Government is providing around £300 million this Parliament for consumer incentives, worth up to £5,000 per car, and further support for the research, development and demonstration of new technologies.

31. **During the 2020s**, we will move towards the mass market roll-out of ultra-low emission vehicles, although further improvements in the efficiency of conventional vehicles and sustainable biofuels are also anticipated to play a key role. Based on current modelling the Government anticipates that average new car emissions could need to be 50–70 gCO_2/km and new van emissions 75–105 gCO_2/km by 2030.

Chart 3: Projected average new car and van emissions over the first three carbon budgets and illustrative ranges of average new car and van emissions in the fourth carbon budget period and to 2050



32. While cars and vans make up the largest share of emissions, other sectors will need to decarbonise over time.

33. To support people to make lower carbon travel choices, such as walking, cycling or public transport, the Government is providing a £560 million Local Sustainable Transport Fund over the lifetime of this Parliament.

34. Industry is leading the drive to reduce emissions from freight. The Logistics Carbon Reduction Scheme, for example, aims to reduce emissions by 8% by 2015, through improved efficiency and some modal shift to rail. For the longer term, to make deeper reductions in emissions, innovation will be needed in ultra-low emissions technologies such as sustainable biofuels and electric, hydrogen or hybrid technologies.

35. Emissions from aviation will be capped by being part of the EU Emissions Trading System (EU ETS) from 2012, ensuring that any increases in aviation emissions are offset by reductions elsewhere in the EU economy, or internationally.

36. By 2027, based on the scenarios set out in this plan, emissions from transport should be between 17% and 28% lower than 2009 levels.

Low carbon industry

37. Industry makes up nearly a quarter of the UK's total emissions. Over 80% of these emissions originate from generating the heat that is needed for industrial processes such as manufacturing steel and ceramics, and the remainder from chemical reactions involved in processes such as cement production. By 2050, the Government expects industry to have delivered its fair share of emissions cuts, achieving reductions of up to 70% from 2009 levels.

38. The Government will work with industry to ensure that low carbon growth continues into the future. Industry must make significant reductions in the emissions intensity of production, while the Government assists in maintaining the competitiveness of strategically important sectors. Emissions reductions will come from three sources: first, driving further efficiencies in the use of energy and materials and the design of industrial processes; second, replacing fossil fuels with low carbon alternatives such as bioenergy

and electrification; and third, from carbon capture and storage (CCS) to address combustion and process emissions, for example in cement and steel.

39. **Over the next decade**, the main chances for industry to decarbonise will come from taking up the remaining opportunities for energy efficiency, and beginning the move to low carbon fuels, such as using sustainable biomass to generate heat for industrial processes. Through the EU ETS and domestic policies such as Climate Change Agreements and the CRC Energy Efficiency Scheme the Government is helping to ensure that these cost effective energy efficiency measures are being taken up. Innovation efforts during this period will also be important, bringing down the cost of decarbonising industrial processes and moving technology options such as electrification and CCS closer to commercial reality. CCS technology research projects are being strongly backed by UK and international sources of funding, with the aim of turning CCS into a viable option for the coming decades.

40. **During the 2020s**, in addition to energy efficiency measures, reductions will be driven by switching to low carbon fuels. As with buildings, the Government expects industry to take advantage of the Renewable Heat Incentive, replacing expensive fossil fuels with low carbon heat alternatives and thereby accelerating the decarbonisation of industry in the 2020s. CCS technology is also expected to start to be deployed during this decade.

41. Throughout this transition the Government will work closely with industry to address the principal risks, including the impact of anticipated increases in energy costs, to ensure that UK industry remains internationally competitive. The Government announced a package of measures to support sectors which are particularly exposed to these risks.

42. By 2027, emissions from industry should be between 20% and 24% lower than 2009 levels.

Low carbon electricity

43. The power sector accounts for 27% of UK total emissions by source. By 2050, emissions from the power sector need to be close to zero.

44. With the potential electrification of heating, transport and industrial processes, average electricity demand may rise by between 30% and 60%. We may need as much as double today's electricity capacity to deal with peak demand. Electricity is likely to be produced from three main low carbon sources: renewable energy, particularly onshore and offshore wind farms; a new generation of nuclear power stations; and gas and coal-fired power stations fitted with CCS technology. Renewable energy accounted for approximately half of the estimated 194 GW of new electricity capacity added globally during 2010.[6] Fossil fuels without CCS will only be used as back-up electricity capacity at times of very high demand. The grid will need to be larger, stronger and smarter to reflect the quantity, geography and intermittency of power generation. We will also need a more flexible electricity system to cope with fluctuations in supply and demand.

45. While the overall direction is clear, major uncertainties remain over both the most cost effective mix of technologies and the pace of transition. The Government is committed to ensuring that the low carbon technologies with the lowest costs will win the largest market share.

46. **Over the next decade**, we need to continue reducing emissions from electricity generation through increasing the use of gas instead of coal, and more generation from renewable sources. Alongside this, we will prepare for the rapid decarbonisation required in the 2020s and 2030s by supporting the demonstration and deployment of the major low carbon technologies that we will need on the way to 2050. The reforms to the electricity market will be the most important step in making this happen. The introduction of Feed-in Tariffs with Contracts for Difference from 2014 will provide stable financial incentives for investment in all forms of low carbon generation.

6 REN21 (2011) *Renewables 2011: Global Status Report.*

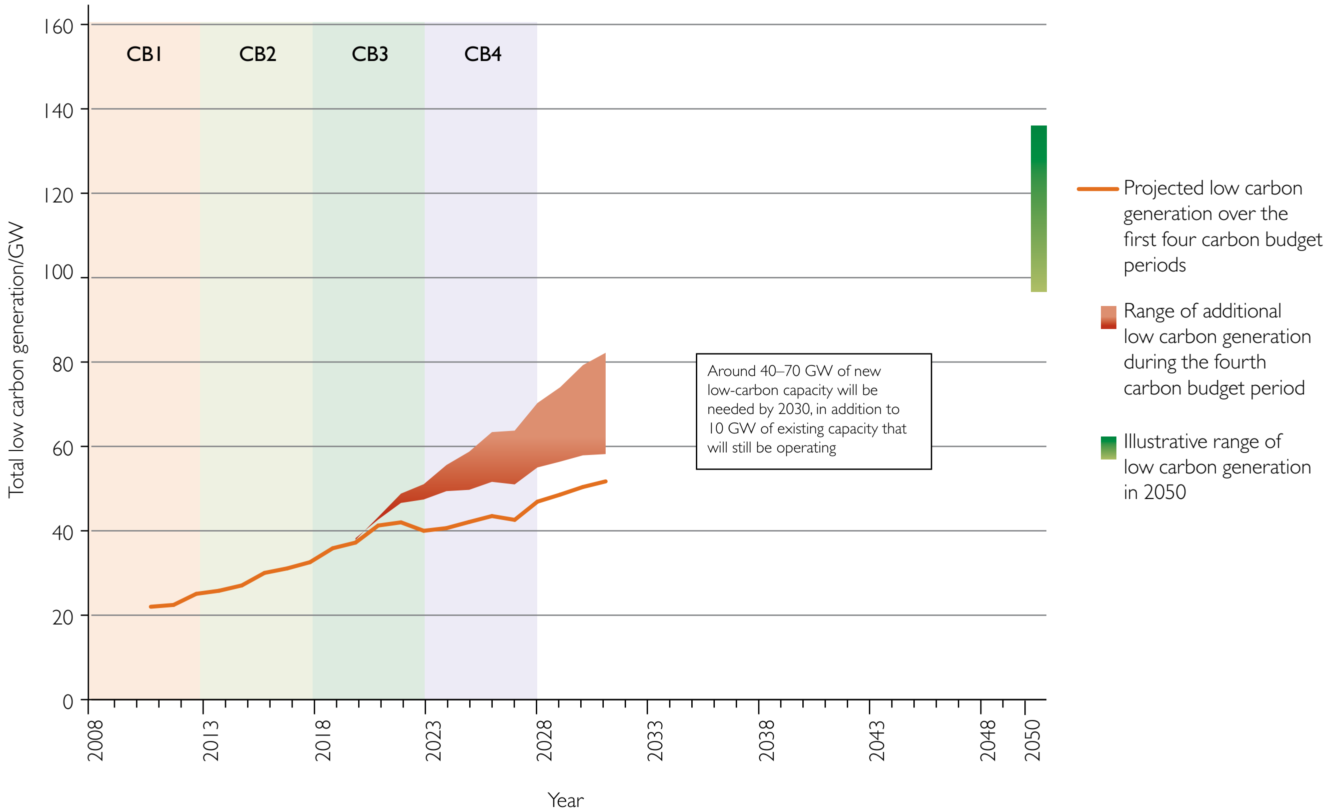
47. In addition, the Government is:

- helping industry to reduce the costs of offshore wind by setting up an Offshore Wind Cost Reduction Task Force with the aim of driving down the cost of offshore wind to £100 per megawatt hour (MWh) by 2020;
- supporting the development of CCS technology at scale in a commercial environment, to bring down costs and risks, with £1 billion set aside to support the programme;
- supporting the demonstration of less mature renewable technologies, and committing up to £50 million over the next four years to support innovation in marine and offshore technologies;
- enabling mature low carbon technologies such as nuclear to compete by addressing the barriers to deployment such as an under-developed UK supply chain; and
- working with Ofgem and the industry to deliver the investment required to ensure that the electricity transmission and distribution networks will be able to cope in the future.

48. Maintaining secure energy supplies remains a core government priority. New gas-fired generation will play a significant supporting role as 19 GW of existing generation capacity closes over the next decade.

49. Over the 2020s, large-scale deployment of low carbon generation will be needed, with, we estimate, 40–70 GW of new capacity required by 2030. This will drive a huge reduction in emissions from electricity supply. In the 2020s, the Government wants to see nuclear, renewables and CCS competing to deliver energy at the lowest possible cost. As we do not know how costs will change over time, we are not setting targets for each technology or a decarbonisation target at this point.

Chart 4: Projected deployment of low carbon generation over the first three carbon budgets and illustrative ranges of deployment potential in the fourth carbon budget period and in 2050



Source: Department of Energy and Climate Change, Redpoint modelling, 2050 Calculator

50. The scenarios modelled in this plan show that by 2030 new nuclear could contribute 10–15 GW, with up to 20 GW achievable if build rates are higher; fossil fuel generation with CCS could contribute as much as 10 GW; and renewable electricity could deliver anywhere between 35 and 50 GW – depending on assumptions about costs and build rates.

51. By the end of the fourth budget period, our analysis suggests that emissions from electricity generation could be between 75% and 84% lower than 2009 levels.

Agriculture, land use, forestry and waste

52. As set out above, the majority of emissions reductions will come from action in buildings, transport, industry and electricity generation. However, efforts elsewhere will continue to contribute – in the next decade, during the fourth carbon budget period, and ultimately to meeting the 2050 target.

53. In 2009, agriculture, forestry and land management together accounted for around 9% of UK emissions. The Government is encouraging practical actions which lead to efficiencies such as improved crop nutrient management and better breeding and feeding practices, which save both money and emissions. The Government is also working to improve its evidence base to better understand what this sector can feasibly deliver in the future. The Government will undertake a review of progress towards reducing greenhouse gas emissions from agriculture in 2012 which will assess the impact of existing measures and highlight further policy options. Next spring an independent panel will provide advice on the future direction of forestry and woodland policy in England.

54. In 2009, emissions from waste management represented a little over 3% of the UK total. The Government is committed to working towards a zero waste economy, and by 2050 it is estimated that emissions of methane from landfill (responsible for around 90% of the sector's emissions) will be substantially below current levels. The Government is working to improve our scientific understanding of these emissions so that they can be managed better. Our strategy over the next decade was set out in the Action Plan which accompanied the Review of Waste Policy in England, and includes increases to the landfill tax. By the end of 2013 the Government will develop a comprehensive Waste Prevention Programme, and work with businesses and other organisations on a range of measures to drive waste reduction and re-use.

A plan that adds up

55. Part 3 of this report outlines some illustrative scenarios to demonstrate different ways in which the fourth carbon budget could be met through different combinations of the various ambitions in the different sectors. As the Government develops its policy framework further it will look to meet the fourth budget in the most cost effective and sustainable way and keep costs under review, developing clear impact assessments and consulting publicly on policies before it implements them. A full list of the Government's energy and climate change commitments for this Parliament is set out at Annex C.

56. We will also continue to work on the international stage to ensure that this is a genuinely collaborative global effort. Other countries are already taking actions to decarbonise their economies and we will continue to push for ambitious action both in the EU and globally. At the EU level, the UK is pushing for the EU to show more ambition by moving to a tighter 2020 emissions target, which in turn will drive a more stringent EU ETS cap. We will review our progress in 2014. If at that point our domestic commitments place us on a different emissions trajectory than the ETS trajectory agreed by the EU, we will, as appropriate, revise up our budget to align it with the actual EU trajectory.[7]

[7] Before seeking Parliamentary approval to amend the level of the fourth carbon budget, the Government will take into account the advice of the Committee on Climate Change, and any representations made by the other national authorities.

Building a coalition for change

57. To make this transition, industry, the Government and the public need to be pulling in the same direction.

58. For industry, the global low carbon market is projected to reach £4 trillion by 2015 as economies around the world invest in low carbon technology. The innovation challenge for industry is in business models as well as technologies, with electric vehicles, renewable electricity and solid wall insulation requiring upfront investment, but delivering large savings in operating costs.

59. Industry must lead, but the Government can facilitate. This plan provides more clarity on the scale of the UK market opportunity and the pace of transition. In the next decade, the state will support innovation to ensure that key technologies can get off the ground. Rather than pick a winning technology, the Government will create markets that enable competing low carbon technologies to win the largest market share as the pace of change accelerates in the 2020s. New business models require new institutional frameworks that underpin long-term investment. That is the purpose behind both the Green Deal and Electricity Market Reform. As we make the transition, the state will need to solve co-ordination problems and ensure that the system as a whole coheres – for example, to understand when infrastructure decisions are required relating to the electricity grid, the gas network and charging points for electric cars.

60. The plans for new electricity infrastructure and changes in the way in which we travel and heat our homes will require public support. While public opinion is in favour of tackling climate change, there is little agreement over how to go about it. This plan shows that the UK can move to a sustainable low carbon economy without sacrificing living standards, but by investing in new cars, power stations and buildings. However, it will require the public to accept new infrastructure and changes to the way in which we heat homes, and to be prepared to invest in energy efficiency that will save money over time. As part of this Carbon Plan, the Government is launching a new 2050 Calculator, to enable a more informed debate about UK energy choices and develop a national consensus on how we move to a low carbon economy. The Government will also use this plan to build more consensus globally on how moving to a low carbon transition is a practical and achievable goal.

Part 1: The Government's approach to energy and climate change

Introduction

1.1 The UK, in common with other countries, faces two great risks over the coming decades:

- First, if we are not able to constrain global greenhouse gas emissions, the world faces the prospect of dangerous **climate change**, which will have unprecedented impacts on global security and prosperity.
- Second, the UK faces challenges to its **energy security** as our current generation of power stations closes and we must ensure supplies of energy which are resilient to volatile fossil fuel prices.

The threat of climate change

1.2 Climate change is one of the greatest threats facing the world today. There is an overwhelming scientific consensus that climate change is happening, and that it is primarily the result of human activity. There is now almost 40% more carbon dioxide in the atmosphere than there was before the industrial revolution, the highest level seen in at least the last 800,000 years. As a consequence, global average temperatures continue to rise. 2000–09 was the warmest decade on record, and 2010 matched 2005 and 1998 as the equal warmest year.[8]

1.3 The UK accounts for less than 1.5% of global greenhouse gas emissions,[9] so we have a clear national interest in ensuring that the world tackles climate change together. Climate change is a global problem, and it requires a global solution. Therefore the UK's international approach focuses on:

- encouraging the European Union to demonstrate leadership on climate change;
- influencing global political and economic conditions to secure action from other countries to limit greenhouse gas emissions;
- helping developing countries to build the climate resilience of their economies and move towards low carbon growth in the future; and
- working for a comprehensive global climate change agreement.

1.4 At the same time as mitigating climate change, the Government is committed to ensuring that the UK is resilient to the effects of a changing climate. The Climate Change Risk Assessment to be published next year will provide an assessment of climate change risks and opportunities for the UK. The assessment will underpin the development of a National Adaptation Programme establishing priorities for UK adaptation policy over the next five years.

[8] For further information on climate science see: Royal Society (2010) *Climate Change: A summary of the science*. Available at: http://royalsociety.org/climate-change-summary-of-science/

[9] Climate Analysis Indicators Tool. Available at: http://cait.wri.org/

Maintaining our energy security

1.5 We face three challenges to our energy security. First, by 2020, the UK could be importing nearly 50% of its oil and 55% or more of its gas. At a time of rising global demand, and continued geopolitical instability, the risk of high and volatile energy prices, and physical disruptions will remain. Second, we will lose a fifth of our electricity generating capacity due to the closure of coal and nuclear plants over the coming decade. Third, in the long term, while dependence on imported energy is expected to fall, we will face a new challenge in balancing more intermittent supply of energy from renewables with more variable electricity demand from electric cars, or electric heating. Our system will need to be resilient to mid-winter peaks in heating demand due to cold weather, and troughs in supply due to low wind speeds.

1.6 To meet our energy security needs, gas and oil will continue to play a valuable role as we make the transition to a low carbon economy. Gas will be needed over the coming decades both for heating and for electricity generation. Even in 2050, gas will contribute to electricity supply in the form of power stations fitted with carbon capture and storage (CCS) technology or as back-up to intermittent renewable generation. Our energy strategy seeks to underpin secure and diverse energy supplies, both domestically and internationally. This involves encouraging investment in oil and gas production; promoting reliable supply through more efficient markets and strengthened bilateral trading relations; and enhancing price stability through improved transparency and dialogue.

Our principles

1.7 The Government is determined that we should address the twin challenges of tackling climate change and maintaining our energy security in a way that **minimises costs and maximises benefits to our economy**.

1.8 To achieve this, we will follow a clear set of principles:

- **We should always aim for the most cost effective means to achieve our aims.** This necessitates using less energy across the economy. And it requires using the most cost effective technologies to drive further efficiencies and meet remaining demand.
- **A diverse portfolio of technologies, competing against each other for market share, can drive innovation and cost reduction.** While our principle is to choose the most cost effective mix of technologies in any sector, the reality is that we do not yet know how these technologies will develop, how their costs will change, or what other technologies may yet emerge. In transport this could mean electric, plug-in hybrid or hydrogen cars, or the use of biofuels. In heating this could mean building-level technologies such as air- and ground-source heat pumps or network-level options such as district heating. For that reason, the Government aims to encourage a portfolio of technologies and create competitive market conditions in which the most cost effective succeed over time.
- **Clear long-term signals about the regulatory framework can support cost reduction.** There is a role for the Government in providing clear, unambiguous signals to the market and a stable long-term regulatory framework to create the conditions for the investment that is fundamental to economic growth and the move to a low carbon economy.
- **The Government should help to tackle market failures and unblock barriers to investment to encourage growth in newer technologies.** While competition between technologies and businesses is the best way to ensure that we find the most cost effective mix, there is a role for the Government in identifying where it can constructively enable the market, particularly where technology deployment relies on the creation of new infrastructure.
- **Costs must be distributed fairly.** The Government will continue to focus on the distributional impacts of the low carbon transition. We are supporting consumers by

providing subsidised insulation, delivered by energy companies, to the most vulnerable households, as well as bill rebates to more than 600,000 vulnerable pensioners. The Government also recognises the challenges confronting energy-intensive industries, including the difficulties some face in remaining internationally competitive while driving down domestic emissions. We are taking active steps to support these industries through the transition, recognising the future role these sectors will play in delivering economic growth.

1.9 Reducing emissions will have wider impacts. Creating a low carbon and resource efficient economy means making major structural changes to the way in which we work and live, including how we source, manage and use our energy. The Government is committed to identifying a sustainable route for making that transition by balancing greenhouse gas benefits, cost, energy security and impacts on the natural environment. By adopting these principles, we seek to maximise the potential economic benefits to the UK from making the transition to a low carbon economy, as well as to minimise adverse impacts for the environment and public.[10] Doing this in the most cost effective way will help to enable us to:

- **use our resources more efficiently.** Managing energy and resource demand reduces costs to businesses and consumers, releasing spending power that can increase growth and productivity elsewhere. Lower demand for energy reduces risks to the security of our energy supplies;
- **reduce our exposure to fossil fuel price volatility.** According to the Office for Budget Responsibility, a temporary 20% increase in the oil price (adjusted to remove inflation) would lead to a loss of potential output in the UK of over 0.3% in the following year;[11] and
- **create long-term comparative advantages.** Being an early mover in technologies such as renewables and CCS could give the UK a long-term comparative advantage in growing global markets for these technologies.

The vision for 2050

1.10 These principles will underpin our vision for a long-term transition to a low carbon economy. By 2050 we will have transformed our buildings, transport and industry, the way in which we generate electricity and our agriculture and forestry.

1.11 **Low carbon buildings:** Heating and powering buildings produced 38% of the UK's emissions in 2009. Those emissions are a result of burning fossil fuels to heat buildings, and generating the electricity that powers our lighting and appliances. Buildings will need to be much better insulated and make use of Smart Meters and heating controls, and more efficient lighting and appliances, to reduce their demand for energy. At the same time, we will move away from the use of fossil fuels for heating and hot water and towards low carbon alternatives such as heat pumps or heating networks. By 2050, emissions from heating and powering our buildings will be virtually zero.

1.12 **Low carbon transport:** Transport is a major contributor to the UK's energy demand and greenhouse gas emissions, creating 24% of the UK total in 2009. Most of those emissions come from the oil-based fuels we rely upon for road transport. A step-change is needed to move away from fossil fuels and towards ultra-low carbon alternatives such as battery electric or fuel cell vehicles. New technologies will have implications for energy security, with increased demands likely to be placed on the grid by ultra-low emission vehicles (such as electric cars), as well as presenting new opportunities for vehicles to help balance variations in demand for electricity over time and reducing our exposure to volatile oil prices.

[10] In summer 2012 the Government will launch a research programme on sustainable pathways to 2050 which will consider the cumulative impacts of and interactions between different low carbon technologies. See Annex B for further details on the wider environmental impacts of reducing emissions and meeting carbon budgets.

[11] OBR (2010) *Assessment of the Effect of Oil Price Fluctuations on the Public Finances*. Available at: http://budgetresponsibility.independent.gov.uk/wordpress/docs/assessment_oilprice_publicfinances.pdf

1.13 **Low carbon industry:** Industry currently accounts for nearly one quarter of UK emissions, generated by burning fossil fuels for heat and by the chemical reactions involved in some industrial processes. Production of goods – from paper to steel – will need to become more energy efficient and switch over to low carbon fuel sources.

1.14 **Low carbon power generation:** The power sector currently accounts for 27% of UK emissions. As heating, transport and industry become increasingly electrified, the amount of electricity we need to generate is very likely to increase from today, and it will need to be almost entirely carbon-free. By 2050, the three sources of UK electricity are likely to be renewables (in particular onshore and offshore wind farms); coal, biomass or gas-fired power stations fitted with CCS technology; and nuclear power.[12] The grid will need to be larger, stronger and smarter to reflect the quantity, geography and intermittency of power generation. We will also need to ensure the security of the fossil fuel resources required to make the low carbon transition.

1.15 **Low greenhouse gas agriculture and forestry:** Emissions from agriculture, land use and forestry – mostly in the form of nitrous oxide and methane – made up around 9% of total emissions in 2009, but will account for an increasingly large share of overall UK greenhouse gas emissions as other sectors decarbonise over the next three decades. In order to meet our 2050 target, the agricultural sector will need to contribute to reducing emissions by adopting more efficient practices. We will also ensure the development of a sustainable and expanding forestry sector.

2050 futures

1.16 While our vision for 2050 is clear, there are huge uncertainties when looking 40 years ahead as to exactly how that vision will be achieved. Our approach has been to try to explore a range of plausible scenarios for what the UK might look like in 2050 and to seek to draw lessons from the similarities and differences between those scenarios. In line with our principle of seeking the most cost effective technology mix, our starting point for this has been to take the outputs of the 'core' run of the cost-optimising model, MARKAL, which was produced as part of the Department of Energy and Climate Change's analysis to support the setting of the fourth carbon budget.[13]

1.17 On the supply side, the core MARKAL run produces a balanced generation mix, with 33 gigawatts (GW) of nuclear, 45 GW of renewables and 28 GW of fossil fuel with CCS power capacity by 2050. On the demand side, the model run drives a sharp reduction in per capita energy demand; in this run, everybody in the UK would use half as much energy in 2050 as they do today, due to the adoption of more energy efficient technologies, with heat pumps, district heating, battery electric and fuel cell vehicles.

1.18 This is only a starting point. Attempting to pick a single pathway to 2050 by relying on a single model is neither possible nor a helpful guide in the face of great uncertainty. But it does give insight into the most cost effective way to achieve the low carbon transition, illustrating the technologies likely to contribute to reducing emissions, and the most cost effective timing for their deployment. It shows that achieving a cost-optimal transition overall often necessitates deploying technologies in the medium term that may not yet be statically cost effective against the carbon price.[14]

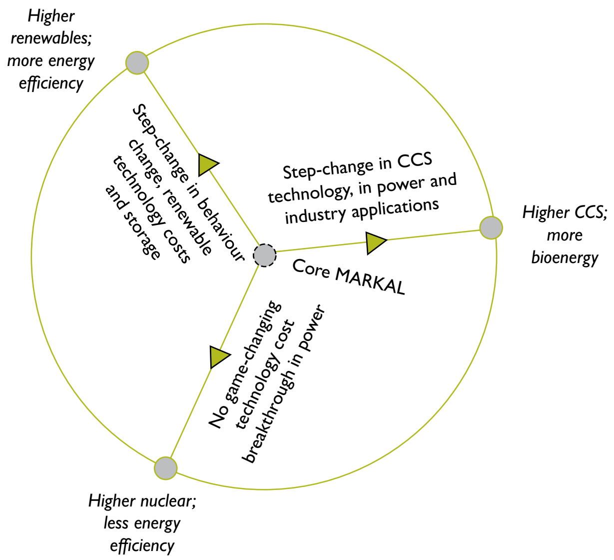
[12] The UK Government works in partnership with the Devolved Administrations in Northern Ireland, Scotland and Wales to deliver the targets set by the Climate Change Act 2008. While the administrations have a shared goal of reducing the impacts of climate change, policies on how to achieve this vary across the administrations – the Scottish Government, for example, is opposed to the development of new nuclear power stations in Scotland. It believes that renewables, fossil fuels with CCS and energy efficiency represent the best long-term solution to Scotland's energy security. This document focuses largely on UK Government policy on climate change, with Devolved Administration views set out in 'Working with the EU and Devolved Administrations' on page 99.

[13] HMG (2011) *Fourth Carbon Budget Level: Impact Assessment (final)*. MARKAL is discussed further at Annex A.

[14] The cost effectiveness of measures is affected by the scale and timing of their deployment. Static cost effectiveness does not account for changes to a measure's cost effectiveness due to variations in the scale and timing of its deployment.

1.19 Alongside this core MARKAL run the Government has developed three further 'futures' that attempt to stress test the results of the core run by recognising that there will be changes that we cannot predict in the development, cost and public acceptability of different technologies in every sector of the economy.

Figure 1: 2050 futures



1.20 Future **'Higher renewables, more energy efficiency'** assumes a major reduction in the cost of renewable generation alongside innovations that facilitate a large expansion in electricity storage capacity. This helps to manage the challenges of those renewables that are intermittent. It is consistent with a world where high fossil fuel prices or global political commitment to tackling climate change drives major investment and innovation in renewables.

1.21 As a consequence, the power generation mix includes deployment of wind, solar, marine and other renewable technologies, as well as back-up gas generation. This future also assumes a major reduction in per capita energy demand driven by people embracing low carbon behaviour changes and smart new technologies such as heating controls, and recognising the financial benefits of taking up energy efficiency opportunities. We electrify the majority of our demand for heat, industry and transport using ground- and air-source heat pumps in buildings and electrified industrial processes, and we travel in ultra-low emissions vehicles.

1.22 Future **'Higher CCS, more bioenergy'** assumes the successful deployment of CCS technology at commercial scale and its use in power generation and industry, supported by significant natural gas imports, driven by changes such as a reduction in fossil fuel prices as a result of large-scale exploitation of shale gas reserves. It also assumes low and plentiful sustainable bioenergy resources (see box 2).

1.23 In this future, significant amounts of relatively low cost, sustainable biomass result in CCS also being used with biomass (BE-CCS) to generate negative emissions.[15] Negative emissions production is a game-changer in that it could offset the continued burning of fossil fuels elsewhere in the energy system. In this scenario, BE-CCS creates around 50 million tonnes carbon dioxide equivalent ($MtCO_2e$) of negative emissions – equivalent to almost 10% of today's total – which creates 'headroom' for some fossil fuel use. As a result, this pathway has less electrification of heat and transport, with more heat demand met through network-level heating systems such as district heating or combined heat and power. In transport, more demand is met through sustainable biofuels use in cars and buses, while strong effort is made to improve the efficiency of UK land management. No unabated gas generation is needed to balance the system in this future.

1.24 Future **'Higher nuclear, less energy efficiency'** is a future that is more cautious about innovation in newer technologies. CCS does not become commercially viable. Innovation in offshore wind and solar does not produce major cost reductions. Lack of innovation in solid wall insulation results in low public acceptability of energy efficiency measures.

[15] In the 2050 modelling, biomass fuel sources are typically assumed to be 'zero carbon' because the CO_2 released with their combustion is equal to the amount sequestered through the process of growing the biomass. Capture of this CO_2 through use of CCS technology (BE-CCS) removes it from the system altogether by pumping it underground – thereby creating 'negative emissions'.

Box 2: Sustainable bioenergy

Sustainable bioenergy is a versatile source of low carbon energy which will play a key role in meeting carbon budgets and the 2050 target. It has applications in each sector – including for the generation of electricity and heat, and as a replacement for more emissions-intensive transport fuels. In 2010 the UK used 73.6 terawatt hours (TWh) of bioenergy.

The *UK Renewable Energy Roadmap* stated that bioenergy could deliver around half of the total generation needed to meet our 2020 renewable targets. To achieve this level of deployment we will need to make the most of domestic supplies such as residues and wastes, increased use of under-managed woodlands and energy crop production on marginal land while also using globally traded feedstocks.

A key condition for the use of bioenergy is its ability to generate genuine emissions reductions. Clear sustainability standards – which account for greenhouse gas emissions throughout the lifecycle and also consider wider environmental impacts – are critical. Current estimates suggest that global and UK biomass demand is likely to increase towards 2050. However, sustainability concerns may constrain the availability of particular feedstocks.

The Government's forthcoming Bioenergy Strategy will set out the role that sustainable bioenergy can play in cutting greenhouse gas emissions and meeting our energy needs. It will provide the strategic direction on the future role of sustainable bioenergy against which future policies in this area can be assessed and developed.

1.25 As a result, nuclear is by far the largest source of electricity in 2050. Natural gas plays a role in matching peaks in demand. Compared with the core MARKAL run, there is less insulation of existing homes and less use of smart technologies and appliances in homes to reduce energy use. Individuals travel more than they do today and continue to make the most of their journeys using cars. We succeed in electrifying most of our demand for heat and transport, with remaining demand met through a mix of other technologies, such as district heating.

Planning for the future

1.26 These three futures, alongside the core MARKAL run, can help us to understand the choices we face as we make the transition to a low carbon economy by 2050. By looking at the commonalities and differences between them, we can try to understand which technologies and efforts now may be 'safe bets' in the face of future uncertainty, and to identify the points in time between now and 2050 when choices between technologies will need to be made if we are to keep different possible futures open. The Government's approach in this document, and in planning for the first four carbon budgets, is to ensure that we are supporting the safe bets; that we are acting to keep open different possibilities where we do not yet know what the cost effective and appropriate path may be; and that we identify and plan for decision points where possible paths diverge.

1.27 The three futures suggest parameters around the key uncertainties in the transition: the degree of energy efficiency that may be achieved across the economy; the lowest cost technology mix for decarbonising remaining energy demand (especially heating and transport demand); and the lowest cost technology mix for decarbonising electricity supply.

1.28 All three futures are published in the 2050 Calculator web tool at http://2050-calculator-tool.decc.gov.uk and further detail on their specific choices and implications can be found at Annex A. These futures indicate a range of deployment for key technologies in 2050, acknowledging that a number of factors – notably cost – will ultimately determine the level of deployment within this range.

1.29 The 2050 futures set out a helpful framework for developing the Government's strategy to achieve carbon budgets on the way to 2050. In each sector, we need to ensure that our strategy for meeting the first four carbon budgets puts us on a path to deliver this range of ambition in 2050. Part 2 of this document sets out how we will do this in each sector. Part 3 provides a range of scenarios for ways in which we could meet the fourth carbon budget, all of which would put us on track to deliver these 2050 futures.

Table 1: Summary of 2050 futures

(All figures in 2050)	Measure	Core MARKAL	Renewables; more energy efficiency	CCS; more bioenergy	Nuclear; less energy efficiency
Energy saving per capita, 2007–50		50%	54%	43%	31%
Electricity demand increase, 2007–50		38%	39%	29%	60%
Buildings	Solid wall insulation installed	n/a[16]	7.7 million	5.6 million	5.6 million
	Cavity wall insulation installed	n/a[16]	8.8 million	6.9 million	6.9 million
	House-level heating	92%	100%	50%	90%
	Network-level heating	8%	0%	50%	10%
Transport	Ultra-low emission cars and vans (% of fleet)	75%	100%	65%	80%
Industry	Greenhouse gas capture via CCS	69%	48%	48%	0%
Electricity generation	Nuclear	33 GW	16 GW	20 GW	75 GW
	CCS	28 GW	13 GW	40 GW	2 GW
	Renewables[17]	45 GW	106 GW	36 GW	22 GW
Agriculture and land use	Bioenergy use	~350 TWh	~180 TWh	~470 TWh	~460 TWh

[16] MARKAL does not provide figures for numbers of specific insulation measures deployed. The 2050 futures figures are taken directly from the 2050 Calculator, and should be taken as illustrative rather than precise targets for deployment.

[17] Note that the 2050 futures do not assume that existing renewables generation is repowered at the end of its lifetime. The 2050 Calculator assumes that wind turbines have a lifetime of 20 years.

Part 2: Our strategy to achieve carbon budgets

Achieving carbon budgets

2.1 As set out in Part 1, the Government's approach to avoiding the risk of dangerous climate change has at its heart the Climate Change Act 2008. The Act requires that five-yearly 'carbon budgets' be set three budget periods ahead, so that it is always clear what the UK's emissions pathway will be for the next 15 years.

Achieving carbon budgets one to three

2.2 The first three carbon budgets, for the years 2008–12, 2013–17 and 2018–22, were set in May 2009. Table 2 overleaf shows the level of the first three carbon budgets.

Our current policy framework

2.3 The 2050 futures give us a clear vision of the longer-term changes we will need to see in each sector of the economy. The Government already has a comprehensive package of policies in place to deliver the emissions reductions necessary to meet the first three carbon budgets and to provide incentives for the development and take-up of the portfolio of technologies necessary to put us on track to 2050. Domestic policies such as the Green Deal, the Renewable Heat Incentive and roll-out of Smart Meters, along with EU-wide policies such as the EU Emissions Trading System (EU ETS) and regulations on new car and van CO_2 emissions standards, are forecast to drive down emissions in the UK over this decade and provide a platform for further, deeper, cuts in emissions during the 2020s and beyond. More information on these policies can be found later in this report.

Emissions projections for carbon budgets one to three

2.4 The Government's emissions projections[18] provide forecasts for UK emissions over the short and medium term. These take into account the estimated energy and emissions savings from our current policy framework, and reflect estimates of the key economic factors that drive energy use and emissions, such as economic growth and fossil fuel prices (see box 3 on page 23). These projections are an essential tool for projecting progress and assessing risks to meeting carbon budgets. The table overleaf shows the latest emissions projections (central scenario) for the first three carbon budgets.

[18] DECC (2011) *Updated Energy and Emissions Projections 2011*. See: www.decc.gov.uk/en/content/cms/about/ec_social_res/analytic_projs/en_emis_projs/en_emis_projs.aspx

Table 2: October 2011 emissions projections (million tonnes of carbon dioxide equivalent ($MtCO_2e$))

	First carbon budget (2008–12)	Second carbon budget (2013–17)	Third carbon budget (2018–22)
Legislated interim budgets[19]	3,018	2,782	2,544
Percentage reduction from 1990 baseline[20]	23%	29%	35%
Net UK carbon account	2,922	2,650	2,457
Projected performance against first three carbon budgets (negative implies emissions under budget)	−96	−132	−87
Uncertainty range in projected over-achievement (high to low emissions projection)	−73 to −124	−73 to −172	−19 to −142

2.5 As can be seen, with current planned policies, the latest projections suggest that the UK is on track to meet its first three carbon budgets and that we expect to reduce emissions to below their levels by 96, 132 and 87 million tonnes carbon dioxide equivalent ($MtCO_2e$) respectively, based on central forecasts.

2.6 This forecast over-achievement suggests that the UK is in a strong position to deliver on more ambitious carbon budgets out to 2020. We continue to lobby strongly in Europe for a move to a more ambitious 2020 target and, if successful, we will amend our second and third carbon budgets accordingly, following effort share negotiations with other Member States, to ensure that they are consistent with new EU obligations.

Achieving the fourth carbon budget

2.7 On 30 June 2011, the level of the fourth carbon budget for the years 2023–27 was set in law, committing the UK to reduce emissions to 50% below 1990 levels. The Low Carbon Transition Plan, published in July 2009, set out the strategy for meeting the first three carbon budgets.[21] This Carbon Plan updates and supersedes the 2009 report and presents the Government's strategy for meeting all four carbon budgets, with a particular focus on the fourth carbon budget.

2.8 The level of the fourth carbon budget (1,950 $MtCO_2e$) assumes a split between emissions that will fall in the traded sector (690 $MtCO_2e$) and emissions that will fall in the non-traded sector (1,260 $MtCO_2e$). In the traded sector, emissions are capped by the EU ETS – see box 4 on page 24 for more information.

2.9 Whether or not we manage to reduce emissions by the amount required to meet carbon budgets will depend on the level of the UK's share of the EU ETS cap. We know that the current EU ETS cap is not sufficiently tight to deliver the

[19] The 'interim' carbon budgets are set on the basis of the current EU target to reduce emissions by 20% from 1990 levels by 2020.

[20] These percentages have changed since 2009 when quoted in the Low Carbon Transition Plan (HM Government (2009) *The UK Low Carbon Transition Plan: National strategy for climate and energy*, www.decc.gov.uk/publications/basket.aspx?FilePath=White+Papers%2fUK+Low+Carbon+Transition+Plan+WP09%2f1_20090724153238_e_%40%40_lowcarbontransitionplan.pdf&filetype=4) owing to an update in the greenhouse gas inventory which revised total 1990 baseline UK greenhouse gas emissions from 777.4 $MtCO_2e$ to 783.1 $MtCO_2e$. This number is the denominator in this calculation, hence while the budget levels (in $MtCO_2e$) have not changed, the 1990 baseline and percentage reductions have.

[21] HM Government (2009) *The UK Low Carbon Transition Plan: National strategy for climate and energy*.

Box 3: The Government's emissions projections

Emissions projections are inherently uncertain and the outturn could be higher or lower than the projections. This is due to uncertainty over future temperatures, fossil fuel prices, carbon prices, economic growth, demographic trends and the impact of our policies. There is also modelling uncertainty surrounding the ability to forecast economic relationships, for example the relationship between economic growth and emissions, uncertainty which is likely to increase over time as the structure of the UK economy and economic relationships evolve. As an example, while on central projections we expect the over-achievement in the third carbon budget to be 87 $MtCO_2e$ over the five-year period, the over-achievement might be as much as 142 $MtCO_2e$ (under low emissions projections) or as little as 19 $MtCO_2e$ (under high emissions projections). In the case of the traded sector, the uncertainty increases significantly beyond 2020 due to the fact that we do not have renewables targets beyond 2020: removing a key input such as this naturally increases the range of uncertainty. Not yet knowing the level of the future EU ETS cap similarly adds to uncertainty beyond 2020. The Government's approach is to focus on the central projections when setting carbon budgets, which require a single value to compare with emissions in 1990, and to carefully monitor the outturn.

necessary emissions reductions to meet the fourth carbon budget. The UK is pushing for the EU to show more ambition by moving to a tighter 2020 emissions target, which in turn will drive a more stringent EU ETS cap. We will review our progress in 2014. If at that point our domestic commitments place us on a different emissions trajectory than the ETS trajectory agreed by the EU, we will, as appropriate, revise up our budget to align it with the actual EU trajectory. Before seeking parliamentary approval to amend the level of the fourth carbon budget, the Government will take into account the advice of the Committee on Climate Change (CCC), and any representations made by the other national authorities.

Emissions projections for the fourth carbon budget

2.10 On central projections based on our current policy framework, UK territorial emissions are forecast to be around 2,207 $MtCO_2e$ over the fourth carbon budget (or 441.4 $MtCO_2e$ a year). This assumes that emissions savings from the legacy of current policies will continue, even where those policies do not currently extend beyond 2020. This is particularly the case for efficiency standards, such as the new car CO_2 target, where even without the 2020 car CO_2 target being extended and tightened, it is assumed that – as more new cars are sold beyond 2020, replacing older, less efficient vehicles in the fleet – emissions from transport will continue to fall.

2.11 The projections therefore show that our current suite of policies on its own is not likely to be sufficient to deliver the fourth carbon budget. On central projections, there is an expected shortfall in emissions of around 181 $MtCO_2e$ in the non-traded sector over the five-year period (or 36.2 $MtCO_2e$ a year).[22]

How to achieve the fourth carbon budget

2.12 The CCC was set up under the Climate Change Act to advise the Government on carbon budgets. Its fourth carbon budget report, published in December 2010,[23] gave a clear illustration of the kind of actions that the UK Government and Devolved Administrations would need to take to deliver the necessary emissions reductions. All sectors of the economy will need to play their part by the time of the fourth carbon budget but the CCC's advice focuses on the need for greater energy efficiency, particularly from energy use in buildings; for greater electrification of both heat and transport; and for decarbonisation of the power sector.

[22] Section B2 of Annex B contains further discussion of emissions projections for the fourth carbon budget period.

[23] See: www.theccc.org.uk/reports/fourth-carbon-budget

Box 4: The EU Emissions Trading System

The EU Emissions Trading System (EU ETS) is an EU-wide carbon cap and trade system which started in 2005, covering electricity generation and the main energy-intensive industries, including refineries and offshore, iron and steel, cement and lime, paper, glass and ceramics. It sets a declining limit on emissions and allows participants to trade the right to emit with each other, enabling emissions cuts to be made where they are cheapest.

Power and industries covered by the EU ETS together make up around 40% of UK emissions, and are collectively known as the traded sector. The level of emissions in the traded sector is governed by the UK's share of the declining level of the EU ETS cap. While the current ETS cap trajectory enables us to achieve the first three carbon budgets, the fourth carbon budget was set assuming that the ETS cap will be tightened further in the future. Continuing the current trajectory of the cap into the 2020s would not be sufficient to deliver the deep emissions reductions needed in the UK power and heavy industry sectors during the fourth carbon budget.

The scarcity of allowances in the ETS creates a carbon price. While the current carbon price set by the EU ETS is important to incentivising low carbon generation, it is not enough on its own – it has not been stable, certain or high enough to encourage sufficient investment in the UK. The Government therefore plans to introduce a Carbon Price Floor to support the carbon price, described further in paragraph 2.156.

2.13 The non-traded sector covers all sectors that fall outside of the EU ETS, including the buildings, transport and agricultural sectors. In the non-traded sector, there are three areas that have the potential to contribute significantly to emissions reductions over the fourth carbon budget period, in line with our vision for 2050. They are:

- ensuring that our homes are better insulated to improve their **energy efficiency**;
- replacing inefficient **heating systems** with more efficient, sustainable ones; and
- ensuring a step-change in our move towards **ultra-low carbon vehicles**, such as electric vehicles.

2.14 The traded sector covers all sectors that fall within the EU ETS, including power generation and most of the industry sector. The main area to contribute towards meeting the fourth carbon budget will be the installation of **low carbon electricity generation**.

2.15 The sections that follow illustrate the Government's plans in each of these areas.

Box 5: The Government's response to the Committee on Climate Change's Renewable Energy Review

In May 2010, the Department of Energy and Climate Change asked the Committee on Climate Change (CCC) to undertake a review of the potential for renewable energy deployment for 2020 and beyond, including whether there is scope to increase the current target, taking into account technical potential, costs and practical delivery.

The CCC approached the work in two phases. Phase 1 provided interim conclusions in September 2010, which agreed that the UK 2020 target was appropriate, and should not be increased. Phase 2, published in May 2011, provided recommendations on the post-2020 ambition for renewables in the UK, and the possible pathways to maximise their contribution to the 2050 carbon reduction target.

The Government thanks the Committee for its work and advice. We welcome its recognition that 15% renewables by 2020 is both an appropriate and achievable scale of ambition.

We are committed to achievement of the 2020 renewables target and agree with the CCC that our focus should now be on delivering that ambition, while working with industry to drive down costs. The *UK Renewable Energy Roadmap*, published in July 2011, sets out a programme of actions that Governments across the UK are taking to set us on the path to achieving the target.[24]

We acknowledge that renewables have the potential to provide 30–45% of energy by 2030 and possibly higher levels in the longer term and that, before making any future commitments, we need to resolve current uncertainties and reduce costs. We have considered and responded to the CCC's advice on the post-2020 potential for renewables in the electricity, buildings, industry and transport sections of this report.

[24] See: www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/re_roadmap/re_roadmap.aspx

Box 6: Emissions data in the Carbon Plan

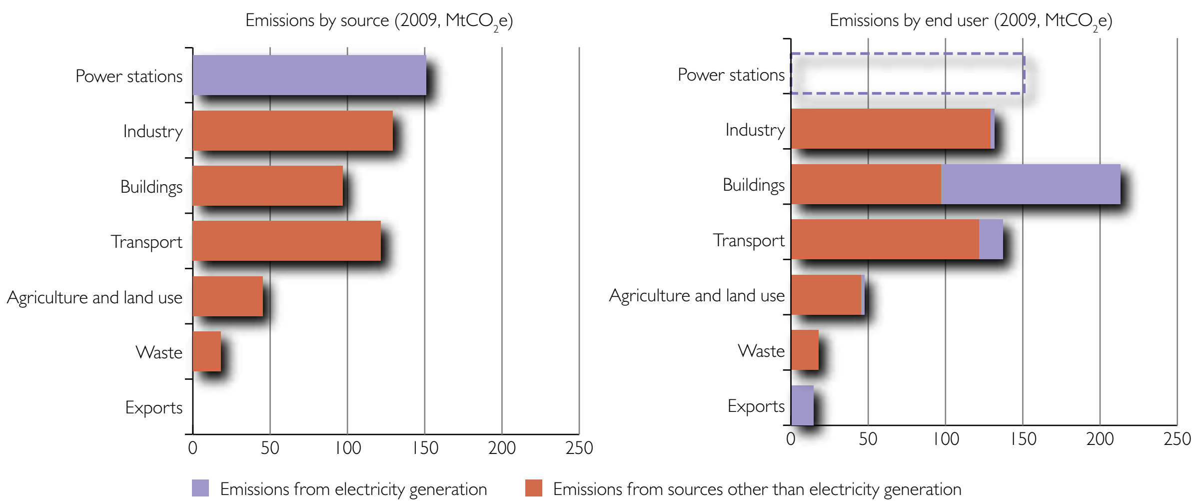
This report explains the progress the UK has already made in reducing greenhouse gas emissions since 1990. The sections which follow describe the Government's strategy to reduce emissions over the fourth carbon budget in each area of the economy. We have disaggregated historic and projected emissions along different lines to the National Communication (NC) sector classification[25] and the Standard Industrial Classification (SIC),[26] in order to clarify which areas make the most substantial contribution to emissions.

For the purpose of presenting historic emissions, we have allocated emissions from electricity generation to the **end user** of that electricity. This has been done in all sections except electricity generation where the emissions reported are **by source**. This breakdown is particularly important for some areas, such as buildings, where emissions from electricity generation make up the majority of the total. In most areas, the package of policies discussed targets both emissions relating to electricity use in that area, as well as emissions from other sources.

For all other figures (save historic emissions), emissions have been allocated by source, i.e. the emissions directly produced by that sector.[27]

The chart below shows a comparison of source and end user emissions.

Chart 5: Emissions by source and end user for each section in this report



Source: DECC National Statistics
Note: The 'exports' category relates to emissions within the UK from producing fuels (e.g. from a refinery or coal mine) which are subsequently exported for use outside the UK.

[25] These are consistent with the UK Greenhouse Gas Inventory. Available at: www.decc.gov.uk/en/content/cms/statistics/climate_change/gg_emissions/uk_emissions/2009_final/2009_final.aspx

[26] The SIC is consistent with the Digest of UK Energy Statistics (DUKES). It is also consistent with the breakdown of the Updated Energy and Emissions Projections (UEP).

[27] The historic emissions data quoted have been created on the basis of the NC sectors; the emissions projections data have been created on the basis of the UEP sectors.

BUILDINGS

Where we are now

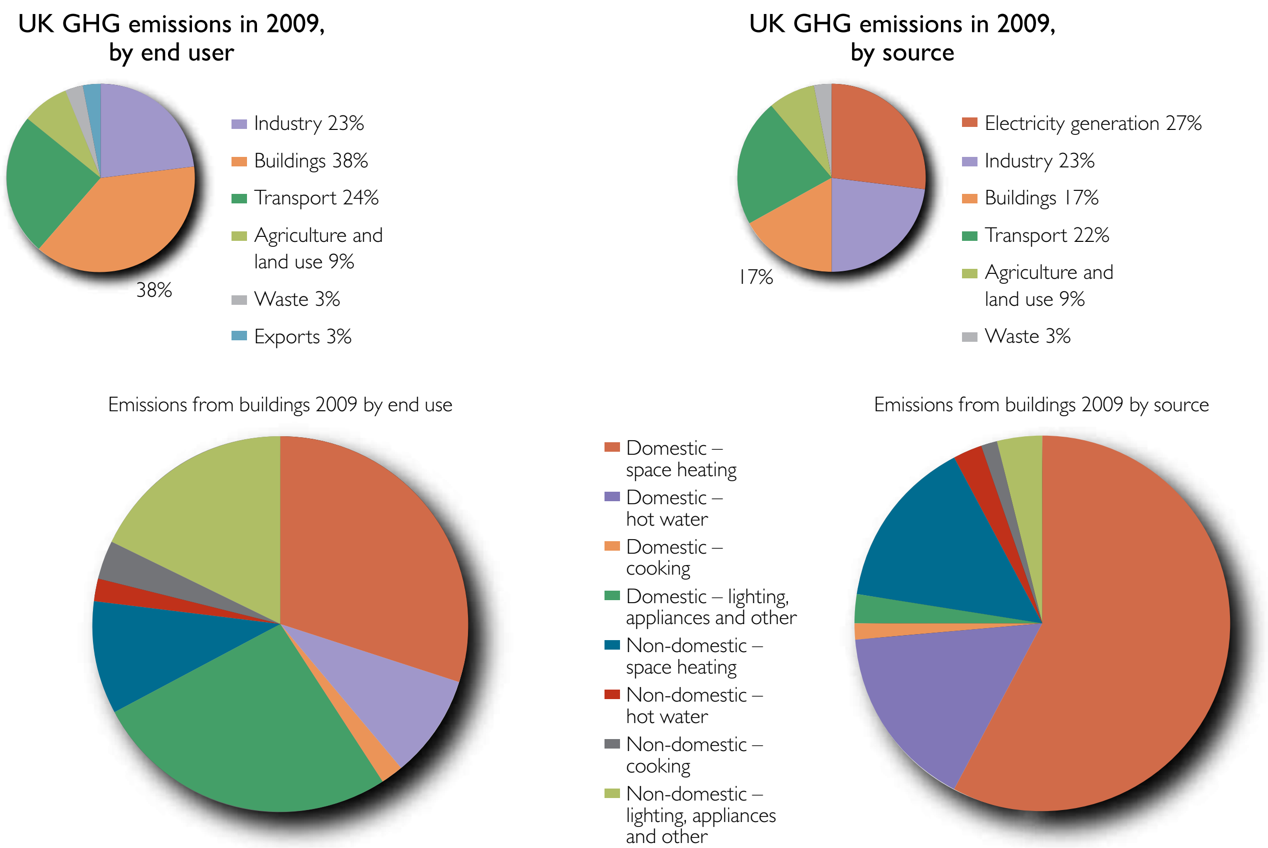
2.16 In 2009, our domestic buildings were responsible for 25% of the UK's emissions and just over 40% of its final energy use. Over three quarters of the energy we use in our homes is for space and hot water heating, most of which comes from gas-fired boilers. Lighting and appliances account for a smaller percentage of domestic energy demand, and emissions here are expected to reduce as the electricity grid is decarbonised.

2.17 The energy we use for heating and powering our non-domestic buildings is responsible for around 12% of the UK's emissions, three quarters of which comes from private businesses, with the remainder from public buildings. In addition, energy use for cooling is more significant in the commercial sector than for residential buildings.

2.18 Since 1990, emissions from buildings have fallen by around 9.2 $MtCO_2e$, or 9%.[28]

2.19 Over this period, government policies, including Warm Front, the Energy Efficiency Commitment and the Carbon Emissions Reduction Target have dramatically accelerated

Chart 6: Proportion of UK emissions from the buildings sector in 2009 (by end use and by source)[29]



Source: UK greenhouse gas statistics

[28] This section covers all heat and power in relation to domestic, commercial, private and public buildings (but not industrial process heat or power). The sectoral breakdowns in this report are for illustrative purposes only. Annex B presents emissions and savings data using the standard Updated Energy and Emissions Projections/National Communication basis.

[29] The emissions estimates in this section refer to greenhouse gas emissions from combustion of fuels (primarily gas, oil and coal) and have been presented both by end use and by source. This breakdown is particularly important where emissions from electricity generation make up a significant amount of the total.

the deployment of cavity wall and loft insulation. In 2010 alone, over 400,000 existing homes received cavity wall insulation and over a million lofts were insulated, leading to warmer homes and savings on energy bills (see chart 7). And, as a result of the 10.8 million cavity walls insulated so far, the UK will save over £1 billion this year on its national heating bill.

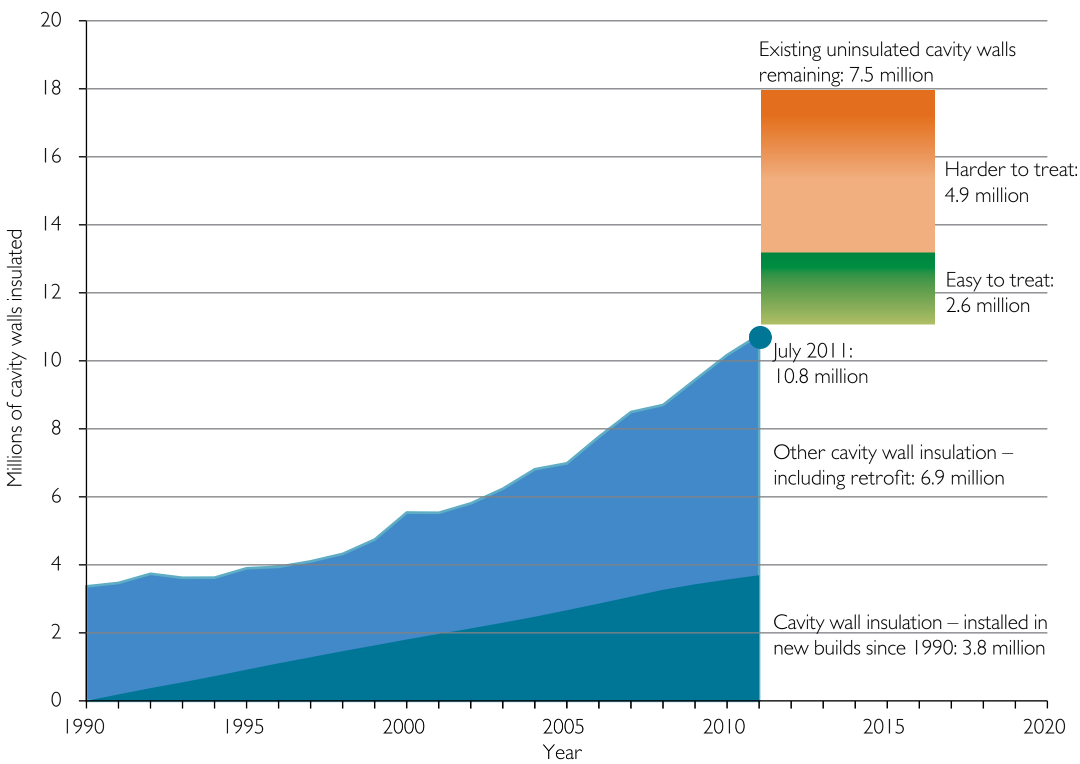
2.20 In addition, new buildings standards mean that a house built today demands only a fraction of the energy for space heating required by a house built before 1990. Improvements in this area have also been supported by new condensing boiler standards. Since legislation was introduced in 2005 mandating the installation of condensing boilers[30] in all but special applications, installation rates have increased to over 1.5 million a year (see chart 8), which in turn has saved 4.1 $MtCO_2e$ alone. This has led to savings for many householders (approximately £95 off their energy bills this year) and at least £800 million for the UK as a whole.[31]

Where we will be in 2050

2.21 By 2050 the emissions footprint of our buildings will need to be almost zero. We can achieve this through a mix of two main changes:

- **Reducing demand for energy in buildings**
  By increasing the thermal efficiency of buildings through better insulation; by encouraging consumers to use smarter heating controls and Smart Meters; and by improving the energy efficiency of lighting and appliances, and encouraging more efficient use of hot

Chart 7: Cavity walls insulated since 1990 and remaining uninsulated cavities



Source: Department of Energy and Climate Change

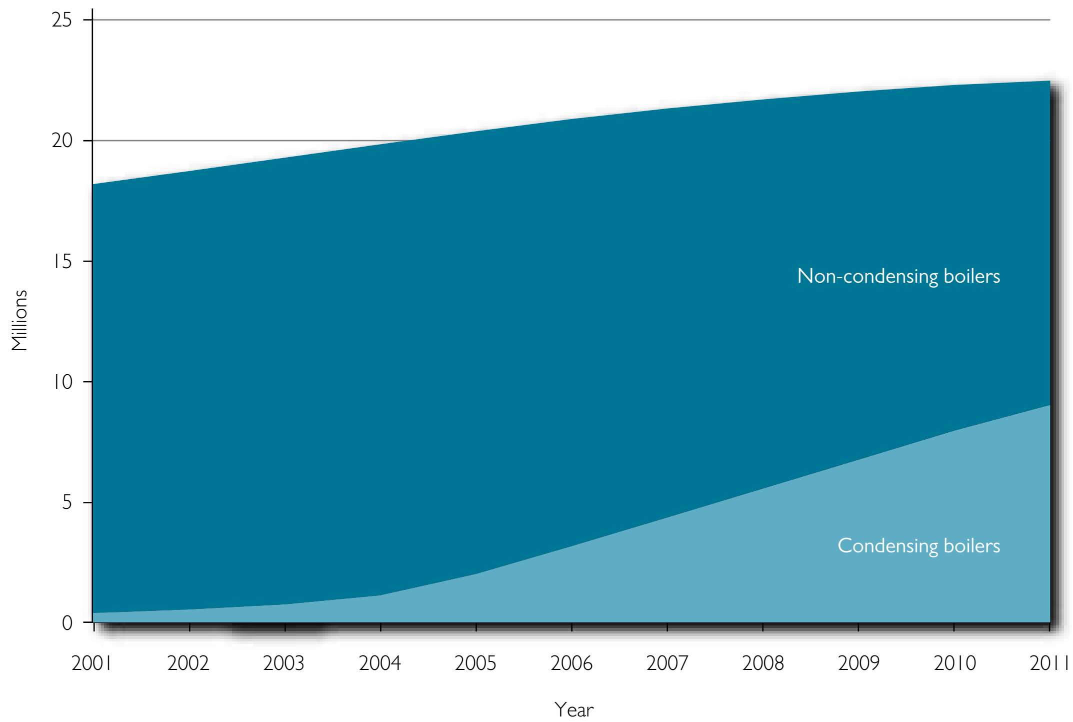
[30] Condensing boilers can reach efficiencies of around 90%.

[31] Savings calculated based on the average efficiency improvements of condensing boilers.

water. Better demand management can save money, bringing down energy bills, and release resources to support other activity and promote growth.

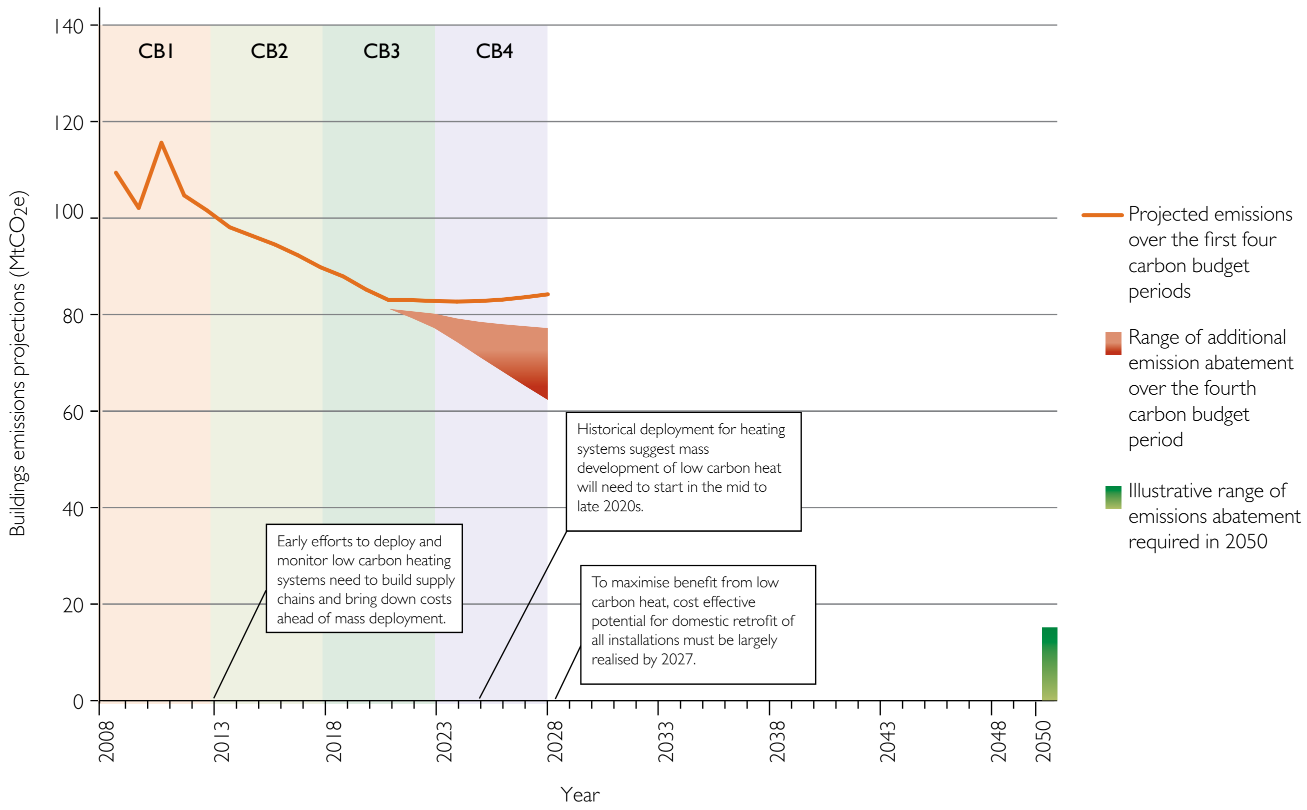
- **Decarbonising heating and cooling supply**
  By supporting the transition from conventional gas and oil boilers to low carbon heating alternatives such as heat pumps and more efficient systems such as heating networks or combined heat and power. A move away from fossil fuels for heating, hot water and appliances can reduce our dependence on imports and associated price volatility, thereby improving the security of our energy supplies.

Chart 8: Deployment of condensing and non-condensing boilers since 2001



Source: Department of Energy and Climate Change

Chart 9: Emissions projections in the buildings sector for the first three carbon budgets and illustrative ranges of emissions abatement potential in the fourth carbon budget period and in 2050[32]



Source: Department of Energy and Climate Change

[32] The emissions projections derive from UEP data. The illustrative ranges for emissions abatement potential for 2050 and the fourth carbon budget derive from the 2050 futures and fourth carbon budget scenarios – these are discussed in Parts 1 and 3 of this report respectively.

How we will make the transition

2.22 Chart 9 on the previous page illustrates the trajectory we expect emissions from buildings to follow over the first four carbon budgets on the way to 2050.

2.23 While we are on track for the first three carbon budgets, the UK will need between 26 and 75 $MtCO_2e$ of additional abatement from buildings during the fourth carbon budget period, over and above what the Government expects to be delivered through current policy. Learning from history, it has taken around 40 years for cavity wall insulation to reach today's level of market penetration. Achieving the scale of change ahead therefore requires us to start now.

2.24 **This decade** we need to **complete the cost effective 'easy wins'** in the buildings sector. This means maximising our energy efficiency efforts over the next decade. This will reduce costs and the amount of low carbon heating needed in future years.

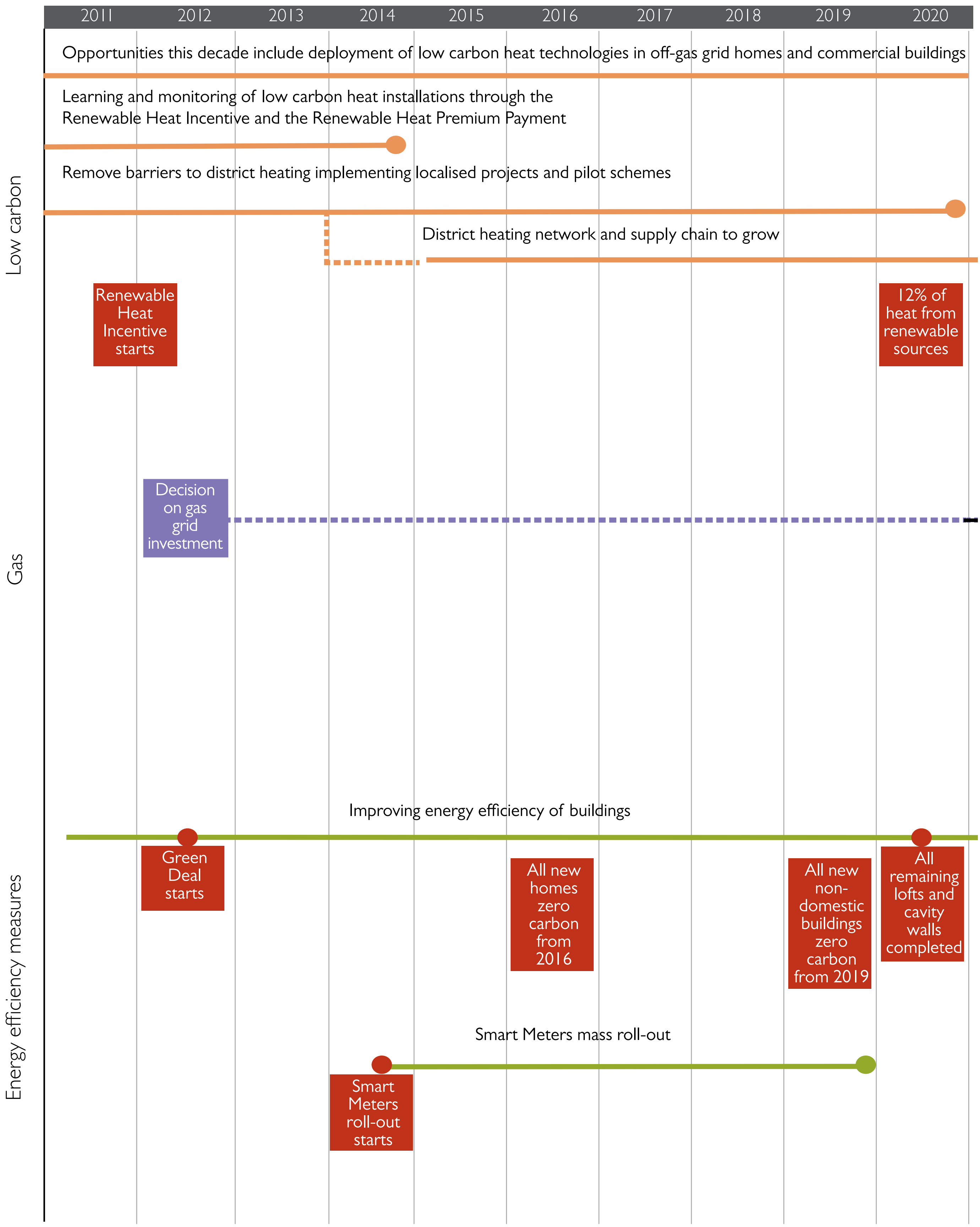
2.25 The Government's current policy package will depend on the final design of the Green Deal and Energy Company Obligation in the light of public consultation. It is likely to result in all practicable cavity walls and lofts having been insulated by 2020, together with up to 1.5 million solid walls also being insulated.

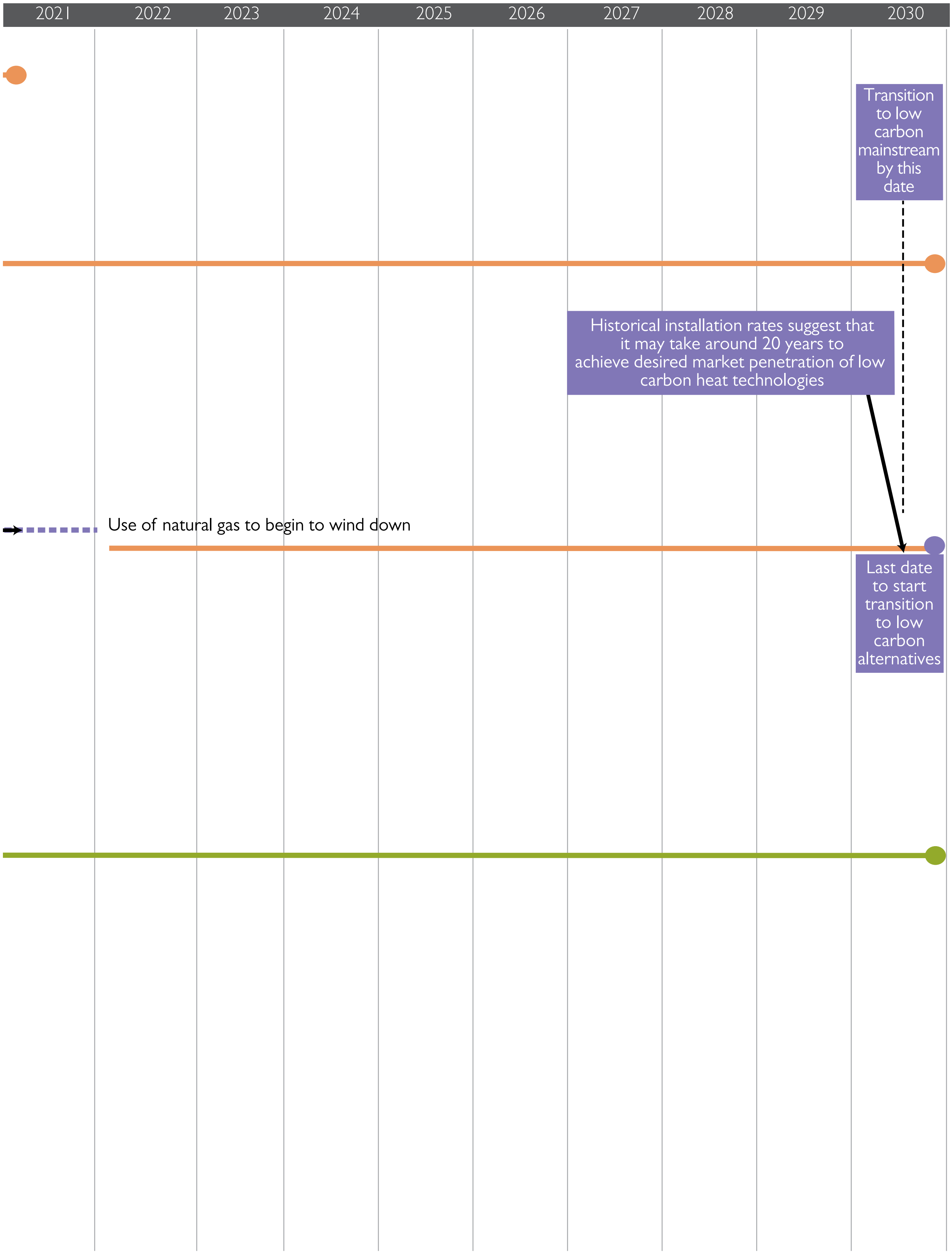
2.26 We also need to **prepare for the future**. In the buildings sector, this means acting now to build the supply chain for low carbon heating, cooling, and lighting and appliances to stimulate the innovation and competition that will bring the cost of these technologies down to a level that will make them competitive with fossil fuel-based (or less efficient) alternatives.

2.27 We will begin building the market for low carbon heating technologies, such as air- and ground-source heat pumps, so that these can displace expensive, carbon intensive alternatives. At the same time, we will encourage further deployment of heating networks, particularly in urban areas where building-level solutions may face more barriers. And in parallel we will continue to improve the efficiency of our existing gas boilers.

2.28 **The 2020s** will be a key transitional decade in delivering mainstream low carbon heat from heating networks and in buildings, and will see the expansion of low carbon heat at scale into residential areas. Progress in the 2020s will be important in ensuring a smooth and cost effective transition to low carbon heat – 2030 would be the latest opportunity at which to begin roll-out at scale taking into account historical deployment trends (see chart 10 overleaf).

Chart 10: Decision points and key actions for buildings to 2030




2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Transition to low carbon mainstream by this date
Historical installation rates suggest that it may take around 20 years to achieve desired market penetration of low carbon heat technologies
Use of natural gas to begin to wind down
Last date to start transition to low carbon alternatives

Reducing demand for energy in buildings

2.29 Reducing our demand for energy is the cheapest way of cutting emissions, and will also benefit consumers and our economy:

- In the **near term**, it will reduce demand for gas and electricity in buildings, helping to bring down emissions.
- In the **medium term**, it will save money on bills, releasing spending power to benefit the economy and it will enable smaller, and therefore cheaper, low carbon heating and cooling systems to be installed.
- In the **long term**, it will help to reduce the challenge of balancing the electricity grid.

2.30 The Government is aiming to lead by example in reducing its energy demand. On 14 May 2010, the Prime Minister committed the Government to **reducing its carbon emissions by 10% in 12 months**. The Government has achieved this target, reducing its emissions by 13.8%.[33] Real-time reporting of energy use has also been implemented across central government headquarters buildings to ensure greater public transparency of government energy efficiency.[34]

2.31 We can achieve a reduction in energy demand either by improving the energy efficiency of buildings, lighting and appliances, or by changing the way we behave so that we use energy more intelligently and reduce the amount we need.

2.32 As a result of the boiler standards introduced in 2005, savings made from the introduction of condensing boilers up to 2020 are expected to amount to around £2 billion a year for the UK as a whole. Over this period total savings from condensing boilers will amount to £15 billion.[35] In addition, by 2020 we will also capture the remaining potential in cavity walls and lofts:

- insulating all cavity walls, where practicable, by 2020 (building on around 11 million since 1990), saving an additional £200 million a year; and
- insulating all lofts, where practicable, by 2020 (building on 9 million lofts since 1990).

Improving the heat efficiency of buildings

2.33 Looking beyond 2020, we may need:

- **between 1 million and 3.7 million additional solid wall insulations** by 2030 (see chart 11 overleaf); and
- **between 1.9 million and 7.2 million other energy efficiency related installations**, such as improved glazing, by 2030.

2.34 Many energy efficiency measures are inherently cost effective and help people and businesses save money on their bills, but barriers such as upfront costs, disruption and lack of information about how to take up these opportunities can present real problems.[36]

2.35 The **Green Deal** is the Government's flagship energy efficiency policy, designed to overcome barriers to improving the UK's building stock. The framework, launching in 2012, will mean that households and businesses will have the opportunity to improve their energy efficiency at no upfront or additional cost, paying back through future savings on their energy bills.

2.36 The Green Deal will promote a 'whole house' approach, offering a comprehensive package of measures and ensuring that the needs of the property are assessed as a whole. This will mean that the improvements happen in the right order and that hassle and disruption are minimised.

2.37 In addition, microgeneration technologies may be eligible for the Green Deal to the extent that they can typically be expected to generate

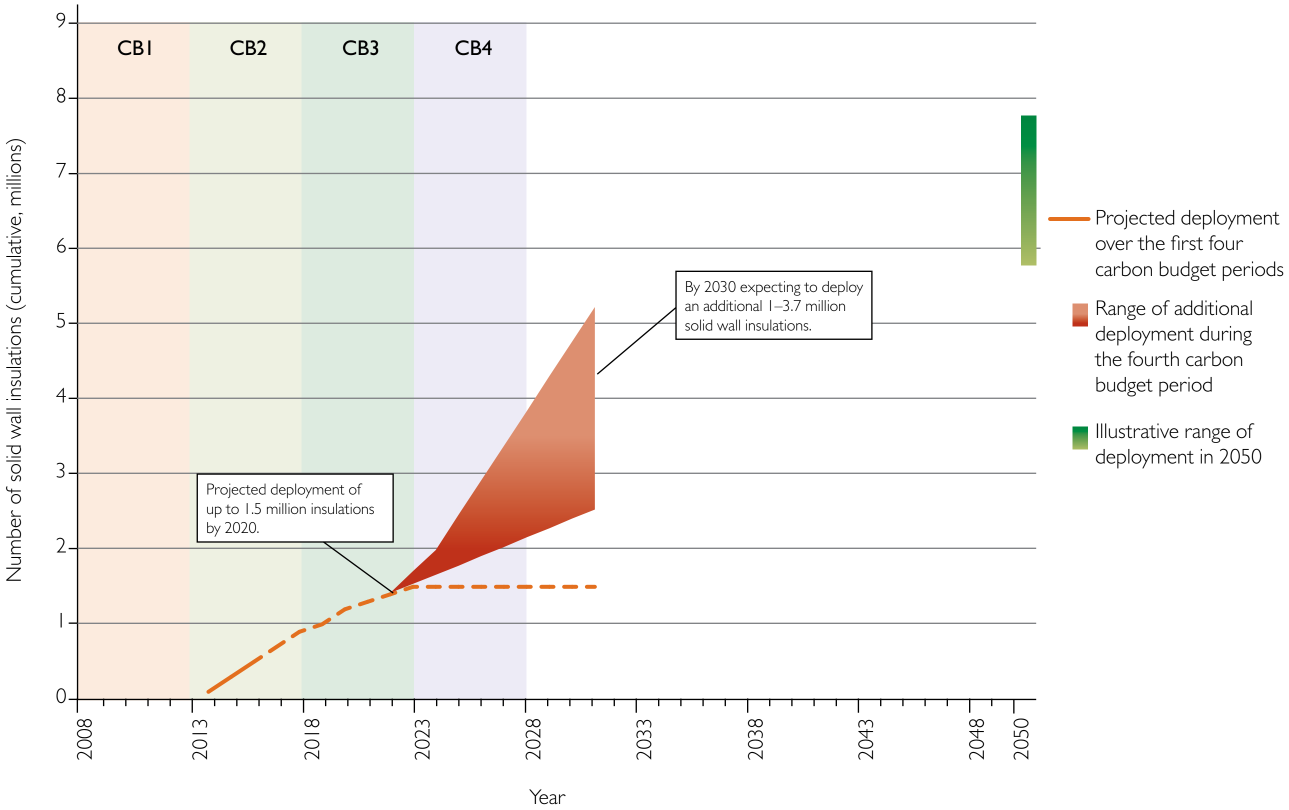
[33] This was an ambitious and challenging commitment on energy efficiency, spanning 3,000 central government office buildings and 300,000 civil servants.

[34] Available on government departments' websites.

[35] Calculated on the basis of 20 million condensing boilers being in place in 2020.

[36] The Energy Efficiency Deployment Office (EEDO), which will be set up in the Department of Energy and Climate Change by the end of the year, will aim to drive a step-change in energy efficiency by supporting existing programmes across government and by identifying and designing a strategy to realise further energy efficiency potential across all sectors of the economy.

Chart 11: Projected deployment of solid wall insulation over the first three carbon budgets and illustrative range of deployment over the fourth carbon budget period and in 2050



Source: Department of Energy and Climate Change

energy efficiency savings. The Government intends to use the Green Deal to provide information on low carbon heat alongside energy efficiency measures. The Government will in the future look to develop policy instruments for low carbon heat in a way which is compatible with our policies for reducing energy demand, so that consumers will be able to assess all options available.

2.38 Private rented buildings are one of the most difficult sectors to improve. While tenants benefit from more energy efficient buildings, it is the landlords who decide whether to pay to make the changes. The Green Deal will help tackle this split incentive.

2.39 The Government will work with the sector to encourage uptake of energy efficiency measures through the Green Deal. From 2016, domestic private landlords will not be able unreasonably to refuse their tenants' requests for consent to energy efficiency improvements. In addition, the Energy Act 2011 contains provisions for a minimum standard for private rented housing and commercial rented property from 2018, and the Government intends for this to be set at **Energy Performance Certificate** band E. Use of these regulation-making powers is conditional on there being no net or upfront costs to landlords, and the regulations themselves would be subject to caveats setting out exemptions. If these powers are used, the Government envisages that landlords would be required to reach the minimum standard or carry out the maximum package of measures fundable under the Green Deal and Energy Company Obligation (even if this does not take them to band E).

2.40 Alongside the Green Deal, the new **Energy Company Obligation (ECO)**, which will provide an additional £1.3 billion a year, will play an important role in supporting the installation of solid wall insulation, and also in providing upfront support for basic heating and insulation measures for low-income and vulnerable households. The costs of ECO are assumed to be spread across all household energy bills in Britain.

2.41 The UK's building stock is one of the oldest in Europe and the Government recognises that, to enable the transition to a decarbonised building sector, standards will need to be raised in every type of housing.

2.42 The Government is committed to successive improvements in **new-build standards** through changes to Part L of the Building Regulations in England and their equivalents within the Devolved Administrations. In October 2010, the new regulations in England and Wales introduced a 25% improvement on 2006 carbon emissions standards for new buildings, while regulation in Scotland delivered a 30% reduction on their 2007 standards. In England, the current review of the Building Regulations is looking at opportunities for further improvements planned for 2013 where these can be achieved while meeting our deregulatory aim. The Government intends to consult on these changes shortly. The review of Part L will also look at ways of generating take-up of greater levels of energy efficiency measures in existing buildings in order to help support demand for the Green Deal.

2.43 In December 2010, the Government committed that all new non-domestic buildings in England would be **zero carbon** from 2019. And in the *Plan for Growth*,[37] published alongside Budget 2011, the Government committed that all new homes from 2016 would be zero carbon. In driving investment in local low carbon energy generation and energy efficiency, zero carbon policy can work closely with local spatial planning in contributing to future growth.

2.44 We also need to tackle the performance of the existing building stock, and ensure that the poorest and most vulnerable households are able to heat their homes affordably, in line with the aim of the Government's efforts to tackle fuel poverty and achieve the statutory target.[38]

2.45 Subject to public consultation, the ECO will therefore include an **Affordable Warmth** target, aiming to provide heating and insulation measures to low-income households and households in private tenures housing someone who is older, disabled or a child. In some circumstances, this will mean delivering low carbon heating, but the focus of this particular element of the ECO policy is likely to be on more efficient gas systems for households.

Improving the electrical efficiency of lighting and appliances

2.46 As well as improving the fabric of our buildings themselves, it will also be important to minimise the energy we use for our lighting and appliances. **Energy-using products** in our homes and offices, such as white goods, lighting and televisions, contribute around 14% of the UK's CO_2 emissions. By removing the least efficient products from the market and promoting the sales of the most efficient, emissions and energy bills are reduced significantly.

2.47 By the end of 2012, minimum EU performance standards and labelling conventions will have been agreed for most domestic and commercial appliances. Looking further ahead, these standards will also cover energy-related products, which may not directly use energy but which contribute to energy consumption, such as double glazing and insulation. The first of these is likely to be regulated from 2014.

2.48 By 2020, the measures agreed so far are projected to save the UK 7 $MtCO_2e$ per annum, and the next tranche of measures are expected to save a further 6 $MtCO_2e$ per annum, subject to the stringency and timing of these measures being finalised in Europe.

Changing behaviour to reduce demand

2.49 The choices consumers and businesses make about how to use energy can have a huge impact on energy demand and on the costs they face. To help homes make the best use of their energy and prevent waste, the Government is mandating **Smart Meters** to be installed in every home by 2019. Rolling out Smart Meters will enable people to understand their energy use and maximise

[37] See: http://cdn.hm-treasury.gov.uk/2011budget_growth.pdf

[38] Target to eradicate fuel poverty as far as reasonably practicable by 2016 (Warm Homes and Energy Conservation Act 2000).

opportunities for energy saving. The Government is also mandating the provision of in-home displays for domestic customers and ensuring that consumers have the information and advice to make changes that will cut carbon and energy bills (through its consumer engagement strategy).

2.50 **Energy Performance Certificates (EPCs)** are required on the sale, rent or construction of a building. Prepared by accredited and suitably qualified energy assessors, EPCs give consumers A to G ratings for a property's energy efficiency and also provide advice on measures that can be carried out to improve its efficiency. The Energy Saving Trust estimates that the average household could save up to £300 a year by making energy saving improvements. **Display Energy Certificates** are required for buildings occupied by a public authority which are larger than 1,000 m^2 and are frequently visited by the public.

2.51 A revised version of the domestic EPC will be launched in April 2012. It has been redesigned and made more consumer friendly with clear signposting to the Green Deal and information on which measures qualify for Green Deal finance. In future, the EPC will also be used as a mechanism to disclose the existence of a Green Deal on a particular property.

2.52 The Government will also be producing guidance to support local authorities and social landlords to cut carbon emissions and maximise the opportunities for energy efficiency retrofit. This will help to drive forward large-scale retrofit of social housing, helping to stimulate the Green Deal and Energy Company Obligation markets.

2.53 In order to address the energy efficiency potential that exists in large, non-energy-intensive businesses, the Government has put in place the **CRC Energy Efficiency Scheme**. This scheme, currently in its introductory phase, combines a range of mechanisms to address the barriers to energy efficiency deployment. Over 2,000 participants submitted reports in July 2011 for the first compliance year. The Government is aware that a number of stakeholders have raised concerns about the complexity of the scheme. Therefore, in early 2012, the Government will issue a formal consultation on our proposals for a simplified scheme.

2.54 The Government also believes that there may be potential for smarter use of **heating controls** to help save energy, by giving consumers and businesses greater control and flexibility over the way in which they heat and cool their homes. At a relatively simple level, thermostatic radiator valves (currently estimated to be deployed in around 55% of homes with a boiler)[39] allow radiators to be turned down or off in rooms that are not in use. More sophisticated options, such as remote controls and sensors that respond to building occupancy, offer more possibilities. As these technologies develop, this may enable consumers to reduce the average internal temperature of their buildings – delivering savings of around 10% of energy use on space heating for every 1°C reduction – without experiencing a big change in their levels of thermal comfort.

Decarbonising heating and cooling supply

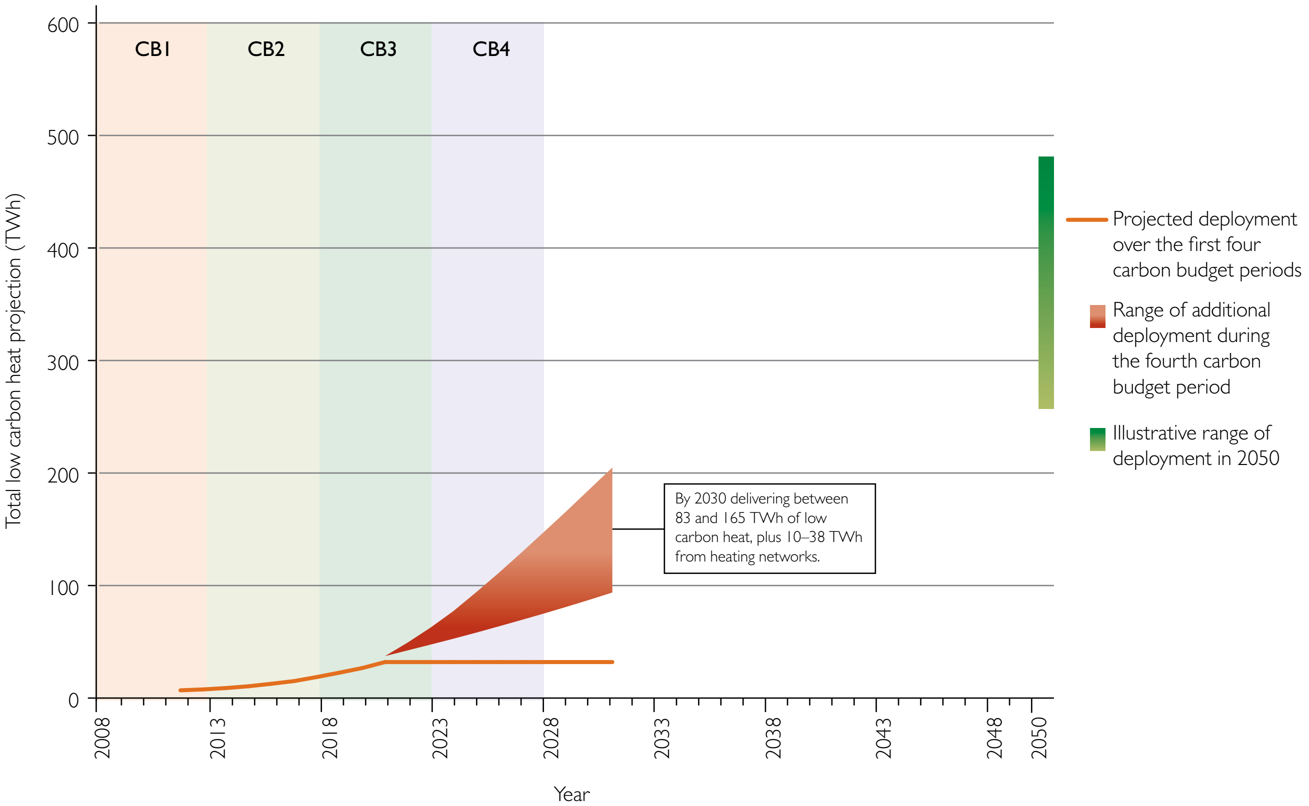
2.55 Achieving a cut in building emissions to virtually zero by 2050 will only be achievable if we decarbonise our supply of heat and cooling as well as reducing demand. It is likely that we will still get most of our heat from natural gas well into the 2020s.

2.56 As things stand, we are increasingly dependent on other countries for our oil and gas supplies, and continuing to use these fuels may mean that we are more exposed to global pressures which lead to price spikes and increases. Keeping the price of energy competitive is crucial. For many years, our domestic consumers have benefited from the UK's competitive energy market – from 2008 to the present day, UK gas prices have been among the lowest in Europe.

2.57 As we look further ahead, the proportion of heat provided directly by natural gas will fall as we see increased use of low carbon technologies, but

[39] BEAMA analysis of EST HEC data and EHCS in the Heating and Hot Water Taskforce (2010) *Heating and Hot Water Pathways to 2020.*

Chart 12: Projected deployment of total low carbon heat in buildings over the first three carbon budgets and illustrative ranges of deployment in the fourth carbon budget period and in 2050[40]



Source: Department of Energy and Climate Change

this will be a gradual process. Deployment of heat pumps and other low carbon heat technologies, and the construction of district heating systems in urban areas with high heat demand, will replace natural gas as the primary source of heat in this country, a process that has already started and will take many decades to complete. Continuing efforts to deploy highly efficient condensing boilers in homes and businesses remains a priority in the transition.

2.58 Looking to the future, between 21% and 45% of heat supply to our buildings will need to be low carbon by 2030. We will therefore need **between 1.6 million and 8.6 million building-level low carbon heat installations by 2030**, delivering 83–165 terawatt hours (TWh) of low carbon heat, alongside 10–38 TWh of low carbon heat delivered through heating networks (see chart 12).[41]

[40] The main differences in assumptions between government modelling and that done by the Committee on Climate Change (CCC) are around the cost and effectiveness of heat pumps where the Government assumes that performance and cost do not improve as quickly as the CCC does, and biomass, where the Government assumes greater availability for low carbon heat than the CCC. However, the differences in assumptions lead to only a small difference in the expected deployment of low carbon heat to 2030.

[41] In the lower range, our modelling shows mainly commercial installations take up low carbon heat, with a large heat load per installation. In the higher range most of the additional installations come from domestic-level heat pumps and biomass boilers, with smaller heat loads per installation.

2.59 The portfolio of technologies through which we can achieve the decarbonisation of heating and cooling supply is diverse.

Box 7: Technology portfolio for low carbon heat

Building-level technologies

Biomass boilers – These work like conventional boilers, but instead of using natural gas or heating oil they burn biomass, such as wood pellets, to produce the heat used to provide heating and hot water.

Electrical resistance heating – This converts electrical energy directly into heat. It can also be used as secondary back-up heating or with a storage system which takes advantage of cheaper electricity, sold during low demand periods such as overnight.

Heat pumps – These use electricity to leverage ambient heat from the air or ground (or in some cases from water), using a compressor just like a fridge. This allows heat pumps to work at efficiencies far higher than even the best gas boilers, typically producing three units of heat for every unit of electricity. Heat pumps can either directly heat the air inside a building or heat up water for central heating and hot water systems. Some heat pumps can also be operated in reverse cycle mode to provide cooling. Heat pumps perform better in houses with low temperature heat emitters.[42]

Micro-combined heat and power (CHP) – CHP is described below and, in the form of micro-CHP, can be used as an alternative to boilers to provide heat and electricity at building level.

Solar thermal hot water – For buildings with sufficient south-facing roof space, solar panels can be fitted and connected to a water tank to provide hot water. This will not usually be sufficient to meet all of a building's hot water needs year round, but it can be an effective, low carbon way to supplement other sources of water heating.

Network-level technologies

Combined heat and power (CHP) – Technologies that generate both heat and electricity are collectively known as CHP. These can use a range of fuels (not necessarily low carbon) including biomass, wastes and bioliquids. At present, CHP is most commonly used by industry to provide heat and electricity for large sites. It can also be used to provide a source of heat for heating networks.

Gas grid biomethane injection – Sustainable biomass and wastes can be converted to gas and upgraded to biomethane, a gas that can directly replace or blend with natural gas in the grid and is compatible with existing boilers. This could be done at a large scale, or in smaller areas of the grid ringfenced for this purpose.

Heating networks – Heat can be generated by commercial-scale low carbon heat installations such as heat pumps or biomass boilers, or using low-grade heat generated in thermal power stations. Heat exchangers then transfer the heat into buildings via a network of steam/hot water pipes to provide space heating and hot water.

[42] Most houses' heat emitters in the UK have small surface area and consequently must operate at higher temperature to maintain comfort. Therefore, heat pump installation is usually accompanied by replacement of radiators (e.g. with underfloor heating, or with radiators more appropriate for use with heat pumps).

Building-level technologies

2.60 Decarbonisation at the level of individual buildings substitutes current heating systems (such as gas boilers) for low carbon alternatives such as heat pumps or biomass boilers. Of the technology choices described in box 7, heat pumps are likely to be a particularly attractive option. Their ability to operate at efficiencies of up to 300%, to use electricity – which will also be decarbonised in the medium to long term – as a fuel, and the flexibility for some to provide cooling as well as heating, makes them a strong candidate to provide space heating, hot water and cooling for domestic and commercial buildings into the future.

2.61 The portfolio of options above have specific strengths and applications for which they are best suited. There are also technical and practical barriers to these technologies and measures, which will need to be addressed if we are to see large-scale deployment.

2.62 All households and businesses will need to play a part in this transformation. The Government aims to create the right conditions for homes and businesses to generate their own heat using low carbon technologies or make use of low carbon heat from a heat network, but there are a number of key obstacles to overcome, including the following:

- Low carbon heat technologies such as heat pumps and biomass boilers are still expensive relative to conventional boilers, costing in excess of £5,000, and payback periods for this investment are often long. This is by far the biggest barrier to deployment.
- Low carbon heat technologies take longer to install compared with a conventional boiler, which offers a particular barrier given that heating systems are often 'distress purchases' – bought only when the old system breaks down.
- The installation of technologies such as ground-source heat pumps requires a specialist skill set, meaning that finding installers with adequate training and skills is a potential barrier to deployment.
- Heat pumps in particular can place added strain on the electricity grid. This can partially be managed through the use of storage, such as hot water cylinders to store heat, or batteries to store electricity generated off-peak.

2.63 While we do not expect mass market deployment ahead of the 2020s, there are important opportunities now to build a market for low carbon heat in buildings, particularly in commercial buildings and off-gas grid homes. Many public and commercial buildings have already taken up energy efficiency measures, and work to develop low carbon heating in public and commercial buildings will help to build the supply chain for low carbon heat in the UK. Cooling demand is also expected to rise significantly in these buildings, so increasing the efficiency of air conditioning units and installing low carbon alternatives such as reversible heat pumps will also be important. In the residential sector, 4 million households are not currently heated by mains gas, and many have to rely on expensive, higher carbon forms of heating. Heating oil is still used in around 2 million homes, for example. These households will gain more from switching to low carbon heating because their heating bills and carbon emissions are higher than average and they currently suffer the inconvenience of having to have fuel delivered.

2.64 The Government is therefore committed to providing financial support for low carbon heat consistent with the UK's 2020 renewables target.[43] The **Renewable Heat Incentive (RHI)** is the first financial support mechanism of its kind in the world to increase the deployment of renewable heat. Under phase 1 of the scheme, communities, charities, and public and private sector organisations can apply to receive a payment for generating heat using eligible low carbon heat technologies. The support levels will be set out in legislation.

[43] The 2009 Renewable Energy Directive sets a target for the UK to achieve 15% of its energy consumption from renewable sources by 2020.

2.65 Under phase 1 of the RHI, the Government expects to deliver:[44]

- an additional 56.5 TWh of low carbon heat by 2020 (of which, 30.5 TWh will be delivered to buildings – up to 112,000 low carbon heat installations), saving 43 $MtCO_2e$ overall (of which over half is from buildings) over the period 2011–20; and
- 11% of our heat coming from new and diversified renewable sources, as part of an overall ambition to achieve 12% by 2020.

2.66 The quality of installations and the supply chain to support low carbon heat need to be first class to ensure consumer confidence. The Government is requiring all RHI installations (up to and including 45 kWh) be installed by an accredited Microgeneration Certification Scheme installer.

2.67 The Government expects to introduce support for the domestic sector under the second phase of the scheme. In the interim, the Government has launched the **Renewable Heat Premium Payment (RHPP)**. The RHPP provides a single payment to households that install low carbon heat, and could deliver up to 25,000 installations. A crucial part of the RHPP is then monitoring a significant number of installations made under the scheme. This information will inform the Government's longer-term approach to support for low carbon heat.

Network-level technologies

2.68 At network level, substituting natural gas with sustainable biomethane in the grid is, at first glance, the least disruptive option. Decarbonising our heat and hot water supply without having to change our heating systems, and while using a gas grid that is already built, initially appears like an attractive option.

2.69 However, injecting biomethane into the gas grid presents a number of challenges. With biomass likely to be needed for sectors that are hard to electrify, such as freight and some industrial processes, combined with doubts over the scale of sustainable global biomass supply, it would be high risk to assume that large-scale biomethane injection into the grid is a viable option. The gasification process or anaerobic digestion of UK-sourced waste(s) or biomass could only meet a small proportion of UK demand, with gas consumption in buildings currently running at close to 500 TWh a year. Relying on imports would leave the UK exposed to international bioenergy prices that may rise substantially. Heat networks, where heat is generated remotely and supplied to buildings, offer a more promising option.

2.70 Up to half the heat demand in England, and much of it in other parts of the UK, is found in areas that potentially have heat loads dense enough to make heat networks a viable means of delivering heating direct to homes and businesses. Combined in the medium and long term with low carbon heat sources, this offers a valuable alternative to building-level heating as a means of decarbonising the UK's heat supply.

2.71 Heating networks have the advantage of convenience and flexibility, and would allow for the cost effective deployment of transitional heat sources. For example, in the nearer term, it may make most sense for heat networks to be supplied by combined heat and power plants fuelled by natural gas but, in the long run, this may be supplanted by heat from nuclear or carbon capture and storage power plants, energy from waste plants or from dedicated large-scale heat generation through heat pumps or biomass boilers large enough to supply whole cities. This approach allows for a portfolio of heating sources to be deployed which best suit local contexts.

2.72 Heat networks require significant deployment of new infrastructure and therefore face a number of barriers, notably the cost of installing the pipes, as well as questions of regulation, ownership and charging structures. Practicalities of geography can also restrict the

[44] The following figures include savings in industry which account for around 26 TWh of renewable heat in 2020, unless specified. These also reflect the impacts of the change in the large biomass tariff as a result of the EU ruling (however, this is not reflected in the annexes to this document).

deployment of heating networks. The Government will set out in the new year how it will work with local authorities and other stakeholders to address barriers to district heating, along with barriers to other approaches to low carbon heat.

2.73 The Government will therefore work with local authorities and other stakeholders to explore potential to remove barriers in these areas.

2.74 The interactions between the different technologies and approaches described here for decarbonising our heat supply are complex, and will make a big difference to how we heat and cool our homes and businesses in future. The Government recognises the importance of low carbon heat to achieving our ambitions for decarbonising the economy and deploying renewable energy, as well as the importance to consumers of heating our homes and businesses in a secure, affordable way, and will therefore **publish a document on its strategy for decarbonising heat in the new year.**

TRANSPORT

Where we are now

2.75 Domestic transport emitted around 137 $MtCO_2e$ in 2009, accounting for around 24% of UK domestic greenhouse gas emissions (see chart 13 below).[45] Domestic emissions from transport rose steadily between 1990 and 2007, driven primarily by rising road traffic levels. They have since fallen back to roughly what they were in 1990. This fall is partly the result of the recent economic downturn, but statistical data suggests that the main factors have been improvements in new car fuel efficiency and the increased uptake of biofuels, driven by existing government and EU policy.

2.76 **By 2030** we project that current policies could mean that transport emissions reduce to around 116 $MtCO_2e$.[46]

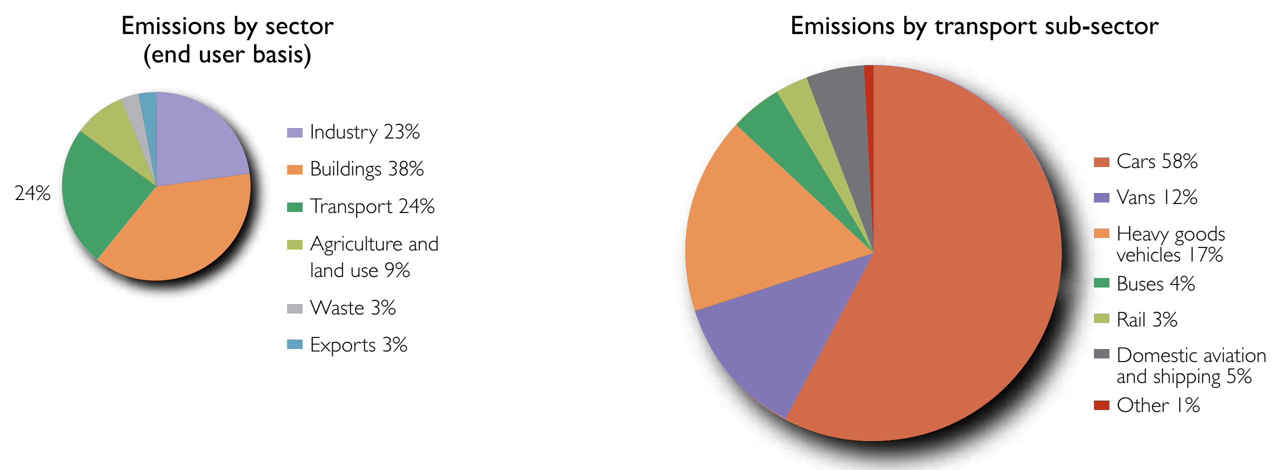
2.77 **By 2050** the transport system will need to emit significantly less carbon than today, while continuing to play its vital role in enabling economic growth, and provide many additional benefits such as lower fuel costs and better energy security.

Where we will be in 2050

2.78 There are many different types of transport and in this report they have been broken down into cars and vans, rail, local sustainable travel, freight, aviation and shipping, as well as considering the role of biofuels.

2.79 The Government's vision is that by 2050 almost every car and van will be an ultra-low emission vehicle (ULEV), with the UK automotive industry remaining at the forefront of global ULEV production, delivering investment, jobs and growth. Due to the time needed for fleet turnover, this requires almost all new cars and vans sold to be near-zero emission at the tailpipe by 2040. These ULEVs could be powered by batteries, hydrogen fuel cells, sustainable biofuels, or a mix of these and other technologies. We cannot say for sure which technologies will emerge as the most effective means of decarbonising car travel, so it is essential that the Government takes a technology neutral approach, allowing us to achieve

Chart 13: Proportion of UK greenhouse gas emissions from the transport sector, 2009



[45] The equivalent figures by source are 121.6 $MtCO_2e$, or 22% of UK emissions.

[46] Transport emissions in the Updated Energy and Emissions Projections include off-road emissions, which are not included in transport emissions as reported on the National Communication basis. This means that 2030 emissions shown here are higher than those reported in emissions statistics. Figures exclude emissions from international aviation and shipping.

emissions reductions in the most cost effective way. Rail travel will be substantially decarbonised through further electrification, more efficient trains and lower carbon fuels. If the Government's proposals for high speed rail go ahead, a new national network linking London to Birmingham, Manchester and Leeds will transform rail capacity and connectivity, promoting long-term and sustainable economic growth. Passengers choosing sustainable travel options such as travel by public transport, cycling and walking will continue to deliver major social and economic benefits, and alternatives to travel, such as working from home, could increasingly do so too.

2.80 The freight sector will have found lower carbon ways of working, such as modal shift to rail and water and more efficient driving techniques, and adopted the necessary ultra-low carbon technologies to continue to supply the UK's factories and consumers while cutting back carbon emissions dramatically.

2.81 Domestic aviation and shipping are already included in UK carbon budgets and so will need to contribute to meeting the 2050 target. International aviation and shipping are not currently included; a decision whether to include them is due by the end of 2012.

2.82 Sustainable biofuels could play a key role in reducing emissions across the different transport sectors, although concerns about sustainable supply may limit their use.

2.83 There are several interdependencies to be considered. Electrifying the car fleet or rail network would reduce tailpipe emissions from individual vehicles to zero, although the positive impact on economy-wide emissions relies on a low carbon grid. As a result there could be substantial benefits in local air quality and reducing traffic noise. Uptake of alternatives to travel could mean more emissions from heating and lighting commercial and residential buildings. There may also be competition for sustainable feedstocks between transport biofuels and bioenergy in other sectors.

How we will make the transition

2.84 **Over the next decade**, the Government will seek to make significant progress towards achieving the 'easy wins' in cutting emissions from transport. Cars and vans make up the largest share of emissions. Incentivising more efficient combustion engines and the use of sustainable biofuels is a central plank of the plan to reduce these emissions. Looking ahead, the emergence of ULEVs and hybrid and electric cars over this period will be crucial in preparing for progress in the 2020s.

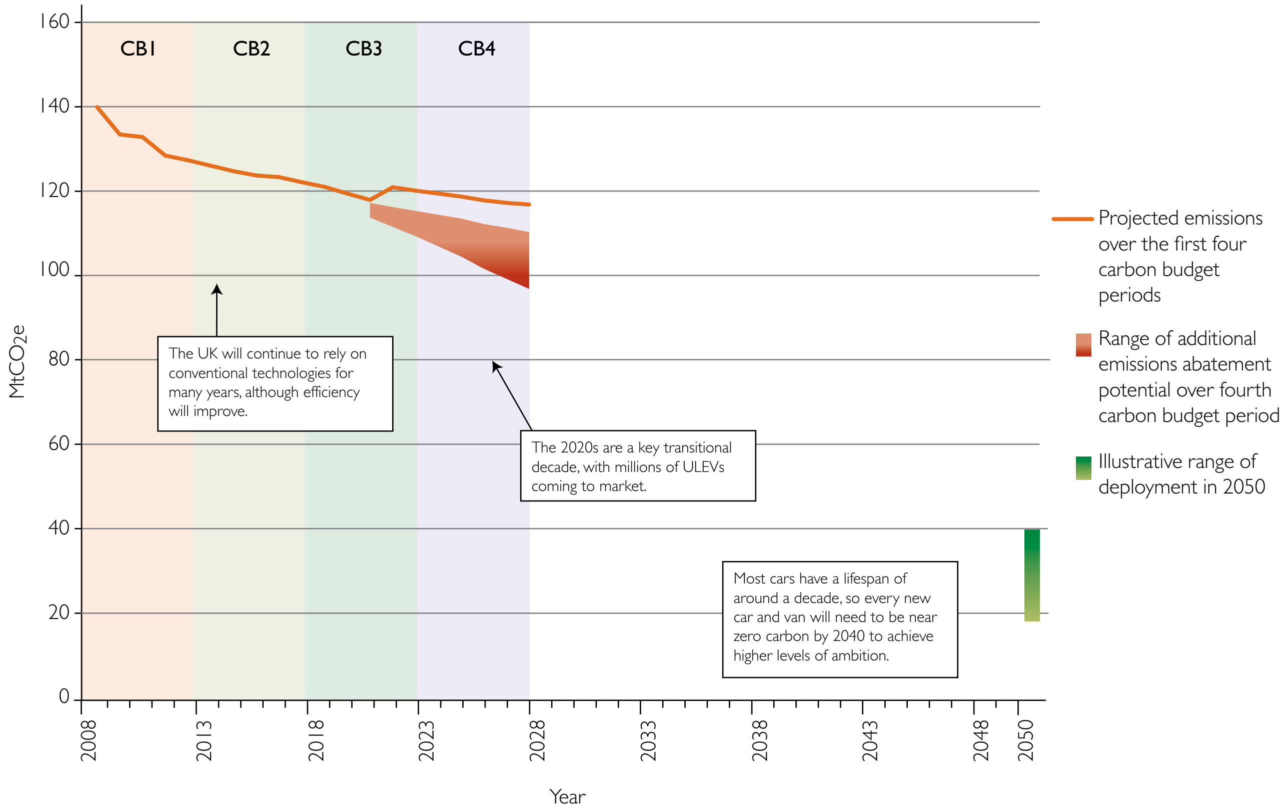
2.85 Other transport sectors will also need to take steps towards decarbonisation in the next decade. The freight industry will begin to reduce its emissions through increased efficiency and government support on infrastructure. Further electrification of the rail network will support low carbon modal shift in the future. Emissions from domestic aviation will be capped as part of the EU ETS. And the public will be encouraged to make lower carbon travel choices, such as taking public transport or cycling more often.

2.86 With deeper cuts required through the 2020s, we will move towards the mass market roll-out of ULEVs, such as those powered by electric batteries, hydrogen fuel cells and plug-in hybrid technology. Further improvements to the efficiency of conventional vehicles and sustainable biofuels are expected to play a vital role. Other sectors will need to continue to play a role.

2.87 Chart 14 illustrates some possible emissions trajectories for decarbonising the transport sector overall over the next decade, over the fourth carbon budget and out to 2050.

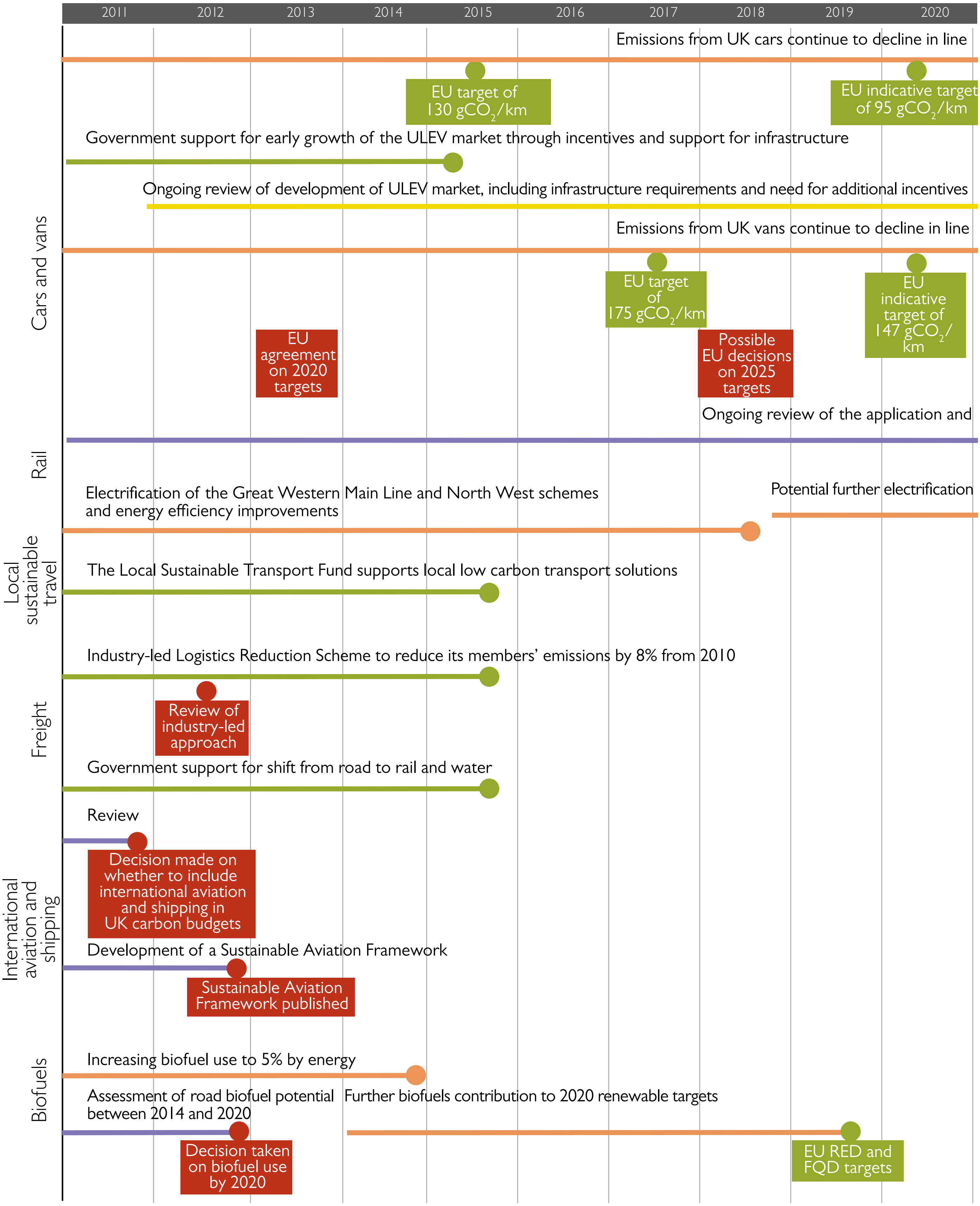
2.88 Details on action needed across the different modes of transport over the next decade and then during the fourth carbon budget are set out below. Chart 15 on pages 50 and 51 gives a summary of some of the key actions and decision points that will set us on the way to decarbonising transport.

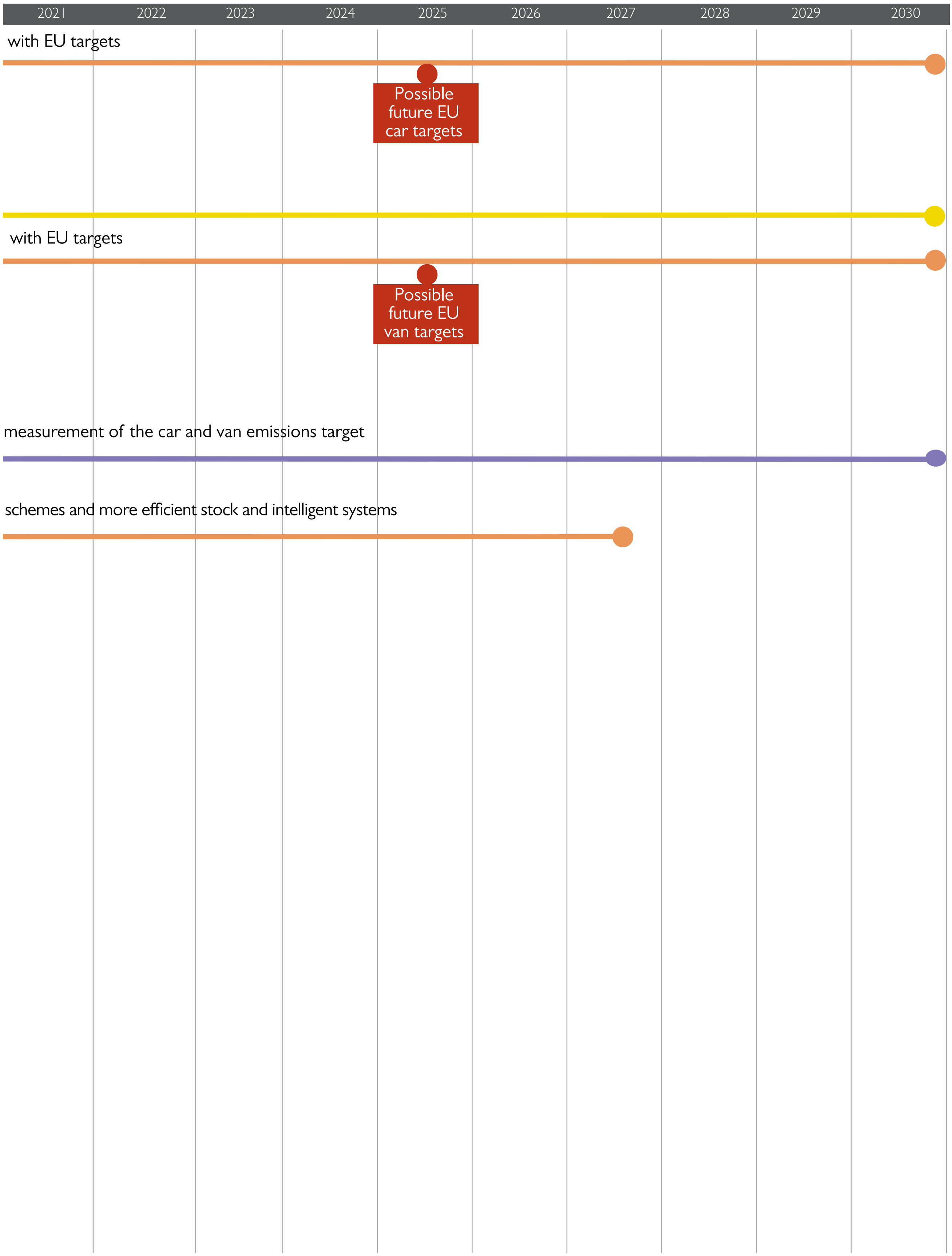
Chart 14: Emissions projections in the transport sector in the first three carbon budgets and illustrative ranges of emissions abatement potential in the fourth carbon budget period and in 2050[47]



47 The emissions projections derive from Updated Energy and Emissions Projections data. The illustrative ranges for emissions abatement potential for the fourth carbon budget and 2050 derive from the 2050 futures and fourth carbon budget scenarios – these are discussed in Parts 1 and 3 of this report respectively.

Chart 15: Decision points for transport to 2030




2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
with EU targets
Possible future EU car targets
with EU targets
Possible future EU van targets
measurement of the car and van emissions target
schemes and more efficient stock and intelligent systems

Cars and vans

2.89 **Over the next decade**, the focus will be on continuing improvements to the efficiency of conventional petrol and diesel cars, welcoming ULEVs to market, and supporting research and development into new ULEV technologies. Many major motor manufacturers have already taken a lead in bringing forward ULEV models and entering the growing UK market. The UK automotive industry is well placed to stay ahead of international competitors and remain a vibrant source of growth in the coming decades.

2.90 The Government's existing policy mix puts it on track to progressively reduce the carbon impact of cars and vans. Currently, a major driver of emissions reductions for both cars and vans are the EU new vehicle CO_2 targets. These are set at 130 gCO_2/km in 2015 and 95 gCO_2/km in 2020 for cars, and 175 gCO_2/km in 2017 and 147 gCO_2/km in 2020 for vans. EU emissions standards will continue to be vital in delivering the Government's carbon reduction goals for cars and vans.

2.91 A review of the 2020 car and van targets is due to complete by 1 January 2013, and in the next few years we expect the European Commission to make proposals for post-2020 new car and van emissions standards. As part of the Government's mission to rebalance the UK economy and foster sustainable economic growth, it is important to create the conditions for long-term investment in the UK automotive industry. We will therefore work towards ambitious but realistic targets for vehicle standards beyond 2020 which, when considered alongside domestic policies, are consistent with both meeting the fourth carbon budget and reaching near-zero average new car emissions by 2040.

2.92 To support early growth of the ULEV market, the Government is taking an integrated and pragmatic approach:

- The 2010 Spending Review made provision for **around £300 million** over the life of this Parliament for consumer incentives to reduce the upfront cost of eligible ULEV vehicles to consumers and businesses. The Plug-In Car Grant provides 25% (up to £5,000) of the cost of an eligible vehicle and will be reviewed regularly to ensure that it remains the most effective way of incentivising uptake. Consumers and businesses also benefit from a favourable tax regime, with plug-in vehicles receiving exemptions from Vehicle Excise Duty and Company Car Tax, as well as Enhanced Capital Allowances.
- The £30 million **Plugged-In Places** programme is the key mechanism for commencing the roll-out of recharging infrastructure in the UK and providing learning to inform future development of a national network.
- The Government published an electric vehicle infrastructure strategy, which set out a clear vision and the steps the Government is taking to remove barriers. There is potential for the **Green Investment Bank** to provide targeted financial solutions for appropriate plug-in vehicle infrastructure projects in the future.
- To ensure necessary technological development the Government is supporting low and ultra-low emission vehicle research, development and demonstration (RD&D), focusing on priorities identified in conjunction with the UK Automotive Council. We will continue to monitor the level of RD&D support to ensure that barriers to the development of ULEV technologies through the 2020s are identified and tackled.

2.93 The Government will continue its role in working with industry to identify and remove potential barriers to ULEV uptake as the market develops, for example in the provision of hydrogen infrastructure should the market develop this way.

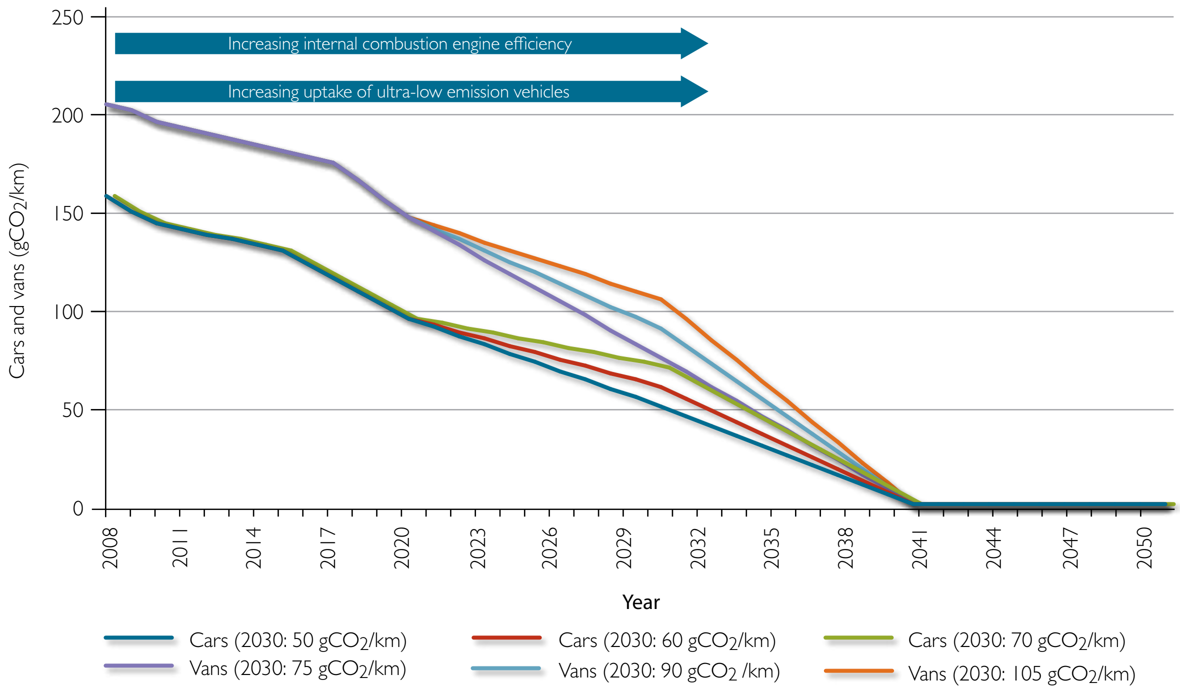
2.94 **Over the fourth carbon budget**, the efficiency of the car and van fleet will need to continue to improve, with accelerated uptake of ULEVs required in order to meet the 2050 target.

2.95 The Government's analysis for the fourth carbon budget has considered what level of average new car and van emissions might be necessary in the 2020s, independent of technology type. For new cars we consider a range of emissions between 50 gCO_2/km and 70 gCO_2/km in 2030 to be plausible, and for vans a range between 75 gCO_2/km and 105 gCO_2/km. These scenarios are seen as credible but challenging by industry, and they are all consistent with the goal of ensuring that average emissions of new cars and vans are near-zero at the tailpipe by 2040 (see chart 16).

2.96 By pursuing a framework for improvements in average fuel efficiency as opposed to specific technology targets, the Government intends to create the incentives for industry to develop the emissions reduction technologies that work best for consumers.

2.97 Barriers to ULEV uptake include costs of ownership including insurance; consumer acceptability, for example over the range of battery electric vehicles, or payload requirements for vans; availability, and cost of natural resources such as lithium and rare earth metals; and the appropriate infrastructure for different ULEV technologies, providing adequate re-charging access and speed. Our strategy is designed to tackle these barriers as detailed at paragraph 2.92. Nevertheless uncertainties around when these barriers will come down could mean mass ULEV uptake is delayed into the 2030s.

Chart 16: Projected average new car and van emissions over the first three carbon budgets and illustrative ranges of average new car and van emissions in the fourth carbon budget period and to 2050



Box 8: Some technology options for road transport

Battery electric vehicle: A vehicle driven by an electric motor and powered by rechargeable batteries, as opposed to a hydrogen fuel cell or a petrol/diesel combustion engine.

Flywheel hybrid vehicle: A vehicle with a mechanical flywheel energy storage device that captures kinetic energy when braking, returning the energy to the wheels on acceleration.

Gas-fuelled heavy goods vehicle: A heavy goods vehicle (HGV) powered by natural gas or biogas rather than diesel.

Hybrid electric vehicle: A vehicle powered by a combustion engine with varying levels of electrical energy storage captured when braking and stored in a battery or supercapacitor.

Hydrogen fuel cell electric vehicle: A vehicle driven by an electric motor powered by a hydrogen fuel cell which creates electricity on board.

Plug-in hybrid electric vehicle: A plug-in version of a full hybrid, usually with a larger battery and a greater electric driving range. In addition to capturing energy when braking, the on-board battery can be charged from an external source when the vehicle is not in use.

Series hybrid: A plug-in hybrid where the wheels are driven exclusively by an electric motor with an additional internal combustion engine connected in series. The engine runs at optimum efficiency to power an on-board generator to charge the battery. 'Range extenders', which use a small combustion engine to charge the battery to enable longer-distance journeys, are a type of series hybrid.

Ultra-low emission vehicle (ULEV): Any vehicle that emits extremely low levels of carbon emissions compared with current conventional vehicles.

Rail

2.98 **Over the next decade**, the Government will make and start to implement decisions about rail which will continue **over the fourth carbon budget**. Government has committed to the electrification of the Great Western Main Line as far west as Cardiff, and routes in the North West, and, as announced in the recent Autumn Statement, will also take forward the electrification of the North Trans-Pennine route from Manchester to York via Leeds. Other schemes are also under consideration for electrification, including of the Midland Mainline and the Welsh Valleys. While additional abatement is likely to be modest, it can nevertheless be a cost effective way to cut carbon, particularly where the technical difficulties of electrifying are small, and the lines are well used delivering considerable wider economic benefits.

2.99 The Government is also working closely with the rail industry to improve energy efficiency and reduce emissions across the rail network. Next year the rail industry will publish its second Rail Technical Strategy assessing how, over the longer term, technology can help to deliver a more cost effective, higher capacity, higher performance and lower carbon railway.

2.100 A decision on the Government's strategy for a national high speed rail network, and on the proposed route of the initial London–West Midlands link, is due in December 2011. This initial phase would be broadly carbon neutral, with the potential for valuable carbon reductions as the network is expanded further north. Such a national network could see as many as 6 million air trips and 9 million road trips switching to high speed rail each year, reducing carbon and cutting congestion on roads and at airports.

Local sustainable travel

2.101 **Over the next decade**, sustainable travel measures, such as encouraging the use of local public transport, cycling or walking, will enable people to make lower carbon travel choices. In doing so they will reduce emissions, boost the local economy through reduced congestion, and improve air quality and health. Alternatives to travel could also grow in prominence: technological advances (such as video conferencing) have the potential to shift the location and pattern of travel for both work and leisure, with potential carbon benefits from reduced travel demand, as well as economic, social, and environmental gains.

2.102 The Government has introduced the Local Sustainable Transport Fund (worth £560 million over the lifetime of the current Parliament) to enable local authorities to deliver transport solutions that build strong local economies and cut carbon emissions. In the recent Autumn Statement the Government announced a further £50 million to be used by local transport authorities for small transport improvement schemes costing less than £5 million, as well as up to a further £25 million for the Green Bus Fund for the purchase of low carbon emission buses.

2.103 **Over the fourth carbon budget**, more people choosing to take public transport, walk or cycle could mean up to a 5% reduction in urban car trips. However, uncertainties around the impact of individual initiatives, and barriers such as convenience, safety and appropriateness to journey, may prevent the highest levels of abatement from being realised.

Freight

2.104 **Over the next decade** there are likely to be a range of measures that will help to reduce the carbon impact of freight. These include eco-driving techniques, better management of logistics supply chains, improved vehicle design using lower carbon fuels, and making best use of other modes such as rail.

2.105 Industry and the Government are already taking a range of actions to drive down emissions from freight:

- There is considerable industry appetite to take the lead in making cost effective carbon reduction happen. The Government has endorsed the Freight Transport Association-led Logistics Carbon Reduction Scheme, which records and reports emissions reductions from road freight and has set a target for its members of an 8% reduction in emissions between 2010 and 2015. The success of this industry-led approach will be reviewed in 2012.
- The Government provides the Mode Shift Revenue Support and Waterborne Freight Grant schemes in England and Wales, to support modal shift which is not always commercially viable for the operator. The Government is also facilitating provision of infrastructure, such as improved capacity at our ports by consenting for major container terminal developments. In addition, Network Rail is funded to deliver over £200 million in Strategic Freight Network enhancements through to 2014, with an additional £55 million funding being made available in the Logistics Growth Review to improve rail connectivity to Felixstowe port.

2.106 The Government has also launched a trial of longer semi-trailers which will help to identify the potential carbon benefits that could be achieved from their wider introduction and the consequent reduction in the number of lorries on the roads.[48] The recently published Logistics Growth Review also includes a package of measures to overcome some of these barriers and uncertainties and to help put the UK on track to deliver a deep cut in road freight emissions by 2050. These measures will support green growth by encouraging the adoption of low emissions HGV technologies and the development of the UK manufacturing base in these technologies. The Government is making available £8 million to pump-prime investment in low emissions HGVs and their supporting infrastructure.

[48] See: www.dft.gov.uk/publications/longer-semi-trailers

2.107 **Over the fourth carbon budget**, significant further efficiency improvements could be possible, although there are considerable uncertainties. In the longer term the sector will require alternative technologies and fuels to deliver more substantial carbon reductions. The Government believes that initial market take-up of some of these low emission technologies, such as gas-fuelled lorries and flywheel hybrids, is challenging but achievable during the fourth carbon budget. This would require barriers, such as uncertainties over costs and infrastructure requirements, and concerns over vehicle range, weight and size issues with some low emissions options, to be overcome.

Aviation and shipping

2.108 **Over the next decade**, emissions from domestic aviation are included in the EU Emissions Trading System (EU ETS). Domestic aviation and shipping are included in UK carbon budgets, although they contribute a very small proportion of total emissions.

2.109 International aviation and shipping emissions are not currently included in the UK's 2050 target and carbon budget system, although international aviation is included in the EU ETS. The Government must decide whether to include them by the end of 2012, or explain to Parliament why it has not done so. This decision will need to be considered alongside development of the UK's sustainable aviation policy framework through 2012/13, which will also consider whether to adopt the previous administration's 2050 aviation CO_2 target.

Biofuels

2.110 **Over the next decade**, use of biofuels in the UK is covered by the EU Renewable Energy Directive (RED),[49] which requires that 15% of total energy consumption and 10% of energy for transport come from renewable sources by 2020, and the EU Fuel Quality Directive, which requires a 6% reduction in the greenhouse gas intensity of fuel by 2020.[50] The Government has committed to the target of 5% biofuels use by volume by 2014 but has not yet decided on an appropriate level of biofuel ambition post-2014, pending further consideration of sustainability issues (including those about indirect land use change) and cost effective delivery of the 15% target. The Government proposes to consult in 2012 on the approach for biofuels to 2020.

2.111 The main driver of increasing biofuel uptake is the Renewable Transport Fuels Obligation. This requires suppliers of liquid fossil fuel intended for road transport to increase the proportion of biofuel in their fuel annually until April 2013, when it will reach 5% of total road transport fuel supplied by volume. The Government consulted on changes to this legislation earlier this year and published a response in November 2011.[51]

2.112 It is important to ensure that the negative indirect impacts of biofuels are minimised, and that in the longer term there remains scope to deploy biofuels in sectors where there are few other options to decarbonise. The Government's forthcoming Bioenergy Strategy will address these issues.

2.113 **Over the fourth carbon budget**, given this uncertainty, for the purposes of analysis for the fourth carbon budget we have assumed biofuel uptake in 2020 of 8% by energy, in line with recommendations of the Committee on Climate Change. Over the fourth carbon budget period, we have modelled scenarios in which this level increases to 10%, decreases to 6%, or stays constant at 8% out to 2030. These scenarios do not prejudge the policy decisions to be made.

[49] Under the RED some biofuels, such as those made from waste, can be double counted towards the 10% target, although not towards the 15% target.

[50] Relative to the lifecycle greenhouse gas emissions from fossil fuels.

[51] See: www.dft.gov.uk/consultations/dft-2011-05

Next steps

2.114 The key challenge in transport is decarbonising travel in a way that is both cost effective and acceptable to consumers. In the fourth carbon budget, increasing efficiency in cars, vans and freight practices, ultra-low emission vehicle technologies, sustainable biofuels, sustainable travel choices and electrified rail will all have a role to play, and the Government's technology neutral approach will allow industry to develop the low carbon technologies most appropriate for users. The existing policy mix puts the Government on a pathway to realise this vision for low carbon transport, but it will continue to be reviewed regularly, and in future will require further ambitious measures such as EU car and van emissions targets for beyond 2020.

INDUSTRY

Where we are now

2.115 UK industry was responsible for 131.6 $MtCO_2e$ of emissions in 2009, accounting for 23% of the UK's total emissions.[52] Over 80% of these emissions originate from generating the heat that is needed for industrial processes such as manufacturing steel and ceramics, and the remainder from chemical reactions involved in processes such as cement production.

2.116 Between 1990 and 2009, end user emissions from industry have reduced by 111 $MtCO_2e$. While the UK industrial sector has grown by an average of 1% a year over the last 40 years, the sector's emissions have fallen by 46% since 1990. Embracing cost effective, energy efficiency measures, as well as sectoral readjustments towards higher-value products, has helped to drive this lower carbon growth. The energy intensity of UK industry has fallen on average by 2.7% a year since 1970. Since 1990 this average has declined to 1.3% a year.[53]

2.117 Around a quarter of UK energy demand is consumed by industry. Natural gas, electricity and oil/petroleum are the main energy sources for the sector. UK industry employs over 4 million people, accounting for around 15% of the UK workforce and a third of the national GDP.[54] The sector is varied and complex, covering very different modes of production, material demands, ownership and end products. It is one of the main drivers of a flexible and strong UK economy.

Where we will be in 2050

2.118 If industrial emissions were to remain steady over the coming decades, they would grow from 23% now to over half of the emissions allowed by the 2050 target. In order to achieve the UK's commitment to cutting emissions by 80% by 2050, this level of industry emissions would require an excessive reduction from other sectors. Thus, the industry sector has to contribute its fair share.

2.119 Decarbonising the UK economy could require a reduction in overall industry emissions of up to 70% by 2050. Achieving this while maintaining competitive growth in the sector could entail the following:[55]

- The historical growth trend of 1970 to 2009 continues, leading to industrial output increasing by over 30% to 2050.
- Energy demand by industry decreases by up to a quarter from today's levels.
- Industry achieves a decrease of up to 40% in energy intensity through a mix of fuel switching and taking up remaining efficiency opportunities.
- Over half of industrial energy demand is supplied by either bioenergy or electricity.
- Carbon capture and storage rolls out during the 2020s, and by 2050 could capture around a third of industry's emissions.[56]

2.120 This low carbon transition will inevitably be challenging, but at the same time it has the potential to bring real benefits for UK industry:

- Taking up the remaining opportunities for energy, material and process efficiency will reduce manufacturing costs and boost the competitiveness of UK industry.

[52] The equivalent figure by source is 129.1 $MtCO_2e$ (23% of UK emissions).

[53] See DECC (2010) *Energy Consumption in the UK: Industrial data tables*. Available at: www.decc.gov.uk/en/content/cms/statistics/publications/ecuk/ecuk.aspx, table 4.5.

[54] Office for National Statistics (2009) *Annual Business Survey*, Production and Consumption Sectors (B–E).

[55] See Annex A of this document and, for more detail, 2050 Futures from the 2050 Pathways Calculator spreadsheet.

[56] AEA Technology (2010) *Analysing the Opportunities for Abatement in Major Emitting Industrial Sectors: Report for The Committee on Climate* Change.

- Low carbon manufacturing, using inputs such as sustainable biomass and future supplies of decarbonised electricity may increasingly be demanded by both UK and export markets.

- Moving to low carbon technologies in other sectors of the economy will create new markets for the goods produced by UK industry: the steel for wind turbines, the aluminium for electric vehicles and the cement for new homes. We also depend on industry to manufacture components for power stations, ships, planes and home appliances – products which need to become ever more energy efficient and low carbon over the coming decades.[57]

How we will make the transition

2.121 A number of technologies will be needed to make the transition to low carbon industry. These technologies are at varying stages of development and commercialisation, and range from well established, mature technologies to those which are still at laboratory stage, meaning there remains significant uncertainty about how and where they will be deployed.

2.122 **This decade**, we expect industry to focus on cost effective measures such as **energy, process and material efficiency**. Industry needs to continue to seize opportunities to boost energy, process and material efficiency, and new opportunities will arise as new technologies and materials are developed. As technologies mature, energy efficiency is likely to continue to improve over the coming decades, albeit at a decreasing rate.

2.123 Action this decade will also help industry **prepare for the future**, to support the innovation needed for more technically challenging or costly measures involving advanced fuel switching or carbon capture and storage.

2.124 **The 2020s** and beyond will see the continued take-up of remaining efficiency measures, but also greater deployment of more advanced decarbonisation measures in two main areas:

- **Fuel switching** – The majority of industrial emissions arise from generating heat from fossil fuels for manufacturing processes, meaning that changing to lower carbon fuels such as sustainable biomass and biogas represents one of the most important means by which the sector can decarbonise over time. The type of fuel switching possible will differ between sub-sectors.[58] For lower temperature processes a range of options may be possible, for example using biomass boilers to generate the steam required, or 'process integration' for exploiting heat already used in higher temperature processes. Higher temperature processes often present a greater challenge, and may need innovative solutions such as sustainable biomass to replace coke, or a shift towards the electrification of processes. Fuel switching will develop gradually, depending on the needs of each sub-sector of UK industry and, in particular, the temperature of the heat required.

- **Carbon capture and storage (CCS)** – For some industrial processes, greenhouse gas emissions are an intrinsic part of the chemistry and can only be mitigated through innovative options such as CCS. In the long term, the deployment of a combination of sustainable biomass and further CCS should be able to address remaining combustion and the carbon dioxide component of process emissions.

[57] See, for example, CBI (2011) *Protecting the UK's Foundations: A blueprint for energy-intensive industries*. Available at: www.cbi.org.uk/media-centre/policy-briefs/2011/08/protecting-the-uks-foundations-a-blueprint-for-energy-intensive-industries/

[58] The industrial sector can be disaggregated into the energy-intensive industry (EII) sector, which tends to require significant amounts of high grade heat at 1,000°C and above (e.g. iron and steel or aluminium), and the non-EII sector, for which demand is generally for lower grade heat, typically around 100–300°C (e.g. food and drink, pharmaceuticals).

2.125 Process emissions will also need to be tackled. Fluorinated gas (F-gas) emissions from air conditioning and refrigeration currently make up around 2% of UK emissions. They are expected to decrease as a result of the impact of the current regulatory framework and voluntary moves by businesses to replace F-gases with other refrigerants with lower global warming potential.

Energy, process and material efficiency

2.126 The Government's latest projections suggest that industrial energy consumption will fall by 12% by 2030 compared with 2008 levels (see chart 17 overleaf). The main drivers of this drop in energy consumption will be as follows:

- **Conventional energy efficiency** – While much has been achieved, there remain opportunities for greater energy efficiency in some areas, for instance through process optimisation and control or use of continuous processes rather than having to start and stop equipment. Many measures can be retrofitted, with rapid payback periods and little upfront capital investment.
- **Process and thermal efficiency** – There are additional opportunities to reduce emissions through changing processes as well as making them more efficient, for instance through changes to improve process integration, or recovering and re-using heat.
- **Material efficiency** – A number of measures can reduce the economy's demand for the primary manufacture of energy-intensive goods and therefore reduce associated emissions. These include greater recycling, greater reuse with re-melting and greater commoditisation of products.

2.127 The Government will continue to incentivise these efficiency improvements during this decade and beyond via a set of European and national policy frameworks:

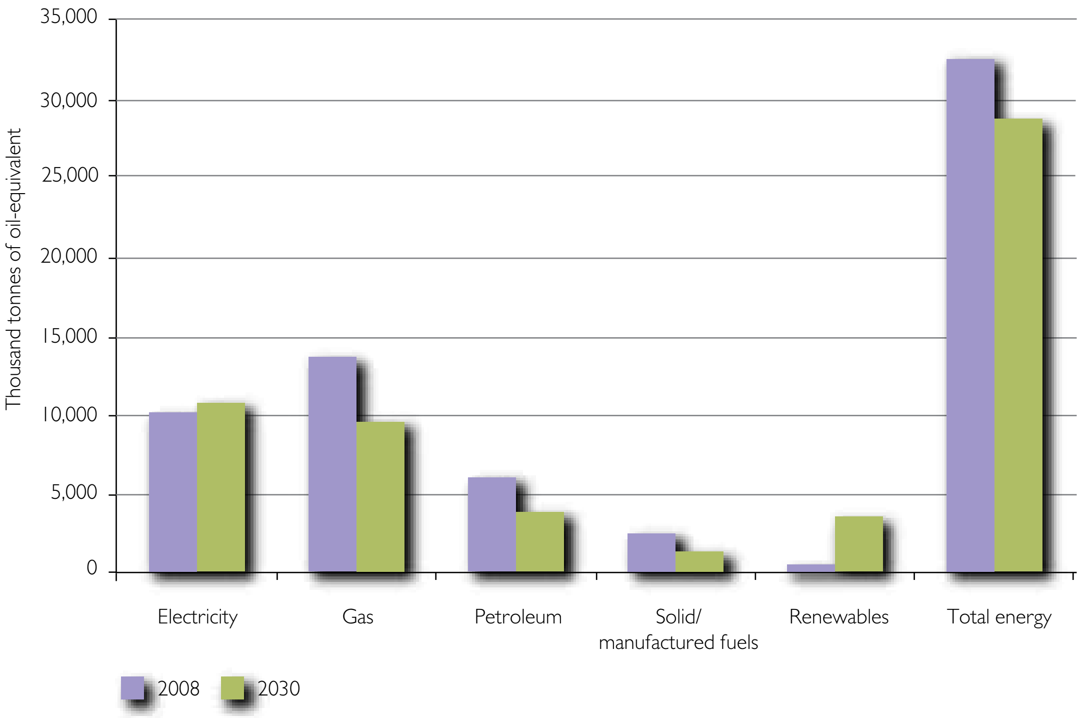
- **European Union Emissions Trading System (EU ETS)** – The cap-and-trade system covers over 70% of direct and indirect industrial sector emissions. The main incentive mechanism for emissions savings within this system is the gradual tightening of the cap as well as a resulting carbon price. The Government intends the EU ETS to remain a critical driver for the UK's industrial low carbon transition for this decade and beyond.
- **Climate Change Levy (CCL) and Climate Change Agreements (CCAs)** – Cost effective energy efficiency measures are also being supported by government policy instruments through the CCL. This is a tax charged on high carbon energy supplied to businesses and the public sector. The Government introduced the CCAs to reduce the impact of the CCL on the competiveness of energy-intensive industry, while still incentivising industry to take action to reduce emissions. These voluntary agreements provide a discount on the CCL for eligible industries in return for meeting challenging energy efficiency or emissions reduction targets.[59]

[59] Current CCAs entitle participants to claim CCL discount until the end of March 2013. The Government announced in the 2011 Budget that the scheme will be extended to 2023, and is currently developing proposals that will simplify the scheme. These proposals will provide targeted financial benefits to business in the range of £2.4–£3.4 million from 2012 to 2020.

Fuel switching

2.128 Alongside energy efficiency-driven reductions in demand, government projections show a shift in energy consumption patterns. Industry currently receives the majority of energy from gas use. Towards 2030 government predicts a switch to more low carbon energy sources, such as bioenergy and electricity.[60]

Chart 17: Energy use in 2008 and 2030 by fuel type and total for UK industry



Source: Department of Energy and Climate Change (Updated Energy and Emissions Projections)[61]

[60] Analysis using the Energy End-Use Simulation Model (ENUSIM) suggests that there is remaining potential for further energy efficiency improvements. Further detail on future abatement potential has been derived from work undertaken by AEA Technology. We have undertaken analysis to expand the potential abatement beyond those considered in the AEA work (AEA Technology (2010) *Analysing the Opportunities for Abatement in Major Emitting Industrial Sectors: Report for The Committee on Climate Change*). In addition, we have undertaken modelling to calculate abatement due to the uptake of renewable heat and the initial deployment of CCS.

[61] See: DECC (2011) *Energy and Emissions Projections Annex C*. Available at: www.decc.gov.uk/en/content/cms/about/ec_social_res/analytic_projs/en_emis_projs/en_emis_projs.aspx. Note: offshore refinery processes are excluded from this chart.

2.129 Fuel switching in the industry sector is expected to take place via several routes:

- **Cogeneration/combined heat and power (CHP)** – The combined production of heat and electricity can reduce primary energy demand by up to 15% regardless of the fuel input, making gas CHP an efficient way of using fossil fuels in industrial processes. Biomass and biogas can be used for the combined production of heat and electricity to provide further emissions reductions.

- **Sustainable biomass and biogas** – Sustainable biomass and biogas offer a direct alternative to fossil fuels as a means of generating hot water and steam for low temperature processes up to around 300°C. To maximise energy efficiency in the use of sustainable biomass, it can be combined with cogeneration of electricity and heat. Some high temperature applications, such as cement kilns, may be suitable for biomass or waste combustion. Some applications, such as ceramics or glass furnaces, require high calorific value and clean burning fuels, and may therefore require the use of biogas.

- **Electrification of processes** – As the grid decarbonises, electricity will become an important source of low carbon energy for industrial processes. Electricity is currently used to drive motors and machinery, compressors and refrigeration. It is also used to supply heat demand, particularly where volatile or flammable products are used or low temperature controllable heat is required. Some sectors already make extensive use of electricity especially where this is the only commercially available process, as it is for aluminium. Other processes may require further innovation and capital investment before being able to use low carbon electricity.

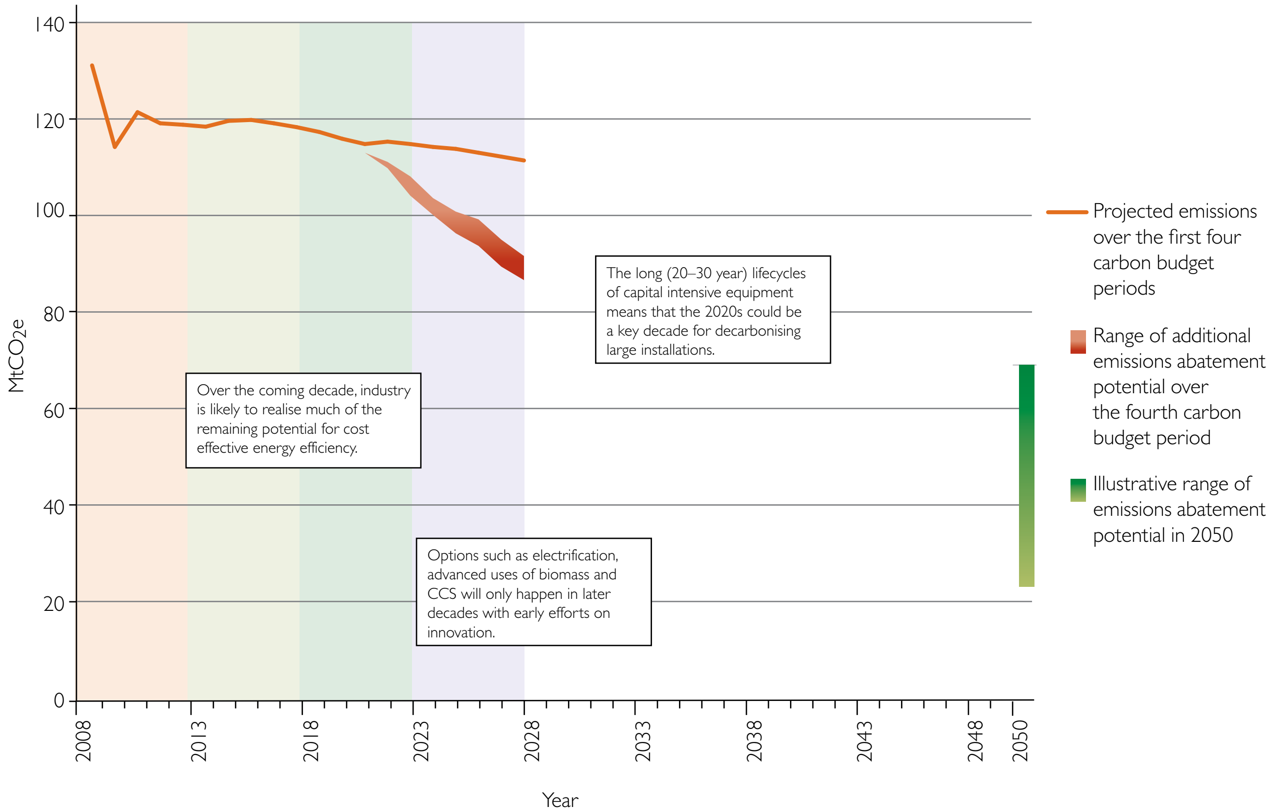
2.130 In practice, it is likely that in the short term industry will exploit large-scale CHP opportunities, and will take up the cost effective potential for fuel switching to sustainable biomass (including energy from waste). In the 2020s and beyond, we may see deployment of options with longer payback periods and those which require greater innovation such as use of biomass in high temperature processes and, as we move towards a decarbonised electrical grid, electrification of industrial processes.

2.131 Some critical technologies for fuel switching (such as advanced forms of sustainable bioenergy and electrolysis) are not yet at commercial stage. Public and private support to address innovation gaps, both in the UK and internationally, will be critical if we are to make these technologies a viable part of a low carbon future.

2.132 The **Renewable Heat Incentive (RHI)** will support substantial deployment of bioenergy for the generation of low carbon heat within the commercial and industrial sectors. The Government estimates that up to 48% of the additional low carbon heat anticipated to provide the 12% low carbon heat necessary to meet the overall renewable energy target in 2020 will come from the industrial sector, including the generation of energy from waste.

2.133 The Government will continue to incentivise a combination of natural gas-fired and renewable

Chart 18: Emissions projections in industry for the first three carbon budgets and illustrative ranges of emissions abatement potential in the fourth carbon budget period and in 2050[62]



Source: Department of Energy and Climate Change

CHP. CHP, especially for large-scale industrial plants, constitutes a significant opportunity to enhance energy efficiency and lower emissions from the industrial sector.

2.134 Chart 18 above illustrates the emissions trajectory for decarbonising the UK industry sector up to 2050, focusing in particular on the range of abatement potential over the fourth carbon budget period.

2.135 The fourth carbon budget range on the above chart indicates the level of emissions abatement industry could achieve by taking up cost effective (that is, measures whose cost is lower than the projected carbon price) energy efficiency and fuel switching measures over the coming one and a half decades. These include measures incentivised through the European Union Emissions Trading System and Climate Change Agreements, for example process optimisation, and the Renewable Heat Incentive (RHI), using

[62] The emissions projections derive from Updated Energy and Emissions Projections data for the industry and refineries sectors for CO_2 emissions and the National Communication industrial processes and energy supply sectors for non-CO_2 emissions. The illustrative ranges for emissions abatement potential for 2050 and the fourth carbon budget derive from the 2050 futures and fourth carbon budget scenarios – these are discussed in Parts 1 and 3 of this report respectively. Please also see: AEA Technology (2010) *Analysing the Opportunities for Abatement in Major Emitting Industrial Sectors: Report for The Committee on Climate Change*.

bioenergy to produce hot water and steam for industrial processes. The variation between the fourth carbon budget range is due to different levels of low carbon heat take-up incentivised under the RHI. A central set of assumptions on what energy efficiency and CCS measures industry may choose to take up is included in the range. We recognise that there is uncertainty around the precise choices that will be made in such a diverse sector of the economy.[63]

Industrial carbon capture and storage

2.136 CCS has a role to play in capturing emissions from combustion of industrial heat, for example from the continued use of coke-fired blast furnaces for steel production, or for processes where emissions result directly from the chemistry of the process itself, such as the manufacture of cement or lime. Initial deployment of CCS technology is expected during the fourth carbon budget period, particularly for sectors with lower capture costs, e.g. ammonia production.

2.137 Today, **CCS technology research projects** are supported by UK and international sources of funding – with the aim of turning it into a viable option for the coming decades.[64]

2.138 Deployment of CCS needs to be planned within sufficiently long time spans. In the industrial sector, assets are typically of high capital value, with lifetimes of up to 40 years. It is often only possible to make significant changes or innovations to integrated processes when these assets are replaced or renewed, which may limit the rate at which technology can be adopted.

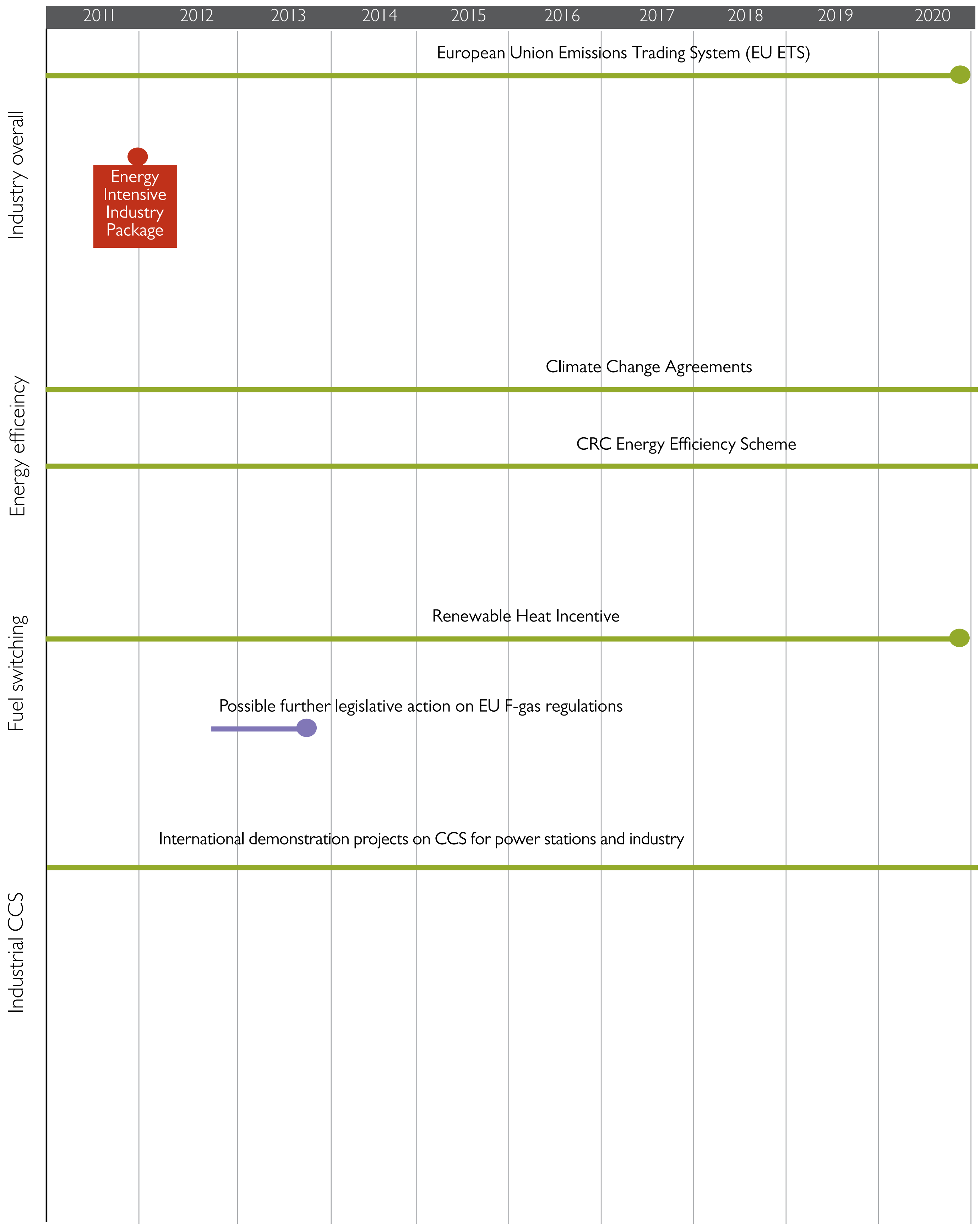
2.139 Critical technologies – such as industrial CCS, high temperature use of biomass, or further electrification of thermal processes – may not be available at commercial scale for 10–15 years. While the exact phasing of the low carbon transition is uncertain and depends on investment choices by industry as well as international action and competition, we can identify some possible stages and decision points along the way (see chart 19 on pages 66 and 67).

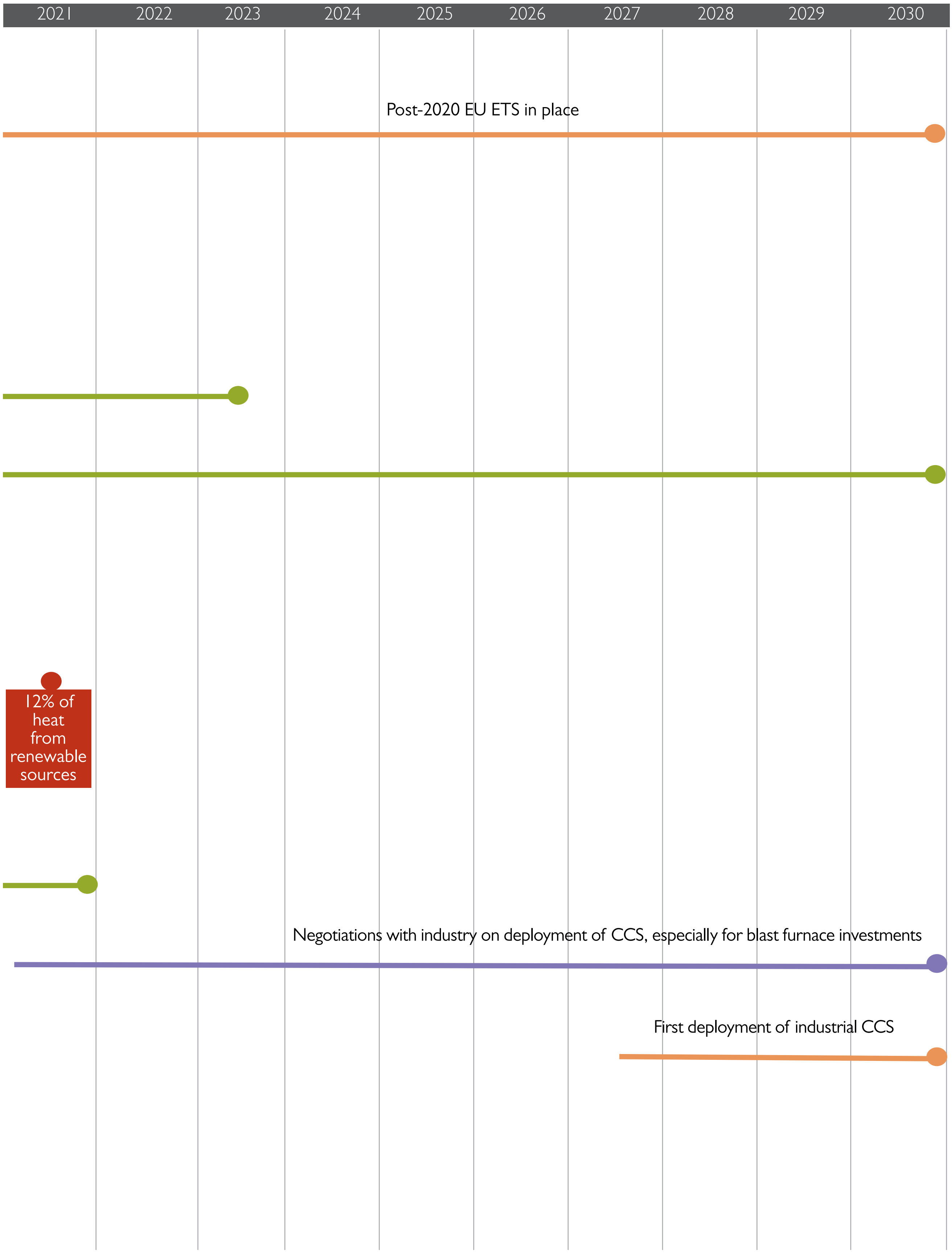
2.140 The Government will work with industry to address key risks of this low carbon transition, such as reducing the impact of the anticipated increasing cost of energy, to ensure that UK industry remains competitive internationally. This will be particularly important in those sectors which are especially exposed to rising energy costs as well as to international competition, where there is a role for government in helping these industries to manage the transition. As part of this work, the Government recently announced a package of measures to support sectors which are particularly exposed to these risks.

63 There have been significant revisions undertaken to the 2011 Updated Energy and Emissions Projections (www.decc.gov.uk/en/content/cms/about/ec_social_res/analytic_projs/en_emis_projs/en_emis_projs.aspx). This may impact upon previously undertaken analysis of abatement potential from, for example, AEA Technology. Therefore, we have taken up a lower level of 'realistic' energy efficiency abatement in our projections. For further information see: AEA Technology (2010) *Analysing the Opportunities for Abatement in Major Emitting Industrial Sectors: Report for The Committee on Climate Change.*

64 See, for example, the EU-funded project for industrial CCS where CO_2 capture is being applied at a steel plant in Florange, France.

Chart 19: Decision points for industry to 2030




2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Post-2020 EU ETS in place
12% of heat from renewable sources
Negotiations with industry on deployment of CCS, especially for blast furnace investments
First deployment of industrial CCS

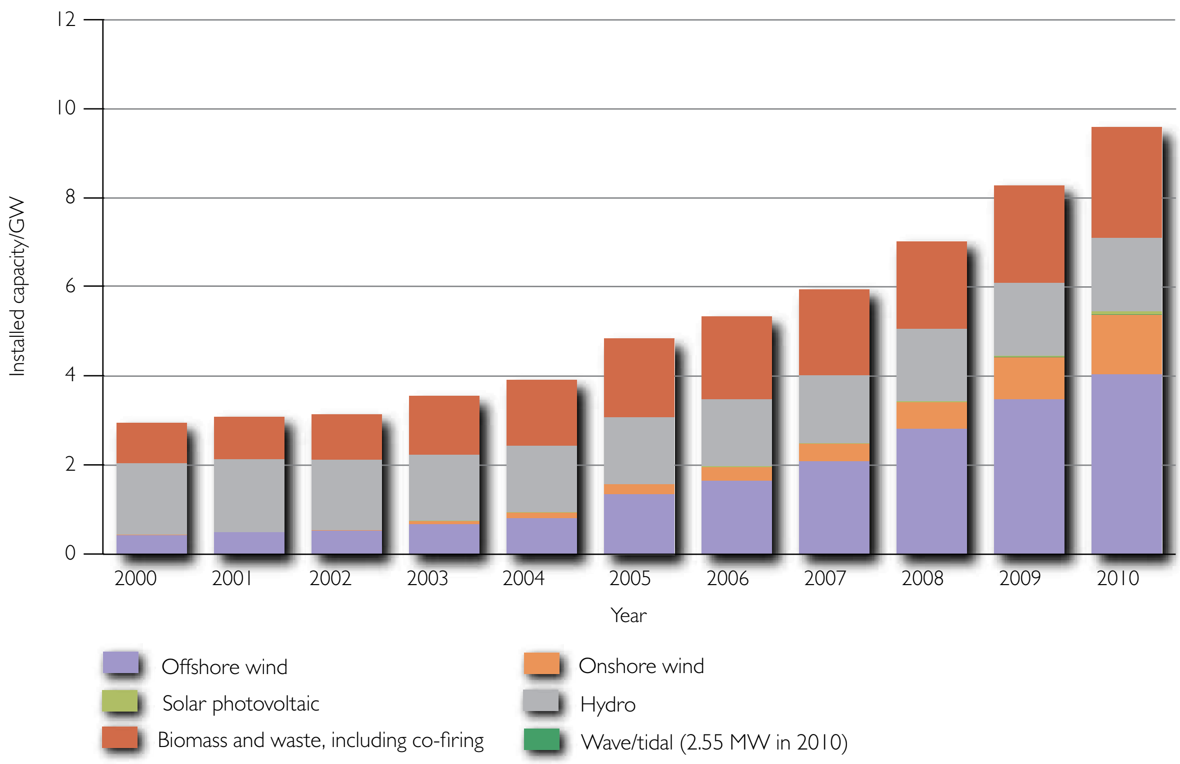
SECURE, LOW CARBON ELECTRICITY

Where we are now

2.141 The power sector is the single largest source of UK emissions today, accounting for 27% of emissions – 156 $MtCO_2e$ – in 2010. By 2050, emissions from the power sector need to be close to zero. Historically, the UK has benefited from robust security of supply, due to domestic natural resources and to competitive markets underpinned by independent regulation. We currently have around 90 GW[65] of generating capacity, giving us around 16%[66] surplus capacity (known as a capacity margin) over electricity demand at peak times.

2.142 Emissions from power stations have fallen by 23% since 1990. While demand has increased by 18% since 1990, the carbon intensity of power generation has fallen from 690 gCO_2/kWh in 1990 to 448 gCO_2/kWh in 2009. This is primarily due to the switch from coal-fired generation to less carbon intensive gas-fired generation during the 1990s, with use of coal roughly halving, as well as increased power station efficiency.[67] Generation from renewable sources has steadily increased since 2006, reaching over 7% of electricity generation in 2010.[68]

Chart 20: Cumulative renewable electricity installed capacity, by technology, from 2000 to 2010



[65] DECC (2011) *Digest of UK Energy Statistics 2011* Table 5.7 Plant Capacity.

[66] National Grid (2011) *Winter Outlook 2011/12.*

[67] DECC/Defra (2011) *2011 Guidelines to Defra/DECC's GHG Conversion Factors for Company Reporting* Annex 3 Table 3a.

[68] DECC (2011) *Energy Trends, June 2011.*

2.143 Latest projections show that as a result of government policies, emissions from the power sector are expected to fall by around two thirds during the next two decades, to 49 $MtCO_2e$ a year in 2030. Over the five years of the fourth carbon budget period, power stations are projected to emit 357 $MtCO_2e$.[69]

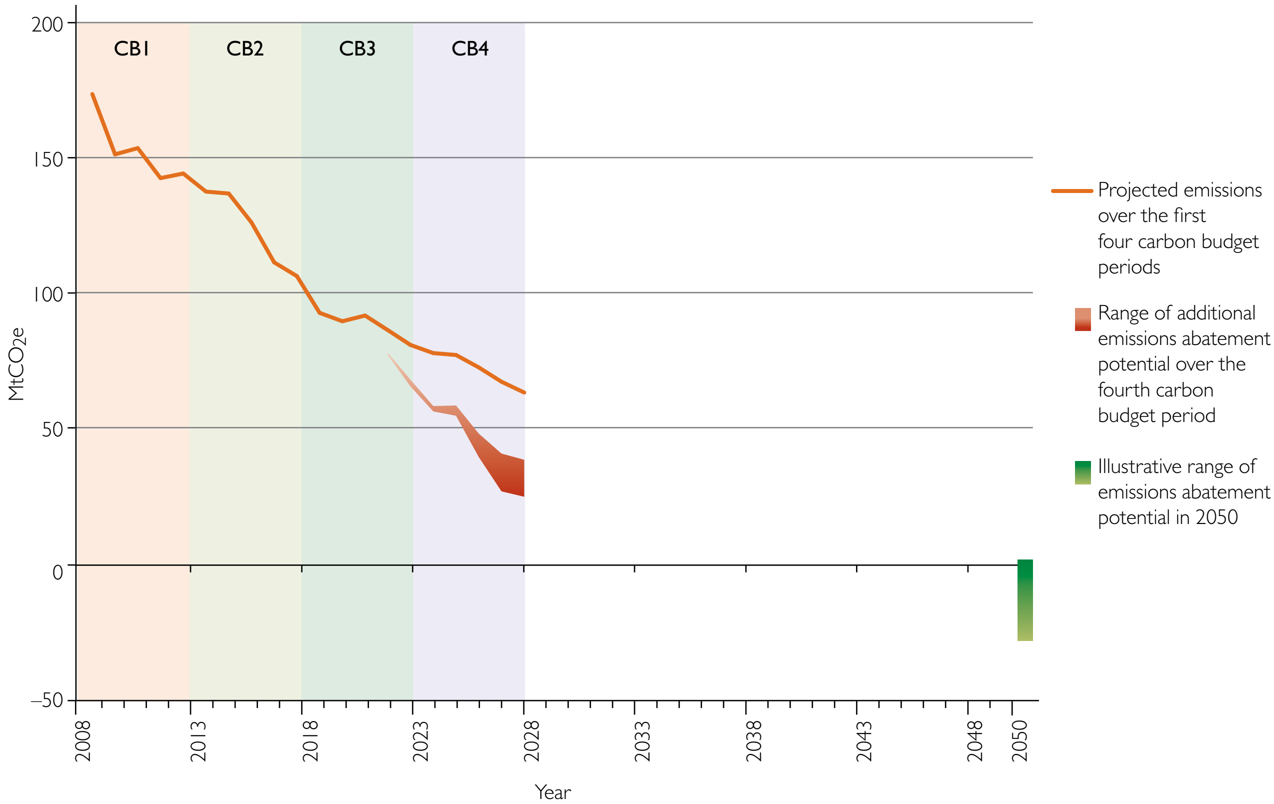
Where we will be in 2050

2.144 By 2050, we are likely to need much more electricity. The 2050 futures set out in Part 1 suggest that electricity supply may need to increase by around 30–60%. We may need as much as double today's electricity capacity to deal with peak demand. While more energy efficiency will reduce demand per head of population by 30–50%, this will be outweighed by rising demand from electrification of heating, transport and parts of industry, and economic and population growth.

2.145 By 2050, electricity supply will need to be almost completely decarbonised. Power will be generated largely from renewables, and nuclear and fossil fuel stations fitted with CCS technology. Experience from other countries demonstrates that this is possible: almost 90% of the electricity supply of both Sweden and France is zero carbon, using mainly nuclear and hydro power.

2.146 The nature of the electricity system will also need to change. Wind and solar power are intermittent. Nuclear power is hard to turn on or off quickly. Meanwhile, demand for electricity, if heating and cars are plugged into the grid, will also be more variable. As a result, our electricity system will need to become smarter at balancing demand and supply. This will mean a combination of back-up generation capacity, bulk storage of electricity and greater interconnection, but also smarter ways of managing energy demand. On

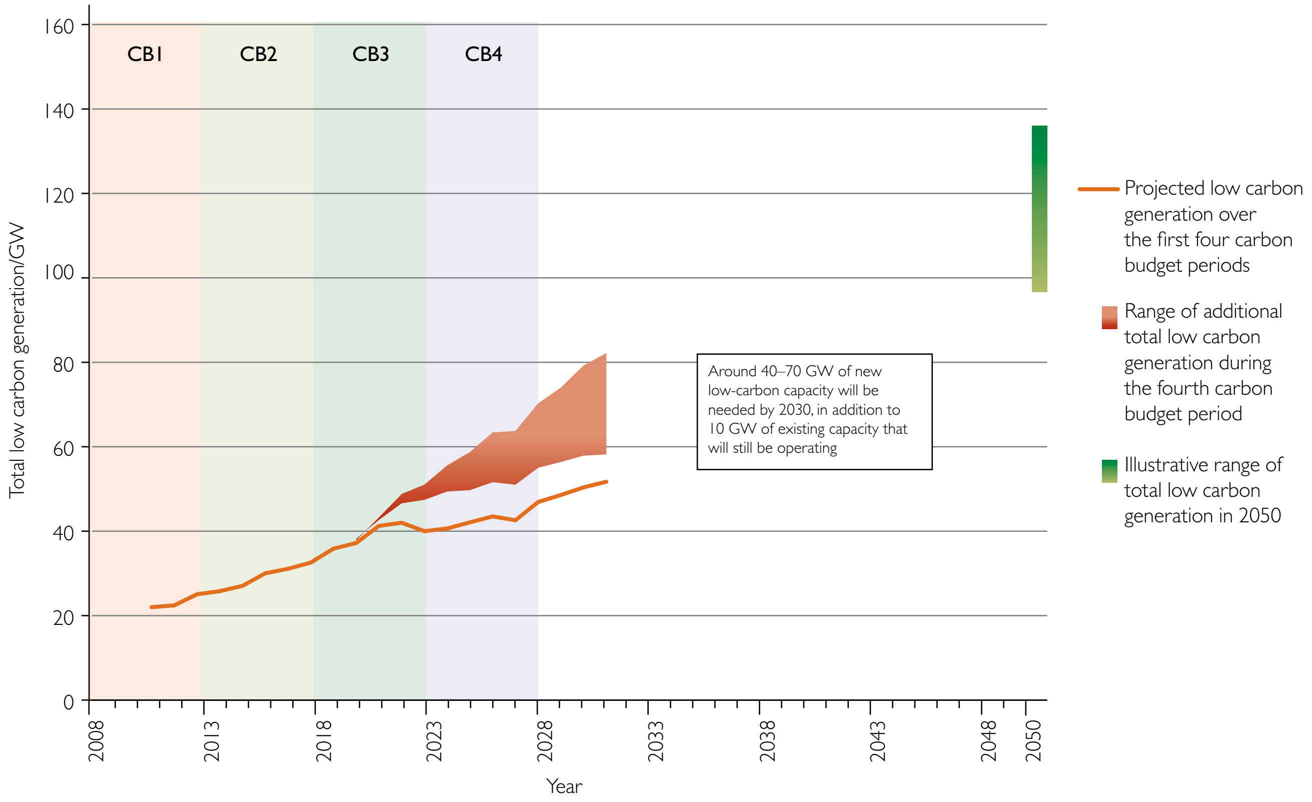
Chart 21: Emissions projections for electricity for the first three carbon budgets and illustrative ranges of emissions abatement potential in the fourth carbon budget period and in 2050[70]



[69] DECC (2011) *Updated Energy and Emissions Projections 2011*. Available at: www.decc.gov.k/en/content/cms/about/ec_social_res/analytic_projs/en_emis_projs/en_emiss_projs.aspx. These do not take into account the measures due to be introduced as a result of the Electricity Market Reform.

[70] The emissions projections derive from Updated Energy and Emissions Projections data. The illustrative ranges for emissions abatement potential for 2050 and the fourth carbon budget derive from the 2050 futures and fourth carbon budget scenarios – these are discussed in Parts 1 and 3 of this report respectively.

Chart 22: Projected deployment of low carbon generation over the first three carbon budgets and illustrative ranges of deployment potential in the fourth carbon budget period and in 2050



Source: Department of Energy and Climate Change, Redpoint modelling, 2050 Calculator

the way to 2050, some flexible fossil fuel plant is likely to be needed to ensure security of supply. In 2050, the role of fossil fuels is likely to be limited to power stations fitted with CCS, although it is possible that some unabated gas could still be used as back-up capacity without compromising our emissions targets.

How we will make the transition

2.147 **Over the next decade**, the UK will need to invest in new generation capacity to replace the coal and nuclear power stations that are set to close by the early 2020s in order to maintain our energy security, while meeting our legal commitments to reduce carbon emissions and increase renewable electricity generation.

2.148 To do this, the coming years will see a continuation of previous trends: more switching from coal to gas-powered generation, and renewable electricity rising to 30% of electricity generation by 2020. In common with other countries, the UK will move to a more diverse range of energy sources to increase energy security and reduce exposure to volatile fossil fuel prices, as well as to cut emissions.

2.149 In addition to cutting emissions this decade, the UK also needs to prepare for the rapid decarbonisation required in the 2020s and 2030s by demonstrating and deploying the major low carbon technologies that we will need on the way to 2050. CCS, renewables and nuclear power need to be deployed during this decade, and costs minimised, if they are to be deployed at scale in the next. Industry will lead, but the Government is playing a facilitating role for each technology.

2.150 **During the 2020s**, deep cuts in emissions from the power sector are necessary to keep us on a cost effective path to 2050. There is a clear opportunity for large-scale new low carbon capacity in the next two decades, created by the combination of existing plant closures and an increase in demand. Government modelling suggests that around 60–80 GW of new electricity capacity will need to be built by 2030, and of this around 40–70 GW will need to come from low carbon technologies, such as nuclear, renewables and fossil fuel stations with CCS.[71]

2.151 The Government does not have targets for particular generation technologies for 2030. As the 2050 futures in Part 1 illustrate, different combinations of the three key low carbon technologies are all plausible. The Government's aim is therefore to run a low carbon technology race between CCS, renewables and nuclear power. Diversity will bring competition between technologies that will drive innovation and cost reduction, and will hedge against the risk of one technology failing to reduce costs or become publicly acceptable. The low carbon power that can deliver at least cost will gain the largest market share.

2.152 The transition to low carbon power will not happen overnight. Over the next two decades, gas-fired power plants will provide the flexibility that we will need to meet peak demand and manage intermittent generation from some renewables, as well as baseload generation capacity, while new nuclear and renewable capacity is built.

2.153 **Beyond 2030**, as transport, heating, and industry electrification occurs, low carbon capacity will need to rise significantly. The futures described in Part 1 show that we are likely to need 100 GW or more of new low carbon generation capacity in 2050; the exact amount will depend on the technology mix and electricity demand. We currently have only 20 GW of low carbon capacity,[72] meaning that we need to build an average of around 2.5 GW of new low carbon capacity a year for the next 40 years. Although challenging, these build rates are achievable: the UK has built coal-fired power stations at an equivalent rate in the past, and nuclear power stations have been built at a rate of up to 4.5 GW a year.[73] As set out in the Electricity Market Reform White Paper,[74] the mix of low carbon technologies that is built on the way to 2050 is for the market to decide: the technologies with the lowest costs will win the biggest market share.

[71] Based on modelling by Redpoint Energy commissioned for the Carbon Plan. Please see Annex B for further details.

[72] DECC (2011) *Digest of UK Energy Statistics 2011* Table 5.7. Plant capacity – 9.6 GW renewable capacity and 10.9 GW nuclear.

[73] Nuclear Energy Association (2008) *Nuclear Energy Outlook 2008* p.318 – France, 1979–88, an average of 4.5 GW a year.

[74] DECC (2011) *Planning Our Electric Future: A White Paper for secure, affordable and low carbon electricity*. Available at: www.decc.gov.uk/en/content/cms/legislation/white_papers/emr_wp_2011/emr_wp_2011.aspx

Box 9: Decarbonisation of the power sector to 2030

There are many different ways to achieve the decarbonisation of the power sector. It is impossible to predict which will be the most cost effective route and what the power generation sector will look like in 2030. Nevertheless, we can use economic models to produce projections using the best evidence currently available. The scenarios modelled for this report suggest that around **40–70 GW of new low carbon electricity generating capacity will be needed by 2030**, depending on demand and the mix of generation that is built.

The analysis considered a range of decarbonisation scenarios which are consistent with meeting carbon budgets and the 2050 goal. The Government is not setting an explicit decarbonisation goal for 2030 now given the uncertainties involved in setting a target this far in the future – but the actions being taken now are intended to ensure that we are keeping a range of options in play.

These outcomes should not be interpreted as government technology targets. The Government is happy for fossil fuels with CCS, nuclear or renewables to make up as much as possible of the 40–70 GW we think we may need. The Government would like to see the three low carbon technologies competing on cost in the 2020s to win their share of the market.

- **Nuclear** is currently projected to be the cheapest low carbon technology in the future. Depending on assumed possible build rates, new nuclear contributed anywhere from 10–15 GW by 2030 in the scenarios modelled. Actual build rates could make this range higher or lower: industry has announced ambitions to build 16 GW by 2025, and if one reactor could be completed each year from 2019 onwards, it would be possible to reach around 20 GW by 2030.

- Fossil fuel generation with **CCS** could make a significant contribution by 2030, depending on whether it can compete on cost with other low carbon technologies. CCS contributed as much as 10 GW by 2030 in the scenarios modelled. This should not be seen as an upper limit to its potential – more could be deployed if costs reduce quickly as a result of government and industry actions. Industry has set out in their strategy for CCS ambition for at least 20 GW of fossil plant with CCS in operation by 2030.

- The role of **renewable electricity** during the 2020s will depend on the extent of deployment to 2020 and the pace at which costs reduce as a result of the ongoing joint government/industry work. The analysis showed that renewable electricity could provide 35–50 GW by 2030, with the upper end assuming either high electricity demand or significant cost reductions. The Committee on Climate Change's Renewable Energy Review suggests that we could have over 55 GW of renewable electricity capacity by 2030, subject to resolution of current uncertainties such as cost reductions and barriers to deployment, and industry has expressed similar levels of ambition.

2.154 The rest of this section looks in more detail at six key areas that will enable the low carbon transition: reform of the electricity market; and specific action to facilitate nuclear, CCS, renewables, unabated gas and investment in the electricity system. More detail on energy efficiency is set out in the sections on buildings (page 29) and industry (page 59).

Overcoming barriers to low carbon generation

2.155 There are common problems faced by all low carbon generators:

- The carbon price has not been high or certain enough to encourage sufficient investment in low carbon generation.
- The current electricity price is driven mainly by gas power stations. Gas plant has much lower fixed costs relative to its running costs than low carbon plant, which tends to be expensive to build but cheap to run. It is therefore difficult to make the case for capital investment in low carbon in a market where electricity prices move in line with the price of gas.
- There are high barriers to market entry, including poor market liquidity and regulatory burdens.

2.156 The reforms that the Government has proposed in the Electricity Market Reform White Paper are designed to address these problems, creating a level playing field for low carbon technologies:

- A Carbon Price Floor to be introduced from April 2013 to reduce investor uncertainty, place a fair price on carbon and provide a stronger incentive to invest in low carbon generation now.
- The introduction of new long-term contracts from 2014 (Feed-in Tariffs with Contracts for Difference), to provide stable financial incentives to invest in all forms of low carbon electricity generation. These will replace the existing Renewables Obligation (although they will run in parallel with it to 2017);
- An Emissions Performance Standard set at 450 gCO_2/kWh starting in 2013, to reinforce the requirement that no new coal-fired power stations are built without CCS, while allowing the necessary short-term investment in gas to take place.

2.157 The Government is concerned that by the end of this decade there will be a risk of insufficient electricity capacity to meet peak demand, and therefore it recently consulted on options for a capacity mechanism to ensure future security of electricity supply. The options are either a targeted mechanism in the form of a strategic reserve (whereby an amount of generating capacity is procured and held outside of the normal market and only despatched when required) or a market-wide mechanism (whereby all reliable capacity – either generation or non-generation technologies such as demand-side response – is rewarded). Further detail on this and the institutional arrangements needed to deliver Electricity Market Reform will be published at the turn of the year, as part of a Technical Update.

2.158 Timely planning decisions are also critical to the deployment of low carbon infrastructure. The Government is reforming the major infrastructure planning regime as follows:

- To ensure accountability, the Planning Inspectorate will consider applications for energy infrastructure over 50 megawatts (MW) and advise the Secretary of State for Energy and Climate Change, who will make the final decision.

- To provide a clear decision-making framework for applications for nationally significant energy infrastructure, the Secretary of State designated six National Policy Statements for energy in July 2011.

2.159 Electricity Market Reform and planning reform will address the main barriers that face all low carbon generation. But the Government is also addressing barriers specific to each technology, as outlined below.

Nuclear

2.160 Nuclear power is a proven technology able to provide continuous low carbon generation, and to reduce the UK's dependence on fossil fuel imports. New nuclear power stations will help to ensure a diverse mix of technology and fuel sources, which will increase the resilience of the UK's energy system.

2.161 Nuclear is currently cost-competitive with other electricity generation technologies, and recent independent studies indicate that new nuclear is likely to become the least expensive generation technology in the future.[75] The recent Weightman Report on lessons from Fukushima confirmed that there are no fundamental safety weaknesses in the UK's nuclear industry.[76]

2.162 The Government believes that new nuclear power should be free to contribute as much as possible towards the UK's need for new low carbon capacity. The Nuclear National Policy Statement identifies those sites which the Government believes are potentially suitable for deployment by 2025,[77] although it is for energy companies to develop new nuclear power stations, and to decide at what point they wish to develop a site. An application for a new nuclear power station at Hinkley Point (3,260 MW output) was submitted to the Infrastructure Planning Commission by EDF Energy on 31 October 2011.[78] Energy companies have announced intentions to bring forward 16 GW of new nuclear power stations by 2025 (see chart 24). To enable this to happen, the Government has taken forward a series of targeted facilitative actions, including the following:

- **Reducing regulatory and planning risks** for investors and ensuring that owners and operators have **robust funding plans for waste management and decommissioning.**[79]

- **Ensuring that there is an appropriately skilled workforce to deliver industry's ambitions on new nuclear build** – Cogent, the Sector Skills Council, has produced labour market intelligence that allows the Government to identify, monitor and, working with skills bodies, take action where necessary to address skills gaps. The Nuclear Energy Skills Alliance, a grouping of key skills bodies, has been set up to continue to identify mitigating actions and track progress against them.

[75] Parsons Brinckerhoff (2011) *Electricity Generation Cost Model 2011 Update Revision 1*. Available at: www.decc.gov.uk/assets/decc/11/meeting-energy-demand/nuclear/2153-electricity-generation-cost-model-2011.pdf. This includes the costs of decommissioning.

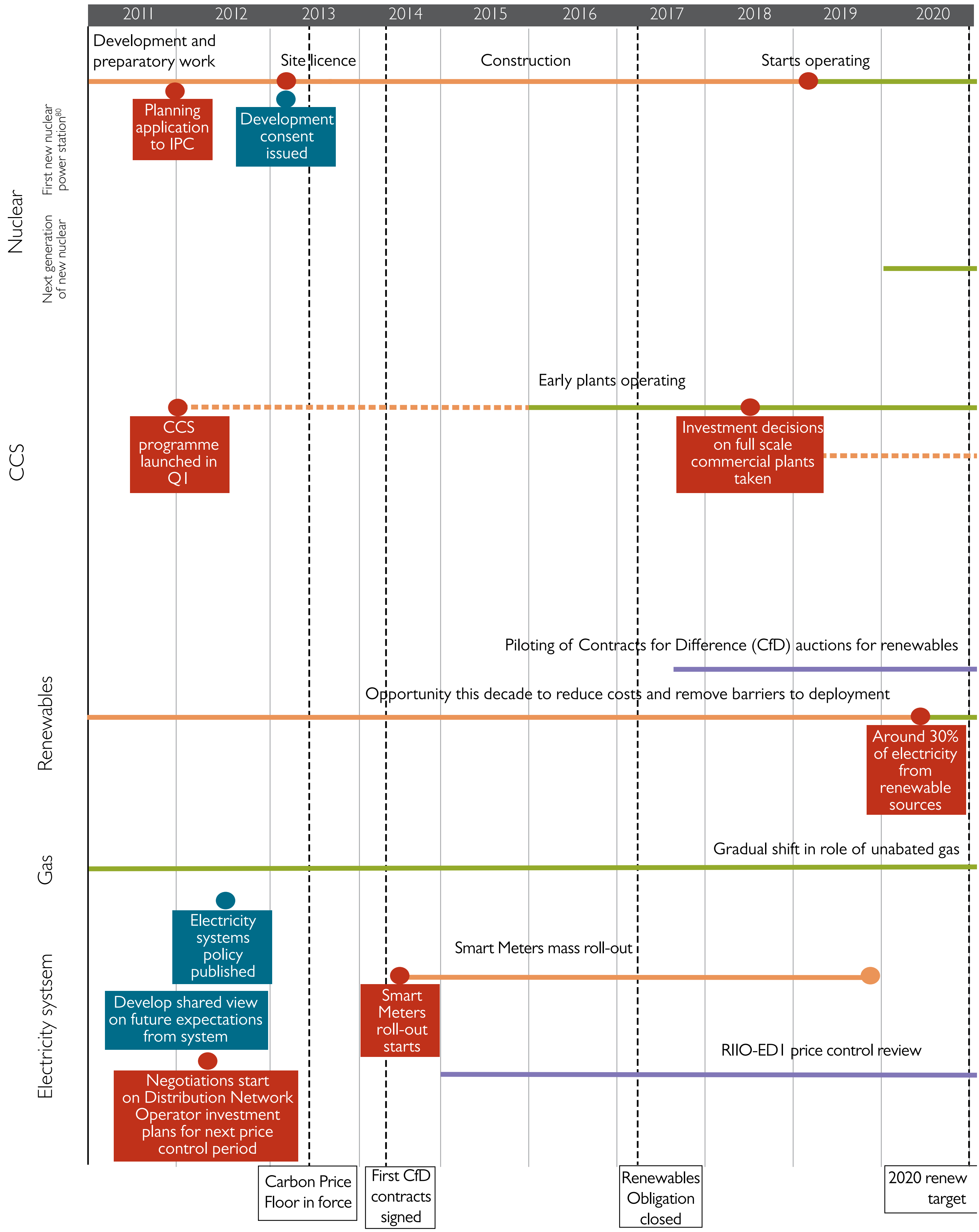
[76] Office for Nuclear Regulation (2011) *Japanese Earthquake and Tsunami: Implications for the UK nuclear industry*. Available at: www.hse.gov.uk/nuclear/fukushima/

[77] HM Government (2011) *National Policy Statement for Nuclear Power Generation (EN-6)*.

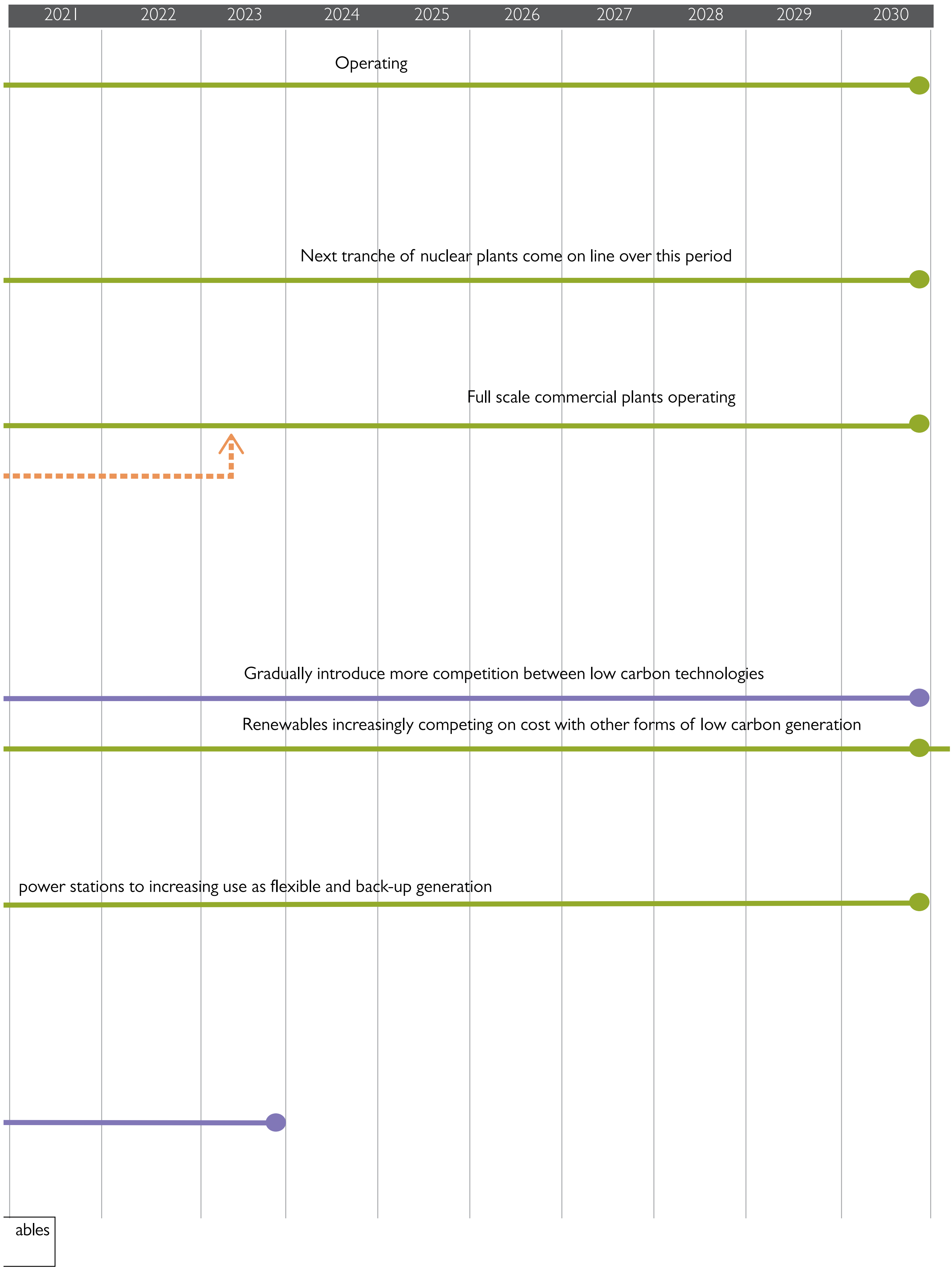
[78] The Infrastructure Planning Commission has 28 days from the day after the date of receipt to review the application and decide whether or not they can accept it.

[79] These are National Policy Statement; Regulatory Justification; Funded Decommissioning Programme; and Generic Design Assessment.

Chart 23: Decarbonisation of the power sector to 2030



[80] All subject to development consent.


2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Operating
Next tranche of nuclear plants come on line over this period
Full scale commercial plants operating
Gradually introduce more competition between low carbon technologies
Renewables increasingly competing on cost with other forms of low carbon generation
power stations to increasing use as flexible and back-up generation
ables

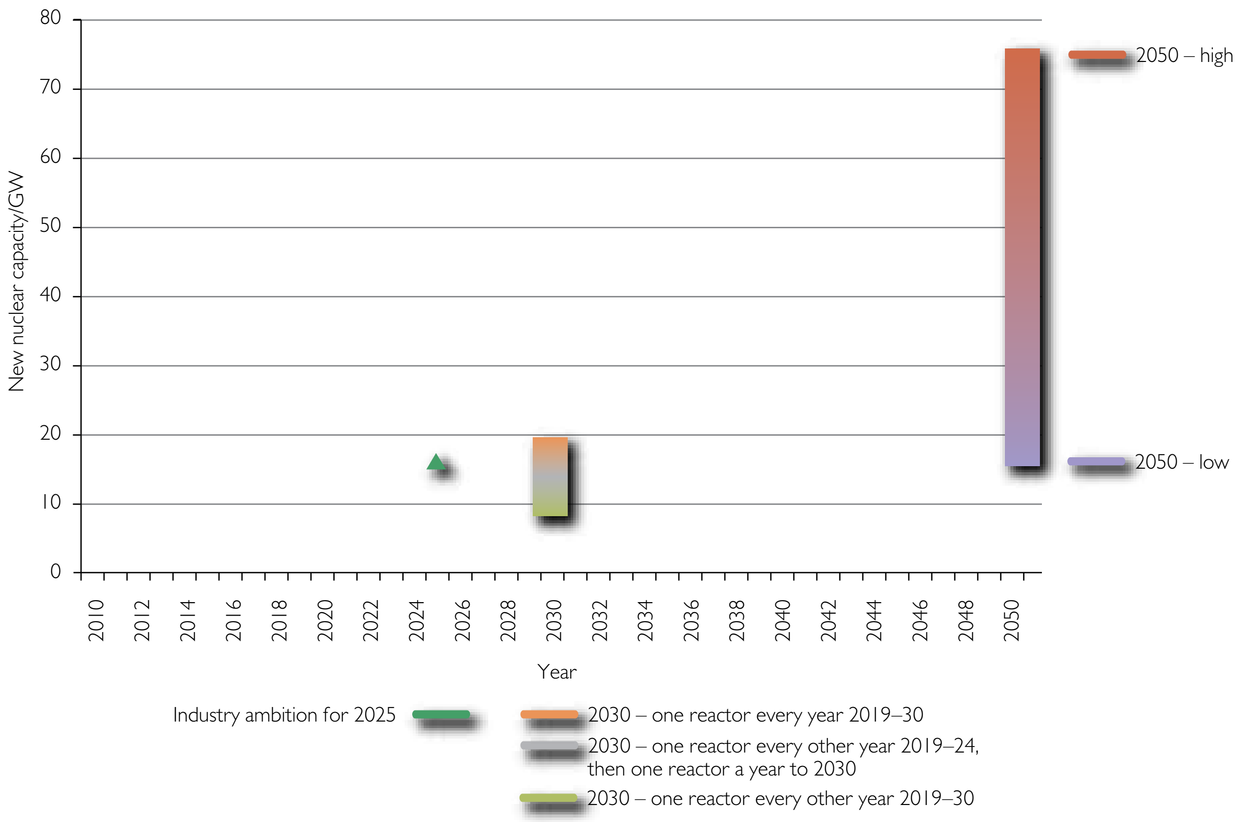
- **Rebuilding the nuclear supply chain** – The Government is working with the industry-led 'sc@nuclear' programme, which aims to engage companies with the nuclear sector and raise the profile of opportunities presented by new build. The Government is collaborating with the Nuclear Advanced Manufacturing Research Centre as it works to attract and improve the capabilities of UK companies through the Fit 4 Nuclear programme. It is also working with the Nuclear Industry Association to facilitate increased co-ordination across those with contracts to let, in order to make best use of supply chain capacity.

Carbon capture and storage

2.163 CCS is a chain of processes for capturing, transporting and storing greenhouse gases underground to reduce emissions from large sources such as fossil fuel power stations. CCS has the potential to become an important low carbon technology over the next 40 years (see chart 25). Successful deployment of CCS will allow fossil fuels to continue to contribute to security of supply by providing flexible electricity generating capacity that will help to balance continuous nuclear power, intermittent wind power and variable demand. Without CCS, the role of unabated fossil fuels in the electricity market by 2050 will be limited to back-up for periods of high demand.

2.164 As yet there are no full-chain commercial-scale CCS power projects in the world, but there are eight operational CCS plants, nearly all linked to natural gas processing. Each of the individual components is already used in other applications, such as injection facilities for the use of CO_2 in enhanced oil recovery operations. Studies show that in the 2020s fossil fuel generation with CCS is expected to be cost-competitive with some other low carbon electricity generation technologies, and will provide a flexible generation source.[81]

Chart 24: Trajectory for new nuclear capacity to 2050



Source: Modelling by Redpoint Energy for the Carbon Plan; Department of Energy and Climate Change

[81] Parsons Brinckeroff (2011) *Electricity Generation Cost Model 2011 Update Revision 1*. Available at: www.decc.gov.uk/assets/decc/11/meeting-energy-demand/nuclear/2153-electricity-generation-cost-model-2011.pdf

2.165 The next step is to bring down costs and risks by supporting development of the technology at scale in a commercial environment. That is why the Government is firmly committed to CCS. There are a number of promising CCS projects proposed in England and Scotland and we expect to commence a selection process as soon as possible, with £1 billion set aside to support the programme. Progress is also being made around the world – the US and Canada have both just broken ground on their first industrial-scale CCS projects on power plants.

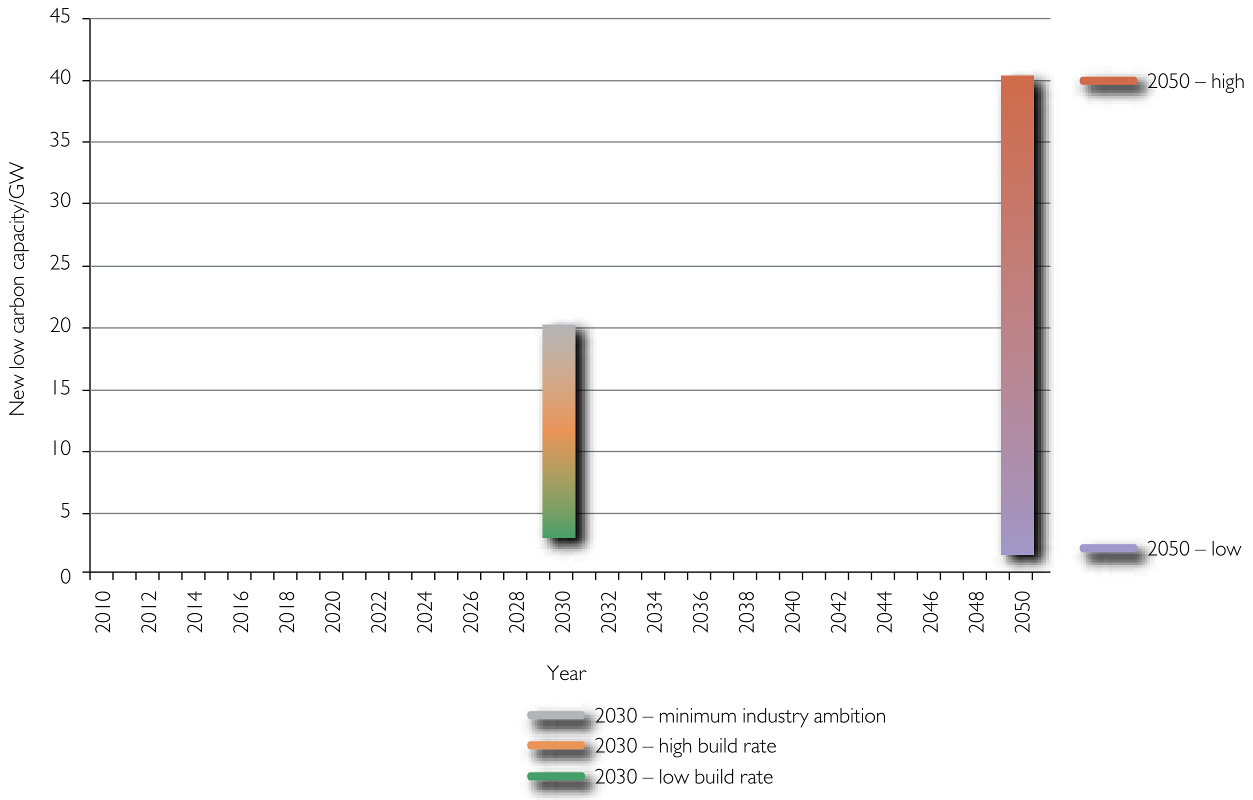
2.166 The Government is also undertaking other actions which will be set out in the CCS Roadmap that will be launched alongside the call for projects. These include development and implementation of the regulatory framework necessary to facilitate CCS projects, and implementation of the policy that there can be no new coal without CCS (enforced by an Emissions Performance Standard).

Renewable electricity

2.167 The Government is committed to dramatically increasing the amount of renewable electricity generation in the UK. Meeting the 2020 renewables target is likely to require renewables to provide over 30% of electricity generation in 2020. Making use of some of the best wind and marine resources in Europe will help to lower emissions and the demand for fossil fuels.

2.168 Looking out to the fourth carbon budget period and beyond, the Government agrees with the conclusions of the Committee on Climate Change's (CCC's) Renewable Energy Review that renewable electricity has the potential to provide over 40% of power generation by 2030 (see chart 26). However, delivering this will require costs to be significantly reduced. To drive cost reductions in offshore wind to £100/MWh by 2020, the Government has established an industry-led Task Force, which will report by spring 2012. It has also committed up to £50 million over the next four

Chart 25: Trajectory for CCS capacity to 2050



Source: Modelling by Redpoint Energy for the Carbon Plan; Department of Energy and Climate Change.

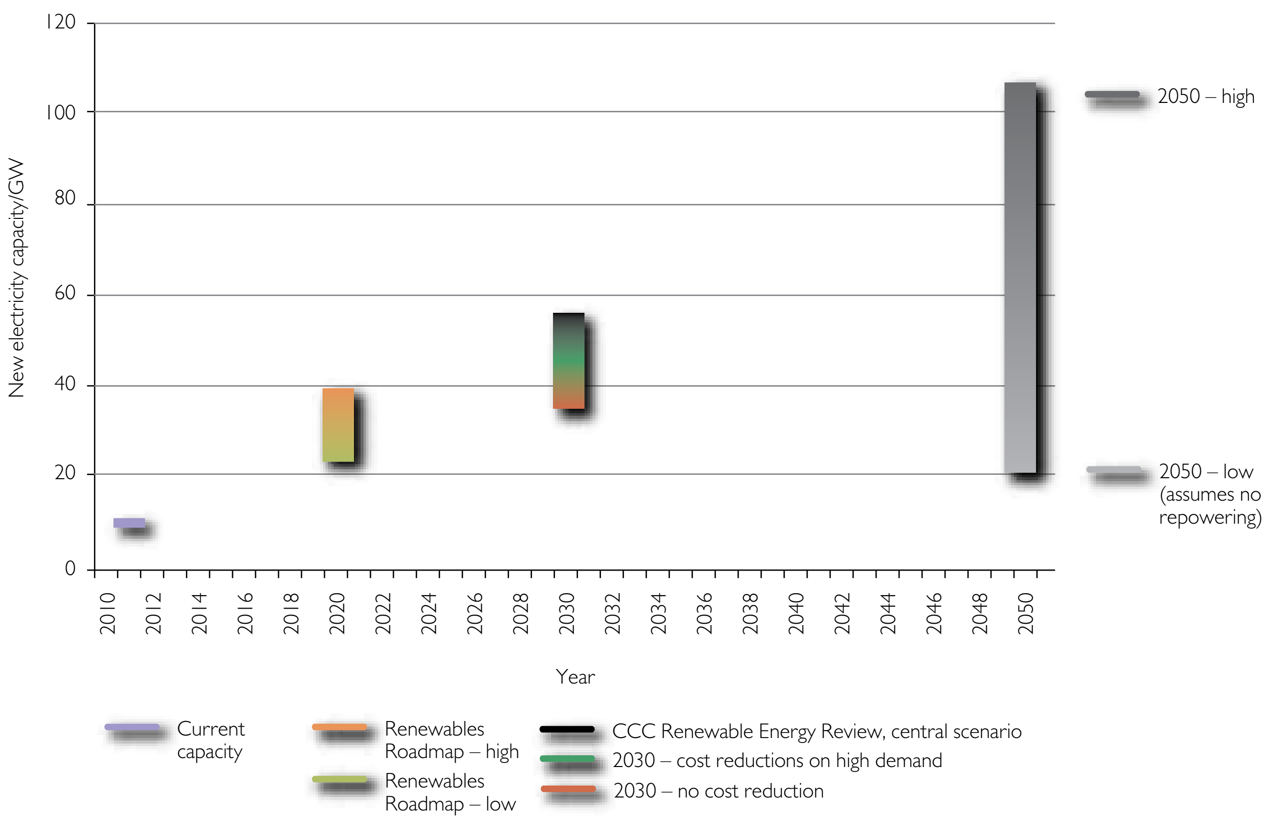
years to support innovation in offshore and marine technologies.

2.169 Levels of renewable energy penetration greater than 40% by 2030 may be technically feasible, but the Government also needs to consider the costs, sustainability and deliverability of such deployment levels, including the challenges for balancing variable electricity supply with demand.

2.170 The Government's immediate focus for renewables is on delivery. In addition to tackling the common barriers to deployment across all low carbon technologies described above, the Government is taking further targeted action on renewables as follows:

- **Reforming the local planning system to make it simpler and swifter** – In addition to reforming the major infrastructure planning regime, the Government recently consulted on a draft National Planning Policy Framework, setting out its objectives for the local planning system, including information on how local plans and development management decisions should support the delivery of renewable and low carbon energy and supporting infrastructure. The Government is also looking at how the planning application process can be improved, including reducing the amount of information expected from applicants and introducing a Planning Guarantee that no application should take longer than one year to reach a final decision, including any appeal.
- **Introducing a new system of marine planning and licensing to deliver sustainable development in the marine environment** – The UK administrations are introducing new marine planning and licensing systems designed to provide regulatory simplicity and certainty for developers.[82]

Chart 26: Trajectory for renewable electricity capacity to 2050



Source: Modelling by Redpoint Energy for the Carbon Plan; Department of Energy and Climate Change.

[82] Marine plans will for a framework for the sustainable development of marine renewables, informing licensing decisions and major infrastructure decisions for larger offshore projects.

- **Access to investment capital** – Offshore wind and energy from waste are likely to be priorities for support from the Green Investment Bank (GIB), which should be able to lend money from 2015, when most funding for the construction of Round 3 offshore wind is required.[83] Prior to the GIB's creation, there will be £775 million of government funding available in 2012/13 to invest in the low carbon economy.

- **Ensuring sustainable bioenergy feedstock supply** – The Government is currently developing a Bioenergy Strategy, which will help to provide strategic direction in ensuring that biomass feedstocks used for bioenergy are sustainable and that they are directed towards the most appropriate uses in electricity, heat and transport.

- **Facilitating development of renewable supply chains** – The Government has committed up to £60 million to encourage the development of port and manufacturing facilities for offshore wind and marine energy parks.

- **Facilitating access to the electricity grid** – The Government has reformed grid access, and is now working to ensure the delivery of new onshore grid investment, and to establish the offshore framework necessary to deploy future levels of renewable electricity.

Unabated gas

2.171 Gas generation capacity will continue to play an important role in providing flexibility and balancing the system. We are likely to need new gas plant within the next decade to replace coal and nuclear closures. There is currently 8.7 GW of gas power station capacity with consent to build and around 4.3 GW under construction. The capacity mechanism should continue to ensure sufficient reliable capacity, including gas, to meet our electricity needs.

2.172 The precise share of gas in the overall energy mix over the fourth carbon budget will be determined by a number of factors. Government modelling suggests that unabated gas could retain a significant role in electricity generation through the 2020s, potentially still producing up to two thirds of today's generation levels in 2030.[84] As the share of renewables in the electricity mix rises, increasing the amount of intermittency on the system, we are likely to need increased back-up gas generation.

2.173 In the longer term, there will be a more fundamental shift in the role of gas in electricity supply. From 2030 onwards, a major role for gas as a baseload source of electricity is only realistic with large numbers of gas CCS plants.[85] However, we may still need unabated gas for back-up even in 2050 – the 2050 futures in Part 1 suggest the need for significant volumes of back-up gas operating at low load factors in scenarios with high levels of renewable generation.

[83] Third round of offshore wind site allocations by the Crown Estate.

[84] Based on modelling by Redpoint Energy commissioned for the Carbon Plan. Please see Annex B for further details.

[85] HM Government (2011) *2050 Pathways Analysis: Response to the Call for Evidence.*

Reducing electricity demand and balancing the electricity system

2.174 The Government is also currently assessing whether sufficient support and incentives already exist to make efficiency improvements in electricity usage, or whether there is a need for additional measures. The results of this work will be published in summer 2012. At the same time, the Government will publish its policy on balancing the future electricity system. This will cover the whole electricity system and set out the role for government in ensuring that the electricity system supports the low carbon transition in the most secure and affordable way, the most efficient use of assets.

Ensuring that the grid is able to deliver

2.175 The scale of investment required in the electricity network is unprecedented. This is illustrated by plans submitted to Ofgem by the GB electricity Transmission Owners (TOs) for up to £15 billion of new network investment for 2013–21. The Government is working with Ofgem and industry to help meet the network challenges to support a secure, efficient and affordable, low carbon future.

2.176 Onshore, a new grid connection regime introduced in 2010 has meant that projects, particularly renewables, are now getting much speedier connection dates. To date, 73 large projects – with a total capacity of 26 GW – have advanced their connection dates by an average of six years. Work is under way to ensure that the transmission system can be extended and reinforced to connect newer generation that will increasingly be in areas located further away from the main network, in particular through Ofgem's new investment framework, RIIO (Revenue=Incentives+Innovation+Outputs). In 2009 the Electricity Networks Strategy Group (ENSG), a high-level industry group chaired by the Department of Energy and Climate Change and Ofgem, assessed the potential transmission network investment required to 2020. Since then, the TOs have been submitting their priority investments to Ofgem, which has resulted in approval of around £400 million of investment to date. The ENSG is currently refreshing this '2020 vision' and considering analysing possible network requirements post-2020.

2.177 The Government is taking action now to ensure that distribution networks can cope in the future. The Department of Energy and Climate Change and Ofgem co-chaired Smart Grid Forum is developing shared assumptions of future electricity demands and necessary investment levels. At the same time Ofgem has set up the Low Carbon Networks Fund, which is making £500 million available to networks that introduce new innovation and commercial models onto the network.

2.178 Connecting offshore renewable electricity quickly will also require significant investment in offshore transmission assets. The Government has put in place an innovative regulatory regime to deliver offshore energy connections in a cost effective, timely and secure manner. A key element of the regime is the competitive tender process run by Ofgem to appoint Offshore Transmission Owners (OFTOs) to construct (where a generator chooses not to do so itself), and own and operate the offshore transmission assets.

2.179 In recognition of the importance of developing a co-ordinated offshore and onshore transmission network and the potential benefits this could bring, the Government and Ofgem are currently undertaking an Offshore Transmission Co-ordination Project to consider whether additional measures are required within the competitive offshore transmission regime to further maximise the opportunity for co-ordination. Interim conclusions will be published this winter.

AGRICULTURE, FORESTRY AND LAND MANAGEMENT

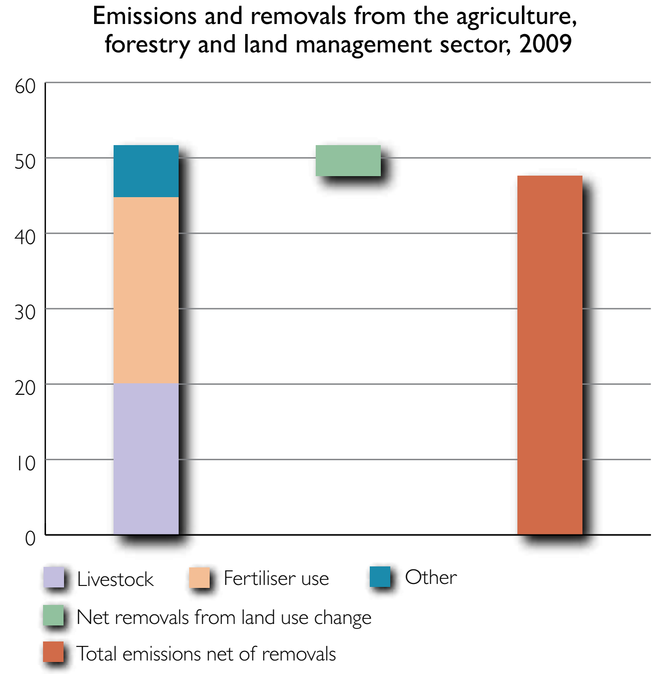
Where we are now

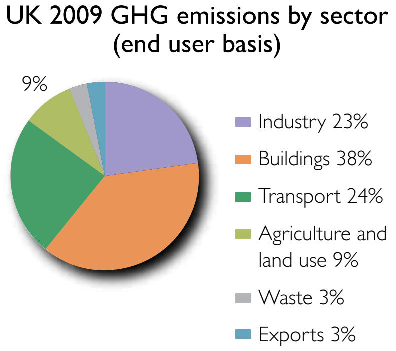
2.180 Agriculture, forestry and land management together accounted for around 9% of UK emissions in 2009.[86] We expect that emissions will be reduced further between now and 2050, but unlike some areas it will not be possible to eliminate those emissions entirely which, to a substantial degree, result from natural processes in soils and the digestive systems of farm animals.

2.181 Good progress has already been made since 1990, with emissions from the agriculture sector down by more than 30%, partly due to lower livestock numbers, but also to the more efficient use of fertilisers in crop production and the decoupling of subsidies from production. Over the same period, the land use, land use change and forestry sector has changed from a net source of emissions to a net carbon sink. This is primarily because of lower emissions from soils due to less intensive agriculture, and increased removals by forests due to high levels of afforestation from the 1950s to the 1980s.

2.182 Because the agricultural sector covers a diverse range of practices that are part of complex biological systems, emissions from agriculture are heavily affected by variable, uncontrolled elements such as climate, weather and soil conditions, as well as by controlled activities such as livestock diet. One element of uncertainty arises from the fact that there are considerable variations in the level of emissions created, even where farmers are

Chart 27: Proportion of UK greenhouse gas emissions from the agriculture, forestry and land management sector, 2009





86 On source and end user basis. The figure by end user is slightly higher (48 $MtCO_2e$ compared with 45 $MtCO_2e$ by source). This includes both emissions and the removal of carbon from the atmosphere by sinks such as forests.

adopting the same practices. For example, different soil types and moisture conditions will lead to different levels of emissions from the same degree and method of fertiliser application. As a result, estimates for emissions from agriculture lie within an uncertainty range of around +250%/–90%. This is the reason for the Government's focus on research to expand the evidence base.

Where we will be in 2050

2.183 The Government is committed to reducing emissions from agriculture and land use, and the strategy is to focus on the following practical action:

- In the **agriculture** sector, improvements in crop nutrient management and in breeding and feeding practices will reduce emissions, are likely to increase productivity and save money, and in many cases may also bring environmental co-benefits.
- **Sustainable forest management** can deliver significant emissions savings through carbon sequestration in new woodlands, and through increased use of sustainable wood products which store carbon and act as substitutes for materials with higher emissions associated with their production.
- **Soils**, which naturally store carbon and are important in climate regulation, need to be managed in a way that protects – and, where possible, increases – these stores, particularly as climate change may affect natural processes in a way that could cause some of the store to be lost.[87]

2.184 The pressures of a growing global population and increasing demands for a more resource intensive diet were highlighted in the Foresight Report on the future of food and farming,[88] which identified managing the contribution of the food system to the mitigation of climate change as one of the most important challenges for policy makers. The Government has committed to champion a more integrated approach to **global food security** by governments and international institutions that makes the links with climate change, poverty, biodiversity, energy, water and other policies. The Government has also committed to work in partnership with the whole food chain, including consumers, to ensure that the UK leads the way in sustainable intensification of agriculture. This will ensure that agriculture and the food sector can contribute fully to the low carbon economy by increasing productivity and competitiveness while reducing emissions, protecting and enhancing the natural environment, and using resources more sustainably.

2.185 The sector could also play a role in supporting the diversification of our energy supply by providing sustainable feedstocks for bioenergy.[89]

How we will make the transition

2.186 Whereas in other sectors of the economy a portfolio approach has been proposed – where the most cost effective technologies are supported and a range of possible abatement levels in the fourth carbon budget period are presented – the uncertainties in the agriculture and land management sector mean that our analysis assumes one level of possible emissions abatement potential that might be delivered in the first four carbon budgets. The trajectory graph in chart 28 below provides an illustrative view of this emissions reduction scenario.

2.187 In agriculture the Government is taking a phased approach to reducing emissions. Over the next decade it will focus on encouraging production efficiencies such as improving crop nutrient management, and breeding and feeding practices, which save both money and emissions. The Government recognises that further action will be needed in the future that goes beyond this, but that there is a great deal of uncertainty around

[87] UK soils hold around 10 billion tonnes of carbon, half of which is in peat habitats. This is more than in all the trees in the forests of Europe (excluding Russia), and equivalent to more than 50 times the UK's current annual greenhouse gas emissions. Source: Defra (2009) *Safeguarding Our Soils: A strategy for England.* Available at: http://archive.defra.gov.uk/environment/quality/land/soil/documents/soil-strategy.pdf

[88] Government Office for Science (2011) *The Future of Food and Farming: Challenges and choices for global sustainability*. Available at: www.bis.gov.uk/assets/bispartners/foresight/docs/food-and-farming/11-546-future-of-food-and-farming-report.pdf

[89] Annex A sets out the amount of demand for sustainable bioenergy in the three 2050 futures.

what actions can successfully reduce emissions to the levels that will be required by 2050. We are therefore also putting in place the research and structures that will give us the knowledge and practical tools to reduce emissions in the longer term.

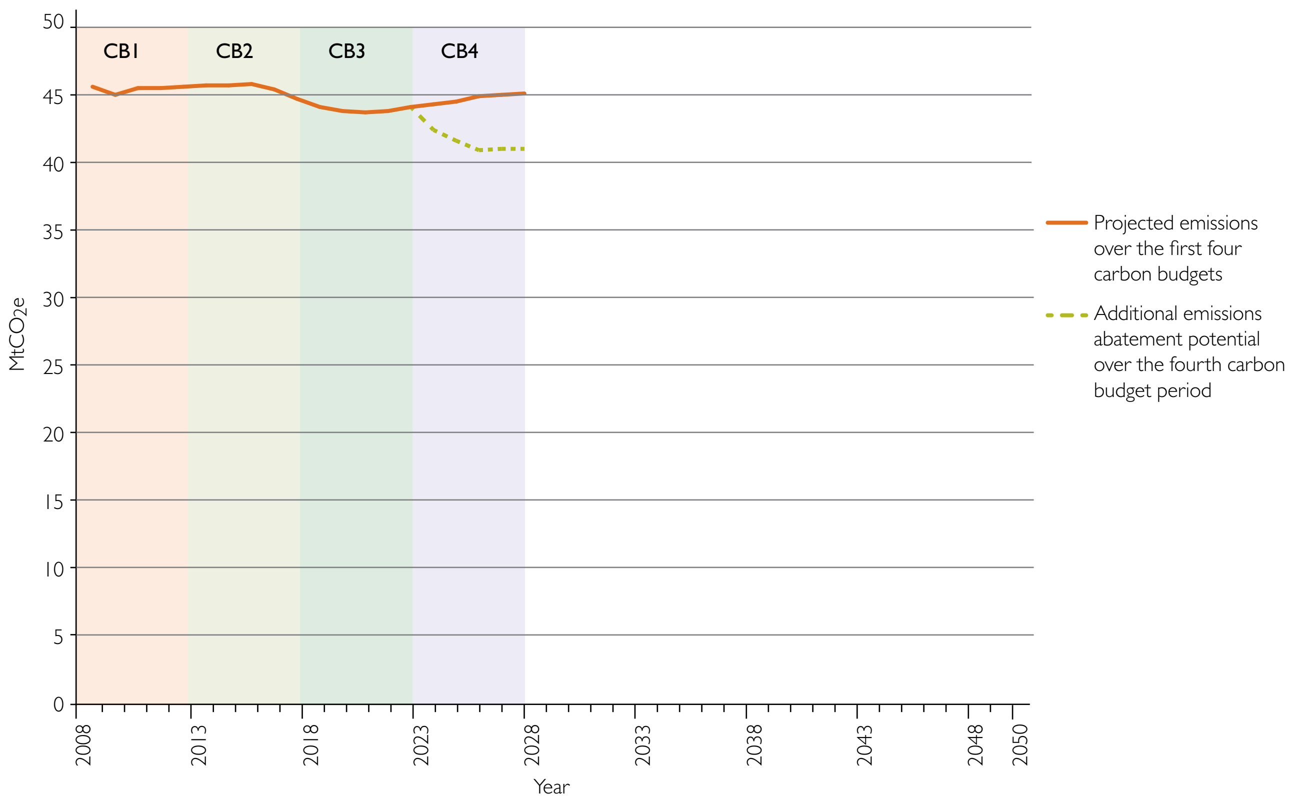
2.188 Chart 29 on page 90 shows some of the key actions and decision points that will set us on the way to further reducing emissions from the sector to 2030.

Agriculture

2.189 **Over the next decade**, a range of actions are being taken in the agriculture sector – both industry- and government-led – which will keep us on track towards the level of emissions abatement identified in the fourth carbon budget period.

2.190 In England, the agricultural industry partnership published the *Agriculture Industry GHG Action Plan: Framework for Action* in 2010, outlining how reductions could be delivered by the end of the third carbon budget period through the uptake of more resource efficient practices.[90] It has committed to reducing emissions by 3 $MtCO_2e$ a year during the third carbon budget period, and in 2011 published a Phase 1 Delivery Plan which explained how the Action Plan will be implemented. Many of the measures identified – such as better use of nutrients, improving livestock productivity and better use of on-farm energy and fuel – could be adopted at minimal or no cost and would help to improve industry competitiveness. The meat and dairy sector bodies have also delivered industry-led environmental product roadmaps, which encourage farmers to employ more sustainable farming practices and management techniques.[91]

Chart 28: Greenhouse gas emissions projections in the agriculture sector in the first three carbon budgets and illustrative emissions abatement potential in the fourth carbon budget period[92]



[90] For further information see: www.nfuonline.com/ghgap

[91] See: www.eblex.org.uk/documents/content/publications/p_cp_testingthewater061210.pdf and www.dairyco.net/library/research-development/environment/dairy-roadmap.aspx

[92] The emissions projections derive from Updated Energy and Emissions Projections data. The illustrative emissions abatement potential for the fourth carbon budget derives from the fourth carbon budget scenarios discussed in Part 3 of this report.

2.191 To support these industry-led efforts to reduce emissions, the Government has undertaken a number of initiatives, including the following:

- Investing £12.6 million, in partnership with the Devolved Administrations, to strengthen understanding of on-farm emissions, and enable better reporting of actions taken on the ground and more targeted advice.
- Investing in a wider programme of research on measures with potential to reduce emissions, for example the impact and cost effectiveness of tackling endemic diseases in cattle, improving nutrient use through better feed management and optimising lifetime protein use for milk production.
- Engaging in partnerships with Research Councils and industry through the Technology Strategy Board, and internationally through the Global Research Alliance, to promote exchange of data, training and research to help improve how agricultural greenhouse gas research is conducted and to enhance scientific capability.
- Funding a pilot project to trial methods for delivering integrated environmental advice for farmers – including on greenhouse gas emissions – with a view to wider delivery by the Government and industry advisors.
- Including climate change mitigation as a topic of advice under the Farm Advisory System contract during 2012 and 2013.
- Committing, in the Natural Environment White Paper, to review use of advice and incentives for farmers and land managers, to create a more integrated, streamlined and efficient approach that is clear and that can yield better environmental results.

2.192 There is a close relationship between the level of agricultural production and emissions from the sector. The Common Agricultural Policy (CAP) and other factors that impact on production levels are likely to be strong drivers of action on emissions. Alongside the EU's budget negotiations for 2014–20, the shape of the CAP for this period is currently being re-negotiated. The European Commission's proposals for the future of the CAP were formally released on 12 October 2011.[93] These will be negotiated by Member States in the Agriculture Council and, for the first time, with the European Parliament through co-decision.[94] Through funding for the UK's agri-environment programme, the CAP already incentivises actions that deliver emissions reductions and the Government is committed to making the CAP more effective in delivering environmental benefits. The negotiations are expected to last throughout 2012 and 2013, and final legislation is due to come into effect on 1 January 2014.

2.193 In 2012 the Government will involve a number of interested organisations in evaluating the likely impact of all these policies in England, as well as in assessing the progress being made by the industry-led Action Plan, in order to identify the policy options for the future.[95] It is probable that the sector will reduce emissions through a combination of on-farm measures that can be successfully implemented (and others that may emerge over time or as a result of further improvements in technology), supported by developments in the broader policy and economic landscape.

2.194 **Over the fourth carbon budget period**, the Government's analysis (based on a review of the Scottish Agricultural College's (SAC's) analysis for the Committee on Climate Change) suggests that, at a carbon price of zero, there is around 7.5 $MtCO_2e$ a year (central estimate, of which 5 $MtCO_2e$ is in England) of total annual abatement potential from the application of on-farm measures.[96]

[93] See: www.defra.gov.uk/food-farm/farm-manage/cap-reform/

[94] This means joint decision making by both the European Parliament and the Council.

[95] See: www.defra.gov.uk/corporate/about/what/business-planning/

[96] In their 2008 advice on the level of the first three carbon budgets, the Committee on Climate Change relied on analysis carried out by SAC, which considered a range of measures that can be adopted by farmers, including measures to improve crop nutrient management, manure treatment and storage, plant breeding, soil drainage and the modification of livestock diets. The central estimate includes the abatement that industry expects to deliver during the third carbon budget period. This is within a range of between 3 $MtCO_2e$ and 19 $MtCO_2e$ by the end of the fourth carbon budget period.

2.195 While in theory this represents an additional 16.9 $MtCO_2e$ of abatement over the fourth carbon budget period compared with baseline projections, the uncertainty in our data means that it is difficult to determine the exact potential for reductions in the fourth carbon budget period and beyond.[97] Work is under way to improve the agriculture greenhouse gas inventory, which will help to refine the analysis of what is feasible.

Forestry and land management

2.196 The Government is committed to strong support for woodland creation and for bringing more woodland into active management. An independent panel will provide advice to the Government in spring 2012 on the future direction of forestry and woodland policy.[98] The measures outlined in this section are therefore subject to the panel's findings and the Government's response.

2.197 **Over the next decade**, the Government will continue to support woodland creation through a number of measures, including the following:

- **Rural Development Programme funding and the Woodland Carbon Task Force** – The Government will continue to support woodland creation through woodland grant schemes. The Woodland Carbon Task Force was set up by the Forestry Commission to enable a step-change in the level of woodland creation to help deliver abatement in the sector. It will help to ensure that the contribution of woodland creation to carbon budgets is recognised, and will develop a spatial framework to identify where woodland creation will have the most benefit.
- **The Woodland Carbon Code**, which helps to promote high quality UK-based forest carbon projects, and – together with recent changes to the guidance for businesses on measuring and reporting greenhouse gas emissions[99] – encourages investment in domestic woodland creation projects by helping organisations to report these reductions as part of their net emissions.[100] The **Woodfuel Implementation Plan**, which outlines the actions that Forestry Commission England will take to support the development of a robust woodfuel supply chain over the next four years.[101] This helps to fulfil commitments made under the EU Renewable Energy Directive, and is part of a wider programme to increase sustainable timber production from privately owned woodlands.
- A revised **UK Forestry Standard**, supported by new Forests and Climate Change Guidelines, promotes carbon management in the UK's woodlands,[102] and also provides guidance on adapting woodlands to the impacts of climate change, promoting resilience and ensuring that future abatement is delivered.[103]

2.198 However, in the land use, land change and forestry (LULUCF) sector there are still significant uncertainties about current emissions, future trends, and the potential for permanent sequestration of greenhouse gas emissions through land management. Further work is therefore being carried out to explore the potential to refine further the LULUCF inventory and also to understand the effect of land management practices on soil carbon within current policies.

[97] It is also important to note that some of the mitigation measures SAC identified are likely to be unacceptable because of the potential adverse impacts on biodiversity or animal welfare, and some may even have perverse effects on greenhouse gas emissions which have yet to be fully assessed. The estimates of abatement potential make no allowance for such issues, so the level of cost effective abatement achieved from these measures is unlikely to be at the upper bound suggested by the analysis.

[98] See: www.defra.gov.uk/forestrypanel/

[99] See: www.defra.gov.uk/environment/economy/business-efficiency/reporting/

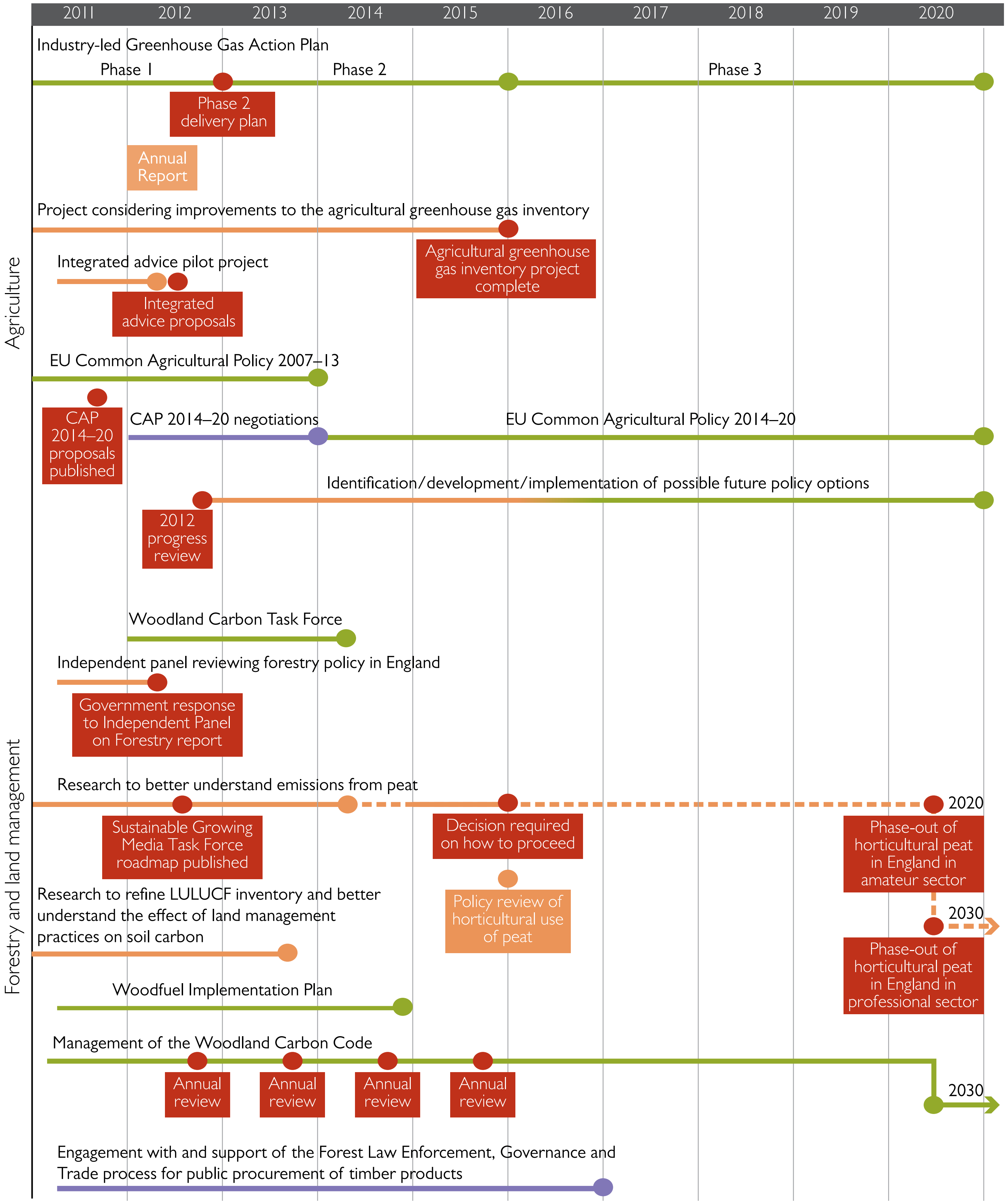
[100] See: www.forestry.gov.uk/carboncode

[101] See: www.forestry.gov.uk/england-woodfuel

[102] See: www.forestry.gov.uk/ukfs

[103] In this context the Defra and Forestry Commission's *Action Plan for Tree Health and Plant Biosecurity* addresses the risk of future tree pest and disease outbreaks to forest carbon storage.

Chart 29: Decision points for agriculture, forestry and land management to 2030



2.199 Internationally, continuing support for the Forest Law Enforcement, Governance and Trade process and chain of custody requirements for public procurement of timber products,[104] together with the development of biomass sustainability criteria for renewable energy production, will promote sustainable approaches to forest management, helping to reduce emissions from deforestation and forest degradation globally.

2.200 The Soil Protection Review[105] addresses threats to soil degradation and contains measures to protect soil organic matter, and so soil carbon. In addition, given the importance of peatlands as carbon stores, the Government is undertaking research to further our knowledge of emissions from peat. This includes a review of restoration methods used in blanket peatlands to assess which could provide the best outcomes for reducing peatland emissions. Peat extraction in the UK causes around 0.4 $MtCO_2e$ of emissions annually, and in the Natural Environment White Paper the Government committed to phase out the use of peat in horticulture in England by 2030.[106]

2.201 **Over the fourth carbon budget**, the Committee on Climate Change has indicated that increased woodland creation could deliver 1–3 $MtCO_2e$ abatement a year by 2030,[107] although assessing the cost effectiveness of abatement is complex because of the dynamics of forest growth and carbon uptake, the nature of the woodland and approaches to its management, and the end use of harvested wood products.

2.202 Looking ahead to 2050, current projections indicate that increasing woodland planting to an average of 24,000 hectares per annum across the UK between now and 2050 would increase forest carbon uptake by 7.7 $MtCO_2e$ per annum in 2050, compared with the level which would be achieved by maintaining 2010 planting rates (6,000 hectares per annum).[108]

Next steps

2.203 The uncertainty in the agricultural greenhouse gas emissions inventory means that a continued focus is required on research and statistics. For example, the Farm Practices Survey provides information on behaviours for a range of on-farm practices across the whole sector.[109] The 2012 progress review will evaluate the results of evidence such as this with interested organisations.

[104] The Government's timber procurement policy is set out at: www.cpet.org.uk/uk-government-timber-procurement-policy

[105] See: www.defra.gov.uk/food-farm/land-manage/soil

[106] In 2009, of the 3 million cubic metres of peat sold in the UK as growing media and soil improvers, around 80% was sold in England.

[107] Indicative estimates of the cost of abatement through woodland creation are of the order of £0–£70 per tonne CO_2e.

[108] This is based on the analysis presented in Read, DJ, Freer-Smith, PH, Morrison, JIL et al. (eds) (2009) *Combating Climate Change – A role for UK forests* (the Read Report). Available at: www.forestry/gov/uk/readreport

[109] See: www.defra.gov.uk/statistics/foodfarm/enviro/farmpractice/

WASTE AND RESOURCE EFFICIENCY

Where we are now

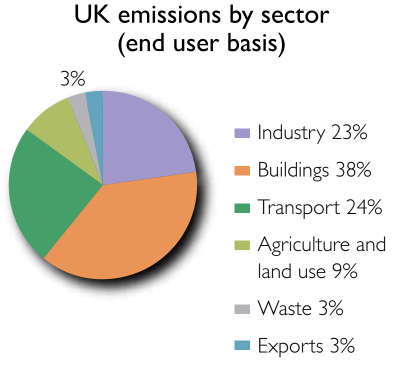
2.204 In 2009, emissions from the waste management sector represented a little over 3% of the UK total.[110] Between 1990 and 2009 emissions were reduced by nearly 70%, primarily due to the landfill tax – which incentivises reductions in the amount of biodegradable waste sent to landfill – and the increased capture and use of landfill gas for energy.

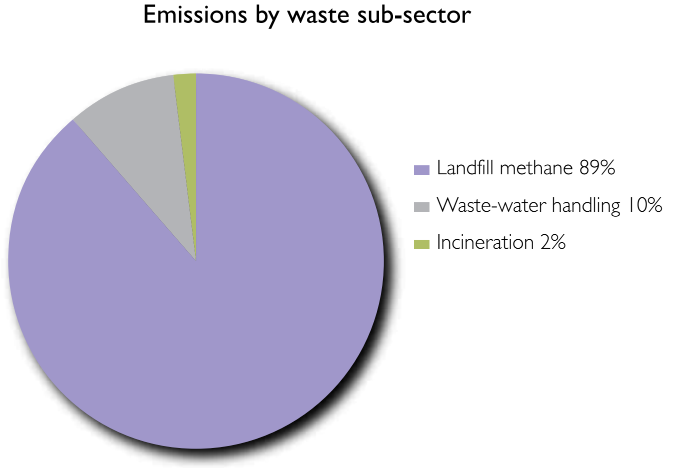
2.205 It will not be possible to eliminate these emissions completely as some biodegradable waste takes a long time to fully decompose, but by 2050 it is estimated that emissions of methane from landfill – which accounted for nearly 90% of emissions from the sector in 2009 – will be substantially below current levels. The Government is working to improve our scientific understanding of these emissions so they can be predicted with more certainty.

2.206 The Government is committed to working towards a zero waste economy, and the three broad strands of the Government's approach to tackle emissions from the sector relate to the following areas:

- **Preventing waste arising** – The best thing that can be done to minimise the greenhouse gas impacts of waste is not to produce it in the first place. This eliminates the need to manage waste, and removes the embedded carbon throughout the supply chain that went into the product, thereby reducing emissions both in other sectors of the UK economy and in other countries.[111] More efficient use of resources – including energy and water – by businesses will help the UK to move to a greener economy and deliver economic and environmental benefits.

Chart 30: Proportion of UK greenhouse gas emissions from the waste sector, 2009





[110] On source and end user basis. The waste management sector comprises emissions from landfill, waste-water handling and waste incineration.

[111] Direct emissions from the management and disposal of waste are only a small proportion of the total greenhouse gas emissions caused by wasteful use of resources. The majority of these emissions occur outside the UK.

- **Reducing methane emissions from landfill** – There are three broad approaches that may be taken: preventing biodegradable waste from arising in the first place; diverting biodegradable waste that is produced away from landfill to other forms of treatment, such as recycling or waste to energy facilities; and reducing methane emissions from landfill sites, for example by increasing the proportion of methane that is captured and converted to energy. There are, however, considerable uncertainties in the way we calculate emissions from landfill, which the Government is working to address.
- **Efficient energy recovery from residual waste** – Recovering energy from waste rather than sending it to landfill displaces energy produced from fossil fuels, avoids methane emissions from landfill and is generally a good source of feedstocks to meet UK bioenergy needs.

How we will make the transition

2.207 Emissions from waste management have already fallen by nearly 70% between 1990 and 2009. In the next decade the Government will continue to take action on reducing waste with the increase of the landfill tax to £80 per tonne in 2014/15. We are also undertaking a consultation on restricting wood waste to landfill. Legacy issues mean that it will not be possible to eliminate emissions completely by 2050, as some biodegradable waste takes longer than this to fully decompose, but by 2050 we expect levels to be substantially below where they are now.

2.208 Chart 33 on page 98 gives a summary of some of the key actions and decision points that will help to reduce emissions from the waste sector and improve resource efficiency.

Preventing waste arising

2.209 The Government's approach to reducing waste is underpinned by the waste hierarchy (see chart 31), a framework that ranks waste management options according to what is best for the environment.[112]

2.210 The further up the hierarchy waste is treated, the greater the emissions savings: preparing for re-use is often a less intensive way of replacing primary production of products than recycling.[113] An example of this is textiles, where preparing 1 tonne for re-use could save 12 tonnes more CO_2e than recycling. However, waste prevention incorporates a wide number of different actions and behaviours, and the barriers to these behaviours becoming embedded are complex and will be different for individuals and businesses. They include the costs of innovation and market development of new products or business models, lack of access to information to enable decisions, and lack of incentives to change behaviours.

2.211 Recent research has identified savings of around £23 billion and 29 $MtCO_2e$ a year available to UK business from resource efficiency measures to minimise waste and use of materials that pay back within a year or less, including around £18 billion from waste measures alone. This figure could be more when longer-term investment is considered – an estimated additional £33 billion, resulting in a total opportunity of around £55 million and 90 $MtCO_2e$ in total for all measures.[114]

2.212 In addition, using water more efficiently helps both to adapt to the impacts of climate change, where more variable rainfall is expected, and to reduce the greenhouse gases associated with pumping and treatment, and heating.[115]

[112] Guidance on applying the principles of the waste hierarchy can be found at: www.defra.gov.uk/publications/files/pb13530-waste-hierarchy-guidance.pdf

[113] It is possible to deviate from the hierarchy where lifecycle evidence suggests that to do so would have a better environmental impact, such as for lower grade wood where energy recovery is better than recycling due to the level of contaminants; and for anaerobic digestion, which sits above recycling for food waste because it produces both energy and digestate (which can displace artificial fertilisers).

[114] This analysis is based on a 2009 base year and refers to annual savings from low or no cost measures which deliver within one year; all potential longer-term measures up to 2050. See: Oakdene Hollins (2011) *The Further Benefits of Business Resource Efficiency* at: http://randd.defra.gov.uk/Default.aspx?Document=EV0441_10072_FRP.pdf

[115] The water industry currently produces about 1% of the UK's overall greenhouse gas emissions in the supply of water and treatment of waste water.

Measures that increase the efficiency of use of hot water may be financed under a Green Deal, as reductions in the energy used will generate savings.

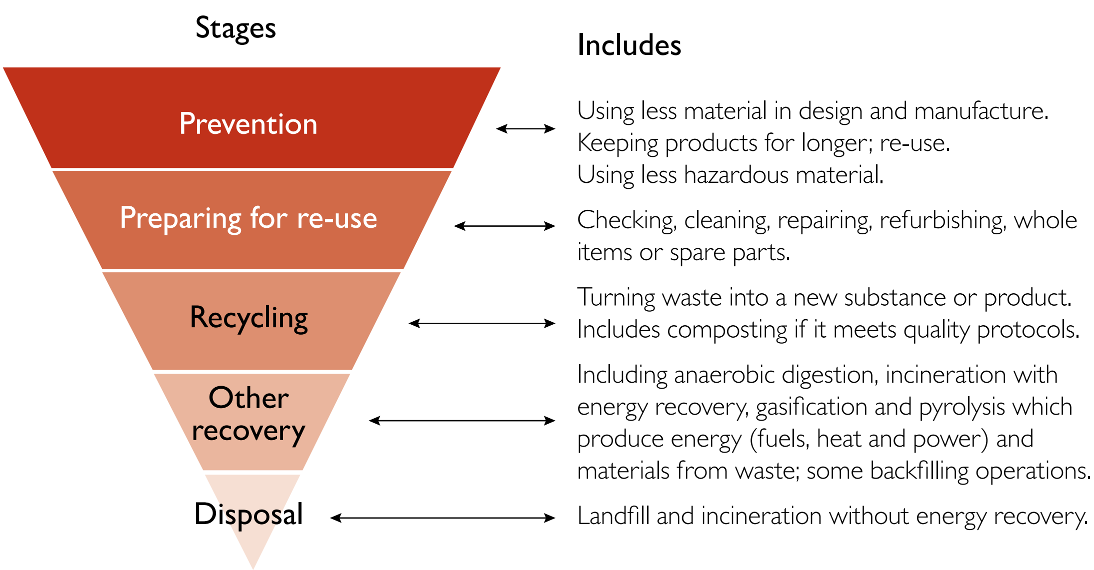
2.213 **Over the next decade**, government action will include the following:

- Development of a **comprehensive Waste Prevention Programme by the end of 2013**, alongside a range of measures under a broader resource efficiency programme to drive waste reduction and re-use, working with businesses and other organisations across supply chains.
- Working closely with business to explore the **potential for responsibility deals in a number of sectors that would cover products and materials identified as having high embedded carbon.** On packaging, the Government intends to launch a consultation on increased recycling targets for packaging producers in the period 2013–17.
- Working to make **corporate reporting of greenhouse gas emissions** – which helps organisations to manage their emissions, and allows informed decisions about how a company is managing climate change risks – more widespread and consistent. Guidance was published in 2009 to help organisations with this process, and the Government will announce whether it intends to introduce regulation in this area later in 2011.

2.214 In addition, the **Waste and Resources Action Programme (WRAP)** works to help businesses realise the benefits of being more resource efficient, through partnerships and voluntary agreements. WRAP is focusing its work up the waste hierarchy to minimise waste production and associated greenhouse gas emissions. One priority for action is to tackle food waste and divert it from landfill, with a goal of aiming to reduce emissions associated with avoidable food and drink waste by 3.2 $MtCO_2e$ by 2015.

2.215 One of the ways this will be achieved is through the **Love Food Hate Waste** initiative, which helps consumers to reduce avoidable food waste. Overall, WRAP achieved like-for-like savings of 5.5 $MtCO_2e$ per annum between 2008 and 2011.[116] WRAP's emissions target for the next period, from 2011–15, is for a further 4.8 $MtCO_2e$ per annum savings (excluding water savings).

Chart 31: The waste hierarchy



[116] From 1 April 2010 WRAP took on additional responsibilities for resource efficiency; therefore the figures quoted compare WRAP performance against original WRAP targets as set out at the beginning of the business plan period.

Reducing landfill methane emissions

2.216 **Over the next decade**, the Government's actions to reduce landfill methane emissions include the following:

- **The landfill tax**, which provides a financial incentive for local authorities and business waste producers to find alternative ways of handling their waste by gradually increasing the costs of landfill and which is the primary mechanism for reducing biodegradable waste to landfill. It was introduced in 1996 and set at £7 per tonne (for non-inert waste); it has increased to £56 per tonne and the Government has announced that it will continue to increase to £80 per tonne in 2014/15.
- A commitment in the Government Review of Waste Policy in England 2011[117] to a **consultation on restricting sending wood waste to landfill**. This is a significant source of biodegradable waste to landfill: on average, every tonne of wood waste diverted from landfill would save around 1 tonne of CO_2e.
- A **review of the case for restricting sending other wastes to landfill**, including textiles and all biodegradable waste, before the end of this Parliament.

2.217 Each of these measures will help to deliver emissions reductions **over the fourth carbon budget**:

- The continued increases to the landfill tax are projected to further reduce methane emissions from landfill to a projected 84% reduction from 1990 levels by 2025.
- Any restriction on sending wood to landfill would likely start reducing emissions during the third and fourth carbon budget periods, depending on how and when it were to be implemented.
- Any further restrictions on sending other waste to landfill would likely take effect – and start reducing landfill methane emissions – during the fourth carbon budget period.

2.218 The steps outlined in the Review of Waste Policy, plus the continued increases to the landfill tax, mean that the Government's central estimate of methane emissions from landfill in 2050 is that they will be around 61% below 2009 levels (see chart 32 below).

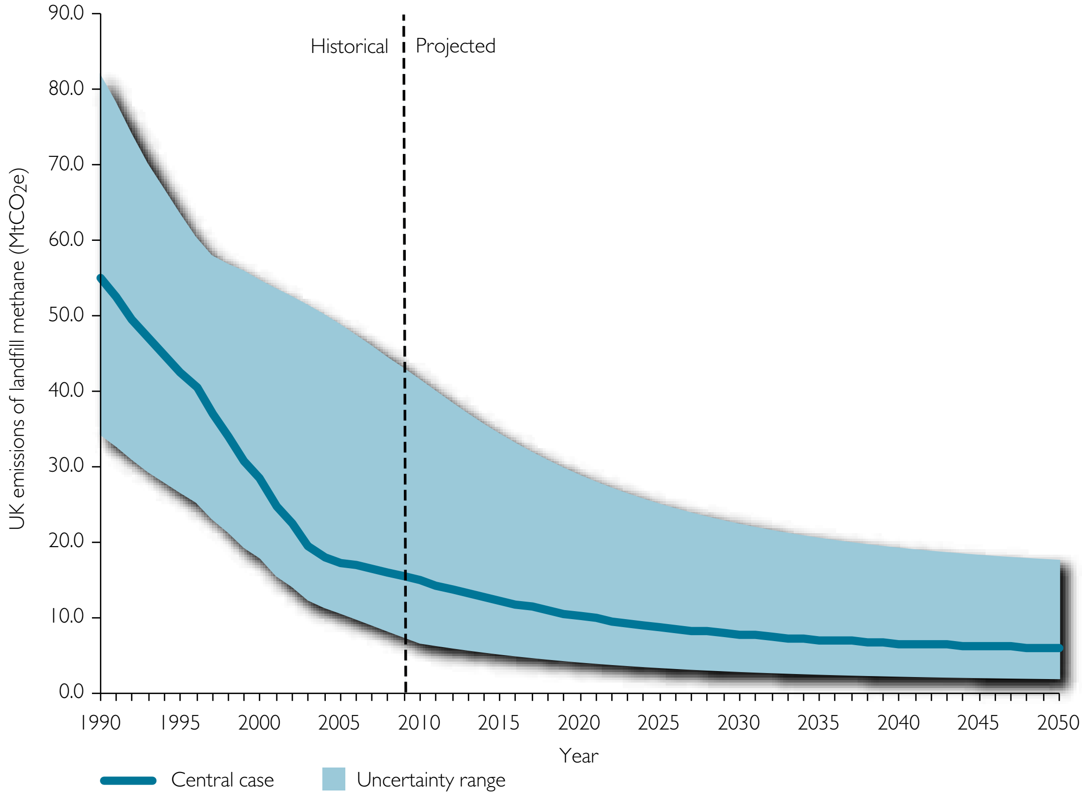
2.219 However, unlike energy-related emissions, methane emissions from landfill are modelled, not measured. Calculations of total emissions from landfill are therefore very sensitive to the amount of methane that is assumed to be captured at landfill sites. While there has been a substantial investment programme in methane capture technology over the last two decades, the precise rate of methane capture remains highly uncertain and could potentially be lower than assumed. This is reflected in the uncertainty range in chart 32, which shows estimated emissions in 2050 of between 1.7 and 17.6 $MtCO_2e$ (equal to reductions of 96.9% and 68.1% respectively from the 1990 central case scenario).

2.220 In addition, the volume of waste generated, the rate of change of this volume and the composition of the waste are dynamic, and experience has shown that these are difficult to model accurately over longer time frames. Developments in key variables such as economic growth, commodity markets, consumption patterns, consumer attitudes and behaviours, and waste treatment technology mean that there are markedly different pathways for how the UK waste system could evolve to 2050.

2.221 The Government is keen to improve the accuracy of modelling projections and has put in place a programme of action to help improve our scientific understanding of both landfill methane formation and the amount of methane that is captured. This includes a survey of landfill sites, taking actual measurements of methane emission,

[117] See: www.defra.gov.uk/publications/files/pb13540-waste-policy-review110614.pdf

Chart 32: Historical and projected emissions of methane from landfill, 1990–2050



Source: UK Greenhouse Gas Inventory and government analysis

oxidation and capture. The results of the survey will inform further opportunities for capturing more methane at landfill sites.

2.222 In addition, the Government is undertaking an ongoing programme of work in conjunction with the Environment Agency (EA) to improve the scientific understanding of landfill methane generation and capture rates at landfill sites. The Government is also committed to working closely with industry and the EA to continue reductions in the amount of methane emitted from landfill sites. This work will explore opportunities to capture methane from closed sites that do not have infrastructure for capturing landfill gas, and resulting improvements to methane capture rates could deliver emissions savings as early as the second carbon budget period.

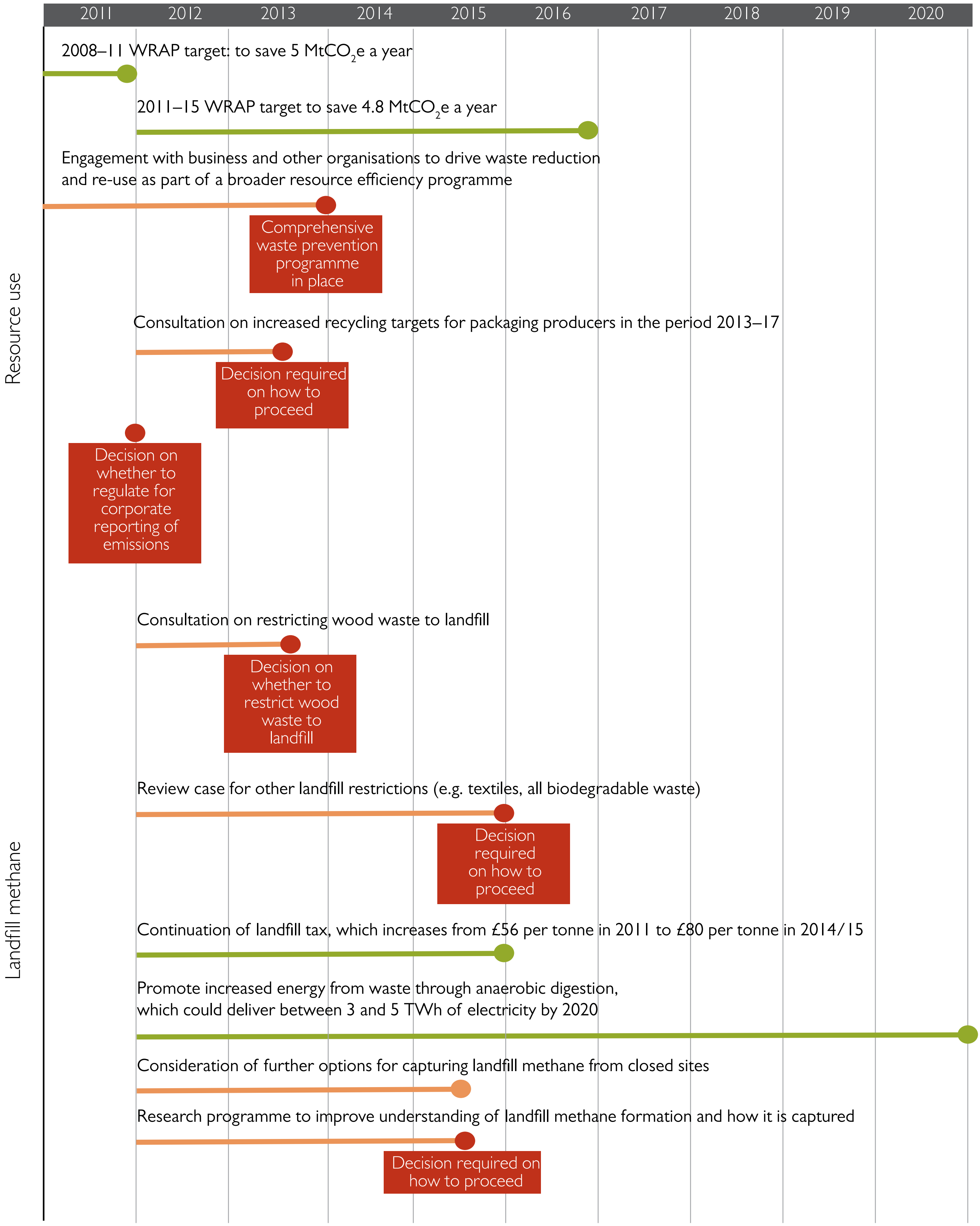
Energy from waste

2.223 The Government's aim is to get the most energy out of waste, not to get the most waste into energy recovery. Through effective prevention, re-use and recycling, residual waste will eventually become a finite and diminishing resource. However, until this becomes a reality, efficient energy recovery from residual waste can deliver environmental benefits and provide economic opportunities.

2.224 Efficient energy recovery from waste prevents some of the negative greenhouse gas impacts of waste in landfill and helps to offset fossil fuel power generation. **Over the next decade**, the Government is taking forward a range of measures through the Review of Waste Policy Action Plan and the *UK Renewable Energy Roadmap*[118] to overcome barriers to deployment of energy from waste through a range of existing and more innovative technologies.

[118] DECC (2011) *UK Renewable Energy Roadmap*. Available at: www.decc.gov.uk/assets/decc/11/meeting-energy-demand/renewable-energy/2167-uk-renewable-energy-roadmap.pdf

Chart 33: Decision points for waste to 2020



Next steps

2.225 The actions set out in the Review of Waste Policy, at each level of the waste hierarchy, will all contribute to reducing the volume of material that ends up in landfill and tackle emissions from the sector.

2.226 The challenge for the Government is how to move beyond the existing trajectory to deliver the vision of a zero waste economy. It is likely that further action will be needed, working closely with local government, industry, civil society, consumers and communities, if the goals are to be achieved. The Government will continue to review how the measures outlined are contributing to the zero waste economy vision and identify areas where we can go further and faster.

Working with the EU and Devolved Administrations

The European Union

2.227 The UK's policies should be seen in the context of the European Union's (EU's) wider objective of transition to a low carbon, resource efficient and climate resilient economy and its political commitment to reduce carbon emissions by at least 80% by 2050, while maintaining secure and affordable energy supplies and preserving the EU's international competitiveness. The interconnected nature of Member States' trading and energy supply relationships means that much of the change needed to achieve these objectives will need to be delivered at the EU as well as the national level.

2.228 The EU has the opportunity to demonstrate to others the benefits of low carbon growth, and to strengthen economic and trading relationships with other countries that want to collaborate on low carbon development. Strong EU leadership will be crucial in building momentum internationally and, by making the transition to a sustainable low carbon economy, the EU can significantly enhance its long-term economic and energy security interests. The Government will work with its partners in Europe to look for opportunities to secure the transition to an EU low carbon economy, encouraging greater ambition in areas including energy, transport, product standards and finance.

2.229 The Prime Minister and the Government are fully committed to increasing the EU's emissions reduction target from 20% to 30% by 2020 compared with 1990 levels. This should act as a means of showing its commitment to the longer-term vision of a sustainable low carbon economy, and driving the investment in new technologies necessary to achieve the level of change that this would require. The Government will share with other Member States evidence which shows that the costs of greater ambition are manageable and can deliver tangible economic and environmental benefits, especially when compared with a scenario of delayed action.

2.230 The Government will work with its European partners to build support for policies to promote energy efficiency, and facilitate investment in new energy infrastructure (with significant investment in low carbon infrastructure) and decarbonisation of transport through development of electric and other low carbon vehicles, as part of the delivery of these ambitious plans.

Northern Ireland

2.231 The Northern Ireland Executive is committed to tackling climate change and to building a sustainable low carbon economy that will bring prosperity for all. By demonstrating leadership, the Executive will inspire business, industry, the public sector and individuals to work together to help reduce UK emissions by 80% below 1990 levels by 2050.

2.232 The Executive views the transition to a low carbon economy as a potentially powerful driver of economic growth, and is committed, through its Sustainable Development Strategy,[119] to build a dynamic, innovative economy that delivers the prosperity required to tackle disadvantage and lift communities out of poverty. The Strategy sets strategic objectives to increase the number of jobs in the low carbon economy; increase the energy efficiency and resource efficiency of businesses; and ensure that our provision of learning and skills responds to the needs of the low carbon economy.

2.233 Although current projections suggest that Northern Ireland is ahead of its 2025 emissions reduction target, the Northern Ireland Environment Minister has pledged greater ambition and has tasked the Committee on Climate Change to consider the shape of further legislation to underpin longer-term targets.

2.234 The agriculture sector in Northern Ireland is an instrumental part of our low carbon future.

[119] See: www.ofmdfmni.gov.uk/index/economic-policy/economic-policy-sustainable-development.htm

It encompasses wider social and economic sustainability factors in addition to environmental considerations, playing a larger role in the local economy when compared with the rest of the UK. The government-led Greenhouse Gas Stakeholder Group is developing a range of primary production-focused mitigation measures based on a review of available scientific evidence to support the sector. A forthcoming strategy will focus on delivering a steady reduction trajectory up to 2020 and beyond. With improved measurement and inventories available from 2015, the sector will be able to prioritise actions to ensure that producers in Northern Ireland are at the forefront of demonstrating the sustainability of food production while ensuring their own business competiveness.

2.235 Within Northern Ireland, we are almost entirely dependent on imported fossil fuels for most of our energy needs. The Northern Ireland Energy Minister leads an Interdepartmental Working Group on Sustainable Energy to ensure a co-ordinated approach across government to the promotion of sustainable energy. Looking to 2050, we are seeking to shift the balance of our energy mix towards cost effective decarbonisation of our electricity supply as far as is practicable. The Executive's Strategic Energy Framework[120] seeks to achieve 40% of electricity consumption from both onshore and offshore renewable sources by 2020. The Offshore Renewable Energy Strategic Action Plan[121] sets out a target of at least 600 MW of offshore wind and 300 MW of tidal energy by 2020 and provides the framework for the current Northern Ireland Offshore Leasing Round. The draft Onshore Renewable Electricity Action Plan,[122] which has been subject to a Strategic Environmental Assessment, looks at potential onshore renewable energy mixes to contribute to that 40% target. In parallel, significant work is ongoing to underpin low carbon/renewables with an electricity infrastructure that is robust, flexible and able to respond to future demand for renewable energy and smart grids/demand-side management.

2.236 The Northern Ireland Executive believes that current transport arrangements and the high level of dependency on the private car, particularly in urban areas, are not sustainable. Active Travel promotes travel alternatives that lead to public health benefits through walking, cycling and reducing our reliance on the car. Travelwise engages with businesses, schools and commuters to promote and encourage sustainable modes of travel. Measures are already in place to reduce carbon intensity in road construction and maintenance, and to recycle construction materials and by-products where feasible. Translink, the main public transport provider, has started a major investment in techniques to reduce fuel use on its bus fleet. A revised Regional Transportation Strategy[123] proposes a range of high-level aims and strategic objectives that will inform how emissions will be reduced into the future. Consideration will also be given to new forms of transportation, such as light rail, and a pilot programme for electric vehicles is under way.

2.237 Northern Ireland has a unique geographical position in the UK. Given the unavoidable reliance on aviation and shipping, both in terms of the economy and wider social considerations, there is a need to ensure that transport-related carbon policy interventions developed at UK and EU level do not have a disproportionate and differential impact.

2.238 Social housing has already seen a significant drive to improve energy efficiency, as this is a key component in reducing not only carbon emissions but also rates of fuel poverty. Other pressures in the private residential sector, such as increased recycling and waste to landfill targets, planning policy and building regulations, and increased energy prices, will increase the need for improved energy efficiency. Behavioural changes and the availability of new renewable technology with condensed payback periods for householders will be key to reducing emissions. The Executive has set a target of a 10% increase in the amount

[120] See: www.detini.gov.uk/strategic_energy_framework__sef_2010_-3.pdf

[121] Following the recent completion of a Habitats Regulations Appraisal, the draft Plan is being finalised for publication. See: www.offshoreenergyni.co.uk/data/draft_strategic_action_plan.pdf

[122] See: www.detini.gov.uk/deti-energy-index/draft_onshore_renewable_electricity_action_plan.htm

[123] See: www.drdni.gov.uk/rts_2011_consultation_document.pdf

of heat from renewable sources by 2020, supported by a Northern Ireland Renewable Heat Incentive.[124] In addition, natural gas roll-out continues to around 150,000 gas customers in Northern Ireland and, if greater gas roll-out were to follow, this would reduce emissions in a region where some 70% of energy consumers remain dependent on oil for their heating needs.

2.239 The Cross-Departmental Working Group on Climate Change will support sectoral initiatives by bringing together government departments to ensure that they are working towards a common goal, reporting annually to the Executive to ensure that they are on course to achieve set targets. The group will improve data sources and measurement, and accountability and governance, and strengthen the delivery framework through focused strategies and policies.

2.240 The Northern Ireland Executive is committed to creating a low carbon future, ensuring that by 2050 Northern Ireland is economically competitive, socially prosperous and delivering an environmental legacy to be proud of.

Scotland

2.241 The Scottish Government is committed to the low carbon agenda over the long term. Scotland has a competitive advantage in attracting low carbon jobs, investment and trade which will drive economic growth. Through our world-leading Climate Change (Scotland) Act 2009, we have provided certainty for business and the public about Scotland's low carbon future.

2.242 The Scottish Government believes that decarbonisation of electricity supply, heat use and transport will be key to meeting Scotland's emissions targets, particularly those in the 2020s and beyond. This should be achieved without resorting to new nuclear generation development.[125] Increasing the amount of available clean electricity will be important in lowering the carbon intensity of other sectors of the Scottish economy, notably heat and transport which, as they reduce their reliance on gas, petrol and diesel, will increasingly draw on electricity for power.

2.243 To create a transition to a low carbon economy, continuing development and deployment of technologies that enable more efficient use of the energy we produce will also become increasingly important.

2.244 The two cornerstones of energy supply transition in Scotland are renewables and carbon capture and storage (CCS). The Scottish Government believes that Scotland is well placed to take a leading role in the development and commercialisation of renewables and CCS[126] into the 2020s, and has targeted developing renewable generation in Scotland to be equivalent to 100% of demand by that time.[127]

2.245 Heat makes up about half of all energy demand and is integrally linked to the Scottish Government's aims to improve energy efficiency. The target to provide 11% of heat demand from renewables by 2020 is the platform for renewable heat to play an increasingly significant role in the following decades. The Scottish Government is taking a number of steps to assist the penetration of heat-based technologies in future years.[128]

2.246 Progress towards a decarbonised road transport system by around 2030 will continue, as will efforts to develop more sustainable communities which encourage active travel and other positive travel choices. Digital technologies offer the prospect of an overall reduction in travel demand, while freight policy will continue to encourage more sustainable goods movement.

[124] See: www.detini.gov.uk/the_development_of_the_northern_ireland_renewable_heat_incentive.pdf

[125] The UK Government works in partnership with the Devolved Administrations in Northern Ireland, Scotland and Wales to deliver the targets set by the Climate Change Act 2008. While the administrations have a shared goal of reducing the impacts of climate change, policies on how to achieve this vary across the administrations – the Scottish Government, for example, is opposed to the development of new nuclear power stations in Scotland. It believes that renewables, fossil fuels with carbon capture and storage, and energy efficiency represent the best long-term solution to Scotland's energy security.

[126] Scottish Government (2010) *Carbon Capture and Storage – A Roadmap for Scotland*. Available at: www.scotland.gov.uk/Publications/2010/03/18094835/0

[127] Scottish Government (2011) *2020 Routemap for Renewable Energy in Scotland*. Available at: www.scotland.gov.uk/Publications/2011/08/04110353/0

[128] Scottish Government (2009) *Renewable Heat Action Plan for Scotland: A plan for the promotion of the use of heat from renewable sources*. Available at: www.scotland.gov.uk/Publications/2009/11/04154534/0

2.247 Indications are that fuel prices are likely to increase further over the next decade. Improving the energy efficiency of the homes and heating of those at risk from fuel poverty will therefore continue to be a vital part of the Scottish Government's efforts to reduce emissions and increase energy security. A strategic group will co-ordinate stakeholder input into the delivery on commitments on sustainable housing and help to develop a Strategy for Sustainable Housing in Scotland.

2.248 It is not just the impacts of climate change itself that can have particular consequences for remote, rural and island communities, but also the effects of measures intended to reduce emissions. It will be important to ensure that, in moving to a low carbon economy, the differential impacts of policies on these communities are fully considered and tailored, and flexible solutions found for the future.

Wales

2.249 The Welsh Government remains fully committed to leading and delivering meaningful action to tackle the causes and consequences of climate change. The *Climate Change Strategy for Wales*, published in 2010, confirms its commitment to drive down emissions and sets out the action it will take in specific sectors.[129] The Welsh Government is now taking forward work to deliver on its commitments, and solid progress has been achieved since the Strategy's publication.

2.250 The Strategy confirms the Welsh Government's principal target to reduce greenhouse gas emissions in areas of devolved competence by 3% a year from 2011 against a baseline of average emissions between 2006 and 2010. The Welsh Government is also committed to achieving at least a 40% reduction in all emissions in Wales by 2020 against a 1990 baseline. The Strategy confirms a range of sector specific emissions reduction targets in the following areas: transport, agriculture and land use, waste, residential, public and business.

2.251 The Welsh Government's approach to tackling climate change is managed as part of its wider agenda on sustainable development. The Welsh Government is one of only a few administrations in the world that has a legal duty in relation to sustainable development. As a result, its approach focuses on enhancing people's quality of life, both now and in the future. This principle has informed the selection of measures it has adopted to reduce emissions as the action it is taking to ensure that Wales is well prepared to manage the consequences of a changing climate.

2.252 An example of this is *arbed*, the Welsh Government's flagship strategic energy efficiency programme. By the end of the first phase of *arbed* earlier this year, the scheme had provided £30 million of funding for energy efficient homes, skills and long-term jobs. As a result, at least 6,000 homes have benefited from the *arbed* scheme to date.

2.253 The second phase of *arbed* shares the same objectives as the first phase, but, in order to fulfil EU funding requirements, the delivery model will be adjusted. The first set of project proposals for the second phase of *arbed* will be reviewed by the end of 2011.

2.254 Over the next five years, Nest, the Welsh Government's fuel poverty scheme, is expected to help up to 15,000 households a year in Wales with advice and home energy improvements to reduce their fuel bills, maximise their income and improve the energy efficiency of their homes. Around 4,000 households a year are expected to receive energy improvement packages.

2.255 The three key elements of the Welsh Government's energy policy – energy savings and efficiency, low carbon energy generation and the maximisation of long-term job opportunities for Wales – will ensure that it makes the most of Wales' potential and the predicted investment. Ultimately, the goal is to place Wales at the forefront of the drive towards a low carbon energy economy.

[129] Welsh Government (2010) *Climate Change Strategy for Wales*. Available at: http://wales.gov.uk/topics/environmentcountryside/climatechange/tacklingchange/strategy/walesstrategy/?lang=en

2.256 Wales has the potential annually to produce up to 40 TWh of electricity from renewable sources by 2025, with 25% of this from marine, 50% from wind (both offshore and onshore), and the majority of the remainder secured from sustainable biomass power or smaller local (including micro) heat and electricity generation projects using wind, solar, hydro or indigenous biomass.

2.257 Practical measures include the *Ynni'r Fro* programme, which supports investment in community-scale energy generation projects and gives practical and financial support for installers to gain Microgeneration Certification Scheme accreditation.

2.258 To date, Wales has some 830 MW of renewable energy operational, which represents a doubling in renewable energy operating capacity since 2007. This capacity represents enough electricity to power almost a half a million homes in Wales.

2.259 If the Welsh Government is to deliver its emissions reduction targets, every sector and community in Wales will need to contribute. Consequently, it is working with the Climate Change Commission for Wales and other delivery partners to help achieve this.

2.260 The Welsh Government's approach, set out in its Climate Change Engagement Strategy published earlier this year,[130] focuses on enabling people to act, and providing the tools at a national level which makes action at the local level effective. The Welsh Government will:

- provide the vision of a low carbon future, which will inspire action at all levels;
- develop the capacity for action at the local level; and
- provide the evidence base to inform and focus action.

2.261 To support its engagement work in this area, the Welsh Government launched the Support for Sustainable Living grant scheme in March 2011, which funds engagement on climate change and will also help to develop capacity within Wales to produce demonstrable outcomes from this engagement. It has also enabled access to expert advice and support for delivery and evaluation through its Support for Sustainable Living service. The combination of grant funding and expertise is already enabling local action across Wales.

2.262 In terms of delivery of the Climate Change Strategy itself, the Welsh Government is putting in place a comprehensive monitoring framework to measure the progress it is making on meeting its emissions reduction targets. To do this, it is developing a suite of indicators to track implementation of each of the measures contained in the Delivery Plan for Emission Reduction[131] to ensure that they are delivering the anticipated emissions savings. This framework is consistent with that being developed by the UK Government for monitoring progress against its own carbon budgets.

2.263 The Welsh Government will also be monitoring external factors that drive emissions, such as wider economic performance, so that its performance in delivering its specific commitments can be reported in its annual report early in 2012 within the context of wider emissions trends.

[130] See: http://wales.gov.uk/docs/desh/publications/111102engagementen.pdf

[131] See: http://wales.gov.uk/docs/desh/publications/101006ccstratdeliveryemissionsen.pdf

Part 3: Delivering the fourth carbon budget

Scenarios to deliver the fourth carbon budget

3.1 Part 2 has set out the potential for each sector of the economy to deliver emissions reductions over the fourth carbon budget period. As the Government's approach is to encourage a portfolio of technologies in each sector, there is uncertainty about the exact level of emissions reductions that will be delivered over the fourth budget period. In this part of the report we set out a series of illustrative scenarios that combine different levels of emissions from all sectors of the economy in order to deliver the fourth carbon budget.

3.2 As well as delivering the fourth carbon budget, these scenarios would all put us on track to deliver the 2050 target (as illustrated in the 2050 futures in Part 1).

Delivering non-traded sector emissions reductions

3.3 The non-traded sector consists of those sectors of the economy not covered by the European Union Emissions Trading System (EU ETS). The level of emissions required in the non-traded sector is 1,260 million tonnes carbon dioxide equivalent ($MtCO_2e$) over the fourth budget period, in order to meet the overall budget of 1,950 $MtCO_2e$. This section considers four illustrative scenarios showing how emissions could be reduced to meet this 1,260 $MtCO_2e$ level in the non-traded sector. Further details on these scenarios can be seen at Annex B.

3.4 In these scenarios we focus on those areas that have the most potential to contribute to emissions reductions over the fourth budget period, in line with our vision to 2050. These include:

- replacing inefficient heating systems with more efficient, sustainable ones;
- ensuring a step-change in our move towards ultra-low carbon vehicles, such as electric vehicles; and
- ensuring that our homes are better insulated to improve their energy efficiency.

3.5 In the scenarios that follow, we flex the level of deployment and consequent emissions expected from these major sectors. Other sectors, such as industry and agriculture, are also assumed to deliver additional emissions reductions. However, given their relatively small impact on the fourth carbon budget, we do not flex the amount delivered by these sectors in the scenarios.

Scenario 1: High abatement in low carbon heat

3.6 This scenario assumes a very high level of emissions reductions from the uptake of low carbon heat in buildings and industry, along with significant emissions reductions from other sectors. The scenario would deliver emissions of 1,253 $MtCO_2e$ in the non-traded sector over the fourth carbon budget period.

3.7 This scenario assumes that:

- around 8.6 million low carbon heat installations have been deployed in buildings by 2030, in domestic, commercial and public buildings, delivering 165 terawatt hours (TWh) of low carbon heat, and a further 38 TWh from heating networks;
- significant improvements to the thermal efficiency of buildings, including completing most cavity wall and loft insulations by 2020 and insulating up to 5.2 million solid walls by 2030; and
- average fuel efficiency of new cars and vans in 2030 of 60 gCO_2/km and 90 gCO_2/km respectively, and sustainable biofuel penetration of 8% through the 2020s.

Scenario 2: High abatement in transport and bioenergy demand

3.8 This scenario assumes a very high level of emissions reductions from transport and bioenergy, with comparatively lower reductions from low carbon heat. This scenario reflects a situation where bioenergy is plentiful, with sustainability concerns addressed effectively and technological innovation leading to more advanced feedstocks becoming viable. Significant uptake of ultra-low emission vehicles is driven by increased consumer demand following reductions in cost or improvements in range, or strong policy drivers such as an EU-wide car and van emissions target. The scenario would deliver emissions of 1,248 $MtCO_2e$ in the non-traded sector over the fourth carbon budget period.

3.9 Scenario 2 assumes:

- average fuel efficiency of new cars and vans in 2030 at 50 gCO_2/km and 75 gCO_2/km respectively, and sustainable biofuel penetration of 10% in 2030;
- approximately 7.2 million low carbon heat installations in buildings by 2030, delivering 138 TWh of low carbon heat, and a further 10 TWh from heating networks; and
- significant improvements to the thermal efficiency of buildings, including completing most cavity wall and loft insulations by 2020 and insulating up to 5.2 million solid walls by 2030.

Scenario 3: Focus on high electrification

3.10 This scenario assumes the very high levels of emissions reductions in both low carbon heat (as in Scenario 1) and transport (as in Scenario 2), alongside comparatively lower emissions reductions from domestic energy efficiency upgrades and lower uptake of biomass in industry. This scenario might reflect a situation where consumer acceptance of new technologies, such as electric or hydrogen fuel cell vehicles, and low carbon heat installations, is high, or where exogenous factors, such as high fossil fuel prices, drive a consumer search for low carbon alternatives. Although a situation where low carbon heat installations are deployed in homes that already have insulation would clearly be most cost effective, this scenario represents the possibility of consumer reluctance to take up solid wall insulation. Finally in this scenario, bioenergy supply is constrained (perhaps due to sustainability concerns), leading to a prioritisation of its use in industry rather than transport and buildings. The scenario would deliver emissions of 1,249 $MtCO_2e$ in the non-traded sector over the fourth carbon budget period.

3.11 This scenario assumes:

- around 8.6 million low carbon heat installations in buildings by 2030, delivering 165 TWh of low carbon heat, and a further 38 TWh from heating networks;
- average fuel efficiency of new cars and vans in 2030 at 50 gCO_2/km and 75 gCO_2/km respectively, and sustainable biofuel penetration of 10% in 2030; and
- most cavity wall and loft insulations completed by 2020 and up to 2.5 million solid walls insulated by 2030.

Scenario 4: Purchase of international credits

3.12 Under this scenario, some effort to hit the 2050 target is delayed until the 2030s and 2040s, with a lower level of emissions reductions over the fourth budget period. This scenario would require greater action (and therefore potentially higher costs) during later decades in order to remain on track to hit the 2050 target. Emissions over the fourth carbon budget period would be reduced to 1,345 $MtCO_2e$ in the non-traded sector, above the 1,260 $MtCO_2e$ budget level.

3.13 This scenario shows that achieving relatively lower levels of abatement in both low carbon heat **and** transport could necessitate the Government relying on other flexibility mechanisms under the Climate Change Act in order to meet the fourth carbon budget. In this scenario, the Government would need to purchase around 85 $MtCO_2e$ worth of carbon credits. At the forecast carbon price of £32/tCO_2e (average over the fourth budget period), this would cost the Government £2.7 billion. This cost will be at least partly offset by the lower cost of delivering less abatement in heat and transport. Alternatively or in addition to buying credits, the Government could bank over-achievement from earlier carbon budgets or borrow forwards from the fifth carbon budget.

3.14 This scenario assumes:

- 1.6 million low carbon heat installations in buildings by 2030, delivering 83 TWh of low carbon heat – achieved through roll-out of a portfolio of heat pumps and biomass boilers in domestic, commercial and public buildings – and a further 10 TWh from heating networks;[132]
- significant improvements to the thermal efficiency of buildings, including most cavity wall and loft insulations completed by 2020 and up to 4.5 million solid walls insulated by 2030; and
- in transport, average fuel efficiency of new cars and vans in 2030 of 70 gCO_2/km and 105 gCO_2/km respectively, and 6% penetration of biofuels in 2030.

[132] In scenario 4, our modelling shows mainly commercial installations take up low carbon heat, with a large heat load per installation. In scenario 1, most of the additional installations come from domestic-level heat pumps and biomass boilers, with smaller heat loads per installation.

Delivering traded sector emissions reductions

3.15 The level of emissions reductions in the traded sector is dictated by the level of the EU ETS cap. In this section we will look at two illustrative scenarios showing how traded sector emissions could be reduced. In both scenarios, the level of emissions reductions in the UK would be sufficient to fall within an EU ETS cap of 690 $MtCO_2e$. This is the level currently assumed for the fourth carbon budget period. However, this will be reviewed in 2014, as set out in the 'Achieving carbon budgets' section on page 21. As a consequence, under these scenarios UK businesses covered by the EU ETS would be net sellers of EU ETS allowances. Both scenarios have been modelled under a central assumption of electricity demand and an assumption of high electricity demand. Further details on these scenarios can be seen at Annex B.

Scenario A: Power sector carbon intensity of 50 gCO_2/kWh

3.16 Under this scenario, emissions over the fourth carbon budget period would be reduced to 592–596 $MtCO_2e$ in the traded sector (based on central and high electricity demand respectively – see Annex B for more detail).

3.17 This scenario assumes that emissions in the power sector are reduced significantly. To illustrate this, we have modelled a situation where the carbon intensity of generating electricity falls to 50 gCO_2/kilowatt hour (kWh) by 2030. The 'Secure, low carbon electricity' section on page 69 sets out further detail on the implications of this scenario for the generation mix. Since this scenario reduces emissions to well below the required 690 $MtCO_2e$ level, it would leave UK businesses in the EU ETS with 94–98 $MtCO_2e$ worth of surplus EU ETS allowances that could be sold to others, generating £4.8–5.0 billion at the forecast carbon price of £51/tCO_2e, or banked for future use.

Scenario B: Power sector carbon intensity of 100 gCO_2/kWh

3.18 Under this scenario, emissions over the fourth carbon budget period would be reduced to 626–629 $MtCO_2e$ in the traded sector (based on central and high electricity demand respectively – see Annex B for more detail).

3.19 Scenario B assumes that emissions in the power and heavy industry sectors are reduced, but at a lower level in the power sector than that assumed in Scenario A. This illustrative scenario assumes that the carbon intensity of electricity generation falls to 100 gCO_2/kWh by 2030. In this scenario, emissions are still reduced sufficiently to meet the 690 $MtCO_2e$ level, leaving UK businesses in the EU ETS with 61–64 $MtCO_2e$ worth of surplus EU ETS allowances that could be sold to others, generating £3.1–3.3 billion at the forecast carbon price of £51/tCO_2e, or banked for future use.

Considerations for achieving the fourth carbon budget

3.20 In developing the scenarios presented in this report, the Government has explored and taken into account the wider impacts on the UK economy that this range of decarbonisation could produce, as well as weighing up costs and benefits. In this section, we set out these considerations in brief; Annex B provides further detail.

Managing uncertainty

3.21 The current EU ETS Directive sets a cap on net emissions from the power and industry sectors for the whole EU, and this cap shrinks by a fixed amount each year from 2013 to ensure that overall emissions reductions are delivered in these sectors across the EU. The Government will review the EU ETS trajectory in early 2014. If at that point our domestic commitments place us on a different emissions trajectory to the EU ETS trajectory agreed by the EU, we will, as appropriate, revise our budget up to align it with the actual EU trajectory. Before seeking Parliamentary approval to amend the level of the fourth carbon budget, the Government will take into account the advice of the Committee on Climate Change (CCC) and any representations made by the other national authorities. A change in the EU ETS cap will not change the level of emissions reductions required outside of the EU ETS.

3.22 While it is not possible to speculate now on what the EU ETS cap will be in the future, we can consider some examples of what it might be, to analyse the potential implications. If the legislation setting out the trajectory of the EU ETS cap is not changed, then the UK cap on emissions in the traded sector over the fourth budget period could be around 860 $MtCO_2e$ and we could amend the fourth carbon budget to a level of 2,120 $MtCO_2e$ (1,260 $MtCO_2e$ in the non-traded sector plus 860 $MtCO_2e$ in the traded sector). Under the two scenarios in the traded sector outlined above, this would mean UK businesses covered by the EU ETS having a greater number of surplus EU ETS allowances to sell – 264–268 $MtCO_2e$ in Scenario A and 231–234 $MtCO_2e$ in Scenario B. The revenues raised from this surplus would depend on the carbon price, which is likely to be a lower price than a scenario where the EU ETS cap is lower. Alternatively, the Government could decide to decarbonise at a slower rate, resulting in lower surplus EU ETS allowances, although this would have implications for the pace of decarbonisation required in later carbon budgets to reach the 2050 target.

3.23 On the other hand, we are pushing strongly for the EU to move to a more ambitious target for 2020. As an example, if the EU agreed to a target to reduce emissions by 30% from 1990 levels by 2020, this could potentially mean a tighter EU ETS cap which reduces the cap on traded sector emissions to 590 $MtCO_2e$.[133] In this instance, the fourth carbon budget could be amended to 1,850 $MtCO_2e$ (1,260 $MtCO_2e$ in the non-traded sector and 590 $MtCO_2e$ in the traded sector). Scenario A would result in emissions falling to 592–596 $MtCO_2e$, 2–6 $MtCO_2e$ above the required level. UK-based businesses covered by the EU ETS would therefore need to buy corresponding EU ETS allowances. Scenario B would result in emissions in the traded sector falling short of the 590 $MtCO_2e$ required in the traded sector by 36–39 $MtCO_2e$ and UK-based businesses under the EU ETS would need to purchase EU ETS allowances. In these scenarios, the price of allowances would be likely to be greater due to the tighter EU ETS cap.

Domestic action and international credits

3.24 The Climate Change Act allows credits purchased from overseas to be used for compliance with UK carbon budgets. A limit on how many credits can be bought in any given carbon budget period must be set 18 months before the start of that period. As announced in May 2011, the Government intends to reduce emissions domestically as far as is practical and affordable. However, keeping open the option of

[133] This assumes that the tighter EU ETS cap agreed as part of an EU deal on moving to a 30% target would continue at the same rate of reduction beyond 2020.

trading is prudent in order to retain maximum flexibility in minimising costs in the medium-to-long term.

3.25 As explained in Part 2, emissions projections suggest that we will reduce emissions to below the level of the first three carbon budgets, and this over-achievement could in theory be banked for later use.[134] It is not government policy to rely on over-achievement in a given carbon budget to help meet future carbon budgets, or to factor it into future plans and there are two reasons why this is a sensible approach. First, the UK is pushing Europe to adopt a more ambitious 2020 target and this would lead to tighter second and third carbon budgets, meaning that we would have less (or even no) over-achievement to bank. Second, there is significant uncertainty in projections – if emissions are higher than projected we may have little or no over-achievement.

3.26 While we are aiming to meet future carbon budgets without counting on any over-achievement in previous carbon budgets, we do see a role for banking to provide flexibility for short-term adjustments and smoothing of unexpected fluctuations in emissions and as a contingency for unexpected events. We are therefore not ruling out the use of banking at this stage and may look to bank any over-achievement into future carbon budgets to maintain this contingency to manage uncertainty. Any future decisions on banking will need to be taken in the light of EU and international decisions.

Costs of meeting the fourth carbon budget

3.27 The fourth carbon budget scenarios have been developed taking into account a number of factors:

- static cost effectiveness – comparing the estimated cost of a measure with the forecast carbon price for the same time period;
- dynamic cost effectiveness – considering what action needs to be taken in the fourth budget period to be on track to meet the 2050 target in the most cost effective way;
- technical feasibility – taking account of likely technological development and necessary build rates; and
- practical deliverability and public acceptability – considering potential barriers to delivery.

3.28 As explained in the 'Achieving carbon budgets' section on page 21, the Government already has a robust policy framework in place to meet the first three carbon budgets that will continue to deliver emissions reductions over the fourth budget period. The total net present cost over the lifetime of the policies included in the current policy package is estimated at £9 billion (excluding the value of greenhouse gas (GHG) emissions savings in the non-traded sector). Including the value of GHG savings in the non-traded sector results in the package delivering a net benefit, on central estimates, of £45 billion.[135] The fourth carbon budget is not expected to lead to any additional costs over the course of this Parliament. Beyond that, the cost of meeting the fourth carbon budget will depend on the policies that are implemented over the coming decade.

3.29 The Impact Assessment on the level of the fourth carbon budget explained how an 'early action' pathway – where greater emissions reductions are made early on – is more likely to be cost effective than an emissions pathway that leaves greater levels of emissions reductions to later years.[136] Over the fourth budget period, this

[134] The Climate Change Act allows banking and borrowing and this offers a further flexibility mechanism in meeting our carbon budgets. Banking is where the Government reduces emissions to below the level of the carbon budget and 'banks' the savings into future carbon budgets, making them easier to meet. Borrowing is where the Government takes part of a future carbon budget and brings it forward to cover higher emissions in the current carbon budget period. No more than 1% of the future carbon budget can be borrowed and the future carbon budget is reduced (i.e. made tougher to meet) by the same amount as is borrowed. Before banking or borrowing the Government must obtain and take into account the views of the CCC and Devolved Administrations.

[135] Excludes EU ETS.

[136] The Impact Assessment is available at: www.decc.gov.uk/media/viewfile.ashx?filetype=4&filepath=What%20we%20do/A%20low%20carbon%20UK/Carbon%20budgets/1685-ia-fourth-carbon-budget-level.pdf&minwidth=true. Further detail on the economic benefits of early action is set out at Annex B.

may require implementing some measures that might not be cost effective when considering the fourth carbon budget alone, but would support a more efficient transition to meeting the 2050 target.[137] Doing so is likely to avoid higher costs in the longer term for a number of reasons. For instance, early innovation can help to bring new technologies to market and drive down costs, as well as avoiding expensive lock-in to sub-optimal transition technologies. Our current evidence suggests that the net cost of meeting the fourth carbon budget ranges from £26 billion to £56 billion (excluding the value of the reduction in greenhouse gas emissions).[138] This includes the costs and benefits over the lifetime of the measures (which often stretches well beyond the fourth budget period), discounted to today's prices. When the benefits of the carbon savings that will be delivered by our scenarios are also taken into account, the net present value ranges from a net benefit of £1 billion to a net cost of £20 billion.

3.30 Action to meet the fourth carbon budget can be achieved without large impacts on overall economic output. The macro impact of meeting the fourth budget level is estimated to be an average cost of around 0.6% of GDP a year over the period 2023–27 (the average cost of meeting the first three carbon budgets is estimated at around 0.4% of GDP a year). This compares favourably with the expected cost of not tackling global climate change (see Annex B for more detail). For example, the Stern Review (2006) estimated the cost of not tackling climate change to be between 5% and 20% of global GDP.

3.31 Importantly, the modelling results do not account for the benefit of tackling global climate change, which will lead to future changes in temperature and shifts in precipitation patterns. This benefit includes avoiding risks to future UK growth.

3.32 Annex B provides further details on the breakdown of costs for the non-traded sector Scenarios 1–4 and traded sector Scenarios A and B, and an explanation of how we have combined scenarios to produce the cost estimates above. The costs quoted above are subject to significant uncertainty given the range of assumptions we need to make about the evolution of future economic growth, fossil fuel prices and technology costs so far out into the future. Sensitivity analysis of fossil fuel price and technology cost assumptions shows that the overall costs of delivering the fourth carbon budget could vary significantly. See box 10 overleaf for more detail on sensitivities.

3.33 This uncertainty highlights the need to continue to appraise costs and abatement potential as the evidence base evolves. The Government will continue to draw up detailed impact assessments for individual policies before they are introduced, to assess as accurately as possible the costs and benefits of the specific policies necessary to deliver carbon budgets.

3.34 In addition, the portfolio approach outlined earlier in this report ensures that the Government retains the flexibility to achieve a cost effective transition: if costs do not fall as fast as we have assumed in one sector, we would have to rely on greater savings from other sectors in order to meet the fourth carbon budget.

[137] More information on the cost effectiveness of the abatement potential considered for the fourth carbon budget scenarios can be found at Annex B.

[138] The costs of delivering the fourth carbon budget scenarios will depend on how the traded and non-traded sectors are combined. Scenarios 1–4 in the non-traded sector imply different levels of electricity demand. To understand the cross-economy picture it is important to combine these with the traded sector scenario that best reflects the implications for electricity demand from levels of electrification in the transport and heat sectors. For example, Scenario 3, which includes high levels of electrification in heat and transport, has the effect of increasing electricity demand by about 10% in 2030. This scenario is compatible with either traded sector Scenario A or B under high electricity demand. Levels of abatement in Scenario 4 suggest that Scenario A or B under central demand would be more appropriate.

Box 10: Case study on transport costs

The fourth carbon budget scenarios have been modelled on the basis of assumptions about the improvement to fleet average new car and van CO_2 emissions. This improvement could be delivered by a number of different vehicle mixes, all of which will have different cost implications. The costs also depend heavily on the assumptions we make regarding factors such as technology costs, fossil fuel prices and the rebound effect (where people drive more as cars become more efficient and therefore cheaper to drive). For example, under central assumptions, **Scenario 3** in the non-traded sector has a net present value (NPV) of **–£2 billion** (i.e. a net cost). But this number could vary widely under different assumptions:

- Battery costs today are reported up to around $1,000/kWh. In our analysis we assumed battery costs falling to $300/kWh in 2030. If battery costs were lower in 2030 – $150/kWh (compared with the CCC's assumption of $200/kWh) – then the NPV of Scenario 3 would be £7 billion (i.e. a net benefit). If battery costs only came down to $800/kWh then the NPV of Scenario 3 would be –£36 billion (i.e. a net cost).
- In respect of fossil fuel prices, our analysis was based on the Government's central view of fossil fuel prices. However, under high fossil fuel price assumptions, Scenario 3 would have an NPV of £4 billion (i.e. a net benefit), whereas under low fossil fuel price assumptions the NPV of Scenario 3 could be –£10 billion.
- We believe that a rebound effect from more efficient vehicles is likely. However, if we were to assume no rebound effect then Scenario 3 would have a zero NPV (i.e. the benefits would roughly equal the costs), as the additional costs associated with the rebound effect, such as increased congestion, would be avoided.

These are all individual effects – in reality, a number of the assumptions could differ from our central forecasts, meaning that the scale of change to the cost numbers could be greater still.

Innovation

3.35 Innovation will be crucial to delivering the cost reductions we expect to see in technologies (such as ultra-low emission vehicles) that are critical to delivering the fourth carbon budget. This innovation will transform UK infrastructure to support the transition to a low carbon economic base. The long-term certainty provided to business by carbon budgets is a necessary but not sufficient factor in ensuring that investment in innovation takes place: success in this area over the coming years will depend on the policies that are implemented.

3.36 The Government directly supports innovation through measures that support the research, development and demonstration (RD&D) of low carbon technologies. In the 2010 Spending Review, the Department of Energy and Climate Change was allocated over £150 million to support innovation in energy generation and demand-side technologies. Programmes for innovation in offshore wind (£30 million), marine energy (£20 million) and buildings (£35 million) have already been announced and, subject to value for money assessments, these will be launched in the coming months. Together with other innovation funding streams, total public funding for low carbon energy innovation delivered by members of the Low Carbon Innovation Group (LCIG) will amount to over £800 million during the Spending Review period.[139]

3.37 The Government also indirectly supports innovation by creating long-term, credible markets

[139] LCIG comprises representatives of the Department of Energy and Climate Change, the Department for Business, Innovation and Skills, the Carbon Trust, the Energy Technologies Institute, the Technology Strategy Board and the Research Councils.

for low carbon technologies and by removing barriers to their uptake, giving businesses and industry the confidence to invest in RD&D. The EU ETS and Electricity Market Reform in the power sector, or EU new vehicle emissions standards in the transport sector, are examples of policies which seek to create long-term certainty in markets.

3.38 Low carbon innovation also creates opportunities for UK businesses to capture a greater share of the global low carbon market. This market was worth more than £3.2 trillion in 2009/10 and is projected to reach £4 trillion by 2015 as economies around the world invest in low carbon technologies across a broad range of sectors. The UK share of the market was more than £116 billion in 2009/10, and could be much larger.[140] The Government provides support for UK businesses to maximise these opportunities and grow their low carbon exports, in particular through UK Trade & Investment's Green Export Campaign and services for business.

Cost, price and bill impacts and competitiveness

Direct impacts

3.39 A key factor when delivering the fourth carbon budget is understanding the potential impact on consumers, businesses and industry through energy prices and bills. Some policies, such as home energy efficiency measures or improving process efficiency in industry, can help to reduce bills. Today, the bulk of increases in domestic energy bills have been caused by the rise in wholesale gas prices, with costs of climate change and energy measures only contributing a small proportion of the overall increase. See box 11 below for more details. The Government is committed to keeping these impacts under review and updated estimates of the impact of policies on energy prices and bills will be published alongside future Annual Energy Statements.

Box 11: Energy bill impacts

Alongside the Annual Energy Statement on 23 November 2011, the Department of Energy and Climate Change published a comprehensive updated assessment of the estimated impacts of energy and climate change policies on energy prices and bills.[141] This covers policies and proposals put forward by the previous Government, as well as changes to those policies and new policies announced by the current Government. Only those policies in place or that have been planned to a sufficient degree of detail (i.e. with quantified estimates of costs and benefits) have been included in the modelling. It does not estimate the impacts of scenarios to meet the fourth carbon budget as the policy mechanisms to deliver these have yet to be determined. The key messages were:

- Recent increases in energy bills have been largely driven by rising international prices for fossil fuels, particularly gas, and not by energy and climate change policies. Energy bills are likely to continue on an upward trend over time, with or without policies, due to rising fossil fuel prices and network costs.
- Government policies are estimated to be adding just 2% on average to a typical household energy bill in 2011, compared with a bill in the absence of policies. By 2020 households will, on average, save money (£94 or 7%)[142] on their energy bills compared with what they would have paid in the absence of policies. The impact of policies in helping people to save energy, or use it more efficiently, is expected to more than offset the impact that policies delivering low carbon investment will have on energy prices.

[140] BIS (2011) *Low Carbon and Environmental Goods and Services Report for 2009/10*. Available at: www.bis.gov.uk/assets/biscore/business-sectors/docs/l/11-992x-low-carbon-and-environmental-goods-and-services-2009-10

[141] See: www.decc.gov.uk/en/content/cms/meeting_energy/aes/impacts/impacts.aspx

[142] Real 2010 prices.

Box 11: Energy bill impacts *(continued)*

The UK ranks well internationally for household energy prices. When compared with the EU 15, UK consumers have faced the lowest domestic gas prices for the last three years (2008–10) and the third or fourth lowest electricity prices for the past two years.

The impact of policies on energy bills for businesses is typically larger than for households because households are supported by a greater number of energy efficiency policies than are available for the business sector. For most businesses, however, direct energy costs are a relatively small proportion of total costs. For example, in 2009 purchases of energy and water accounted for around 2.7% of total costs for the UK manufacturing sector. This means that a 10% rise in direct energy costs increases total costs by just 0.27%. In contrast, employment costs represented around 20% of total manufacturing sector costs in 2009.

Businesses that are medium-sized users of energy currently face energy bills that are on average 18% higher as a result of policies. By 2020 the impact of policies is estimated to be 19%.

Businesses that are large energy-intensive users – where energy costs represent a significant proportion of their total operating costs – face varying impacts depending on, among other things, their mixture of gas and electricity use, the extent to which they consume on-site generated electricity (exempt from a number of policy costs, such as the Renewables Obligation) and their ability to use their buying power to negotiate lower prices. Policies are estimated to be adding 3–12% to energy bills for these users in 2011 and between 2% and 20% in 2020.

Average UK gas prices for all sizes of industrial users have been the lowest in the EU 15 since mid-2009. UK electricity prices have historically been similar to the EU 15 median for both medium and large industrial users.

The estimated impact of policies on household and business energy bills has fallen since the previous analysis that the Department of Energy and Climate Change published in July 2010. This reflects, among other things, the Coalition Government's proposals on Electricity Market Reform (EMR), the Green Deal and proposed new cost effective levels of support for large-scale renewable electricity, as well as the decision to make a £40 million saving in 2014/15 on spending for the small-scale Feed-in Tariffs scheme. It also reflects the decision to fund the Renewable Heat Incentive from general taxation rather than through a levy on fossil fuel suppliers, and to consider several alternative funding options for the Government's CCS commitments rather than through their own levy.

3.40 The Government is paying careful attention to distributional impacts of the transition to a low carbon economy. We are working to ensure that consumers are able to find information that allows them to compare and switch suppliers to get the best deals. In the domestic sector we are particularly conscious of lower income households at risk of fuel poverty. The Government is taking a range of actions, through mechanisms such as the Warm Home Discount Scheme and Winter Fuel Payments, to ensure that vulnerable households are protected.

3.41 In the business sector, increased costs as a result of higher energy prices and climate change and government policies represent a potential challenge for energy-intensive industries. The Government recognises these issues, and the difficulties some face in remaining internationally competitive while driving down domestic emissions. Therefore, in addition to the measures set out in the 2011 Budget, the Government is taking steps to reduce the impact of policy on the cost of electricity for energy-intensive industries whose international competitiveness is most affected by energy and climate change policies, and to support energy-intensive industries in becoming more energy efficient, where it is cost effective for them to do so.

3.42 In the short term, cost effective energy and resource efficiency measures can deliver both economic and environmental gains. The Carbon Trust found that a 35% improvement in the energy efficiency of UK buildings by 2020 would realise over £4 billion worth of benefits. Such energy efficiency measures could also stimulate activity in the construction sector where lack of effective demand is seen as the immediate constraint on growth. The Government continues to explore the opportunities presented by the low carbon transition and to help UK businesses to capitalise on these. The UK has a comparative advantage in traditional environmental goods and services such as recycling and water treatment, for example, and the strongest growth areas (both in terms of sales and employment) in the environmental goods and services sector are emerging sectors such as wind, solar, photovoltaics and carbon finance.

3.43 In the longer term, establishing credible and consistent long-term commitments through the carbon budget framework helps to reduce uncertainty about the strength of the market for green alternatives, improving incentives for innovation. The low carbon transition will also increase UK resilience to volatility in international fossil fuel prices and the negative impacts on the economy that these can create. The macro economic implications of the transition are considered in more detail at Annex B.

Indirect impacts – carbon leakage

3.44 Not all other countries have yet matched the scale of the UK's low carbon ambitions. There is a risk that imposing relatively higher costs on domestic producers of energy-intensive goods, through climate change policies, will lead companies to consider shifting production and investment to regions of the world with less stringent environmental policies. This potential for 'carbon leakage' is a concern. There is no advantage – either to the UK economy or for global emissions reductions – in businesses relocating to countries where emissions continue unabated.

3.45 There are a number of options to manage the risk of carbon leakage. For instance, in the EU Emissions Trading System, which requires significant reductions from the power and heavy industry sectors, the risk of leakage is addressed and largely mitigated through the provision of free allowances to sectors that are considered to be at risk of leakage. Thus heavy industry is provided with an incentive to reduce emissions, without risks to competitiveness.

Energy security

3.46 There are three different, linked challenges that relate to security of electricity supply:

- **diversification of supply:** how to ensure that we are not over-reliant on one energy source or technology;
- **operational security:** how to ensure that, moment to moment, supply matches demand, given unforeseen changes in both; and
- **resource adequacy:** how to ensure that there is sufficient reliable capacity to meet demand, for example during winter anticyclonic (high pressure) weather conditions when demand is high and wind generation low for a number of days.

3.47 Increasing our sources of low carbon generation as we meet the carbon budgets will help to address the first challenge, though higher levels of intermittent generation potentially increase the second and third challenges. In addition, by 2020 the UK could be importing nearly 50% of its oil and 55% or more of its gas.

3.48 Our strategy for meeting the carbon budgets takes these impacts into account – more detail can be found in the 'Secure, low carbon electricity' section on page 69 and at Annex B.

Sustainability

3.49 The Government's strategy for meeting the fourth carbon budget takes into account wider impacts on sustainability (including potential biodiversity considerations in relation to changes in land use for bioenergy, and the cumulative and indirect environmental impacts of a range of changes to our future energy mix). These impacts are considered in more depth at Annex B.

Consumption emissions

3.50 Finally, the focus of UK climate change policy is on the production of emissions. The Government recognises that the 'consumption' perspective – which accounts for all the emissions produced globally to support UK consumption (including emissions in other countries as a result of the production of goods that we import into the UK) – is increasingly important.

3.51 The Government is working to better understand the impact of consumption emissions. This includes annual monitoring of total emissions associated with UK consumption,[143] and analysis of where these emissions occur and which products they are associated with.[144] This evidence will be used to help inform and target a range of actions including support for UK businesses to measure and reduce emissions throughout their supply chains, and the standards and labelling schemes which apply to products on the UK market.

Managing our performance

3.52 Ensuring delivery of the emissions reductions necessary to deliver carbon budgets requires a robust framework to track progress and flag when issues or policy changes mean that we risk going off track.

3.53 The Climate Change Act provides an effective system of legal accountability. The independent Committee on Climate Change (CCC) publishes an annual report in which it scrutinises the Government's progress in meeting carbon budgets. The Government has to lay a response to the points raised by the CCC before Parliament by 15 October each year. The statutory requirement to produce a report on policies after a new budget has been set also forms part of the accountability regime under the Climate Change Act. This report meets that obligation for the fourth carbon budget.

3.54 In addition, the Government published the draft Carbon Plan in March 2011 to provide further transparency and accountability about the key actions that each government department and the Devolved Administrations are taking in each sector during the lifetime of this Parliament.[145] Annex C updates the Carbon Plan action summary milestones, including those that relate to the flagship actions in each sector set out in Part 2 of this document. These therefore assist Parliament and the public in assessing whether the Government is making sufficient progress in achieving the actions necessary to deliver carbon budgets.

3.55 All departments that lead or have an impact on the majority of policies that affect emissions are held accountable for delivery through a framework of regular monitoring and reporting against their actions and indicators of progress.[146] The wider actions of all government departments are kept

[143] Embedded Carbon Emissions Indicator: http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=17729&FromSearch=Y&Publisher=1&SearchText=emissions%20indicator&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

[144] UK Consumption Emissions by Sector and Origin: http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=17718&FromSearch=Y&Publisher=1&SearchText=consumption%20emissions&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

[145] See: www.decc.gov.uk/en/content/cms/tackling/carbon_plan/carbon_plan.aspx

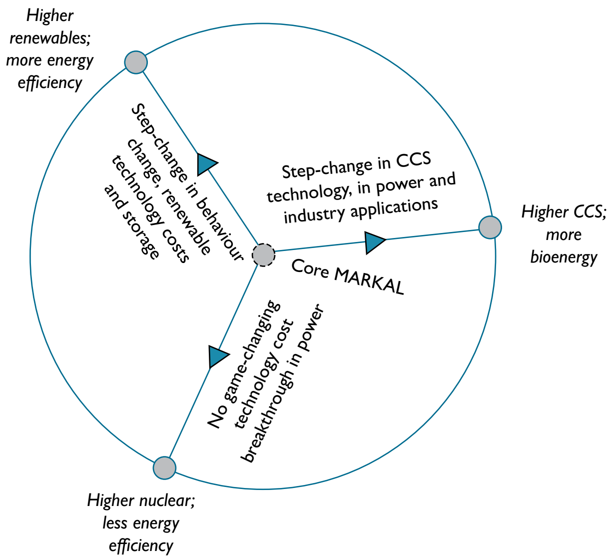
[146] These are the Department for Business, Innovation and Skills, the Department for Environment, Food and Rural Affairs, the Department for Communities and Local Government, the Department for Transport, the Department of Energy and Climate Change and HM Treasury.

under review, with particular attention paid to new initiatives that may have a knock-on effect on emissions. The Government as a whole then reports progress against the actions in the Carbon Plan on a quarterly basis via the Number 10 website, to support Parliament and the public in holding the Government to account.

Annex A: 2050 analytical annex

A1 This annex provides further detail on the 2050 futures and their implications, in particular for costs. The analysis in this annex refers to impacts in 2050 and does not look at the trajectory for getting there. For details of the implications of climate and energy policy during the 2010s and 2020s, please refer to Annex B.

2050 futures

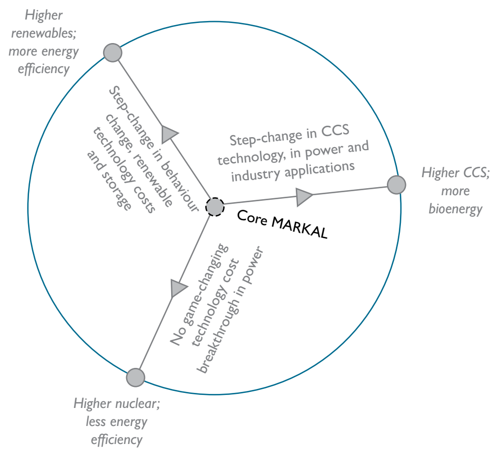


A2 To illustrate a typical cost-optimising model run,[1] we have described a **core MARKAL** (MARKet ALlocation) pathway, one of the runs produced as part of the analysis that the Government used to set the level of the fourth carbon budget target. This run provides a benchmark against which the **three 2050 futures**, referenced in Part 1 and constructed using the 2050 Calculator, can be compared. It should be noted that some environmental impacts, such as noise, landscape and biodiversity, are not quantified here. These are discussed further at Annex B.

A3 To develop 2050 futures, the Government has used the MARKAL and ESME (Energy System Modelling Environment) cost-optimising models in order to understand what levels of ambition in the deployment of technologies may be plausible in 40 years' time. There are many thousands of plausible pathway combinations which could be constructed using the Calculator, and the electricity generation mixes, levels of electrification and levels of demand reduction chosen in these futures should not be seen as the only likely or available combinations. The three futures are consistent with the Government's stated ambitions on specific technologies up to 2020, but do not assume any specific policy measures thereafter.

[1] Cost-optimising models are explained in more detail later in this annex.

Core MARKAL



Energy saving per capita: 50%
Electricity demand: 470 TWh

A4 The core MARKAL run was created using the UK MARKAL model. Further information on the assumptions and modelling structure supporting the core MARKAL (described as run 'DECC-1A') can be found at: www.decc.gov.uk/assets/decc/11/cutting-emissions/carbon-budgets/2290-pathways-to-2050-key-results.pdf

A5 These outputs were produced with a number of underlying assumptions imposed on the model. The results below should be interpreted in the light of these assumptions.

- The UK MARKAL model covers CO_2 emissions from energy use and does not model non-CO_2 greenhouse gases (GHGs), land use, land use change and forestry (LULUCF) and international aviation and shipping sectors. As a consequence, the 80% 2050 target covering all GHGs on the net UK carbon account was translated to a 'MARKAL equivalent' of a 90% reduction for the core MARKAL run.[2]
- The core MARKAL run included the impact of the draft Carbon Plan[3] commitments to 2020 on the basis that policy and initiatives are already in place to achieve them. For key technologies and policies this representation is explicit; actual penetrations of specific technologies and targets were included. For other policies the representation is indirect, and a UK-wide CO_2 emissions constraint in 2020 was imposed to mimic the assumed impact.
- The core MARKAL run was based on **central estimates of fossil fuel prices and central estimates of service demands.**[4]

What is the sectoral picture in 2050?

A6 Electricity generation capacity is split between carbon capture and storage (CCS) (29 gigawatts (GW)), nuclear (33 GW) and renewables (45 GW). Wind power is installed earlier as part of the Carbon Plan commitments, with 28 GW in place by 2020. In terms of energy supplied, nuclear and CCS together deliver the majority (74%). Unabated gas plays a significant back-up role in 2050 to balance the system, but largely fades out as a baseload technology from 2030 onwards. Electricity imports and small-scale combined heat and power (CHP) also contribute. CCS with power generation is an important technology from 2020 onwards, generating more than a third of all electricity. The MARKAL run uses this technology to achieve negative emissions rates for electricity by sequestering the CO_2 associated with the biomass share (25% of fuel input to these generators in 2050 is biomass).

A7 In buildings, a reduction in space and water heating demand is accompanied by a large reduction in final energy consumption. Natural gas disappears from heating almost entirely, while electricity consumption increases significantly. Heat pumps, which draw heat from the surrounding environment with the help of some electricity, serve a larger proportion of heating service demand than any other technology.

A8 The chemicals, iron and steel, and non-ferrous metals sectors all exhibit the maximum allowable demand reductions of 25% from the central estimate of service demand, driven by

[2] The core MARKAL run was constrained both to mimic the achievement of the UK's 80% target in 2050 and to ensure a plausible trajectory for getting there.

[3] HM Government and DECC (2011) *Carbon Plan*.

[4] These two central conditions are also applied to the MARKAL runs used to cost the three 2050 futures which follow.

MARKAL's demand-response assumptions. This central estimate does not reflect the Updated Energy and Emissions Projections that the Government has used in this report, and posits a higher baseline level of demand. The MARKAL model suggests that some industries might scale back operations significantly. Industry also benefits from the ability to adopt CCS in the MARKAL model. By 2050, 48 million tonnes carbon dioxide equivalent ($MtCO_2e$) a year is sequestered from industrial processes.

A9 Of all the end-use sectors, transport shows the lowest demand response in the core MARKAL run, with approximately 5% reductions for most service demand categories. The mix of end-use technologies is extremely varied in 2050 when compared with today. Battery electric, biomass-to-liquids and hydrogen fuelled vehicles are all used. However, conventionally fuelled vehicles are not expected to be significantly used by 2050 under this optimised pathway.

A10 As the MARKAL model does not account for non-CO_2 emissions, much of agriculture's GHG impact is not explicitly accounted for (other than as part of the overall 90% decarbonisation constraint). LULUCF emissions and removals are also not considered. If domestic forestry were to make a significant contribution to bioenergy feedstock supplies, carbon sequestration associated with land use change would deliver additional abatement. The core MARKAL run demands 350 terawatt hours (TWh) of bioenergy a year by 2050.

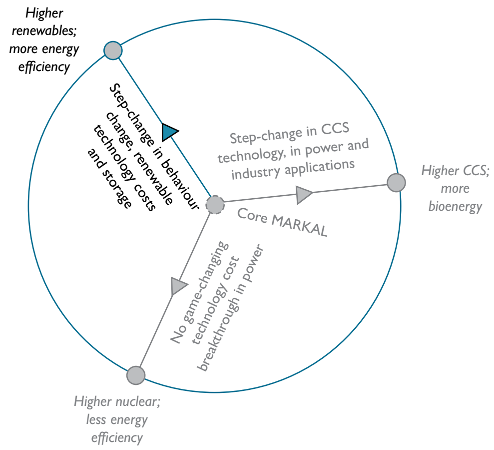
What does this scenario imply for security of supply and wider impacts?

A11 A balanced generation mix with a relatively high deployment of intermittent renewable generation technologies such as wind and marine power means that the back-up requirements of this run are significant. An additional 33 GW of gas plant is needed to meet the system balancing requirements imposed by the model.

A12 Per capita energy demand falls by 50% compared with 2007, while total electricity demand increases by almost a quarter from 2007 levels.

A13 In order to meet the demands of CCS and system back-up generation, natural gas remains an important part of the fuel mix in 2050, with 264 TWh of imports. Oil plays a much smaller role than it does today, with the UK importing roughly a sixth of what was brought into the country in 2000, despite declining natural reserves.

'Higher renewables; more energy efficiency'



Energy saving per capita: 54%
Electricity demand: 530 TWh

A14 **The 'Higher renewables; more energy efficiency' future was created using the 2050 Calculator.** This scenario is presented in the web tool of the Calculator which can be found at: http://2050-calculator-tool.decc.gov.uk

A15 The **'Higher renewables; more energy efficiency' future** is based on a step-change in per capita energy demand reductions and a major reduction in the cost of renewable generation. This is accompanied by innovations to develop a large expansion in electricity storage capacity to manage the challenges of intermittent generation.

What is the sectoral picture in 2050?

A16 'Higher renewables; more energy efficiency' chooses a generation mix with a relatively high installation of renewable generation capacity compared with the other two futures, with wind delivering 55% of the total electricity supply. Other renewable technologies, such as solar PV, marine and hydroelectric power, also play a role. To meet baseload needs and ensure security of supply, there is still a requirement for baseload capacity from nuclear and CCS. Some 20 GW of pumped storage provides 400 GWh of extra storage capacity, compared with 9 GWh today.

A17 Some 7.7 million solid walls and 8.8 million cavity walls are insulated by 2050. In buildings, behaviour change and smarter heating controls result in lower average home temperatures (one and a half degrees below today) complementing more energy efficient homes. All domestic heating demand across the UK is met through house-level electrified heating systems.

A18 Industry grows steadily and achieves energy demand reductions of a third. Some 48% of remaining emissions are captured by CCS.

A19 All cars and buses are fuelled by batteries or hydrogen fuel cells. These technologies create improved energy efficiency, allowing people to drive as far as today while using less energy than they do today. There is an increase in the use of public transport, walking and cycling; 63% of the distance travelled domestically is made by cars in 2050, compared with 83% in 2007.

A20 Thanks to high levels of demand reduction, extensive electrification of both heating and transport, and the deployment of CCS in industrial applications, sustainable bioenergy has a relatively small role in comparison with the other scenarios, delivering 182 TWh of final energy demand.

What does this scenario imply for security of supply and wider impacts?

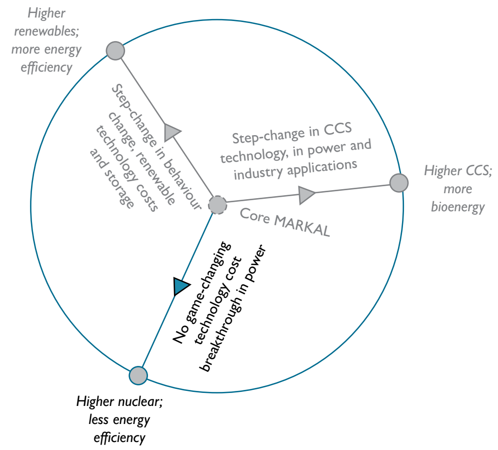
A21 A generation mix with a high proportion of intermittent generation means that there is a pressing need to balance the system to cope with adverse weather conditions, such as a drop in North Sea wind. Twenty-four GW of back-up gas plant is required to meet a five-day wind lull and demand peak across the UK as well as innovation success and cost reductions in electricity storage.

A22 Because of efforts made to improve energy efficiency across the economy, the increase in electricity demand is not the highest of the three scenarios despite having the highest proportion of energy demand being met by electric low carbon technologies. However, electricity demand is still over a third higher than in 2007.

A23 Apart from its electricity back-up role, gas plays a much smaller role than it does today, as the UK becomes more energy independent. Net natural gas imports are almost zero in 2050 with total domestic consumption at 100 TWh a year.

A24 Bioenergy is harvested from approximately 25,000 km^2 of land area in the UK and other countries. Local air quality is likely to be better in this pathway than it is today. In particular, the damage to human health arising from air pollution, principally particulate matter, could be around 60%–85% lower in 2050 compared with 2010.

'Higher nuclear; less energy efficiency'



Energy saving per capita: 31%
Electricity demand: 610 TWh

A25 **The 'Higher nuclear; less energy efficiency' future was created using the 2050 Calculator.** This scenario is presented in the web tool of the Calculator which can be found at: http://2050-calculator-tool.decc.gov.uk

A26 The **'Higher nuclear; less energy efficiency' future** describes what we might do if it proved difficult to deploy newer technologies (such as CCS technology in power and industry). The extent to which individuals change their behaviour and energy consumption patterns to reduce energy demand is lower in this future.

What is the sectoral picture in 2050?

A27 'Higher nuclear; less energy efficiency' relies heavily on nuclear power (75 GW of installed capacity) with the lowest deployment of CCS, wind and other renewable generation in 2050 across the three futures. Although deployment is relatively low, there is still 20 GW of wind capacity present on the grid, as the UK's natural advantages and previous investments in earlier years mean that some installations will remain cost effective.

A28 Some 5.6 million solid walls and 6.9 million cavity walls are insulated by 2050. Average internal temperatures by 2050 are half a degree higher than they are today. Domestic and commercial heating is largely decarbonised through a combination of air- and ground-source heat pumps, while 10% of demand is met through local-level district heating.

A29 CCS is not successful at a commercial scale and, alongside steady growth, this means that industry is responsible for a large proportion of remaining emissions, making up more than half of the total by 2050.

A30 Around 80% of cars are ultra-low emission vehicles (ULEVs), powered by batteries or hydrogen fuel cells. People travel 6% further than today, but there is a gradual movement away from using cars towards more efficient public transport. Some 80% of distance travelled domestically is made by cars in 2050, 3% lower than in 2007.

A31 As it is not possible for CCS to generate 'negative emissions' in this scenario, sustainable bioenergy is extremely important for decarbonising 'hard to reach' sectors like industry. Bioenergy supply is 461 TWh of final energy demand, with industry the second highest demand sector after transport.

What does this scenario imply for security of supply and wider impacts?

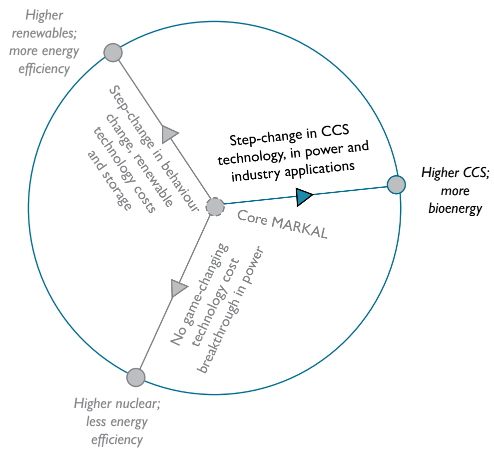
A32 Nuclear power's role means less back-up is required to balance the system. An additional 14 GW of gas plant is required to meet a five-day wind lull and demand peak across the UK.

A33 Per capita energy demand reductions are the smallest of the three futures. Because of electrification technologies being widely deployed for heating and transport, the demand for electricity is the highest, increasing by more than 50% compared with 2007.

A34 Natural gas imports fall by 2050 as the lack of CCS removes the most important long-term low carbon role for the fuel. The UK imports less than a quarter of the amount of gas bought in 2010, with total domestic use of 189 TWh in 2050.

A35 Local air quality is likely to be better in this pathway than it is today. In particular, the damage to human health arising from air pollution, principally particulate matter, could be around 45%–80% lower in 2050 compared with 2010. The land use impact is considerable – bioenergy is harvested from approximately 45,000 km^2 of land area in the UK and other countries.

'Higher CCS; more bioenergy'



Energy saving per capita: 43%
Electricity demand: 490 TWh

A36 **The 'Higher CCS; more bioenergy' future was created using the 2050 Calculator.** This scenario is presented in the web tool of the Calculator which can be found at: http://2050-calculator-tool.decc.gov.uk

A37 The **'Higher CCS; more bioenergy' future** assumes the successful deployment of CCS technology on a commercial scale and its use in power generation and industry, supported by significant gas use. CCS is also used with sustainable and plentiful biomass supplies (BECCS) to generate 'negative' emissions.

What is the sectoral picture in 2050?

A38 Electricity generation is provided by a balanced mix of cost competitive renewables (36 GW of capacity), CCS (40 GW of capacity) and nuclear power (20 GW of capacity). Biomass-fired CCS technology plays a major role, and helps to bring about negative net emissions from the power sector by 2050.

A39 People embrace new technologies and smart controls in their homes, as well as insulation measures: 5.6 million solid walls and 6.9 million cavity walls are insulated, and domestic and commercial heating is almost entirely decarbonised. Half of domestic heat demand is met by house-level electric heat pumps, with the other half generated using network-level systems such as district heating and CHP.

A40 Industry grows steadily and achieves energy demand reductions of one third. Some 48% of remaining emissions are captured by CCS. Geosequestration has an appreciable impact, taking one million tonnes of CO_2 out of the atmosphere every year by 2050.

A41 Some 65% of cars and all buses are run using ultra-low emission fuel sources. People still travel 6% more than they do today, but there is a substantial shift towards cycling and using public transport more often. Some 74% of distance travelled domestically is still made by cars.

A42 Sustainable bioenergy use in this future is highest of the three futures, delivering 471 TWh of final energy demand. Much of the supply is directed towards power generation in order to meet demand from CCS stations and help create 'headroom' for the continued use of fossil fuels.

What does this scenario imply for security of supply and wider impacts?

A43 A balanced generation mix and a much lower reliance on electrified demand-side technologies mean that the back-up requirements of this scenario are the lowest of the three futures. No additional gas plant is required to meet a five-day wind lull and demand peak across the UK in 2050.

A44 Per capita energy demand falls by 43% compared with 2007, while total electricity demand increases by 29% from 2007 levels. This is the lowest of the three scenarios, as a consequence of a widespread roll-out in non-electric low carbon technologies in heating and transport.

A45 In order to meet the demands of gas-fired CCS, natural gas imports play a bigger role in this scenario, with 215 TWh of imports being the largest of the three scenarios, though still approximately half of what the UK imported in 2010.

A46 Approximately 51,000 km^2 of land area in the UK and other countries is used to grow bioenergy. Heavy use of bioenergy could have a negative impact on local air quality. In particular, the damage to human health arising from air pollution, principally particulate matter, could be between 80% lower to 60% higher in 2050 compared with 2010. Given the scope for adverse implications for air quality, if the UK were to adopt this pathway, the Government would develop a policy framework that ensured that improved pollution abatement technology was fully deployed so that the health impacts of air pollution could be minimised.

Understanding the costs of 2050 futures

A47 The Stern Review *Report on the Economics of Climate Change*[5] concluded that tackling climate change is a rational and prudent macroeconomic strategy, with the benefits of strong, early action on climate change far outweighing the long-term costs of not acting. Figure A1 summarises the costs of action versus inaction on climate change.

Figure A1: Costs of action versus inaction on climate change

Costs of inaction on climate change:

Damage costs of climate change: costs of population movements, deteriorated ecosystems and severe weather damages: up to 20% of GDP globally

Energy security: exposure to fossil fuel price volatility and shortages

Costs and benefits of action on climate change:

Investment, operating and fuel costs: capital, operating and fuel costs associated with transition to a low carbon economy

Efficiency savings and innovation: energy and resource efficiency and innovation spillovers

Wider macroeconomic impacts: structural change in the economy (e.g. jobs supported in the low carbon economy)

A48 History shows us that it is extremely difficult to forecast future costs with any degree of accuracy. To understand the costs of the 2050 futures we have used a range of models: MARKAL, ESME and the new 2050 Calculator, which includes costs data. The history and methodology of each of these models are set out below.

5 Stern, N (2006) *Report on the Economics of Climate Change*. HM Treasury.

Box A1: MARKAL fact box	
History	MARKAL (MARKet ALlocation model) is an internationally peer-reviewed model that has been used in many countries over the last 30 years to model national energy system change over the long and medium term. UK MARKAL has been used extensively by the UK Government and the Committee on Climate Change (CCC) to estimate the costs of meeting the 80% GHG emissions reduction target in 2050. MARKAL results have been recently published in: • AEA (2011) *Pathways to 2050 – Key Results. MARKAL Model Review and Scenarios for DECC's 4th Carbon Budget Evidence Base. Final report*;[6] • Usher, W and Strachan, N (2010) *UK MARKAL Modelling – Examining Decarbonisation Pathways in the 2020s on the Way to Meeting the 2050 Emissions Target. Final Report for the Committee on Climate Change*. University College London;[7] • Department of Energy and Climate Change (2009) *Climate Change Act 2008 Impact Assessment*.[8]
Methodology	MARKAL is a **cost-optimising** model. Targets and assumptions are set in MARKAL (as described in the scenarios that the Government is exploring) to define an end point in 2050; the model then works backwards to construct a pathway to it in the least expensive (optimal) way. The model can be constrained in various ways to show optimal pathways under different conditions. Constraints can encompass variables ranging from technological choices to specific policies. MARKAL is also able to test these pathways against a range of factors that affect **energy security**. MARKAL calculates the **capital, operating expenditure and fuel costs** of the energy system. It can also calculate **welfare** costs (such as the loss of comfort associated with having a colder home or not being able to travel as far). Coverage of the model is limited to **fossil fuel** combustion and industrial processes; it does not cover international aviation and shipping, non-CO_2 greenhouse gases (GHGs) and land use, land use change and forestry (LULUCF). Data in the model takes the form of **point estimates** for technology costs rather than ranges. Learning curves are included and connected to prices, allowing **technology costs to be partially endogenous**, i.e. they are determined partly by learning due to factors within the model, and partly due to factors which are pre-set. MARKAL is a sophisticated model containing over 500,000 data elements. Even so, the model necessarily makes a number of important simplifying assumptions. **Perfect foresight** is assumed, as if knowledge of future technologies and prices were fully available. **Forward-looking and rational consumers** are assumed to apply this foresight in the context of **perfectly competitive markets**, meaning that price distortions do not raise costs.

6 www.decc.gov.uk/assets/decc/11/cutting-emissions/carbon-budgets/2290-pathways-to-2050-key-results.pdf

7 http://downloads.theccc.org.uk.s3.amazonaws.com/4th%20Budget/CCC%20MARKAL%20Final%20Report%20-%20UCL%20Nov10.pdf

8 www.decc.gov.uk/assets/decc/85_20090310164124_e_@@_climatechangeactia.pdf

Box A1: MARKAL fact box *(continued)*	
Methodology *(continued)*	MARKAL has a number of variants which cover gaps in its central analysis. For example, stochastic MARKAL introduces uncertainty, and in MARKAL Macro the model includes the interaction with UK economic growth to model the wider **macroeconomic** effects. For this exercise we have used the MARKAL Elastic Demand model, with model database version 3.26. This is the same version that was used in analysis supporting the *Impact Assessment of Fourth Carbon Budget Level* published in May 2011.[9]

Box A2: ESME fact box	
History	ESME (Energy System Modelling Environment) was developed by the Energy Technologies Institute (ETI) using technology assumptions supplied by businesses and industry. Completed in late 2010 and already used by the Department of Energy and Climate Change, the CCC and the ETI's industrial members, the key findings are due to be published in early 2012. The model aims to identify those technologies likely to be most important for an affordable, secure and sustainable energy system that meets the 2050 GHG Emissions Reduction Target of 80%.
Methodology	Like MARKAL, ESME back-casts and optimises to find least-cost solutions to meet energy targets. It **optimises technology costs** in the form of investment, operating, fuel and resource costs. It focuses on the **engineering system design for 2050**, characterising optimal outcomes at the energy system, sector and individual technology levels. It does not model specific government policies, and **learning rates are exogenously set**. Similarly, **demand for energy services is prescribed by input scenarios and is not responsive to prices**. Also like MARKAL, ESME includes the **capital, operating** and **fuel costs** of the energy system to 2050. Unlike MARKAL, ESME does not compute welfare costs. The ESME model has a wider coverage than MARKAL. In addition to sources of fossil fuel emissions, it also includes **international aviation and shipping** and a valuation for **housing stock**. But like MARKAL it does not include non-CO_2 GHGs or LULUCF. The model represents uncertainty of technology costs and other key assumptions by probability distributions. Perfect foresight is assumed in each run, with the costs being drawn from these probability distributions. A particular feature of ESME is the ability to define demands and resources at a UK regional level and show the **geographical location** of energy infrastructure solutions.

[9] www.decc.gov.uk/assets/decc/what%20we%20do/a%20low%20carbon%20uk/carbon%20budgets/1685-ia-fourth-carbon-budget-level.pdf

Box A3: 2050 Calculator fact box	
History	The new 2050 Calculator is **released alongside this report** as a **Call for Evidence**. Comments on the cost estimates and assumptions used are requested by **8 March 2012**. The new 2050 Calculator builds on the original **2050 Calculator** first released in **July 2010**. This tool enabled the public to join in an informed debate on the future of the UK's energy system, and to support policymakers in making the best choices for the long-term. The 2050 Calculator is an engineering model based on physical and technical potential which allows users to consider the implications of the pathway for energy security, land use, electricity demand and other wider impacts. Following a Call for Evidence, the Government decided to add costs to the 2050 Calculator to allow users to also compare pathways on this basis. The Government has been working to develop the analysis needed to update the Calculator, consulting with experts in industry and academia to develop the strongest evidence base available.
Methodology	The 2050 Calculator includes costs for **all activities associated with GHG emissions**. This includes fossil fuel combustion, international aviation and shipping, industrial processes, agriculture, waste and LULUCF.[10] Therefore, the coverage of the 2050 Calculator is wider than that of MARKAL and ESME. There are over 100 technologies in the 2050 Calculator and **capital**, **operating expenditure** and **fuel costs** are included for each of these to 2050. Unlike MARKAL, the 2050 Calculator excludes welfare costs. The 2050 Calculator shows the lower, higher and default point estimates for each technology and fuel in 2050. Since there is considerable uncertainty about costs in 40 years' time, the Calculator uses cost ranges that are intended to be sufficiently wide as to capture the views of all credible experts. In particular: • The **lower cost** estimate for 2050 is the most optimistic assessment of future technology costs published by a credible evidence source. It assumes both technological progress to drive costs down over time and sufficient availability of skilled staff and materials to build and operate the technology. • The **upper cost** estimate for 2050 is the most pessimistic view, assuming minimal technological progress[11] over the next 40 years. In practice this usually means assuming that technology costs remain frozen at today's prices.

[10] The 2050 Calculator includes all emissions which count towards the UK's 2050 target. The only exception is international aviation and shipping: the Government has yet to decide whether this will contribute towards the UK's 2050 target. However, for illustrative purposes this sector has been included in the Calculator in the meantime. The 2050 Calculator does not include embedded emissions because these do not count towards the UK's 2050 target.

[11] This assumes incremental improvements in energy efficiency only.

Box A3: 2050 Calculator fact box *(continued)*	
Methodology *(continued)*	• The **default point estimate** is a point within the high–low range consistent with the latest cost assumptions from MARKAL.[12] The default fossil fuel price is the Department of Energy and Climate Change central fossil fuel price assumption and the default finance cost is 7% for all technologies. The cost estimates in the 2050 Calculator are drawn from a **wide range of credible, published sources**. These include economic and energy models (MARKAL and ESME), sectoral analysis,[13] UK government departments, independent analytical bodies such as the Committee on Climate Change and, wherever possible, the real-world cost of technologies as reported by financial bodies or the media. The 2050 Calculator includes no new evidence about costs; it simply brings together existing published assumptions. Critically, unlike MARKAL and ESME, the 2050 Calculator has no inbuilt **cost-optimisation** function; all choices are left up to the user. **Functionality** The 2050 Calculator is designed to be **easy to use**. Users can quickly design their own pathway (or select examples) and see a clear description of the cost implications. The user can compare the cost of their pathway with those from **experts** including Friends of the Earth, the ETI, Atkins, the Campaign to Protect Rural England and the National Grid. The user can see how costs are broken down **by sector and within sector**, and can choose to override the default cost assumptions and test the sensivity of the total cost of their pathway to alternative assumptions. The 2050 Calculator is particularly well suited to answering questions such as: • What is the cost of pathway X relative to pathway Y? • What are the biggest component costs of pathway X? • How could the cost of pathway X change if, say, nuclear costs are high and the cost of, say, renewables are as low as credible experts believe is possible?

[12] MARKAL cost assumptions have been used for approximately half the technologies in the 2050 Calculator where the mapping between both models is fairly straightforward. This includes power sector technologies, road transport, heat insulation, bioenergy and hydrogen production costs. For those sectors where it is more problematic to map from MARKAL to the 2050 Calculator (aviation, shipping, heat and industry) and for sectors which MARKAL does not cover (agriculture and waste), we have used a 35th centile assumption. Finance costs are set at 7% default. Fossil fuel prices for 2050 will default to the DECC central projection for 2030 ($130/barrel).

[13] Including Parsons Brinckerhoff; Mott MacDonald; AEA; and NERA.

Box A3: 2050 Calculator fact box *(continued)*	
Methodology *(continued)*	**Caveats** There are a number of important caveats to bear in mind when interpreting results from the 2050 Calculator. **Does not represent an impact on energy bills**. Results from the 2050 Calculator are presented as £/person/year, but this should not be interpreted as the effect on energy bills. The impact on energy bills of, say, building more wind turbines will depend on how the policy is designed and implemented (e.g. via tax, subsidy, regulation, etc). Taxes and subsidies are not captured in the 2050 Calculator so we cannot use the tool to examine these effects. The Government uses other, more sophisticated models to examine the effect of specific policy interventions on electricity and energy prices. **Pathway costs should be understood relative to other pathways**. The total cost of pathways is presented in the 2050 Calculator but for these to be meaningful they should be compared with the costs of another pathway. This is because there is no 'zero cost' option (unless the UK were to stop using energy altogether). Not tackling climate change and remaining fossil fuel dependent would still entail an energy system and it would still have a cost. **The costs presented exclude energy security impacts, costs arising from the damaging impacts of climate change, welfare costs and wider macroeconomic impacts**. The damage costs of climate change could be particularly significant – up to 20% of GDP. Other welfare costs excluded from the analysis include costs associated with living in cooler buildings, travelling less, changes to landscape, and air and noise pollution. The 2050 Calculator does not take into account taxes or subsidies, R&D costs, administrative costs associated with delivering policies, or wider macroeconomic costs. **Long-term, not short-term analysis**. The 2050 Calculator is best suited to long-term analysis of the energy system in 2050 rather than policy implications over the 2010s and 2020s. **User-driven model, not market based**. The 2050 Calculator costs the combination of technologies chosen by the user. Consequently it does not take into account price interactions between supply and demand. For example, if the cost of electricity generation increases then the Calculator does not capture any elasticity of demand response from the electricity user. The cost optimising model MARKAL better handles such price responses. **Costs are exogenous**. Technology costs do not vary depending on the level of technology roll-out. However, if the user has beliefs about how they would expect the costs of particular technologies to change in their pathway, they can test the effect of varying these assumptions.

Costs of 2050 futures

A49 We have used MARKAL and ESME to calculate the **aggregate** costs of these 2050 futures. As the two models operate in slightly different ways, we have used different methodologies for mapping the futures created using the 2050 Calculator into the more complex cost-optimising models.

A50 For **MARKAL**, we used the same baseline assumptions as those described in the core MARKAL run. The key elements of each future are characterised in terms of imposed constraints on the model. For example, **'Higher renewables; more energy efficiency'** assumes large-scale deployment of wind power. In order to model this outcome, we introduced constraints to force a minimum or maximum amount of wind (both offshore and onshore), nuclear, CCS, solar and marine technologies onto the system to broadly match the capacity levels set in the 2050 futures. We imposed investment or capacity constraints on the technologies. As back-up gas plant is built to provide reserve capacity in the MARKAL model subject to the contributions of intermittent technologies, the model endogenously determines its capacity.

A51 On the demand side, we have adopted the revised estimates of the energy efficiency savings that can be achieved in the residential sector, taken from the analysis carried out for the Fourth Carbon Budget Impact Assessment.[14] We introduced constraints to replicate the figures used in the Calculator for uptake of heating technologies and ultra-low emission vehicles.

A52 For **ESME**, we took a different approach. Using version 1.2 of the ETI ESME assumption database, we made the minimum set of changes to reflect the spirit of the 2050 futures. Where possible, we changed the cost of different technologies to see how that influenced deployment rather than fixing deployment levels. Differences in behaviour change across the three scenarios were not modelled.

- For **'Higher renewables; more energy efficiency'** this meant making lowest cost assumptions for wind, electric vehicles and electric heating but upper end cost assumptions for CCS, nuclear and bioenergy. In each case 'lowest cost' means the technology cost was set at the bottom end of the ETI ESME 1.2 assumption database cost range while 'upper end' means it was set at the top.
- For **'Higher nuclear; less energy efficiency'** this meant prohibiting CCS; making lowest cost assumptions for nuclear and bioenergy; assuming that wind, electric heating and electric vehicles are at the upper end of predicted costs; and assuming that bioenergy is more abundant and nuclear power possible in more locations than the ESME default.
- For **'Higher CCS; more bioenergy'** this meant making lowest cost assumptions for CCS; but setting costs at the upper end for nuclear, wind power, electric heating and electric vehicles. It also assumes that bioenergy is more abundant than the ESME default.

A53 The technology and fuel cost assumptions used by MARKAL and ESME are towards the lower end of the range that credible experts believe possible by 2050. However, the use of these relatively optimistic cost assumptions in our analysis reflects confidence that the UK and other countries will successfully implement policies that are effective in stimulating businesses and industry to innovate to bring down costs down. Annex B sets out the policies the Government already has in place to stimulate innovation. If innovation does not drive technology costs down, the costs of the pathways would be higher than shown here. The results for the three 2050 futures are set out in table A1 overleaf.

[14] HM Government (2011) *Impact Assessment of Fourth Carbon Budget Level*. Available at: www.decc.gov.uk/assets/decc/what%20we%20do/a%20low%20carbon%20uk/carbon%20budgets/1685-ia-fourth-carbon-budget-level.pdf

Table A1: Cost of pathways to 2050 compared with doing nothing on climate change (£bn in 2050)[15]

	MARKAL core run	Higher renewables; more energy efficiency	Higher nuclear; less energy efficiency	Higher CCS; more bioenergy
MARKAL	13	36	26	43
ESME	n/a	36	88	33

Sensitivity testing the three futures

A54 As set out above, we have represented the three 2050 futures in MARKAL by imposing the minimum number of constraints on the model.

A55 However, this simple representation does not capture the different energy demand profiles set out in the three futures pathways. For example, the 'Higher renewables; more energy efficiency' pathway assumes significant behaviour change: the average temperature of homes is one and a half degrees lower than it is today and travel behaviour is curbed (people travel the same distance as today and there is a significant shift to public transport).[16]

A56 We have deliberately not reflected different energy demand characteristics in the MARKAL modelling because we sought to maintain consistency with the MARKAL modelling practice of keeping demand assumptions the same in the baseline and the abatement pathway.[17]

A57 Relaxing this assumption reveals that the cost of achieving the 'Higher renewables; more energy efficiency' scenario could be significantly lower. Using a lower demand profile (compared with a baseline with central demand assumptions), this pathway actually saves the economy £8 billion in 2050 compared with taking no action on climate change.

A58 We have also sensitivity tested these results using the 2050 Costs Calculator to identify the major components of costs and where the most significant uncertainties are in the 2050 futures.

'Higher renewables; more energy efficiency' future

A59 Results from MARKAL and ESME suggest that the aggregate additional investment and operating cost of the **'Higher renewables; more energy efficiency'** scenario could be £36 billion[18] in 2050 compared with taking no action on climate change or energy security (see table A1). It is worth noting that all figures cited for 2050 costs are highly sensitive to methodological decisions.

'Higher nuclear; less energy efficiency' future

A60 The additional investment and operating cost of the **'Higher nuclear; less energy efficiency'** scenario could be perhaps £26–88 billion[19] in 2050 compared with taking no action on climate change or energy security (see table A1). There is a saving from less use of fossil fuels and an increase in costs in other sectors (in order of importance: finance costs, bioenergy and buildings).[20]

A61 Using the 2050 Calculator, we can see that, irrespective of the wider benefits of tackling climate change, the **'Higher nuclear; less energy efficiency'** future could be cheaper than the counterfactual if fossil fuel prices are high ($170/bbl for oil and 100p/therm for gas).

[15] This is the annual cost incurred in 2050 over and above doing nothing on climate change. Based on estimates of total undiscounted system costs in 2011 prices from MARKAL and ESME model runs

[16] In the 2050 Calculator this is characterised as effort level 4 for domestic transport behaviour and average temperature of homes.

[17] The MARKAL results set out in this annex are calculated using central demand assumptions in the baseline and abatement pathway unless stated otherwise.

[18] This is the annual cost incurred in 2050 over and above taking no action on climate change. Based on estimates of total undiscounted system costs in 2011 prices from MARKAL and ESME model runs.

[19] This is the annual cost incurred in 2050 over and above taking no action on climate change. Based on estimates of total undiscounted system costs in 2011 prices from MARKAL and ESME model runs.

[20] Analysis from the 2050 Calculator.

'Higher CCS; more bioenergy' future

A62 The additional investment and operating cost of the **'Higher CCS; more bioenergy'** scenario could be perhaps £33–43 billion[21] in 2050 compared with taking no action on climate change or energy security (see table A1). There is a saving from less use of fossil fuels and lower transport costs and an increase in costs in other sectors (in order of importance: buildings, finance costs and bioenergy).[22]

A63 Using the 2050 Calculator, we can see that, irrespective of the wider benefits of tackling climate change, the **'Higher CCS; more bioenergy'** future could be cheaper than the counterfactual if:

- fossil fuel prices are high ($170/bbl for oil and 100p/therm for gas);
- the cost of solid wall insulation on a house falls to around £2,000/household compared with £7,000 or more today;
- the cost of bioenergy falls (to £20/MWh for imported solid fuels); and
- cost of finance is 5%.

[21] This is the annual cost incurred in 2050 over and above taking no action on climate change. Based on estimates of total undiscounted system costs in 2011 prices from MARKAL and ESME model runs.

[22] Analysis from the 2050 Calculator.

Annex B: Carbon budgets analytical annex

Contents

Note on methodology

All analysis presented in this annex is consistent with the methodology laid out in Department of Energy and Climate Change/HM Treasury Green Book guidance on the appraisal of emissions impacts.[1]

Energy and emissions savings have been valued using an updated set of fossil fuel[2] and carbon values[3] consistent with the Department of Energy and Climate Change's Updated Energy and Emissions Projections baseline,[4] all of which were published in October 2011. An interim set of energy prices was used to value changes in energy use. Further details on the appraisal approach are set out in relevant sections throughout this annex.

[1] DECC (2010) *Valuation of Energy Use and Greenhouse Gas Emissions for Policy Appraisal and Evaluation*. Available at: www.decc.gov.uk/assets/decc/statistics/analysis_group/122-valuationenergyuseggemissions.pdf

[2] DECC (2011) *DECC fossil fuel price projections*. Available at: www.decc.gov.uk/en/content/cms/about/ec_social_res/analytic_projs/ff_prices/ff_prices.aspx

[3] DECC (2011) *Update Short Term Traded Carbon Values for UK Public Policy Appraisal*. Available at: www.decc.gov.uk/assets/decc/11/cutting-emissions/carbon-valuation/3137-update-short-term-traded-carbon-values-uk.pdf

[4] DECC (2011) Updated Energy and Emissions Projections 2011. Available at: www.decc.gov.uk/assets/decc/11/about-us/economics-social-research/3134-updated-energy-and-emissions-projections-october.pdf

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B1. Carbon budget levels and the net UK carbon account

Legislated carbon budgets

B1.1 The first three legislated carbon budgets are consistent with the UK's share of the current European Union (EU) target to reduce emissions by 20% below 1990 levels by 2020. There is a commitment to tighten the second and third carbon budget levels following an EU move to a more stringent 2020 emissions target.

B1.2 In June 2011, the Government set in legislation the fourth carbon budget at the level recommended by the Committee on Climate Change (CCC),[5] 1,950 million tonnes of CO_2 equivalent ($MtCO_2e$), equivalent to a 50% reduction below the 1990 baseline. See the Impact Assessment accompanying that decision for details of the evidence base for setting the level of the fourth carbon budget.[6]

Scope of the UK carbon budgets and the net UK carbon account

B1.3 **The UK's performance against its legislated carbon budgets is assessed relative to the net UK carbon account** (section 27 of the Climate Change Act 2008[7]). The net UK carbon account:

- includes emissions from the UK (not including Crown Dependencies and UK Overseas Territories) of the 'Kyoto basket' of greenhouses gases (GHGs) which includes all carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) emissions;
- includes net emissions/removals[8] from land use, land use change and forestry (LULUCF); and
- is net of the purchase and sale of international carbon units. Carbon units include allowances issued under cap and trade systems, such as the EU Emissions Trading System (ETS) (see below), and international carbon units representing developing country emissions reductions issued under the Clean Development Mechanism.[9]

Table B1: UK's legislated carbon budgets ($MtCO_2e$)

	First carbon budget (2008–12)	Second carbon budget (2013–17)	Third carbon budget (2018–22)	Fourth carbon budget (2023–27)
Legislated budgets[10]	**3,018**	**2,782**	**2,544**	**1,950**
of which traded	1,233	1,078	985	690
of which non-traded	1,785	1,704	1,559	1,260
Average annual percentage reduction from 1990[11]	**23%**	**29%**	**35%**	**50%**

5 CCC (2010) *The Fourth Carbon Budget: Reducing emissions through the 2020s*. Available at: www.theccc.org.uk/reports/fourth-carbon-budget

6 DECC (2011) *Impact Assessment of Fourth Carbon Budget Level*. Available at: www.decc.gov.uk/assets/decc/what%20we%20do/a%20low%20carbon%20uk/carbon%20budgets/1685-ia-fourth-carbon-budget-level.pdf

7 www.legislation.gov.uk/ukpga/2008/27/contents

8 In this context, 'removals' refers to where emissions are taken out of the atmosphere. See box B1 on page 145 for further details.

9 Under the Clean Development Mechanism, emissions reduction projects in developing countries can earn Certified Emissions Reduction credits. These credits can be used by countries to meet a part of their emissions reduction targets under the Kyoto Protocol, or to meet targets under domestic legislation.

10 Assumed share for the second and third carbon budgets, based on the best estimate of the UK share of an EU 20% reduction target when the first three carbon budgets were legislated in 2009.

11 These percentages have changed since 2009 when legislated and quoted in the Low Carbon Transition Plan (DECC (2009) *The UK Low Carbon Transition Plan*. Available at: www.decc.gov.uk/en/content/cms/tackling/carbon_plan/lctp/:aspx) owing to an update in the *National Greenhouse Gas Inventory* which revised total 1990 baseline UK GHG emissions from 777.4 $MtCO_2e$ to 783.1 $MtCO_2e$. This number is the denominator in this calculation, hence while the budget levels (in $MtCO_2e$) have not changed, the 1990 baseline and percentage reductions have.

B1.4 Each carbon budget sets a maximum level for the total net UK carbon account over a five-year period, in tonnes of carbon dioxide equivalent (tCO_2e). The first four carbon budgets are set out in table B1. More information on the net UK carbon account and carbon accounting rules can be found on the Department of Energy and Climate Change website.[12]

B1.5 The Climate Change Act 2008, and therefore by definition the net UK carbon account, currently excludes emissions from international aviation and shipping. The Act requires the Government, by the end of 2012, either to make regulations to specify the circumstances in which, and the extent to which, emissions from international aviation or international shipping[13] are to be included in carbon budgets and the 2050 target, or to lay before Parliament a report explaining why such regulations have not been made.[14] This decision will need to be considered alongside development through 2012/13 of the UK's sustainable aviation policy framework, which will also consider whether to adopt the previous administration's 2050 aviation CO_2 target.

The European Union Emissions Trading System

B1.6 The EU ETS covers direct emissions from power generation and heavy industry (and aviation from 2012) and sets a cap at the EU level for these emissions. In the UK this represents around 40%[15] of emissions (referred to as the traded sector). For the purposes of calculating the net UK carbon account, emissions in the traded sector are taken to be equal to the UK's share of the EU ETS cap. While there is volatility in the level of UK territorial emissions, driven by variables such as the carbon price and fossil fuel prices, there is near certainty over the traded sector share of the net UK carbon account, which derives from the established level of the EU ETS cap.[16]

B1.7 The UK share of the EU ETS cap is the sum of the allowances allocated for free to UK installations[17] covered by the EU ETS and the UK's share of auctioned allowances. Once negotiated, this share of the fixed cap is relatively stable.[18] This certainty over the traded sector component of the net UK carbon account provides a significant advantage in managing carbon budgets, and the EU ETS is an important instrument for guaranteeing emissions reductions.

B1.8 The overall environmental outcome (total EU-wide emissions from the traded sector) is fixed, although the level of territorial emissions in the UK or any other EU Member State may vary.

- If the UK went further and reduced territorial emissions below the UK share of the EU ETS cap, this would not lead to an additional reduction in global emissions. Going further would, in the absence of other measures, result in a net outflow of allowances from the UK, increasing the availability of allowances to

[12] DECC (2009) *Guidance on Carbon Accounting and the Net UK Carbon Account*. Available at: www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/carbon_budgets/carbon_budgets.aspx

[13] Note that international aviation emissions associated with all flights arriving at and departing from European Economic Area (EEA) airports will be included in the EU ETS from 2012. The European Commission is also encouraged, by recitals in Directive 2009/29/EC and Decision 406/2009/EC, to introduce legislation to limit international maritime emissions, in the event that a global agreement has not been reached in the International Maritime Organization or United Nations Framework Convention on Climate Change by the end of 2011.

[14] Climate Change Act 2008, section 30.

[15] On average over the first three carbon budgets.

[16] The Government has informed UK installations of their provisional levels of free allocation for Phase III (2013–20), although these are not yet finalised. Exact levels of free allocation for each installation will not be known until the Commission publishes details of the level of the cross-sectoral correction factor (in 2012). At the same time, we expect the Commission to publish figures on the number of allowances each Member State will receive to auction. Some uncertainty will remain over the extent to which UK installations have access to the New Entrants' Reserve or have their free allocation reduced as a result of closures. The latter will also affect the number of allowances to auction that the UK receives and this uncertainty will not be reduced until the end of the trading period.

[17] For the purposes of carbon budgets, this includes all allowances received by static installations located in the UK along with a proportion of aviation allowances which correspond to UK domestic aviation.

[18] It varies only with small changes to the distribution of allowances resulting from closures and new entrants to the system, and current uncertainty associated with the level of free allocation each installation is likely to receive. This will not be known until after all Member States have submitted their National Implementation Measures (NIMs) Plan, which is likely to be in early 2012.

installations outside the UK, whose emissions could increase within the overall EU ETS cap. The net UK carbon account would be unchanged because the increased export of allowances from the UK would cancel out the reduction in UK territorial emissions.

- Likewise, if UK territorial emissions exceed the UK share of the cap, then compliance requires that UK installations covered by the scheme purchase allowances from other installations with a surplus in other Member States, or (subject to strictly defined limits) international offset credits.

Baseline emissions levels and the 2050 target

B1.9 The baseline level of UK greenhouse gas (GHG) emissions in 1990 from which the emissions reduction targets in the Climate Change Act 2008 are referenced is 783.1 $MtCO_2e$. This is referred to as 'the 1990 baseline' and consists of net UK emissions in 1990 for CO_2, methane and nitrous oxide GHGs, and 1995 for fluorinated gases (as recorded in the latest GHG emissions inventory[19] and calculated according to the latest international reporting practice as required by the Act).

B1.10 The long-term target set out in the Climate Change Act, to reduce emissions levels by at least 80% below the 1990 baseline, would therefore require the net UK carbon account to decline to at most 156.6 $MtCO_2e$ by 2050.

B2. Meeting carbon budgets

Progress against the first three carbon budgets

B2.1 The provisional emissions estimates for 2010[20] published in early 2011 show that the net UK carbon account (which includes the impact of emissions trading) increased by 1.8% to 585.6 $MtCO_2e$ in 2010 from 575.4 $MtCO_2e$ in 2009.[21] This increase in emissions resulted primarily from a rise in residential gas use related to the fact that 2010 was, on average, the coldest year since 1986.

B2.2 The net UK carbon account in 2010 was 25.2% below 1990 levels. The first carbon budget requires that total UK GHG emissions do not exceed 3,018 $MtCO_2e$ over the five-year period 2008–12, which is approximately 23% below the 1990 level, on average, over the period.

B2.3 Table B2 summarises the UK's progress towards meeting the first carbon budget by comparing the average emissions per annum required to meet the budget with the average emissions to date in the first budgetary period.

[19] DECC (2011) UK Greenhouse Gas Inventory. Available at: www.decc.gov.uk/en/content/cms/statistics/climate_change/gg_emissions/uk_emissions/2009_final/2009_final.aspx

[20] Please note that territorial emissions and the net UK carbon account estimate for 2010 are provisional and may be subject to change. More details on the provisional emissions figures for 2010 can be found at: www.decc.gov.uk/en/content/cms/statistics/climate_stats/gg_emissions/uk_emissions/2010_prov/2010_prov.aspx

[21] Territorial emissions which exclude the impact of trading within the EU ETS increased by 2.9% to 577.9 $MtCO_2e$ from 561.8 $MtCO_2e$ in 2009.

Table B2: Actual emissions against the first carbon budget ($MtCO_2e$)

First carbon budget		Actual emissions including EU ETS $MtCO_2e$					Average emissions p.a. required in 2011/12 to meet budget
Total emissions (2008–12)	Equivalent average emissions p.a.	2008	2009	2010 (p)	Cumulative emissions to date (2008–10)	Average emissions p.a. (2008–10)	
3,018	604	597	575	586	1,758	586	630

B2.4 Emissions have averaged 586 $MtCO_2e$ over the course of 2008–10, which means that emissions in the remaining two years would have to exceed 630 $MtCO_2e$ per annum in order to miss the first budget. The latest emissions projections suggest that the UK will be comfortably below this level during the remaining two years.

Future projections

B2.5 The Department of Energy and Climate Change's Updated Energy and Emissions Projections,[22] published in October 2011, provide forecasts for UK emissions over the short and medium term and are an essential tool for tracking progress and risks towards meeting the carbon budgets.

Box B1: The Department of Energy and Climate Change's emissions projections

The Department of Energy and Climate Change's energy and emissions model projects energy demand using econometric equations of the interaction between supply and demand for each sub-sector of the economy, models of the UK energy market, various assumptions on the key external drivers of energy demand (i.e. expectations of future GDP growth, international fossil fuel prices, carbon prices and UK population) and the impacts of government policies.

The input data and assumptions in the model are subject to uncertainty. For example:

- the exogenous inputs (GDP, fossil fuel prices and UK population growth) are all subject to their own assumptions and levels of uncertainty about what the actual level may be in the future;
- expected policy savings are uncertain – numerous factors can affect whether policies will deliver as expected; and
- the parameters in the model are uncertain, particularly in the longer run. For example, the energy demand responses to prices and output are estimated from analysis of past data trends.

The model is calibrated to the 2009 UK Greenhouse Gas Inventory and the latest available Digest of United Kingdom Energy Statistics (DUKES) data, the former is currently based on 2009 levels (published February 2011, the latest available to carry out this modelling exercise).

[22] For full details of these projections, see DECC (2011) Updated Energy and Emissions Projections 2011. Available at: www.decc.gov.uk/assets/decc/11/about-us/economics-social-research/3134-updated-energy-and-emissions-projections-october.pdf

Box B1: The Department of Energy and Climate Change's emissions projections *(continued)*

The Department of Energy and Climate Change's non-CO_2 GHG projections use the methodologies set out in the Greenhouse Gas Inventory report.[23] Projections are calculated using forecast activity statistics, emissions factors and various other sector specific assumptions for each of the main sources of emissions. GHG emissions projections are calculated by sector and aggregated to provide an estimate of total projected emissions. The projections system is designed to be transparent, flexible and easy to update.

The Department of Energy and Climate Change's LULUCF projections cover CO_2 emissions from forestry, crop and grassland management, and other land uses. It is the only sector where CO_2 can be removed from the atmosphere (through photosynthesis). LULUCF can therefore show net emissions, net removals or zero change, if emissions and removals are in balance. Projections are estimated by the Centre for Ecology and Hydrology[24] under contract to the Department of Energy and Climate Change, using methods consistent with the UK Greenhouse Gas Inventory, coupled with projections of future land use and land use change, based on what has happened historically and possible future scenarios. The LULUCF projections have recently been revised to reflect the latest survey and inventory data available.[25]

Monte Carlo simulation is used in all three areas of emissions projections to take account of the uncertainty inherent in the range of input assumptions necessary to produce these projections.

B2.6 These projections suggest that the UK is on track to meet its first three legislated carbon budgets with current planned policies. By 2020, the UK is forecast to reduce net UK emissions by 38% from 1990. Territorial emissions over the first three carbon budgets are expected to be 2,877, 2,604 and 2,322 $MtCO_2e$ respectively, while the net UK carbon account is expected to be 2,922, 2,650 and 2,457 $MtCO_2e$ respectively (see table B3). We therefore expect, on central projections, to reduce emissions to below the level of the first three carbon budgets. This means that the UK is expected to exceed the first three carbon budgets by 96, 132 and 87 $MtCO_2e$ respectively.

B2.7 In respect of the fourth carbon budget, the Department of Energy and Climate Change's emissions projections set the baseline against which to assess the level of additional abatement required to reach the fourth carbon budget. UK territorial emissions are projected to be 2,207 $MtCO_2e$ over the fourth budget period (average of 441.4 $MtCO_2e$ per annum). This represents a 43.6% emissions reduction on average over the budget period relative to 1990 levels.

B2.8 In the traded sector, the UK's level of emissions over the fourth budget period will be dictated by the UK's share of the EU ETS cap over the period. However, there is uncertainty about the level of ambition of the EU ETS, and the UK's share of the cap, beyond 2020. Analysis suggests that the UK's share of the assumed cap could be between 590 and 860 $MtCO_2e$ over the period, depending on the level of ambition to reduce emissions leading up to the period, and the methodology for determining the UK's share. The fourth budget was set assuming that the UK's traded sector cap would be at 690 $MtCO_2e$ over the period.[26]

B2.9 The UK's net carbon account, assuming a cap on traded sector emissions of 690 $MtCO_2e$, is projected to be 2,131 $MtCO_2e$ over the fourth carbon budget (426 $MtCO_2e$ per annum). This represents a reduction in emissions of around 46% relative to 1990 levels.

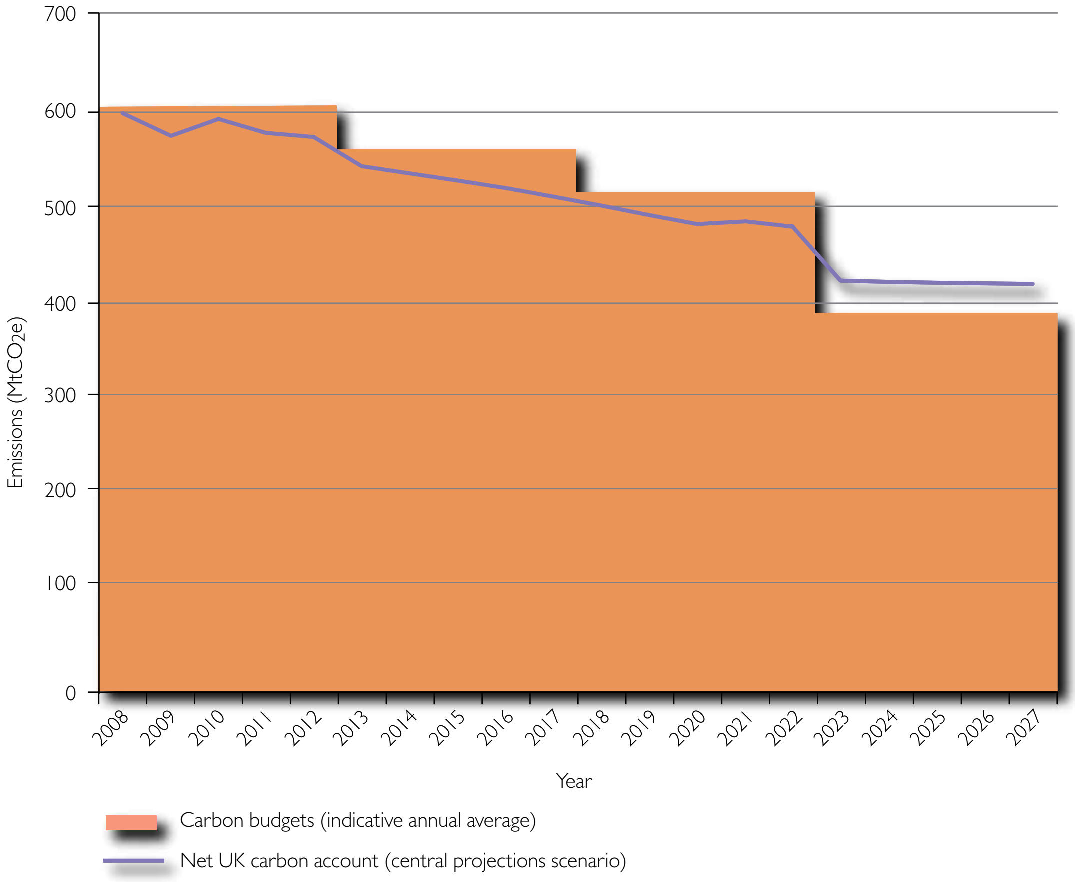
[23] AEA (2011) *National Inventory Report*. Available at: http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/5888.php

[24] Available at: www.ceh.ac.uk

[25] DECC (2011) *Non-CO_2 Land and Land Use Change and Forestry (LULUCF) GHG emissions projections summary tables*. Available at: www.decc.gov.uk/en/content/cms/about/ec_social_res/analytic_projs/en_emis_projs/en_emis_projs.aspx

[26] In line with the CCC's recommendation. See footnotes 5 and 6.

Chart B1: Historic and projected net UK carbon account, 2008–27 ($MtCO_2e$)



Source: DECC energy model CO_2 energy projections, non-CO_2 GHG projections and LULUCF projections

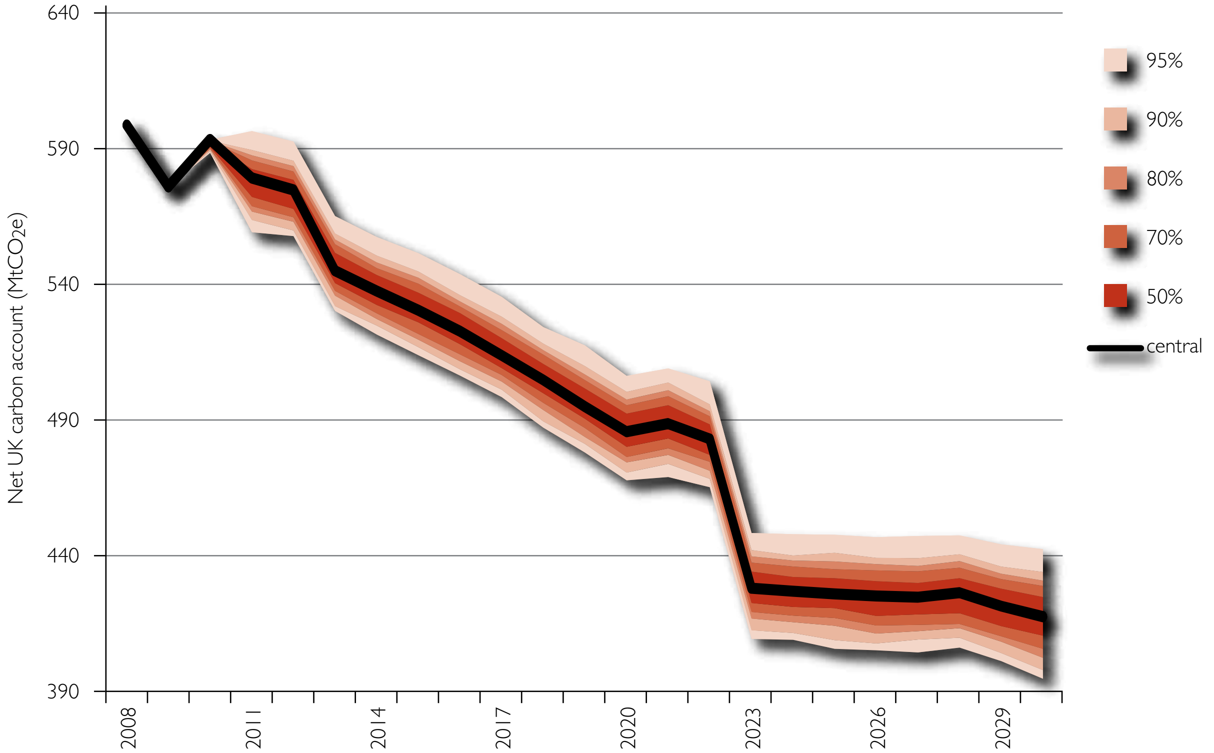
B2.10 On a net UK carbon account basis, the shortfall to the fourth budget of 1,950 $MtCO_2e$ is therefore projected to be around 181 $MtCO_2e$ over the fourth budget period. This incorporates a significant legacy of impacts from the current policy package over the fourth carbon budget.

Uncertainty around projections

B2.11 Projections of emissions levels are inherently uncertain as they depend upon projected future levels of a number of key factors, including economic and population growth and fossil fuel prices. The Department of Energy and Climate Change's emissions projections capture some of this uncertainty through the use of Monte Carlo simulations, using assumed distributions of the levels of the key variables to provide a range of outcomes. This analysis provides an indication of the impact of uncertainty in fossil fuel prices, economic growth, temperature, policy delivery, power station capital costs, non-CO_2 GHG emissions and LULUCF emissions and removals.[27] Chart B2 reflects the range of uncertainty around net UK carbon account projections.

[27] This does not account for all sources of uncertainty. In particular, uncertainties over the modelling parameters, which will increase over time, are only partially reflected. The emissions projections also do not attempt to take account of climate science uncertainty.

Chart B2: Indicative uncertainty around the net UK carbon account projections, 2008–30 ($MtCO_2e$)[28]



Source: DECC energy model CO_2 energy projections, non-CO_2 GHG projections and LULUCF projections

B2.12 Table B3 below provides the Department of Energy and Climate Change's latest emissions projections for the net UK carbon account for the first four carbon budgets, and the projected over-achievement margins under central, low and high modelled uncertainty ranges.

Table B3: Projected performance against carbon budgets 1 to 4 ($MtCO_2e$)

	Carbon budget 1 (2008–12)	Carbon budget 2 (2013–17)	Carbon budget 3 (2018–22)	Carbon budget 4[28] (2023–27)
Legislated carbon budgets	3,018	2,782	2,544	1,950
Territorial emissions	2,877	2,604	2,322	2,207
Net UK carbon account	2,922	2,650	2,457	2,131
Projected performance against carbon budgets (negative implies emissions under budget)	−96	−132	−87	181
Uncertainty range (high to low emissions projections)	−73 to −124	−73 to −172	−19 to −142	250 to 117

Source: DECC energy model CO_2 energy projections, non-CO_2 GHG projections and LULUCF projections

[28] The projected performance against the fourth carbon budget assumes an EU ETS cap of 690 $MtCO_2e$ from 2023.

Annual indicative range

B2.13 Section 12 of the Climate Change Act 2008 requires the Government to publish, as soon as possible after making an Order setting a carbon budget, an indicative annual range for the net UK carbon account for each year within the period. An indicative annual range in relation to a year is a range within which the Secretary of State expects the amount of the net UK carbon account for the year to fall. The annual indicative range for the first three carbon budgets was set in July 2009. Table B4 shows these ranges, to reflect the latest data and updated projections, along with the annual indicative range for the fourth carbon budget.

Table B4: Indicative annual uncertainty range for the net UK carbon account projections, 2008–27 ($MtCO_2e$)[29]

	Carbon budget 1					Carbon budget 2				
Net UK carbon account projections ($MtCO_2e$)	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Upper bound	599	576	593	596	593	565	557	552	544	535
Central	599	576	593	579	575	545	538	531	523	514
Lower bound	599	576	593	559	558	530	522	514	506	498

	Carbon budget 3					Carbon budget 4				
Net UK carbon account projections ($MtCO_2e$)	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Upper bound	524	518	506	509	504	449	448	448	447	447
Central	505	495	486	489	483	428	427	426	425	425
Lower bound	487	478	468	469	465	409	409	406	405	405

Source: DECC energy model CO_2 energy projections, non-CO_2 GHG projections and LULUCF projections

Carbon budgets management

B2.14 The uncertainty inherent in emissions projections means that the Government cannot rely on central estimates alone to demonstrate that the UK is on track to meet carbon budgets. There are a number of things which the Government is doing to ensure that the UK remains on track.

B2.15 First, the EU ETS, which covers emissions from the power generation and industrial sectors, effectively eliminates uncertainty in these sectors as emissions are capped and, for carbon budget accounting purposes, the traded sector contribution to the net UK carbon account is equal to the UK's share of the EU ETS cap (rather than territorial emissions). On this basis the UK cannot under- or over-perform on its traded sector share of the carbon budgets. Given that this represents around 40% of the UK carbon account, the EU ETS is an important instrument for guaranteeing net emissions reductions.

B2.16 In the remaining non-EU ETS sectors there are a number of ways in which the Government is working to increase confidence that the budgets will be met:

[29] The tables show the indicative annual uncertainty around the net UK carbon account. For the fourth carbon budget, an EU ETS cap of 690 $MtCO_2e$ is assumed. The upper and lower bounds represent the 95% confidence interval.

- the surpluses projected (on the central scenario) in each budget period provide a contingency reserve that will offer some resilience to unexpected events, such as higher than anticipated emissions driven by fossil fuel prices that are significantly lower than assumed in our central scenario;
- the Climate Change Act 2008 provides the flexibility to bank over-achievement across carbon budget periods or undertake limited borrowing (constrained at 1%) from the next budget. This increases the contingency to cope with unanticipated increases in emissions;
- the Government is continuing to explore new, cost effective policy options to further reduce emissions in a variety of areas over the first three budget periods, e.g. ways to help small businesses to save carbon; and
- the Government recognises the importance of placing the UK on an appropriate pathway to meet its longer-term carbon targets and it aims to meet the first four carbon budgets through domestic action. However, the Government also recognises the benefits of international offsets in allowing emissions reductions to occur where they are least costly and as a mechanism to help decarbonise developing economies. Consequently, purchasing international credits to offset UK emissions remains an option, although a limit must be set for each budgetary period. The limits for the first and second carbon budget periods are zero and 55 $MtCO_2e$ (outside the EU ETS) respectively.

Policy savings

B2.17 The emissions projections take into account the estimated impact of government policies and proposals announced to date. Re-evaluations of policies are made periodically and, where appropriate, savings are adjusted and reflected in the emissions projections. See box B2 overleaf for details on appraisal methodology.

Box B2: Greenhouse gas appraisal guidance

Valuing energy use and GHGs is vital to ensure that the Government takes full account of climate change and energy impacts when appraising and evaluating public policies and projects. In consultation with analysts across government, the Department of Energy and Climate Change and HM Treasury have jointly produced supplementary guidance to the HM Treasury Green Book that provides government analysts with a set of rules for valuing energy use and emissions.[30] The guidance helps the appraisal and evaluation of proposals leading to an increase or reduction in energy use and/or GHG emissions in the UK. It covers proposals that have a direct impact on energy use and supply and those with an indirect impact through planning, construction, land use change or the introduction of new products that use energy.

Moreover, it helps analysts to quantify the carbon impacts of their policies and to value significant impacts using the revised carbon valuation methodology (July 2009),[31] as required by the revised Impact Assessment guidelines[32] of the Better Regulation Executive (BRE). There is also a complementary spreadsheet calculation 'toolkit' designed to convert increases or decreases in energy consumption into changes in GHG emissions and to value the changes in both emissions and energy use.[33] This spreadsheet also contains the latest assumptions for carbon values, energy prices, long run variable energy supply costs, emissions factors and air quality damage costs to be used in UK policy appraisal.

Avoiding double counting of emissions savings

Monitoring overall progress against legislated carbon budgets requires precise and robust projections of emissions savings from a package of policies and an assessment of their combined, aggregated effectiveness.

The primary purpose of the aggregation is to show the total costs, benefits and impacts of the package of policies and proposals to meet the carbon budgets. In this respect, it is important to avoid the 'double counting' of energy and GHG emissions impacts when assessing the combined, aggregated effectiveness of a package of policies. Emissions savings from policies have been sequenced with respect to the following criteria: permanency; bindingness; cost effectiveness; timing of implementation; and pragmatism. This means that emissions impacts vary from those set out in individual Impact Assessments which analyse policies on a purely chronological basis in order to identify the marginal impact of their introduction.

30 DECC and HM Treasury (2010) *Valuation of Energy Use and Greenhouse Gas Emissions for Policy Appraisal and Valuation*. Available at: www.decc.gov.uk/assets/decc/statistics/analysis_group/122-valuationenergyuseggemissions.pdf

31 DECC (2009) *Carbon Valuation in UK Policy Appraisal: A Revised Approach*. Available at: www.decc.gov.uk/en/content/cms/emissions/valuation/valuation.aspx

32 See: www.berr.gov.uk/whatwedo/bre/index.html

33 See: www.decc.gov.uk/en/content/cms/about/ec_social_res/iag_guidance/iag_guidance.aspx

B2.18 As set out above, the Department of Energy and Climate Change's Updated Energy and Emissions Projections indicate that current policies are projected to over-achieve against the first three carbon budgets and will continue to deliver savings over the fourth carbon budget (see chart B3 below). See tables B25 to B28 for full details on the emissions savings delivered by individual policies.

Aggregate costs of the current policy package

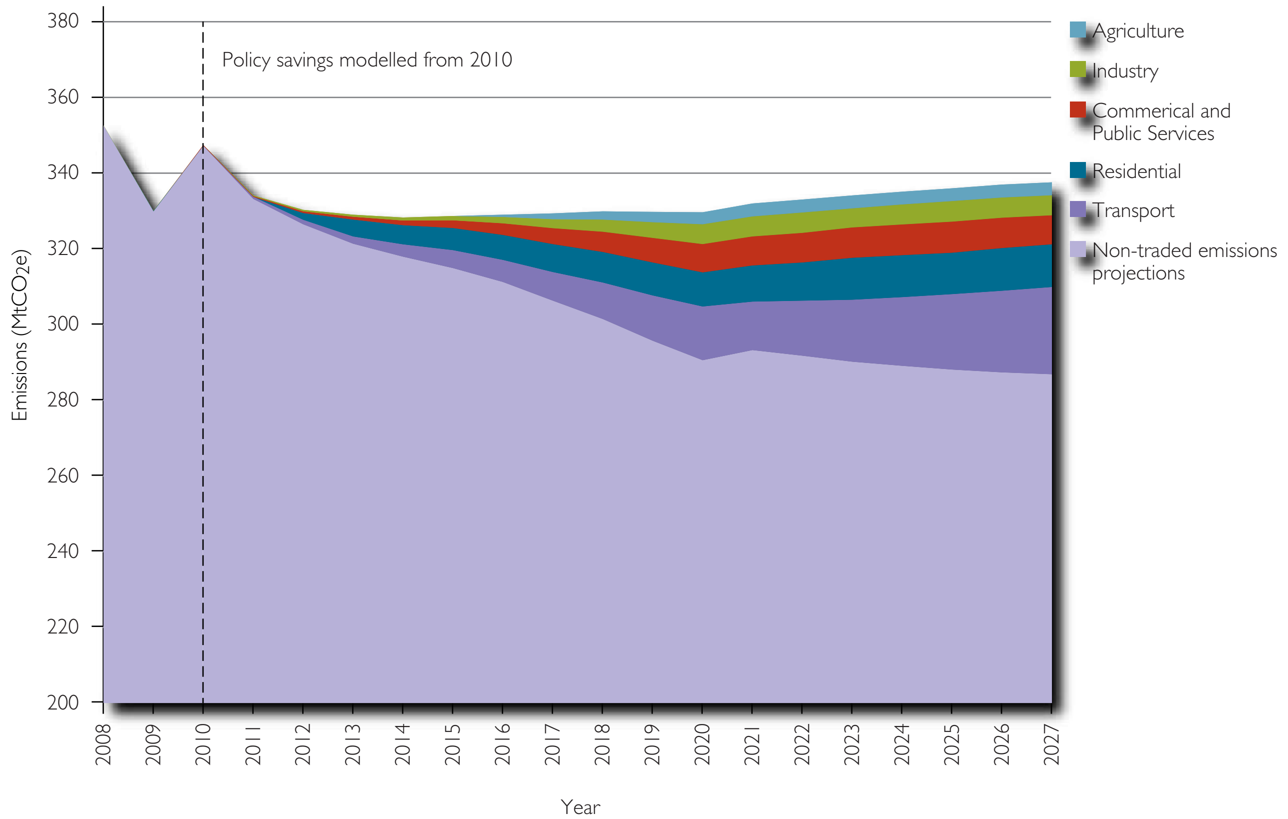
B2.19 The total net present lifetime cost of the current policy package is estimated at £9 billion (excluding the value of GHG emissions savings in the non-traded sector). Including the value of GHG savings in the non-traded sector results in the package delivering a net benefit, on central estimates, of £45 billion.

B2.20 This represents the net present value of the Government's current policy package that places the UK on track to meet its first three carbon budgets, reducing the UK's net carbon account by 38% in 2020 versus 1990.

B2.21 In line with HM Treasury Green Book guidance, the costs are presented as net present values that reflect discounted societal costs and benefits over the lifetime of the policy, some of which may extend over six decades. The resource costs of low carbon technologies are relative to the cost of technologies that would have been installed in the baseline counterfactual, i.e. without legislated carbon budgets.

B2.22 Table B5 sets out the net present cost of delivering the emissions savings over the first three carbon budgets. It excludes the value attributed to the GHG emissions themselves.

Chart B3: Illustrative reduction in non-traded emissions by sector, 2008–27 ($MtCO_2e$)[34]



[34] Does not include indirect effects of policies. Only shows impact of non-traded savings additional to the baseline (Low Carbon Transition Plan and newer policies).

Table B5: Net present value of policy by measure, excluding value of non-traded emissions (£ million 2011)[35]

Policy (positive = benefit)	Central fossil fuel prices	Low fossil fuel prices	High fossil fuel prices
EU Emissions Trading			
EU Emissions Trading System[36]	−3,290	n/a	
Power and low carbon heat			
Carbon Price Floor[37]	−620	−6,250	4,260
Carbon capture and storage demonstration	−8,940	−9,710	−8,510
Carbon capture readiness[38]	−6 to −80[39]	n/a	
Large-scale electricity (Renewables Obligation (RO))[40]	−42,820	−67,450	−33,130
Small-scale electricity Feed-in Tariffs (FiTs)	−3,370	n/a	
Renewable Heat Incentive (RHI)[41]	−6,530	n/a	
Total	**−62,280 to −62,350**	**n/a**	
Transport[42]			
8% of transport fuel from renewable sources by 2020	−5	−320	110
EU new car average fuel efficiency standards – CO_2 mid-term target (130g CO_2/km)	10,780	2,510	16,850
Additional impact of further new car efficiency improvements to 95g/km	−22,010	−35,430	−11,640
EU new van CO_2 regulation	180	−2,690	2,060
Low carbon emissions buses	890	310	1,290
EU new car complementary measures	−4,060	−5,500	−3,230
Local Sustainable Transport Fund (LSTF)	1,480	1,650	1,580
HGV low rolling resistance tyres	1,100	640	1,300
Industry-led action to improve HGV efficiencies	1,710	910	2,140
Rail electrification	2,310	2,210	2,530
Total	**−7,640**	**−35,710**	**13,010**

35 Values have been rounded to the nearest £10 million.

36 The costs of the EU ETS are made up of the costs to UK installations of abatement incentivised by the carbon price, project credits purchased, EUA allowances purchased, minus the revenues earned from the UK Government and installations selling allowances. The estimates shown in the table reflect the costs over the period 2008–20 and include all UK (static) installations plus domestic aviation. In estimating these figures, the baseline excludes all policies in and announced since the Low Carbon Transition Plan (LCTP) (2009). The choice of baseline is critical in determining the costs; use of a baseline which included recently implemented policies would actually show a negative cost of the EU ETS, as the UK is expected to be a large net seller of allowances once these policies have been introduced.

37 New policy since the Low Carbon Transition Plan.

38 There are no fossil fuel price sensitivities, as energy savings are not a significant component of the costs and benefits.

39 Range of costs reflects the varying complexities of projects, in particular variations in the cost of land.

40 An approximate adjustment has been made to the large-scale (mainly RO) net present values (NPVs) and costs per tonne of carbon saved to avoid double-counting with the small-scale renewable electricity data also given in this table. This adjustment was made on the basis of estimated small-scale generation, and does not take into account the generally higher unit costs of small-scale renewable electricity compared with large-scale renewable electricity. It is therefore likely to slightly overestimate the large-scale (mainly RO) renewable electricity costs.

41 The RHI figures in this annex have not been updated to reflect the most recent changes to policy, Impact Assessment, including the change of large biomass tariff as a result of EU ruling, meaning that they differ from the RHI IA published in Q4 2011.

42 Transport costs include technology costs associated with improved fuel efficiency and costs associated with the rebound effect (the additional kilometres driven as the fuel cost of driving decreases with improved efficiency), including congestion, accidents, noise, infrastructure and air quality. Costs for rail electrification include operating costs.

Table B5: Net present value of policy by measure, excluding value of non-traded emissions (£ million 2011) *(continued)*

Policy	Central fossil fuel prices	Low fossil fuel prices	High fossil fuel prices
Energy efficiency policies			
Carbon Reduction Commitment	1,690	n/a	
Climate Change Agreements (CCAs)[43]	0	n/a	
Community Energy Saving Programme[44]	110	n/a	
Carbon Emissions Reduction Target (CERT)	12,970	8,780	21,140
CERT extension	6,950	3,960	11,940
Energy Company Obligation (ECO) and Domestic Green Deal	1,897	−3,658	6,839
Non-Domestic Green Deal	1,320	530	1,900
Building Regulations 2010 Part L[45]	13,550	n/a	
Zero Carbon Homes	−2,090	−2,510	−1,690
Smart Metering (households)[46]	−4,510	n/a	
Smart Metering (small and medium-sized enterprises (SMEs))[47]	−1,820	n/a	
Energy Performance of Buildings Directive[48]	−830	n/a	
Products Policy (Tranche 1)	11,080	n/a	
Products Policy (Tranche 2)[49]	5,450	n/a	
Carbon Trust[50]	1,040	n/a	
Total	**48,110**	**n/a**	
Agriculture			
Voluntary Action Plan[51] (England only)	6,110 (6,410 to 4,890)[52]	n/a	
Total[53]	**−9 billion**	**−82 billion**	**45 billion**

Source: Consolidation of individual policy cost benefit analysis, drawing on evidence from the Department for Transport, the Department for Environment, Food and Rural Affairs and the Department for Communities and Local Government

43 Energy intensive business package in LCTP. Net costs have been re-estimated at zero, as CCAs are considered to not incentivise additional abatement beyond the revised baseline.

44 Not updated since the LCTP.

45 This analysis is from the implementation stage of the Impact Assessment (www.communities.gov.uk/publications/planningandbuilding/partlf2010ia) and was based on the December 2008 DECC/HMT GHG Appraisal Guidance. While energy and carbon values have been updated using values published in 2009, these are not consistent with the 2011 values used in most of the policy assessments presented here. The Impact Assessment included benefits in its NPV calculation from the avoided cost of renewables. This benefit has been removed in the numbers presented here for consistency with other policy NPVs.

46 All Smart Metering (household) figures in this document are based on the latest published Impact Assessment, available at: www.decc.gov.uk/assets/decc/11/consultation/smart-metering-imp-prog/2549-smart-meter-rollout-domestic-ia-180811.pdf

47 All Smart Metering (SMEs) figures in this document are based on the latest published Impact Assessment, available at: www.decc.gov.uk/assets/decc/11/consultation/smart-metering-imp-prog/2550-smip-rollout-small-and-med-non-dom.pdf

48 See: www.communities.gov.uk/archived/publications/planningandbuilding/regulatoryimpactenergyperformanc

49 New policy since the LCTP.

50 Carbon Future, Salix and Interest Free loans are not included.

51 No fossil fuel price sensitivities are included as energy savings are not a significant component of net costs.

52 There is sensitivity about non-GHG costs and benefits, given high uncertainties in this area.

53 Where figures from published Impact Assessments have been listed in the table, an adjustment factor has been applied in order to ensure that all policies are incorporated into the total figure on a consistent basis.

B2.23 The full net present value of the policies delivering emissions reductions in the non-traded sector are shown below – where GHG reductions in the non-traded sector have been valued using the Department of Energy and Climate Change's non-traded price of carbon, part of the Government's revised carbon valuation methodology published in July 2009.[54] Table B6 also shows the cost per tonne of GHG abatement delivered.

Table B6: Net present value and cost effectiveness of non-traded sector policies by measure (£ million 2011)[55]

Policy (positive = benefit)	Net present value (£ million)	Cost effectiveness (£/tCO_2e non-traded)
Transport		
8% of transport fuel from renewable sources by 2020	820	0
EU new car average fuel efficiency standards – CO_2 mid-term target (130gCO_2/km)	14,310	−136
Additional impact of further new car efficiency improvements to 95g/km	−13,870	118
EU new van CO_2 regulations	1,440	−6
Low carbon emissions buses	1,430	−73
EU new car complementary measures	−2,380	108
Local Sustainable Transport Fund (LSTF)	1,810	−224
HGV low rolling resistance tyres	1,540	−110
Industry-led action to improve HGV efficiencies	2,330	−122
Rail electrification	2,880	−202
Energy efficiency policies		
Renewable Heat Incentive (RHI)[56]	2,450	26
Carbon Reduction Commitment	2,750	−71
Climate Change Agreements (CCAs)[57]	n/a	n/a
Community Energy Saving Programme	170	−90
Carbon Emissions Reduction Target (CERT)	16,870	−163
CERT extension	9,830	−118
Energy Company Obligation (ECO) and Domestic Green Deal	6,430	−20
Non-Domestic Green Deal	2,140	−74
Building Regulations 2010 Part L	20,380	−74
Zero Carbon Homes	−660	68
Smart Metering (households)[58]	5,200	−304

[54] See: www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/valuation/valuation.aspx

[55] Values have been rounded to the nearest £10 million.

[56] See footnote 41.

[57] See footnote 43.

[58] All Smart Metering (household) figures in this document are based on the latest published Impact Assessment, available at: www.decc.gov.uk/assets/decc/11/consultation/smart-metering-imp-prog/2549-smart-meter-rollout-domestic-ia-180811.pdf

Table B6: Net present value and cost effectiveness of non-traded sector policies by measure (£ million 2011) *(continued)*

Policy	Net present value (£ million)	Cost effectiveness (£/tCO_2e non-traded)
Smart Metering (SMEs)[59]	2,280	−211
Energy Performance of Buildings Directive	−380	85
Products Policy (Tranche 1)	10,140	n/a
Products Policy (Tranche 2)	5,500	n/a
Carbon Trust[60]	1,240	−181[61]
Agriculture		
Voluntary Action Plan (England only)	7,570	−181
Total (non-traded sector only)[62]	**101 billion**	–

Changes since the last assessment

B2.24 The Low Carbon Transition Plan (LCTP)[63] in 2009 estimated the net cost of delivering the first three carbon budgets at £28–34 billion (£2011 prices),[64] significantly higher than the updated estimate of £9 billion presented in this report. This reduction in net costs is predominantly driven by the inclusion of new policies since 2009 that deliver significant net benefits. These include:

- **Building Regulations 2010 Part L:** The Building Regulations typically apply at original point of build, subsequent conversion and renovation, and on replacement of specified fixed components and systems. Part L of the Building Regulations sets requirements for the conservation of fuel and power on a technology-neutral basis, helping to encourage the take-up and innovation of more energy efficient and low carbon technologies. For more details on Building Regulations, see the Planning Portal website.[65]

- **Products Policy extension (Tranche 2):** Tranche 2 refers to a number of minimum energy efficiency standards that are in the process of being agreed at European level that will provide a stream of energy and emissions savings and other related benefits. Examples of items affected by these measures are household and non-domestic ICT, household tumble dryers, commercial refrigeration and non-domestic air conditioning.

- **Voluntary Action Plan for agriculture:** The Voluntary Action Plan (VAP) is being taken forward by the Climate Change Taskforce and is an industry-led partnership that is working with sector bodies and farmers to improve the GHG performance of English agriculture. The VAP is expected to deliver cost effective abatement from English agriculture over the third and fourth carbon budgets.

[59] All Smart Metering (SMEs) figures in this document are based on the latest published Impact Assessment, available at: www.decc.gov.uk/assets/decc/11/consultation/smart-metering-imp-prog/2550-smip-rollout-small-and-med-non-dom.pdf

[60] Carbon Future, Salix and Interest Free loans are not included.

[61] This refers to the lifetime impact of savings implemented in 2010/11 (latest data available).

[62] Where figures from published Impact Assessments have been listed in the table, an adjustment factor has been applied in order to ensure that all policies are incorporated into the total figure on a consistent basis.

[63] DECC (2009) *The UK Low Carbon Transition Plan*. Available at: www.decc.gov.uk/en/content/cms/tackling/carbon_plan/lctp.aspx

[64] A figure of £25–29 billion (£ 2009 prices) was published in the LCTP as the net cost of delivering the first three carbon budgets. The comparable present value of the same policy package is £28–34 billion. This represents an increase of 14% and reflects two adjustments: a nominal cost increase of 6% from 2009 based on HM Treasury's GDP deflator; and an uplift from 2009 present values of 7% based on the Green Book discount rate.

[65] www.planningportal.gov.uk/buildingregulations/approveddocuments/partl/

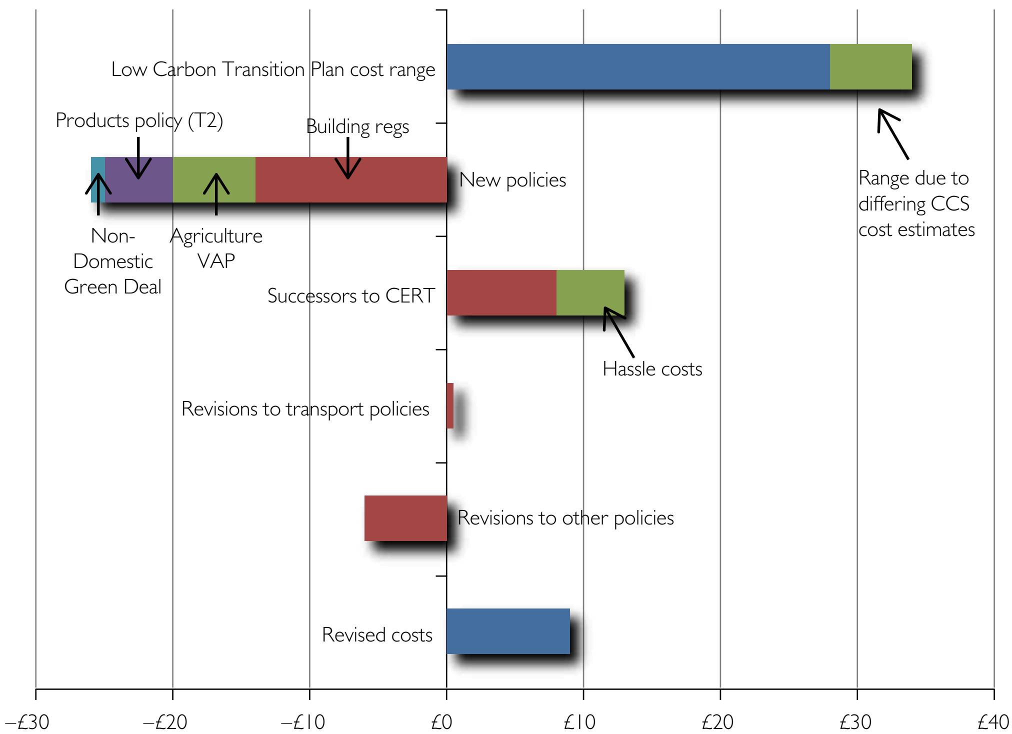
- **Non-Domestic Green Deal:** As with the Domestic Green Deal, this provides a finance mechanism for investment in energy efficiency measures with no upfront cost to the consumer. Measures are paid for by charges that are attached to energy bills. A supporting regulation in the non-domestic private rented sector would require buildings with an Energy Performance Certificate (EPC) rating of G or F to install cost effective energy efficiency measures to move to an EPC rating of E.

B2.25 The benefits from these policies have the effect of offsetting increased costs elsewhere. For example, improvements to the appraisal methodology used for the Energy Company Obligation (ECO) and Domestic Green Deal have led to the inclusion of assessment, financing and 'hassle' costs.[66] The monetisation of these costs and new cost estimates for the measures themselves have pushed up the cost figures. Chart B4 illustrates some of the key changes to the net cost figures since the estimates that were provided in the LCTP.

B2.26 There have been a number of other changes to modelling and cost–benefit analysis that have affected the emissions savings and cost estimates of policies, namely:

- there have been a number of significant updates to key input assumptions for policy cost–benefit analysis (e.g. fossil fuel prices, GDP growth assumptions) and, where possible, all policies have been reappraised in line with these updated assumptions; and
- there have also been revisions to input assumptions in respect of individual sectors such as transport. For instance, the analysis assumes that biofuels will make up 8% of transport energy in 2020, rather than 10% as previously assumed. The change of assumption is made for purely analytical reasons and is not intended to pre-empt policy decisions on biofuel use in road transport fuel beyond 2014. It is consistent with the Committee on Climate Change's recommendation for biofuel use in 2020. The change in modelling assumption leads to lower savings from biofuel than have previously been estimated.

Chart B4: Changes to the total net present value of policy, excluding the value of non-traded emissions, since the Low Carbon Transition Plan (£ million 2011)



[66] Revised methodology based on research commissioned by DECC in 2009 that highlighted the real and substantial time and financial costs associated with domestic energy efficiency and carbon saving measures. These were excluded from the previous appraisal methodology. See ECOFYS (2009) *The hidden costs and benefits of domestic energy efficiency and carbon saving measures*, ECOFYS, May 2009.

Policy cost effectiveness

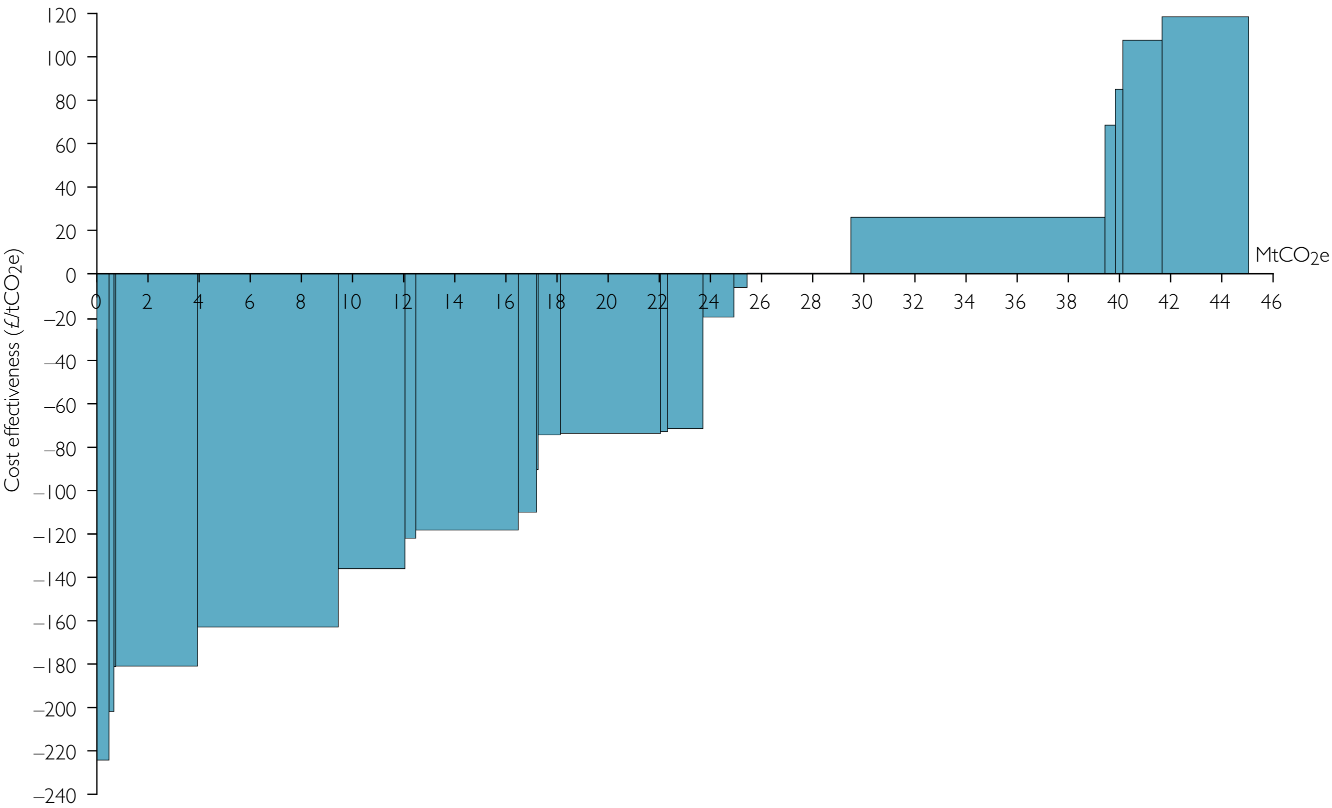
B2.27 The policy marginal abatement cost (MAC) curve set out in chart B5 provides a static 'snapshot' of the potential emissions reductions and average costs in 2020 of government policies to deliver the first three carbon budgets in the non-traded sector (each policy being represented by its own bar).

B2.28 MAC curves provide a useful tool for comparing the cost effectiveness of policies by ranking them in order of cost per tonne of CO_2e saved,[67] such that measures below the horizontal axis indicate negative costs or savings to society and measures above the horizontal axis indicate costs to society.

B2.29 The cost effectiveness figure for each of the policies represents the cost effectiveness of the whole policy per tonne of abatement in the non-traded sector. Where the policy has an impact in the traded sector, the costs and benefits of this impact are included in the cost effectiveness calculation.

B2.30 It must be remembered that MAC curves are sensitive to input assumptions and that policies reflected in them may not monetise all costs and benefits associated with each policy. This will inevitably result in the cost effectiveness of policies changing as input assumptions change.

Chart B5: Non-traded emissions policy marginal abatement cost curve, 2020



Key

0.0 – 0.5	Local Sustainable Transport Fund
0.5 – 0.7	Rail electrification
0.7 – 0.7	Carbon Trust
0.7 – 3.9	Agriculture Voluntary Action Plan
3.9 – 9.4	Carbon Emissions Reduction Target (CERT)
9.4 – 12.2	EU new car average fuel efficiency standards (130 gCO_2/km)
12.2 – 12.7	HGV technology measures
12.7 – 16.7	CERT extension
16.7 – 17.4	HGV low rolling resistance tyres
17.4 – 17.5	Community Energy Savings Programme
17.5 – 18.3	Non-Domestic Green Deal
18.3 – 22.2	Building Regulations 2010 part L
22.2 – 22.5	Low carbon emission buses
22.5 – 23.9	Carbon Reduction Commitment
23.9 – 25.1	Energy Company Obligation (ECO) and Domestic Green Deal
25.1 – 25.7	EU new van CO_2 regulation
25.7 – 30.0	8% transport fuel from renewable sources by 2020
30.0 – 40.0	Renewable Heat Incentive
40.0 – 40.4	Zero Carbon Homes
40.4 – 40.7	Energy Performance of Buildings Directive
40.7 – 42.2	EU new car complementary measures
42.2 – 45.8	Further new car efficiency improvements to 95 gCO_2/km

[67] Further information on the cost effectiveness methodology is available at: www.decc.gov.uk/en/content/cms/about/ec_social_res/iag_guidance/iag_guidance.aspx

B3. Potential for the fourth carbon budget

Additional abatement potential

B3.1 As indicated above, on a net UK carbon account basis, the shortfall to the fourth budget of 1,950 $MtCO_2e$ is projected to be around 181 $MtCO_2e$. This shortfall is in the non-traded sector, as the UK's traded sector emissions will be determined by the EU Emissions Trading System cap.

B3.2 This means that additional effort beyond current policy is required to meet the fourth carbon budget. An economy-wide UK marginal abatement cost (MAC) curve evidence base has been developed to investigate potential sources of additional abatement. It consolidates information on abatement potential through various technology measures over the fourth budget period, and the associated cost effectiveness of these measures. See box B3 for further information on the UK MAC curves evidence base.

B3.3 Abatement opportunities have been assessed by considering varying levels of abatement potential over the period for each sector, and do not consider the policy mechanisms through which abatement could be delivered. Assumptions about the feasible roll-out, emissions savings and costs of these technologies have been made to produce scenarios of potential abatement.

B3.4 The evidence base includes abatement opportunities through energy efficiency measures and low carbon heat technologies in the residential, services and industry sectors; abatement technologies in domestic and commercial transport; and abatement opportunities in agriculture. Although some consideration has been given to further abatement potential through small-scale electricity generation, and through abatement in the land use, land use change, forestry and waste sectors, scenarios of abatement have not been assessed for these measures.

Box B3: UK MAC curves evidence base

The Government's UK MAC curves evidence base contains information on the abatement potential, cost and cost effectiveness of measures to reduce emissions over the fourth budget period. This information was consolidated across a range of models and sources as set out below.

- **Residential energy efficiency in existing buildings**

Scenarios for abatement potential in the domestic housing stock have been modelled in econometric work supporting the Impact Assessment of the Green Deal consultation. Analysis incorporated findings from consumer research to differentiate between abatement potential across different segments of the domestic housing stock, and modelling reflected updated information on the trajectories of supply capacity and costs.

- **Services energy efficiency in existing buildings**

Data from the Valuation Office Agency gives the number and rateable value of buildings by sector in the year 2010, to a substantial level of disaggregation. The scale of abatement potential from Green Deal eligible measures is estimated using the National Non-Domestic Buildings Energy and Emissions Model (N-DEEM), together with technology penetration rates as estimated by consultants Element Energy. This potential is then adjusted for take-up brought about by other, non-Green Deal policies, based on projected policy savings that are derived from the Department of Energy and Climate Change energy model. A decision tree is used to determine the process of moving towards a decision to take out a Green Deal.

Box B3: UK MAC curves evidence base *(continued)*

A review and update of the evidence base on non-domestic energy efficiency is planned. An initial pilot to determine an appropriate methodology, using the food and mixed retail sector as a test case, should be complete in spring 2012. A full economy-wide study may be launched shortly afterwards.

- **Services and residential energy efficiency in new buildings**

The cost effectiveness information for new buildings is based on evidence published in the *Implementation Stage Impact Assessment of revisions to Part L of the Building Regulations*, published in March 2010.[68]

- **Industrial process efficiency and carbon capture and storage (CCS)**

Abatement potential from industrial processes and further energy efficiency improvements has been derived from four principal sources:

- The Energy End-Use Simulation Model (ENUSIM) is a technology based, bottom-up industrial energy end-use simulation model which projects the uptake of energy-saving and/or fuel-switching technologies taking into account the cost effectiveness of technology options under future carbon and fossil fuel prices.[69]
- Further detail on future abatement potential has been derived from work undertaken by AEA Technology. The major sources of abatement covered within this work focus on six major sectors: cement, refineries, glass, chemicals, food and drink, and iron and steel.[70]
- The Department of Energy and Climate Change commissioned further analysis to assess abatement potential beyond that considered in the AEA work. This project is based on top-down energy and abatement projections for 17 wider groups of manufacturing.
- In addition, the Department of Energy and Climate Change has undertaken further modelling analysis to estimate abatement from the uptake of low carbon heat and the initial deployment of CCS.[71]

- **Low carbon heat in residential, services and industry**

Scenarios for low carbon heat have been modelled using the detailed cost effectiveness model developed for the Committee on Climate Change by consultants NERA and AEA. This model looks at the potential for low carbon heat technologies to replace fossil fuel use up to 2030. The model has drawn upon and extended the evidence base used for previous low carbon heat modelling in the Department of Energy and Climate Change, and includes technology assumptions and input data that have been extended to 2030. Additional technologies have been incorporated to reflect a wider range of possible future developments (e.g. synthetic biogas from the gasification of biomass, and heat pumps with heat storage that can shift electricity load profiles).

[68] See: www.communities.gov.uk/publications/planningandbuilding/partlf2010ia

[69] See: http://downloads.theccc.org.uk/AEAUpdateofUKabatementtCh6.pdf

[70] See: www.aeat.com/cms/assets/Documents/Final-Report-CCC.pdf

[71] Element Energy (2010) *Potential for the Application of CCS to UK Industry and Natural Gas Power Generation*, Report for the Committee on Climate Change, Final Report, Issue 3.

Box B3: UK MAC curves evidence base *(continued)*

- **Transport**

Scenarios for transport abatement potential in the 2020s have been developed reflecting research and evidence on possible uptake rates and the costs for new technologies; and through consultation with industry.

The Department for Transport's National Transport Model (NTM) has been used to assess the emissions savings that the measures could deliver, with off-model adjustments made to reflect the impact of an illustrative technology mix of plug-in vehicles. The NTM also provides the changes in vehicle kilometres driven; fuel consumption; air quality and congestion associated with the measures and that are used in the cost–benefit analysis of the measures.

- **Agriculture**

There is considerable uncertainty over estimates of emissions from the agricultural sector due to the complex nature of the biological systems that are the source of greenhouse gas emissions from the sector. External research, based on detailed assessment of on-farm measures, has, however, identified cost effective abatement potential from the sector – i.e. it reduces farmer costs.[72] The voluntary action plan being taken forward by industry is expected to deliver annual savings of around 3 $MtCO_2e$ from English agriculture by 2020. These are expected to be delivered from measures that improve crop nutrient, livestock breeding, feeding and manure management practices.

The Department for Environment, Food and Rural Affairs, in collaboration with the Devolved Administrations, has an extensive research programme that will help to deliver an improved agricultural inventory. This research will help to reduce the uncertainties over the current inventory and potentially support identification of further mitigation potential from the sector.

B3.5 To assess potential abatement it is necessary to project emissions forward, making assumptions about the level and source of emissions, and the possible abatement technologies available. There is significant uncertainty around the level of emissions and abatement potential available owing, among other things, to uncertainties over how technologies may develop, as well as public acceptance of new technologies. Further information on uncertainty in the analysis of marginal abatement costs is set out in the *Impact Assessment of Fourth Carbon Budget Level*.[73]

B3.6 This uncertainty will also affect the anticipated achievement, costs and cost effectiveness associated with the measures installed. The analysis in this report represents a best estimate of the impacts of measures under central assumptions about underlying fundamentals, such as fossil fuel prices, GDP growth and technology cost assumptions. If these fundamentals change significantly, the emissions impact, costs and cost effectiveness associated with abatement measures could be significantly different.

[72] Scottish Agricultural College (2010) *Review and Update of UK Marginal Abatement Cost Curves for Agriculture*.

[73] DECC (2011) *Impact Assessment of Fourth Carbon Budget Level*. Available at: www.decc.gov.uk/assets/decc/what%20we%20do/a%20low%20carbon%20uk/carbon%20budgets/1685-ia-fourth-carbon-budget-level.pdf

B3.7 The ranges of abatement potential have been assessed accounting for potential overlaps and interdependencies between technology measures. As such, the traded and non-traded sector scenarios are consistent with one another and with the Updated Energy and Emissions Projections baseline published in October 2011.[74]

B3.8 Tables B7 and B8 below set out the range of abatement potential identified for the traded and non-traded sectors (abatement potential in the power sector is considered separately below). These ranges are illustrative, and reflect a judgement on feasible abatement potential in each sector.

Table B7: Range of additional potential abatement in the non-traded sector, 2023–27 ($MtCO_2e$)

	Ambition	2023	2024	2025	2026	2027	Total
Agriculture	–	1.9	3.0	4.0	4.0	4.0	16.9
Residential new build	–	0.4	0.4	0.5	0.5	0.5	2.4
Industrial processes	High	3.2	4.0	4.2	4.2	4.3	19.9
	Low	1.2	1.5	1.6	1.6	1.6	7.6
Low carbon heat (business)	High	1.7	2.2	2.7	3.2	3.7	13.6
	Low	0.7	0.9	1.1	1.2	1.4	5.3
Low carbon heat (industry)	High	3.6	4.6	5.7	6.9	8.0	28.9
	Low	1.2	1.6	2.0	4.9	5.5	15.3
Low carbon heat (public)	High	1.0	1.3	1.6	1.9	2.2	8.0
	Low	0.5	0.6	0.7	0.9	1.0	3.7
Low carbon heat (residential)	High	4.2	6.0	8.0	10.1	12.3	40.7
	Low	0.8	0.9	1.1	1.2	1.3	5.3
Residential retrofit	High	0.5	1.0	1.4	1.9	2.4	7.2
	Low	0.1	0.3	0.4	0.5	0.6	1.9
Services new build	High	0.1	0.1	0.1	0.1	0.1	0.5
	Low	0.1	0.1	0.1	0.1	0.1	0.3
Services retrofit	High	1.2	1.1	1.1	1.1	1.2	5.7
	Low	0.7	0.6	0.6	0.6	0.7	3.2
Transport	High	12.5	14.2	16.1	18.0	20.0	80.8
	Low	4.9	5.1	5.6	6.0	6.4	28.0
Total	High	30.2	38.0	45.5	52.0	58.7	224.3
	Low	12.5	15.0	17.6	21.5	23.3	89.9

[74] DECC (2011) *Updated Energy and Emissions Projections*. Available at: www.decc.gov.uk/assets/decc/11/about-us/economics-social-research/3134-updated-energy-and-emissions-projections-october.pdf

Table B8: Range of additional potential abatement in the traded sector (excluding power sector, 2023–27) ($MtCO_2e$)

	Ambition	2023	2024	2025	2026	2027	Total
Industrial processes	High	6.0	7.4	7.5	7.7	7.9	36.5
	Low	3.9	4.8	4.9	5.2	5.6	24.5
Low carbon heat (industry)	High	3.5	4.1	4.7	6.7	7.4	26.3
	Low	2.3	2.6	2.8	3.2	4.9	15.7
Total	High	9.5	11.5	12.1	14.4	15.3	62.8
	Low	6.2	7.4	7.8	8.4	10.5	40.2

Abatement potential in the power sector

B3.9 In the power sector, analysis for the fourth carbon budget is based on the ongoing Electricity Market Reform (EMR) programme, which aims to undertake fundamental reforms to the electricity market. The section on 'Secure, low carbon electricity' in Part 2 of the main report provides further details on the programme.

B3.10 The quantitative analysis that informed the EMR White Paper and accompanying Impact Assessment (IA)[75] was undertaken using a dynamic model of the British electricity market, developed by consultants Redpoint Energy. This model simulates how investment decisions are made, and the results provide an illustrative narrative to the potential impacts of the options examined.

B3.11 Since the publication of the EMR White Paper and IA, the Department of Energy and Climate Change has updated its projections of fossil fuel and carbon prices, technology costs and electricity demand. The EMR White Paper analysis was modelled to meet a decarbonisation ambition of 100 gCO_2/kilowatt hour (kWh) in 2030. A sensitivity of 50 gCO_2/kWh was also examined. While these aspects remain unchanged, it was also assumed that renewables would increase to a 35% share of generation by 2030 to drive the decarbonisation ambition. The revised approach does not impose a specific renewables target but assumes that low carbon technologies are deployed on the basis of least cost to achieve that illustrative decarbonisation ambition. In light of the revisions to input assumptions and methodology, the analysis underpinning the lead EMR package, i.e. Feed-in Tariffs with Contracts for Difference (FiT CfD, or CfD) with a capacity mechanism, has been updated.

B3.12 The updated analysis shows that a baseline without the EMR has more new gas-fired power stations owing to favourable conditions on profitability for gas-fired compared with coal-fired generation. In addition, a significant percentage of existing coal plant retires (around 2020), the majority of which is also replaced by new gas plants. Moreover, the modelling suggests that the first nuclear plant becomes operational in 2027, with three more new nuclear plants being built by 2030.[76] Renewables capacity to 2030 remains around a similar level to that presented in the EMR White Paper. Under this baseline scenario, the carbon intensity of the power generation sector is 216.74 gCO_2/kWh in 2020, which then falls to 165.96 gCO_2/kWh in 2030 as a result of increased generation from new nuclear, carbon capture and storage (CCS) and wind.

[75] See: www.decc.gov.uk/en/content/cms/legislation/white_papers/emr_wp_2011/emr_wp_2011.aspx

[76] The results reported here differ from those reported in the Department of Energy and Climate Change latest published Updated Energy and Emissions Projections (www.decc.gov.uk/en/content/cms/about/ec_social_res/analytic_projs/en_emis_projs/en_emis_projs.aspx). This is because the Department of Energy and Climate Change emissions model differs from the Redpoint Energy model in the assumptions about how electricity producers behave. In the Department of Energy and Climate Change model, producers behave as if they know what future demand and prices will be (i.e. the model assumes perfect foresight). The model used for EMR analysis takes account of the impact of uncertainty about future returns on decisions made under current market arrangements.

B3.13 As mentioned earlier, the lead EMR proposal was for a FiT CfD with a capacity mechanism (strategic reserve (SR) or capacity market (CM) – the choice to be finalised). The package is also to be implemented alongside an Emissions Performance Standard (EPS).

B3.14 Meeting a decarbonisation ambition of 100 gCO_2/kWh in 2030 with these mechanisms results in more low carbon generation than in the baseline, in the form of new nuclear and biomass, owing to the levels of financial support provided through FiT CfDs. Over the fourth carbon budget period (2023–27) this scenario would reduce UK territorial emissions by around 120 $MtCO_2$ relative to the baseline without EMR.

Decarbonisation with 50 gCO_2/kWh ambitions

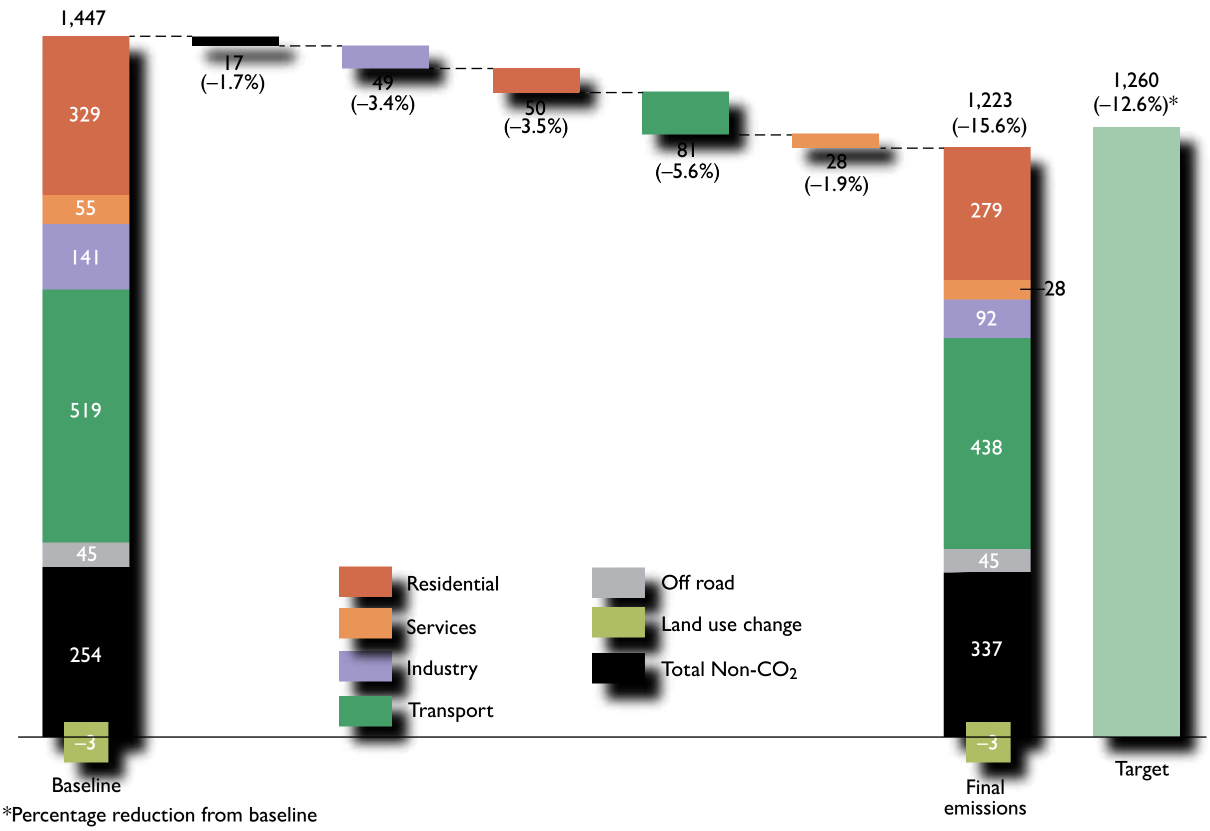
B3.15 This sensitivity is an update to that in the EMR White Paper and examines the implications of following a more stringent decarbonisation pathway on the CfD with SR package.

B3.16 The results show that a more stringent decarbonisation pathway would lead to greater amounts of low carbon generation being incentivised through the CfD mechanism. With central electricity demand assumptions, investment in new nuclear is the same as under the CfD with SR package and is constrained by assumptions related to nuclear plant build rates. However, under this sensitivity there is significant investment in new CCS capacity as well as greater investment in wind and biomass. The introduction of such large quantities of low carbon generation (towards the mid to late 2020s) allows the carbon intensity of the power generation sector to drop to 50 gCO_2/kWh in 2030, compared with 223 gCO_2/kWh in 2020. Over the fourth carbon budget period (2023–27) this scenario would reduce UK territorial emissions by an additional 40 $MtCO_2$ relative to the 100 gCO_2/kWh pathway.

Overview of abatement potential across the economy

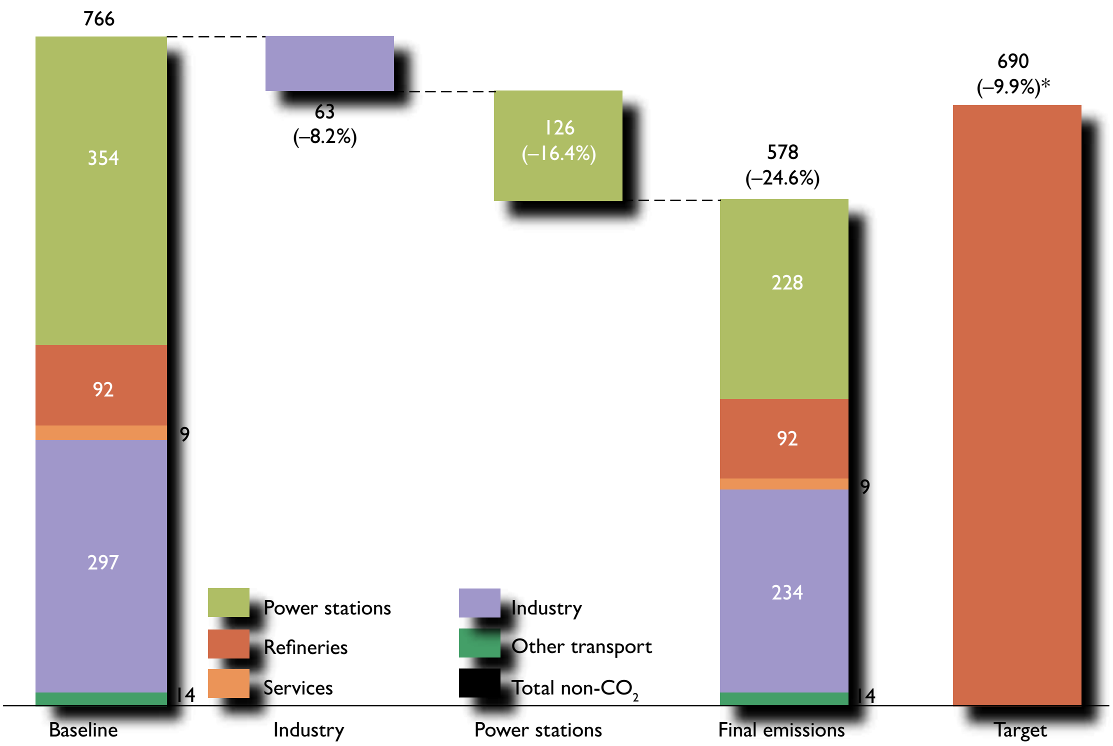
B3.17 A consolidated assessment of the additional abatement potential beyond 2022 indicates that there is sufficient abatement potential to meet the fourth carbon budget. Charts B6 and B7 reflect the highest levels of abatement potential identified in the non-traded and traded sectors.

Chart B6: Total potential abatement identified in the non-traded sector, 2023–27 ($MtCO_2e$)



*Percentage reduction from baseline

Chart B7: Total potential abatement identified in the traded sector, 2023–27 ($MtCO_2e$)



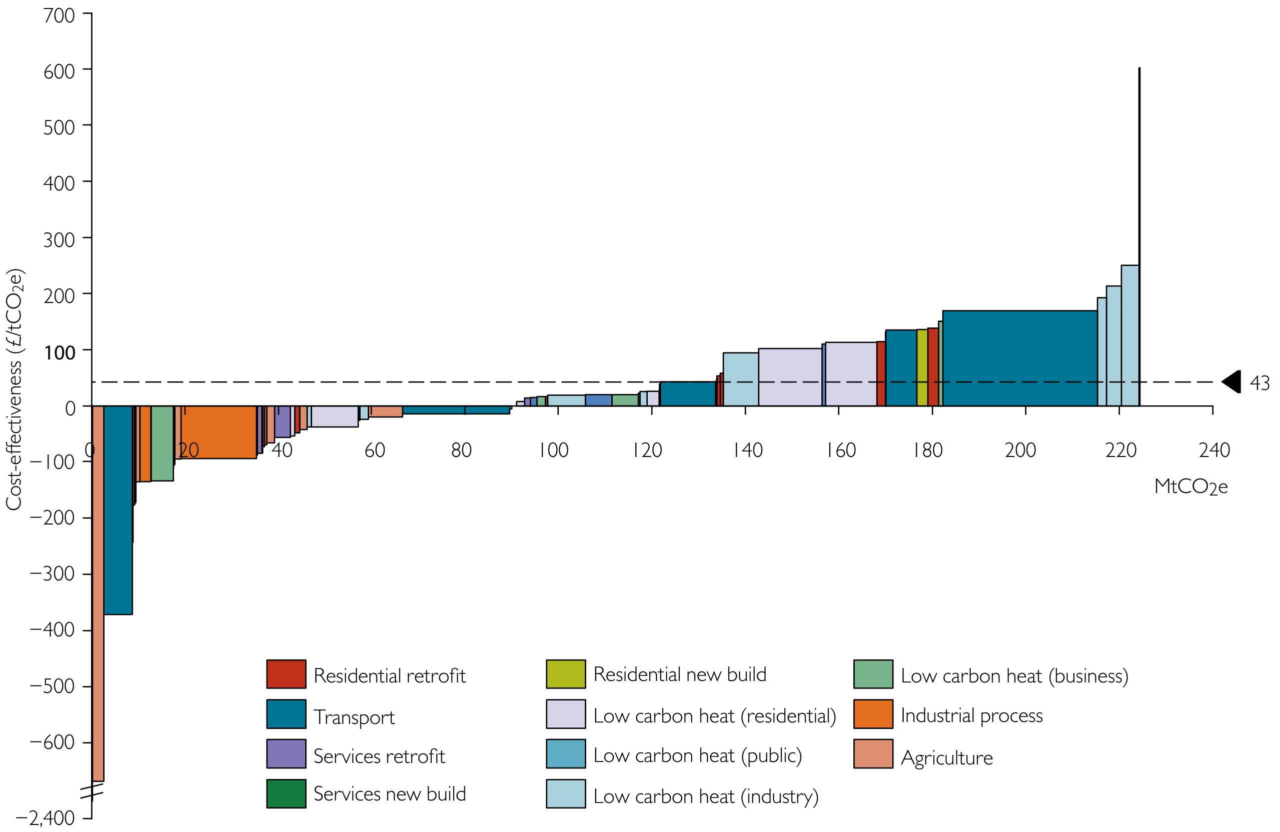
*Percentage reduction from baseline

Cost effectiveness of abatement potential

B3.18 The Government's approach to meeting the fourth carbon budget aims to ensure that we can manage the low carbon transition cost effectively. In order to do so, it has been necessary to consider a wide range of factors that will influence the total cost.

B3.19 Chart B8 reflects all the abatement potential identified in the non-traded sector compared against the weighted average discounted (WAD) carbon price of £43/tCO_2e. See box B4 for an explanation of this metric. Chart B8 also shows the marginal abatement cost (MAC) associated with the identified abatement measures, but has several limitations, which are highlighted in box B5. These limitations have been accounted for in the development of the carbon budget scenarios.

Chart B8: Marginal abatement cost curve of the total potential abatement identified in the non-traded sector, 2023–27 (MtCO_2e)



Box B4: Weighted average discounted (WAD) cost of carbon

The WAD cost of carbon is designed to provide a single carbon value that is reflective of the value of all the greenhouse gas emissions saved by a package of abatement. It is calculated using the Government's standard carbon valuation methodology, in which all emissions savings are valued at the carbon price relevant to the year in which they are realised, and then discounted to get a present value figure. This aggregate value for the present value of emissions saved is then divided by the total number of emissions saved to get the relevant WAD cost of carbon. The cost is weighted, because more weight is effectively given to years in which emissions savings are larger. Consequently, two abatement measures that save the same amount of emissions, but at different times, will have different WAD costs of carbon to reflect the different value of carbon when the savings are expected to be realised. The £43/tCO_2e noted above is the WAD cost of carbon in the non-traded sector discounted to 2011 for each of the non-traded sector scenarios. It can be compared with the cost per tonne saved in order to determine whether or not the scenario package as a whole is cost effective.

Box B5: Limitations of marginal abatement cost (MAC) analysis

While MAC analysis is a useful tool, it does have a number of limitations and needs to be used appropriately.

Cost effectiveness estimates may not reflect non-monetised impacts of abatement opportunities, such as impacts on competitiveness, distributional impacts and impacts on other environmental and social considerations.

The lack of granularity in the analysis may misrepresent individual increments and measures; for example, a relatively cost ineffective block of abatement could include a mix of measures that are cost effective and cost ineffective.

There may be a substantial difference between the costs identified in this analysis, and the policy costs required to deliver this potential for some measures. For example, negative cost abatement measures identified in this analysis are not always fully taken up without policy and government intervention. This may result in costs increasing substantially.

MAC curves are limited in portraying the range of uncertainty surrounding abatement potential and cost effectiveness. There are considerable uncertainties over the development of technologies and their associated costs so far into the future, as well as uncertainties around other key factors such as fossil fuel prices. The estimated abatement potential and cost effectiveness presented in this document are best estimates and are based on assumptions about technology uptake rates and costs that may need to be revised in future. While every attempt has been made to be comprehensive in this analysis, some technical options and savings may be omitted, for example potential opportunities for emissions abatement through forestry, savings from improved landfill methane capture rates and demand reduction measures.

B3.20 In addition to these limitations, MAC curve analysis suffers from an inability to account for the dynamic impact of different abatement options. The cost of each measure is a single number and cannot reflect how the cost of different technologies is likely to evolve with different levels of take-up over time. It is also limited in reflecting interdependencies across measures, both within and across different sectors.

B3.21 MAC curves also fail to account for the lead-in time necessary to implement various technologies or measures and so are limited in informing decisions on the optimal timing of different abatement options. In considering levels of action in the period 2023–27 therefore, government needs to combine information from static comparisons of cost effectiveness with a consideration of the dynamic cost efficiency of different implementation timescales. Fundamentally, it must consider how the timing and scale of implementation affects the evolution of costs, and ensure that sufficient cost effective abatement is made available in future decades to meets its 2050 target.

B3.22 Investment in the research, development and demonstration of emerging low carbon technologies is likely to be crucial in ensuring the availability of key technologies, such as carbon capture and storage. It is also important in developing new, enabling technologies, such as in heat and electricity storage, and for bringing down the costs of low carbon technologies that reach the deployment stage. As well as incentivising early-stage investment, market-pull policies can enable/accelerate deployment and dramatically bring down the costs of emerging technologies. This suggests that there is a case for pushing the development and deployment of technologies before they are considered statically cost effective (i.e. cost effective in a given year). The rationale for this is that by doing so, the costs of the technology could be reduced in future periods through learning-by-doing or induced innovation, and that their availability could be increased through the development of the supply chain.

B3.23 This approach could apply to a range of critical technologies, for instance heat pumps and low carbon vehicles. Additionally, although some relatively low carbon technologies may be useful for decarbonising over the next few decades, they may not satisfy longer-term abatement needs in a least-cost pathway to 2050.

B3.24 Uncertainty over the future structure of the economy, future technology costs, technical performance and dynamic interactions within the economy make it difficult to determine today a least-cost/maximum-benefit pathway to 2050. Consequently, it may be beneficial to adopt a diverse range of measures in order to mitigate the risk that some of these currently immature technologies do not work as expected or that viable alternative/substitute technologies become available in the future. This approach is advocated by the Committee on Climate Change and cited in their recommendations in chapter 3 of their report,[77] where they emphasise the importance of flexibility and of keeping a range of abatement scenarios in play. The option value of a diverse range of measures has to be balanced against the cost of developing more solutions and the risk of diverting resources from the right technology families to the wrong technology families on the basis of flawed information.

B3.25 In light of these factors, government has sought to develop options that meet the fourth carbon budget cost effectively while still leaving open probable least-cost options to meet the 2050 target. This additional constraint can suggest the need to use abatement measures that might not be cost effective considering the fourth carbon budget target alone, but should nevertheless support a more efficient transition to the 2050 goal.

[77] Committee on Climate Change (2010) *The Fourth Carbon Budget: Reducing emissions through the 2020s*. Available at: www.theccc.org.uk/reports/fourth-carbon-budget

Scenarios to deliver the fourth carbon budget

B3.26 Part 3 of the main report set out illustrative scenarios for how the additional emissions reductions to meet the fourth carbon budget could be delivered. These scenarios were developed using evidence on the abatement potential and cost effectiveness identified and with regard to the Government's desire to encourage a portfolio of technologies. Consequently, the fourth carbon budget scenarios have been developed taking into account a number of factors:

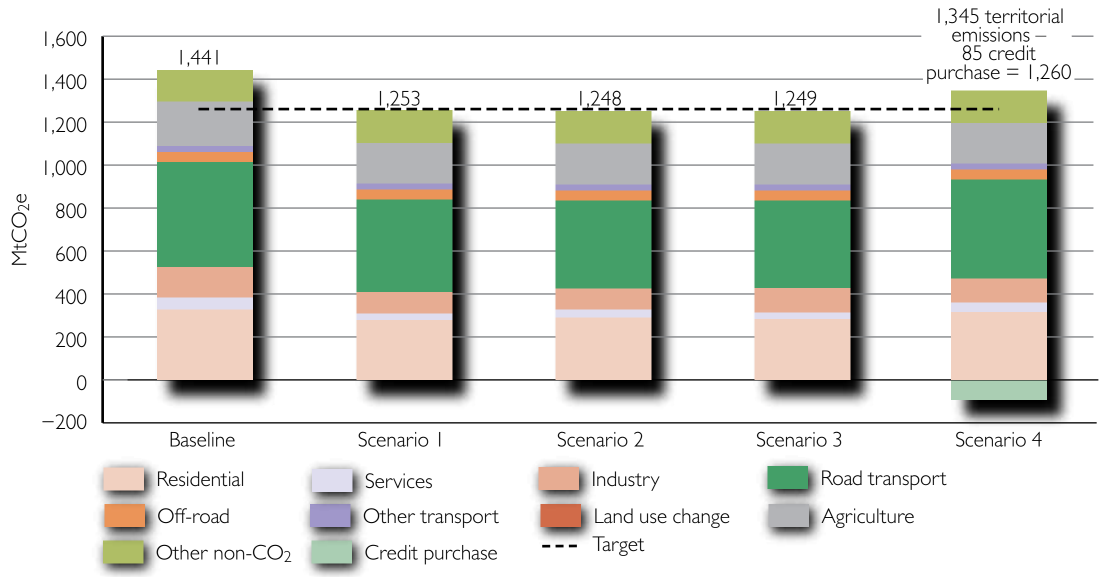
- static cost effectiveness – comparing the estimated cost of a measure with the forecast carbon price for the same time period;
- dynamic cost effectiveness – considering what action needs to be taken in the fourth budget period to be on track to meet the 2050 target in the most cost effective way;
- technical feasibility – taking account of likely technological development and necessary build rates; and
- practical deliverability and public acceptability – considering potential barriers to delivery.

B3.27 These illustrative scenarios focus on the sectors that are key to achieving the 2050 target in a cost effective way and offer the greatest potential for emissions reductions over the fourth carbon budget period, although these scenarios do not directly link to any specific 2050 future set out in Part 1. This section provides detail on the composition of these scenarios in the non-traded and traded sectors separately before considering the cross-economy implications and wider impacts of the different scenarios.

Delivering emissions reductions in the non-traded sector

B3.28 The four scenarios for the non-traded sector illustrate different ways in which emissions could be reduced to 1,260 $MtCO_2e$, the level of emissions required in the non-traded sector over the fourth carbon budget period to meet the overall 1,950 $MtCO_2e$ level. Chart B9 shows greenhouse gas emissions under each scenario and the contribution from different sectors.

Chart B9: Aggregate non-traded emissions under the illustrative scenarios to meet the fourth carbon budget, 2023–27



Scenario 1: High abatement in low carbon heat

B3.29 Under this scenario, emissions over the fourth carbon budget period would be reduced to 1,253 $MtCO_2e$ in the non-traded sector. The table below summarises the key components of this scenario.

Table B9: Expected activity under illustrative Scenario 1

Sector	Expected activity
Buildings	• 3.7 million solid walls insulated over the period 2023–30 • 8.6 million low carbon heat installations in total by 2030, delivering around 165.5 terawatt hours (TWh) of low carbon heat and a further 38.6 TWh from district heating
Transport	• Average new car emissions = 60 gCO_2/km in 2030 • Average new van emissions = 90 gCO_2/km in 2030 • 8% biofuel, by energy • 5% heavy goods vehicle (HGV) efficiency improvement over five years
Industry	• All 'realistic' and some further cost effective measures, including whole-refinery optimisation in the refineries sub-sector, clinker substitution in the cement sector and increased recycling in iron and steel • Committee on Climate Change's central scenario of industrial carbon capture and storage • 44,000 additional low carbon heat installations in industry by 2030, delivering around 95 TWh of low carbon heat in industry
Agriculture	• On-farm measures such as improved management of nutrients (excluding introducing new species), improved soil drainage, anaerobic digestion, livestock breeding and livestock diet and health measures • Woodland creation rates across the UK are assumed to increase, maintaining the sector as a sink and providing about 1 $MtCO_2e$ abatement in the fourth budget period over and above current planting rates

Detail

B3.30 This scenario envisages very significant levels of low carbon heat in buildings and significant improvements in the thermal efficiency of buildings. For example, we might need as much as 166.5 TWh of low carbon heat from more than 8.6 million low carbon heat installations by 2030 (cumulative total, including low carbon heat delivered prior to the fourth carbon budget). The majority of these installations are likely to be heat pumps, with low carbon heat also coming from biomass boilers. District heating will contribute a further 38.6 TWh.

B3.31 In terms of thermal efficiency, this scenario assumes that most cavity and loft insulations have been completed by 2020. It also assumes that a high number of properties with solid walls (as opposed to cavity walls) are insulated, with 3.7 million insulations being carried out by 2030, in addition to the up to 1.5 million by 2020 that we expect from current policy. Elsewhere in buildings, it is assumed that the zero carbon homes standard is met in 2016 and 2019 for the residential and business sectors respectively. In the business sector, cost effective energy efficiency improvements are made to buildings. This scenario also envisages high ambition on low carbon heat in industry, mostly from biomass boilers and the use of biogas for combustion.

B3.32 In the transport sector, this scenario assumes that average new car emissions (including conventional combustion engine cars as well as ultra-low emission cars such as battery electric, plug in hybrid and fuel cell electric vehicles) improve to 60 gCO_2/km by 2030 and average new van emissions (again, including conventional vans and ultra-low emission vans) improve to 90 gCO_2/km by 2030. This could be delivered through different mixes of conventional vehicles and ultra-low emission vehicles, such as electric, plug-in hybrid and even hydrogen vehicles. The analysis considers an illustrative technology mix where emissions from conventional cars and vans improve to 80 gCO_2/km and 120 gCO_2/km respectively, and 40% of new cars and vans sold are battery electric, range extended electric or plug-in hybrid vehicles in 2030.[78]

B3.33 This scenario assumes that the proportion of biofuels by energy in the road transport sector remains at 8% through the 2020s. This might reflect a situation where sustainability concerns are not resolved, or where there is relatively little innovation in new feedstocks, or where there is greater uptake of bioenergy in other sectors.

B3.34 Elsewhere in transport, this scenario assumes continuing improvement in HGV efficiencies (a cumulative 5% improvement over each five-year period between 2016 and 2030). It assumes a 2% reduction in car trips in urban areas owing to either continued funding of sustainable travel measures or no diminution of the impacts of the Local Sustainable Transport Fund, as assumed in the baseline for the fourth carbon budget analysis.

B3.35 In addition to the low carbon heat measures mentioned in the summary table, this scenario assumes some initial uptake of carbon capture and storage in industry and energy efficiency improvements such as clinker substitution in cement, elimination of flaring in refineries, reduction in energy consumption during the melting process in glass furnaces, nitrous oxide reduction from nitric acid production in the chemicals sector, increased recycling of steel in the steel sector, and some additional savings through switching to electric arc furnaces.

B3.36 In agriculture we have assumed the take-up of measures such as improved nutrient management (excluding introducing new species), improved soil drainage, anaerobic digestion, improved livestock breeding, and diet and health measures. In forestry, woodland creation rates across the UK are assumed to increase, maintaining the sector as a sink and providing about 1 $MtCO_2e$ abatement in the fourth budget period over and above current planting rates.

[78] There is currently insufficient evidence to include fuel cell vehicles explicitly in the modelling of the illustrative technology mix.

Scenario 2: High abatement in transport and bioenergy demand

B3.37 Under this scenario, emissions over the fourth carbon budget period would be reduced to 1,248 $MtCO_2e$ in the non-traded sector.

Table B10: Expected activity under illustrative Scenario 2

Sector	Expected activity
Buildings	• 3.7 million solid walls insulated over the period 2023–30 • Around 7.2 million low carbon heat installations in total by 2030, delivering around 138.0 TWh of low carbon heat and a further 9.6 TWh from district heating
Transport	• Average new car emissions = 50 gCO_2/km • Average new van emissions = 75 gCO_2/km • 10% biofuel, by energy • 8% HGV efficiency improvement over five years
Industry	As Scenario 1
Agriculture	As Scenario 1

Detail

B3.38 This scenario sees a high uptake of home insulation (specifically solid wall insulation), owing to high consumer acceptance (e.g. hassle factors regarding solid wall insulation are limited), strong policy drivers (e.g. attractive long-term financing options for domestic retrofit) and strong exogenous drivers (e.g. high energy prices). But this scenario illustrates a situation where specific barriers to the uptake of low carbon heat installations are encountered, resulting in a lower number of heat pumps and lower biomass use in buildings than in Scenario 1. The high use of biomass in industry, however, suggests that this is a cost effective use of bioenergy resource in this scenario.

B3.39 This scenario assumes around 138 TWh of low carbon heat from around 7.2 million low carbon heat installations in buildings by 2030 (cumulative total, including low carbon heat delivered prior to the fourth carbon budget). A further 9.6 TWh is provided by district heating. The same level of ambition in non-domestic retrofit measures, and domestic and non-domestic new build, as in Scenario 1 is assumed.

B3.40 To still be able to meet the fourth carbon budget under this scenario, greater fuel efficiency improvements in road transport would be required relative to Scenario 1. Scenario 2 therefore assumes that average new car emmisions (including conventional combustion engine cars as well as ultra-low emission cars such as electric and plug-in hybrid vehicles) improve to 50 gCO_2/km, and average new van emissions (again, including conventional vans and ultra-low emission vans) improve to 75 gCO_2/km. As in Scenario 1, this could be delivered through different mixes of conventional vehicles and ultra-low emission vehicles such as battery electric, range extended electric, plug-in hybrid vehicles and even hydrogen vehicles. The analysis assumes an illustrative technology mix where the emisssions from conventional cars and vans fall to 80 gCO_2/km and 120 gCO_2/km respectively, as in Scenario 1, with battery electric, range extended electric and plug-in hybrid vehicles making up 50% of new car and van sales (compared with 40% in Scenario 1).

B3.41 This scenario assumes that the proportion of biofuels by energy in road transport increases from 8% in 2020 to 10% by 2030. Elsewhere in transport, this scenario assumes that HGV efficiency improves by a cumulative 8% over each five-year period between 2016 and 2030. It also assumes that rail electrification is extended to the Midland Mainline and the Welsh Valleys. There is a 5% reduction in urban car trips, which might be seen if additional funding of sustainable travel measures leads to, for example, learning benefits across local authority borders.

B3.42 As this scenario envisages high ambition in transport biofuels, as well as significant biomass use in industry, it could be considered as a high bioenergy demand scenario and gives a sense of what the maximum demand implications might be. This might reflect constraints around sustainability being overcome and technological innovation that make more advanced feedstocks viable. See paragraphs B4.42–B4.49 of this annex for an assessment of the sustainability of bioenergy supply under the fourth carbon budget scenarios.

Scenario 3: Focus on high electrification

B3.43 Under this scenario, emissions over the fourth carbon budget period would be reduced to 1,249 $MtCO_2e$ in the non-traded sector.

Table B11: Expected activity under illustrative Scenario 3

Sector	Expected activity
Buildings	• 1 million solid walls insulated over the period 2023–30 • 8.6 million low carbon heat installations in total by 2030, delivering around 165.5 TWh of low carbon heat and a further 38.6 TWh from district heating
Transport	• Average new car emissions = 50 gCO_2/km • Average new van emissions = 75 gCO_2/km • 10% biofuel, by energy • 8% HGV efficiency improvement over five years
Industry	• All 'realistic' and some further cost effective measures, including whole-refinery optimisation in the refineries sub-sector, clinker substitution in the cement sector and increased recycling in iron and steel • Committee on Climate Change's central scenario of industrial carbon capture and storage • 22 ,000 additional low carbon heat installations in industry by 2030, delivering around 42 TWh of low carbon heat in industry
Agriculture	As Scenario 1

Detail

B3.44 In low carbon heat the level of ambition in Scenario 1 (8.6 million low carbon heat installations, delivering 165.5 TWh of low carbon heat in buildings by 2030) is assumed. In transport the level of ambition in Scenario 2, 50 gCO_2/km average new car emissions is assumed. Depending on the mix of conventional and ultra-low emission cars in the fleet, this could be delivered by up to 50% of new car and van sales being battery electric or plug-in hybrids.

B3.45 This scenario assumes a lower level of ambition on residential sector retrofit (solid wall insulations) than previous scenarios. This might reflect specific consumer barriers to taking up insulation of solid walls, such as a lack of financing options. It assumes 1 million insulations being carried out by 2030, in addition to the almost 1.5 million expected by 2020 under current policy.

Scenario 4: Purchase of international credits

B3.46 Under this scenario, emissions over the fourth carbon budget period would be reduced to 1,345 $MtCO_2e$ in the non-traded sector. The Government would therefore need to purchase around 85 $MtCO_2e$ worth of carbon credits. At the forecast carbon price of £51 tCO_2e (£ 2011, undiscounted) on average over the fourth carbon budget period, this would cost the Government £2.7 billion in present value terms. In this scenario, both transport and low carbon heat are assumed to deliver levels of emissions reductions that are at the lower end of the ranges described in Part 2. This will necessitate faster levels of technology uptake beyond 2030, and more detail is given in the relevant sections of Part 2.

B3.47 This scenario assumes 3 million solid wall insulations over the fourth carbon budget period. The level of ambition in sectors other than transport and buildings is as in Scenarios 1, 2 and 3.

Table B12: Expected activity under illustrative Scenario 4

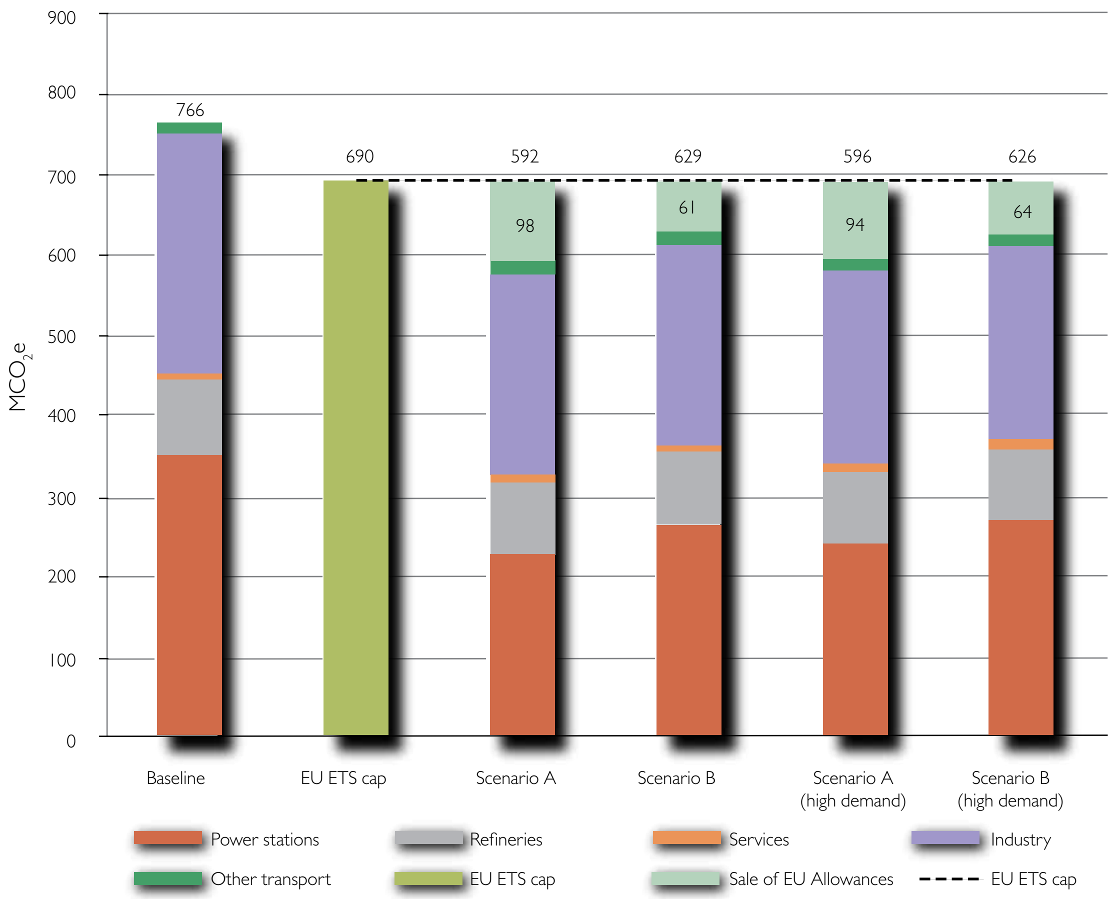
Sector	Expected activity
Buildings	• 3 million solid walls insulated over the period 2023–30 • Around 1.6 million low carbon heat installations in total by 2030, delivering around 83.3 TWh of low carbon heat and a further 9.6 TWh from district heating
Transport	• Average new car emissions = 70 gCO_2/km • Average new van emissions = 105 gCO_2/km • 6% biofuel, by energy
Industry	As Scenario 3
Agriculture	As Scenario 1
Credit purchase	85 million credits at a cost of £2.7 billion

Delivering emissions reductions in the traded sector

B3.48 The level of emissions reductions in the traded sector is dictated by the level of the EU Emissions Trading System (ETS) cap. As set out in paragraphs B3.1–B3.8 above, the trajectory at which the EU ETS cap is currently set to shrink would not be sufficient to deliver the emissions reductions needed in the power and heavy industry sectors to meet a fourth carbon budget of 1,950 $MtCO_2e$. In this respect, the fourth carbon budget was set on the assumption that the EU ETS cap will be tightened in the future.

B3.49 This report considers two illustrative scenarios showing how emissions could be reduced to 690 $MtCO_2e$, the level of traded sector emissions required over the fourth carbon budget period to meet the overall 1,950 $MtCO_2e$ level. Chart B10 below shows by how much each scenario would reduce emissions and the contribution from different sectors. Both scenarios in the traded sector assume that the EU ETS cap is tightened sufficiently to meet the fourth carbon budget. Given the assumed level of the EU ETS cap, however, both scenarios provide an opportunity for EU Allowances (EUAs) to be sold.

Chart B10: Aggregate territorial traded sector emissions under the illustrative traded sector scenarios, 2023–27



Scenario A: Power sector carbon intensity of 50 gCO_2/kWh

B3.50 Under this scenario, emissions over the fourth carbon budget period would fall to either 592 $MtCO_2e$ or 596 $MtCO_2e$ in the traded sector, depending on the level of electricity demand assumed.

B3.51 In this scenario, it is assumed that emissions in the power and heavy industry sectors are reduced sufficiently in the UK to deliver the traded sector component of the fourth carbon budget. This will require significant decarbonisation of the power sector, and in Scenario A the carbon intensity of electricity generation has been modelled to reach 50 gCO_2/kWh by 2030. The power sector section in Part 2 gives more details on the potential implications of this for the generation mix.

B3.52 In the industry sector the same assumptions as in Scenarios 1–4 have been made.

Scenario B: Power sector carbon intensity of 100 gCO_2/kWh

B3.53 In this scenario, emissions in the power and heavy industry sectors are reduced in the UK but with a lower level of decarbonisation in the power sector than assumed in Scenario A. This illustrative scenario assumes that the carbon intensity of electricity generation falls to 100 gCO_2/kWh by 2030. Emissions in this scenario are reduced to either 629 $MtCO_2e$ or 626 $MtCO_2e$ in the traded sector, depending on the level of electricity demand.[79]

B3.54 In the industry sector the same assumptions as in Scenarios 1–4 have been made.

Combined impacts of traded and non-traded sector scenarios

Electricity demand implications

B3.55 The high levels of electrification in heat and transport included in the non-traded sector scenarios imply increased levels of electricity demand to be met by the power sector. For instance, Scenario 3 includes significant electrification of both heat and transport which is partially offset by increases in energy efficiency but still implies a level of electricity demand that is about 10% higher than the current government assumption of approximately 410 TWh in 2030. As a result, sensitivities reflecting high electricity demand have been modelled in both Scenario A (50 gCO_2/kWh) and Scenario B (100 gCO_2/kWh).

Bioenergy demand implications

B3.56 Scenarios reflecting increased abatement in transport, heat and electricity generation imply increased demand for bioenergy. For instance, the demand for biofuels in transport, biomass and biogas for heat and the use of biomass and waste in electricity generation require a consideration of whether sufficient, sustainable supplies of bioenergy will be available. An assessment of current estimates of sustainable bioenergy supply compared with the demand trajectories implied by the fourth carbon budget scenarios is set out in paragraphs B4.42–B4.49 of this annex.

Costs of delivering the fourth carbon budget

B3.57 Delivering the emissions reductions set out in the illustrative fourth carbon budget scenarios will impose costs on the UK economy but will also deliver benefits well beyond the end of the fourth carbon budget period. As discussed above, costs will be determined by the combination of traded and non-traded sector scenarios. On this basis, the net discounted costs of meeting the fourth carbon budget are estimated to range from **£26 billion to £56 billion (excluding the value of greenhouse gas emissions savings)** depending on the choice of ambition in different sectors and the associated electricity demand implications. When the benefits of the carbon savings that will be delivered by the illustrative scenarios are also taken into account, the net present value (NPV) ranges from a **net benefit of £1 billion to a net cost of £20 billion**.

[79] Emissions are lower under high demand owing to higher assumed low carbon heat in the industrial sector.

B3.58 These cost and benefit estimates draw on best available evidence from the UK marginal abatement cost curves evidence base and appropriate values for energy resource costs and carbon benefits as described in the methodological note that begins this annex. The costs include technical costs associated with the abatement measures in each of the scenarios, energy consumption and wider impacts such as air quality, congestion and hidden or hassle costs, where it is possible to monetise these. In the traded sector, the EUA cost of complying with the EU Emissions Trading System is also valued. Since the illustrative scenarios do not include specific policies, this assessment does not include any policy costs associated with the delivery of measures. See charts B13–B18 (pp. 204–207) of this annex for the abatement and cost effectiveness of the measures contained in each of the illustrative scenarios.

B3.59 Costs will vary between scenarios as each one comprises different levels of abatement in the key sectors. Table B13 provides a breakdown of the overall costs and benefits of each illustrative scenario in the non-traded sector of the economy.

B3.60 Scenario 4 delivers the fourth carbon budget at the lowest cost (£27 billion) since the cost of purchasing international credits is cheaper than undertaking further territorial abatement. However, Scenarios 1 and 3 have the highest net present values because of their additional emissions savings.

B3.61 The key driver of the variation in costs between the scenarios is the level of ambition in the transport and low carbon heat sectors. The effects of the different levels of ambition on costs can be counter-intuitive. For example, district heating is only included in the higher ambition scenarios for low carbon heat. District heating is considered ambitious because of a number of barriers to deployment that will need to be addressed. These include planning and consent from local authorities, identifying and matching demand for heat with supply, and raising capital for investment in heat networks. Nevertheless, the network benefits of district heating mean that it is relatively cost effective compared with installing large numbers of heat pumps. For this reason, Scenario 2, which does not include district heating,

Table B13: Emissions levels and NPV of the illustrative non-traded sector scenarios

	Fourth carbon budget emissions ($MtCO_2e$)	Costs (£ billion 2011)				Benefits (£ billion 2011)					
Scenario	Non-traded	Capital	Admin	Other	Credit purchase	Energy savings	EU Allowances savings	Other	Non-traded savings	NPV	Net present cost (excluding the value of greenhouse gas emissions)
1	1,253	−77.6	−1.5	−5.7	–	37.4	−3.0	6.6	41.8	−2.0	−43.8
2	1,248	−79.5	−1.5	−4.6	–	33.0	−2.9	7.3	36.5	−11.7	−48.2
3	1,249	−80.9	−0.5	−0.3	–	37.8	−3.4	5.7	39.3	−2.4	−41.6
4	1,260 (1,345)	−38.2	−1.2	−11.1	−2.7	21.5	−0.1	5.3	19.0	−7.5	−26.5

Table B14: NPV of the illustrative traded sector scenarios, central electricity demand (£ billion 2011)

	Costs		Benefits			
Scenario	Capital	Other	Energy savings	EU Allowances savings	Other	NPV
A (50 gCO_2/kWh)	–31.8	–1.4	11.6	17.5	1.7	–2.5
B (100 gCO_2/kWh)	–23.2	–1.4	8.8	14.6	1.7	0.5

appears to be relatively costly despite its lower level of ambition in low carbon heat.

B3.62 In the traded sector of the economy, the difference in costs between the two illustrative scenarios is driven by the different levels of ambition in the power sector. For instance, decarbonising the power sector to reach a carbon intensity target of 50 gCO_2/kWh by 2030 is more costly – imposing a net cost – than aiming for a target of 100 gCO_2/kWh by 2030, which delivers a small net benefit. Table B14 provides a breakdown of the overall costs and benefits of the traded sector scenarios under a central electricity demand scenario.

B3.63 The high levels of electrification in heat and transport included in the non-traded sector scenarios imply increased levels of electricity demand to be met by the power sector. For instance, Scenario 3 includes significant electrification of both heat and transport which is partially offset by increases in energy efficiency but still implies a level of electricity demand that is about 10% higher than the current government assumption of approximately 410 TWh in 2030. To take account of this impact, sensitivity analysis of the power sector under both Scenarios A and B has been conducted.

B3.64 Table B15 provides a breakdown of the overall costs and benefits of the traded sector scenarios under a high electricity demand scenario. The energy savings shown have been adjusted to avoid the double counting of costs when the traded and non-traded scenarios are combined. For this reason, it is not possible to compare costs of the high electricity demand scenario directly with those of the central electricity demand scenario.

Table B15: NPV of the illustrative traded sector scenarios, high electricity demand (£ billion 2011)

	Costs		Benefits			
Scenario	Capital	Other	Energy savings*	EU Allowances savings	Other	NPV
A (50 gCO_2/kWh)	–38.0	–1.7	11.7	18.4	1.7	–7.9
B (100 gCO_2/kWh)	–28.7	–1.7	16.1	15.6	1.7	3.0

*Adjusted to allow summation with non-traded scenarios

Combined impact of traded and non–traded sector scenarios

B3.65 Scenarios 1–4 in the non-traded sector imply different levels of electricity demand. Consequently, it is important to combine the non-traded and traded sector scenarios so that the electricity demand assumptions are consistent when assessing the whole-economy effects of the illustrative scenarios. For example, Scenario 3, which includes high levels of electrification in heat and transport, has the impact of increasing electricity demand by about 10% in 2030. This scenario is only compatible with traded sector Scenarios A or B under high electricity demand. Levels of electrification in Scenario 4 suggest that Scenarios A or B under central demand would be an appropriate combination. The electricity demand implications for Scenarios 1 and 2 fall between the central and high demand levels shown for the traded sector scenarios and could be consistent with either of the Government's central or high electricity demand assumptions. Consequently, Scenarios 1 and 2 could potentially be combined with Scenarios A or B under either central or high electricity demand. Table B16 reflects the aggregate costs of the fourth carbon budget scenarios under the various appropriate traded and non-traded sector combinations.

Table B16: Cumulative NPV of the illustrative non-traded and traded scenarios (£ billion 2011)

	Net present cost (excluding value of greenhouse gas emissions)	NPV
Central electricity demand		
Scenarios A + 1	−£46bn	−£4bn
Scenarios A + 2	−£51bn	−£14bn
Scenarios A + 4	−£29bn	−£10bn
Scenarios B + 1	−£43bn	−£2bn
Scenarios B + 2	−£48bn	−£11bn
Scenarios B + 4	**−£26bn**	−£7bn
High electricity demand		
Scenarios A + 1	−£52bn	−£10bn
Scenarios A + 2	**−£56bn**	**−£20bn**
Scenarios A + 3	−£49bn	−£10bn
Scenarios B + 1	−£41bn	**+£1bn**
Scenarios B + 2	−£45bn	−£9bn
Scenarios B + 3	−£39bn	+£1bn

*The upper and lower bounds in each column have been highlighted

Uncertainty in cost estimates

B3.66 Cost estimates for all the illustrative scenarios are subject to significant uncertainty given the range of assumptions included about the evolution of future economic growth, fossil fuel prices and technology costs so far into the future.

B3.67 The tables below reflect the results of some limited sensitivity analysis on fossil fuel prices, technology costs and the extent of transport rebound effects and indicate that the overall costs of delivering the fourth carbon budget could vary significantly.

Technology sensitivities

B3.68 In transport, government's central assumption is that battery costs will fall to \$300/kWh by 2030 (from up to \$1,000/kWh reported currently). This contrasts with the Committee on Climate Change (CCC) analysis, which assumed that battery costs in 2030 would be \$200/kWh. Table B17 shows how the NPV of the high transport ambition scenarios would change under different battery cost assumptions.

Table B17: Sensitivity of the NPV estimates to vehicle battery costs (£ billion 2011)

High ambition transport	Low battery costs (\$150/kWh)	High battery costs (\$800/kWh)
Scenario 2 −£12bn NPV	−£3bn	−£45bn
Scenario 3 −£2bn NPV	+£7bn	−£36bn

B3.69 The modelling on the costs and benefits of low carbon heat shown here assumes that heat pumps' coefficient of performance (COP) improves by 0.7 by 2030. This contrasts with the CCC's assumption that the COP will improve by 1.5 by 2030. Table B18 shows how the NPV of Scenario 2 would change under different assumptions. The low improvement sensitivity assumes that the COP improves by no more than 0.1. The high improvement sensitivity assumes that the COP improves by 1.5.

Table B18: Sensitivity of the NPV estimates to improvements in heat pumps' coefficient of performance

Central ambition low carbon heat	Low improvements in heat pump COP	High improvements in heat pump COP
Scenario 2 −£12bn NPV	−£15bn	−£11bn

Fossil fuel price sensitivities

B3.70 Many of the abatement measures included in the illustrative scenarios also reduce the consumption of fossil fuels. This reduction in energy use is valued as a benefit. Given the uncertainty around energy prices, the Department of Energy and Climate Change frequently shows how costs and benefits would differ under different energy price assumptions. Table B19 shows how the NPV of the high transport ambition scenarios would change if different fossil fuel price assumptions were used for the transport analysis.[80] Note that these changes reflect changes to the NPV of the transport measures only. If the effect of different fossil prices were accounted for in all sectors, the change would be significantly larger.

Table B19: Sensitivity of the NPV estimates to the fossil fuel price assumptions used for the transport analysis only (£ billion 2011)

High ambition transport	Low fossil fuel prices	High fossil fuel prices
Scenario 2 −£12bn NPV	−£20bn	−£6bn
Scenario 3 −£2bn NPV	−£10bn	+£4bn

B3.71 Table B20 shows how the NPV of Scenario 2 would change if different fossil fuel price assumptions were used for the low carbon heat analysis. Note that these changes reflect changes to the NPV of the low carbon heat analysis only.

[80] For more information on the Department of Energy and Climate Change's fossil fuel price assumptions see: www.decc.gov.uk/en/content/cms/about/ec_social_res/analytic_projs/ff_prices/ff_prices.aspx

Table B20: Sensitivity of the NPV estimates to the fossil fuel price assumptions used for the low carbon heat analysis only (£ billion 2011)

Central ambition low carbon heat	Low fossil fuel prices	High fossil fuel prices
Scenario 2 −£12bn NPV	−£12bn	−£11bn

B3.72 Table B21 shows how the NPV of Scenario B (central demand) would change if different fossil fuel price assumptions were used for the power sector analysis. Note that these changes reflect changes to the NPV of the power sector analysis only.

Table B21: Sensitivity of the NPV estimates to the fossil fuel price assumptions used for the power sector analysis only (£ billion 2011)

Central ambition power sector	Low fossil fuel prices	High fossil fuel prices
Scenario B (central demand) +£1bn NPV	−£8bn	+£6bn

Rebound effect sensitivities

B3.73 Evidence suggests that greater vehicle efficiency will result in a rebound effect, in which lower driving costs encourage additional driving. The costs of this additional driving, such as increased congestion, are included in the estimated total costs of the scenarios. Table B22 shows how the NPV of the high transport ambition scenarios would change if the rebound effect were omitted, in order to demonstrate the significance of assumptions on the scale of the rebound effect.

Table B22: Sensitivity of the NPV estimates to the rebound effect in the transport analysis only (£ billion 2011)

High ambition transport	No rebound effect
Scenario 2 −£12bn NPV	−£10bn
Scenario 3 −£2bn NPV	−£0bn

B4. Wider impacts

Impact of energy and climate change policies on UK growth

B4.1 Overall, studies indicate that the long-term growth benefit from avoiding climate change will exceed the cost of co-ordinated global action to tackle climate change by helping to avoid the potentially catastrophic implications of failing to act.[81] In the shorter term, policies to meet the UK carbon budgets can bring economic benefits from increased resource and energy efficiency, innovation in low carbon technologies, and resilience to the impacts of high fossil fuel prices. However, there will be transition costs from the increased costs of energy for some businesses and households, the investment and innovation foregone in other areas, and the competitiveness impact if UK policy is out of step with competitor countries. Current economic circumstances highlight the need for climate policy to be cost effective, to maximise the economic benefits and growth opportunities and minimise negative impacts.

B4.2 Most published analysis suggests that current UK ambition on climate change can be achieved without large impacts on overall short-term economic output. The impacts of the policies to meet the first three carbon budgets and illustrative measures to meet the fourth budget have been modelled using the HM Revenue and Customs Computable General Equilibrium model. Results indicate that the first three carbon budgets could be met at an average cost of around 0.4% of GDP a year over the period 2011–22, and the fourth carbon budget could be met at an average cost of around 0.6% of GDP a year over the period 2023–27. The impacts on GDP could be lower or higher depending on a range of factors, including primary (fossil) energy costs and the costs of low carbon technologies.

B4.3 It should be noted that this modelling does not reflect all the potential benefits and costs. On the benefits side, it does not reflect social externalities such as health benefits from, for example, improved air quality and lower congestion, innovation benefits are not fully captured, and the modelling largely assumes that the UK acts unilaterally, rather than reflecting action to reduce emissions by other countries. Importantly, the modelling results also do not account for the benefit of avoiding significant risks to future UK growth (particularly in the long term) from global climate change. On the costs side, the modelling assumes that policies are implemented both on time and to cost, and does not take account of any social costs such as the welfare impacts of any behaviour change (e.g. reduced travel).

Fiscal impact of energy and climate change policies

B4.4 Meeting the fourth carbon budget requires no new policies this Parliament, and thus is consistent with Government's deficit reduction plans as set out in Spending Review 2010, Budget 2011, and the recent Autumn Statement.

B4.5 In the longer term, government will take into account the fiscal impact, including the impacts on taxation, public spending and public borrowing, when deciding upon the mix of policies used to meet the fourth carbon budget. The technical abatement characterised in section B3 of this annex could be accessed by a range of different policies including voluntary agreements, regulation, taxation and spending. The fiscal impacts of climate policy will also depend upon a range of factors such as technology costs, carbon prices, fossil fuel prices and policy effectiveness.

[81] The Stern Review (www.hm-treasury.gov.uk/sternreview_index.htm) found that the global costs of climate change could be between 5% and 20% of GDP per annum if we fail to act, dwarfing the costs of effective international action, estimated at 1–2% of global per capita consumption by 2050. The lower figure is a minimum. When the model incorporates non-market impacts and more recent scientific findings, the total average cost is 14.4%. The 20% figure also reflects the disproportionate burden of impacts on poor regions of the world.

B4.6 Broadly speaking, the taxable capacity of the economy is linked to GDP. Within overall taxable capacity, as noted by the Committee on Climate Change[82] and the Office for Budget Responsibility,[83] the move to a low carbon economy could increase receipts from some taxes while putting downward pressure on others, suggesting that the contribution of different taxes to revenues is likely to change over the long term. In the Coalition Agreement,[84] the Government committed to increase the proportion of tax revenue accounted for by environmental taxes.

Impacts on electricity security of supply

B4.7 There are three different linked challenges under the general banner of security of electricity supply:

- **diversification of supply:** how to ensure that we are not over-reliant on one energy source or technology and reduce our exposure to high and volatile prices;
- **operational security:** how to ensure that, moment to moment, supply matches demand, given unforeseen changes in both; and
- **resource adequacy:** how to ensure that there is sufficient reliable capacity to meet demand, for example during winter anticyclonic conditions where demand is high and wind generation low for a number of days.

B4.8 Increasing amounts of inflexible and/or intermittent low carbon generation should help to address the first challenge. However, a higher level of intermittent generation potentially makes the second and third challenges greater.

B4.9 As part of the Electricity Market Reform (EMR) programme, the Department of Energy and Climate Change has concluded that there are risks to future security of electricity supply. The analysis and evidence underpinning that judgement are contained in the EMR White Paper and the accompanying Impact Assessment.[85] In order to reduce the risks to security of electricity supply, the Department of Energy and Climate Change has indicated that a capacity mechanism is necessary and, as part of the EMR White Paper, the Government has consulted on the most appropriate type of capacity mechanism. The Government will publish its decision on the choice of capacity mechanism at the turn of the year.

B4.10 The assessment of future security of electricity supply has been updated to take account of revised fossil fuel prices, demand assumptions and carbon values as part of the Carbon Plan. Evidence from modelling of the electricity system by consultants Redpoint Energy suggests that in the absence of a capacity mechanism, margins could fall to low levels and increase risks to security of supply. Chart B11 shows de-rated capacity margins over the period to 2030 under both 100 gCO_2/kWh and 50 gCO_2/kWh scenarios (i.e. the percentage by which generation exceeds peak demand taking into account the probability that plants of different types will be unavailable). It also shows that with a capacity mechanism, margins can be maintained at a higher level.[86]

B4.11 The years immediately after 2010 are characterised by increasing capacity margins. This is a result of a combination of pre-committed

[82] Committee on Climate Change (2010) *The Fourth Carbon Budget: Reducing emissions through the 2020s*. Available at: www.theccc.org.uk/reports/fourth-carbon-budget

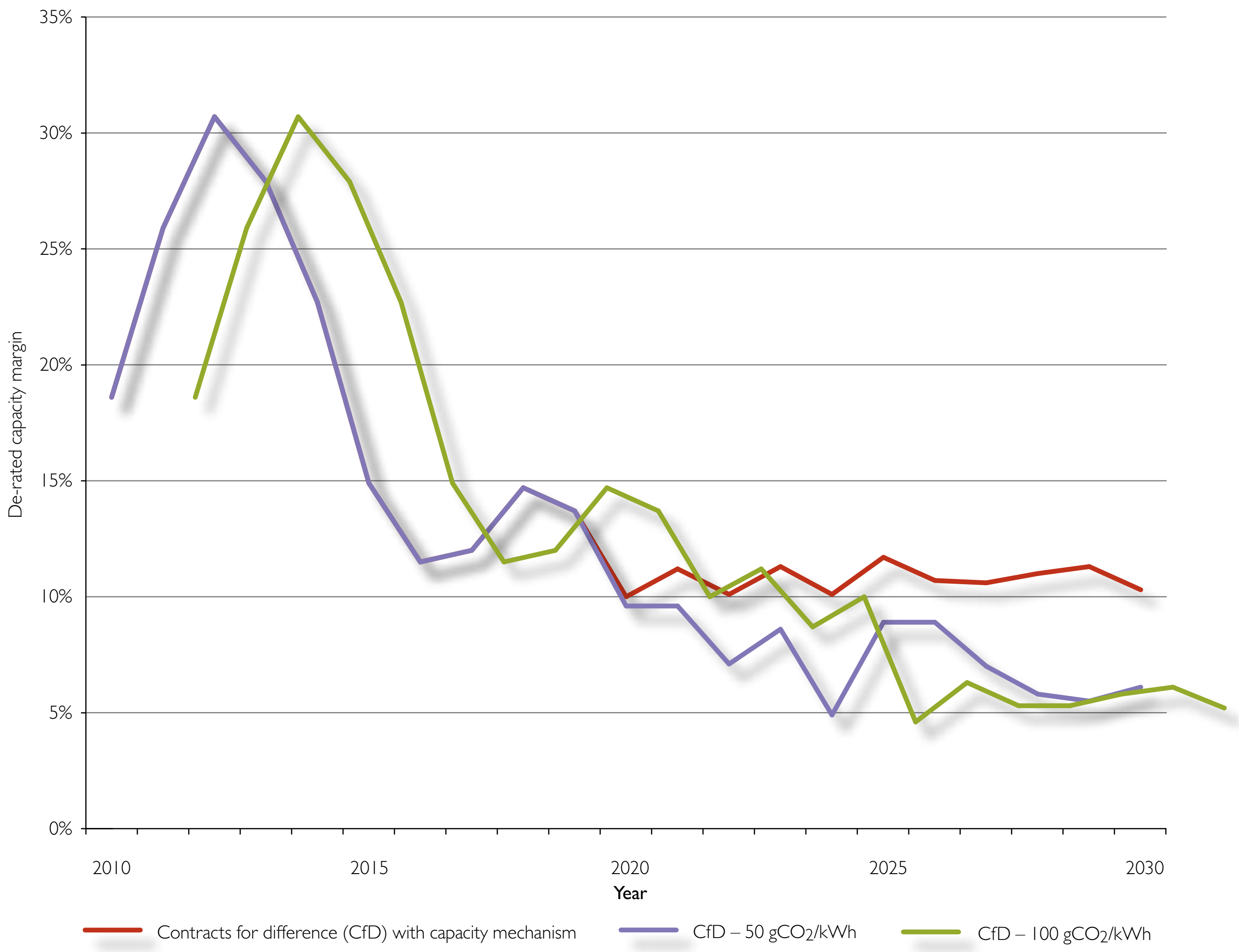
[83] Office for Budget Responsibility (2011) *Fiscal Sustainability Report*. Available at: http://budgetresponsibility.independent.gov.uk/fiscal-sustainability-report-july-2011/

[84] www.cabinetoffice.gov.uk/news/coalition-documents

[85] See: www.decc.gov.uk/en/content/cms/legislation/white_papers/emr_wp_2011/emr_wp_2011.aspx

[86] Note that the capacity mechanism reflected in this chart is a strategic reserve, but in the modelling, either a strategic reserve or a market-wide mechanism will have the effect of increasing de-rated capacity margins to around 10% or as close as is possible given the lumpy nature of investment.

Chart B11: De-rated peak capacity margins under different power sector scenarios



gas-fired stations coming online and demand being lower than expected given the economic downturn. After 2012, the de-rated capacity margin falls as old coal stations are scheduled to retire under the Large Combustion Plant Directive around the middle of the decade, and nuclear plants reach the end of their scheduled lifetimes. Note that demand is not projected to rise to 2020 due to relatively low economic growth forecasts and improvements in energy efficiency. However, plant retirements and increasing amounts of intermittent generation lead the de-rated capacity margin to fall below 10% in the early 2020s and reaching 5% in more than one year under both decarbonisation policies.

B4.12 Note that in the modelling analysis, following a 100 gCO_2/kWh or 50 gCO_2/kWh decarbonisation trajectory makes relatively little difference in terms of capacity margins as the modelling assumes that retirement and new build decisions for unabated fossil fuel plant adjust to the different wholesale price signals under the two scenarios. In the 100 gCO_2/kWh scenario, the wholesale electricity market provides sufficient price signals for investment in new gas stations. In the 50 gCO_2/kWh scenario, wholesale electricity prices fall significantly due to the amount of new low carbon, low generating cost plant in the generation mix, thereby reducing the opportunities for conventional generators to earn a return on their investment. Consequently, there is no new investment in gas power stations beyond the pre-committed gas plant that comes online around 2012. Under both scenarios, a capacity mechanism reduces the risk of demand not being met.

Sustainability and wider environmental impacts

Summary

B4.13 Policies to meet the fourth carbon budget pose risks and opportunities relating to air quality, water, noise, biodiversity and landscape and their associated ecosystem services. Increased **use of bioenergy** in particular appears to have the greatest potential impacts on the wider environment.

B4.14 **Scenario 3**, which assumes high abatement from **electrification**, has the highest potential benefits for air quality and noise.

B4.15 Various mechanisms exist already to limit extreme impacts on the wider environment from decarbonisation policies; however, the use of an **ecosystem approach** at policy and project level is needed to achieve a more optimal use of natural capital that addresses risks and synergies at the appropriate spatial scale.

Purpose, scope and approach

B4.16 This section offers a preliminary and broad assessment of the wider environmental impacts of the policy directions and scenarios envisaged for the fourth carbon budget. Section 13(3) of the Climate Change Act 2008 states that proposals and policies for meeting carbon budgets must, when taken as a whole, 'be such as to contribute to sustainable development'. Tackling climate change is essential for maintaining a healthy, resilient natural environment, as highlighted in the Government's **Natural Environment White Paper**,[87] published in June 2011. The White Paper re-committed to ensuring that the value of nature (which is often hidden) is appropriately reflected in all relevant policy decisions.[88]

B4.17 The White Paper, building on the ground-breaking **UK National Ecosystem Assessment** (NEA), uses the concept of 'natural capital': nature represents a stock of assets, which provides flows of 'ecosystem services'[89] from which society benefits in numerous although often undervalued ways. It includes living things in all their diversity, the landscape and its heritage, wildlife, rivers, lakes and seas, urban green space, woodland and farmed land. Natural capital interacts with produced, human and social capital to support economic activity and human wellbeing.[90]

B4.18 **Monetised estimates of the ecosystem values at stake are partial and uncertain but substantial.** For instance, one major study found that optimising climate change policies to improve air quality could yield benefits of £24 billion by 2050; the annual value of protecting marine biodiversity in UK waters is estimated at £1.7 billion, and the annual benefits of achieving good ecological status for water bodies are in the region of £1 billion. The NEA sets out further evidence on monetised values classified by ecosystem service type.[91]

B4.19 A range of policies at domestic and European level have been developed to safeguard and enhance these values, such as air emission limits, the Water Framework Directive, the Birds and Habitats Directive, the Environmental Noise Directive and marine planning. In October 2010 the UK Government played a key role in concluding the historic global agreement in Nagoya to protect and enhance biodiversity worldwide, which led to the England Biodiversity Strategy, launched in August 2011. The strategy, like the NEA, emphasises the importance of long-term planning to achieve a more integrated use of natural capital that delivers multiple ecosystem services. The White Paper and the NEA also stress

[87] Defra (2011) *The Natural Choice: securing the value of nature*. Available from: www.defra.gov.uk/environment/natural/whitepaper/

[88] This assessment is intended to also inform the White Paper commitment to 'establishing a research programme to fill evidence gaps about impacts on the natural environment of the level of infrastructure needed to meet 2050 [low carbon] objectives'.

[89] See: Millennium Ecosystem Assessment and TEEB (2010) *The Economics of Ecosystems and Biodiversity*. These services have been categorised as: **provisioning** (e.g. food, timber); **regulating** (e.g. water purification, pollination); **cultural** (e.g. recreation, aesthetic) and **supporting** (e.g. soil formation, genetic diversity).

[90] Defra (2010) *A Framework for Understanding the Social Impacts of Policy and their Effects on Wellbeing*. Available from: www.defra.gov.uk/publications/files/pb13467-social-impacts-wellbeing-110403.pdf

[91] See: www.defra.gov.uk/publications/files/pb13583-biodiversity-strategy-2020-110817.pdf

the need for decision making at appropriate spatial scales, valuing changes in services where possible but considering 'shared social values' as well as economic valuations.

B4.20 The Department for Environment, Food and Rural Affairs (Defra) environmental appraisal guidance incorporates this ecosystems approach and the White Paper has also committed to publishing supplementary HM Treasury Green Book guidance on valuing the natural environment in appraisals.[92] **This guidance has informed this initial assessment and will be important to incorporate into policy and project development.**

Assessment of risks and opportunities

B4.21 Table B23 below summarises the most important risks, synergies and trade-offs that the fourth carbon budget presents to the wider environment. The rest of this section provides a more detailed assessment by type of measure and sector, and the potential for mitigating risks, drawing on qualitative and (for air and noise) quantitative analysis.

B4.22 A high-level assessment of the impacts from the fourth carbon budget scenarios in the wider environment is set out in the list on page 186, followed by more detail on particular technologies and their wider impacts.

Table B23: Risks and opportunities associated with the fourth carbon budget

	Risks	Opportunities
Air quality	• Use of biomass, with an estimated cost of £48 million in Scenario A and £31 million for the non-traded Scenario 2 • **Transport** – increased fuel efficiency leading to increased vehicle usage	• **Clean electricity production** (excluding biomass) has potential benefits of between £25 million and £72 million for Scenarios A and B respectively • **Electrification of transport** creates potential benefits of approximately £102 million (as per Scenario 1)
Biodiversity	• Potential long-term impacts from the conversion of natural habitats to comply with high **bioenergy** scenarios (i.e. increased use of biomass and biofuels from first generation crops)	• Potential benefits if domestic **bioenergy** expansion brings unmanaged woodland into management and diversifies range of habitats • **Cleaner power stations** could reduce eutrophication
Landscape	• Potential risks from siting and design of **new electricity generation** infrastructure	• Potential benefits where fourth carbon budget policies incentivise active management of woodlands (**bioenergy**)
Noise and nuisance	• **Transport** – increased vehicle efficiency leading to increased vehicle usage • Noise from some **renewable sources** may lead to unwelcome neighbourhood-level impacts	• **Impacts of transport measures, including sustainable travel measures**, could reduce noise, with a net benefit of £61 million in Scenario 1
Marine	• Risk of impacts to marine habitat and noise-sensitive species from expansion of **offshore activities and tidal energy**	• Possible ecological benefits from the artificial reef provided by foundations to **offshore wind turbines**
Water	• Impacts on water availability arising from abstraction by new power stations, depending on location and climate • Ground-source heating and cooling schemes impact water quality and ecology	• Fourth carbon budget policies could incentivise active management of woodlands (**bioenergy**)

[92] See: www.defra.gov.uk/corporate/about/how/policy-guidance/env-impact-guide/

- **Scenario 1**, having a focus on high abatement in low carbon heat, implies that higher tensions are expected from noise.
- **Scenario 2**, which has a focus on high abatement in transport and bioenergy demand, is associated with higher tensions in air quality and biodiversity from increased biomass use, although there may be some biodiversity and landscape benefits.
- **Scenario 3**, which has a focus on high electrification, has the highest potential benefits for air quality and noise.
- **Scenario 4** and **Scenario B** allow for the **use of international credits** and so the ambition of domestic climate change mitigation policies is reduced. As a result, both potential opportunities and risks could be shifted abroad.
- **Scenario A** refers to **high ambition in the power sector** and presents a wider range of potential for tensions: air quality, landscape, noise, water and marine. There is potential for mixed impacts in biodiversity and waste, but also some potential opportunities for air quality.

Agricultural measures

B4.23 On-farm voluntary measures contained in the fourth carbon budget offer both synergies and tensions between reducing greenhouse gas emissions and other environmental outcomes, such as air quality, biodiversity and water pollution. Broader soil measures to reduce carbon (such as measures to maintain soil organic matter and reduction in the horticultural use of peat as outlined in the Natural Environment White Paper) could bring carbon and biodiversity benefits. Defra will be working with stakeholders to minimise adverse impacts and develop integrated advice for farmers.

Low carbon heat and bioenergy expansion

B4.24 One of the fourth carbon budget scenarios focuses on the **expansion of low carbon heat** using technologies such as ground-source heat pumps and air-source heat pumps (**Scenario 1**). There is a need to carefully balance the desire to see take-up in these technologies with the need to ensure that local impacts are acceptable. Unless properly designed, ground-source heat pumps can pose risks to water ecology. Air-source heat pumps can also produce unwelcome **noise** for the surrounding neighbourhood; poor siting, installation and maintenance can exacerbate these effects. Where the fourth carbon budget scenarios focus on the expansion of **biomass use for electricity** and/or low carbon heat (as per Scenario 2 in the non-traded sector and Scenario A in the traded sector), this can have unintended environmental impacts that must also be considered. A large-scale move to biomass boilers could emit levels of harmful particulate matter and nitrous oxide that impact on **air quality**. This may in turn threaten compliance with both ambient air quality and national emission ceilings directives. The air quality impacts of the increased use of biomass under Scenario A are around £48 million and approximately £31 million for Scenario 2 where there is low carbon heat ambition but relatively higher use of biomass compared with Scenarios 1 and 3.

B4.25 Domestically, a change of **land management** from arable crops or grassland to biomass or energy crops brings opportunities as well as risks. More active and sustainable management of woodlands for wood fuel could lead to landscape, recreational and biodiversity gains. Analysis in the National Ecosystem Assessment (NEA) (using Wales as a case study) highlights the potential for major recreational benefits where woodland is created in lowland urban fringe areas, close to population centres. It also indicates the dual risks where the planting of forests in peatland areas dries out wetlands and can result in net carbon release rather than storage. There is strong evidence to support woodland creation in appropriate locations to achieve water management and water quality objectives, including tackling diffuse pollution and regulating water flow.

B4.26 Department of Energy and Climate Change analysis on the sustainability of bioenergy supply highlights that certain sectors may need to rely on imports to meet demand in the near and longer term (i.e. biofuels for transport, and woody biomass and domestic biogas for heat). This could lead to land use change abroad, with direct or indirect loss of natural or near natural habitats/ ecosystems and the services provided to local populations if adequate sustainability controls are not in place. See from paragraph B4.42 below for a discussion on bioenergy supply.

B4.27 Combined heat and power could also have air quality impacts by moving combustion closer to residential locations. Some of these negative impacts may be offset through associated increases in efficiency and emissions control.

B4.28 **Potential to mitigate risks:** Air pollution from the combustion of biomass can be controlled through strong limits on the levels of emissions on both large-scale use (through the Industrial Emissions Directive) and small-scale sources (such as introducing emissions standards on domestic boilers). Negative landscape impacts could be minimised by carefully considering the location of land use changes and uptake of sustainable management practices. The ability to reduce site specific impacts on biodiversity is reinforced by current requirements to carry out Environmental Impact Assessments (EIAs) where there are likely to be significant environmental effects. Through judicious choice of location, good design and good management, there will be opportunities to mitigate and in some places enhance biodiversity and associated ecosystem services as envisaged in national biodiversity action plans.

New power plants

B4.29 Virtually all nationally significant energy infrastructure projects will have effects on the **landscape**. Landscape effects depend on the existing character of the local landscape, how highly it is valued and its capacity to accommodate change. Impacts on biodiversity may be reduced by the construction of cleaner power stations (coal power stations produce nitrogen oxides that cause eutrophication and acidification), but there may also be potential for habitat disturbance from construction of stations and power lines.

B4.30 Impacts on **water** availability could occur in the future if new stations are built in areas where water or discharge capacities are not adequately developed. These impacts could exacerbate future water availability issues as a result of climate change and population growth. Traditional power plants tend to have low water loss[93] factors, which vary depending on the generation type and the method of cooling used, yet volumes of water abstracted can impact on fish and other aquatic life. Reduction in river flows due to climate change could exacerbate this issue. **Carbon capture and storage (CCS)** can increase water use. Recent studies of the extra water demand associated with CCS indicate that it can increase **water** use by 91–100%,[94] which may have implications in the catchments where fossil fuel power stations are currently clustered. This could make such CCS power stations more vulnerable at low water flow times (late summer), with potential to affect security of electricity supply. Defra is working closely with the Department of Energy and Climate Change and the Environment Agency over the coming year to further understand these issues.

B4.31 CCS could also have an impact on air quality as CCS requires more power (in particular for capture and compression) than conventional plants. However, it should be noted that plants fitted with CCS will have to comply with emissions limits set by the Industrial Emissions Directive. CCS generation as assumed in **Scenario A**, where carbon intensity in the power sector falls to 50 g/kWh by 2030, leads to an estimated air quality cost of around £69 million relative to a counterfactual without the Electricity Market Reform measures. In contrast, **Scenario B**, with a carbon intensity of 100 g/kWh by 2030 and a lower reliance on CCS generation relative to the same counterfactual, leads to an estimated benefit of £3 million.

B4.32 **Potential to mitigate risks:** There are various ways to minimise the wider environmental impacts of new power stations, including measures that can be taken at the planning and design

[93] Water that is not returned to the river after being used for cooling (such as water losses produced by evaporation).

[94] Zhai, H and Rubin, ES (2010) Performance and cost of wet and dry cooling systems for pulverised coal power plants with and without carbon capture and storage. *Energy Policy* 38(6):5653–5660; National Energy Technology Laboratory (2005) *Power Plant Water Usage and Loss Study*. United States Department of Energy.

stage. The *Overarching National Policy Statement for Energy* sets out guidance for considering the wider impacts of nationally significant energy developments, including when they are proposed within a protected area.[95]

Offshore and onshore wind power

B4.33 Commercial-scale wind turbines by their nature (typically 125–150 m tall) will have an impact on the **landscape** and **seascape**. There may also be impacts on areas that are important for nature and heritage conservation. Large-scale wind farms, especially offshore, also pose significant demands for new cable links and substations that can cover large areas (around 20 ha).

B4.34 The construction of offshore turbines mainly poses risks for **marine biodiversity**. Noise from exploration, construction, operation and decommissioning of wind power can have a negative impact on noise-sensitive species. While new offshore turbine foundations that provide a hard substrate can increase the diversity of the immediate environment, they can also act as stepping stones for invasive species that can colonise and spread.

B4.35 **Potential to mitigate risks:** National Policy Statements (NPSs) for energy infrastructure and other planning policy steer major and large-scale commercial development of onshore turbines away from protected landscapes and internationally designated sites. For onshore wind turbines that are likely to have significant environmental effects, an EIA will be necessary, which should identify mitigation measures to remove or reduce the effects to acceptable levels.

B4.36 Larger offshore wind developments will be covered by NPSs for energy instrastructure, while wider decisions on offshore development[96] will now be taken under the new system of marine planning and licensing. Regulators will also require an EIA for any renewable energy licence applications where there is a likelihood of significant environmental effects and will identify mitigation options. There are explicit requirements under the Marine Strategy Framework Directive to ensure that permanent alterations to hydrographical conditions, including underwater noise, do not adversely affect the marine environment.

Tidal and wave power generation

B4.37 Tidal energy generation and installation can affect **marine biodiversity** through habitat change and loss, depending upon the type of device and habitat. Devices with moving parts are likely to have greater impacts than those without. Tidal power may also affect the characteristics of the flow regime in estuaries. There may also be the potential for direct impacts on species, for example barrier effects (especially for migratory species), collisions and noise from installation, operation and decommissioning.

Transport

B4.38 There are potential synergies and tensions for **air quality** in the transport sector that relate to measures identified in the fourth carbon budget. The transport measures assumed in Scenario 1 lead to potential improvements in air quality of around £102 million over the period (2011–27). This figure only takes into account the direct impacts on transport emissions, with the additional power sector impacts accounted for elsewhere.

B4.39 **Noise** benefits under this scenario would be approximately £61 million and relate to sustainable transport measures, which reduce car kilometres travelled, as well as some additional benefits from increased electrification.

B4.40 Improvements in average fuel efficiency that are achieved through increased conventional car fuel efficiency would have notable noise impacts. Analysis of the impacts of current policies that help to meet the first three carbon budgets reveals significant costs associated with increased noise and nuisance (approximately £402 million over the period). This is mainly a consequence of the increase in kilometres driven in response

[95] DECC (2011) *Overarching National Policy Statement for Energy (EN-1)*.

[96] This framework also applies to tidal and wave power generation as described in the next section.

to greater fuel efficiency and the resultant fall in driving costs.

B4.41 **Potential to mitigate impacts:** Higher blends of biofuels than are currently envisaged for use in the UK vehicle fleet could potentially increase emissions from vehicles[97], whereas others – such as biomethane – can deliver air quality benefits. Moving away from diesel vehicles could also have a positive impact on air quality. Any actions that encourage the electrification of the vehicle fleet are expected to improve both environmental noise by reducing engine noise and air pollution by reducing emissions.

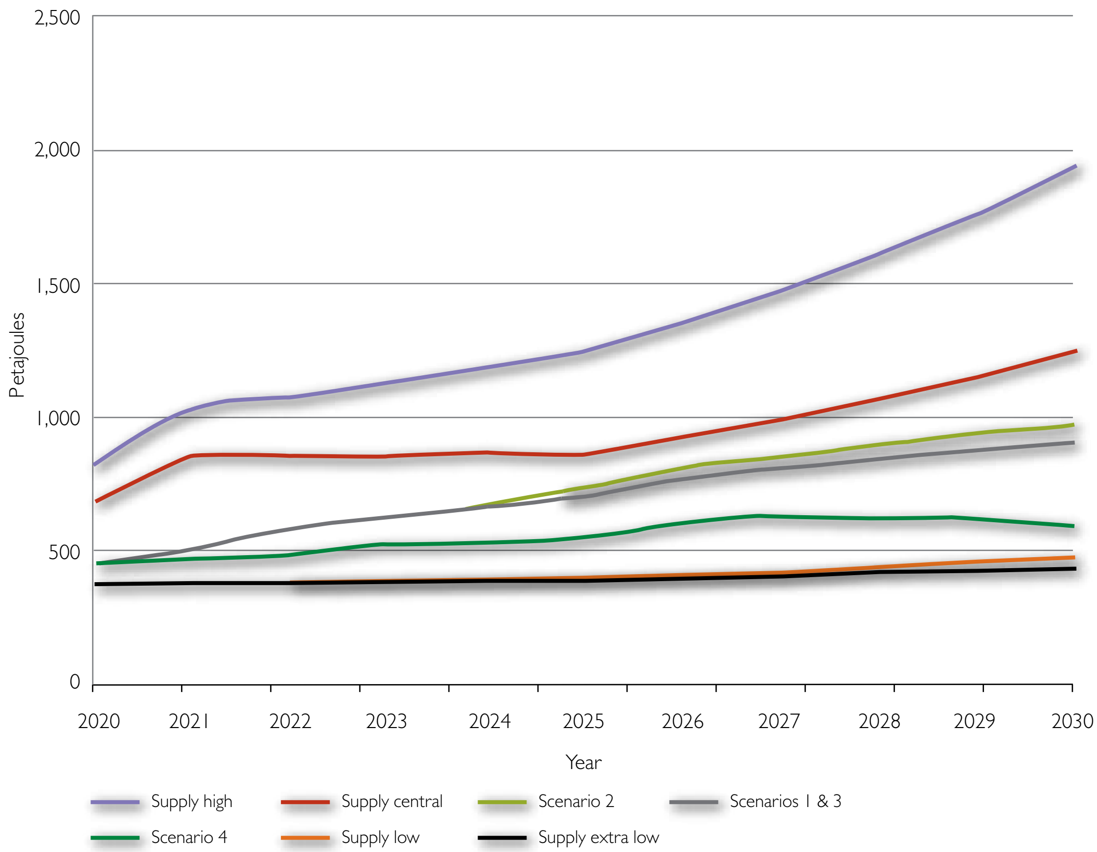
Sustainability of bioenergy resource supply

B4.42 A high-level assessment was carried out to compare current estimates of sustainable bioenergy supply with the bioenergy demand trajectories forecast for the Carbon Plan.

B4.43 The potential range of bioenergy demand was derived from the emissions projections and analysis of the additional abatement measures described from paragraph B3.26. This consolidated the demand for biofuels from transport; the demand for biomass and biogas from low carbon heat measures; and the use of waste and biomass in electricity generation. The available supply of bioenergy was considered drawing on three scenarios from AEA's *UK and Global Bioenergy Resource* report[98] and E4Tech's[99] biofuel supply projections for the Department for Transport Modes work.

B4.44 **The analysis suggests that, when considering bioenergy as a whole, there should be sufficient sustainable supply to meet demand**

Chart B12: Biomass supply and demand, including heat, power and transport, 2020–30 (petajoules)



[97] Such as NOx from high strength biodiesel or aldehydes from bioethanol.

[98] AEA (2011) *'UK and Global Bioenergy Resource – Final report'.*

[99] See: www.e4tech.com/en/consulting-projects.html#Bioenergy

trajectories. Chart B12 shows total biomass supply and demand for the heat, power and transport sectors.

B4.45 However, considering biomass as a whole can mask the sustainable supply constraints that may be felt for certain sectors and technologies. Although the actual deployment levels are highly uncertain and will depend on investment decisions that renewable energy generators choose to make based on the economics of the technologies, scenario analysis of the potential pathways indicates that some tensions between supply and demand for feedstocks could appear during the 2020s.

B4.46 Although domestic resources will play an important role in the supply of woody biomass, the UK is likely to require significant **woody biomass** imports in addition to UK resources. To meet the demand of the potential deployment trajectories to 2030 would require a greater proportion of woodland resource to be managed for wood fuel production, more woody feedstocks to be harvested and, possibly, the establishment of new energy forests and short rotation coppice. Higher demand trajectories might also require a significant expansion of marginal land devoted to woody biomass production to meet the demand from domestic sources. The use of energy crops would also play an important role in meeting potential needs. Removing energy crops from supply estimates in order to test for the uncertainties of the availability of these resources given potential land availability and indirect impact constraints shows that supply could be sufficient to meet demand in the near term but that tensions could start appearing from the mid 2020s onwards.

B4.47 In addition, demand for **biofuels** may also prove constrained in low sustainable supply scenarios for the fourth carbon budget period, especially when considering biodiesel feedstocks. However, testing higher availability scenarios based on the existing literature shows that sustainable supply could be sufficient to meet the potential ranges of demand. Future supply for biodiesel and bioethanol will largely depend on the sustainability of first generation feedstocks and the impact of forthcoming policy on indirect land use change.

B4.48 Finally, the scenario analysis also shows that the supply of feedstocks for **biogas in the heat sector** may prove constrained and potentially hinder the significant deployment in the sector over the fourth carbon budget period. In contrast, supply of biogas to the power sector, which uses different feedstocks[100] than the heat sector, is expected to surpass demand for the whole period.

B4.49 The analysis highlights that, in future, different technologies and sectors are likely to experience different pressures on the availability of sustainable feedstocks. This will have an impact on the price at which the UK can access these feedstocks and will depend not only on the UK's ability to successfully exploit domestic resources but also on the development of international markets and associated demand. The forthcoming cross-government Bioenergy Strategy will make a more thorough assessment of the potential availability of sustainable feedstocks to 2020 and beyond and the implications of this on the potential role of bioenergy across electricity, heat and transport as a way of achieving cost effective carbon reductions.

[100] This analysis assumes total supply of biogas from: sewage sludge, landfill gas, food waste and livestock manure. It is assumed that the power sector uses only biogas from sewage sludge and landfill.

B5. Detailed tables

Emissions by sector

The table below shows the updated emissions projections (UEP) broken down by the main National Communication sectors.[101]

Table B24: Projected net UK carbon account by sector, National Communication basis ($MtCO_2e$)

Total greenhouse gas emissions ($MtCO_2e$)																				
National Communication sector breakdown	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
Energy supply	219	195	196	184	185	178	177	166	150	145	131	127	129	124	118	116	115	110	104	100
Business	97	86	94	91	90	90	91	91	89	88	86	84	82	82	81	79	78	78	77	77
Industrial processes	16	10	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Transport	128	122	122	118	117	117	116	115	114	113	112	111	109	112	111	111	110	109	108	108
Residential	83	79	88	79	76	72	71	70	69	68	68	67	66	67	67	68	68	69	70	70
Public	9	8	9	10	10	10	10	10	10	9	9	8	8	8	8	8	8	8	8	8
Agriculture	50	49	50	49	49	49	49	49	48	47	47	46	46	45	46	46	46	46	46	46
Land use change	−4	−4	−4	−3	−3	−3	−3	−2	−2	−2	−2	−2	−1	−1	−1	−1	0	0	0	0
Waste management	18	18	18	17	17	16	15	15	15	14	14	13	13	13	12	12	12	12	11	11
Total	**618**	**564**	**586**	**557**	**553**	**541**	**538**	**524**	**505**	**495**	**476**	**467**	**463**	**461**	**454**	**450**	**448**	**442**	**436**	**431**
EU ETS allowances purchased by UK	**19**	**−12**	**−7**	**−23**	**−21**	**−4**	**1**	**−6**	**−17**	**−19**	**−29**	**−28**	**−22**	**−27**	**−29**	**22**	**21**	**16**	**11**	**6**
Net UK carbon account[102]	**599**	**576**	**593**	**579**	**575**	**545**	**538**	**531**	**523**	**514**	**505**	**495**	**486**	**489**	**483**	**428**	**427**	**426**	**425**	**425**

[101] See: www.decc.gov.uk/en/consent/cms/about/ec_social_res/analytic_projs/en_emis_projs/en_emis_projs.aspx

[102] The net UK carbon account estimates for the fourth carbon budget (2023–27) assume an EU ETS cap of 690 $MtCO_2e$.

Emissions savings by policy

The tables in this section set out the updated policy emissions savings to deliver the first three carbon budgets.[103, 104]

Table B25: Projected non-traded sector emissions savings by policy in the baseline ($MtCO_2e$)[105]

	Carbon budget 1					Carbon budget 2					Carbon budget 3					Carbon budget period		
																1	2	3
Residential	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2008–12	2013–17	2018–22
Building Regulations Part L (2002 and 2005/06)	2.6	3.2	3.7	4.5	4.9	5.4	5.8	6.2	6.5	6.8	7.1	7.3	7.5	7.3	6.9	18.8	30.6	36.1
Warm Front and fuel poverty measures	−1.2	−1.4	−1.7	−1.8	−1.8	−1.7	−1.4	−1.2	−1.1	−0.9	−0.8	−0.7	−0.5	−0.4	−0.2	−7.9	−6.3	−2.7
Supplier Obligation (EEC1, EEC2, original CERT)	1.9	2.7	3.9	5.2	5.4	5.4	5.5	5.4	5.4	5.7	5.8	5.8	5.5	5.1	4.8	19.0	27.4	27.0
Total	**3.3**	**4.4**	**5.9**	**7.8**	**8.5**	**9.1**	**9.8**	**10.4**	**10.8**	**11.5**	**12.0**	**12.4**	**12.5**	**12.0**	**11.6**	**30.0**	**51.6**	**60.5**
Commercial and public services																		
Carbon Trust measures	1.2	1.1	1.1	0.9	0.7	0.6	0.4	0.3	0.3	0.3	0.2	0.1	0.0	0.0	0.0	4.8	2.0	0.5
Energy Performance of Buildings Directive[106]	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	1.5	1.5	1.5
UK Emissions Trading Scheme	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Building Regulations Part L (2002 and 2005/06)	0.7	0.9	1.0	1.2	1.2	1.3	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.5	1.4	5.1	7.0	7.5
Total	**2.2**	**2.3**	**2.4**	**2.4**	**2.2**	**2.2**	**2.1**	**2.0**	**2.1**	**2.1**	**2.0**	**1.9**	**1.9**	**1.8**	**1.7**	**11.5**	**10.4**	**9.4**

[103] For detail on how the policy emissions savings have been modelled please see chapter 4 of the latest published Updated Energy and Emissions Projections report available from: www.decc.gov.uk/en/content/cms/about/ec_social_res/analytic_projs/en_emis_projs/en_emis_projs.aspx

[104] Demand reduction through the impact of price uplifts are included in the baseline and have generally not been quantified in these tables. The exceptions are the impact of the EU ETS carbon price and Carbon Price Floor in the ESI, which are quantified. Such price impacts arise from: CCL fuel duties, the need to purchase CRC allowances and the cost recovery of policy measures undertaken by energy suppliers, this includes supply side measures such as grid reinforcement, RO and FiTs, as well as CERT/ECO.

[105] For the purposes of this table, baseline is akin to the updated emissions projections baseline (pre-Low Carbon Transition Plan policies). The table shows emissions savings from only some of the policies included in the baseline. It is not possible to quantify the emissions savings from all baseline policies individually. However, it should be noted that this does not impact on either the baseline or any of the newer policy emissions projections scenarios. Savings in the transport sector from the Renewable Transport Fuels Obligation and EU voluntary agreements on new car emissions have been published previously. These have not been re-estimated for this publication.

[106] The original Energy Performance of Buildings Directive (EPBD) introduced Energy Performance Certificates, Display Energy Certificates and other measures to improve the energy performance of buildings. Carbon savings given here only reflect the impact of the policy on the small and medium-sized enterprises sector, to avoid overlap with policies in other areas. The numbers relating to the EPBD in this annex are the same as given in the *Low Carbon Transition Plan* (DECC, 2009) and so are not consistent with numbers for the other policies here, which use updated energy and carbon assumptions. The EPBD recast currently being developed does not feature in these numbers owing to overlaps with the savings already accounted for elsewhere.

Industry	Carbon budget 1					Carbon budget 2					Carbon budget 3					Carbon budget period 1	Carbon budget period 2	Carbon budget period 3
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2008–12	2013–17	2018–22
Carbon Trust measures	0.5	0.5	0.5	0.4	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	2.2	0.9	0.3
UK Emissions Trading Scheme	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.9	0.4	0.1
Building Regulations Part L (2002 and 2005/06)	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.6	0.6	2.1	3.0	3.2
Total	**1.0**	**1.0**	**1.1**	**1.1**	**1.0**	**0.9**	**0.9**	**0.8**	**0.8**	**0.8**	**0.8**	**0.7**	**0.7**	**0.7**	**0.6**	**5.2**	**4.3**	**3.5**
Overall total	**6.5**	**7.7**	**9.4**	**11.2**	**11.7**	**12.2**	**12.8**	**13.3**	**13.7**	**14.4**	**14.8**	**15.1**	**15.1**	**14.5**	**13.9**	**46.6**	**66.4**	**73.4**

Table B26: Projected non-traded sector emissions savings by policy additional to the baseline ($MtCO_2e$)[107]

	Carbon budget 1					Carbon budget 2					Carbon budget 3					Carbon budget period 1	Carbon budget period 2	Carbon budget period 3
Residential	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2008–12**	**2013–17**	**2018–22**
Supplier Obligation (CERT +20% and CERT extension)	0.0	0.1	0.2	0.4	2.0	4.1	4.1	4.1	4.0	4.0	4.0	4.1	4.0	3.9	3.9	2.7	20.3	19.9
Building Regulations Part L (2010)	0.0	0.0	0.0	0.0	0.4	0.8	1.1	1.5	1.8	2.1	2.4	2.7	3.0	3.2	3.5	0.4	7.4	14.9
Smart Metering[108]	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.4	0.6	0.8	0.9	1.0	1.0	1.0	1.0	0.1	2.1	5.0
EU Products policy (Tranche 1, Legislated)[109]	0.0	0.0	−0.2	−0.5	−0.7	−1.0	−1.2	−1.4	−1.6	−1.7	−1.9	−2.0	−2.0	−2.0	−1.9	−1.4	−7.0	−9.8
EU Products policy (Tranche 2, Proposed)[110]	0.0	0.0	0.0	0.0	−0.1	−0.1	−0.1	0.0	0.1	0.2	0.3	0.4	0.5	0.5	0.5	−0.1	0.0	2.1
Community Energy Saving Programme	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.3
Zero Carbon Homes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.0	0.1	2.0
Energy Company Obligation and Domestic Green Deal[111]	0.0	0.0	0.0	0.0	0.0	0.3	0.6	0.9	1.2	1.3	1.4	1.5	1.2	1.4	1.5	0.0	4.4	6.9
Renewable Heat Incentive	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.8	0.9	0.9	0.9	0.1	1.6	4.1
Total	**0.0**	**0.1**	**0.1**	**0.0**	**1.8**	**4.4**	**5.0**	**5.8**	**6.6**	**7.4**	**8.1**	**8.7**	**9.0**	**9.5**	**10.0**	**1.9**	**29.2**	**45.3**

[107] This table shows non-traded emissions savings additional to the baseline (Low Carbon Transition Plan and newer policies).

[108] All Smart Metering emissions savings are based on the latest published Impact Assessment, available at: www.decc.gov.uk/assets/decc/11/consultation/smart-metering-imp-prog/2549-smart-meter-rollout-domestic-ia-180811.pdf

[109] Products policy includes legally binding EU minimum standards on energy-related products, which raise the minimum level of efficiency of energy-using products available in the market. It also includes labelling which encourages manufacturers to go beyond the minimum standards. The first tranche of measures has been delivered; the energy savings are taken from the related Impact Assessments.

[110] The second tranche of measures has not been completed and therefore any projected savings are less well understood, as the scope, timing and stringency of these measures has not been finalised. The current modelling reports projections of energy savings from products policy. These are more uncertain over later years as it becomes less clear whether products policies drive efficiency improvements, or whether this would be driven regardless by (i) consumers' future preferences for better products, and/or (ii) forecast energy prices and traded carbon prices that increase at a faster rate post-2020. Tapers are applied post-2020 to signal uncertainties in the long run on energy savings. For the net present values, further caution still is applied, with the estimates provided only for the savings until the end of the third carbon budget reporting period – given that it is unclear whether the market will have responded or whether energy efficiency improvements will need to continue to be delivered through products policy in later years.

[111] All ECO and Domestic Green Deal emissions savings are based on the latest Impact Assessment. The latest estimates differ from the estimates included in the October 2011 Updated Emissions Projections which are based on the December 2010 Impact Assessment and include heating measures. Non-traded emissions savings fall in 2020 owing to assumptions about the roll-out of heat systems in fuel poor households. See the Impact Assessment for further details: www.decc.gov.uk/assets/decc/11/consultation/green-deal/3603-green-deal-eco-ia.pdf

Commercial and public servicesl	Carbon budget 1					Carbon budget 2					Carbon budget 3					Carbon budget period 1	Carbon budget period 2	Carbon budget period 3
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2008–12**	**2013–17**	**2018–22**
Building Regulations Part L (2010)	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.1	1.7	3.4
Business Smart Metering	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.4	0.6	0.7	0.7	0.8	0.7	0.7	0.0	1.4	3.6
EU Products policy (Tranche 1, Legislated)	0.0	0.0	0.0	0.0	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.6	−0.7
EU Products policy (Tranche 2, Proposed)	0.0	0.0	0.0	0.0	0.0	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.2	−0.2	−0.2	−0.1	−0.4	−0.7
Small business energy efficiency interest-free loans	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Salix, public sector loans, 10% commitment for central govt	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0
Non-Domestic Green Deal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.4	0.5	0.6	0.6	0.6	0.7	0.0	0.8	3.0
Carbon Reduction Commitment Energy Efficiency Scheme	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.3	0.4	0.6	0.7	0.8	0.9	1.0	1.1	0.2	1.8	4.5
Renewable Heat Incentive	0.0	0.0	0.0	0.1	0.2	0.4	0.7	1.2	1.7	2.4	3.2	4.0	4.9	4.9	4.9	0.3	6.4	21.8
Total	**0.0**	**0.0**	**0.1**	**0.2**	**0.5**	**0.8**	**1.2**	**2.1**	**3.0**	**4.2**	**5.4**	**6.5**	**7.5**	**7.7**	**7.8**	**0.8**	**11.3**	**34.8**

Industry	Carbon budget 1					Carbon budget 2					Carbon budget 3					Carbon budget period 1	Carbon budget period 2	Carbon budget period 3
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2008–12**	**2013–17**	**2018–22**
Building Regulations Part L (2010)	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.0	0.6	1.3
EU Products policy (Tranche 1, Legislated)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EU Products policy (Tranche 2, Proposed)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	−0.1
Small business energy efficiency interest-free loans	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Climate Change Agreements (2011–18)[112]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Non-Domestic Green Deal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.0	0.3	1.2
Carbon Reduction Commitment Energy Efficiency Scheme	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.6	0.1	1.0	2.5
Renewable Heat Incentive	0.0	0.0	0.0	0.1	0.2	0.4	0.5	0.7	1.2	1.7	2.4	3.3	4.2	4.2	4.2	0.4	4.5	18.3
Total	**0.0**	**0.0**	**0.0**	**0.2**	**0.4**	**0.6**	**0.8**	**1.1**	**1.7**	**2.4**	**3.2**	**4.1**	**5.2**	**5.3**	**5.4**	**0.6**	**6.5**	**23.2**

[112] CCAs and the Climate Change Levy are estimated to have no additional savings beyond business as usual emissions projections. CCA targets will be set in 2012 following negotiations with industry.

Transport[113]	Carbon budget 1					Carbon budget 2					Carbon budget 3					Carbon budget period 1	2	3
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2008–12	2013–17	2018–22
EU new car CO_2 mid-term target 130 gCO_2/km in 2015	0.0	0.0	0.0	0.1	0.3	0.5	0.7	1.0	1.4	1.7	2.0	2.3	2.6	3.1	3.4	0.4	5.3	13.4
EU new car CO_2 long-term 95 gCO_2/km in 2020	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.7	1.4	2.3	3.4	5.0	6.1	0.1	1.5	18.2
Renewable Energy Strategy transport biofuel (8% by energy in 2020)[114]	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.1	1.8	2.4	3.0	3.5	4.1	0.0	0.0	0.0	5.7	10.5
EU new van CO_2 regulation 147 gCO_2/km in 2020	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.5	0.8	1.0	0.0	0.6	3.0
EU complementary measures for cars	0.0	0.0	0.0	0.1	0.2	0.3	0.5	0.7	0.9	1.0	1.1	1.3	1.5	1.8	1.9	0.3	3.4	7.7
Low rolling resistance tyres for HGVs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.4	0.6	0.7	0.7	0.7	0.0	0.5	3.2
Industry-led action to improve HGV efficiencies	0.0	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.4	0.5	0.6	0.7	0.4	0.4	0.6	0.3	2.2	2.7
Local Sustainable Transport Fund	0.0	0.0	0.0	0.2	0.4	0.6	0.8	1.0	0.8	0.6	0.5	0.5	0.5	0.4	0.2	0.6	3.7	2.0
Low carbon buses	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.3	0.3	0.4	0.0	0.2	1.4
Rail electrification[115]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.0	0.1	1.0
Total	**0.0**	**0.0**	**0.0**	**0.6**	**1.2**	**2.0**	**3.3**	**4.7**	**5.8**	**7.6**	**9.6**	**12.0**	**14.2**	**12.8**	**14.6**	**1.8**	**23.4**	**63.1**

[113] Transport savings for the EU new car and van regulations and Renewable Energy Strategy biofuel are modelled directly in the Department of Energy and Climate Change's Energy Model. Other transport savings are forecast using the Department for Transport's National Transport Model.

[114] Estimates of the savings from Transport biofuels are based on achievement of 8% fuel share by 2020. An assumption of 10% was used in the June 2010 projections. This change is for modelling purposes only and does not imply any change in policy or in the Government's commitment to renewables.

[115] Electrification of the Great Western Main Line as far as Cardiff, and the North West.

	Carbon budget 1					Carbon budget 2					Carbon budget 3					Carbon budget period 1	Carbon budget period 2	Carbon budget period 3
Agriculture and waste (non-CO_2) emissions[116]	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2008–12**	**2013–17**	**2018–22**
Agriculture Action Plan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.5	2.2	2.7	3.2	3.4	3.4	0.0	2.1	14.9
Landfill tax	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Defra waste policy	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Overall total	**0.0**	**0.1**	**0.2**	**0.9**	**3.8**	**7.7**	**10.3**	**13.7**	**17.8**	**23.0**	**28.4**	**34.0**	**39.1**	**38.7**	**41.2**	**5.1**	**72.5**	**181.4**

[116] Latest projections for waste emissions do not include an explicit estimate of the impact of landfill tax or waste policy: these have been absorbed into a single baseline projection.

Table B27: Projected traded sector emissions savings by policy included in the baseline ($MtCO_2e$)[117]

	Carbon budget 1					Carbon budget 2					Carbon budget 3					Carbon budget period		
																1	2	3
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2008–2012	2013–2017	2018–2022
Power																		
EU Emissions Trading System	13.0	9.5	7.6	12.2	7.6	5.5	5.2	5.3	4.5	4.9	6.1	7.4	8.2	6.0	5.6	49.8	25.4	33.3
Renewables	8.0	9.3	9.6	11.6	13.6	14.0	14.5	15.0	16.1	17.2	18.6	20.0	21.5	22.0	22.0	52.0	76.9	104.2
Large Combustion Plant Directive	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	8.4	0.0
Total	**23.8**	**21.6**	**20.0**	**26.6**	**23.9**	**22.4**	**22.5**	**23.1**	**20.6**	**22.2**	**24.7**	**27.4**	**29.8**	**28.0**	**27.6**	**115.8**	**110.7**	**137.5**
Residential																		
Building Regulation Part L (2002 and 2005/06)	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.8	1.0	1.1
Warm Front and fuel poverty measures	1.2	1.4	1.7	1.8	1.8	1.7	1.4	1.2	1.0	0.9	0.8	0.7	0.6	0.4	0.2	7.9	6.2	2.7
Supplier Obligation (EEC1, EEC2, original CERT)	1.4	2.7	3.7	4.2	4.2	4.0	3.8	3.7	3.6	3.0	2.4	1.8	1.8	1.7	1.6	16.2	18.2	9.3
Total	**2.7**	**4.3**	**5.5**	**6.2**	**6.1**	**5.9**	**5.5**	**5.1**	**4.9**	**4.1**	**3.4**	**2.7**	**2.6**	**2.3**	**2.1**	**24.9**	**25.4**	**13.1**
Commercial and public services																		
Carbon Trust measures	1.2	1.2	1.2	0.9	0.7	0.6	0.4	0.4	0.4	0.4	0.3	0.1	0.0	0.0	0.0	5.2	2.0	0.5
Energy Performance of Buildings Directive	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	2.2	2.2	2.2
UK Emissions Trading Scheme	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Building Regulations Part L (2002 and 2005/06)	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	1.3	1.8	1.9
Total	**1.9**	**1.8**	**1.9**	**1.7**	**1.5**	**1.3**	**1.2**	**1.2**	**1.2**	**1.2**	**1.1**	**1.0**	**0.9**	**0.9**	**0.8**	**8.8**	**6.1**	**4.7**

[117] For the purposes of this table, baseline is akin to the updated emissions projections baseline (Pre-Low Carbon Transition Plan policies). The table shows emissions savings from only some of the policies included in the baseline. It is not possible to quantify the emissions savings from all baseline policies individually. However, it should be noted that this does not impact on either the baseline or any of the newer policy emissions projections scenarios.

	Carbon budget 1					Carbon budget 2					Carbon budget 3					Carbon budget period		
																1	2	3
Industry	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2008–2012	2013–2017	2018–2022
Carbon Trust measures	0.9	0.9	1.0	0.7	0.6	0.5	0.4	0.3	0.3	0.3	0.2	0.1	0.1	0.0	0.0	4.1	1.7	0.5
UK Emissions Trading Scheme	0.5	0.4	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	2.0	1.0	0.1
Building Regulations Part L (2002 and 2005/06)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.7	0.7
Total	**1.5**	**1.4**	**1.4**	**1.2**	**1.0**	**0.9**	**0.7**	**0.6**	**0.6**	**0.6**	**0.5**	**0.3**	**0.2**	**0.2**	**0.2**	**6.6**	**3.4**	**1.3**
Overall total	**29.8**	**29.2**	**28.9**	**35.7**	**32.6**	**30.5**	**29.9**	**30.0**	**27.3**	**28.0**	**29.7**	**31.5**	**33.4**	**31.3**	**30.7**	**156.0**	**145.6**	**156.6**

Table B28: Projected traded sector emissions savings by policy additional to the baseline ($MtCO_2e$)[118]

	Carbon budget 1					Carbon budget 2					Carbon budget 3					Carbon budget period		
																1	2	3
Power	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2008–12**	**2013–17**	**2018–22**
Industrial Emissions Directive	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	1.3	1.3	0.0	0.0	2.8
Carbon Capture and Storage Demonstration Programme	0.0	0.0	0.0	0.0	0.0	0.0	1.1	1.5	2.1	2.3	4.4	5.6	5.6	5.6	5.6	0.0	7.0	26.8
Carbon Price Floor	0.0	0.0	0.0	0.0	0.2	5.7	0.9	0.7	0.9	1.8	2.7	1.1	0.3	0.8	5.8	0.2	9.9	10.8
Renewables[119]	0.0	0.0	0.0	0.0	0.6	3.3	5.8	10.1	14.2	16.3	17.8	19.8	21.1	22.4	23.5	0.6	49.7	104.6
Total	**0.0**	**0.0**	**0.0**	**0.0**	**0.7**	**9.0**	**7.8**	**12.3**	**17.1**	**20.4**	**24.9**	**26.7**	**27.1**	**30.1**	**36.2**	**0.8**	**66.7**	**145.0**
Residential																		
Supplier Obligation (CERT +20% and CERT extension)	0.0	0.1	0.2	0.3	0.5	0.9	0.8	0.8	0.8	0.8	0.7	0.6	0.6	0.6	0.6	1.2	4.1	3.0
Building Regulations Part L (2010)	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.1	1.3	2.5
Smart Metering	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.5	0.7	0.9	1.1	1.2	1.2	1.2	1.2	0.1	2.4	5.9
EU Products policy (Tranche 1, Legislated)	0.0	0.0	0.5	1.4	2.2	3.0	3.7	4.3	4.9	5.3	5.7	6.0	6.2	6.1	5.9	4.1	21.2	29.9
EU Products policy (Tranche 2, Proposed)	0.0	0.1	0.2	0.3	0.6	1.0	1.4	1.7	2.1	2.4	2.6	2.8	3.1	3.1	3.1	1.2	8.6	14.8
Community Energy Saving Programme	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.4	0.4
Zero Carbon Homes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.3	0.0	0.0	1.0
Energy Company Obligation and Domestic Green Deal	0.0	0.0	0.0	0.0	0.0	0.3	0.6	1.0	1.3	1.6	1.9	2.2	2.9	2.9	2.9	0.0	4.9	12.8
Renewable Heat Incentive	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.0	0.1	0.7
Total	**0.0**	**0.2**	**0.9**	**2.1**	**3.5**	**5.5**	**7.1**	**8.7**	**10.1**	**11.4**	**12.6**	**13.6**	**14.9**	**14.9**	**14.9**	**6.7**	**42.7**	**70.9**

[118] This table shows traded emissions savings additional to the baseline (Low Carbon Transition Plan and newer policies).

[119] Renewables savings include savings from the Renewables Obligation, Electricity Market Reform (Feed-in Tariffs with Contracts for Difference) and small-scale Feed-in Tariffs.

Commercial and public services	Carbon budget 1					Carbon budget 2					Carbon budget 3					Carbon budget period 1	2	3
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2008–12	2013–17	2018–22
Building Regulations Part L (2010)	0.0	0.0	0.0	0.0	0.2	0.4	0.6	0.8	1.0	1.1	1.3	1.5	1.6	1.8	1.9	0.2	3.9	8.0
Business Smart Metering	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.0	0.6	1.6
EU Products policy (Tranche 1, Legislated)	0.0	0.0	0.2	0.5	0.9	1.2	1.5	1.6	1.8	2.0	2.2	2.3	2.4	2.4	2.3	1.6	8.2	11.6
EU Products policy (Tranche 2, Proposed)	0.0	0.0	0.1	0.2	0.3	0.5	0.7	0.9	1.1	1.2	1.4	1.6	2.0	2.1	2.1	0.6	4.4	9.3
Small business energy efficiency interest-free loans	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Salix, public sector loans, 10% commitment for central govt	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0
Non-Domestic Green Deal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.4	0.5	0.6	0.6	0.6	0.6	0.0	0.8	2.9
Carbon Reduction Commitment Energy Efficiency Scheme	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.4
Renewable Heat Incentive	0.0	0.0	0.0	0.0	0.0	−0.1	−0.1	−0.2	−0.3	−0.5	−0.7	−0.9	−1.0	−1.0	−1.0	0.0	−1.2	−4.6
Total	**0.0**	**0.1**	**0.4**	**0.8**	**1.5**	**2.1**	**2.9**	**3.4**	**4.0**	**4.6**	**5.1**	**5.5**	**6.1**	**6.2**	**6.4**	**2.8**	**16.9**	**29.2**

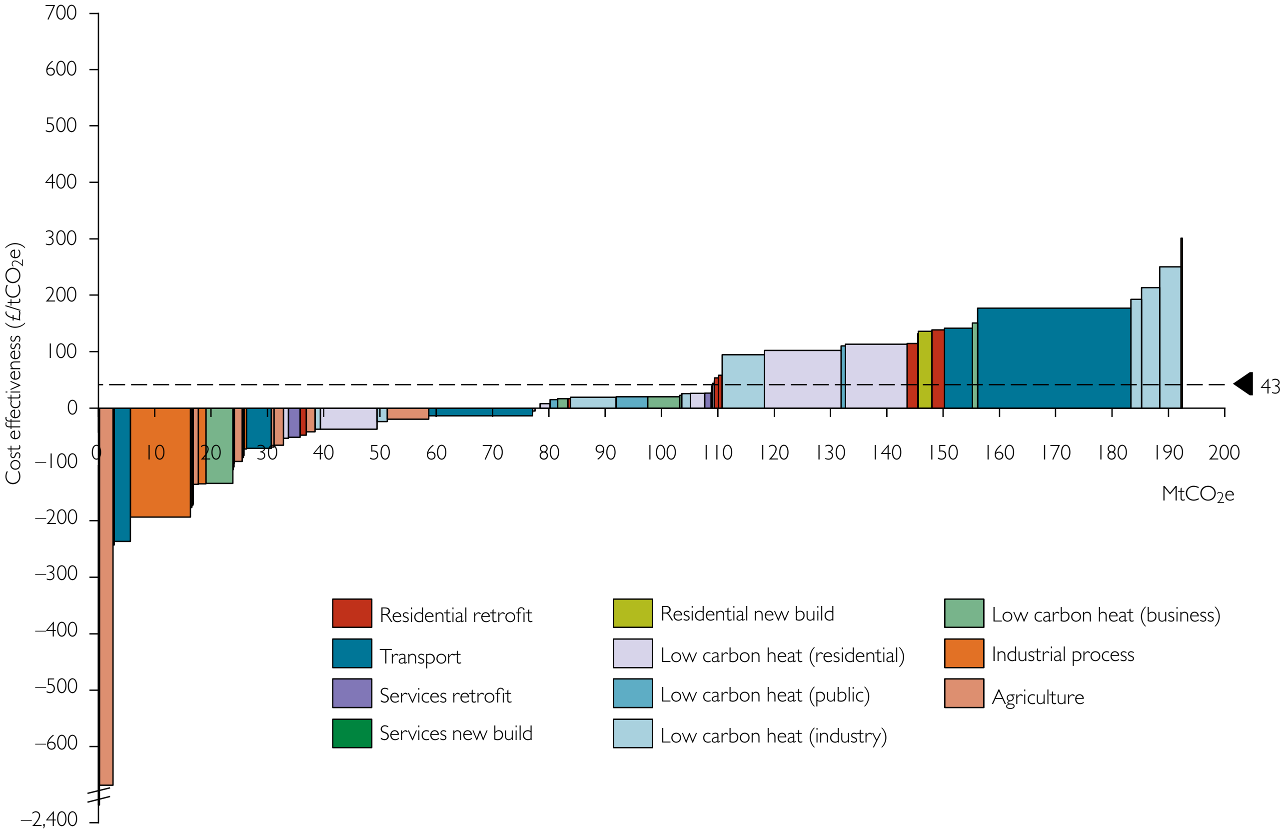
Industry	Carbon budget 1					Carbon budget 2					Carbon budget 3					Carbon budget period 1	2	3
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2008–12	2013–17	2018–22
Building Regulations Part L (2010)	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.1	1.3	2.6
EU Products policy (Tranche 1, Legislated)	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.7	0.6	0.6	0.2	1.5	3.0
EU Products policy (Tranche 2, Proposed)	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.1	0.7	1.6
Small business energy efficiency interest-free loans	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.1
Climate Change Agreements (2011–18)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Non-Domestic Green Deal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.3	0.0	0.4	1.3
Carbon Reduction Commitment Energy Efficiency Scheme	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Renewable Heat Incentive	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.6	0.8	1.1	1.5	1.9	2.4	2.4	2.4	0.1	3.2	10.6
Total	**0.0**	**0.0**	**0.1**	**0.2**	**0.4**	**0.7**	**1.0**	**1.4**	**1.8**	**2.4**	**2.9**	**3.6**	**4.2**	**4.2**	**4.2**	**0.7**	**7.2**	**19.2**
Transport																		
Rail electrification	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	0.0	−0.1	−0.5
Overall total	**0.0**	**0.3**	**1.4**	**3.1**	**6.1**	**17.3**	**18.7**	**25.8**	**33.1**	**38.6**	**45.4**	**49.2**	**52.2**	**55.4**	**61.6**	**10.9**	**133.4**	**263.7**

Fourth carbon budget scenarios marginal abatement cost curves

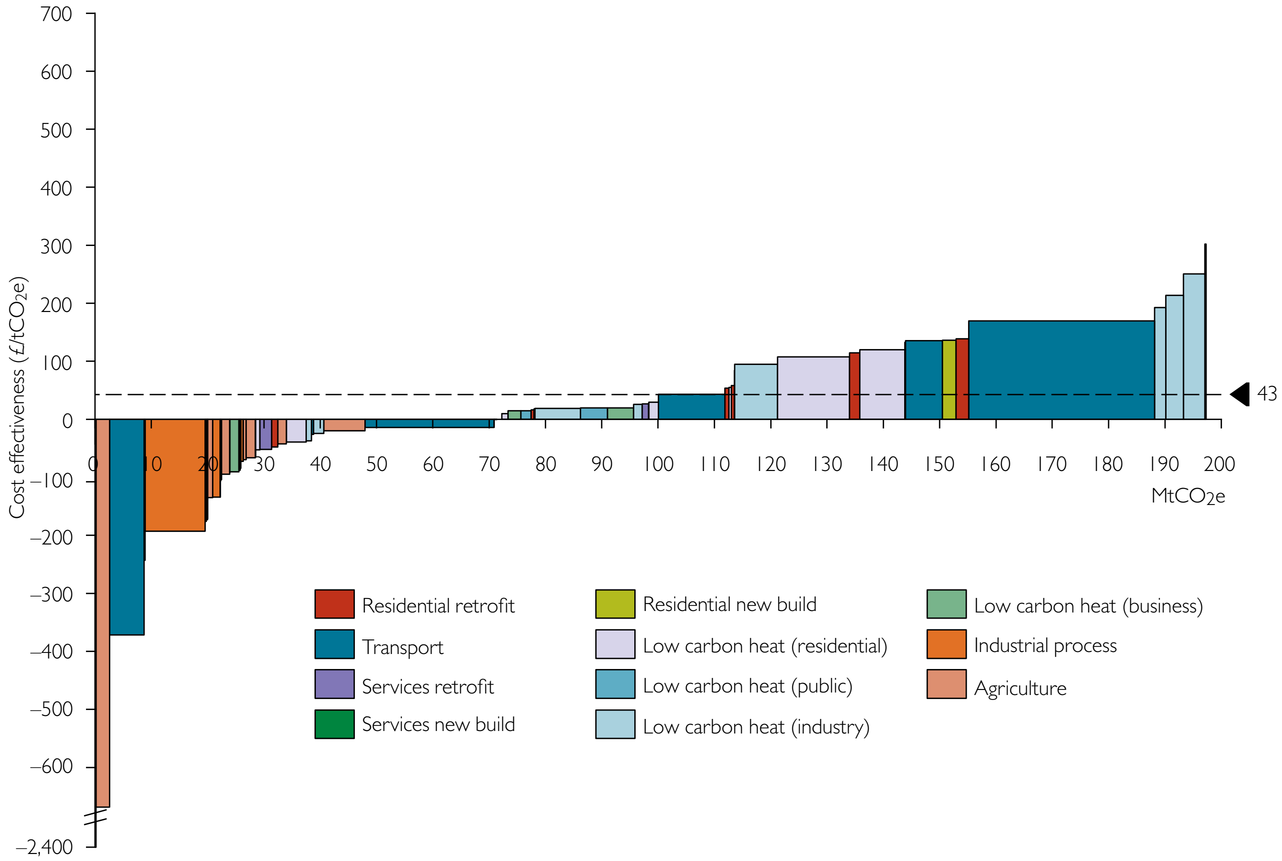
Charts B13–B16: Abatement included under illustrative Scenarios 1 to 4

The marginal abatement cost (MAC) curves below show the abatement and cost effectiveness of those measures taken up under the fourth carbon budget scenarios and described in section B3 of this annex. The abatement covers the five-year fourth carbon budget (2023–27). The cost effectiveness covers the lifetime of the measure. They do not purport to show all potential abatement, only that abatement potential that is actually taken up under the scenario.

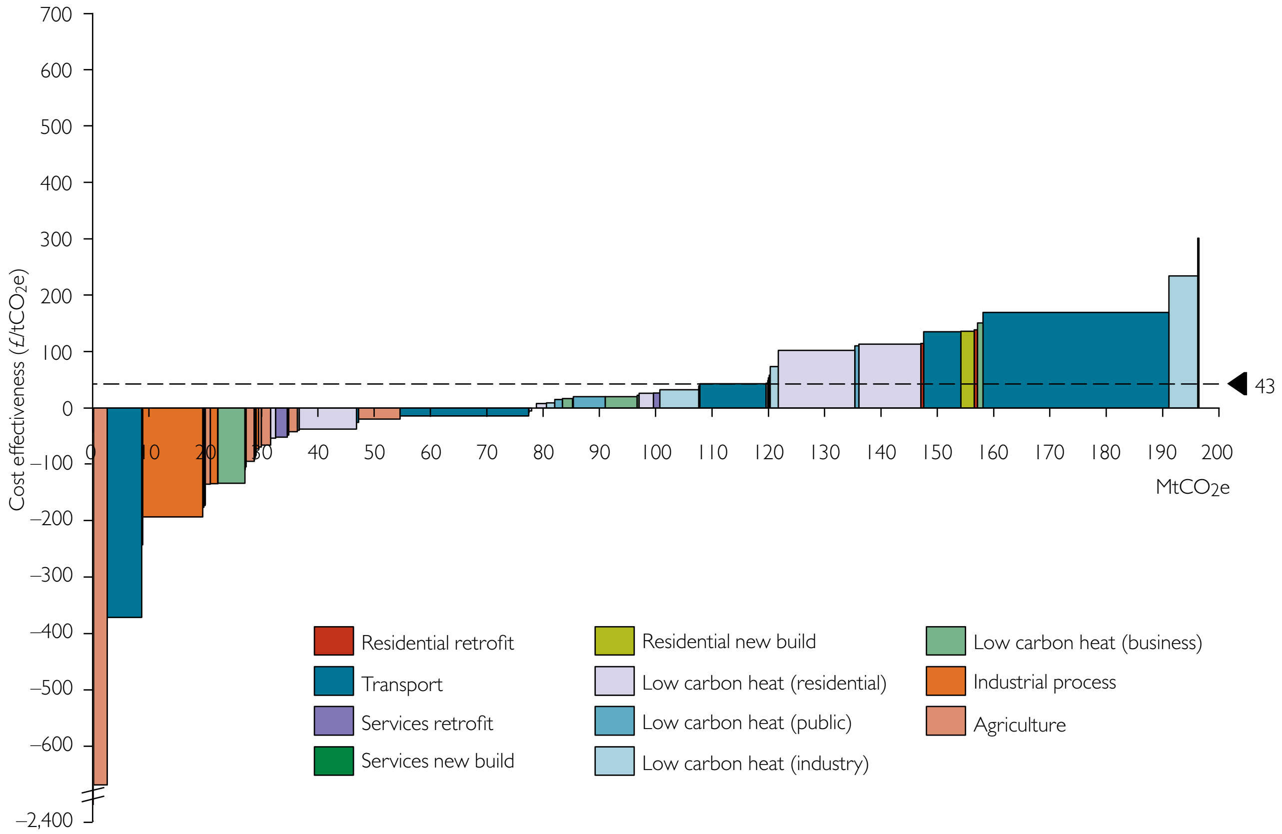
Scenario 1



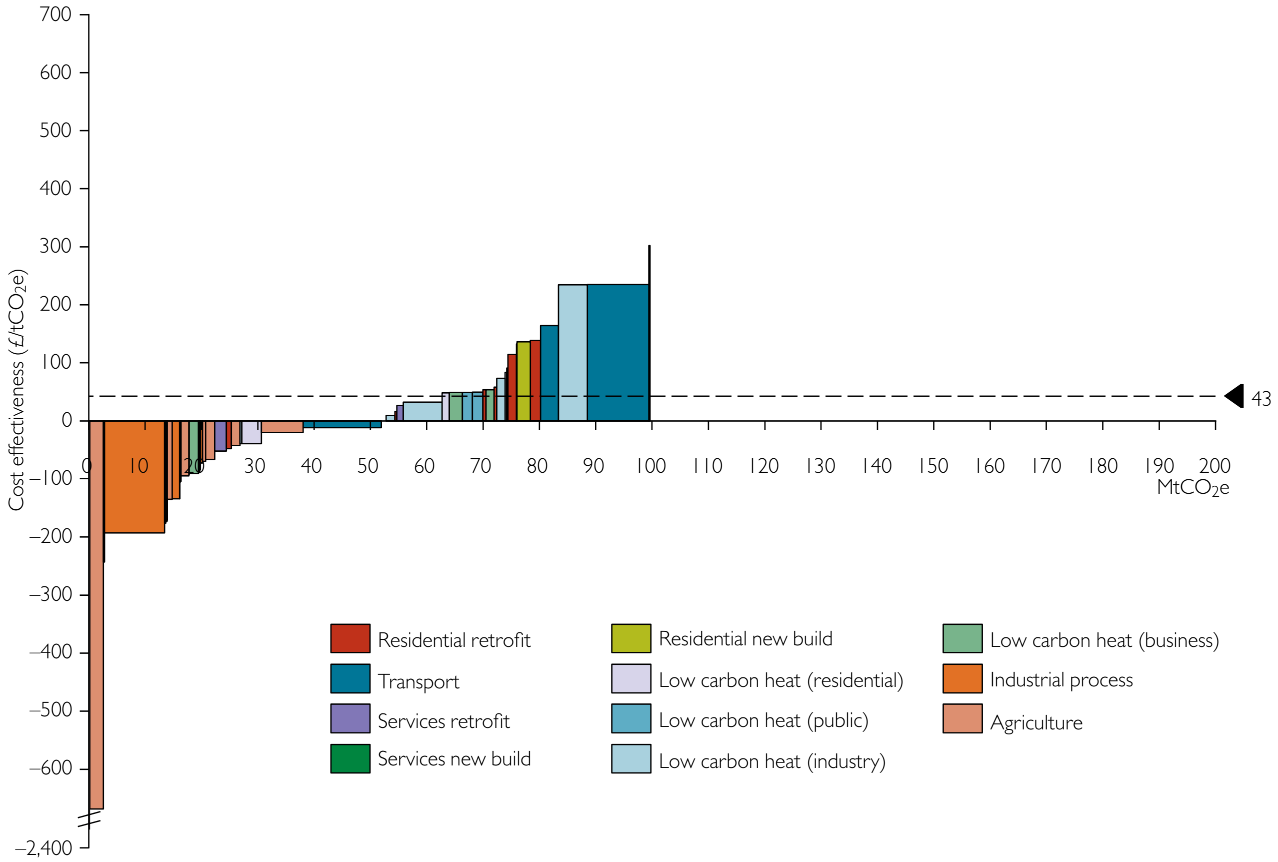
Scenario 2



Scenario 3



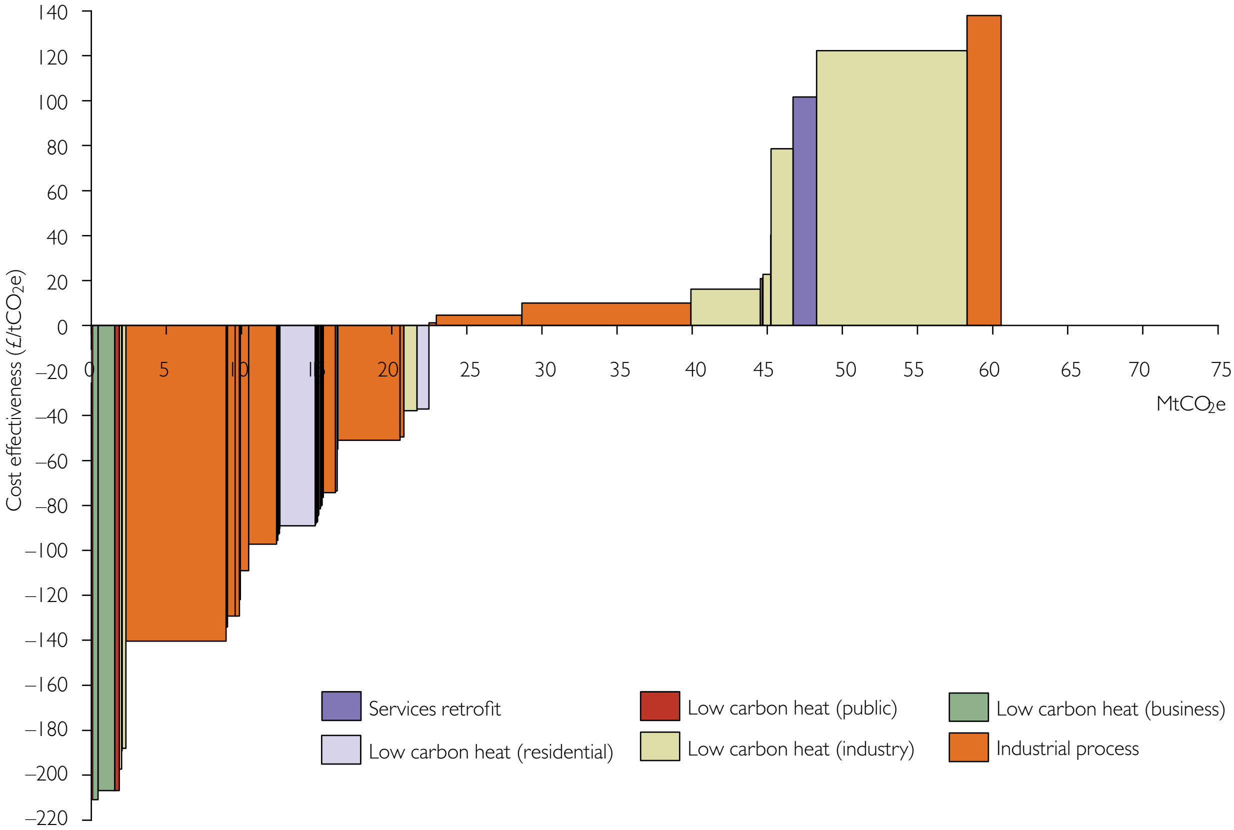
Scenario 4



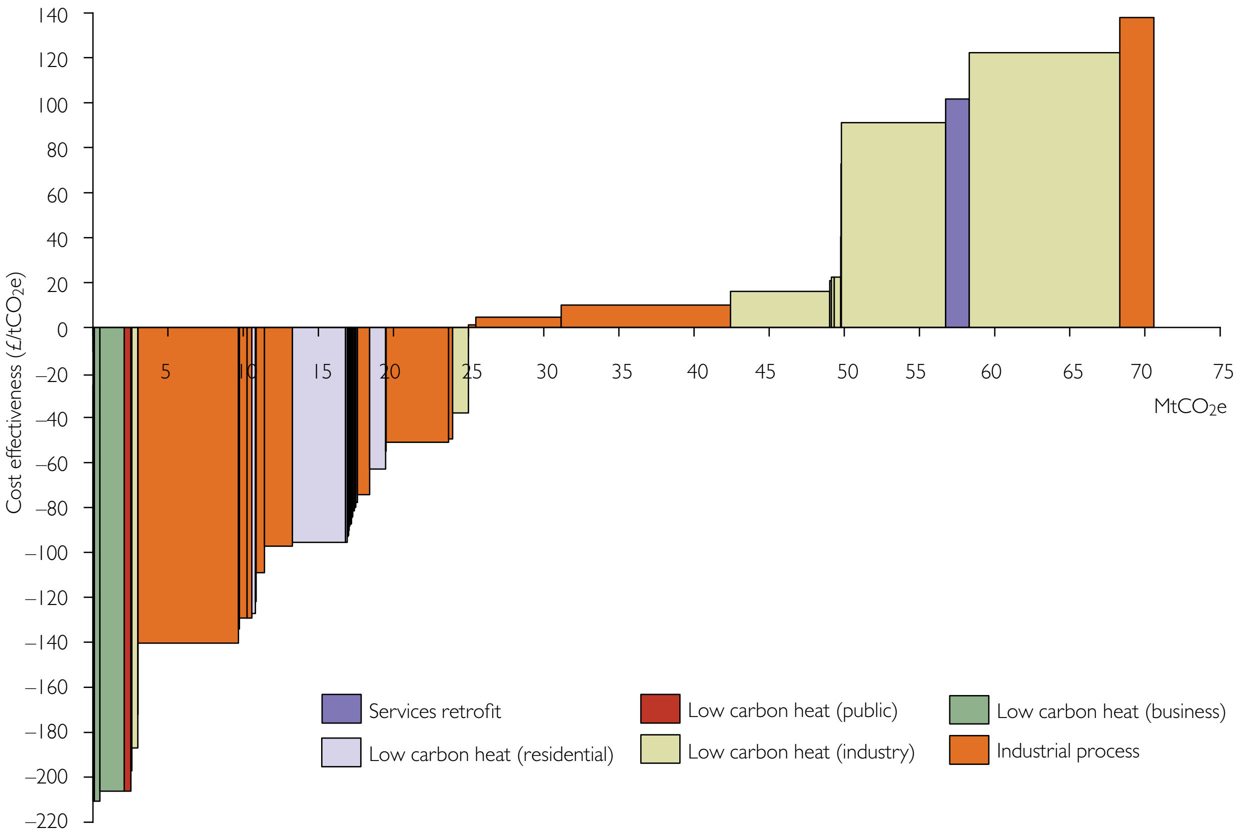
Cost effectiveness (£/tCO2e)
700
600
500
400
300
200
100
0
–100
–200
–300
–400
–500
–600
–2,400
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
MtCO2e
43
Residential retrofit
Transport
Services retrofit
Services new build
Residential new build
Low carbon heat (residential)
Low carbon heat (public)
Low carbon heat (industry)
Low carbon heat (business)
Industrial process
Agriculture

Charts B17–B18: Abatement included under the illustrative traded sector scenarios (excluding Electricity Market Reform) under central and high electricity demand

Central demand



High demand



Annex C: Carbon Plan action summary

Area	Start date	End date	Description	Department(s) responsible	Is action in Departmental Business Plan published Nov 2010?
Secure, sustainable low carbon energy	Started	Dec-2011	Publication of refreshed Electricity Networks Strategy Group (ENSG) analysis of potential transmission network requirements to meet 2020 renewable energy targets (2020 Vision)	DECC	N
	Started	Dec-2011	Set arrangements for the independent assessment of the safety, security and environmental impact of new reactor designs	DECC	Y(DECC)
	Started	Dec-2011	Finalise the framework that will ensure that new nuclear operators have arrangements in place to meet the full costs of decommissioning and their full share of waste management costs through publication of statutory Funded Decommissioning Guidance and a pricing methodology for government taking ownership of the operator's waste	DECC	Y(DECC)
	Started	Apr-2012	Publish National Planning Policy Framework	DCLG	Y(DCLG)
	Started	Apr-2012	Introduce as part of the national planning framework a strong presumption in favour of sustainable development	DCLG	Y(DCLG)
	Started	Apr-2012	Undertake first major review of Feed-in Tariffs for small-scale renewable energy; consult and implement changes (fast-track consideration of some aspects to be completed in 2011)	DECC	Y(DECC)
	Apr-2012	Apr-2012	Transfer relevant functions from the Infrastructure Planning Commission (IPC) into the Major Infrastructure Planning Unit	DCLG	Y(DCLG)
	Started	May-2012	Deliver Electricity Market Reform (EMR) clauses for inclusion in an early second session Energy Bill, which will implement: a new Feed-in-Tariff with Contracts for Difference (FIT CfD) for all low carbon technologies; a Capacity Mechanism to ensure security of supply; an Emissions Performance Standard (EPS); and the institutional arrangements necessary to deliver them	DECC	N

Area	Start date	End date	Description	Department(s) responsible	Is action in Departmental Business Plan published Nov 2010?
Secure, sustainable low carbon energy (continued)	Dec-2012	Dec-2012	Publish, with the nine other nations in the North Seas Countries' Offshore Grid Initiative, North Sea grid configuration options and proposals for tackling regulatory, legal, planning and technical barriers	DECC	Y(DECC)
	Started	Apr-2013	Work with the Department for Communities and Local Government to allow communities that host renewable energy projects to keep the additional business rates they generate – implement business rate retention for renewable energy development	DECC	Y(DECC)
	Started	Apr-2013	Conduct four-yearly review of Renewables Obligation (RO) Banding (levels of financial support for different technologies) to ensure that the RO provides the correct level of support to maintain investment in large-scale renewable energy generation	DECC	Y(DECC)
	May-2012	Apr-2013	Legislation will be brought forward as soon as Parliamentary time allows for the establishment in statute of an independent Office for Nuclear Regulation	DECC	N
	Apr-2013	Apr-2013	New RO Bands implemented (except for offshore wind)	DECC	Y(DECC)
	Apr-2014	Apr-2014	New RO Bands implemented for offshore wind	DECC	Y(DECC)
Saving energy in homes and communities	Started	Dec-2011	To set up a new Energy Efficiency Deployment Office (EEDO)	DECC	N
	Started	Jun-2012	Review water efficiency advice to be given as part of broader sustainability information available under the Green Deal	Defra	N
	Started	Apr-2012	Improve the content, format and quality of Energy Performance Certificates (EPCs) to support the Green Deal, and ensure requirements are complied with	DCLG, DECC	N
	Started	Jul-2012	Subject to consultation, work with industry to confirm technical specifications and begin roll-out of Smart Meters across Britain	DECC	Y(DECC)
	Started	Oct-2012	Develop policies to increase demand for the Green Deal, alongside core finance offer	DECC	Y(DECC)
	Started	Oct-2012	Support Green Deal implementation by providing access to EPC data	DCLG, DECC	N

Area	Start date	End date	Description	Department(s) responsible	Is action in Departmental Business Plan published Nov 2010?
Saving energy in homes and communities (continued)	Started	Oct-2012	Drive Green Deal demand by introducing energy efficiency regulations for private rented sector housing and commercial rented property from 2018 (conditional on there being no net or upfront costs to landlords) and consider as part of the Part L 2013 Building Regulations review ways of generating take-up of greater levels of energy efficiency measures in existing buildings in order to help support demand for the Green Deal.	DCLG, DECC	N
	Started	Oct-2012	Encourage local authorities to become involved in delivering energy efficiency in their areas and social landlords to take action to improve the energy performance of their social housing stock, which will also stimulate the Green Deal and provide greater certainty to suppliers, e.g. through Permissive Guidance to be published by April 2012	DCLG, DECC	N
	Started	Jan-2012	Consult on secondary legislation to enable the Green Deal, including the new obligation on energy companies	DECC	Y(DECC)
	Dec-2011	Mar-2012	Consult on revisions to Part L 2013 conservation of fuel and power of the Building Regulations	DCLG	Y(DCLG)
	Jan-2012	Mar-2012	Lay secondary legislation to enable the Green Deal before Parliament	DECC	Y(DECC)
	2016	2016	Zero carbon standard comes into effect for new homes	DCLG	N
Reducing emissions from business and industry	Started	Dec-2011	Put staff and back office systems in place for the Green Investment Bank, in preparation for the launch of the incubation phase	BIS	Y(BIS)
	Started	Dec-2011	Publish report outlining abatement potential, barriers and opportunities for key energy intensive sectors	BIS, DECC, HMT	N
	Started	Dec-2011	Continue market testing for the role of the Green Investment Bank beyond the incubation phase	BIS	Y(BIS)
	Started	Jan-2012	Consult on secondary legislation to enable the Green Deal, including the new obligation on energy companies	DECC	Y(DECC)
	Jan-2012	Jan-2012	Lay secondary legislation to enable the Green Deal before Parliament	DECC	Y(DECC)
	Dec-2011	Mar-2012	Consult on revisions to Part L 2013 conservation of fuel and power of the Building Regulations	DCLG	Y(DCLG)

Area	Start date	End date	Description	Department(s) responsible	Is action in Departmental Business Plan published Nov 2010?
Reducing emissions from business and industry (continued)	Started	Jun-2012	Review water efficiency advice to be given as part of broader sustainability information available under the Green Deal	Defra	N
	Sep-2012	Sep-2012	Green Investment Bank operational	BIS	Y(BIS)
	Started	Mar-2013	Encourage voluntary take-up of Display Energy Certificates to the commercial sector	DCLG, DECC	N
	Started	Oct-2012	Develop policies to enable application of the Green Deal to the commercial sector, alongside household offer	DECC	N
	May-2013	May-2013	First annual data released on the funds in and size of investments made by the Green Investment Bank	BIS	Y(BIS)
	2019	2019	Zero carbon standard comes into effect for new non-domestic buildings	DCLG	N
Towards low carbon transport	Dec-2011	Dec-2011	Complete transposition of transport elements of the Renewable Energy Directive	DfT	N
	Dec-2011	Dec-2011	Complete transposition of greenhouse gas (GHG) savings requirements of the Fuel Quality Directive	DfT	N
	Started	Jan-2012	Implement the inclusion of aviation within the EU Emissions Trading System	DfT	Y(DfT)
	Started	Mar-2012	Review strategy to support transition from early ultra-low emission vehicle market to mass market	DfT	Y(DfT)
	Started	Mar-2012	Push for early EU adoption of electric vehicle infrastructure standards	DfT	Y(DfT)
	Dec-2011	May-2012	Establish (a) a National Chargepoint Registry that will allow chargepoint manufacturers and operators to make information on their infrastructure, including location, available in one place; and (b) a Central Whitelist that enables users of chargepoint networks to access chargepoints across the country	DfT	N
	May-2012	May-2012	Release details on the second tranche of projects to be supported by the Local Sustainable Transport Fund	DfT	N
	Mar-2012	Jul-2012	Consult on sustainable aviation framework for UK	DfT	Y(DfT)
	Mar-2012	Aug-2012	Launch of competition for low carbon trucks demonstration trial.	DfT	N
	Jun-2012	Jun-2012	Release details on the large projects to be supported by the Local Sustainable Transport Fund	DfT	N

Area	Start date	End date	Description	Department(s) responsible	Is action in Departmental Business Plan published Nov 2010?
Towards low carbon transport (continued)	Mar-2012	Aug-2012	Launch of competition for public gas refuelling infrastructure projects (for gas-fuelled trucks)	Dft	N
	Jan-2012	Sep-2012	Review progress from industry-led schemes to reduce fuel consumption and emissions from the freight sector and reconsider the case for government intervention	DfT	N
	Dec-2012	Dec-2012	Decide whether or not to include international aviation and shipping in UK carbon budgets and 2050 target	DfT, DECC	N
	Started	Jan-2013	Provide input into the European Commission's ongoing review of the EU's new car and van CO_2 targets for 2020	DfT	N
	Started	Mar-2013	Release second round funding to successful bidders for Plugged-in Places pilots programme to encourage the establishment of electric vehicle recharging infrastructure	DfT	Y(DfT)
	Mar-2013	Mar-2013	Adopt sustainable aviation framework	DfT	Y(DfT)
	Mar-2013	Jun-2013	Provide an update to the Plug-in Vehicle Infrastructure Strategy	DfT	N
Cutting emissions from waste	Started	May 2015	Implement the set of actions outlined in the Review of Waste Policies in England	Defra	N
Managing land sustainably	Started	Jun-2012	Conduct a pilot project to develop and trial methods for delivering integrated environmental advice for farmers (including on reducing GHG emissions)	Defra	Y(Defra)
	Apr-2012	Apr-2012	The Independent Panel on Forestry makes recommendations on the future direction of forestry and woodland policy in England. The Government will respond in due course.	Defra, Forestry Commission	N
	Started	Jun-2012	Publication of Sustainable Growing Media Taskforce roadmap	Defra	N
	Apr-2012	Nov-2012	Review of progress made towards reducing GHG emissions from agriculture	Defra	Y(Defra)
	Jan-2015	Dec-2015	Horticultural Use of Peat policy progress review	Defra	N
	Started	2016	Invest £12.6 million to improve the GHG inventory for agriculture, thereby strengthening our understanding of on-farm emissions	Defra, Devolved Administrations	Y(Defra)
	May-2012	2017	Initiate a research programme on Sustainable Pathways for Low Carbon Energy to help understand what a sustainable energy mix would look like in 2050, taking account of cost, GHG savings and wider impacts	Defra	N

Area	Start date	End date	Description	Department(s) responsible	Is action in Departmental Business Plan published Nov 2010?
Reducing emissions in the public sector	Started	Mar-2015	Reduce GHG emissions, waste generated, water consumption and domestic business air travel and encourage sustainable procurement for the whole central government estate	CO, All departments	N
Developing leadership within the European Union	Started	Dec-2011	Support the European Commission to publish an energy roadmap to 2050 which sets out scenarios for how the power industry can be decarbonised and maximise Member States' support	DECC	Y(DECC)
	Started	Dec-2011	Encourage a strong EU position in the UN Framework Convention on Climate Change negotiations in Durban, South Africa	FCO, DECC	Y(FCO)
	Started	Dec-2011	Agree EU legislation on transparency and integrity of wholesale energy markets	DECC	N
	Started	Jun-2012	Agree EU legislation on energy infrastructure to support projects of European interest and facilitate commercial infrastructure investment needed for security of supply and low carbon transition	DECC	Y(DECC)
	Started	Oct-2012	Support the European Commission in implementing the low carbon roadmap	DECC	N
	Started	Dec-2012	Complete review of EU regulation on fluorinated greenhouse gases and conclude possible negotiations on any proposals	Defra	N
	Started	Dec-2012	Work with the EU to agree energy efficiency and labelling standards for remaining energy using products in residential and tertiary sectors, and some industrial products	Defra	Y
	Started	Dec-2012	Work with international partners to increase take-up of effective product policies and to move towards harmonised global product standards	Defra	N
	Started	Dec-2012	Work with partners in Europe to establish standards for smart grids and Smart Meters by the end of 2012	DECC	N
	Dec-2012	Dec-2012	Complete negotiations on next EU budget spending period (Multiannual Financial Framework (MFF)) – including agreeing an increase in the share of low carbon spending within an MFF settlement that increases by no more than inflation overall	HMT	N

Area	Start date	End date	Description	Department(s) responsible	Is action in Departmental Business Plan published Nov 2010?
Developing leadership within the European Union (continued)	Dec-2012	Dec-2012	Publish proposals for tackling the regulatory, legal, planning and technical barriers to co-ordinated offshore grid development in the North and Irish Seas	DECC	Y(DECC)
	Started	Dec-2014	Develop EU technical codes to improve functioning/integration of EU energy markets	DECC	N
	Started	May-2015	Drive efforts within the EU to amend the Emissions Trading Scheme Directive to deliver full auctioning of allowances	DECC	Y(DECC)
	Started	May-2015	Accelerate the global transition to a low carbon climate resilient economy, working with EU institutions and partners	FCO	Y(FCO)
	Started	May-2015	Extend the internal market, energy security and liberalisation; promote global free trade with a special regard for global poverty alleviation and co-ordinated action to build a low carbon economy and avoid dangerous climate change; implement the Energy Third Package effectively	FCO	Y(FCO)
Building the case for global ambition with key countries and international institutions	Started	Dec-2011	Subject to funding, UK Climate Security Envoy to have engaged with US, Canada, Japan, African Union and Australia on national and global security risks of climate change	FCO, MOD, DECC	N
	Started	Dec-2011	Agree action plan for co-operation with Norway on oil and gas, carbon capture and storage and renewables	DECC	Y(DECC)
	Started	Dec-2011	Support the Government of India in its work to improve industrial energy efficiency, including through the PAT scheme and building of capacity to enable Indian industry to take full advantage of the scheme	DECC, DFID	N
	Started	Feb-2012	Monitor the carbon impacts of UK consumption of goods and services by obtaining updated annual estimates of 'embedded' carbon emissions	Defra	N
	Apr-2012	Apr-2012	UK hosts Clean Energy Ministerial meeting, securing further progress on practical collaborations on key low carbon technologies	DECC	N
	May-2012	May-2012	Secure continued commitment to ambitious action on international climate change via the G8 summit	DECC, FCO	N
	Jun-2012	Jun-2012	Take part in UN Conference on Sustainable Development (Rio+20) discussions on Green Economy in the context of sustainable development and poverty eradication and institutional frameworks	Defra	Y(Defra)

Area	Start date	End date	Description	Department(s) responsible	Is action in Departmental Business Plan published Nov 2010?
Building the case for global ambition with key countries and international institutions (continued)	Started	Dec-2012	Continued in principle support for phase-down of hydrofluorocarbon production and use, using the Montreal Protocol	Defra	Y(Defra)
	Started	Dec-2012	Work with the Convention on Biological Diversity to improve synergies between climate change and biodiversity policy, including on biodiversity safeguards in REDD+ strategies to reduce emissions from deforestation	Defra	N
	Started	May-2015	Low carbon campaign in priority markets of India, China, Brazil and US West Coast, in addition to support for low carbon exporters in other markets	UKTI	N
Supporting the development of low carbon, climate resilient economies	Started	Dec-2011	Agree action plan for co-operation with Norway on oil and gas, carbon capture and storage (CCS) and renewables	DECC	Y(DECC)
	Started	Nov-2012	Continuing to engage bilaterally with key countries and international fora involved in CCS such as the Carbon Sequestration Leadership Forum, the International Energy Agency, the Global CCS Institute and European CCS bodies	DECC	N
	Nov-2012	Nov-2012	Publish final EU report on fast-start funding	DECC, DFID, HMT	N
	Started	Dec-2012	Encourage governments, through a range of initiatives, to design and deliver low carbon development	DECC	N
	Started	Dec-2012	Establish the Capital Markets Climate Initiative to use private sector expertise to test new and innovative instruments for leveraging private finance to tackle climate change in developing countries	DECC, DFID	Y(DECC)
	Started	Dec-2012	Deliver £300 million of UK fast start finance to reduce emissions from deforestation	DECC, DFID, Defra	Y(DECC)
	Started	Dec-2013	Roll out Strategic Climate Programme Reviews in all programme countries to ensure that climate issues are addressed in DFID country business plans	DFID	Y(DFID)
	Started	Dec-2014	Support, together with commitments from other donors, the Global Environment Facility (GEF)	DFID	N

Area	Start date	End date	Description	Department(s) responsible	Is action in Departmental Business Plan published Nov 2010?
Supporting the development of low carbon, climate resilient economies (continued)	Started	Apr-2015	Support for a range of programmes at country level through DFID's bilateral programme to support poor countries to adapt to climate change, protect forests and support low carbon development	DFID	N
	Started	Apr-2015	Support the Climate and Development Knowledge Network (CDKN) to enable developing countries to access the best climate change knowledge, research and data to enable them to build resilience to climate change, adopt low carbon growth and tackle poverty	DFID	N
	Started	Apr-2015	Complete the disbursement of £2.9 billion of climate finance	DECC, DFID, HMT, Defra	N
Ensuring progress within international climate negotiations	Started	Dec-2011	Design a new international Green Fund with international partners	DECC	Y(DECC)
	Started	Dec-2011	Work for a comprehensive global agreement on climate, including securing significant progress at the UN Framework Convention on Climate Change (UNFCCC) negotiations in Durban, South Africa	FCO, DECC	Y(FCO)
	Dec-2012	Dec-2012	Work through the UNFCCC negotiations to make progress towards a global deal on reducing emissions and the provision of climate finance	DECC	N
	Sep-2012	Mar-2013	Monitor and evaluate the impact and value for money of the Advocacy Fund to help the poorest countries take part in international negotiations	DFID	Y(DFID)
	Dec-2013	Dec-2013	Negotiations under the International Civil Aviation Organization and the International Maritime Organization to encourage reduction in emissions from the aviation and maritime sectors	DfT	N
	2013	2015	Support work through the UNFCCC to review progress towards the 2 degree target and its adequacy in the light of the latest science	DECC	N

Area	Start date	End date	Description	Department(s) responsible	Is action in Departmental Business Plan published Nov 2010?
Action in Northern Ireland, Scotland and Wales	Started	Dec-2011	Achieve emissions reductions from new buildings through a progressive tightening of thermal standards required under Building Regulations. Department of Finance and Personnel (DFP) to take this forward in two stages – 2011 and 2013	DFP	n/a
	Started	Mar-2012	Consider Planning Policy Statement 1 (Sustainability) which is being undertaken to take account of, and give support to, planning reform implementation	DOE	n/a
	Started	Dec-2012	Achieve renewable electricity target of 12% as part of the Department of Enterprise, Trade and Investment (DETI) Strategic Energy Framework (SEF)	DETI	n/a
	Jan-2013	Mar-2013	Achieve emissions reductions from new buildings through a progressive tightening of thermal standards required under Building Regulations. DFP to take this forward in two stages – 2011 and 2013	DFP	n/a
	Started	Mar-2014	Deliver Sustainable Development Plan	Office of the First Minister and deputy First Minister (OFMDFM)	n/a
	Started	Mar-2015	Refine agricultural greenhouse gas inventories	DARD	n/a
	Jan-2011	2020	Achieve renewable electricity target of 40% as part of the DETI SEF	DETI	n/a
	Jan-2011	2020	Achieve heat from renewable sources target of 10% as part of the DETI SEF	DETI	n/a
	Dec-2011	Dec-2011	Limit on use of carbon units to be set for 2013–17 (with successive batches at five-year intervals thereafter)	Scottish Government	n/a
	Dec-2011	Dec-2011	Target to generate 31% of final electricity demand from renewables	Scottish Government	n/a
	Jan-2012	Jan-2012	Report on progress requested from the Committee on Climate Change (and annually thereafter)	Scottish Government	n/a
	Mar-2012	Mar-2012	Scottish Government response to Committee on Climate Change progress report (and annually thereafter)	Scottish Government	n/a

Area	Start date	End date	Description	Department(s) responsible	Is action in Departmental Business Plan published Nov 2010?
Action in Northern Ireland, Scotland and Wales (continued)	Jun-2012	Jun-2012	Report on Proposals and Policies for 2023–27	Scottish Government	n/a
	Oct-2012	Oct-2012	Scottish Government report on whether annual target met (and annually thereafter)	Scottish Government	n/a
	Jan-2013	Jan-2013	Implementation of outcomes of review of new-build domestic energy standards for 2013 – intention of further improvement to achieve a 60% reduction in emissions compared with 2007	Scottish Government	n/a
	Dec-2013	Dec-2013	50% of waste collected from households to be recycled, composted and prepared for re-use	Scottish Government	n/a
	Oct-2011	Oct-2011	UK Climate Change Committee advice to Welsh Government on delivery of Climate Change Strategy and review of actions (and annually thereafter)	Welsh Government	n/a
	Dec-2011	Dec-2011	Climate Change Commission for Wales report on Welsh Government delivery of Climate Change Strategy (and annually thereafter)	Welsh Government	n/a
	Jan-2012	Mar-2012	Welsh Government report to National Assembly for Wales on delivery of Climate Change Strategy and refresh of Delivery Plans (and annually thereafter)	Welsh Government	n/a
	Sep-2012	Sep-2012	Final greenhouse gas emissions inventory figures for 2010, enabling confirmation of 2006–10 average emissions baseline (against which the 3% target is measured)	Welsh Government	n/a
	Sep-2013	Sep-2013	Greenhouse gas emissions inventory figures for 2011, enabling accurate reporting of progress for first year of 3% target (and annually thereafter)	Welsh Government	n/a

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