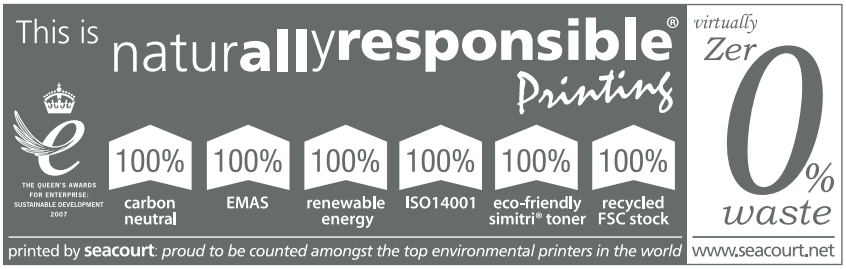
Committee on Climate Change

The Fifth Carbon Budget

The next step towards a low-carbon economy

November 2015



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The next step towards a low-carbon economy

Committee on Climate Change
November 2015

Presented to the Secretary of State pursuant to
section 34 of the Climate Change Act 2008

Preface

The Committee on Climate Change (the Committee) is an independent statutory body which was established under the Climate Change Act (2008) to advise UK and devolved administration governments on setting and meeting carbon budgets, and preparing for climate change.

Setting carbon budgets

In December 2008 we published our first report, 'Building a low-carbon economy – the UK's contribution to tackling climate change', containing our advice on the level of the first three carbon budgets and the 2050 target; this advice was accepted by the Government and legislated by Parliament.

In December 2010 we published our advice on the level of the fourth carbon budget, covering the period 2023-27. The fourth budget was legislated in June 2011 at the level we recommended. Following a request from Government, the Committee carried out a detailed review of the fourth carbon budget, published in two parts in November and December 2013. The Committee recommended no changes to the legislated fourth budget level. The Government accepted that advice.

Progress towards meeting carbon budgets

The Climate Change Act requires that we report annually to Parliament on progress meeting carbon budgets; to date we have published seven progress reports on carbon budgets (October 2009, June 2010, June 2011, June 2012, June 2013, July 2014 and June 2015) and will publish our eighth report in June 2016. The 2015 report was also the Committee's first joint report, covering progress towards meeting carbon budgets and progress on adaptation to climate change.

Advice requested by Government

We provide ad hoc advice in response to requests by the Government and the devolved administrations. Under a process set out in the Climate Change Act, we have advised on reducing UK aviation emissions, Scottish emissions reduction targets, UK support for low carbon technology innovation, design of the Carbon Reduction Commitment, Welsh emissions reduction targets and on many other areas. In April 2013 we published advice on reducing the UK's carbon footprint and managing competitiveness risks.

In September 2010, we published our first report on adaptation, assessing how well prepared the UK is to deal with the impacts of climate change, and in June 2015 we published our first statutory progress report on adaptation, including a detailed assessment of the UK's National Adaptation Programme.

In March 2016, we will publish statutory advice on Scotland's emissions targets for the fifth carbon budget period, and a report – required under the Infrastructure Act 2015 – on the compatibility of onshore petroleum with meeting UK carbon budgets.

Advice on the fifth carbon budget

This report sets out our advice on the fifth carbon budget, covering the period 2028-2032, as required under Section 4 of the Climate Change Act; the Government will propose draft legislation for the fifth budget in summer 2016.

Acknowledgements

The Committee would like to thank:

A number of organisations for their support, including: the AVOID 2 consortium, Bloomberg, Climate Action Tracker, Climate Change Capital, the Confederation of British Industry (CBI), The Crown Estate, DECC, DfT, the Energy Technologies Institute, the Forestry Commission, the Grantham Institute on Climate Change, KPMG, the Northern Ireland Executive, Rothschild Group, the Scottish Government, Shell, the Solar Trade Association, the Sustainable Energy Association, the Welsh Government and Willis.

A number of individuals who provided significant support: Bevan Freake, Sarah Livermore, Laura McNaught, Jon Tecwyn and the Heat, Central modelling and Science & Engineering teams at DECC; Professor Jillian Anable, Dr. Catherine Bale, Dr. Tim Chatterton, Professor Philip Eames, Matthew England, Dr. Robert Gross, Kirsty Hamilton, Keith James, Louise Jeffery, Jules Kajtar, Alex Luta, Carman Mak, Damien Morris, Professor David Newbery, Professor Martin Parry, Joeri Rogelj, Professor Dale Southerton, Professor Goran Strbac and team, and David Vaughan.

The team that prepared the analysis for this report: This was led by Matthew Bell, Adrian Gault, Mike Thompson and David Joffe and included Owen Bellamy, Ute Collier, Taro Hallworth, Mike Hemsley, Jenny Hill, Gemma Holmes, Alex Kazaglis, Ewa Kmietowicz, Eric Ling, Amy McQueen, Dean Pearson, Stephen Smith, Jack Snape, Kavita Srinivasan, Indra Thillainathan and Ladislav Tvaruzek.

Other members of the Secretariat who contributed to this report: Jo Barrett, Phil Cohen, Benjamin Henshall, Yogini Patel, Nisha Pawar, Penny Seera, David Style, Sean Taylor, Stephanie Wildeshaus and Hannah Witty.

A wide range of stakeholders who attended our expert workshops and responded to our Call for Evidence, engaged with us, including through our public dialogue, or met with the Committee bilaterally.

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Foreword

This report fulfils the Committee's duty, under the Climate Change Act, to recommend to the Government the level of the fifth carbon budget. This budget will set the limit on UK emissions of greenhouse gases in the period 2028-32.

The timing for providing our recommendation is set by the Climate Change Act. It is coincidence that it comes at the same time as the meeting in Paris for the 21st Conference of the Parties (COP21). COP21 aims to reach a comprehensive and binding international agreement on emission reductions beyond 2020. However, the timing does remind us that countries around the world are taking serious action to tackle climate change, and the UK should be acting alongside them.

The UK Government is a strong advocate for an ambitious deal in Paris. In advance of the meeting, more than 160 countries have submitted pledges to reduce emissions. Assessment by the UNFCCC secretariat suggests that these pledges, fully implemented, could reduce expected global temperature rise to 2.7°C by the end of the Century. That is not enough to meet the internationally agreed limit of 2°C, but much better than the 4 to 5°C to which we would be committed on a business-as-usual course.

To meet the globally agreed 2°C limit, further actions will be required. There will be discussion in Paris of how that can be achieved, including through transparent evidence about progress and a ratchet mechanism by which national contributions can be adjusted upwards over time.

For the UK, we are already committed to a reduction in emissions of at least 80% in 2050, as against 1990 levels. We also have, through the Committee on Climate Change, an independent and transparent process for verifying and maintaining the UK's contribution to global efforts. Our recommendation for the fifth carbon budget reflects the outcome of the Committee's careful deliberations.

In developing our recommendation, we have published – in 2 separate reports in October 2015 – our emerging thinking in relation to climate science, international circumstances, and trajectories for the power sector through the 2020s. The advice in this report now brings together that thinking, alongside all the criteria we are required to consider, to make our formal recommendation.

In the period since 1990, UK emissions have fallen by 36%, on average around 12MtCO_2e a year. Meeting the fifth carbon budget will require emissions to fall at broadly that same rate to 2032, continuing the progress that the Government is already committed to for the fourth carbon budget (2023-27).

It is for the Government to lay a proposed level for the fifth budget before Parliament, which must be legislated by June 2016. Our recommendation reflects all the factors that should be taken into account.

In developing our advice we have benefited from a substantial level of engagement with interested parties. This has included responses to our call for evidence, extensive engagement with a wide range of businesses and other stakeholders in workshops and roundtable discussions and independent analysis undertaken by the Committee and others. The advice is better informed for that engagement.

I am, of course, grateful to the members of the Committee for their work in guiding development of the advice. Preparation has also been a substantial task for the Committee's secretariat and I am immensely grateful for all their hard work in bringing this report to fruition.

Lord Deben
Chairman, Committee on Climate Change

The Committee

The Rt. Hon John Gummer, Lord Deben, Chairman

The Rt. Hon John Gummer, Lord Deben, was the Minister for Agriculture, Fisheries and Food between 1989 and 1993 and was the longest serving Secretary of State for the Environment the UK has ever had. His sixteen years of top-level ministerial experience also include Minister for London, Employment Minister and Paymaster General in HM Treasury.

He has consistently championed an identity between environmental concerns and business sense. To that end, he set up and now runs Sancroft, a corporate responsibility consultancy working with blue-chip companies around the world on environmental, social and ethical issues. Lord Deben is Chairman of Valpak Limited and the Association of Professional Financial Advisors.

Professor Samuel Fankhauser

Professor Samuel Fankhauser is Co-Director of the Grantham Research Institute on Climate Change and Deputy Director of the ESRC-funded Centre for Climate Change Economics and Policy, both at the London School of Economics. He is a Director at Vivid Economics and a former Deputy Chief Economist of the European Bank for Reconstruction and Development.

Sir Brian Hoskins

Professor Sir Brian Hoskins, CBE, FRS is the Chair of the Grantham Institute for Climate Change and the Environment at Imperial College London and Professor of Meteorology at the University of Reading. His research expertise is in weather and climate processes. He is a member of the scientific academies of the UK, USA, and China.

Paul Johnson

Paul Johnson has been director of the Institute for Fiscal Studies since January 2011. He is a visiting professor at UCL. Paul has published and broadcast extensively on the economics of public policy including tax, welfare, inequality and poverty, pensions, education, climate change and public finances. He is author of major books on pensions, tax and inequality. He is one of the authors of the "Mirrlees review" of tax system design. Paul has previously worked at the FSA and has been chief economist at the Department for Education and director of public spending in HM Treasury as well as deputy head of the UK Government Economic Service.

Paul is currently a member of the council and executive committee of the Royal Economic Society, a member of the banking standards board and has just completed an independent review of consumer price inflation statistics for the UK Statistics Authority. He has previously served on the council of the Economic and Social Research Council. He was a founder council member of the Pensions Policy Institute and in 2010 he led a review of the policy of auto-enrolment into pensions for the new government.

Julia King, The Baroness Brown of Cambridge

Julia King DBE FREng, The Baroness Brown of Cambridge is a Fellow of the Royal Academy of Engineering (FREng) and was made a CBE for 'Services to Materials Engineering' in 1999. She was appointed by the Chancellor of the Exchequer in March 2007 to lead the 'King Review' to examine the vehicle and fuel technologies that, over the next 25 years, could help to reduce carbon emissions from road transport.

She is currently Vice-Chancellor of Aston University, and is one of the UK's Business Ambassadors, supporting UK companies in the areas of low-carbon and transport. Following on from a career as an academic researcher and lecturer in materials engineering at the Universities of Cambridge and Nottingham, Julia King joined Rolls-Royce PLC in 1994. At Rolls-Royce, she held a number of senior executive appointments, including Director of Advanced Engineering for the Industrial Power Group and Engineering Director for the Marine Business. Julia returned to academia in 2004 as Principal of the Engineering Faculty at Imperial College, London, moving to Aston in 2006.

Lord John Krebs

Professor Lord Krebs Kt FRS FMedSci ML is Emeritus Professor of Zoology at Oxford University. He was Principal of Jesus College, Oxford between 2005 and 2015. Previously, he held posts at the University of British Columbia, the University of Wales, and Oxford, where he was lecturer in Zoology, 1976-88, and Royal Society Research Professor, 1988-2005. From 1994-1999, he was Chief Executive of the Natural Environment Research Council and, from 2000-2005, Chairman of the Food Standards Agency. He is a member of the U.S. National Academy of Sciences.

He was chairman of the House of Lords Science and Technology Select Committee from 2010 to 2014, President of the British Science Association in 2012 and is a member of the House of Lords Energy and Environment Subcommittee of the EU Select Committees.

Lord Robert May

Professor Lord May of Oxford, OM AC FRS holds a Professorship at Oxford University. He is a Fellow of Merton College, Oxford. He was until recently President of the Royal Society, and before that Chief Scientific Adviser to the UK Government and Head of its Office of Science and Technology.

Professor Jim Skea

Professor Jim Skea has research interests in energy, climate change and technological innovation. He has been RCUK Energy Strategy Fellow since April 2012 and a Professor of Sustainable Energy at Imperial College since 2009. He was Research Director of the UK Energy Research Centre 2004-12 and Director of the Policy Studies Institute 1998-2004.

He has operated at the interface between research, policymaking and business throughout his career. He is President of the Energy Institute and was elected co-Chair of IPCC Working Group III in 2015. He was awarded a CBE for services to sustainable energy in 2013 and an OBE for services to sustainable transport in 2004.

The Fifth Carbon Budget – Executive Summary

The Climate Change Act sets the framework for the UK to transition to a low-carbon economy. The Act requires that UK emissions of greenhouse gases in 2050 are reduced to at least 80% below 1990 levels. The Act describes a range of factors – including affordability, competitiveness, the public finances, energy policy, technological progress, international and EU circumstances, scientific knowledge about climate change and the differences between the devolved administrations – that must be balanced to determine how best to reduce emissions to the level required by 2050.

To date, in line with advice from the Committee, four carbon budgets have been legislated. They set the required reduction in emissions, commensurate with balancing those factors, to 2027. The first carbon budget (2008-2012) was met and by 2014 emissions were 520 $MtCO_2e$, 36% below 1990 levels. Emissions over the five years of the fourth carbon budget (2023-2027) are capped at 1,950 $MtCO_2e$, equivalent to an average 52% below 1990 levels.[1]

We recommend that the fifth carbon budget is set at 1,765 $MtCO_2e$, including emissions from international shipping, over the period 2028-2032. That would limit annual emissions to an average 57% below 1990 levels. This balances the range of factors the Committee must consider, keeps the UK on its cost-effective path to 2050 and continues the UK's historical rate of emissions reduction (Figure 1). Our full set of recommendations is set out in Box 1. This statutory report presents our advice. It is accompanied by a technical report, published on our website that sets out the full analysis that supports this advice: *Sectoral scenarios for the fifth carbon budget*.

Our proposed budget requires a continuation of the increase in take-up of ultra-low emission vehicles (e.g. electric and plug-in hybrid cars and vans) and low-carbon heat (e.g. heat networks and heat pumps) required by the fourth carbon budget. These changes will require bigger behavioural adjustments than emissions reductions to date, but are needed to prepare for the 2050 target. To involve genuine emissions reductions they should be accompanied by deep reductions in emissions from electricity generation.

It is important to signal this direction in advance given the time required to develop new policies, to grow currently nascent markets, for consumer behaviours to adapt and to invest in supporting infrastructure and innovation. A looser budget would fail to send that signal and would involve stop-start investment, storing up higher costs for the future. A tighter budget would go beyond what is required to prepare for the 2050 target and beyond existing international commitments by comparable countries.

1 The fourth carbon budget was legislated to require a 50% reduction in emissions from 1990 levels. Revisions to the estimate for 1990 emissions mean the budget now requires a 52% reduction on 1990.

Box 1: Recommendations on the fifth carbon budget

1. **The budget.** The fifth carbon budget should be set at 1,765 $MtCO_2e$ for 2028-2032, including emissions from international shipping. On the current accounting basis (i.e. excluding emissions from international aviation and shipping), the budget would be 1,725 $MtCO_2e$.

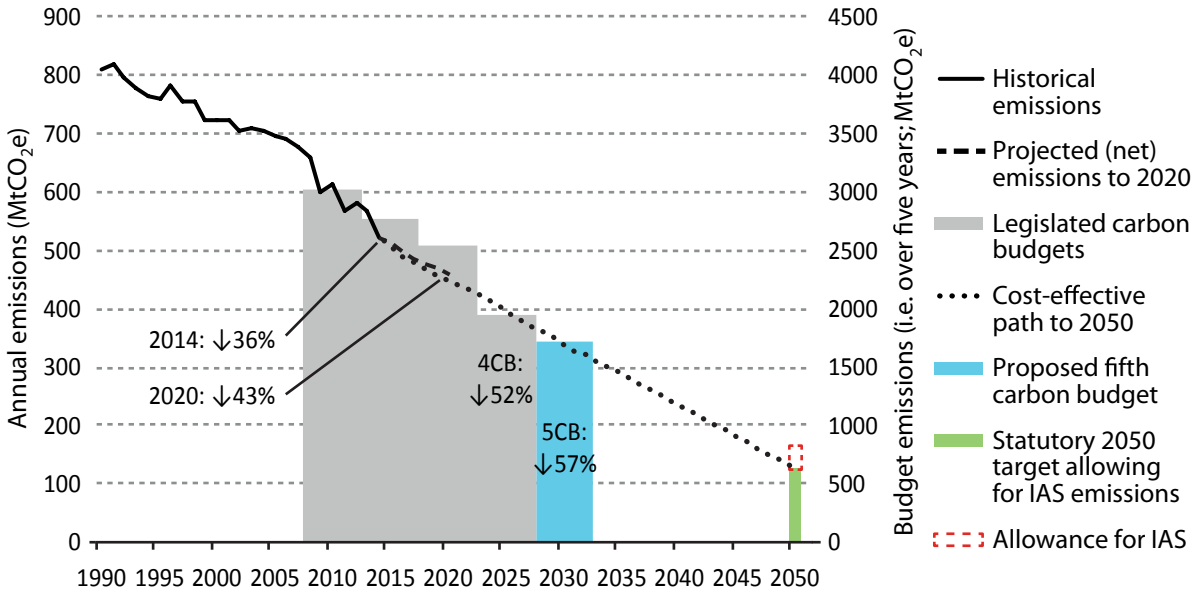
2. **International aviation.** Emissions from international aviation should continue to be allowed for by setting the budget on the path to meeting the 2050 target with international aviation emissions included. However, the accounting for these emissions remains uncertain, so they should not be formally included in the fifth carbon budget.

3. **Credits.** The budget should be met without the use of international carbon units (i.e. credits) outside the EU Emissions Trading System. If unexpected circumstances mean the budget cannot be met cost-effectively without recourse to purchase of credits, the Committee would revisit this advice, including an assessment of the strength and validity of the credit market at that time. Credits could also be used to go beyond the proposed budget to support international action to reduce emissions.

4. **Policy: low-carbon power.** The Government should develop policy approaches consistent with reducing carbon intensity of the power sector to below 100 gCO_2/kWh in 2030 (compared to 450 gCO_2/kWh in 2014 and 200-250 gCO_2/kWh expected by 2020).

5. **Policy: other sectors.** For sectors outside the EU Emissions Trading System the Government should develop policies to drive an average rate of emissions reduction of 2% (6 $MtCO_2e$) per year from 2014 to 2030. The Carbon Accounting Regulations should be set to ensure that emissions from these sectors are limited to 1,175 $MtCO_2e$ over 2028-2032 (1,135 $MtCO_2e$ excluding emissions from international shipping), which is the Committee's best estimate of the cost-effective path to the statutory 2050 target.

Figure 1: The recommended fifth carbon budget would continue emissions reduction on the path to the UK's 2050 target



Source: DECC (2015) *Final UK greenhouse gas emissions national statistics: 1990-2013*; DECC (2015) Provisional UK greenhouse gas emissions national statistics; DECC Energy Model; CCC analysis.
Notes: Data labels show reductions in annual emissions relative to 1990. Historical emissions are on a 'gross' basis (i.e. actual emissions). Projections and carbon budgets are on the current budget accounting basis: net carbon account excluding international aviation and shipping (IAS), but allowing for IAS to be included in the 2050 target.

Our fifth carbon budget recommendation follows the requirements of the Climate Change Act

Our advice reflects the full range of criteria set out in the Climate Change Act (section 10):

- The recommended budget is on the cost-effective path to the 2050 target in the Act, allowing for emissions from international aviation and shipping and recognising the differences in circumstances between England, Wales, Scotland and Northern Ireland.
- Potential impacts of the recommended budget for energy security, UK competitiveness, fuel poverty and the fiscal balance have been analysed and can be managed. In the case of competitiveness, suitable measures are currently being put into place. Between now and the start of the fifth budget period, in 2028, there is time to introduce further measures if required.
- The recommended budget is consistent with international and European commitments. It is on the path to the 2050 target which remains an appropriate contribution to the global effort that the latest climate science suggests is required to keep a likely chance of limiting global temperature increase to 2°C.

As required in the Climate Change Act (section 34), we identify the respective contributions towards meeting the carbon budget that should be made by 'traded' and 'non-traded' sources of emissions:

- **The 'traded' sector** refers to those sectors of the economy covered by the EU Emissions Trading System (EU ETS), primarily electricity generation and energy-intensive industry. Emissions from these sectors have reduced by 44% since 1990, and are projected to be 60% below 1990 levels by 2020. Under the accounting rules of the Climate Change Act (Box 2), the contribution of those sectors to the carbon budget will be determined by the emissions allowances allocated to the UK in the EU ETS, which is currently uncertain. Our proposed budget is based on our current best estimate of 590 $MtCO_2e$ for the fifth budget period, an average of 66% below 1990.[2]
- **The 'non-traded' sector** covers all emissions outside the EU ETS, including transport, heating in buildings, agriculture, waste and some industry. Emissions from these sectors have reduced by 29% since 1990, and are projected to be 35% below 1990 by 2020. For these sectors, performance against the budget is judged on actual emissions. Our proposed budget is based on our best estimate of the cost-effective path for emissions from today to the 2050 target in the Act. This implies emissions of 1,175 $MtCO_2e$ for the non-traded sector over the fifth budget period (1,135 $MtCO_2e$ excluding emissions from international shipping), an average of 51% below 1990.

The Committee has been told repeatedly by businesses that the value of the budget is in setting a clear, medium-term vision for the UK. Once legislated, carbon budgets provide a common guide for policymakers and signal to businesses and consumers.

To ensure that carbon budgets fulfil that role effectively they must be met through genuine actions. There is a specific risk that the accounting rules for the EU ETS, which are not yet finalised for the fifth carbon budget period, could undermine the integrity of the budget. If the UK ends up with a smaller share of the EU ETS cap than assumed in our analysis, then the budget could be met with less effort from the rest of the economy, and vice versa. The intention of the proposed budget is that emissions in the non-traded sector should fall an average of 2% (6 $MtCO_2e$) annually to 2030, whatever the UK share of the EU ETS cap. To ensure this is clear, **we recommend** that the Government uses the Carbon Accounting Regulations to fix the net carbon account for the traded sector at the assumed level (i.e. 590 $MtCO_2e$ over 2028-2032).

2 This estimate for the traded sector is an update from the estimate the Committee published in its October report on the scientific and international context for the fifth carbon budget. The change reflects the latest information about uncertain inputs, including the eligibility of UK installations for free emissions allowances allocated under the EU ETS. As when previous budgets have been set, the Committee will continue to work with Government officials in the coming months to ensure that when the budget is legislated it reflects any further significant developments in the evidence.

We also recommend (in line with our duty in section 35 of the Act) that the scope of the budget be broadened to include international shipping. To preserve the effort required in the budget, the inclusion of international shipping requires a higher limit for the fifth carbon budget at 1,765 $MtCO_2e$, rather than 1,725 $MtCO_2e$ were the budget to be set without including emissions from international shipping.

Carbon budgets are set to ensure the UK is on track to meet its 2050 obligation including emissions from international aviation as well as international shipping. However, continuing uncertainties over aviation's accounting within the EU ETS mean inclusion would be impractical at this time. We therefore recommend a fifth carbon budget that continues the approach to date: carbon budgets are set on the path to meeting the 2050 target including emissions from international aviation and shipping, but international aviation emissions are not formally included in the budget figures.

Box 2: Accounting rules in the Climate Change Act

Under the Climate Change Act, performance against carbon budgets is measured by the net UK carbon account. In practice, this means that the part of the budget for the power sector and energy-intensive industry, which is covered by the EU Emissions Trading System (EU ETS), is based on the UK's share of the ETS cap rather than the actual emissions in those sectors.

It is clear that in order to stay on track to the 2050 target in the Act, actual emissions must be reduced. The accounting rules should not be used to mask the real progress to the UK's legal commitment.

Our proposed budget implies a 57% reduction in emissions from 1990 to 2030 on the accounting basis in the Act. We also identify the cost-effective path for actual emissions across the UK economy (ignoring the allocation of emissions allowances in the EU ETS). For actual emissions the recommended budget requires a 61% reduction from 1990 to 2030. The larger reduction in actual emissions reflects our scenarios for the power sector. Under the cost-effective path the power sector should reach a carbon intensity of below 100 gCO_2/kWh in 2030. This would result in emissions in the traded sector of around 450 $MtCO_2e$ across the fifth carbon budget period, lower than the Committee's current best estimate of the allocation of emissions allowances to the UK.

To stay on track to the 2050 target and to support emissions reductions elsewhere in the economy, the power sector will need to reduce emissions at around the rate in our estimate of the cost-effective path. In line with our approach to date, the Committee will continue to assess progress towards carbon budgets and the 2050 target on the basis of both the net carbon account and actual emissions across the economy.

Meeting the fifth carbon budget will require progress in increasingly difficult areas to continue reducing emissions

To date, emissions reductions (beyond those resulting from general economic trends) have come from several sources. Energy efficiency has been improved in buildings and transport, while there has been a shift to lower-carbon fuels in electricity generation – namely natural gas and more recently renewables. There have also been reductions in non-CO_2 gases, in particular because less waste has been sent to landfill.

These trends will continue to be important in future, but will not be enough to reach the 2050 target alone. They must also be supplemented by more challenging measures, including switching to low-carbon energy sources in sectors beyond electricity generation.

Our proposed budget requires those measures to be implemented (Box 3). For example, the budget requires important contributions from electric vehicles (making up the majority of new car and van purchases in 2030), low-carbon heat (providing heat supply for around one in seven homes and over half of business demand), solid wall insulation (in around a quarter of suitable homes) and around a 15% reduction in agriculture emissions, alongside more conventional energy efficiency improvements. These changes will require bigger behavioural adjustments than required for emissions reductions to date.

It is important to commit to these changes in advance given the time required for consumer behaviours to adapt as well as time needed to develop new policies, to grow currently nascent markets and to invest in supporting infrastructure and innovation. A looser carbon budget would therefore not be appropriate. For example, a budget set solely to meet the UK's obligations under the EU's 2030 climate package would fail to prepare sufficiently for the 2050 target as it could be met without roll-out of low-carbon vehicles or heating in the 2020s.

A tighter budget could reflect a greater UK contribution to the international 2°C target[3], but would go beyond existing commitments in other comparable countries and beyond what is required to prepare for the UK's 2050 target. A tighter budget could still be achieved in future if required through increased UK effort and/or the purchase of emissions credits – potentially as part of a ratcheting up process for global effort.

Notwithstanding the accounting rules of the Climate Change Act, the power sector has a vital role in meeting carbon budgets. In 2030, almost a third of the reduction in emissions in other sectors in our scenarios is dependent on availability of low-carbon power. By 2050, over half of emissions abatement is reliant on low-carbon power. Furthermore, direct emissions from the power sector must be almost eliminated to achieve the final 2050 objective. Investments in generating capacity in the 2020s will still be on the system in 2050 and should be largely low-carbon. Investments in the 2020s should therefore be consistent with reducing carbon intensity of the UK power sector to below 100 gCO_2/kWh by 2030 and reducing actual UK emissions in 2030 from sectors covered by the EU ETS by around 75% on 1990 levels.

3 For a detailed discussion of different shares for the UK and EU in meeting an international 2°C target, see our recent report on The scientific and international context for the fifth carbon budget, available at https://www.theccc.org.uk/publication/the-scientific-and-international-context-for-the-fifth-carbon-budget

Box 3: Central scenario for meeting the fifth carbon budget

In developing its advice the Committee has built various scenarios for reducing emissions on the path to 2050. These scenarios are not prescriptive paths that must be followed. The scenarios allow the Committee to satisfy itself that its overall budget recommendation meets all the requirements under the Act. Our central scenario would meet the recommended budget and is our best estimate of the cost-effective path for the UK to reach the 2050 target in the Climate Change Act. It includes:

- In **Power**, the carbon intensity of generation decreases from around 450 gCO_2/kWh in 2014 to 200-250 g/kWh in 2020, and to below 100 g/kWh in 2030. This reduction could be delivered by a range of different mixes of low-carbon generation (i.e. renewables, nuclear and plants fitted with carbon capture and storage – CCS) to reach a total share of around 75% of generation by 2030. It is important that the low-carbon portfolio includes roll-out in the 2020s of offshore wind and CCS given their long-term importance and the role of UK deployment in driving down costs. Improvements to energy efficiency (e.g. increased use of LED lighting and more efficient appliances) will support progress in the power sector. The demand side also has an important role in increasing the flexibility of the power system, alongside interconnection, storage and flexible back-up capacity.
- In **Industry**, there is improved energy management and process control, use of more energy efficient plant and equipment, waste heat recovery, use of bioenergy in space and process heat and development of a CCS cluster allowing the use of CCS in the iron and steel and chemicals sectors. Hydrogen could provide an alternative to CCS depending how technologies develop.
- In **Buildings**, deployment of low-carbon heat increases so that heat pumps and heat networks from low-carbon sources provide heat for around 13% of homes and over half of business demand. Insulation increases (including around a further 1.5 million solid walls and 2 million cavity walls in the 2020s) and there is more use of heating controls and efficient lights and appliances. Alternatively, low-carbon heat could be provided via hydrogen added to the gas grid or using hybrid heat pumps, which include a gas boiler to top-up heat supply on the coldest days. The success of any of these measures will depend on public acceptance and wider behavioural factors that, along with skills and technological issues, currently limits their roll-out.
- In **Transport**, efficiency of conventional vehicles continues to improve in the 2020s (e.g. conventional car emissions fall from 125 gCO_2/km in 2014 to 102g/km in 2020 then 86g/km in 2030 on a test-cycle basis; we allow for 'real world' emissions in our scenarios), alongside deployment of electric vehicles across cars, vans and smaller HGVs (e.g. the combination of plug-in hybrids and battery electric vehicles reach 9% of new car and van sales in 2020 and around 60% in 2030). We include hydrogen buses (reaching 25% of sales in 2030), with the possibility of a bigger contribution from hydrogen for other vehicles types. On the demand side we assume some behavioural change results in modest reductions in total distance travelled and more fuel-efficient travel.
- In **Agriculture**, there is increased take-up of: crops and soils measures that mainly target the reduction of N_2O through improved efficiency of fertiliser use (e.g. use of cover crops and improved manure management practices); livestock measures targeting animal diets, health, and breeding that reduce methane; waste and manure management, including anaerobic digestion; and improvements in the fuel efficiency of stationary machinery.
- In **Waste**, the main biodegradable waste streams, including paper and food waste, are fully diverted away from landfill across the UK by 2025.
- **F-gases** are replaced by low-carbon alternatives in refrigeration, air conditioning and other uses by 2030.

Source: CCC analysis.

The recommended budget continues on the lowest cost path to the UK's 2050 target

The proposed budget continues on the lowest cost path to the UK's 2050 target. Meeting it will ensure costs are kept as low as possible in the long term. However, there is a financial cost to climate action since low-carbon technologies currently have higher costs than high-carbon alternatives, which do not face the full cost of their emissions:

- We estimate that meeting the proposed fifth carbon budget will involve an annual cost in 2030 that is up to £3 billion (around 0.1% of expected GDP) more than the cost of meeting the fourth carbon budget that has already been legislated. Costs would be lower to the extent that reduced carbon emissions mean UK firms can purchase fewer emissions allowances in the EU ETS.
- The total annual cost of meeting the fifth carbon budget in 2030 is therefore similar to our estimate of the cost of meeting the fourth carbon budget in 2025: less than 1% of GDP.
- Offsetting some of these costs, there are wider benefits to climate action through reduced air pollution and other health and environmental benefits. Using government valuation methods, we have previously estimated the monetary value of these to be around 0.1-0.6% of GDP in 2030. Our scenarios also involve a 40% reduction in imports of oil and gas compared to a scenario with no climate action, reducing the UK's exposure to volatile international fuel prices.

The Committee recommends setting the budget at this level because it is on the lowest cost path to the legislated 2050 target, and meets the other considerations required under the Act. Even in the absence of this target, not acting to tackle climate change is not an option given the much higher costs of unmitigated climate change and the international commitments in place. If the world is to stay credibly on track to the internationally-agreed objective to limit global temperature increase to 2°C, then the UK's share of the necessary global emissions reduction is likely to be at least as large as that required by our proposed budget.

The budget is therefore a low-regret course to follow.

Competitiveness and fuel poverty

Differences in the level and timing of effort and policy around the world could result in UK firms facing costs that differ from their international competitors. Where this could pose a competitive concern, compensations and exemptions are planned or in place, consistent with earlier advice from the Committee. Industries, including steel and cement plants, that are judged to be exposed to a loss of international competitiveness are allocated free allowances through the EU ETS and will be compensated or exempted from costs of supporting low-carbon investment in electricity generation. These plans are in place to 2020 and may need to be extended, depending on the ambition and policy approaches adopted internationally. The Committee will continue to monitor the need for compensation to be awarded to affected industries.

The additional impact on fuel poverty of the fifth carbon budget is small.

- The causes of fuel poverty are complex, dependent on heating needs (themselves dependent on factors including family composition, type and size of home, energy efficiency of home), type of fuel, as well as income. There is also a policy choice about how the costs of low-carbon measures – some of which currently flow through to electricity prices – should be funded.
- Support for low-carbon investment in the power sector, including the carbon price, added around £45 to the annual electricity bill for a typical household in 2014 (out of an average electricity bill of £470, and a typical energy bill of around £1,200). Government policies will increase this cost to around £105 in 2020. Assuming the current funding approach continues, our scenarios imply that this cost, including the carbon price impact, would increase to around £120 in 2030, before falling.[4] The increase in bills in the 2020s as a result of the fifth carbon budget would therefore be about £15 on a typical household bill.
- On top of this, households paid around £35 per year in 2014 to support energy efficiency improvements, which have contributed historically to a reduction in energy use without which bills would be higher. Continuing these or similar policies a little above this level, around £50 per year per household, should be enough to support the additional 1.5-2 million solid walls and around 3 million cavity walls insulated between now and 2030 in our scenarios. This would result in further energy saving and lower bills to the households that install them.

As we have shown in previous work, if energy efficiency measures can be effectively targeted at the fuel poor then overall numbers in fuel poverty would fall even as costs from supporting low-carbon investment increase.[5]

4 Exemptions proposed for industrial consumers at risk of competitiveness impacts would increase the costs to household consumers. We estimate they would add around an extra £5 to the annual bill for a typical household.

5 Letter from Lord Deben to the Parliamentary Under Secretary of State (October 2014), available at https://www.theccc.org.uk/publication/letter-fuel-poverty-strategy-consultation-response/

Meeting the fifth carbon budget will require new and extended climate policies

Under the Climate Change Act, the Government is required to legislate the fifth carbon budget by the end of June 2016, and must then develop its proposals and policies to meet the budget as soon as is reasonably practicable.

Policies are in place to continue reducing emissions to 2020. New policies will be needed to meet both the fourth and the fifth carbon budgets. The Government has recognised the need for policy development. In their response to the Committee's June 2015 Progress Report, the Government states: *"After we set the fifth carbon budget (by the end of June 2016), we will be able to set out more detail about our expectation for how we intend to meet the targets. Our new emissions reduction plan towards the end of 2016 will set out our proposals in full."*

Particular priorities are:

- Developing effective, low-cost approaches to energy efficiency in buildings and to drive a shift to low-carbon forms of heating (e.g. heat pumps and heat networks).
- Continuing efficiency improvement in vehicles, especially by shifting towards ultra-low emission (e.g. electric and plug-in hybrid) vehicles.
- Ensuring that low-cost, low-carbon power is rolled out in the 2020s.
- Supporting development of key emerging options such as carbon capture and storage.

The Climate Change Act sets statutory deadlines that mean the Committee is giving its advice before the 21st Conference of the Parties (COP21) to the UNFCCC takes place in Paris in December 2015. The COP21 negotiations are due to end on 11 December 2015 and could produce significant new developments. The Committee will write to the Secretary of State for Energy and Climate Change in early 2016 to set out if and how the outcomes of Paris, or other significant changes, affect our published advice.

Chapter 1: Approach to setting the Fifth Carbon Budget

1. The value of carbon budgets
2. Scope of carbon budgets
3. Balancing the criteria in the Climate Change Act
4. Feasibility of delivery
5. Areas of uncertainty and implications for budget setting

The Climate Change Act (2008) requires the Committee on Climate Change to provide advice to the Government about the appropriate level for the fifth carbon budget (covering the years 2028 to 2032) before the end of 2015. The Act specifies the factors the Committee must consider in that advice. These are discussed in detail below but, in essence, they mean that the Committee's advice should be based on the cost-effective path to the Act's ultimate 2050 objective (i.e. to reduce emissions by at least 80% from 1990 levels), consistent with international commitments and considerations such as affordability, competitiveness, energy security and the Government's fiscal position.

This report contains the final advice based on a very broad review of the evidence accompanied by detailed, independent analysis and expert judgment. It reflects the Committee's view that the progress made to date must continue in the future. Underneath that steady overall progress is a varying rate of progress across the different sectors of the economy: some have reduced emissions more quickly but cannot continue that to 2050 (like the power sector), others have reduced more slowly but must do more in the future (like heating for buildings, agriculture). Much of the detail contained in this advice report, and the accompanying Technical Report, is about the most cost-effective balance in emission reduction across the sectors in the period from 2028 to 2032.

Chapters 2-5 present analysis and evidence relevant to the criteria that the Committee are required to balance in recommending the carbon budget:

- science and international and European circumstances (Chapter 2),
- technology and economics (Chapter 3);
- fiscal circumstances, competitiveness, fuel poverty and security of supply (Chapter 4); and
- the differences in circumstances between England, Wales, Scotland and Northern Ireland (Chapter 5).

Chapter 6 pulls these together and sets out the recommended level of the fifth carbon budget. It also includes accompanying recommendations that are required under the Act, such as the treatment and implications of emissions from international aviation and shipping.

This report is supplemented by a Technical Report on *Sectoral scenarios for the fifth carbon budget*.[1] It sets out more detail about the scenarios we have developed to support this advice. The scenarios discuss the evidence the Committee has used to reach the view that the reduction in emissions in its final advice can be delivered while balancing all the factors it is required to consider. They are not intended as a prescriptive path and deliberately acknowledge the uncertainty inherent in the time-frames of carbon budgets. In advance of this advice the Committee has also published two reports with specific evidence about particular factors the Committee must consider: *The scientific and international context for the fifth carbon budget*[2] and *Power sector scenarios for the fifth carbon budget*[3].

The rest of this chapter gives a background to carbon budgets, expands on the criteria that the Committee must consider and sets out some of the challenges in doing so over a decade in advance.

1 available from https://www.theccc.org.uk/publications
2 available from https://www.theccc.org.uk/publication/the-scientific-and-international-context-for-the-fifth-carbon-budget
3 available from https://www.theccc.org.uk/publication/power-sector-scenarios-for-the-fifth-carbon-budget

1. The value of carbon budgets

Carbon budgets set five-year caps on net emissions of greenhouse gases across the UK economy. They are set 12 years ahead of their start year to provide time for actions to minimise costs and maximise benefits to households and businesses of achieving the budgets. They must be set to be consistent with the UK's long-term statutory goal to reduce emissions by at least 80% on 1990 levels by 2050.

The Committee on Climate Change is an independent body. Its advice is based on a systematic review of wide-ranging evidence about the costs and benefits of reducing emissions in all parts of the economy. That review incorporates understanding of the implications of the inherent uncertainty about future developments.

The Climate Change Act sets out the criteria that must be considered in setting carbon budgets (see section 3). The Committee provides an independent assessment of those criteria based on the best available evidence and extensive stakeholder engagement (Figure 1.1 and Box 1.1).

The carbon budgets combine stability in the overall target (the desired end or outcome in terms of emissions reduction) with flexibility in the balance of effort across different sectors and between options within sectors (the means by which that emissions reduction is achieved). This recognises the uncertainties in setting budgets 12 years ahead while preserving the advantages of doing so. In particular:

- **Stability of ends**. The carbon budgets are enshrined in law under the Climate Change Act, which specifies that the budgets can only be altered in response to a significant change in circumstances since the budget was set. This stability is important in order to provide clarity for those making decisions about how best to deliver the required reduction in emissions.
- **Flexibility in the means to that end**. The design of carbon budgets allows for flexibility for different balances of effort to reduce emissions across sectors and technologies. Between now and the start of the fifth carbon budget period in 2028, households, businesses, investors and the Government will learn more about the most effective combination of actions to meet the carbon budget. Some of that learning will come from the efforts to meet previous carbon budgets.

The fifth carbon budget covers the years 2028-2032 and marks the halfway point from the first carbon budget to the 2050 target.

It follows on from the first four carbon budgets which require a 52% reduction in emissions from 1990 by 2025.[4] The first carbon budget was met, and emissions in 2014 were below the level required by the second carbon budget, 36% below 1990 levels (Figure 1.2). This reflects a combination of steady progress to date and the ongoing impact of the financial crisis.

The Government must legislate the fifth carbon budget by the end of June 2016, taking account of the advice contained in this report. In line with the requirement in the Climate Change Act, the Government will then publish its proposals and policies for meeting the budget (Figure 1.3). The Committee will provide an assessment of these plans as part of our annual statutory reports to Parliament.

4 The budget was originally set to require a 50% reduction in emissions on 1990, but since then the 1990 inventory has been revised in line with UNFCCC guidelines.

Figure 1.1: Evidence and engagement for this report

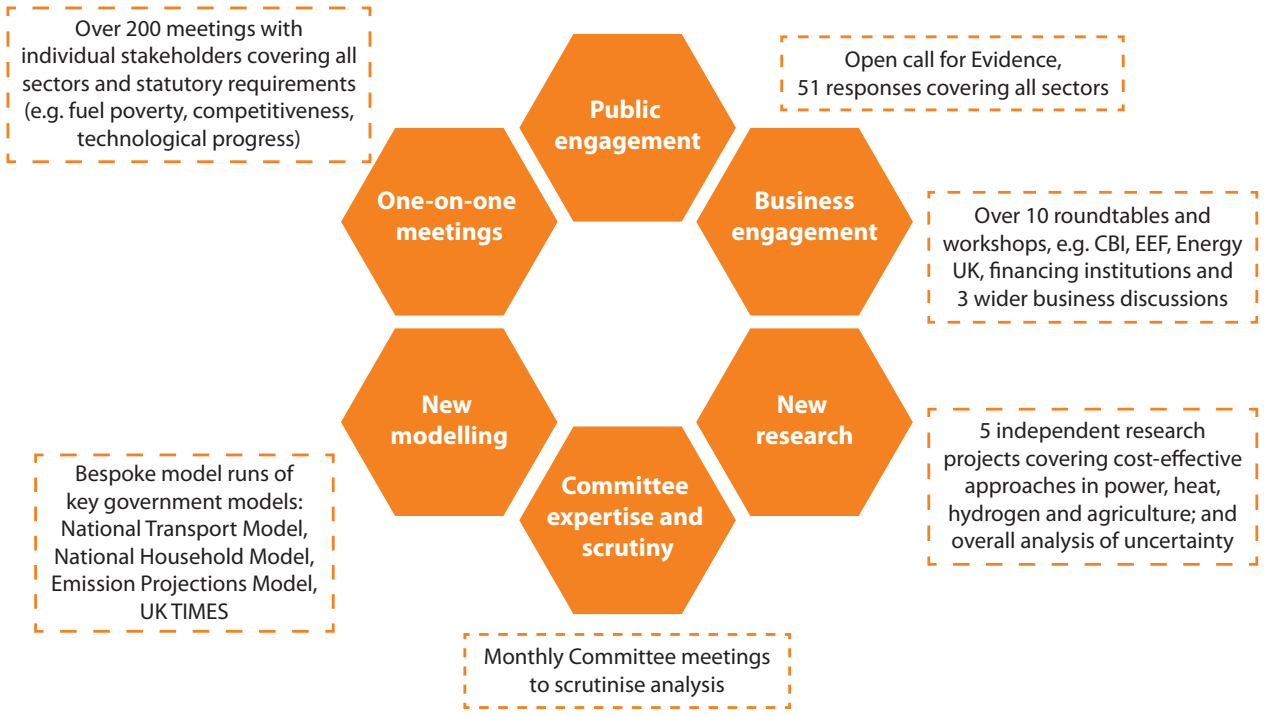
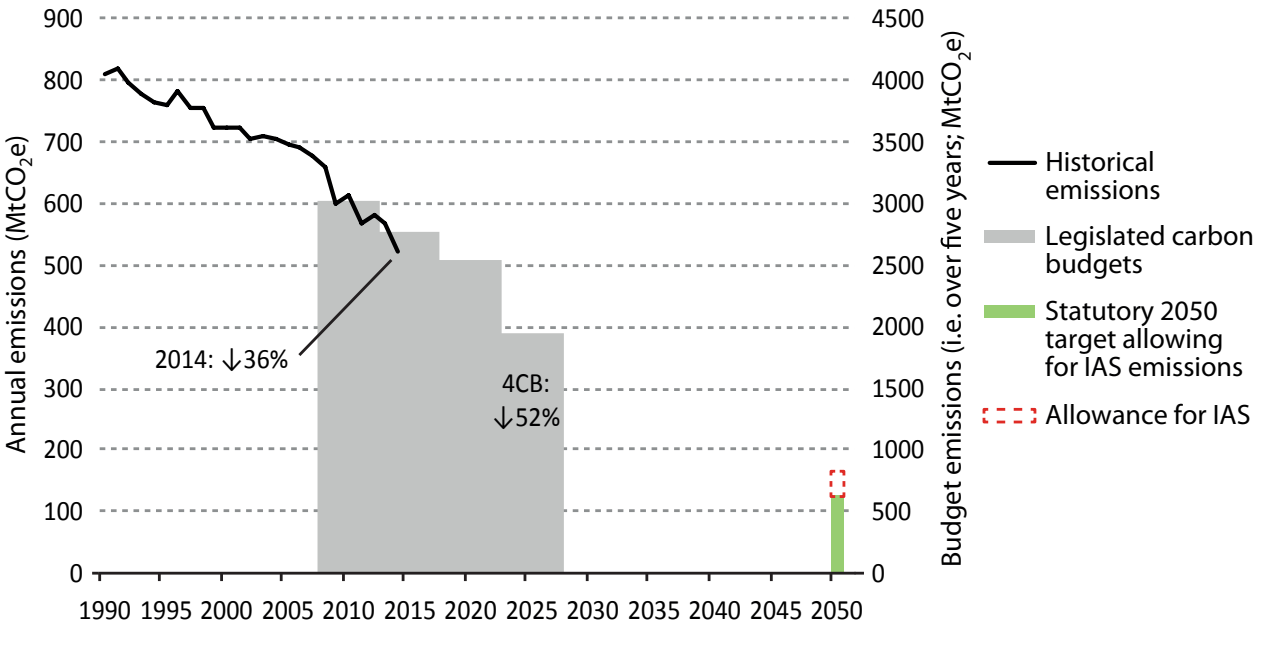


Figure 1.2: Legislated carbon budgets and the 2050 target



Source: CCC analysis.
Notes: IAS = International aviation and shipping.

Box 1.1: Call for Evidence responses and stakeholder workshops

Call for evidence

On 25 March 2015 we published a Call for Evidence on the CCC website, containing 15 questions climate science and international circumstances. It was open for a 10-week period and closed on 1 June 2015.

We received 51 responses spanning power, buildings, transport, industry, agriculture, bioenergy and community energy, from a range of companies, trade associations, NGOs and academics, as well as a local authority. All responses will be published in full on our website, www.theccc.org.uk, along with a list of organisations.

Stakeholder workshops

As an input to the fifth carbon budget advice, we held and contributed to over 20 workshops and roundtables that covered a variety of sectors and issues. These were attended by representatives from umbrella organisations, a wide range of individual businesses, NGOs, academia and Government departments. These included:

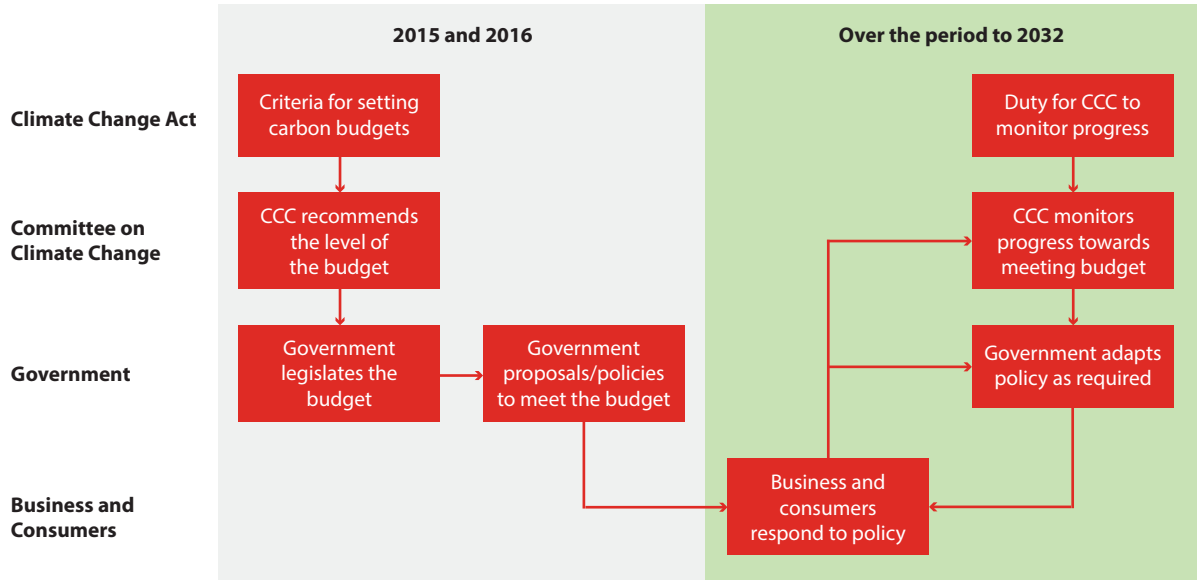
- Roundtables hosted at Shell, KPMG and the CBI on the value and impact of the fifth carbon budget on business. Participants included a range of businesses to ensure the discussion covers impacts across the UK business sector.
- Events on specific areas including science and international circumstances, electricity market reform, carbon capture and storage, finance for power sector investment, post-2020 vehicle emissions targets, low-carbon heat, solid wall insulation, industrial decarbonisation roadmaps and agriculture.

This engagement was valuable in gathering evidence on the opportunities for emissions reduction across the economy, the barriers to doing so and the potential impacts of carbon budgets, and policies to meet them, on business and wider society.

We also heard about the value of carbon budgets themselves. A common message was that while the carbon budgets are important in providing an overall point of reference, they need to be supported by a sufficient degree of clarity over the policies to achieve them in order to provide the confidence to make investments.

Many larger businesses have head offices and Boards located outside the UK. Those Boards do not follow every policy detail but reach judgments based on their sense of overall direction. That is particularly important when it comes to whether to invest limited corporate financial capital in the UK or another country.

Figure 1.3: Process for setting and meeting carbon budgets



2. Scope of carbon budgets

The carbon budgets cover emissions of all six greenhouse gases included under the Kyoto Protocol (i.e. carbon dioxide, methane, nitrous oxide and the three F-gases: HFCs, PFC and SF_6). Each greenhouse gas is treated consistently (based on the Global Warming Potential 100-year index) to allow a like-for-like comparison consistent with the Protocol. The accounting framework for the final budget divides the sources of emissions into the 'traded' sector and the 'non-traded' sector depending on whether they are covered by the EU emissions trading system (EU ETS) (see Chapter 2).

Only one non-negligible source of emissions is currently excluded from carbon budgets. The UK share of emissions from international aviation and shipping (IAS) is not currently within the scope of carbon budgets. Regardless of whether the IAS sectors are included in carbon budgets, the Act requires those emissions are "taken into account" because the ultimate 2050 objective must incorporate those emissions to be consistent with international goals supported by the UK and the latest scientific understanding. In practice, that means carbon budgets need to allow for emissions from IAS by ensuring that emissions from other sectors are at a level consistent with meeting the overall 2050 target when IAS emissions are included (see section 2 of Chapter 3).

The Government will decide in 2016 whether or not international aviation and/or international shipping will be brought into the scope of carbon budgets. We provide advice on this issue in Chapter 6. We do not know what the Government will decide, so our recommendation for the fifth carbon budget is set in a way that enables the budget recommendation (also in Chapter 6) to be legislated once this decision has been taken.

3. Balancing the criteria in the Climate Change Act

Under the Climate Change Act, the Committee's carbon budget recommendation is required to take account of a range of considerations (Box 1.2).

- The latest climate science indicates how much action is required globally to reduce emissions consistent with limiting global temperature increase to 2°C, as currently agreed internationally and supported by the UK (Chapter 2).
- The latest European climate and energy package for 2030 defines a minimum UK contribution to that goal and defines the UK 'net carbon account' for sectors of the economy within the EU Emissions Trading System (also Chapter 2).
- Economic circumstances and technology are reflected in our assessment of scenarios for the cost-effective path to the 2050 target (Chapter 3).
- Considerations of competitiveness, and of social circumstances including fuel poverty and energy affordability, help us to choose between scenarios and identify opportunities and challenges posed by the carbon budgets (Chapter 4).
- Differences between England, Wales, Scotland and Northern Ireland give us a more granular understanding of what is feasible and the challenges in delivering it (Chapter 5).

Box 1.2: Criteria for setting carbon budgets in the Climate Change Act

The Climate Change Act sets out how the Committee is legally required to advise on and how the Government must set carbon budgets, which:

- *"must be set with a view to meeting … the target for 2050"*; and
- Must take into account:
  - *"scientific knowledge about climate change*;
  - *technology relevant to climate change*;
  - *economic circumstances, and in particular the likely impact of the decision on the economy and the competitiveness of particular sectors of the economy*;
  - *fiscal circumstances, and in particular the likely impact of the decision on taxation, public spending and public borrowing*;
  - *social circumstances, and in particular the likely impact of the decision on fuel poverty*;
  - *energy policy, and in particular the likely impact of the decision on energy supplies and the carbon and energy intensity of the economy*;
  - *differences in circumstances between England, Wales, Scotland and Northern Ireland*;
  - *circumstances at European and international level*;
  - *the estimated amount of reportable emissions from international aviation and international shipping for the budgetary period or periods in question"*.
- while *"complying with the European and international obligations of the United Kingdom"*.

Source: Climate Change Act (2008).

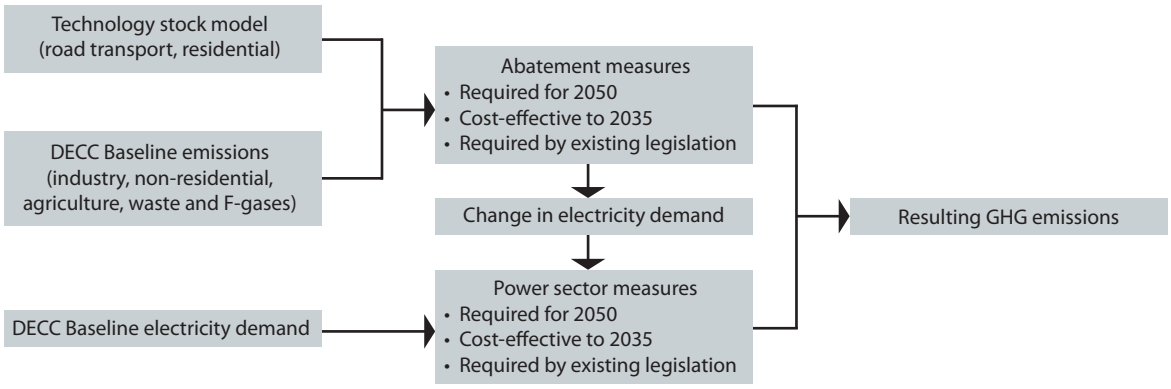
Our recommendation for the level of the fifth carbon budget is built on a detailed assessment of the opportunities to reduce emissions up to and within the budget period (2028-32) and consistent with the need to reduce emissions in 2050 to at least 80% below 1990 levels (Figure 1.4). Where the identified measures to reduce emissions would have important wider implications (e.g. for fuel poverty or industrial competitiveness), these are taken into account in building our scenarios (see Chapter 4):

- We undertake a detailed techno-economic assessment of the opportunities to reduce emissions over the period to 2035, and what is needed to ensure that the necessary level of decarbonisation by 2050 remains feasibly achievable without imposing excessive costs beyond the budget period (see Chapter 3). This includes consideration of barriers to deployment, infrastructure, stock turnover rates and feasible rates of market development.
  - Emissions reduction opportunities that are available at reasonable cost (which we judge against the Government's carbon values, reaching £78/tonne in 2030) are included in our scenarios at a level judged to be feasible.
  - Higher-cost investments that are important to meet the 2050 target are also included on a case-by-case basis. We include these measures where roll-out to 2032 is necessary to develop the option for later years. For example, we include deployment of carbon capture and storage, which is needed to develop the supporting UK infrastructure and the technology, and we include electric vehicle roll-out, which is needed as part of a realistic development towards reaching mass-market in the 2030s.
- Where measures to reduce emissions have wider benefits in areas linked to the Committee's statutory duties, for example reducing fuel poverty through improved insulation, they may be included in our scenarios even if the costs are relatively high when considered purely in terms of the reduction in greenhouse gas emissions they achieve.
- By focusing on the lowest-cost ways to reduce emissions and considering the full path to 2050, our scenarios aim to keep the costs of tackling climate change to a minimum. In areas where affordability is of particular concern, for example in energy-intensive industry, we consider whether or not to include higher-cost measures based on an assessment of the risk of carbon leakage and the potential for suitable policy design to mitigate this.
- We also take into account the impacts of climate change itself on meeting carbon budgets. For example, the impact of changes in heating and cooling demand, infrastructure and land use which arise from climate change that will occur because of historical and ongoing global emissions (see Chapter 4).

Our scenarios give an indication of what is possible through actions that are appropriate for a society committed to tackling climate change. They represent feasible ways to meet future emissions targets. They indicate that the recommended budget is deliverable while balancing the range of factors discussed above. They are not intended to be prescriptive as to which measures should be implemented, but rather identify the most appropriate overall rate of emissions reduction for the UK to pursue, following on from the fourth carbon budget, to stay suitably on track to the 2050 target.

Our scenarios for the fifth carbon budget also confirm that the fourth carbon budget remains the appropriate level of emission reduction for the period from 2023 to 2027.

Figure 1.4: Approach to constructing CCC scenarios



4. Feasibility of delivery

It is 15 years until 2030, the middle year of the fifth carbon budget period. Given the nature of the transformation required, this is not a distant prospect. Decisions are currently being made about infrastructure that may last upwards of a hundred years (e.g. roads, railway lines, airports, buildings), others that will last 20 to 50 years (e.g. electricity and heating infrastructure, large industrial and manufacturing investments) and many that could last at least a decade if not more (e.g. new vehicles, heating systems, farming practices).

In addition to setting the budget, decisions and strategic approaches will be needed in the near future in order to meet the budget in a sensible, least-cost way, and to be on track to meet the 2050 target. These decisions and strategies will be important for clarity over investments, commercialisation of key technologies, necessary development of infrastructure, development of markets for new technologies and consumer acceptance and behaviour:

- **Investment clarity**. Providing sufficient clarity over the future policy context is important to attract the investment required for decarbonisation in infrastructure, the technologies themselves and the supply chains that support them. This can be done via a combination of setting legally-binding targets (e.g. carbon budgets and sectoral agreements such as a 2030 EU target for vehicle emissions) and making regulatory and funding commitments at an appropriate level covering a sufficient timeframe (e.g. setting the Levy Control Framework, which caps funding for low-carbon electricity at an appropriate level for a 10-year window).
- **Technology commercialisation**. Some of the key technologies required to meet the 2050 target are not yet fully mature, and require a strategic approach to commercialisation in order for them to play a full part in a least-cost emissions reduction strategy. For example, the period to 2032 will be vital to the development of carbon capture and storage, which has the potential to almost halve the cost of meeting the UK's 2050 target.[5]

5 CCC (2012) *The 2050 Target* found that the central estimate of the cost of meeting the 2050 target increased from 0.5% of GDP to 0.9% of GDP without CCS. ETI (2015) *Carbon capture and storage - Building the UK carbon capture and storage sector by 2030* found that a "complete failure to deploy CCS would imply close to a doubling of the annual cost of carbon abatement to the UK economy" in 2050.

- **Infrastructure development**. In order to enable the uptake of key technologies, it will be necessary to develop new infrastructures. For example, a crucial part of reducing the cost of carbon capture and storage will entail developing CO_2 infrastructure clusters, decarbonisation of heat supply will require roll-out of heat networks, and uptake of ultra-low emission vehicles will require development of facilities to charge plug-in vehicles and/or refuel hydrogen vehicles.
- **Market development**. Some of the technologies that will be important in reducing emissions in the long term have yet to be deployed on a widespread basis in the UK. Near-term development of markets for ultra-low emission vehicles and heat pumps will be important for roll-out rates to reach levels that allow them to contribute significantly to meeting the fifth carbon budget and the 2050 target.
- **Consumer acceptance and behaviour**: Some of the changes required to reduce emissions will be facilitated by current behavioural trends (e.g. increased control over demand for energy and other products facilitated by technology) and others might require further changes in how we demand and use products (e.g. when and how cars are driven). These changes in behaviour take time to evolve and are partly a function of innovation and actions by private and public institutions.

Each of these aspects requires the Government to take a strategic approach and to put in place effective policies to drive the changes that will be required to meet the fifth carbon budget and be on track to meet the 2050 target.

It will be important that these policies are grounded in an understanding of what works, based on experience around the UK (including the increasing evidence base on different approaches adopted in the different nations of the UK) and elsewhere around the world. This is likely to lead to a mix of policy approaches, depending on the change required, including important roles for markets and regulation to determine both supply-side innovation and product development and demand-side behaviour and product use.

Given a suitable set of policies, measures required to meet the fifth carbon budget can feasibly be delivered. We set out scenarios to do that in Chapter 3 and required policy strengthening in Chapter 6.

5. Areas of uncertainty and implications for budget setting

It is important in recommending carbon budgets out to 2032 that key areas of uncertainty are given due consideration. Our analytical approach to developing scenarios that meet the recommended budget allows for different balances of technologies and behaviour change, both within and across sectors. This includes consideration of the likelihood of different changes over the period to 2032.

In practice, we illustrate the outcome of this process by formalising it in two scenarios that sit on either side of our best estimate of the central scenario that represents the cost-effective path: (see Chapter 3).

- **'Barriers' scenarios**: these achieve less than the central scenario because of difficulties in implementing some of the low-carbon measures included in the central scenario. The "barriers" scenarios are not intended as a "do nothing" or even "do very little" scenario. They are part of a risk assessment of our central scenario that acknowledges the risks of under-delivery in some areas and sets out the implications of that under-delivery.

- **'Max' scenarios**: in which more is achieved compared to the central scenario either because of the inherent uncertainty around the outcome of some measures or because some outcomes may prove quicker or less expensive to deliver than currently anticipated. These scenarios do not represent an upper bound but are intended to assess the upside potential inherent in actions to meet the fifth carbon budget.
- There is also uncertainty over the best mix of technologies to deliver a given level of effort. We characterise that in **'Alternative' scenarios** that meet the central level of effort in a different way.

While this approach sets out the scope for flexibility in meeting the budget, some key uncertainties remain about deployment of new low-carbon technologies, the role of behaviour change and on how much effort will be needed to meet the carbon budget. In recommending a level for the fifth carbon budget we have considered each of these categories of uncertainty and examined the various flexibilities available.

Progress to 2032 and to the 2050 target requires the roll-out of low-carbon technologies. The roll-out will be, in part, driven by changes in behaviour (e.g. consumers demanding new goods and services) and will also itself change behaviour (as consumers and businesses use the technologies). That includes some technologies that currently do not play a significant role and are therefore subject to greater uncertainty. However, in most sectors there is a range of low-carbon technologies available, enabling flexibility in how the budget is met.

- **Heat decarbonisation**. Significant uptake of low-carbon heat technologies is required to meet the 2050 target. While these changes are technically and economically feasible, there is uncertainty over the most cost-effective path to 2032 and over the take-up and use of these technologies by households and businesses.
- **Mainstream ultra-low-emissions vehicles**. Similar issues arise in transport as in low-carbon heat. There is still considerable uncertainty around the acceptability and use of ultra-low-emission vehicles (ULEVs) as well as some, but decreasing, uncertainty over their availability, cost and wider economics. The level of uncertainty in both areas is different when considering cars compared to vans or compared to heavy goods vehicles.
- **Carbon capture and storage (CCS)**. The technological components of CCS have been proven over recent decades in a range of contexts and locations globally. However, until projects show that these can be combined at the scale required at reasonable cost, uncertainty remains over the how much CCS can be deployed by 2050 and what proportion of emissions it will capture.

Even without effort to reduce emissions there is uncertainty over the level of future emissions as there is uncertainty over future economic trends, energy costs and how consumers of energy will respond to these. This adds to uncertainty over the current level of emissions because of difficulties in accurately measuring some sources of emissions, especially for non-CO_2 gases in agriculture and waste. These both translate to an uncertainty over how much effort will be required to meet a given budget.

The presence of these uncertainties requires a strategy that is sufficiently flexible to maintain necessary progress in decarbonising the economy. This includes the creation of options in the medium term, in order to keep open a range of ways of meeting the 2050 target. The need to create options will, in many cases, mean that we need to do more, sooner. In many cases this requires actively supporting a wider range of options (e.g. a range of technologies in power generation, low carbon-heat, vehicles, agricultural practice) ahead of the fifth carbon budget than if we had perfect foresight over the long-term path. It is not necessary that all these options exist in the UK – some can be developed in other countries, though even then UK action may be important in developing the market and encouraging acceptance of new technologies from UK consumers. An important consideration for the Committee in its annual Progress Reports to Parliament is where UK-based action is needed.

Such considerations enable us to propose a carbon budget that is robust to a wide range of eventualities, while remaining on track to meeting the 2050 target. Of course, this cannot cover every eventuality, which is why the Climate Change Act allows for the budget to be reviewed and potentially amended should circumstances change significantly. Consideration of uncertainty does not justify setting of a loose carbon budget now.

Chapter 2: Overview of climate science and international circumstances

1. The science of climate change
2. International action to limit climate change
3. The EU and UK share of international climate action
4. Implications for the fifth carbon budget

Under the Climate Change Act we are required to consider scientific understanding of climate change, international and European circumstances in advising on the level of carbon budgets. We published our assessment of these criteria in a separate report in October this year[1]. This chapter summarises our key findings from that report and their implications for the fifth carbon budget.

The main points from this assessment are:

- The evidence that global warming is happening, driven by human activity and with large potential impacts, is supported by many lines of research and agreed by the world's leading scientific bodies.
- The world is acting to tackle climate change. The internationally-agreed 2°C limit requires substantial global emissions reductions by 2030. The UK should continue to play its part.
- The EU's Member States have agreed to reduce EU emissions by at least 40% below 1990 levels in 2030. Our best estimate is that this requires a UK reduction of 53% below 1990 levels, within the range 50-56%.
- To stay on a cost-effective path with a likely chance of meeting to the 2°C limit, more effort will be required across the world than currently pledged, including from the EU.

Other relevant international aspects of recommending the carbon budget are considered elsewhere in the report. These include impacts on the competitiveness of UK industry (addressed in Chapter 4), plus the issues of whether or not to include the UK's share of international aviation and international shipping emissions, and the role of credits in meeting the budget (Chapter 6).

This chapter is set out in four sections:

1. The science of climate change
2. International action to limit climate change
3. The EU and UK share of international climate action
4. Implications for the fifth carbon budget

1. The science of climate change

The evidence that global warming is happening, driven by human activity and with large potential impacts, is supported by many lines of research and agreed by the world's leading scientific bodies[2]. Much of the information presented here is covered at length in the latest assessment by the Intergovernmental Panel on Climate Change (IPCC AR5)[3].

It is clear that the climate is changing as a result of greenhouse gas emissions. This is leading to rising temperatures and sea levels, retreating ice and other changes to the natural environment. Global average temperature has risen around 0.9°C and sea level around 20cm since the late 19th Century:

- The basic fact that greenhouse gases in the air warm the surface of the Earth has been understood for over a century and is well-established.

1 CCC (2015) *The scientific and international context for the fifth carbon budget*. Available at https://www.theccc.org.uk/publication/the-scientific-and-international-context-for-the-fifth-carbon-budget

2 See for instance Royal Society and US National Academy of Sciences *Climate Change Evidence & Causes* (https://royalsociety.org/~/media/Royal_Society_Content/policy/projects/climate-evidence-causes/climate-change-evidence-causes.pdf); and the *Climate Communique* written by 24 UK academic societies (http://www.iop.org/news/15/jul/file_65971.pdf).

3 https://www.ipcc.ch/report/ar5

- Greenhouse gases are being emitted by human activities (principally carbon dioxide from fossil fuel burning) at an increasing rate and are accumulating in the atmosphere. Emissions of other air pollutants have a net cooling influence, partially offsetting greenhouse warming to date.
- Trends in climate are also influenced by natural factors, including solar variations, volcanic eruptions and natural cycles within the climate system (such as El Niño).
- Global average surface temperature is now about 0.9°C above late-19th Century levels. Observed warming is not uniform and has led to many other changes (Figure 2.1) including changes in rainfall patterns, rising sea levels and the loss of ice from Greenland and Antarctica. Carbon dioxide emissions are also acidifying the oceans.
- The pattern of global warming over the 20th Century matches that expected from natural and human factors combined, and not that from natural factors alone. Human activity has clearly been the dominant driver of global temperature rise since at least the 1950s.

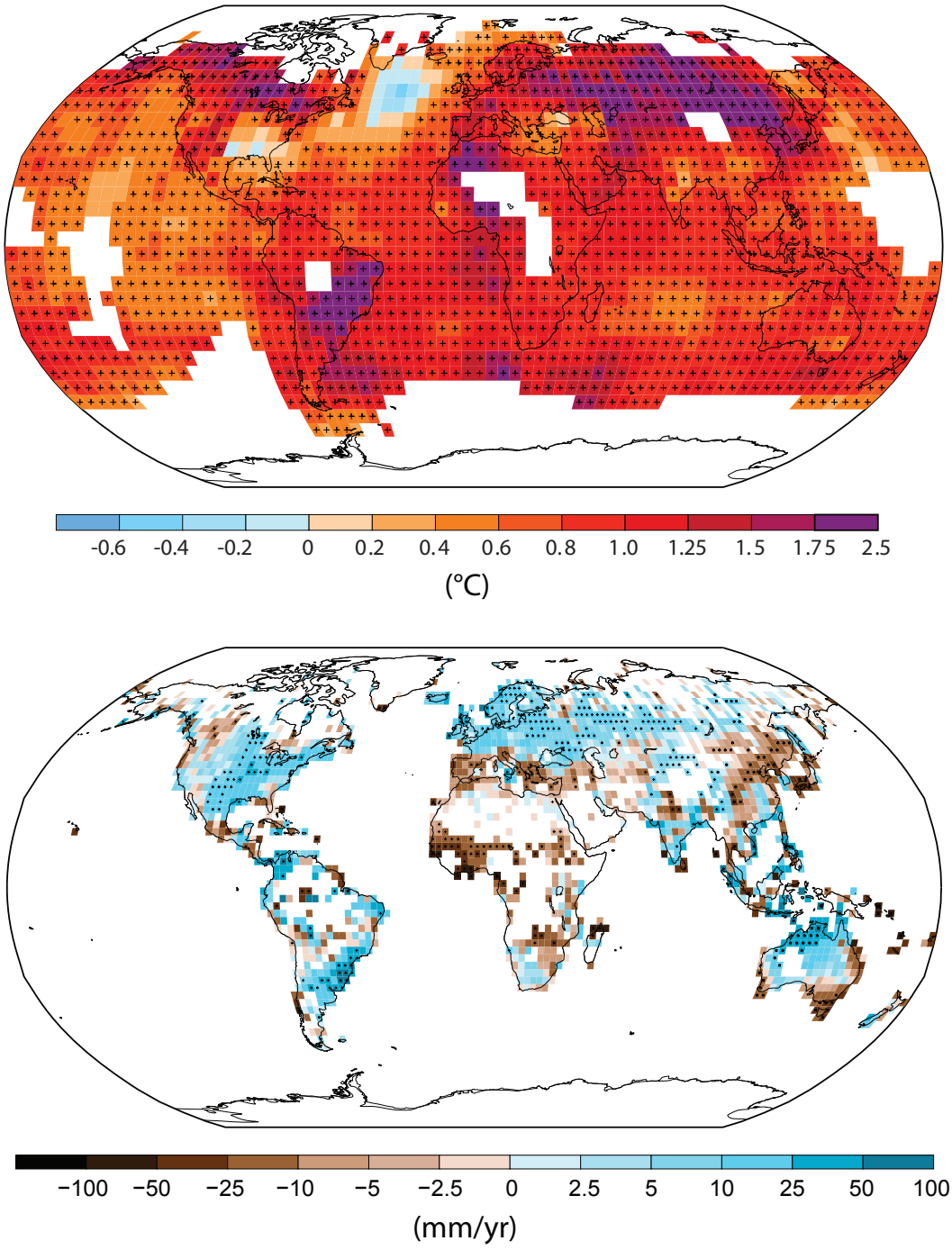
Many impacts are already being detected across the world, from changes in extreme weather and ecosystems to a slowdown in productivity gains for some key crops:

- Scientists are highly confident that, among other impacts, climate change is bleaching coral on reefs worldwide; greening and fruiting trees earlier in the year across Europe; reducing river flows across South Western Australia; forcing plant and animal species towards the poles and to higher elevations around the world; and negatively impacting those living in the Arctic.
- There has been a negative effect on the global growth in productivity of some key crops, with a reduction of 2 %/decade (0-5 %/decade[4]) for wheat, and 1 %/decade (0-3 %/decade) for maize. Some crops in Europe and southern South America have experienced gains due to climate change, while South Asia and wheat in Europe have incurred losses.
- European heat waves as strong as in 2003 (when crop yields fell, power stations were shut down due to overheating and the heat-related death toll ran into tens of thousands) are estimated to have been made at least twice as likely by human activity. A recent update suggests the warming since 2003 now makes it ten times more likely to occur again.
- The coastal surge brought to Manhattan by Hurricane Sandy in 2012 was made 20cm higher by sea level rise, increasing losses in New York by 30%. In addition, the above-average sea surface temperatures at the time increased its wind speeds and rainfall.

These impacts give an indication of the widespread and pervasive nature of climate risks.

4 Brackets indicate 10-90% confidence ranges.

Figure 2.1: Observed patterns of change in surface temperature (top) and precipitation (bottom)



Source: IPCC AR5.
Notes: Temperature changes (top) span the period 1901-2012 while precipitation trends (bottom) span 1951-2010 due to less complete coverage before 1950. Trends are only shown for grid boxes with substantial coverage over the period (other areas are white). Grid boxes where the trend is significant at the 10% level are indicated by a + sign.

Further emissions will lead to further warming and change. With rapid global action to cut emissions, total human-induced warming could be held below 2°C. Under baselines assuming no action, warming could exceed 6°C by the end of the century:

- Under baseline scenarios in which no action is taken, energy system models predict a continued increase in global emissions. As a result global temperature in 2100 would be 2.5-7.8°C (5-95% confidence range) above late 19th Century levels and rising.
- Under an ambitious mitigation scenario considered by the IPCC, in which emissions peak now and decline to zero or further before 2100, global temperature rise would be 0.9-2.3°C.
- Natural variability and other factors will continue to influence climate, especially on shorter timescales and at smaller spatial scales. Large volcanic eruptions, when they occur, will lower global temperature for a year or two. A major downswing in solar activity over several decades, considered possible but unlikely, would also lower global temperature by a few tenths of a degree.

There is no known simple threshold beyond which climate change moves from safe to dangerous. Some disruption and irreversible losses are expected at 2°C. Losses accelerate with warming, and very severe damage is expected in a world reaching 4°C. The impacts will be unevenly distributed and there are currently wide uncertainties about their magnitude:

- In previous CCC advice on the 2050 target and carbon budgets (which predates international agreement on the 2°C limit) we have proposed the world should seek to keep central (i.e. 50%) estimates of global temperature in 2100 close to 2°C above pre-industrial levels, and keep the probability of a 4°C rise to very low levels (e.g. 1%).
- This proposal reflected the fact that there is a range in projected future climate change for any given emissions path. The range comes from uncertainty in accounting precisely for all the processes and feedbacks in the climate system. Research is ongoing to narrow this range, but it remains wide.
- Uncertainty increases when translating climate projections into risks to people and the environment. Estimates point to large potential impacts, especially on the world's poor and vulnerable, but these are incomplete and often based on models which do not capture potentially important nonlinearities and compounding effects.
- IPCC AR5 concluded warming of 1.5°C above late 19th Century levels leads to high risk of damage from extreme weather and of losing sensitive ecosystems (such as those in the Arctic, on mountains and coral reefs). Warming of around 2.5°C brings high risk of large-scale singularities (such as irreversible ice sheet loss, leading to more sea level rise) and severe global impacts on the economy and environment. Warming of around 4.5°C puts global food security in doubt.

The increase in global temperature is determined mainly by cumulative carbon dioxide emissions over time. Annual emissions must therefore fall to near zero in order to limit warming. The allowable cumulative total for a likely chance of staying below 2°C will be exceeded in the mid-2030s if annual global emissions continue at the current rate:

- IPCC AR5 estimated the total carbon dioxide emissions over time consistent with staying below specific global temperature limits. To preserve a 50% likelihood of keeping warming below 2˚C, the total remaining allowable emissions from 2011 is around 1,100 billion tonnes of carbon dioxide ($GtCO_2$). For at least a 66% (i.e. "likely") chance, this total decreases to around 1,000 $GtCO_2$.
- These totals account for projected emissions of other greenhouse gases and particles but apply to global emissions of carbon dioxide only.

- If global emissions continue at the current rate of around 35 $GtCO_2$ per year, the total for a likely chance of staying below 2°C will be exceeded in the mid-2030s, and for a medium chance by the late 2030s.

The nature of climate change risks and the many unknowns make a simple cost-benefit approach to climate action untenable. The internationally-agreed 2°C limit to warming, and the UK's own emissions targets, are based on an approach which seeks to minimise the largest risks. On the basis of the latest climate science we judge that this level of ambition remains broadly appropriate for now.

Remaining uncertainties mean we will keep a watching brief on climate science and periodically review implications for UK emission targets.

2. International action to limit climate change

The UK's carbon budgets are domestic commitments, but set in the context of efforts worldwide to reduce greenhouse gas emissions.

The UN has formally adopted an objective to limit global temperature rise to 2°C, and countries are submitting pledges to reduce emissions beyond 2020. The aim is to adopt a new agreement, with legal status, in Paris at the end of 2015:

- International negotiations on climate change are governed through the United Nations Framework Convention on Climate Change (UNFCCC), to which 195 countries plus the EU are party.
- Under the 2009 Copenhagen Accord countries recognised the goal of limiting global temperature rise to no more than 2°C above pre-industrial levels. 86 countries plus the EU subsequently came forward with pledges to limit or reduce emissions in the period to 2020.
- At the Durban negotiations in 2011 it was agreed to deliver a new and universal greenhouse gas reduction agreement 'with legal force' by 2015, for the period beyond 2020. Key aims for the 2015 negotiations in Paris are a deal governing these post-2020 emissions pledges, financing and adaptation to the impacts of climate change, plus a mechanism to enhance ambition over time.

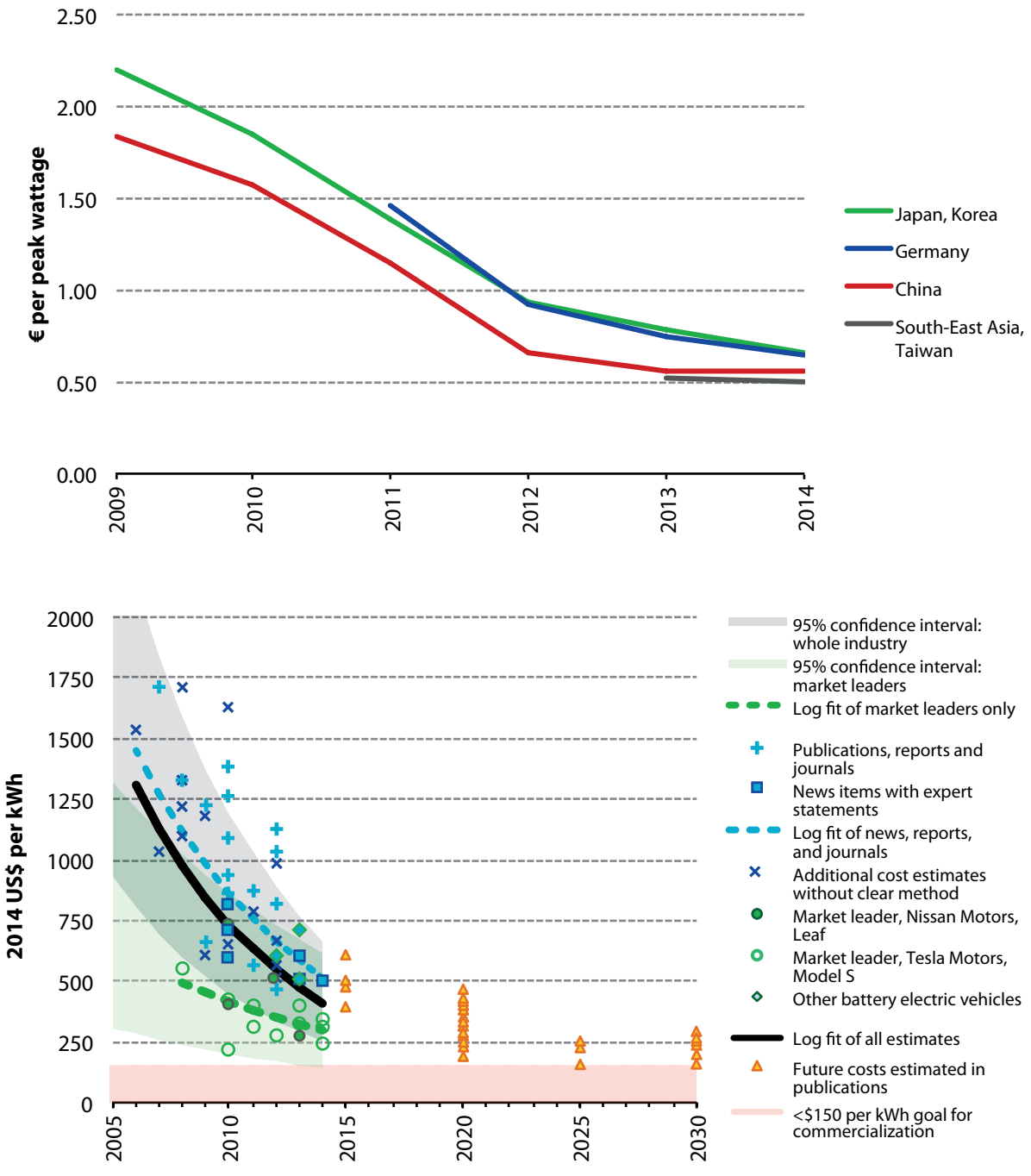
Many countries and sub-national bodies have made commitments for deep emissions reduction and are now delivering against these. Penetration of low-carbon technologies around the world is increasing, although these still account for a relatively small share of global energy production:

- As of November 2015, 162 parties to the UNFCCC had submitted pledges involving intended national actions and emissions targets for the period out to 2030. These currently cover over 95% of territorial emissions (excluding international aviation and shipping)[5].
- In 2013, 18% of global emissions were covered by some form of carbon pricing scheme and 76% of global transport emissions were covered by legislated fuel efficiency/emission standards in 2015.
- Deployment of low-carbon technologies (notably renewables and low-carbon vehicles) is increasing and more large-scale Carbon Capture and Storage (CCS) plants are in development. High deployment rates have led to large cost reductions for some technologies (Figure 2.2). As a result some low-carbon power sources can be cost-competitive with fossil fuel generation in many applications and parts of the world.

5 Correct as of 12 November

Despite these developments, annual global emissions rose 42% during 1990-2012. Fossil fuels are still expected to meet a large share of rising energy demand. Based on the continuation of current policies around the world, the International Energy Agency (IEA) predicts that emissions could grow a further 20% by 2040[6].

Figure 2.2: Developments in solar PV module prices (top) and costs of battery packs for electric vehicles (bottom)



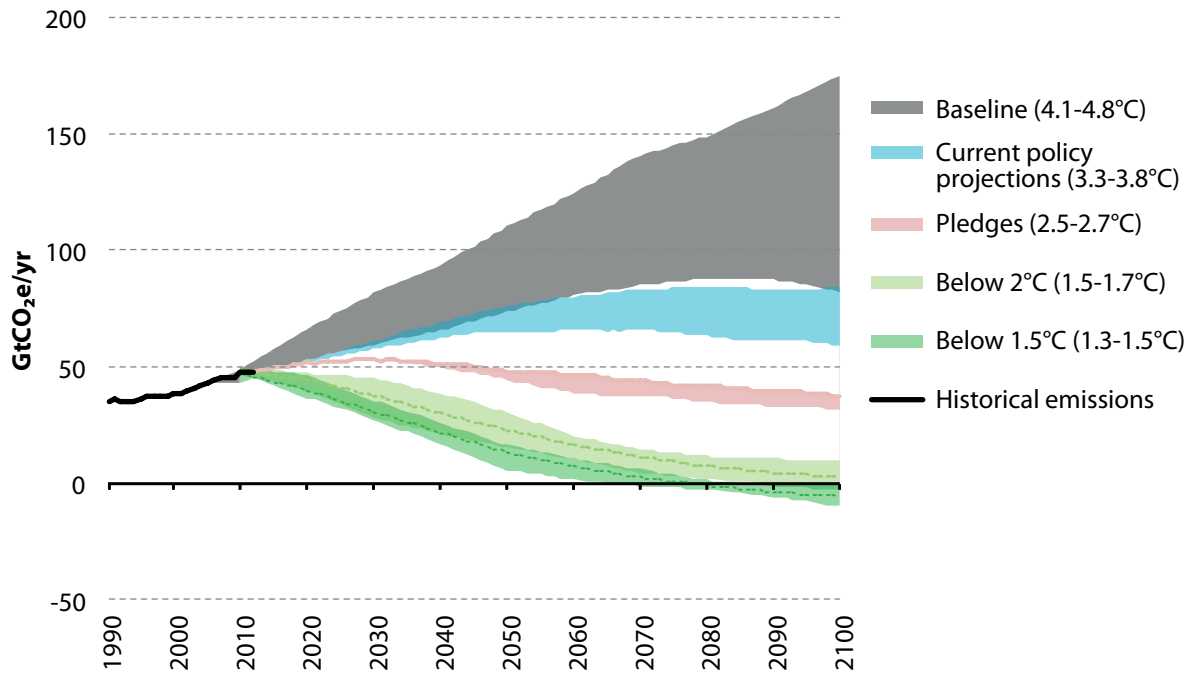
Source: www.pvxchange.com; Nykvist, B. & Nilsson, M. (2015) *Rapidly falling costs of battery packs for electric vehicles*, Nature Climate Change.
Notes: Battery pack costs reflect cost of lithium-ion batteries.

6 IEA (2014) *World Energy Outlook 2014*

Lowest-cost paths with a likely chance of staying below 2°C require global emissions to peak around 2020 with steep reductions thereafter. UN pledges made so far have measurably reduced the forecast of global emissions, but fall short of this lowest-cost path (Figure 2.3). There is scope to reduce the gap through increases in existing ambition and further commitments to reduce emissions beyond 2030:

- IPCC AR5 concluded that pathways likely (i.e. with at a least a 66% chance) to stay below 2°C show a 40-70% reduction in global greenhouse gas emissions by 2050, relative to the 2010 level of 49 $GtCO_2e$, and emissions near zero or below by 2100.
- Of the scenarios considered by the IPCC, those that were likely to stay below 2°C in 2100 but showed limited action to 2020 (consistent with current near-term projections) have emissions in 2030 in the range 29-44 $GtCO_2e$, with a central estimate of 42 $GtCO_2e$.
- Studies by the IEA[7] and the recent Deep Decarbonization Pathways Project[8] confirm such pathways remain technically feasible without changing global economic and development prospects. They do however require very large and rapid changes in energy generation and patterns of investment.
- Analysis of the latest UN pledges by Climate Action Tracker[9] suggests that global emissions are on track to reach 53-55 $GtCO_2e$ in 2030, compared to pre-pledge projections of more than 58-61 $GtCO_2e$. A more recent review by the UN concluded that the pledges add up to 53-59 $GtCO_2e$ in 2030[10].

Figure 2.3: Effect of the UN pledges on long-term global emissions pathway



Source: Climate Action Tracker (2015) *INDCs lower projected warming to 2.7°C: significant progress but still above 2°C.*
Notes: Solid red line reflects best estimate of impact of pledges. Dashed green lines reflect median within 10th to 90th percentile range.

7 IEA (2015) *Energy and Climate Change: World Energy Outlook Special Report*
8 Deep Decarbonization Pathways Project (2015) *Pathways to deep decarbonization 2015 report*
9 Climate Action Tracker (2015) *INDCs lower projected warming to 2.7°C: significant progress but still above 2°C.*
10 UNFCC (2015) *Synthesis report on the aggregate effect of INDCs*

Both the UK and EU have objectives to reduce their greenhouse gas emissions in 2050 to at least 80% below 1990 levels. These objectives remain appropriate in the light of the latest evidence regarding global emissions pathways consistent with 2°C:

- When advising on the UK 2050 target in 2008, we stated it was difficult to envisage a global climate deal which does not involve the UK reducing its emissions to a per person level consistent with the global average needed to meet the climate objective. This is because it will be hard to find other nations much below the average, especially in a world of substantially-declining emissions.
- On the basis of a world population around 9.7 billion in 2050[11], a 40-70% global cut in greenhouse gas emissions below 2010 levels is equivalent to emissions per person of 1.5-3 tCO_2e in 2050.
- Applying this per person average to a projected UK 2050 population of around 77 million[12] equates to a 72-86% reduction below 1990 levels. The UK's 2050 target of at least an 80% reduction is at the centre of this range. This would apply to all emitting sectors including international aviation and shipping.
- Applying the same logic to the EU28 as a whole leads to a 74-87% reduction below its 1990 level (again, including international aviation and shipping).

The UK is an important player in driving forward EU and international ambition. We will continue to monitor closely further international progress, in particular outcomes from the Paris conference and proposals to review and increase ambition post 2030.

11 Medium variant from UN (2015) *World Population Prospects, 2015 Revision*

12 Principal projection from Office of National Statistics (2015) *2014-based National Population Projections*. Note that this is different from the 2013 Low Migration variant projection of 74 million used in our October report.

3. The EU and UK share of international climate action

The EU's Member States have agreed a 2030 target for EU emissions of at least 40% below 1990 levels. This is also the EU's collective pledge for 2030 as part of the UN process. It is currently one of the more ambitious pledges:

- The agreement for at least a 40% reduction in emissions by 2030 compared to 1990 levels (equivalent to 35% below 2005 and 25% below 2012) specifically leaves open the possibility of increasing ambition beyond 40% in light of developments in Paris.
- The target is to be achieved domestically, without purchase of international offset credits.
- A wider set of measures have also been agreed as part of the 2030 framework. These include increases in EU-wide renewable generation and energy efficiency, and introduction of a Market Stability Reserve for the EU Emissions Trading System (EU ETS).

Our best estimate is that the EU 2030 agreement implies a reduction in UK emissions over the fifth carbon budget period of 53% below 1990 levels. The precise UK share cannot be known with certainty until final rules governing Member States' shares are agreed. Reflecting these uncertainties suggests a UK contribution to emissions reductions within a range of 50-56%. This has changed since we published in October an estimate of 54% within a range of 51-57%, to reflect more up-to-date information (Box 2.1):

- We calculate the UK share of the EU agreement in two parts: one part for sectors covered by the EU ETS and another for those not in the EU ETS. The UK share of the EU ETS cap is especially relevant as this is the basis on which participating sectors are currently accounted for in carbon budgets (rather than their direct emissions).
- The share of the EU ETS depends on several elements which make up the cap during the 2020s. Given allocation rules have yet to be finalised the UK share of this is currently uncertain. Our best estimate for the UK's share during the fifth carbon budget period (2028-32) is 590 $MtCO_2e$[13], within a range of 530-650 $MtCO_2e$ (Box 2.1).
- Our estimate assumes the impact of the Market Stability Reserve is neutral over the budget period. To the extent that allowances are placed in or released from the MSR, the UK's share of the cap could differ in specific years.
- The share of the EU agreement for non-traded emissions is subject to legislation that the European Commission is yet to publish, with more detail expected in 2016. Our current best estimate is 1,310 $MtCO_2e$, within a range 1,260-1,360 $MtCO_2e$.
- Countries are free to reduce emissions further than their non-ETS allocation should they deem it cost-effective.

13 All estimates of the UK share of EU action in this section are rounded to the nearest 10 $MtCO_2e$

Box 2.1: UK share of the EU ETS cap over the fifth carbon budget

Final rules have not yet been agreed for the distribution to Member States of the EU pledge to reduce 2030 emissions by at least 40% below 1990 levels. The UK share will depend on allocation rules for each of the traded sectors of the economy (covered by the EU's Emission Trading System – EU ETS) and the non-traded sectors:

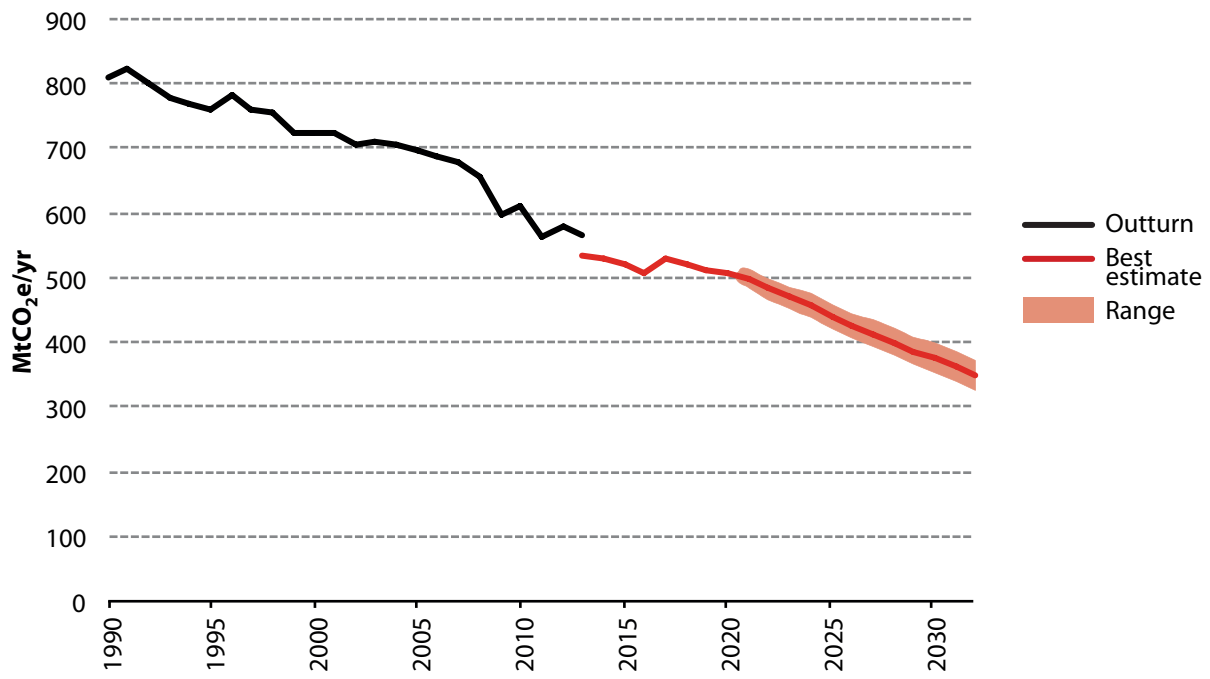
- **The EU ETS traded sectors.** The UK's share of the EU ETS cap – which defines net emissions for the traded sector – is determined by two factors: the level of the EU ETS cap and the proportion of the cap attributable to the UK. The final rules for the fifth carbon budget are unlikely to be known until around 2020.
  - **EU ETS cap.** As part of the agreement to reduce EU emissions by at least 40%, EU Member States have agreed the EU ETS cap will be 43% lower than 2005 levels by 2030. The cap will tighten at a faster rate after 2020 compared to before 2020 (i.e. at an annual linear rate of 2.2% of the average level of the Phase II cap, compared to 1.74% before 2020). The result is that the EU cap, excluding aviation, will reduce from 2,084 $MtCO_2e$ in 2013 to 1,816 $MtCO_2e$ in 2020 and 1,333 $MtCO_2e$ in 2030.
  - **The proportion of the cap attributable to the UK** will reflect the UK's share of each of the four elements which make up the cap in Phase IV: auctioned allowances, freely allocated allowances, and the Innovation and Modernisation Funds. The UK will also have a share of the separate aviation cap (of which only domestic emissions are included in carbon budgets). Auctioned and freely allocated allowances will make up the vast majority of the UK's allocation. The largest uncertainty is around the level of UK free allocation as this depends on: the level of emissions in these sectors across the EU ETS, the efficiency of energy use in industry, and the final rules to allocate allowances. We assume a range around free allocation of ±25% to represent uncertainty in the rules. Our best estimate has the UK's share of the cap falling from 160 $MtCO_2e$ in 2020 to 120 $MtCO_2e$ in 2030, within a range of 110-130 $MtCO_2e$. We assume carbon budgets are set on a neutral basis, with no operation of the Market Stability Reserve.
  - **Timelines for implementation and implications for the fifth carbon budget.** The European Commission has proposed a set of revised rules for Phase IV of the EU ETS. The final implications of these for the fifth carbon budget may not be known until around 2020. Our estimate for the UK's share of the cap for this report is slightly lower than our previous estimate published in October. This reflects changes in the structure of UK industry eligible for free allocation that will affect the level of allowances allocated to the UK over the fifth carbon budget period.
  - **Our best estimate for the UK's share of the EU ETS cap** over the fifth carbon budget period is 590 $MtCO_2e$, within a range of 530-650 $MtCO_2e$.
- **The non-traded sectors.** It has been agreed that EU-wide emissions in sectors not covered by the EU ETS will be 30% below 2005 levels by 2030. It has also been agreed that the maximum required reduction from any Member State will be 40% below 2005 emissions.
  - Our analysis for the UK's likely reduction in non-traded sector emissions under the EU agreement suggests a best estimate of 37.5% below 2005 levels, within a range of 35-40%.
  - The EU 2030 agreement does not include emissions from Land Use, Land-Use Change and Forestry (LULUCF). For consistency with coverage of carbon budgets we therefore add projected LULUCF emissions, based on DECC estimates. However, since our October report these DECC projections have been revised very significantly, from emissions across the five-year budget period of -60 $MtCO_2e$ to +1 $MtCO_2e$.

Box 2.1: UK share of the EU ETS cap over the fifth carbon budget

– Our best estimate for UK non-traded sector emissions over the fifth carbon budget period, based on the EU's 2030 pledge, is 1,310 $MtCO_2e$ (within a range of 1,260-1,360 $MtCO_2e$).

Our overall best estimate for the UK's share of the EU 2030 pledge is a 53% reduction in emissions in 2030 relative to 1990. Reflecting the uncertainties gives a range of 50-56% (Figure B2.1). More detail on the method and assumptions underlying these estimates is set out in Chapter 3 of our report *The scientific and international context for the fifth carbon budget*[14].

Figure B2.1: Range for UK emissions pathway under the EU's 2030 agreement



Source: DECC (2015) *2013 UK Greenhouse Gas Emissions, Final Figures;* CCC analysis.
Notes: Reflects sum of the UK's share of the EU ETS cap and EU non-ETS reduction. Excludes international aviation and shipping emissions. Discontinuity in 2013 due to inventory revisions; we assume this is reflected in EU targets from 2017 onwards.

The EU's agreed 2030 target is at the lower end of ambition compared to the cost-effective path to its 2050 objective of an 80-95% cut in emissions below 1990 levels:

- In 2011 the European Commission published its Low-Carbon Roadmap, which set out its assessment of the cost-effective path to the EU's 2050 goal[15]. This concluded that the aim should be to achieve a 25% reduction in domestic emissions by 2020 and a 40-44% reduction by 2030.
- An independent academic review of energy modelling studies suggests that the median cost-effective path for EU emissions is 48% below 1990 levels by 2030, within a range of 43-52%[16].

14 Available at: https://www.theccc.org.uk/publication/the-scientific-and-international-context-for-the-fifth-carbon-budget

15 European Commission, *A Roadmap for moving to a competitive low carbon economy in 2050*, COM (2011) 112 final

16 Knopf, B. et al (2013) *Beyond 2020 – Strategies and costs for transforming the European energy system*, Climate Change Economics. We add projections of EU non-CO_2 emissions from the EC Low-carbon Roadmap (SEC(2011) 288 final) in order to be comparable to the EU 2030 40% target which covers all greenhouse gases.

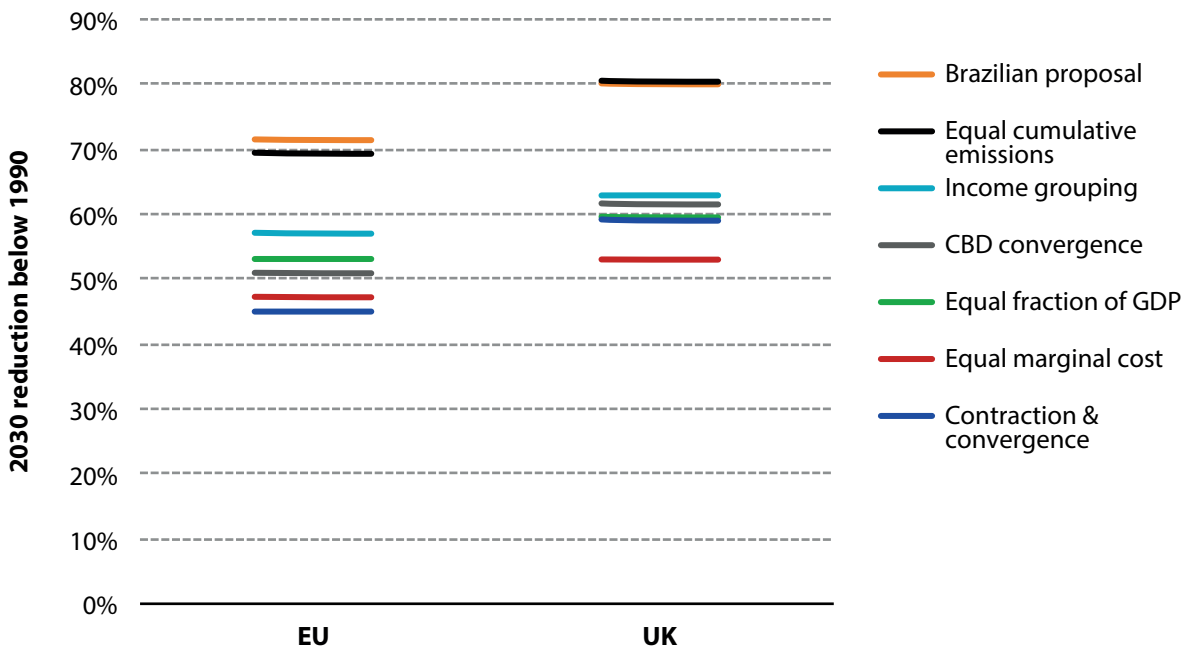
- EU emissions are now likely to substantially outperform the EU's 2020 target of a 20% reduction below 1990 levels. Recent projections suggest EU emissions could fall 24% below 1990 levels by 2020, and possibly close to 30%[17].

The EU 2030 target is also below estimates for a 'fair' EU share of a global 2°C pathway, and the UK's likely contribution is at the low end of ambition compared to its global 'fair' share:

- While there is no single agreed approach to defining a 'fair' share of climate effort between nations, several have been proposed. Each emphasises different dimensions of equity such as economic factors, convergence of emissions and historic responsibility.
- We estimated EU and UK emissions in 2030 under seven different approaches, using the GLOCAF[18] model applied to global emissions of 42 $GtCO_2e$ in 2030 (consistent with a likely chance of staying below 2°C).
- This suggests an indicative range for the EU of 45-71% below 1990 levels, and 53-80% for the UK. The UK takes on a slightly higher reduction than the EU as a whole, given its status as one of the wealthiest nations and high historic emissions (Figure 2.4).
- The results are not evenly distributed across the range. Methods focussing on economic factors and convergence of emissions by 2050 allocate smaller reductions, whereas methods focussing on historical responsibility suggest much larger cuts.

The EU should therefore be prepared to raise its ambition as a contribution to closing a global emissions gap in 2030, alongside similar commitments from other countries.

Figure 2.4: Range for EU and UK 'fair' 2030 reductions under a global 2°C pathway



Source: DECC GLOCAF modelling.
Notes: Excludes international aviation and shipping emissions. Global emissions in 2030 assumed to be 42 $GtCO_2e$. CBD stands for Common But Differentiated. A description of each approach is given in CCC (2015) *The scientific and international context for the fifth carbon budget.*

17 European Environment Agency (2014) *Trends and projections in Europe 2014: Tracking progress towards Europe's climate and energy targets for 2020*; Sandbag (2014) *Is Europe's new climate target a walk in the park?*

18 Averchenkova, A. et al. (2014) *Taming the beasts of "burden sharing": an analysis of equitable mitigation actions and approaches to 2030 mitigation pledges*, Centre for Climate Change Economics and Policy

4. Implications for the fifth carbon budget

Our findings suggest that a fifth carbon budget reflecting current international pledges and EU commitments requires, on a best estimate, a reduction in UK emissions by 2030 of around 53% on 1990 levels:

- **International action.** The world is acting to tackle climate change. The agreement in December 2015, under the UN process, could provide the legal basis for international action beyond 2020. The 2°C limit requires substantial global emission cuts by 2030. The UK should continue to play its part.
- **The EU 2030 pledge.** The EU's Member States have agreed to reduce EU emissions by at least 40% below 1990 levels in 2030. The UK has supported rules for dividing reductions between Member States which imply higher effort from richer countries like the UK, Germany and France. This is a fair, sensible and practical approach. For the current EU agreed pledge our best estimate is that this means a UK reduction of 53% below 1990 levels in 2030, within the range 50-56%.

However, to stay on a cost-effective track to the agreed 2°C objective, guided by the latest climate science, more effort will be required across the world by 2030 than currently pledged, including from the EU:

- **The EU and UK 2050 targets.** The EU and UK targets of at least an 80% reduction compared to 1990 remain an appropriate contribution to global action towards 2°C. The fifth carbon budget needs to be on a path to this target.
- **Expectation of a process beyond Paris to raise ambition.** Current pledges to the UN under the Paris process suggest that, globally, more is needed to limit the risk of going beyond 2°C. There is scope for this in future, given more is possible at low cost and the intention for Paris to include a mechanism to raise ambition. The UK Government has previously suggested a 50% reduction for the EU by 2030, which would entail a greater reduction for the UK.

Given the potential for the Paris conference to produce significant new developments, we will write to the Secretary of State after the Conference to set out if and how this affects our published advice.

Chapter 3: The cost-effective path to 2050

1. Current emissions and projections to 2020
2. Meeting the 2050 target – what this means for the fifth carbon budget
3. Scenarios for the fifth carbon budget
4. Further progress required from 2033 to 2050

The Climate Change Act requires that carbon budgets are set on track to meeting the 2050 target to reduce emissions by at least 80% relative to 1990, taking into account the range of considerations discussed in Chapter 1.

In this chapter we set out our analysis of the cost-effective path to the 2050 target.

Significant ongoing reductions in emissions will be required to 2030 if the UK is to credibly remain on track to the 2050 target. Based on the latest evidence we estimate that the cost-effective path involves around a 61% reduction in emissions by 2030 relative to 1990. That compares to a 36% reduction from 1990 to 2014.

Emissions across the economy would need to fall by around 13 $MtCO_2e$ (3%) per year on average from 2014 to 2030. Emissions in the 'non-traded' sectors (i.e. outside the EU Emissions Trading System - transport, heat in buildings, agriculture) would need to fall around 6 $MtCO_2e$ (2%) each year.

We base our assessment on an analysis of the potential future path of UK emissions and the opportunities to reduce those emissions along with the associated uncertainties. We identify alternative ways of delivering our central scenario for emissions reduction and identify opportunities to go further in some areas to compensate for potential under-delivery in others. This evidence is set out on a sector-by-sector basis in the accompanying Technical Report, *Sectoral scenarios for the fifth carbon budget*[1].

Given the time required to develop and implement new policies, we consider the emissions path to 2020 to be largely locked in. However, policies have not yet been put in place for the 2020s, and investments are yet to be made[2]. The challenge now is therefore to determine the cost-effective path from 2020 to meeting the 2050 target.

We begin our analysis by assessing the likely entry point to the 2020s. We then consider potential scenarios beyond 2020, through the fifth budget period (2028-32) and out to 2050, and we consider the impact of these scenarios for the various criteria set out in the Climate Change Act.

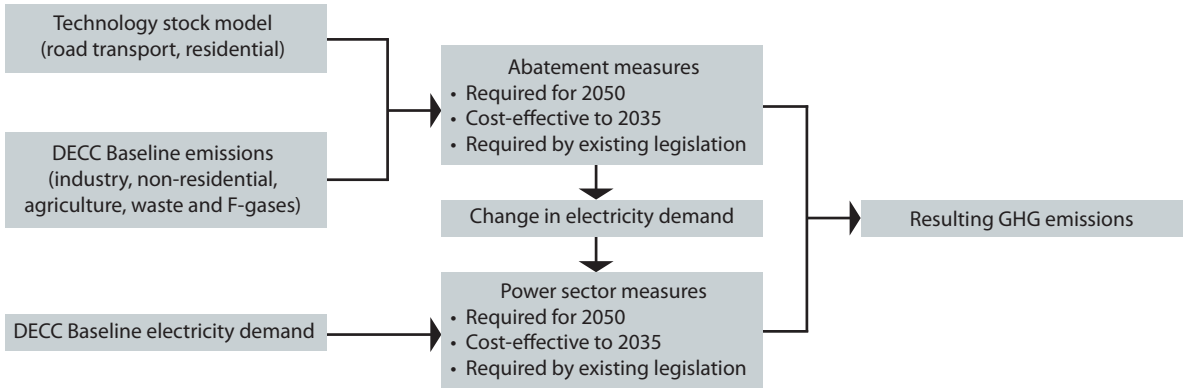
This approach is set out schematically in Figure 3.1. For ease of presentation wider economic and social considerations are described in the next chapter, and our conclusions for budget-setting in Chapter 6. The scenarios are presented in this chapter under the following sections:

1. Current emissions and projections to 2020
2. Meeting the 2050 target – what this means for the fifth carbon budget
3. Scenarios for the fifth carbon budget
4. Further progress required from 2033 to 2050

1 Available on our website, www.theccc.org.uk

2 Whilst the fourth carbon budget (2023-27) has been legislated, policies to meet it are not in place.

Figure 3.1: Approach to constructing CCC scenarios



Source: CCC analysis.

1. Current emissions and projections to 2020

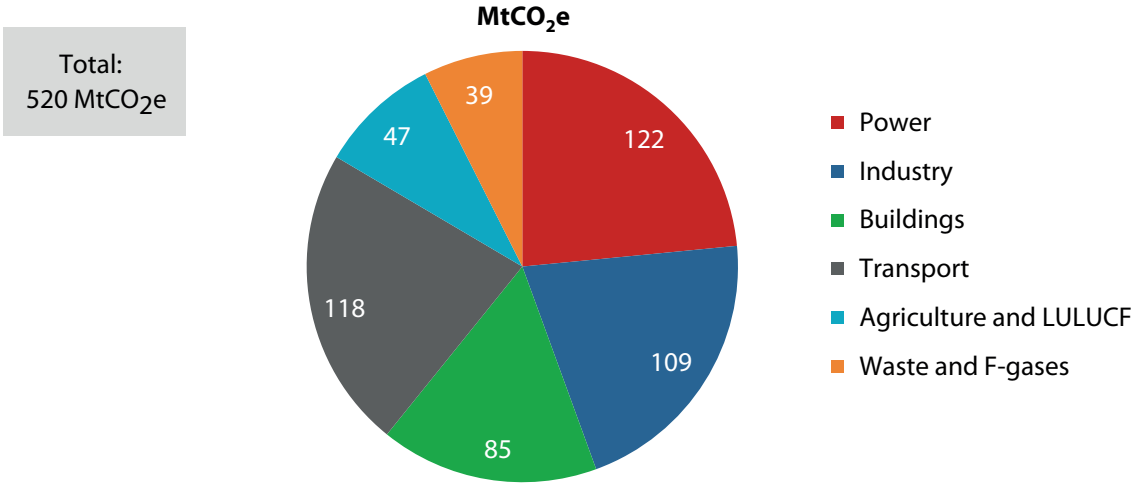
Current emissions and changes since 1990

UK emissions of greenhouse gases (GHGs) covered by carbon budgets were 520 $MtCO_2e$ in 2014. This excludes emissions from international aviation and shipping, for which 2014 estimates are not yet available but were 41 $MtCO_2e$ in 2013.

The UK's net carbon account adjusts these emissions for any implied trading of carbon credits (see Chapter 1). The rest of this chapter refers to actual ('gross') emissions, rather than the net carbon account.

UK emissions are split between six sectors (Figure 3.2): power/electricity generation (23%), industry (21%), buildings (16%), transport (23%), agriculture and land-use, land-use change and forestry (LULUCF) (9%), and waste and fluorinated gases (F-gases) (7%).

Figure 3.2: Current UK emissions of greenhouse gases (2014)



Source: DECC (2015) *Provisional UK greenhouse gas emissions national statistics*; CCC analysis.
Notes: Values include non-CO_2 GHGs allocated to sectors according to their 2013 share (Data are not available for non-CO_2 emissions by sector in 2014).

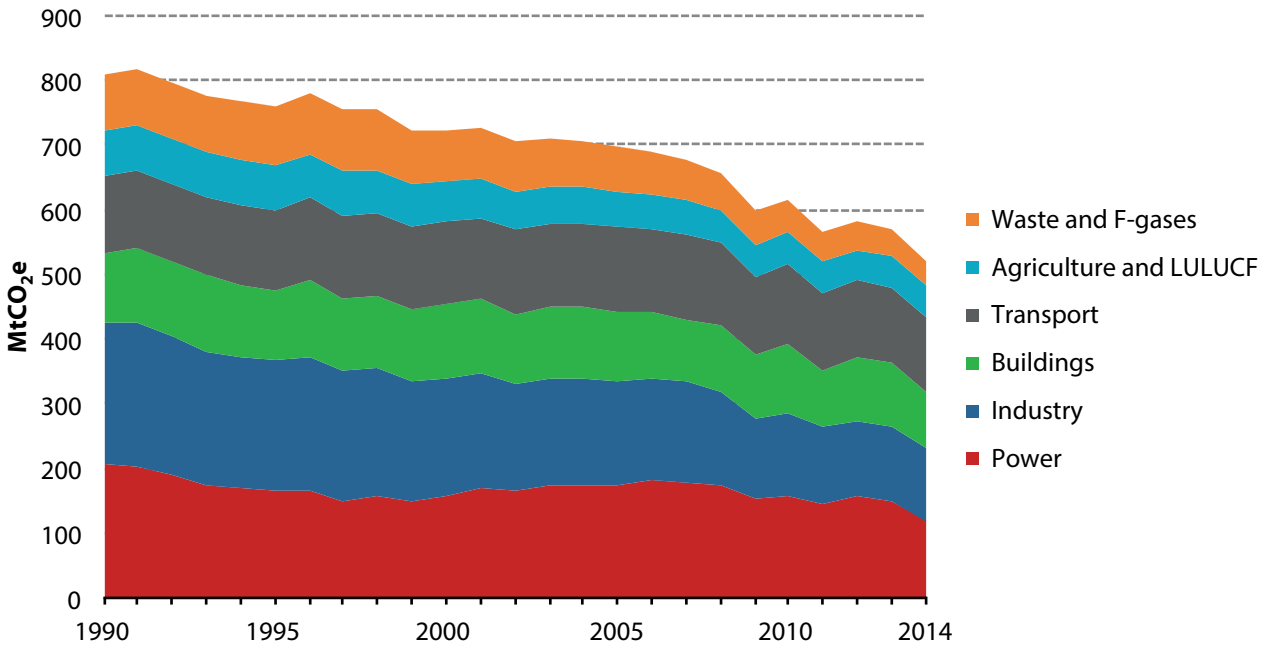
UK greenhouse gas emissions in 2014 were 36% below 1990 levels and 25% below 2005 (Figure 3.3). In part this is due to the economic downturn, in particular a 9% reduction in GHG emissions in 2009. However, the reductions since 1990 also reflect some longer-term trends and more recent impacts of policies aimed at reducing emissions:

- Power sector GHG emissions decreased 28% between 1990 and 2013. This is due to a move away from coal and oil towards gas in generation, and an increase in electricity generated from waste and renewable energy sources. Data are not yet available for total GHG emissions by sector in 2014; however, power sector CO_2 emissions decreased a further 18% in 2014[3], and 41% overall between 1990 and 2014.
- Industry sector direct GHG emissions (i.e. excluding electricity use) decreased 33% between 1990 and 2013. This partially reflects a structural shift away from energy-intensive industries (including iron and steel, for which output decreased by over 30% over the same period). Industry sector CO_2 emissions decreased a further 6% in 2014, and 37% between 1990 and 2014.
- Transport sector GHG emissions rose by 9% between 1990 and 2007, but have subsequently declined such that over the period 1990-2013 they are down 4%. The overall (and recent) decreases are due to improvements in average fuel efficiency of vehicles, the switch from petrol to diesel cars, a reduction in traffic volumes and some substitution of biofuels for fossil fuels since 2002. Transport sector CO_2 emissions increased 1% in 2014, potentially linked to rising incomes.
- Buildings sector direct GHG emissions (i.e. excluding electricity use) fell by 5% between 1990 and 2013, with improved efficiency of boilers and buildings more than offsetting the effect of increased internal temperatures. Buildings sector CO_2 emissions decreased a further 15% in 2014, due largely to higher 2014 temperatures[4], such that overall, CO_2 emissions decreased 19% between 1990 and 2014.
- GHG emissions from land use, land-use change and forestry (LULUCF) and agriculture decreased 31% between 1990 and 2013. This mainly reflects an 18% reduction in methane emissions, due primarily to decreased cattle numbers, and a 17% reduction in nitrous oxide emissions, due primarily to a decline in animal numbers and a decrease in synthetic fertiliser application. GHG data are not yet available for 2014.
- Waste GHG emissions decreased 67% between 1990 and 2014, due to a reduction in biodegradable waste sent to landfill, and the implementation of methane recovery systems. F-gas emissions remain close to 1990 levels.

3 Note: all 2014 GHG data are provisional.

4 Figures are outturn (i.e. not temperature-adjusted). Had temperatures followed their long-term trend, the reduction in emissions from buildings would have been much smaller.

Figure 3.3: Historical UK emissions of greenhouse gases (1990-2014)



Source: DECC (2015) *Final UK greenhouse gas emissions national statistics: 1990-2013;* DECC (2015) *Provisional UK greenhouse gas emissions national statistics;* CCC analysis.

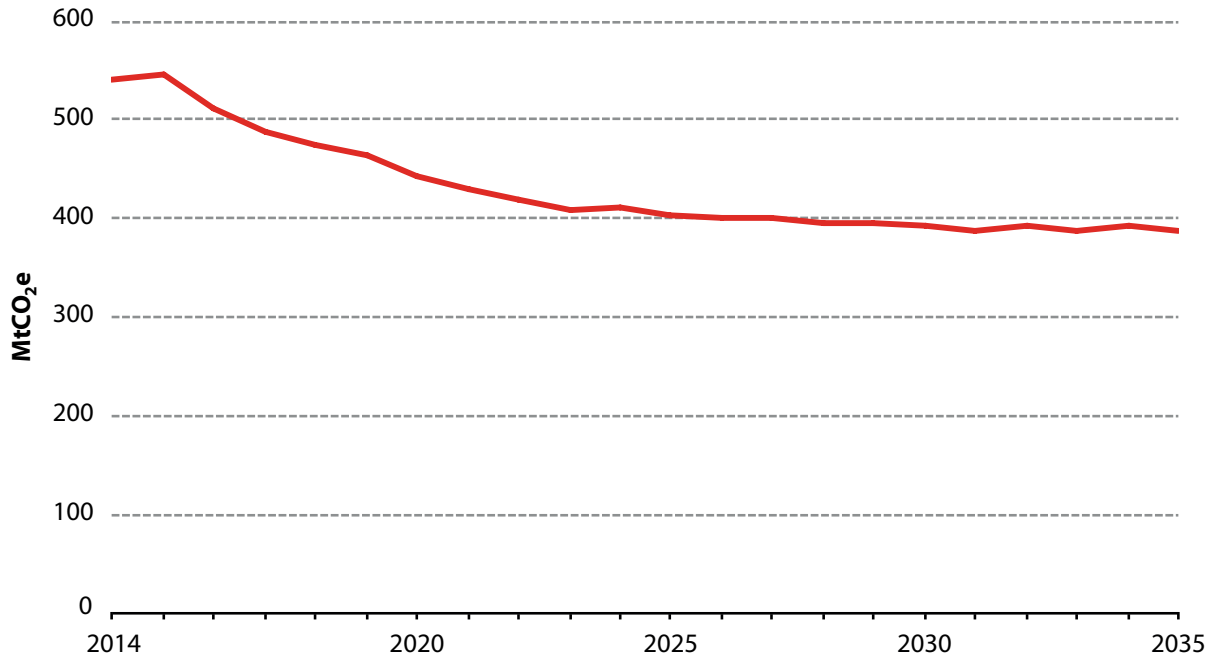
Projected emissions to 2020 – central case

DECC projections allow for the combined impact of current policies (those that are currently implemented or where implementation is underway) and planned policies (those where the Government's intentions have been announced or are still being consulted on). The latest interim projection (October 2015) suggests continued reductions in GHG emissions, by a further 15% between 2014 and 2020:

- Overall, the reduction is driven largely by a very significant reduction in power sector emissions, due in particular to the impact of the 2020 renewables target, and a continued shift away from coal.
- Further significant reductions occur in transport, due to the impact of the EU new car and van CO_2 targets for 2020.

The projection shows UK emissions 45% below 1990 levels in 2020 (Figure 3.4). Projections of emissions in 2020 have varied significantly in the past, reflecting incorporation of more recent data and improvements to the projection methodology (Box 3.1).

Figure 3.4: DECC's emissions projections (2014-2035)



Source: DECC interim projections (October 2015).

Box 3.1: Changes in emissions projections since 2010

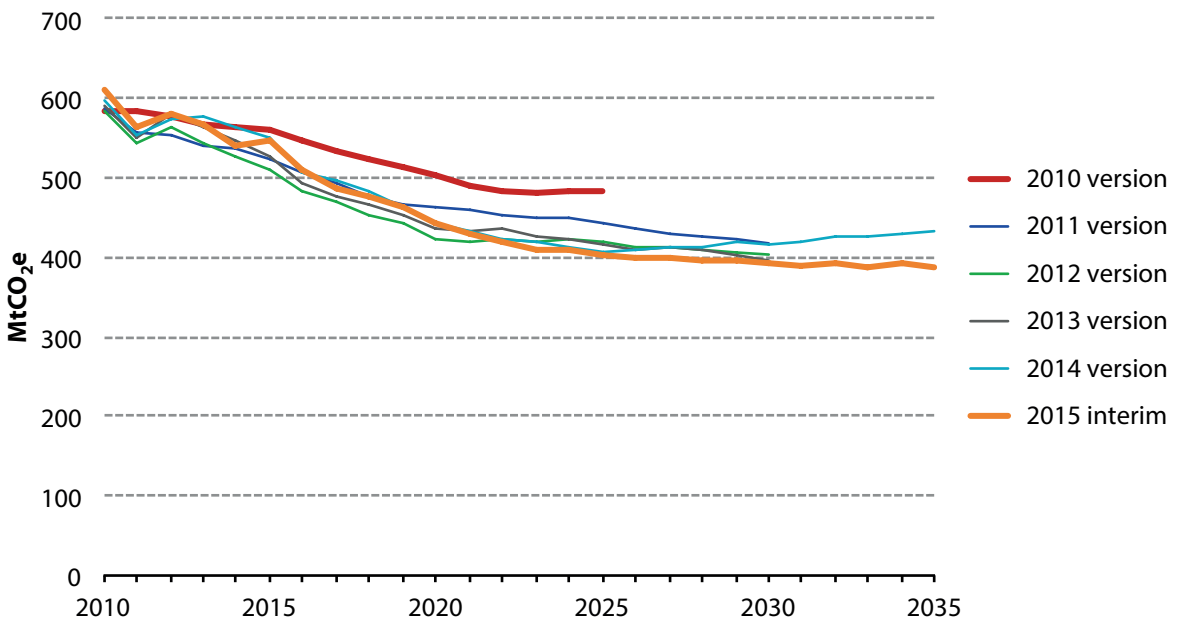
Each year, DECC publishes projections of energy demand, supply and GHG emissions. Since the release of our fourth carbon budget advice in 2010, the projections changed considerably as a result of updates for the latest evidence and methodological improvements (Figure B3.1):

- **2010 projections**. In the year of the fourth carbon budget advice (2010), DECC projected total GHG emissions falling to around 483 $MtCO_2e$ in 2025 (the 2010 projections only go out to 2025).
- **2011 projections**. This release projected significantly lower total GHG emissions, mainly due to the reductions in emissions from power, industry and transport. In the power sector, lower GDP growth together with changes to generation costs and plant efficiencies resulted in lower emissions. Industry emissions decreased primarily due to lower GDP growth assumptions, reduced growth in industrial sub-sectors and higher estimated savings from policy. Projected transport emissions fell because of higher oil prices, revision of the demand equations and revisions in the 2009 UK GHG inventory. In total, 2025 emissions fell to 442 $MtCO_2e$ (a 9% reduction on the 2010 estimate) and 2030 emissions were projected at 418 $MtCO_2e$.
- **2012 projections**. This showed a further fall in projected GHG emissions mainly as a result of reductions in power, transport and industry sectors. In power, a key change in the modelling approach implied a faster decline in coal use. The other main driver was the introduction of Electricity Market Reform (EMR) policies leading to greater support for low carbon technologies. Industry emissions decreased mainly because of lower GDP growth assumptions and combined heat and power projections. Updates in economic assumptions and model changes led to lower transport emissions. Overall, 2030 emissions were projected at 404 $MtCO_2e$, a 3% reduction on the 2011 estimate.

Box 3.1: Changes in emissions projections since 2010

- **2013 projections**. The projection showed slightly higher total GHG emissions by the early 2020s but almost no change by 2030. In industry, refineries emissions increased due to adjustments in the GHG inventory. Residential emissions were higher because of a revision to older supplier obligation schemes. 2030 emissions were projected at 396 $MtCO_2e$, a 2% reduction on the 2012 estimate.
- **2014 projections**. Projected emissions increased slightly due to a revision in the expected impacts of existing policies beyond 2025. Specifically, 2030 emissions were projected at 417 $MtCO_2e$, a 5% increase on the 2013 estimate.
- **2015 interim projections**. DECC published their 2015 projections as this report was sent to print. In this report we use 'interim' emissions projections provided to the Committee in October 2015 and produced on the same basis as the published projections. Revisions to the GHG inventory and emissions projections led to a change in the long-term trend. While the 2014 publication projected emissions to increase from 2025, in the latest projections total GHG emissions are broadly flat in the long-term. Thus, 2030 emissions are projected to be lower (392 $MtCO_2e$), a 6% reduction on the 2014 estimate.

Figure B3.1: DECC Reference projections, 2010-2015 vintages



Source: DECC (2010-2015)*Updated energy and emissions projections, DECC interim projections (October 2015).*
Notes: The 2010 version projected emissions up to 2025 only whilst since 2014, projections go out to 2035.

There is inevitable uncertainty in these projections. We discuss the uncertainty in emissions projections, and its implications for setting and meeting the fifth carbon budget, in Section 3.

DECC's projections assume that current Government policies to reduce emissions deliver in full. In our 2014 and 2015 Progress Reports we noted that a number of these policies are at risk of failing to deliver due to design and delivery problems, or because they are currently unfunded:

- In the non-traded sector (i.e. outside the EU Emissions Trading System) we identified the Agricultural Action Plan, policies to improve the fuel efficiency of HGVs, the Renewable Heat Incentive post-2016, Zero Carbon Homes and the Renewable Transport Fuels Obligation as "at risk" to 2020.
- In the traded sector, we identified fuel switching away from coal as "at risk" to 2020.

Our emissions scenarios are broadly consistent, in terms of ambition, with DECC's 2014 assessment of the impact of current and planned policies. Since then, there has been some weakening of policies, such as the cancellation of Zero Carbon Homes. Delivering our scenario would therefore require strengthening of current and planned policies to ensure they deliver in full.

2. Meeting the 2050 target – what this means for the fifth carbon budget

The 2050 target

The Climate Change Act includes a requirement to reduce 2050 emissions by at least 80% relative to 1990. That follows the Committee's recommendation that emissions for 2050 should be reduced by at least 80% on 1990 levels, covering all sectors *including the UK share of international aviation and international shipping* (IAS)[5]. This implies a level of per capita emissions in 2050, which if replicated globally, would be consistent with a path to limiting global temperature increase to around 2°C.

Accounting complexities mean that the IAS sectors are currently not included formally within the carbon budgets. To ensure consistency with the 2°C goal, emissions from IAS are reflected in the levels of the existing budgets by ensuring these are on the path to meeting the 2050 target with IAS emissions included. This approach has been established over the course of legislating the four previous carbon budgets and the fourth carbon budget review:

- The Committee has recommended budgets on an appropriate path towards a 2050 target that allows room for IAS emissions in achieving an overall 80% reduction. Sensible planning assumptions for IAS emissions (i.e. aviation emissions in 2050 to return to their 2005 level, shipping emissions decline around 35% between 2005 and 2050, as in our Central scenario) imply this would require a reduction of around 85% relative to 1990 for the non-IAS sectors of the economy.
- The Government has followed this approach, both in its own modelling[6], and in legislating the budgets as recommended. In 2012, when reviewing the treatment of IAS emissions, the Government stated that: *"Government reaffirms its overall commitment to the 2050 target and recognises that emissions from international aviation and shipping should be treated the same as emissions from all other sectors, in order to reach our long-term climate goals".*[7]
- Excluding IAS emissions, UK greenhouse gas emissions were 520 $MtCO_2e$ in 2014, 36% below 1990 levels.

5 *Interim advice from the Committee on Climate Change* (2008), available at https://www.theccc.org.uk/publication/letter-interim-advice-from-the-committee-on-climate-change/

6 For example DECC's 2050 Calculator (https://www.gov.uk/guidance/2050-pathways-analysis) and analysis using the RESOM and ESME models for DECC (2013) *The Future of Heating: Meeting the challenge*, available at: https://www.gov.uk/government/publications/the-future-of-heating-meeting-the-challenge. This approach was recognised in the Government's response to the Committee's 2015 Progress Report.

7 DECC (2012) *International aviation and shipping emissions and the UK's carbon budgets and 2050 target*. Available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65686/7334-int-aviation-shipping-emissions-carb-budg.pdf.

Inventory changes

In recent years there have been significant revisions to the UK's emissions inventory, increasing estimated emissions for 1990 and, to a lesser degree, for subsequent years (Box 3.2). This means that an 80% emissions reduction on 1990 levels now implies allowed 2050 emissions, including IAS, of 167 $MtCO_2e$, rather than our earlier estimate of 160 Mt, based on the 2006 inventory. This still implies emissions per capita of just over 2 tonnes, which we estimated was an appropriate level at the time the Climate Change Act was legislated. Using the updated level of allowed emissions in 2050, a further fall of 70% from 2014 is needed in order to meet the 2050 target (Figure 3.5).

Box 3.2: Revisions to the UK emissions inventory

The GHG emissions inventory is reviewed every year. New estimates for historical emissions back to 1990 are produced, based on the latest energy data published in the Digest of UK Energy Statistics (DUKES), as well as any methodological changes or new reporting guidelines from the IPCC.

When we originally recommended the 2050 target in 2008, an 80% reduction on 1990 levels in GHG emissions including international aviation and shipping implied a target of approximately 160 $MtCO_2e$ for 2050. However, improvements in evidence and methodological changes to the inventory mean that the baseline emissions for 1990 have now changed.

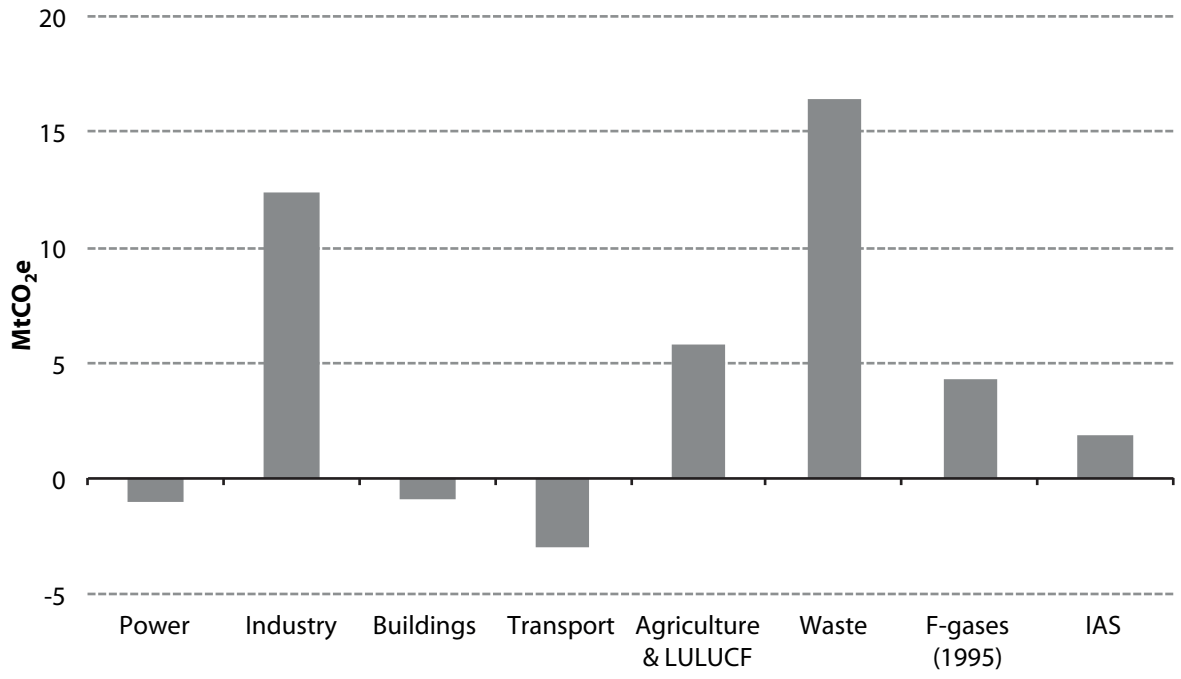
Based on a comparison of the most recent DECC inventory with the 2010 version (the earliest that had an equivalent sectoral breakdown), the largest revisions to estimated GHG emissions in 1990 (Figure B3.2) are:

- **Energy supply and industry**: 1990 emissions were revised upwards by 12 $MtCO_2e$, largely as a result of higher estimates of emissions coming from coal mining (3.5 Mt), exploration, production and transport of oil and gas (1.8 Mt) and other industrial combustion and electricity (4.6 Mt). Some industrial production, such as non-ferrous metal processes, was previously not accounted for, adding a further 2 $MtCO_2e$.
- **Agriculture and LULUCF**: estimates of 1990 emissions increased by around 6 $MtCO_2e$ reflecting new information on the average weights of cattle, manure management practices and UK land areas of cropland on organic soils drained for agricultural purposes.
- **Waste**: 1990 GHG emissions increased by 16.5 $MtCO_2e$, mainly due to changes to estimates of landfill emissions (13 Mt) as new information on the volumes of landfill gas flared at UK sites has been used. In addition, new Defra research estimated the decay rate of biodegradable waste to be slightly higher than previously assessed. Emissions from waste-water handling also rose (3.5 Mt) after the 2012 UNFCCC review concluded that the previous emissions were underestimated.
- **F-gases**: estimates of 1995 emissions are higher by roughly 4 $MtCO_2e$ largely because of the revisions to the emissions from halocarbon production.

Overall, estimates of 1990 GHG emissions including IAS have increased from 798 $MtCO_2e$ in the 2008 inventory, to 802 Mt in the 2010 inventory to the current inventory figure of 837 Mt.

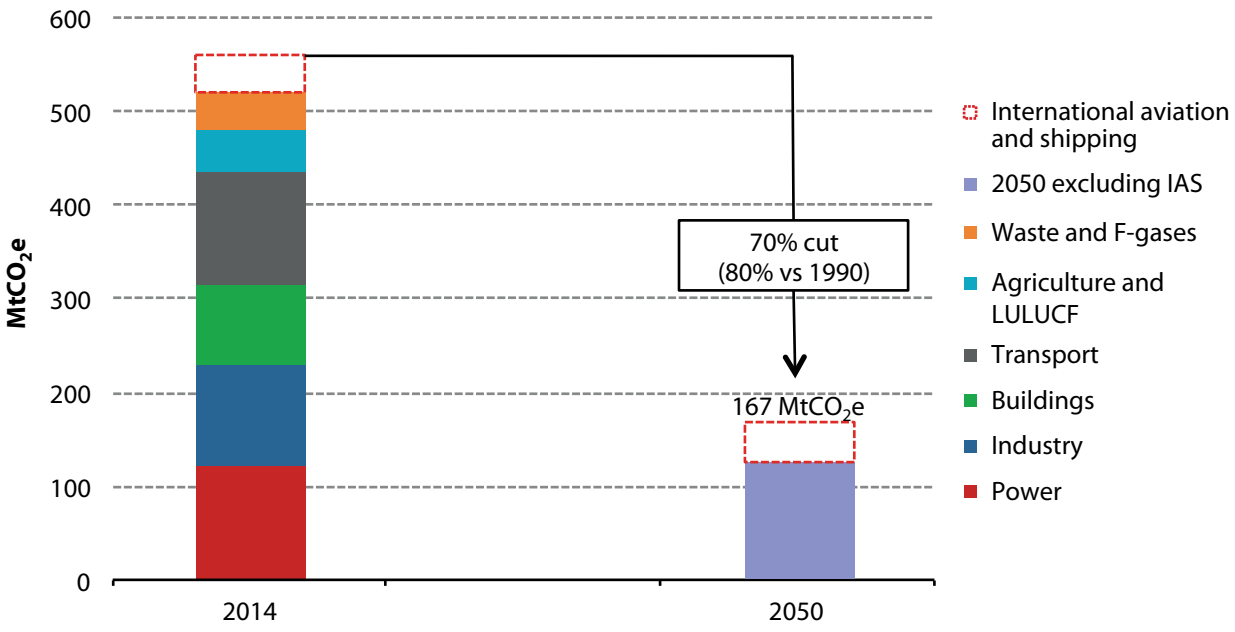
Box 3.2: Revisions to the UK emissions inventory

Figure B3.2: Difference in 1990 GHG emissions estimates between 2010 and 2015 inventories



Source: DECC (2015) *Final UK greenhouse gas emissions national statistics: 1990-2013*; DECC (2010) *Final UK greenhouse gas emissions national statistics: 1990-2008*; CCC analysis.
Notes: F-gases emissions are presented for 1995 which is the year used for those gases, consistent with the Kyoto Protocol.

Figure 3.5: The 2050 challenge



Source: DECC (2015) *Final UK greenhouse gas emissions national statistics: 1990-2013*; DECC (2010) *Final UK greenhouse gas emissions national statistics: 1990-2008*; CCC analysis.
Notes: International aviation and shipping data are for 2013.

As we set out when advising on the 2050 target in 2008, it is sensible to plan now to meet the target without use of emissions trading (Box 3.3). We consider the role of credits in meeting the fifth carbon budget in Chapter 6.

Box 3.3: Potential contribution of trading to meet the 2050 target

The accounting for the 2050 target under the Climate Change Act allows emissions trading to contribute (i.e. the target is set on a 'net' basis). However, as we set out when we recommended the 2050 target, it is not sensible to rely upon being able to purchase emissions credits, given that all countries would need to be pursuing stretching targets and any available credits would be likely to be very expensive.

A more reasonable approach is to plan now to meet the 80% target via domestic effort (i.e. on a 'gross' basis), while retaining the flexibility to use credits as we approach 2050 if they turn out to be available and less costly than domestic action at the margin. This is the basis on which our scenarios to 2050 have been constructed.

Scenarios for meeting the 2050 target

Since the 2050 target was legislated in 2008, the Committee, and others, have produced analysis and modelling on how it can be met, which has been updated as new information emerges (Box 3.4). Different approaches and assumptions have been tested over time.

A number of common themes have emerged from the various approaches[8]:

- **Energy efficiency and behaviour change.** Reducing the level of energy demand through improved efficiency and small changes to consumer behaviour can greatly reduce the cost of meeting the 2050 target. However, it is clear that this alone will not be enough to reduce emissions by 80%, and fuel switching to low-carbon sources will also be needed.
- **Power sector**. Meeting the target is likely to require a power sector with very low emissions intensity in 2050. This is needed to decarbonise existing demands for electricity and to meet new demands in road transport and heat in buildings without increasing emissions (with potential for other applications). Depending on the extent of electrification in transport, heat and other applications, the level of electricity consumption in 2050 could be 50-135% above the level in 2014.
- **Carbon capture and storage (CCS)** is very important in meeting the 2050 target at least cost, given its potential to reduce emissions across heavy industry, the power sector and perhaps with bioenergy, as well as opening up new decarbonisation pathways (e.g. based on hydrogen). Estimates by the Committee[9] and by the Energy Technologies Institute (ETI)[10] indicate that the costs of meeting the UK's 2050 target could almost double without CCS. At the global level the IPCC has estimated that its absence could increase costs by over 100%[11].

8 The evidence for these themes and supporting analysis can be found in the accompanying Technical Report.

9 CCC (2012) *The 2050 target – achieving an 80% reduction including emissions from international aviation and shipping* https://www.theccc.org.uk/archive/aws/IA&S/CCC_IAS_Tech-Rep_2050Target_April2012.pdf

10 ETI (2015) *Building the UK carbon capture and storage sector by 2030 – Scenarios and actions* http://www.eti.co.uk/wp-content/uploads/2015/03/CCS-Building-the-UK-carbon-capture-and-storage-sector-by-2013.pdf

11 138%, IPCC (2014) *Fifth Assessment Report – Synthesis Report*. Available at http://ar5-syr.ipcc.ch/ipcc/ipcc/resources/pdf/IPCC_SynthesisReport.pdf

- **Bioenergy**. Sustainable bioenergy can play an important role. However, there are limits to the sustainable supply (e.g. this could provide around 10% of primary energy in 2050), so its role must be supplementary to other measures. Bioenergy should be allocated to options where it has the largest impact on reducing emissions. Our analysis indicates that use should preferentially be with CCS and/or displacing coal, with further potential for use where alternative low-carbon options are not available (e.g. aviation). The Committee's estimates of sustainable bioenergy supply suggest that use with CCS would provide an extra emissions reduction of around 20 $MtCO_2e$/year relative to use of the same quantity of bioenergy to displace gas in heat for industry and buildings[12].
- **Industry**. In addition to opportunities for energy efficiency and CCS, industry can be decarbonised through switching heat generation from fossil fuel combustion to use of electricity or combustion of hydrogen from low-carbon sources. There may also be opportunities to reduce emissions through materials efficiency and product substitution, but it is difficult to estimate the extent of these. Given the costs and challenges associated with decarbonising industry, residual emissions might be around 65 $MtCO_2e$ in 2050.
- **Agriculture**. Agriculture emissions can be reduced by changed farming practices (e.g. on-farm efficiencies, improved animal fertility), reduced food waste and adjustment of diet towards less carbon-intensive foods. However, there is a limit to what is likely to be achievable, so residual emissions in 2050 may be around 30 $MtCO_2e$.
- **Aviation**. While UK demand for international aviation is likely to grow considerably, there will be a need to limit emissions. Previous analysis by the Committee concluded that aviation should plan for emissions in 2050 to be no higher than those in 2005. That requires strong efficiency improvements to balance demand growth of about 60%.
- **Buildings and surface transport**. With the developments described above, there may be a small amount of room for residual emissions in buildings and/or surface transport. Where emissions remain should depend on how different low-carbon technologies develop. It is therefore sensible to plan now to keep open the possibility of near-full decarbonisation of both buildings and surface transport by 2050.

These scenarios provide a high-level sense of direction for decarbonisation to 2050. They still leave significant flexibility in the mix of effort between sectors, technologies and the role of behaviour change. Further, they provide the flexibility for new innovation and technologies to emerge.

However, a recurrent and robust feature of these analyses is the importance of action to largely decarbonise the power sector over the period to 2030, and expand capacity thereafter to extend low-carbon electricity into other sectors such as transport and buildings (see Box 3.5 in the following section). We set out different scenarios for a decarbonised electricity supply in 2030 in our report on *Power sector scenarios for the fifth carbon budget*[13]. That report considers in detail the issues of security of supply and affordability associated with this change.

Should efforts to reduce or limit emissions be less successful in one area, more effort will be required elsewhere. For example, if CCS were to be unavailable, it might be necessary to find additional emissions reductions of around 35 $MtCO_2e$ in 2050 from the rest of the economy. Given limited scope to reduce emissions beyond our planning assumptions for international aviation and shipping or from agriculture, this could imply near-full decarbonisation of surface transport and heat in buildings.

12 As solid biomass releases a lot of CO_2 on combustion, its use with CCS (e.g. for power generation) to capture most of that CO_2 would lead to a greater emissions reduction than displacing lower-carbon fossil fuels such as natural gas. For a more detailed explanation of this, see CCC (2011) *Bioenergy Review*, available at: https://www.theccc.org.uk/publication/bioenergy-review/

13 Available at https://www.theccc.org.uk/publication/power-sector-scenarios-for-the-fifth-carbon-budget/

Our scenarios to 2032 therefore keep open the possibility of reducing emissions from heat in buildings and from surface transport to very low levels in 2050.

Our analysis of the costs of decarbonisation is consistent with a range of studies which find costs of meeting the 2050 target of no more than 1-2% of GDP. We assessed these costs most recently in our 2012 report on *The 2050 Target*[14]; updates to the evidence base since then do not alter this estimate significantly.

Box 3.4: Modelling of the 2050 target

Previous analysis of meeting the 2050 target has included use of the MARKAL[15] and Energy Technology Institute (ETI) ESME[16] models, joint DECC-CCC modelling on appropriate use of bioenergy within a decarbonising economy[17], as well as the DECC 2050 Calculator[18]. The Government, academia and industry have engaged in similar modelling exercises. In 2012, we also undertook a bottom-up analysis of how the 2050 target could be met, which involved development of scenarios to look at different balances of effort across the energy system[19].

We have supplemented that work for this report by commissioning analysis by DECC using the new UK TIMES model.

The UK TIMES model (UKTM) is the successor to UK MARKAL, and was originally developed at the UCL Energy Institute.

Like MARKAL, and other energy system models such as the Energy Technology Institute's ESME model, UKTM is a technology-rich model that performs a least-cost optimisation in order to meet energy service demands while meeting specified emissions targets.

Such models generally assume perfect foresight and so provide insights into appropriate strategies as if all important strategic considerations were known.

There are considerable uncertainties over options and their costs and benefits over the timeframe to 2050. The "perfect foresight" approach of these models does not allow a risk-based analysis or effectively taking behavioural factors into account. Therefore it is important to undertake a range of sensitivity tests in order to identify robust insights.

UKTM (or any similar model) does not directly produce an appropriate strategy for meeting the 2050 target. Rather, it provides insights that can be incorporated into a strategic approach to long-term decarbonisation, including full consideration of issues such as deliverability, option creation and robustness to uncertainty. Equally, it is not appropriate to judge different long-term decarbonisation strategies simply in terms of the costs estimated by such a model.

In practice, the Committee's final advice and recommendations draw on wider sources of evidence, expert judgment and analysis.

14 CCC (2012) *The 2050 Target*, available at https://www.theccc.org.uk/archive/aws/IA&S/CCC_IAS_Tech-Rep_2050Target_April2012.pdf

15 UCL (2010) *UK MARKAL Modelling – Examining Decarbonisation Pathways in the 2020s on the Way to Meeting the 2050 Emissions Target*. Available at https://www.theccc.org.uk/publication/the-fourth-carbon-budget-reducing-emissions-through-the-2020s-2/

16 CCC (2012) *Renewable Energy Review – Technical Annex – Energy system modelling using the Energy Technologies Institute ESME model*. Available at https://www.theccc.org.uk/publication/the-renewable-energy-review/

17 Redpoint (2012) *Appropriate Uses of Bioenergy*. Available at https://www.theccc.org.uk/publication/bioenergy-review

18 http://2050-calculator-tool.decc.gov.uk/

19 CCC (2012) *The 2050 target – achieving an 80% reduction including emissions from international aviation and shipping*, https://www.theccc.org.uk/archive/aws/IA&S/CCC_IAS_Tech-Rep_2050Target_April2012.pdf

What the 2050 picture means for the nearer term

In order to reduce emissions by at least 80% by 2050 at lowest overall cost, there is a strong case for steady action to reduce emissions. This gives time and incentives for new technologies to emerge and existing technologies to develop. It allows markets to grow and consumers and businesses to adapt their behaviour over time. Roll-out of low-carbon technologies can be aligned to capital stock turnover and investment can build up steadily while supply chains and skills bases have time to develop.

Having a clear decarbonisation strategy based around known technologies does not mean specifying now a precise mix of technologies that will be used over the next 15 or 35 years. It is important to strike a balance between pursuing solutions that currently appear to be the most promising, while retaining flexibility to alter direction. This is reflected in the set of scenarios we have developed for each sector, outlined in the Technical Report.

Based on what we know now about how to reduce emissions by 80%, a range of actions will be important in the medium term to keep in play alternative ways to meet the 2050 target:

- **Power sector decarbonisation**. Continuing decarbonisation of the power sector to 2030 is crucial to meeting the 2050 target at least-cost (Box 3.5). As well as directly reducing emissions from UK electricity generation, it opens up decarbonisation opportunities for other sectors. To ensure that low-cost options are available to meet growing demand beyond 2030 it is important that less-mature options are developed alongside the roll-out of more mature options.
- **Development of CCS**. Given the importance of CCS in meeting the 2050 target, CCS must make significant progress by 2030. This requires continuing deployment in the power sector over the period to 2030, in order to provide anchor loads for CO_2 infrastructures and reduce risk for projects in both power and industry[20].
- **Infrastructure development**. New infrastructures will be required to support the deployment of low-carbon technologies. As well as CO_2 infrastructure, which is key to commercialisation of CCS, development of heat networks and electric vehicle charging networks will be required, and potentially infrastructure for hydrogen applications. Electricity networks will also need to be strengthened in places, to cope with new demands (e.g. from heat pumps) and increasing generation from low-carbon sources.
- **Market development**. Some of the technologies that will be important for decarbonisation, such as heat pumps and electric vehicles, are available but have yet to be deployed widely in the UK. Developing these markets will take time. Deployment over the next 15 years will be required, such that natural stock turnover after 2030 can deliver the necessary decarbonisation by 2050.
- **Strategic decisions**. While it is important in the near term to create options, there will in some cases be a requirement for Government to choose between different paths. Identification of these decision points, and of the information that will be required to inform them, is an important part of a strategic approach to decarbonisation. Such decisions may include whether and when to develop a widespread hydrogen vehicle refuelling network or how to repurpose the gas grid given changes in demand for gas.

As well as laying the groundwork to meet the 2050 target, these actions will also contribute to emissions reductions in the intervening period. Our scenarios for the fifth carbon budget consist of measures that prepare for 2050 as described above or that reduce emissions at low cost (see section 3).

20 Pöyry & Element Energy (2015) *Potential CCS Cost Reduction Mechanisms*, available at https://www.theccc.org.uk/publication/poyry-element-energy2015-potential-ccs-cost-reduction-mechanisms-report; and Gross (2015) *Approaches to cost reduction in carbon capture and storage and offshore wind*, available at https://www.theccc.org.uk/publication/gross-2015-approaches-to-cost-reduction-in-carbon-capture-and-storage-and-offshore-wind

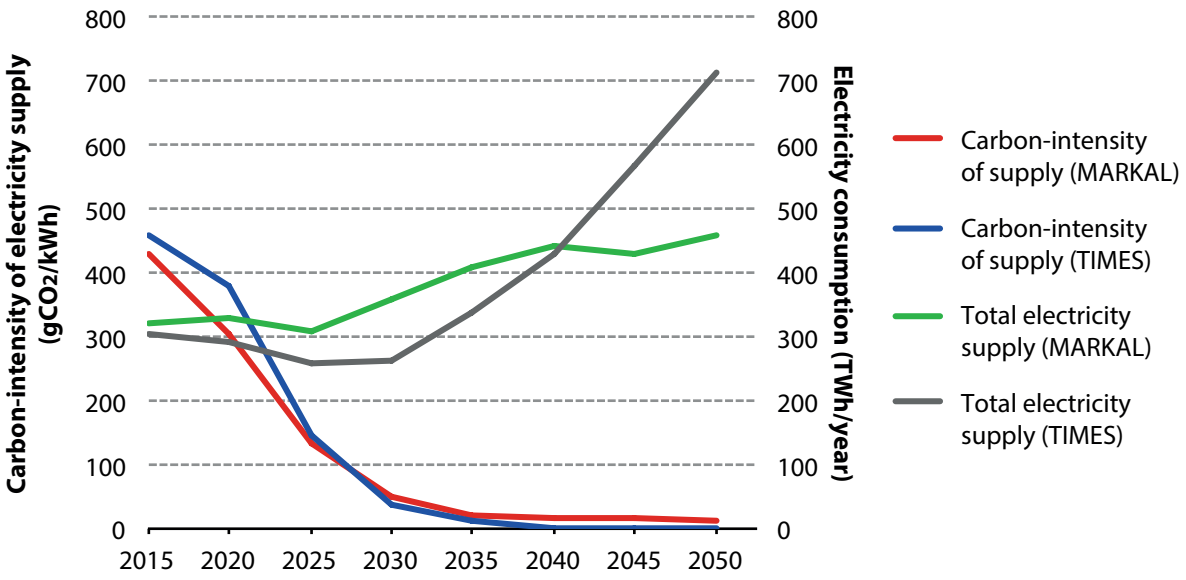
Box 3.5: The rationale for power sector decarbonisation to 2030

The emissions intensity of the UK power sector is currently around 450 gCO_2/kWh. All new generation in recent years has come from low-carbon sources, and the Government has committed to continuing this to 2020. This continued investment, in combination with closures of coal plants, will reduce carbon intensity to 200-250 g/kWh. Further decarbonisation to below 100 g/kWh in 2030 is on the cost-effective path to 2050:

- Our recent report on *Power sector scenarios for the fifth carbon budget*[21] identified that the cost-effective path would be to continue low-carbon investment through the 2020s consistent with reaching below 100g by 2020. This would entail cost-effective deployment of mature low-carbon technologies, commercialisation of key technologies and a rate of low-carbon build consistent with getting to a potentially much larger low-carbon power sector in 2050.
- That is in line with the findings of the 2050 modelling exercises, which reach below 100g in 2030 on the path to close to full decarbonisation by 2050 of a system that could have demand double current levels.

Our power scenarios set out a range of scenarios for low-carbon power sectors in 2030 consistent with this set of considerations.

Figure B3.5: Energy system model trajectories for the power sector (2015-2050)



Source: UCL (2010) *UK MARKAL Modelling – Examining Decarbonisation Pathways in the 2020s on the Way to Meeting the 2050 Emissions Target*; UK TIMES modelling for the CCC by DECC (2015).
Notes: Carbon-intensity calculations exclude the 'negative emissions' benefits of using biomass in conjunction with CCS. While energy system models provide a high-level direction for least-cost decarbonisation, more detailed modelling is required on specific sectors. More detailed modelling of the power sector for our report on *Power sector scenarios for the fifth carbon budget* suggested slightly higher carbon intensity for 2030 than the MARKAL and TIMES results here.

21 CCC (2015) *Power sector scenarios for the fifth carbon budget*, available at https://www.theccc.org.uk/publication/power-sector-scenarios-for-the-fifth-carbon-budget

The role of innovation

Innovation will be critical in developing and implementing new low-carbon technologies, and improving the cost and performance of existing ones.

Government involvement is important to ensure limited resources are best allocated across the innovation process to ensure that carbon budgets, the 2050 target and subsequent decarbonisation can be met at acceptable cost. Our 2010 review of low-carbon innovation[22] identified three broad phases of the innovation process:

- **Research and development (R&D)**, involving both basic research and development of specific technologies, culminating in initial demonstration of feasibility.
- **Demonstration**, involving large-scale pre-commercial demonstration of technologies designed to test and improve reliability, improve designs, and establish and reduce operating costs. Technologies currently at this stage include carbon capture and storage (CCS), and hydrogen fuel cell vehicles.
- **Deployment**, leading to technologies considered 'commercially proven' and achieving economies of scale. Technologies within this stage include nuclear power, heat pumps, offshore wind and electric vehicles.

Product development involves progressing through these three phases. Innovation occurs at each phase but has different characteristics and opens up different options. Innovation is not a strictly linear process: experience at the demonstration and deployment phases frequently reveals the need for additional basic R&D to overcome barriers to further progress, while R&D highlights issues that may have to be tackled when it comes to deployment, and demonstration and deployment both involve new learning.

Our assessment is that while R&D is important, it is sensible to plan for meeting the 2050 target largely through currently-known technologies:

- R&D will be required to develop new low-carbon technologies, and to improve the cost and performance of existing ones. Many of the benefits of early stage R&D may accrue in the period beyond 2050 when, according to IPCC, even deeper reductions in emissions may be required to maintain the expected temperature increase below 2°C.
- Deployment of currently-known technologies at scale will be required to ensure the 2050 target can be met at reasonable cost. It will also drive innovation and learning that feeds back into new R&D as well as potentially creating competitive advantages for the companies and countries involved.

Box 3.6 sets out the rationale for extensive deployment of currently-known technologies to meet the 2050 target. This underpins our approach to developing our emissions scenarios, and the inclusion of considerable volumes of offshore wind, CCS, electric vehicles and district heating in our scenarios, as set out in Section 3.

22 CCC (2010) *Building a low-carbon economy – the UK's innovation challenge*. Available at https://www.theccc.org.uk/publication/building-a-low-carbon-economy-the-uks-innovation-challenge

Box 3.6: The importance of deployment in the 2020s

Deployment of currently known technologies will be of critical importance to meeting the 2050 target due to the remaining time available, the time frame for developing and scaling up new technologies, risks and uncertainty over new technologies, the role of deployment in the innovation process and the need for supporting infrastructure and supply chains:

- **Time available to meet the 2050 target**. Asset lives of 15-30 years require early deployment of the technologies needed to meet the 2050 target. To effectively decarbonise power, transport and heat generation by 2050, it will be necessary to decarbonise all new investment by 2020 for power (with the exception of back-up and balancing plant), 2035 for transport, and 2035 for heat.
- **Time frame to reach deployment at scale**. The development of new technologies, and their deployment at scale, takes time. A recent report by the UK Energy Research Centre (UKERC) found that it can take several decades for new technological innovations to reach commercial maturity (covered further below).
- **Risk and uncertainty of early-stage technologies**. Each phase of innovation carries different risks of failure. Total risk is highest for technologies at the R&D stage, and lowest at the deployment stage (when earlier risks have been eliminated). We therefore have a reasonable degree of confidence that later-stage technologies – e.g. offshore wind, electric vehicles and heat pumps – can be deployed at sufficient scale to meet the 2050 target, given a sensible deployment strategy, supplemented by monitoring and evaluation of costs and technical performance, and measures to address financial and non-financial barriers.
- **Role of deployment in the innovation process**. Deployment of a new technology at scale provides manufacturers, installers and developers with the experience to successfully identify remaining barriers to commercialisation, so that these can be addressed through product redesign, and if necessary, further R&D to improve the product or reduce its cost. It is far from clear that currently unknown technologies will face lower costs than currently known technologies, and will not therefore require the same level of deployment support.
- **Requirement for supporting infrastructure, supply chains and developed markets.** Energy technologies require supporting infrastructure to operate, extensive supply chains to deploy at scale, and developed markets to ensure demand is sufficient for the level of deployment. Infrastructure, supply chains and markets all take time to develop. Early deployment of currently known technologies will help ensure infrastructure, supply chains and markets are in place by the time the technologies need to be deployed at scale in the mid-2030s.

The UK Energy Research Centre (UKERC) recently carried out a review of available evidence for the time new technological innovations take to reach commercial maturity. This covered the innovation timescales of both energy and non-energy technologies, supplemented by five energy-specific case studies.

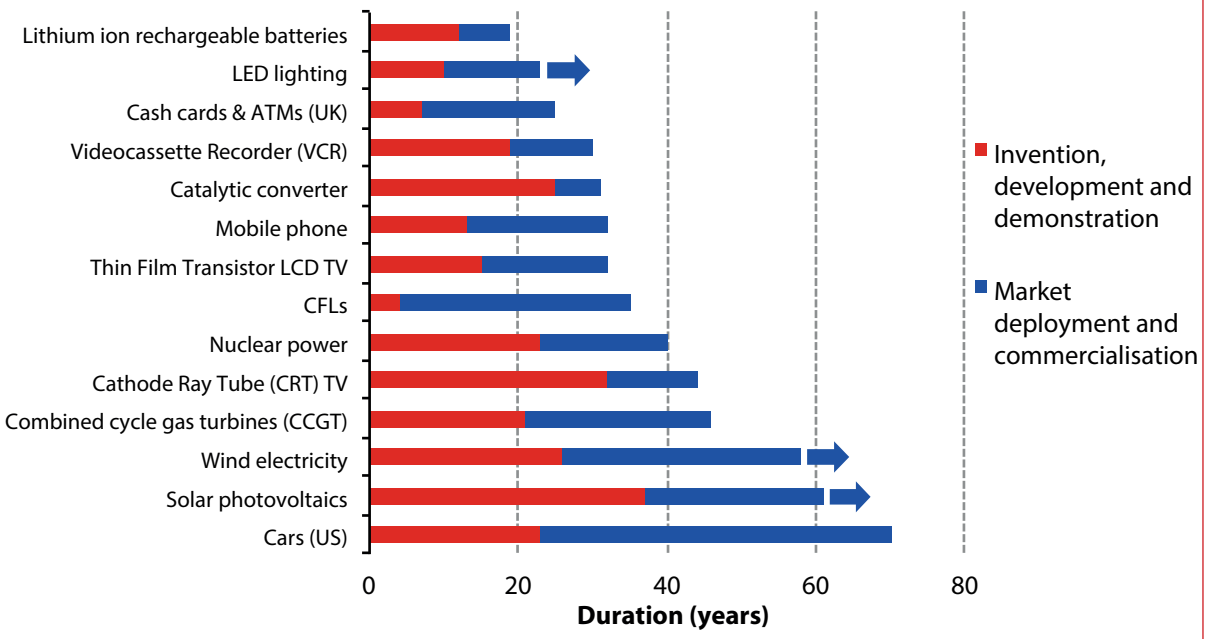
Across the 14 innovations considered, the review examined total time taken from invention to commercialisation, as well as the duration of two broad phases: a first phase of invention, development and demonstration, and a second phase of market deployment and commercialisation:

- The average time taken from invention to commercialisation was 39 years. The shortest time to commercialisation was 19 years (lithium-ion rechargeable battery for consumer electronics), and the longest was 70 years (the car) (Figure B3.6).

Box 3.6: The importance of deployment in the 2020s

- The average time taken for the invention, development and demonstration phase was 19 years. The shortest time to demonstration was four years (compact fluorescent light bulb), and the longest was 37 years (solar PV).
- The average time taken for the market deployment and commercialisation phase was similar, at 20 years. The shortest time to commercialisation was 6 years (catalytic converter), and the longest was 47 years (the car).
- There is considerable variation between the innovations in terms of how quickly they reached market and became commercialised. It is difficult to identify which factors affect the time frames of the two phases; however, the following observations can be made:
  - The average time taken from invention to commercialisation is significantly longer than average for energy generation technologies (48 years), due to a longer market deployment and commercialisation phase.
  - The physical scale of the technology affects the time taken from invention to commercialisation. The overall speed of innovation was significantly lower for large-scale electricity generation technologies than products which are for personal use.
  - The time taken from invention to commercialisation tended to be significantly shorter for products providing the same service as existing products, though this may not be a general finding due to possible outliers such as the car and cathode-ray tube TV, new innovations with relatively long time frames.

Figure B3.6: Time taken for development and commercialisation of a range of innovations



Source: UKERC (2015) *Innovation timelines from invention to maturity: A review of the evidence on the time taken for new technologies to reach widespread commercialisation.*

3. Scenarios for the fifth carbon budget

Alongside the high-level energy system modelling to 2050, we have refreshed our bottom-up scenarios for the fifth carbon budget, based on an analysis of what is possible and meets the criteria in the Climate Change Act in each sector of the economy.

(i) Our approach to building scenarios

We have developed a set of scenarios for reducing UK GHG emissions across the sectors of the economy. In developing our scenarios we have considered:

- The relative cost-effectiveness of different approaches to reducing emissions in the period to 2050. Specifically, the scenarios include measures that are available at lower cost than the Government's published carbon values (Box 3.7).
- The wider criteria set out in the Act, including impacts on affordability and competitiveness (Chapter 4).
- The need to ensure that measures required to meet the 2050 target are available to be deployed when needed, through demonstration and deployment of key technologies, development of markets, and deployment of supporting infrastructure. The scale of the reduction needed to meet the 2050 target is such that a high level of ambition and significant policy intervention will be required across all the emitting sectors.
- The feasibility of deploying particular solutions. This has included consideration of barriers to deployment and measures that can be taken to address these barriers, supply chain constraints, and rates of stock turnover.
- Actions to which the Government is already committed, largely occurring in the period to 2020 (e.g. standards for new car gCO_2/km).

The **Central Scenario** represents our best assessment of the technologies and behaviours required over the fifth carbon budget period to meet the 2050 target cost-effectively, while meeting the other criteria in the Act.

There is inevitable uncertainty over the rates at which technologies will become available, their future costs and the scale of behaviour change likely to occur. Our scenarios are not prescriptive: it may be possible to meet carbon budgets with lower deployment of some options, provided the increase in emissions is offset by higher deployment of others. The scenarios are also not exhaustive: it is possible that some options that are not currently included in our scenarios become more cost-effective than we currently envisage. The scenarios allow the Committee to determine whether the overall budget is deliverable within the statutory duties placed on it by the Climate Change Act and discussed in Chapter 1.

As considered earlier, there are many uncertainties over the possible emissions path over the period to 2030 and beyond. These include macro drivers (the level of future economic activity, fossil fuel prices, population), the evolution of cost and performance of options to reduce GHG emissions, consumer acceptance of these options, and the extent of behavioural change people are prepared to make. Our scenarios take a conservative approach to these uncertainties: they assume demand for energy services grows in line with historical experience, and that there is relatively limited scope for radical behaviour change over the near-to-medium term. This approach minimises the risks of a fifth carbon budget set at our recommended level being too tight and excessively costly or otherwise infeasible.

Our scenarios explicitly recognise uncertainty in two ways:

- In addition to the Central Scenario, we develop Barriers and Max scenarios in each sector. The **Barriers Scenario** represents unfavourable conditions for key measures (technological barriers, failure to achieve cost reductions, or market barriers). The **Max Scenario** represents maximum feasible deployment of key measures. This demonstrates that there is flexibility in how a given carbon budget could be met with varying degrees of effort across sectors.
- We also develop one or more **Alternative** scenarios in each sector, representing deployment of different measures to those in Barriers, Central and Max. For example, one of the Alternative scenarios in the Buildings sector involves greater levels of district heating and lower take-up of heat pumps than the Central scenario; one of the Alternative scenarios in the transport sector involves widespread take up of hydrogen technologies, rather than battery electric vehicles. This demonstrates some robustness within sectors to uncertainty over the types of abatement options that will ultimately prove to be better-performing and cost-effective.

Box 3.7: A target-consistent value of carbon and market expectations for carbon prices

Target-consistent carbon value

- The Government's carbon values for policy appraisal are designed to be consistent with action required under the Climate Change Act. They reflect estimates in the literature and modelled scenarios and have been peer reviewed by an expert panel. The modelling work includes a top-down global sectoral model for the world energy system under low, central and high projections for global technology costs, fossil fuel prices and global energy demand. The model is used to calculate carbon costs consistent with international action to limit the average increase in global surface temperatures to 2°C above pre-industrial levels.
- In a central case the carbon values reach £78/tCO_2e in 2030, growing steadily to £220/t in 2050. Low and high values are 50% below and above the central level. We have previously concluded that these values are in line with estimates in the wider literature for the costs of limiting warming to 2°C, where these do not rely on over-optimistic assumptions for the availability of sustainable bioenergy.
- The UK's 2050 target is aligned to this level of effort globally, and is likely to require actions at the margin that have a similar carbon cost[1].
- The annual rate of increase in the Government carbon values is around 5%. Using this trajectory for carbon values as a guide to low-carbon investment would therefore support a steady increase in effort over time.

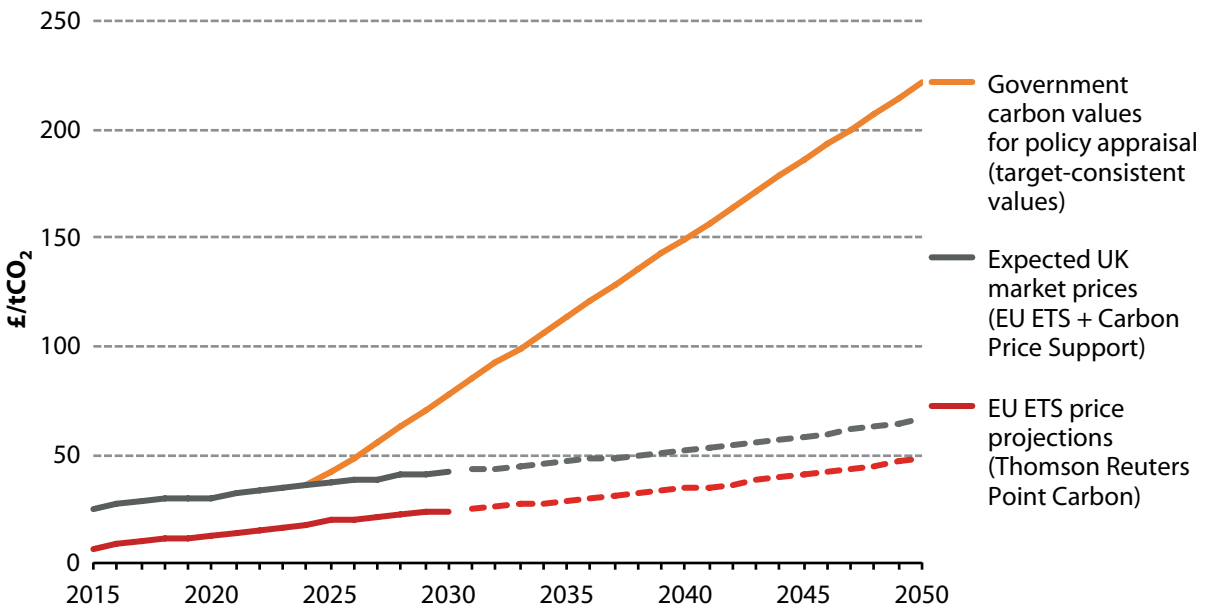
We use the target-consistent carbon value to assess whether low-carbon investments represent good value. Figure B3.7 shows the trajectory of carbon values we consider out to 2050.

Expected market carbon price

- The actual carbon price in the market is expected to be lower than the target-consistent carbon values above. Independent forecasters project a carbon price in the EU Emissions Trading System of £24/tCO_2e in 2030. Although this will be topped up in the UK, with the Government's carbon values as the formal target trajectory, the additional UK carbon price support has been frozen at £18/t. That implies a total market price of £42/t in 2030.
- If the world were to agree action to reduce emissions consistent with a 2°C target and deliver this through an efficient carbon market, then in theory market carbon prices would rise to a level in line with the target-consistent carbon values.

Box 3.7: A target-consistent value of carbon and market expectations for carbon prices

Figure B3.7: Target-consistent carbon values and market prices (2015-2050)



Source: DECC (2009) *Carbon Valuation in UK Policy Appraisal*; DECC (2014) *Updated short-term traded carbon values used for UK policy appraisal*; PointCarbon Thomson Reuters (2015); projected beyond 2030 at 3.5% p.a.
Notes: Expected market prices projected in 2020s and beyond assuming CPS frozen at £18/tCO_2.

Source: DECC (2009) *Carbon Valuation in UK Policy Appraisal: A Revised Approach*; DECC (2014) *Updated short term carbon values for UK policy appraisal*; CCC (2012) *The 2050 target*; Thomson Reuters Point Carbon (June 2015) and Aurora Energy Research (2015) each project a price of £24/tonne in 2030.
Notes: 1) For example, a carbon price at this level was needed to construct scenarios that could meet the 2050 target in CCC (2012) *The 2050 target*.

(ii) Sectoral scenario composition

The sectoral scenarios are discussed in detail in the accompanying Technical Report. They comprise the set of measures that it appears sensible to plan now to deploy, given our current understanding of decarbonisation options in each sector.

To stay on track to the 2050 target, markets for low-carbon heating systems and ultra-low emission vehicles must develop significantly in the 2020s. The Central Scenario requires continuing efficiency improvement across the economy, but also an extension of the shift to low-carbon fuel sources beyond the power sector. Similar emissions reductions could be achieved using a different low-carbon technology mix, as demonstrated by our Alternative scenarios. In summary:

- In **Power**, the carbon intensity of generation decreases from around 450 gCO_2/kWh in 2014 to 200-250 g/kWh in 2020, and to below 100 g/kWh in 2030. This reduction could be delivered by a range of different mixes of low-carbon generation (i.e. renewables, nuclear and CCS), reaching a total share of around 75% of generation by 2030. It is important that the low-carbon portfolio includes roll-out in the 2020s of offshore wind and CCS given their long-term importance and the role of UK deployment in driving down costs (see our supporting report on Power Sector Scenarios). Improvements to energy efficiency (e.g. increased use of LED lighting and more efficient appliances) will support progress in the power sector. The demand side also has an important role in increasing the flexibility of the power system, alongside interconnection, storage and flexible back-up capacity.

- In **Industry**, there is improved energy management and process control, use of more energy efficient plant and equipment, waste heat recovery, use of bioenergy in space and process heat, and development of a carbon capture and storage (CCS) cluster allowing use of CCS in the iron and steel and chemicals sectors. Hydrogen could provide an alternative to CCS depending how technologies develop. The Alternative scenario involves the use of hydrogen instead of CCS.
- In **Buildings**, deployment of low-carbon heat increases so that heat pumps and heat networks from low-carbon sources provide heat for around 13% of homes and over half of business demand; insulation increases (including a further around 1.5 million solid walls and 2 million cavity walls in the 2020s), and there is more use of heating controls and efficient lights and appliances. Alternatively, low-carbon heat could be provided via hydrogen added to the gas grid or using hybrid heat pumps, which include a gas boiler to top-up heat supply on the coldest days. The Alternative scenarios involve either (i) conversion of a proportion of the gas grid to hydrogen use, with use of hydrogen boilers to generate heat in residential, commercial and public buildings; (ii) hybrid heat pumps[23] in place of a mix of conventional heat pumps or gas boilers in residential buildings; or (iii) greater deployment of heat networks, in place of a proportion of heat pumps in residential, public and commercial buildings.
- In **Transport**, efficiency of conventional vehicles continues to improve in the 2020s (e.g. conventional car emissions fall from 125 gCO_2/km in 2014 to 102g/km in 2020 then 86g/km in 2030), on a test-cycle basis; we allow for 'real world' emissions in our scenarios alongside deployment of electric vehicles across cars, vans and smaller HGVs (e.g. the combination of plug-in hybrids and battery electric vehicles reach 9% of new car and van sales in 2020 and around 60% in 2030). We include hydrogen buses (reaching 25% of sales in 2030), with the possibility of a bigger contribution from hydrogen for other vehicles types. On the demand side we assume some behavioural change results in modest reductions in total distance travelled and more fuel-efficient travel. The Alternative scenarios involve either (i) hydrogen transport technologies achieving widespread deployment across all vehicle types; (ii) use of LNG to fuel HGVs with only modest emissions savings; or (iii) a greater role for demand reduction compensating for barriers to electric vehicle deployment.
- In **Agriculture**, there is increased take-up of crops and soils measures that mainly target the reduction of N_2O through improved fertiliser use efficiency (e.g. use of cover crops and improved manure management practices); livestock measures targeting diets, health, and breeding that reduce methane; waste and manure management, including anaerobic digestion and improvements in the fuel efficiency of stationary machinery.
- In **Waste and F-gases**, five main biodegradable waste streams are fully diverted away from landfill across the UK by 2025, and F-gases are replaced by low-carbon alternatives in refrigeration, air conditioning and other uses by 2030.

The impact of the Central Scenario on abatement by sector and residual emissions is set out in Figure 3.6. Sectors covered by the EU Emissions Trading System (the 'traded' sector - power and energy-intensive industry) are shown in Figure 3.7. Those sectors outside the EU ETS (the 'non-traded' sector - transport, heating in buildings, agriculture) are shown in Figure 3.8.

As noted above, we have also developed Barriers and Max scenarios as one way to help understand whether recommendations properly incorporate future uncertainty. It is likely that some areas will prove more difficult than suggested in the Central Scenario (e.g. costs may not fall as quickly as anticipated) and other areas will prove easier (e.g. new innovation will make it easier to achieve the

23 Hybrid heat pumps are heating systems that use a combination of a heat pump and a gas boiler; the heat pump generally provides the heat required, but supplemented by the gas boiler at peak times (i.e. on the coldest winter days).

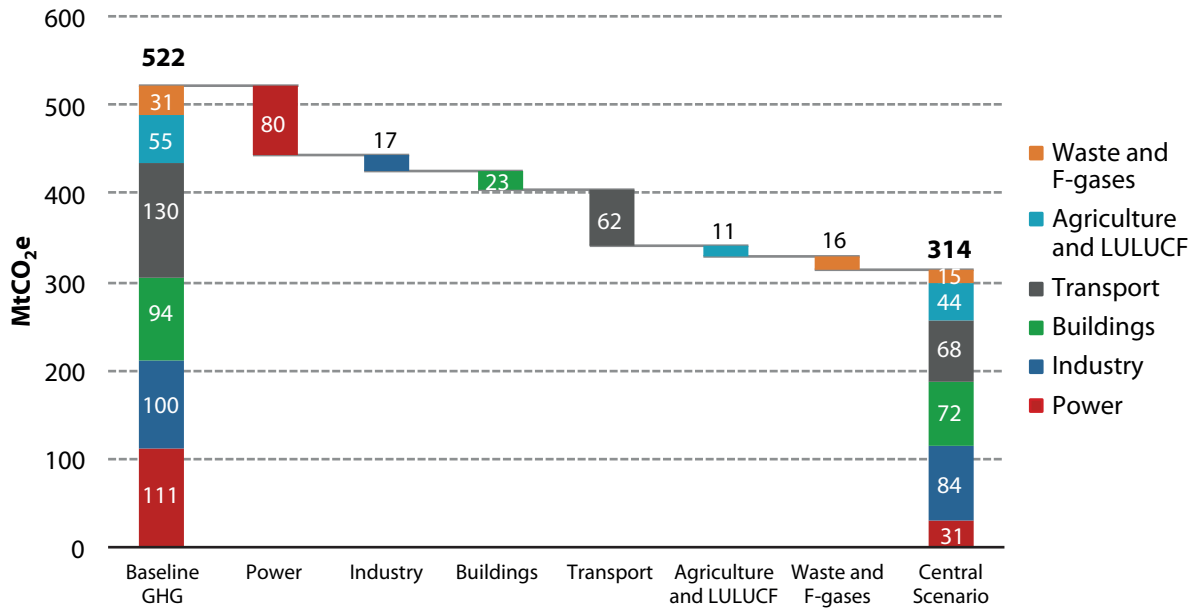
maximum potential). The types of additional barriers or new measures considered in these scenarios are summarised in Table 3.1. Details for each sector are set out in the Technical Report.

Table 3.1: Composition of Barriers and Max sectoral scenario

Sector	Barriers Scenario	Max Scenario
Power	Further delays or failure to roll out nuclear or CCS	Greater deployment of low-carbon generation as costs fall more quickly than anticipated
Industry	Lower uptake of energy efficiency and failure to deploy CCS	Greater electrification in industry and wider adoption of CCS
Buildings	Lower levels of deployment of heat pumps and fewer energy efficiency measures	Greater deployment of low-carbon heat and energy efficiency options
Transport	Reduced uptake of low emissions vehicles	Greater change in travel behaviour, and better alignment of real-world emissions with test cycle
Agriculture	Slow introduction of measures to manage soils and crops, failure to reduce emissions from vehicles	Greater uptake of alternative diets for animals, new crops and more efficient vehicles
Waste and F-gases	More limited diversion of biodegradable waste streams from landfill with less of UK participating in such programmes	No further abatement beyond the Central Scenario due to limited evidence

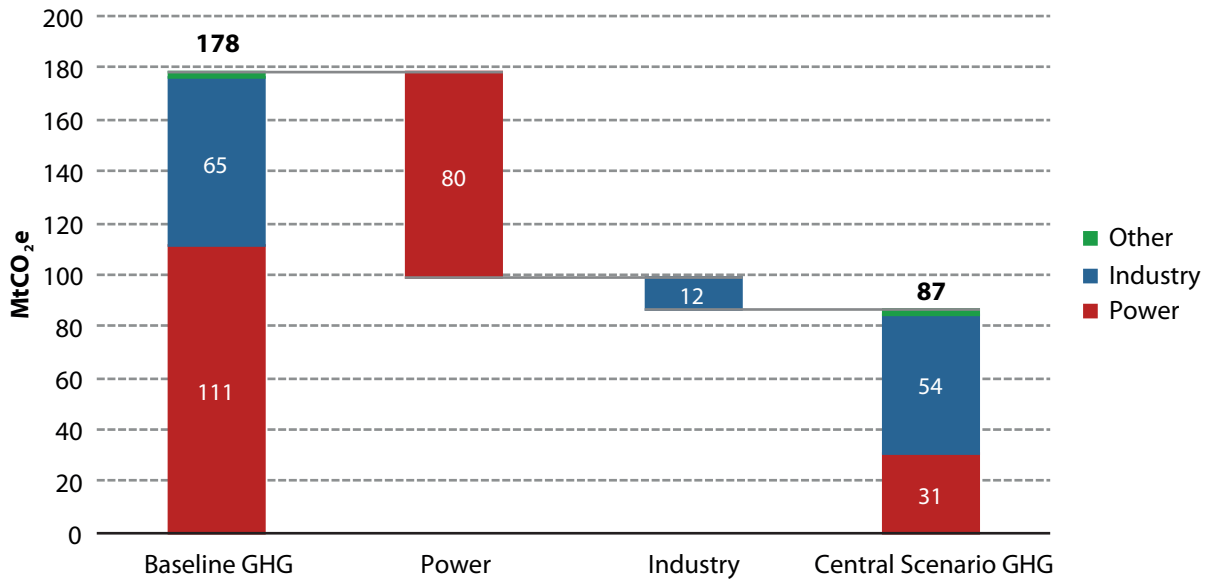
Source: CCC analysis.

Figure 3.6: Abatement in the Central Scenario (total emissions, 2030)



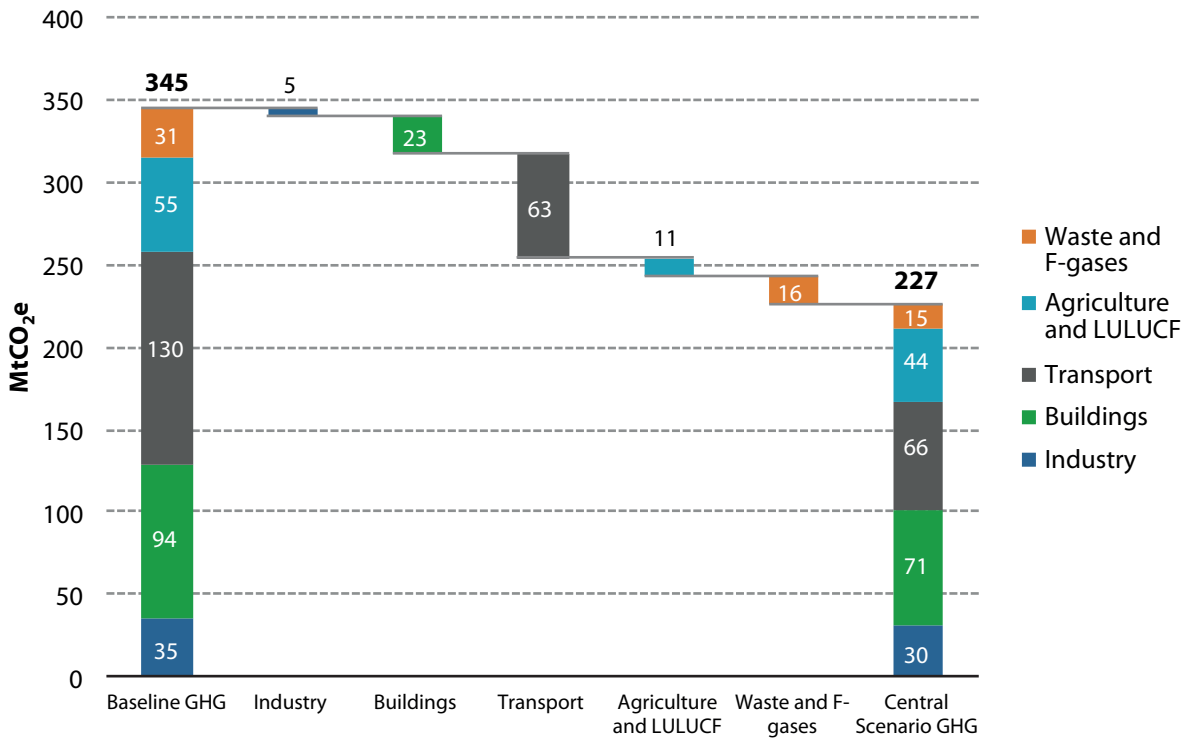
Source: CCC analysis.
Note: The Baseline is a projection of GHG emissions in the absence of absence of further effort to reduce them. Baseline GHG emissions are drawn from Government models and our own modelling at the sector level.

Figure 3.7: Abatement in the Central Scenario (traded sector, 2030)



Source: CCC analysis.
Note: The Baseline is a projection of GHG emissions in the absence of absence of further effort to reduce them. Baseline GHG emissions are drawn from Government models and our own modelling at the sector level. Other includes traded emissions in buildings and transport sectors.

Figure 3.8: Abatement in the Central Scenario (non-traded sector, 2030)



Source: CCC analysis.
Note: The Baseline is a projection of GHG emissions in the absence of absence of further effort to reduce them. Baseline GHG emissions are drawn from Government models and our own modelling at the sector level.

(iii) Economy-wide scenarios

Our central estimate of the emissions path under the Central Scenario implies territorial UK emissions decreasing to 314 $MtCO_2e$ in 2030 (Figure 3.9). This is 61% below 1990 levels, and compares to 61% and 63% reductions in our central 2030 scenarios for the Fourth Carbon Budget, as set out in our original advice in 2010 and our Review in 2013.

The estimated emissions path is subject to considerable uncertainty around macro drivers and their impact on GHG emissions (Box 3.8).

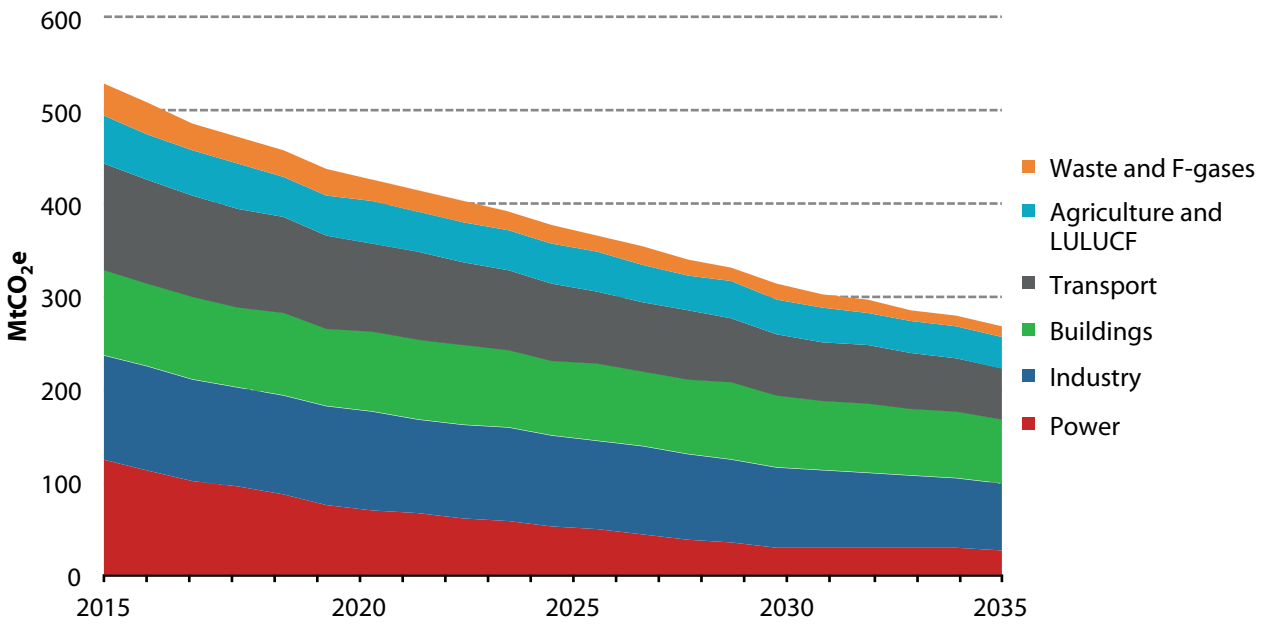
In addition, barriers to deployment of some measures might increase GHG emissions above the Central Scenario emissions path. Should macro drivers or barriers to deployment push emissions upwards, greater levels of emissions reductions consistent with the Max scenarios could compensate for any increase (Figure 3.10).

A combination of all the Max or all the Barriers scenarios would imply total GHG emissions in 2030 of 274 $MtCO_2e$ or 359 $MtCO_2e$ (Figure 3.11), equivalent to 56% or 66% below 1990 levels, respectively.

Under the Central scenario emissions decrease on average around 13 $MtCO_2e$ (3%) per annum between 2014 to 2030, and a further 9 Mt per annum to meet the 2050 target (Figure 3.12). For the non-traded sector (i.e. outside the EU ETS), emissions decrease on average around 6 $MtCO_2e$ (2%) per annum between 2014 and 2030.

We set out the implications of these scenarios for the various criteria in the Climate Change Act in the next chapter and the role of the devolved administrations in Chapter 5.

Figure 3.9: Central Scenario emissions (2015-2035)



Source: CCC analysis.

Box 3.8: Emissions projections and sources of uncertainties identified by Cambridge Econometrics

Emissions projections are inherently uncertain. In addition to the deliverability of measures, and the success of policy instruments to implement those measures, additional uncertainties include: variation in macro drivers of energy demand (population, income, energy prices); the impacts of macro drivers on fuel consumption and GHG emissions; and changes to patterns of energy use that may already be underway but are difficult to identify in the historical data.

We commissioned Cambridge Econometrics (CE) to quantify additional uncertainties in emissions projections[24]. The project identified a range of uncertainties and assessed their potential impact on the emissions path:

- CE developed an alternative emissions projection to DECC's baseline projection (i.e. assuming no policy to reduce GHG emissions) using econometric modelling. For the sectors covered, CE's projection was 4% lower than DECC's in 2035 (though it was higher for some sectors, and significantly lower for others). This variation highlights the impact that different model specification can have on emissions projections. This finding is consistent with the impact of changes to the specification of the DECC model over time: across projections published between 2010 and 2014, DECC's central projection for 2020 has varied by an average of 2%, and by as much as 3% in a single year, due to differences in model specification.
- CE carried out a literature review to identify possible emerging trends in energy consumption that are difficult to identify in a longer period of historical data, and future changes to energy consumption that may be expected to occur, and assessed the likelihood that these current trends or future changes might reasonably be expected to impact the future emissions path. The review identified a range of possible changes to energy demand in the residential sector (the composition of the future housing stock, the use and purchase of appliances, stabilisation of desired room temperatures and demographic factors), industry (the structural composition of industry), and road transport (saturation of road transport demand and improved logistics in the freight sector). CE estimate that the uncertainty range for the impact of these factors is a -13.5% to +4.5% variation in GHG emissions in 2035.
- A comparison of the most recent eight publications of the Digest of UK Energy Statistics (DUKES) identified the scale of revisions to outturn fuel consumption data. Because there is a relationship between current and historical consumption and expected future consumption, any revision to outturn fuel consumption would affect the expected level of future consumption. CE found that data revisions can be significant for coal and bioenergy and waste, but are likely to be small for gas and petroleum. This finding is consistent with the variation in DECC's emissions projections published between 2010 and 2014: due to changes to the UK emissions inventory, DECC's central projection for 2020 has varied by up to 1% in a single year.
- Fuel consumption is affected by a range of factors outside the scope of a forecasting model. CE estimate that the 95% confidence interval for the impact of these factors is a ±6% variation in GHG emissions in 2035; however, the 95% confidence interval for a variation over a 5-year carbon budget period would be expected to be smaller than this.

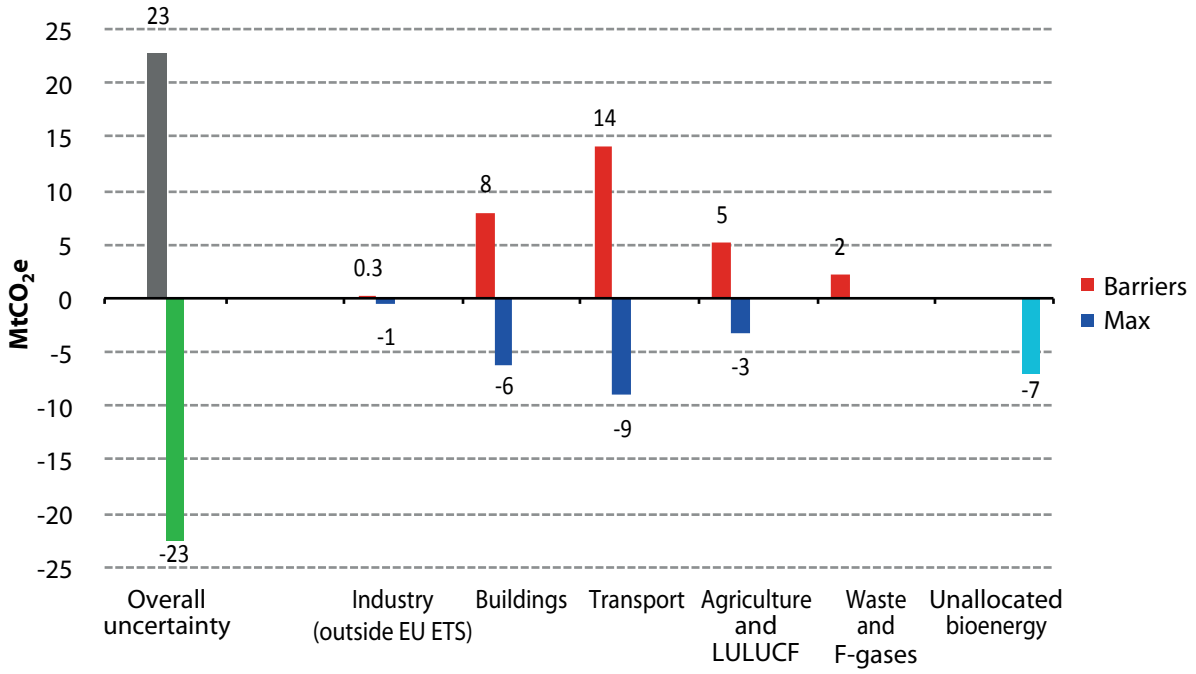
24 Cambridge Econometrics (2015) *Quantifying Uncertainty in Baseline Emissions Projections*. Available on our website, www.theccc.org.uk

Box 3.8: Emissions projections and sources of uncertainties identified by Cambridge Econometrics

- Variation in macro drivers of energy demand (economic activity, energy prices, external air temperature) would be expected to affect fuel consumption and GHG emissions. CE carried out a Monte-Carlo analysis which found that the 95% confidence interval for the impact of these factors ranges from a -6% to a +7% variation in GHG emissions in 2035 (-8% to +10% in the non-traded sector). DECC estimate a slightly wider uncertainty range of -9 to +8% for the fourth carbon budget period.

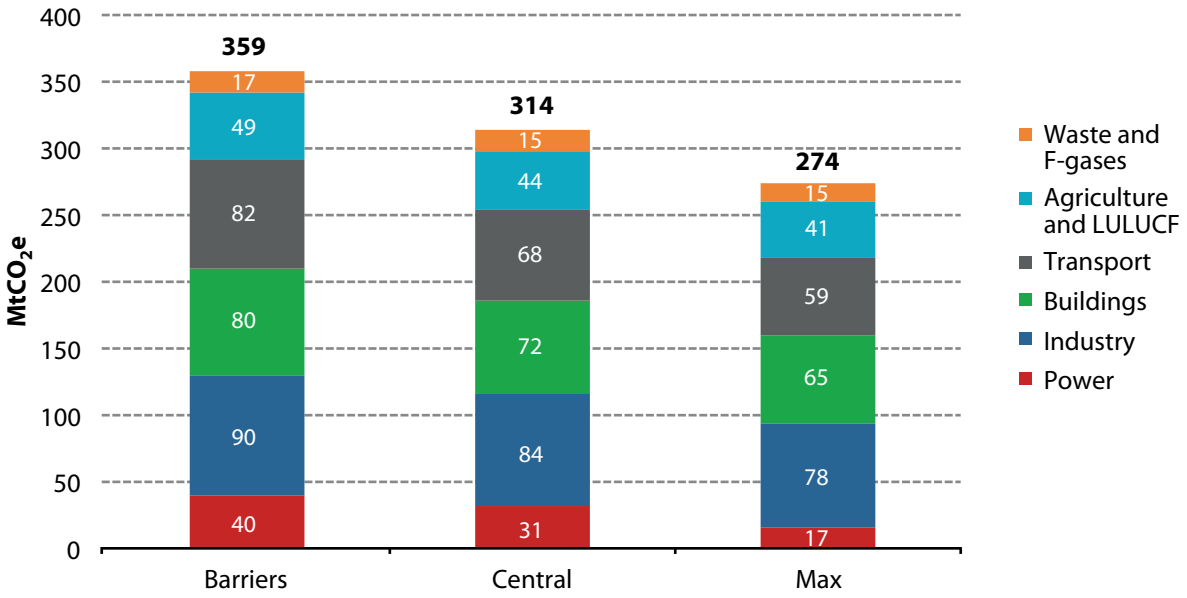
While it is not possible to provide a statistically robust uncertainty range incorporating all the above factors, for illustrative purposes in Figure 3.10 we include a range for overall uncertainty that is up to 10% higher or lower than our central estimates.

Figure 3.10: Impact of uncertainties on 2030 emissions



Source: CCC analysis.
Note: Our scenarios do not use the entire sustainable bioenergy resource estimated to be available to the UK. Further details are given in Chapter 1 of the Technical Report.

Figure 3.11: Total emissions under Barriers, Central and Max scenarios in 2030



Source: CCC analysis.

4. Further progress required from 2033 to 2050

The Central Scenario outlined in the preceding section is designed on the basis of cost-effective emissions reduction to 2032 on the way to meeting the 2050 target. It is not intended to be prescriptive, but is designed to ensure the Committee can satisfy itself that the recommended budget is achievable while meeting the various conditions set out by the Act. In that sense they provide our best assessment now of how to reduce emissions in a cost-effective way in the medium term and prepare for longer-term reductions.

Beyond the fifth carbon budget period, continued emissions reductions will be required at a similar rate across the economy (i.e. an average of around 9 $MtCO_2e$ per year) to the progress embodied in our Central scenario, but with emphasis shifting from power sector decarbonisation towards faster emissions reduction in transport and buildings.

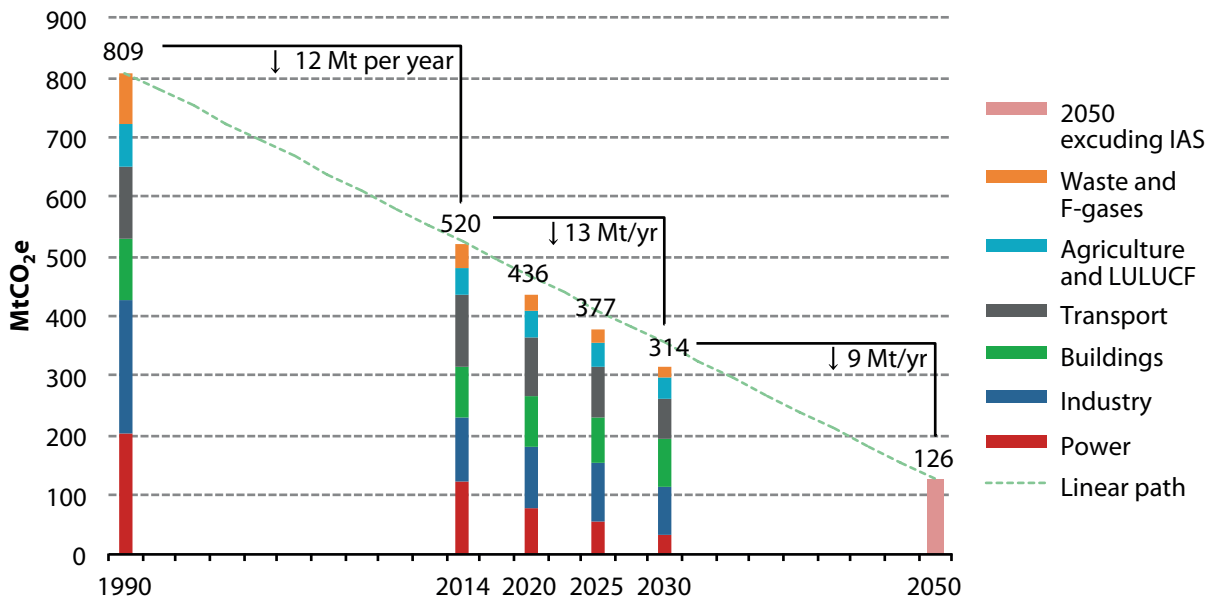
The shape of the emissions path under our scenarios is determined by the set of sector-specific paths, which reflect the different considerations in each case. Our current best assessment of the whole economy cost-effective path to 2050 works out fairly close to a linear reduction in emissions (Figure 3.12).

The Central scenario is designed to keep in play the possibility of emissions reductions in individual sectors towards the ambitious end of the contribution that may be required to meet the overall 2050 target. As set out in section 2, this is appropriate, given that is reasonable to expect that some sectors – although we do not yet know which – could fall short of the level of decarbonisation for which we are currently aiming.

The rate of emissions reduction required after 2032 in the non-traded sector (i.e. outside the EU ETS) will depend on progress in decarbonising the traded sector and limiting emissions from international aviation and shipping (IAS). While the rate of reduction in the non-traded sector embodied in our Central Scenario to 2030 may be similar to that required thereafter, it is also possible that a considerably greater rate of reduction proves necessary (Figure 3.13).

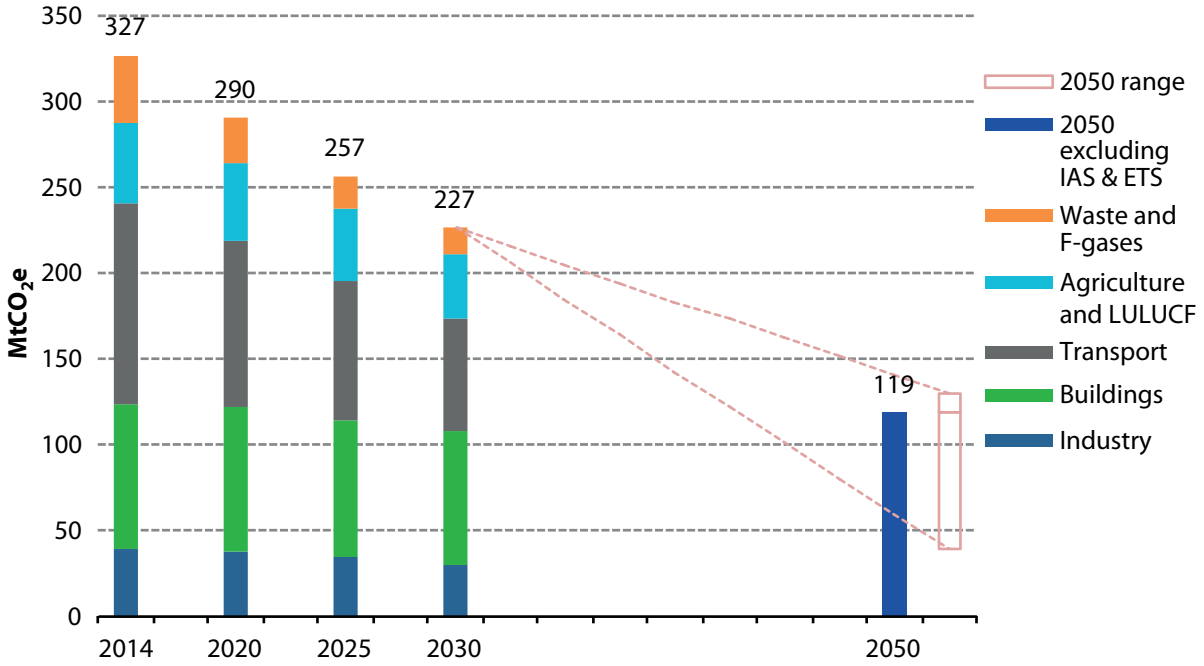
Our approach keeps in play a range of different ways of meeting the 2050 target. A lower level of deployment of measures to prepare for meeting the 2050 target would imply greater risks to, or greater costs of, meeting the 2050 target.

Figure 3.12: Emissions reductions in the Central Scenario and to 2050



Source: CCC analysis.

Figure 3.13: Range of rate of emissions reduction required 2030-50 for non-traded sector cost-effective path compared to 2014-2030



Source: CCC analysis.
Notes: Non-traded sector (NTS) emissions in 2050 based on the CCC's best estimate of their share of emissions in meeting the 2050 target allowing for emissions from international aviation and shipping (IAS) and sectors covered by the EU ETS.. The high end of the range for NTS emissions in 2050 allows for extra emissions due to lower IAS emissions (as in the Max scenarios); the low end of the range allows less emissions due to higher IAS emissions (as in the Barriers scenarios) and the absence of CCS, which lowers abatement in industry and from bioenergy.

Chapter 4: Wider economic and social considerations

1. Competitiveness
2. Fuel poverty
3. Maintaining reliable electricity supplies
4. Import dependency of UK energy supplies
5. Fiscal circumstances
6. Wider health and environmental impacts

The Climate Change Act (2008) sets out a range of considerations that the Committee must take into account when recommending carbon budgets:

- "scientific knowledge about climate change;
- technology relevant to climate change;
- economic circumstances, and in particular the likely impact of the decision on the economy and the competitiveness of particular sectors of the economy;
- fiscal circumstances, and in particular the likely impact of the decision on taxation, public spending and public borrowing;
- social circumstances, and in particular the likely impact of the decision on fuel poverty;
- energy policy, and in particular the likely impact of the decision on energy supplies and the carbon and energy intensity of the economy;
- differences in circumstances between England, Wales, Scotland and Northern Ireland;
- circumstances at European and international level;
- the estimated amount of reportable emissions from international aviation and international shipping for the budgetary period or periods in question".

Climate science and international circumstances were addressed in detail in our report on the *Scientific and International Context for the fifth carbon budget*[1], and are summarised in Chapter 2. The cost-effective path to meeting the 2050 target is considered in Chapter 3, including relevant technologies and economic costs of reducing emissions.

With the exception of the differences in national circumstances (Chapter 5) and international aviation and shipping (Chapter 6), the other considerations are addressed in this chapter.

This chapter is set out in seven sections, with conclusions on each in Box 4.1 and at the end of each section:

1. Competitiveness
2. Fuel poverty
3. Maintaining reliable electricity supplies
4. Import dependency of UK energy supplies
5. Fiscal circumstances
6. Wider health and environmental impacts

These areas encompass a very wide set of potential costs and benefits. We provide individual conclusions in each case but no attempt is made to add up all the differing impacts. That is appropriate since it is not clear that a cost in one area, such as an increase in costs to households, can be offset with a benefit in another, such as reduced dependency on international fossil fuels. Instead, the Committee considers that the Act requires it to satisfy itself in each separate area whether there is a concern and, if so, an appropriate remedy.

1 available at https://www.theccc.org.uk/publication/the-scientific-and-international-context-for-the-fifth-carbon-budget

Box 4.1: Conclusions on issues covered in Chapter 4

The conclusions on each of the issues considered in this chapter are:

- **Competitiveness** risks to energy-intensive sectors from low-carbon policies are manageable: direct impacts are low-cost and sectors at risk are eligible for free allowances under the EU ETS; there are policies in place or planned to compensate or exempt industry from indirect impacts of higher electricity prices. Impacts in the fifth carbon budget period are likely to be lower given increased international pledges and action to implement low-carbon measures. It will be important to closely monitor these after the Paris 2015 agreement, during the development of Phase IV of EU ETS and in the lead up to the fifth carbon budget period. For some sectors, action to tackle climate change may create future opportunities.
- **Fuel poverty**. The additional impact of low-carbon investment on energy bills in the fifth carbon budget period is small. If energy efficiency measures can be effectively targeted at the fuel poor then overall numbers in fuel poverty would fall even as costs from supporting low-carbon investment increase.
- **Maintaining reliable electricity supplies**. Our power sector scenarios maintain security of supply requirements and involve a significant deployment of flexibility options (e.g. demand-side response, storage and interconnection) which bring down overall costs of managing intermittency. Deployment of electric vehicles and heat pumps can provide additional sources of system flexibility, alongside flexible back-up capacity.
- **Import dependency**. Our central fifth carbon budget scenario implies a reduction in imports of oil and gas across the UK economy of over 40%, compared to a world where no action is taken on climate change. This would therefore enhance the UK's energy sovereignty by reducing demand for imported fossil fuels, and also provide a hedge against price volatility and the associated risk of damaging economic impacts.
- **Fiscal impacts**. We have considered the main fiscal impacts likely to arise as a result of our fifth carbon budget scenarios, both positive (e.g. EU ETS auction receipts) and negative (e.g. lower fuel duty receipts as vehicle fuel efficiency improves). Our conclusion is that the overall net impacts are likely to be manageable, given the time available from now to the fifth carbon budget period to make adjustments.
- **Wider health and environmental impacts**. There are wider benefits from actions to meet carbon budgets, in addition to the long-term global benefit in mitigating climate change. These benefits, such as improved air quality, health and reduced noise, accrue immediately and directly to individuals, communities and habitats. Accounting for them strengthens the case for ambitious action to reduce emissions over the next two decades. At the same time, measures can be put in place to reduce local costs from action, including allowing communities to choose which approaches meet their particular priorities. In taking forward policies and plans to meet the fifth carbon budget, the synergies, costs and benefits for both adaptation and mitigation should be considered.

1. Competitiveness

Decarbonisation raises both challenges and opportunities for the competitiveness of UK firms. Challenges can arise if low-carbon policies disadvantage specific sectors or firms, potentially harming profits and driving location of production to other countries (often referred to as 'carbon leakage'). We considered these issues in depth in our 2013 report on *Managing competitiveness risks of low-carbon policies*[2] and found that competitiveness risks of carbon budgets are limited and manageable. We also found that the transition to a low-carbon economy can create opportunities for energy-intensive businesses, for example in investing in new markets and resource efficiency measures, and innovation in new technologies and processes across a range of sectors and applications.

In this section we consider competitiveness developments since our 2013 report. We note international developments towards the climate objective (see Chapter 2), update our assessment of competitiveness risks to the UK and how these risks can be mitigated through abatement measures, and consider other opportunities for UK industry.

International developments towards the climate objective

Competitiveness risks posed by the transition to a low-carbon economy depend in part on how fast the UK moves relative to others. In our report on the *Science and International Context for the fifth carbon budget*[3] we showed that many countries and sub-national bodies have made commitments for deep emissions reduction and are now delivering against these.

Ahead of the Paris conference in December 2015, over 160 of the 196 international parties have submitted emissions pledges to the UNFCCC, covering 95% of global emissions[4]. This includes all the major emitters (China, the US, the EU and India):

- **China** has pledged to peak emissions by 2030, to reduce the carbon intensity of GDP by 65% below 2005 levels in 2030 and to increase the share of non-fossil fuels in primary energy generation to around 20% by 2030.
- **The US** has pledged to reduce its emissions by 26-28% below 2005 levels by 2025. This is achievable with existing federal laws and State actions.
- **The EU** has pledged to reduce its emissions by at least 40% below 1990 levels by 2030.
- **India** has pledged to lower its emission intensity of GDP by 33-35% below 2005 levels by 2030 and to increase the share of non-fossil fuel based power generation capacity to 40%.

As well as national pledges, cities and businesses can have a significant impact on emissions; the top 1,000 emitting companies produce one-fifth of global greenhouse gas emissions. Pledges and collaborative measures among companies have grown in recent years, including in energy-intensive sectors:

- **Chemicals:** Several large chemicals companies have pledged carbon intensity reductions ranging from 11 to 40% for 2016-2020, including BASF (Germany), LG Chem (South Korea) and Tata Chemicals (India). Mitsui Chemicals (Japan) has pledged to reduce CO_2 emissions by 22% over the period 2005-2016.

2 available at https://www.theccc.org.uk/publication/carbon-footprint-and-competitiveness
3 available at https://www.theccc.org.uk/publication/the-scientific-and-international-context-for-the-fifth-carbon-budget
4 Correct as of 12 November.

- **Paper and packaging:** A number of companies in this sector are taking action such as improving energy efficiency, closing inefficient capacity and increasing low-carbon energy. International Paper Company (USA) has pledged to reduce emissions by 20% by 2020; Nippon Paper Industries Co Ltd (Japan) has pledged to reduce emissions from domestic mills by 25% by 2015; and Arkhangelsk Pulp and Paper Mill (Russian Federation) has pledged to reduce operational emissions by 30% by 2020.
- **Cement:** The Cement Sustainability Initiative (CSI) has 10 core members which have developed CO_2 mitigation plans and targets and are reporting progress. Others such as Cemex (Mexico) and Ambuja (India) have pledged to reduce emissions intensity by around 25% over the period 2015-2020 through deployment of energy efficiency and renewables.

Our analysis shows that implementation of low-carbon technologies, laws, measures and pledges have progressed (see Chapter 2). To the extent that other countries and sectors are implementing low-carbon measures, competitiveness risks to the UK are reducing.

We now turn to consider the specific risks posed by our carbon budgets.

Competitiveness risks to the UK

Competitiveness risks from carbon budgets arise where UK firms face higher costs from low-carbon measures than their competitors elsewhere. 'Carbon leakage' through the relocation of businesses or new investments could potentially drive output and jobs overseas. Depending on differences in the emissions intensity of production, industrial relocation could result in higher global emissions overall.

In this section we consider risks posed by measures to reduce direct emissions and risks that arise indirectly through higher electricity prices.

(i) Measures to reduce direct emissions

Industries subject to competitiveness risks due to low-carbon policies are ones that are energy-intensive and have a high degree of international trade:

- Energy-intensive industries are defined as spending more than 10% of their Gross Value Added (GVA) on energy.
- Industries are likely to be more at risk if their products are traded extensively with other countries (particularly countries outside the EU with no or limited climate policies).

Key energy-intensive industries are paper, metals (including iron and steel), non-metallic minerals, coke manufacture and refineries, chemicals, rubber and plastics, wood and textiles.

UK energy-intensive industries are included in the EU Emissions Trading System (ETS), requiring them to surrender allowances to cover carbon emissions associated with their energy consumption. Paying for such allowances would raise the costs of energy-intensive industries relative to competitors outside the EU that do not face carbon costs.

In order to mitigate such risks, the EU has developed an approach whereby free allowances are granted to energy-intensive firms subject to international competition. During Phase III of the EU ETS (2013-20), sectors deemed at risk of carbon leakage are allocated 100% free allowances, subject to industry benchmarks (other sectors receive less on a sliding scale). In Phase IV (2021-2030) benchmarks will become more stringent and the rules should incentivise carbon efficiency by allowing sectors with most improvement to keep some of the benefit of these changes.

For Phase IV of the EU ETS the EU proposes to continue to allocate free allowances, but the rules determining at risk sectors have been tightened and should focus more on sectors at risk compared with Phase III:

- Under ETS Phase III, there is very limited differentiation among industrial sectors since sectors accounting for more than 97% of industrial ETS emissions are on the carbon leakage list.
- Sectors can currently get free allowances under the trade intensity criteria, irrespective of their carbon costs. There is evidence[5] that trade intensity on its own is not a good indicator of leakage risk.
- Our analysis suggests that some sectors have surplus allowances in Phase III, whilst other eligible firms have not received them because the amount of allowances available is less than the amount determined by the 'at risk' criteria.

While this is our best assessment of the changes to the EU ETS rules, the rules have not yet been finalised and therefore the precise impacts of these changes are as yet unknown.

Our updated assessment for this report also identifies abatement measures for industry for the fifth carbon budget period, much of which are cost-saving or low-cost from a social perspective.

- Energy efficiency measures, waste heat recovery systems, materials efficiency and low-carbon electrification of some space and process heat are cost saving.
- Measures such as bioenergy for space and process heat and CHP are low-cost.
- Other measures such as carbon capture and storage have high up-front costs but are cost-effective at projected carbon values.

Where private costs are different to social costs (e.g. for CCS), Government support will be required. But overall our fifth budget abatement measures and continued free allocation of allowances in the EU ETS suggests that measures aimed at reducing direct emissions from industry do not pose competitiveness risks to UK firms to 2030.

(ii) Measures to reduce indirect emissions

Competitiveness risks arise not just through the costs associated with fossil fuel combustion within industry, but also indirectly through measures to decarbonise the power sector which add to electricity prices.

A comparison of current prices shows that the UK has one of the lowest gas prices, but one of the highest electricity prices internationally (Box 4.2).

Box 4.2: Industrial energy prices in the UK and key trading partners

Comparing UK industrial electricity and gas prices in 2014 against other countries shows that the UK had a relatively low industrial gas price, but a relatively high electricity price:

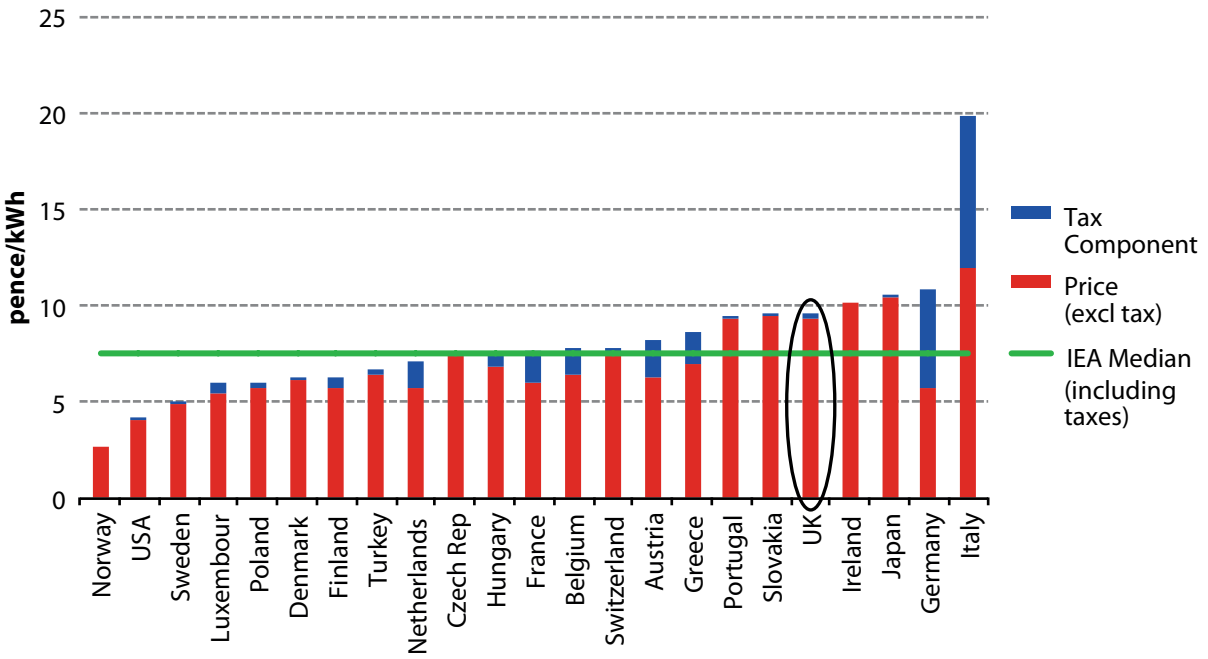
- The UK industrial electricity price is one of the highest internationally. The UK has a higher than average electricity pre-tax price, but a relatively low level of tax on electricity consumption (Figure B4.2a).
- The UK industrial gas price is one of the lowest internationally. This again partly reflects a relatively low level of tax levied on energy consumption (Figure B4.2b).

The International Energy Agency (IEA), which collects these statistics, does not provide a breakdown of taxes or polices encompassed within the pre-tax price (such as support for low-carbon investment).

5 Martin el al. (2012) Industry compensation under re-location risk: a firm-level analysis of the EU ETS.

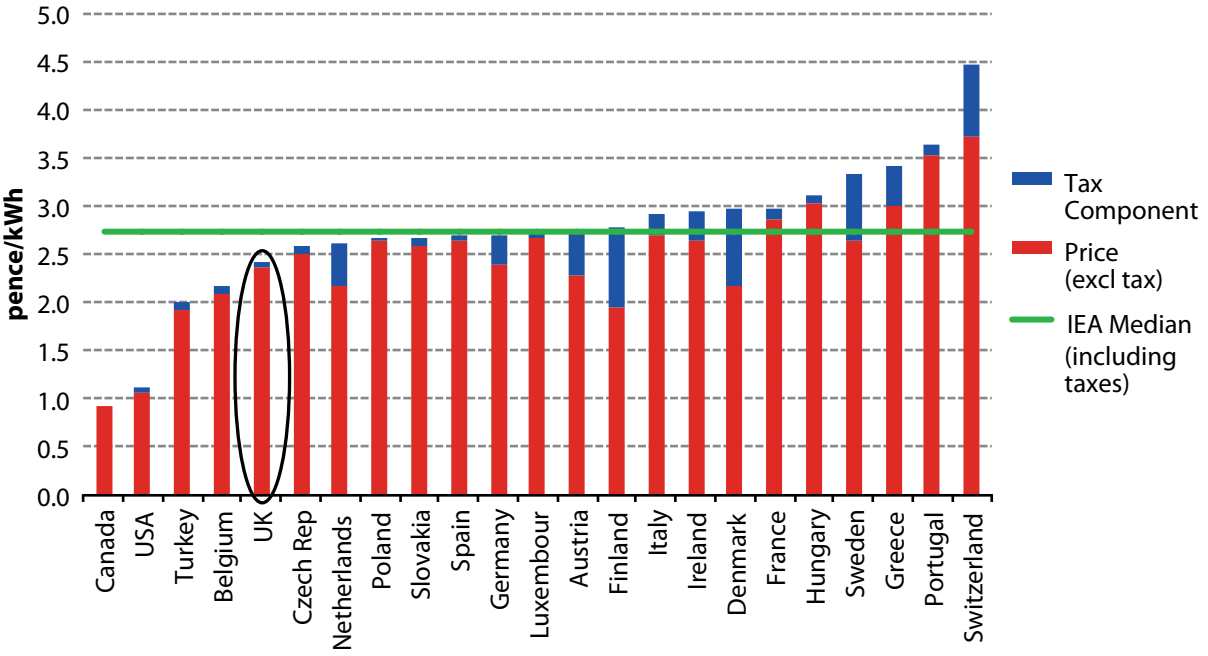
Box 4.2: Industrial energy prices in the UK and key trading partners

Figure B4.2a: International industrial electricity prices across the IEA, with and without taxes (2014)



Source: DECC, International industrial energy prices. Available at: https://www.gov.uk/government/statistical-data-sets/international-industrial-energy-prices.
Notes: Prices converted to pounds sterling using annual average exchange rates. Prices include all taxes where not refundable on purchase. Prices excluding taxes have been estimated using a weighted average of general sales taxes and fuel taxes levied by individual states.

Figure B4.2b: International industrial gas prices across the IEA, with and without taxes (2014)



Source: DECC, International industrial energy prices. Available at: https://www.gov.uk/government/statistical-data-sets/international-industrial-energy-prices.
Notes: Prices converted to pounds sterling using annual average exchange rates. Prices include all taxes where not refundable on purchase. Prices excluding taxes have been estimated using a weighted average of general sales taxes and fuel taxes levied by individual states.

Competitiveness risks for electro-intensive industries over the fifth carbon budget period depend on the path of electricity prices in the UK relative to key trading partners.

In our 2013 report[6], we estimated that higher electricity prices due to legislated carbon budgets could reduce profits of electro-intensive firms by £150-400m in 2020, or by £600m in the extreme case that none of the additional costs can be passed through to higher product prices. The package of compensation announced by government to address these risks is expected to be around £500 million a year from 2016-17, which is towards the top of this range.

The full compensation and exemption package covers:

- Compensation for the indirect costs of the EU ETS and Carbon Price Support (CPS) to 2019-20.
- Exemption of energy intensive industry from Contracts for Difference for low-carbon electricity.
- Compensation to cover the impact of renewables support, which is currently awaiting State Aid clearance by the European Commission.

These plans are in place until 2020 and may need to be extended, depending on the ambition and policy approaches adopted internationally.

Global market conditions facing many energy intensive sectors are challenging as the world continues to recover from the economic downturn. There have recently been site closures, including in the UK steel industry, although this can be attributed to global market conditions rather than UK low-carbon policy (Box 4.3).

Box 4.3: UK steel industry developments and closure of Redcar

In October 2015, the administrators for Redcar steelworks confirmed that the coke ovens and blast furnace would be closed. Following this, there have been announcements of another steel firm, Caparo, going into administration and 'mothballing' of other steel plants in the UK.

Changes in the global market for steel are key contributing factors:

- The **price of steel** has halved over the last year according to UK Steel. The global economy is still recovering from the economic downturn, and the demand for steel worldwide has not returned to pre-financial crash levels. This low demand has meant a relative over-supply of steel globally causing the fall in the price of steel.
- The **strengthening of the pound** by 15% over the last two years has made UK steel more expensive in international markets.
- **Electricity prices** are relatively high in the UK and have increased in recent years. Most of this rise in electricity cost has been due to the increasing wholesale cost of energy rather than government policies to support low-carbon investment. The steel sector is compensated for the carbon price impact on electricity costs and has an exemption from the Climate Change Levy, meaning that uncompensated climate change policies only constitute up to 2% of total costs. This is a lower order of magnitude compared with the global steel price and sterling appreciation.

The current problems in the steel market are global in nature. The UK steel sector has been impacted alongside others, with announcements of plant closure and reduced production across the world including other parts of the EU, US, Korea, South Africa and China.

Source: Exchange rate data can be found at http://www.bankofengland.co.uk/.

6 CCC (2013) *Managing competitiveness risks of low-carbon policies.* Available at: https://www.theccc.org.uk/publication/carbon-footprint-and-competitiveness/

Other opportunities for UK industry

The transition to a low-carbon economy provides economic opportunities for companies and countries which lead the way in developing new technologies, manufacturing new devices and providing supporting services to prosper. Whether UK based companies will gain will depend on a range of factors, including the degree to which they have a comparative advantage, the domestic policy environment and the extent to which early adoption of climate measures in the UK supports development of industry.

In our 2013 report, we highlighted that the UK has a comparative advantage in some key low-carbon technologies including parts of the chemicals and cement sectors, as well as aerospace, electronics and parts of heavy engineering and construction.

Some energy-intensive industries have already developed new low-carbon technologies and processes which make them well placed to compete in new markets on the path to a low-carbon world (e.g. low-temperature detergents, low-resistance tyres and lightweight materials in aircraft and cars).

The UK automotive manufacturing sector has an opportunity to become a world leader in the development and production of ultra-low emissions vehicles (ULEVs) as demand increases both domestically and globally.

- There has been at least £18 billion in low-carbon investment in the UK automotive manufacturing sector between 2003 and 2013[7].
- The Nissan Leaf became the first UK-manufactured ULEV in March 2013 and made up around 30% of all UK PHEV and BEV sales in 2014[8]. Jaguar Land Rover revealed three ULEV demonstration vehicles in September 2015, suggesting that other UK manufacturers could soon begin production of ULEVs[9].

UK industry figures have cited advantages in UK research and development capability and the longstanding, stable policy environment provided by EU legislation and the Climate Change Act as reasons for sustained investment in ULEV development[10].

Success will require innovation in new technologies and use of materials, growth of a skilled workforce, supported by a consistent government policy framework that will help build these supply chains.

Summary: Competitiveness risks to energy-intensive sectors from low-carbon policies are manageable: direct impacts are low-cost and sectors at risk are eligible for free allowances under the EU ETS; there are policies in place or planned to compensate or exempt industry from indirect impacts of higher electricity prices. Impacts in the fifth carbon budget period are likely to be lower given increased international pledges and action to implement low-carbon measures. It will be important to closely monitor these after the Paris 2015 agreement, during the development of Phase IV of EU ETS and in the lead up to the fifth carbon budget period. For some sectors, action to tackle climate change may create future opportunities.

7 LowCVP (2014) *Investing in the low carbon journey.* Available at http://www.lowcvp.org.uk/assets/reports/Investing%20in%20the%20low%20carbon%20journey%20-%20FULL%20REPORT.pdf

8 Society of Motor Manufacturers & Traders (SMMT) http://www.smmt.co.uk

9 http://newsroom.jaguarlandrover.com/en-in/jlr-corp/news/2015/09/jlr_low_and_zero_emissions_powertrain_090915/?&locus=2

10 LowCVP (2014) *Investing in the low carbon journey.*

2. Fuel poverty

Fuel poverty in the UK is a long-standing issue. The number of households in fuel poverty[11] was already high before carbon budgets were legislated. The number of fuel-poor households has risen from 3.3 million in 2007 to 4.5 million in 2013 (the latest data available), primarily due to energy price rises unrelated to carbon budgets[12].

Levels of fuel poverty are particularly high in the devolved administrations (Table 4.1) and some specific areas (e.g. 72% of homes are estimated to be in fuel poverty in the Western Isles of Scotland). These higher levels of fuel poverty are due to a combination of lower incomes, inefficient housing and a greater proportion of households not on the gas grid (and therefore facing higher energy prices).

Table 4.1: Fuel poverty levels and targets across the UK

	Proportion of households in fuel poverty	**Target**
England	12% (2013)	Fuel poor should live in homes of EPC rating C or better by 2030 (statutory, Fuel Poverty (England) Regulations 2014)
Scotland	39% (2013)	Eradicate fuel poverty, as far as is reasonably practicable, by November 2016 (statutory, Housing (Scotland) Act 2001)
Wales	30% (2012)	Eradicate fuel poverty by 2018 (statutory, Warm Homes and Energy Conservation Act 2000)
Northern Ireland	42% (2011)	Eradicate fuel poverty by 2016 (non-statutory, 2004 Fuel Poverty Strategy)

Source: DECC (2015) *Annual Fuel Poverty Statistics Report*, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/468011/Fuel_Poverty_Report_2015.pdf
Notes: This table uses the '10% definition' – i.e. a household is considered to be in fuel poverty if it needs to spend more than 10% of their income on fuel to maintain an adequate standard of warmth. This definition is still used in Scotland, Wales and Northern Ireland. England now uses the 'Low Income, High Cost' definition. Under this, a household is considered to be fuel poor if (a) they have required fuel costs that are above average (the national median level) and (b) were they to spend that amount, they would be left with a residual income below the official poverty line. Under this definition, 10.4% of households in England in 2013 are estimated to have been in fuel poverty.

Fuel poverty is a devolved policy issue. England and the devolved administrations have set ambitious targets for the reduction of fuel poverty (Table 4.1), which are statutory except in the case of Northern Ireland. Scotland has also recently announced that improving the energy efficiency of Scotland's homes and non-domestic building stock will be designated a National Infrastructure Priority. The aim is for all buildings to achieve a good energy efficiency rating over the next 15-20 years, both to achieve carbon reductions and to address fuel poverty.

It is too early to assess progress against the English target, which was legislated in December 2014. However, achievement of the devolved targets now looks unlikely. Given the continuing challenge faced by the UK's governments in dealing with fuel poverty, it is important to consider the potential impact of carbon budgets.

11 Based on the '10%' definition – see Table 4.1.

12 CCC (2014) Energy prices and bills – impacts of meeting carbon budgets. Available at https://www.theccc.org.uk/publication/energy-prices-and-bills-impacts-of-meeting-carbon-budgets-2014

Fuel poverty and energy efficiency

Fuel poverty is caused by a combination of low household income and high energy costs. Energy-inefficient housing is a key driver. The UK Government's fuel poverty statistics[13] show how the depth and likelihood of being fuel poor are associated with lower energy efficiency ratings:

- In England in 2013,[14] almost 50% of fuel poor households were in the least energy efficient properties (i.e. SAP ratings E, F or G) compared with 22% of the non-fuel poor.
- 31% of households living in the least efficient G-rated properties were in fuel poverty, with an average fuel poverty gap of £1,274.[15]
- The incidence of fuel poverty is lowest in households living in dwellings with insulated cavity walls (6%), and highest in dwellings with solid walls (16%), followed by homes with uninsulated cavity walls (11%).

Energy efficiency improvement has therefore been a major focus of government policy responses to fuel poverty. The new English fuel poverty target is specifically focused on improving energy ratings, and the devolved administrations have implemented additional energy programmes to combat fuel poverty.

Fuel poverty and carbon budgets

The energy efficiency measures included in our carbon budget scenarios will help to alleviate fuel poverty. Our central scenario (Chapter 3) includes insulation of an additional 1.5-2 million solid walls and around 3 million cavity walls between now and 2030. This will reduce energy consumption and bills. Low-carbon heat measures can also play a role in reducing fuel poverty, especially for the relatively high proportion of fuel-poor households that do not have gas heating (around 500,000 in England).

At the same time, our carbon budget scenarios also include measures that result in higher energy costs, in particular through power sector decarbonisation. Currently, the additional policy costs for low-carbon electricity over fossil-fuels are generally passed through to consumer energy bills. In contrast, costs for low-carbon heat via the Renewable Heat Incentive have, to date, been funded by public spending. We assume that this continues and that the costs of low-carbon heat in our scenarios are not passed through to bills, affecting fuel poverty, but instead have a fiscal impact (see section 5).

We published an in-depth assessment of the impacts of carbon budgets on energy prices and bills in December 2014[16]. For this advice, we have updated our assessment of policy costs, in line with our new power sector scenarios[17] and updated evidence on technology costs. Our estimates of policy costs in the 2020s are now lower than in December 2014, reflecting lower levels of deployment of low-carbon power generation assumed in the 2020s, as well as lower assumed costs for key technologies (e.g. offshore wind and solar).

- In 2014, a typical household paid around £45 through their annual electricity bill of around £470 (total energy bills are around £1,200) to support investment in low-carbon generation.
- In 2020, this support will increase to around £105. Those costs are already committed through investments that are underway and contracts that have been awarded.

13 DECC (2015) *Annual Fuel Poverty Statistics Report*. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/429873/Fuel_Poverty_Annual_Report_2015.pdf

14 Low Income, High Costs definition.

15 The fuel poverty gap represents the difference between the required annual fuel costs for each household and the median required fuel costs.

16 CCC (2014) *Energy prices and bills – impacts of meeting carbon budgets*. Available at https://www.theccc.org.uk/publication/energy-prices-and-bills-impacts-of-meeting-carbon-budgets-2014

17 CCC (2015) *Power sector scenarios for the fifth carbon budget*. Available at https://www.theccc.org.uk/publication/power-sector-scenarios-for-the-fifth-carbon-budget/

- In our scenarios, this support will increase to around £115 per household in 2025 and £120 in 2030, and fall thereafter.[18,19] The additional impact of this fifth carbon budget is about £15 on a typical household bill.
- Energy efficiency improvements funded through household bills added around £50 to annual energy bills (spread across both gas and electricity bills) in 2013, reduced under Government plans to around £35 in 2014. An increase back to the level in 2013 would be enough to fund future energy efficiency measures in our scenarios.

Taking together impacts on gas and electricity bills, full implementation of energy efficiency opportunities would offset most of the additional costs of supporting low-carbon investment when averaged across all households. However, for individual households the potential for savings will differ. For fuel-poor households specifically, effective design and targeting of energy efficiency policies is vital.

Modelling carried out for the Committee in 2014 using the National Household Model[20] suggested that there is scope for fuel poverty to fall under carbon budgets if measures are well targeted:

- If all fuel-poor households received a targeted share of the energy efficiency (e.g. insulation) and low-carbon heat measures included in our carbon budget scenarios, UK fuel poverty levels could be reduced to 3.3 million by 2030.
- For energy efficiency measures, this would require funding of around £1.4bn per year, a level which was achieved under the Energy Company Obligation until its scope was reduced in 2014.

Due to most of the low-carbon costs falling on electricity bills, households relying on electric heating will pay a higher proportion of their energy bill towards low-carbon policy costs than dual-fuel households. As there is already a higher incidence of fuel poverty amongst electrically heated households, this could further increase fuel poverty and will require a specific policy response.

Successful targeting of measures would greatly improve the achievement of both fuel poverty and carbon targets at least cost.

Meeting Government fuel poverty targets is likely to require additional funding. The marginal impact of measures for the fifth carbon budget is small, but the Committee will continue to monitor and assess impacts and advise on the appropriate response.

Scotland has recently announced that improving the energy efficiency of Scotland's homes and non-domestic building stock will be designated a National Infrastructure Priority. The aim is for all buildings to achieve a good energy efficiency rating over the next 15-20 years, both to achieve carbon reductions and to address fuel poverty. The area has seen numerous policy changes over recent years, so a long-term commitment to addressing fuel poverty and energy efficiency is an important step forward.

For England, the legislation of the new energy efficiency-based fuel poverty target also signals a long-term commitment. As set out in our previous advice on the fuel poverty strategy consultation, achieving the Government's target will require further funding.

Summary: The additional impact of low-carbon investment on energy bills in the fifth carbon budget period is small. If energy efficiency measures can be effectively targeted at the fuel poor then overall numbers in fuel poverty would fall even as costs from supporting low-carbon investment increase.

18 We have projected the carbon price facing UK power generation to be £42/tCO_2 (2014 prices), based on a projected EU ETS price of £24/tCO_2 and the carbon price support held constant at £18/tCO_2.

19 Exemptions proposed for industrial consumers at risk of competitiveness impacts would increase the costs to household consumers. We estimate this would add around an extra £5 to the annual bill for a typical household.

20 Centre for Sustainable Energy (2014) *Research on fuel poverty – The implications of meeting the fourth carbon budget*. Available at https://www.theccc.org.uk/wp-content/uploads/2014/11/CCC_FinalReportOnFuelPoverty_Nov20141.pdf

3. Maintaining reliable electricity supplies

The transition to a low-carbon electricity system brings new challenges in grid management, due to higher levels of intermittent and variable renewable generation (e.g. wind and solar), less flexible generation technologies such as nuclear, and higher demand from other sectors via electrification for heat and transport. These system challenges include the need for back-up firm capacity for wind and solar generation, the risk of excess generation at times of low demand, and the need for additional infrastructure to transmit power generated in more remote locations.

We published a detailed assessment of this challenge in our October report on *Power sector scenarios for the fifth carbon budget*[21]. We concluded that it is possible to manage a deeply decarbonised UK power system in 2030 with high levels of intermittent renewables (e.g. 40% of total generation) while maintaining security of supply.

Managing this transition at lowest cost while ensuring security of supply will require investment in flexible gas-fired generation capacity alongside expansion of international interconnection, flexible demand response and electricity storage:

- **Flexible unabated gas plant.** More efficient and flexible generation technologies are available that can operate stably at lower levels of output, provide faster frequency response than at current levels, and consume less fuel when part-loaded to provide system reserve. Greater use of these would require less overall thermal plant to be built to stabilise the system, be less likely to curtail renewables output, and reduce overall emissions.
- **Interconnection.** Interconnection already provides a valuable source of flexibility to the UK with 4 GW of capacity linked to Ireland, France and the Netherlands. Increased interconnection to these or other electricity markets (e.g. Norway) can improve security of supply and operating efficiency through sharing of back-up capacity as well as ancillary services, and better accommodate intermittent generation by taking advantage of the geographical diversity of renewable output and demand profiles. Studies have shown that greater levels of interconnection are generally associated with better security of supply.[22]
- **Demand-side response.** Shifting electricity demand away from 'peak' time periods, such as on a winter evening, towards periods when demand is lower, is known as Demand-Side Response (DSR). By shifting demand to off-peak periods with higher renewable output or by reducing the requirements for capacity during peak periods, DSR can help to manage large volumes of intermittent renewable generation and can significantly reduce the overall cost of a decarbonised system. New electricity demand from electric vehicles could provide further potential for DSR, as could heat pumps where they are rolled out in thermally efficient buildings or with storage. Widespread deployment and use of smart technologies (such as smart meters) will facilitate increases in demand-side response given sufficient consumer engagement.
- **Energy storage technologies.** There is currently around 3 GW of pumped hydro storage in the UK. Further deployment of bulk and distributed energy storage (e.g. battery technologies) can reduce the need for additional back-up capacity and infrastructure, by storing electricity when demand is low and discharging when demand is high.

21 CCC (2015) Power sector scenarios for the fifth carbon budget, available at https://www.theccc.org.uk/publication/power-sector-scenarios-for-the-fifth-carbon-budget

22 See for example Redpoint Energy (2013) Impacts of further electricity interconnection on Great Britain for DECC. Available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/266307/DECC_Impacts_of_further_electricity_interconnection_for_GB_Redpoint_Report_Final.pdf

There is a cost to deploying these measures and managing intermittency, which for our scenarios we estimate at around £10 per MWh of intermittent renewable output (which may be compared to current costs of onshore wind of around £80/MWh, for example). We include that cost in our assessment of the lowest cost path for emissions (Chapter 3), of fuel poverty (above) and of the total cost of meeting our proposed budget (Chapter 6).

Costs would be likely to increase at much higher shares of intermittent renewables, but we exclude these higher shares from our scenarios. For example, intermittency costs could reach around £25/MWh for solar if capacity exceeds 40 GW or around £15/MWh for wind if capacity exceeds 50 GW, each within a power system reaching 50 gCO_2/kWh.

Our power sector scenarios all meet the Government's current reliability standard[23], and take into account the new evidence on potential system impacts of individual low-carbon technologies in order to balance affordability and security of supply. For example, we constrain deployment of wind and solar to no more than 50 GW and 40 GW respectively in our 2030 power sector scenarios, and our Central scenario reaches an emissions intensity closer to 100 gCO_2/kWh than 50 g/kWh.

Summary: Our power sector scenarios maintain security of supply requirements and involve a significant deployment of flexibility options (e.g. demand-side response, storage and interconnection) which bring down overall costs of managing intermittency. Deployment of electric vehicles and heat pumps can provide additional sources of system flexibility, alongside flexible back-up capacity.

4. Import dependency of UK energy supplies

A diverse energy mix contributes to ensuring security of supply. The more reliant the UK is on imported fuels, the more exposed the economy is to significant changes in price. Moving towards a low-carbon economy will reduce demand for fossil fuels and can therefore mitigate against these risks.

In this section we show how the UK's import dependency on oil and gas varies under our fifth carbon budget scenarios, given Government projections for UK oil and gas production[24]. We do not consider the impact on imports of coal use, which will fall substantially before the fifth carbon budget starts (in 2028) due to the announced phase-out of unabated coal-fired electricity generation:[25]

- **Natural gas.** Under our baseline scenario, where no action is taken on climate change, demand for natural gas is expected to rise out to 2030. Given that UK production is expected to decline over the same period, increasing imports would be required in order to satisfy UK demand. However, under our Central scenario demand for gas falls, meaning that the need for around 45% (425 TWh) of imported gas is avoided in 2030 (Figure 4.1).
  - DECC project UK natural gas production to decrease from 380 TWh in 2014 to 170 TWh in 2030 as North Sea supplies fall, a decline of 55%.
  - Under our Baseline projections, natural gas demand is expected to rise by 39% between 2014 and 2030 from 810 TWh to 1,130 TWh.

23 The UK's electricity system must be managed to meet the Government's reliability standard, which targets a loss-of-load expectation of no more than three hours per year. This represents the number of hours per year in which, over the long term, it is statistically expected that supply will not meet demand.

24 DECC (2015) *UKCS Oil and Gas Production Projections*. Available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/414172/Production_prjections.pdf

25 DECC (2014) Government announces plans to close coal power stations by 2025, https://www.gov.uk/government/news/government-announces-plans-to-close-coal-power-stations-by-2025

  - Under our Central scenario natural gas demand would decrease by 14% between 2014 and 2030 to 700 TWh, reflecting reduced gas consumption (primarily due to more efficient use in meeting demands for heat) as well as a contribution to the gas supply from biomethane.
  - Therefore, net imports of 530 TWh in 2030 under the Central scenario are expected to be 45% lower than baseline net imports of 955 TWh.

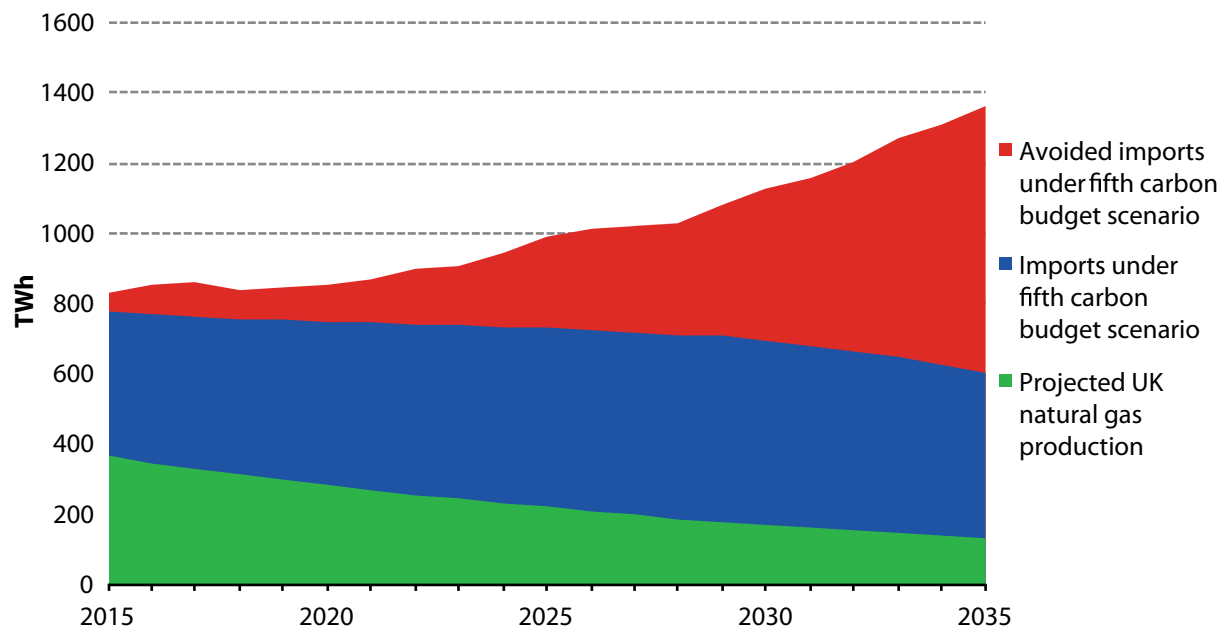
- **Oil.** Under our baseline scenario, where no action is taken on climate change, demand for liquid hydrocarbon fuels is expected to rise out to 2030. Given that UK domestic crude oil production is expected to decline over the same period, this means increasing imports would be required in order to satisfy UK demand. However, under our Central scenario demand for petroleum products falls, meaning that the need for 40% (270 TWh) of imports is avoided in 2030 (Figure 4.2).
  - UK petroleum product production is projected to decrease from 505 TWh in 2014 to 225 TWh in 2030, a decline of 56%.
  - Under our Baseline projections, petroleum product demand is expected to rise by 2% between 2014 and 2030 from 890 TWh to 905 TWh.
  - Under our Central scenario demand for petroleum products would decrease by 29% between 2014 and 2030, to 635 TWh, primarily reflecting progress in decarbonisation of surface transport.
  - Therefore, net imports of 410 TWh in 2030 under the Central scenario are expected to be 40% lower than baseline net imports of 680 TWh.

This analysis presents the UK's import dependency under the Central scenario for gas and oil demand, on the basis of Government projections of production within the UK. If assumed production were to be higher (e.g. due to a significant contribution from UK shale gas production), this would lead to a reduction in imports that is additional to those from decarbonisation.

Overall, the implication of our fifth carbon budget scenarios is that net oil and gas imports would be more than 40% lower compared to a world where no action is taken on climate change. This would reduce the proportion of UK oil and gas demand met by imports from 81% to 70% in 2030.

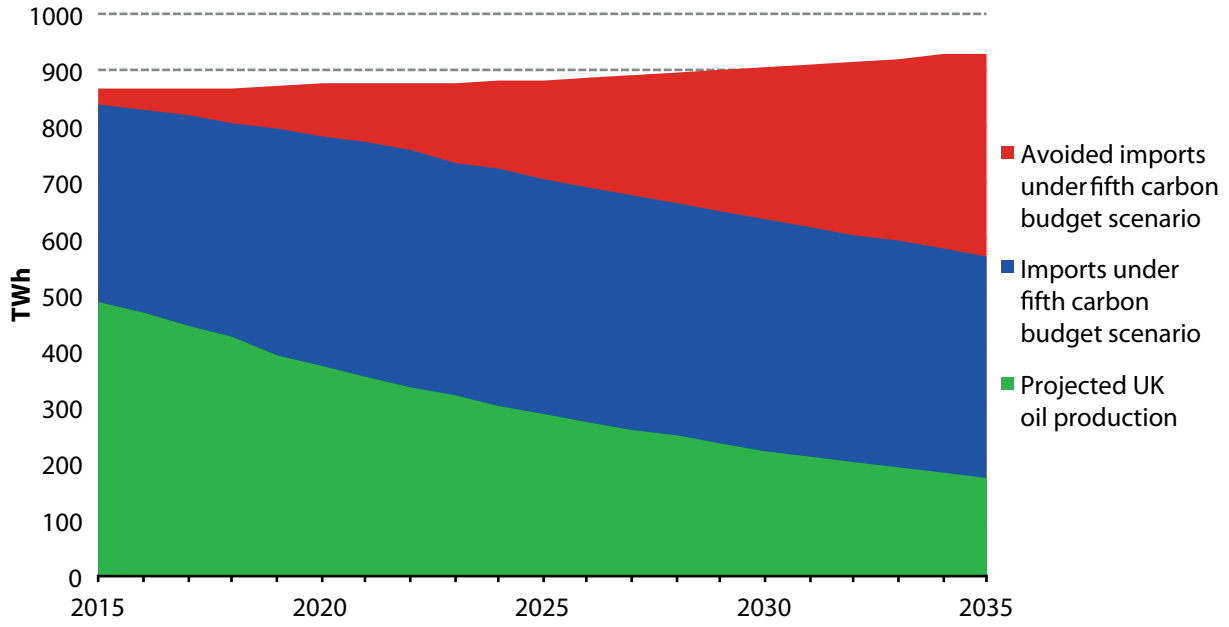
Summary: Our central fifth carbon budget scenario implies a reduction in imports of oil and gas across the UK economy of over 40%, compared to a world where no action is taken on climate change. This would therefore enhance the UK's energy sovereignty by reducing demand for imported fossil fuels, and also provide a hedge against price volatility and the associated risk of damaging economic impacts. Were it to turn out that fossil fuel prices remained low this would increase costs to the UK from its action – a cost we account for when presenting costs of meeting the fifth carbon budget (Chapter 6).

Figure 4.1: UK consumption and imports of natural gas under the CCC central scenario



Source: UK natural gas production from DECC (2015) *UKCS Oil and Gas Production Projections*, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/414172/Production_prjections.pdf.
Notes: Avoided gas consumption based on the difference between consumption under the fifth carbon budget scenario and DECC's baseline scenario. Fifth carbon budget scenario has lower consumption due to lower demand for gas and production of biomethane.

Figure 4.2: UK consumption and imports of oil and petroleum products under the CCC central scenario



Source: UK oil production from DECC (2015) *UKCS Oil and Gas Production Projections*, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/414172/Production_prjections.pdf.
Notes: Avoided petroleum product consumption based on the difference between petrol and diesel consumption under the fifth carbon budget scenario and DECC's baseline scenario.

5. Fiscal circumstances

In our previous advice on the fourth carbon budget we considered the most significant fiscal impacts, both positive and negative, likely to arise as a direct result of the policies used to pursue carbon budgets through the 2020s.

We concluded that fiscal impacts from meeting the fourth carbon budget are likely to be small and manageable relative to total revenues.

We have reconsidered these factors in light of developments since our previous advice and based on our new scenarios. We conclude that fiscal impacts are likely to remain manageable overall for the fifth carbon budget period, particularly given scope for fiscal rebalancing to maintain revenues in the period to 2030:

- **Revenues from EU ETS auctioning and carbon price floor.** UK revenues from auctioning of EU ETS allowances and the carbon price floor could decline slightly through the 2020s in real terms, from around £2.9 billion in 2020 to £2.6 billion in 2030 in a central price scenario. This reflects falling carbon price floor revenues which more than offset rising EU ETS auctioning receipts. Total revenues over the fifth carbon budget period could be around £13 billion, within a range of £8-18 billion.
  - **EU ETS auctioning.** EU countries have agreed the EU ETS cap will fall 27% between 2020 and 2030. Independent projections suggest allowance prices could double over the same period[26]. The combination of these means UK auctioning revenues are projected to rise through the 2020s, from £1.2 billion in 2020 to £1.8 billion in 2030. For indicative purposes, if there was a range of 50% around the carbon price then revenues could be £0.9-2.7 billion in 2030. Overall, total revenues over the fifth carbon budget period could therefore be £9 billion, within a range of £5-14 billion[27].
  - **Carbon price floor.** This is currently frozen at £18/tCO_2. We assume it remains at this level through the 2020s in real terms. Our central power sector scenario has emissions falling 55% between 2020 and 2030 (Chapter 3). The combination of these suggests carbon price floor revenues would fall, from around £1.6 billion in 2020 to £0.7 billion in 2030. Total revenues over the fifth carbon budget period would be around £4 billion in total. If the Government were to stick to its 'target trajectory' for the carbon price floor (reaching £78/tonne in 2030), revenues would be higher at around £2 billion in 2030.
- **Transport revenues.** Current fuel duty and vehicle excise duty (VED) receipts are around £27 billion and £6 billion respectively. With an unchanged fiscal regime, revenues from transport are likely to fall substantially in the future. However, changes to the duty bands and rates, or other measures, could be used to preserve revenues in line with the current taxation burden for drivers.
  - Fuel efficiency of vehicles will improve under a current policy baseline (e.g. the test-cycle CO_2 intensity of new cars will improve from 125 gCO_2/km in 2014 to 95 gCO_2/km in 2020, in line with the EU new car CO_2 target).
  - Our scenarios for meeting the fifth carbon budget would lead to a further incremental reduction in revenues, as conventional vehicles improve faster than the current policy baseline and electric vehicles come into the fleet. For example, under our central scenario in 2030 average new car test-cycle CO_2 intensity falls to around 50 gCO_2/km, with zero-emission vehicles representing around 8% of the fleet.

26 Rising to around £25/tCO_2 in 2030. Market price projection from Point Carbon Thomson Reuters (June 2015).

27 Our analysis assumes a neutral effect of the Market Stability Reserve. See Chapter 2, Box 2.2.

  - Under our current policy baseline scenario, fuel duty revenues in 2030 could fall by up to around £4 billion below current levels. The incremental impact of our fifth carbon budget scenarios could be a further £7 billion reduction below the current policy scenario.
  - The VED system was reformed in 2015 so that from 2017 only the first year charge is differentiated by CO_2 band. For the second year onwards vehicles pay the same rate[28], except zero-emission vehicles which are exempt. These changes limit the impact of improving fuel efficiency on VED receipts. Under a current policy baseline we estimate VED revenue could fall by around £1 billion by 2030 relative to current levels. The incremental impact of our fifth carbon budget scenarios could be a further reduction of around £0.5 billion. However, future VED impacts could be offset by adjusting banding as vehicle efficiency changes over time.

- **Low-carbon heat.** The low-carbon heat measures in our scenarios have relatively low resource costs of £1.1 billion in 2030, as they focus on the more cost-effective opportunities (e.g. in properties off the gas grid and new-build). Given that the current funding approach under the Renewable Heat Incentive is to fund measures from public spending rather than energy bills, we include this as a fiscal impact.
- **The Levy Control Framework.** Costs associated with supporting low-carbon generation in the power sector are capped under the Levy Control Framework (LCF), which is set to increase to £8 billion in 2020 based on existing and committed projects. Our power sector scenarios imply £9 billion of funding by 2025, which would then fall by the time of the fifth carbon budget. While the overall annual cap is set by the Government, the LCF is funded through energy bills (e.g. surcharges) rather than through public spending. We therefore consider the impact of the LCF in our assessment of fuel poverty above and in greater detail in Chapter 4 of our Power Sector Scenarios report[29].
- **Other impacts.** There is also a set of measures that will have smaller impacts on the fiscal balance, both positive (e.g. the Carbon Reduction Commitment) and negative (e.g. remaining support for plug-in vehicles). We do not assess these in detail, given their smaller size and/or uncertainty about policy design in the 2020s. As mentioned above, government has committed £500m for compensation of the indirect impacts of low-carbon policy to energy-intensive industries to 2020. This is likely to reduce to 2030 given increased action to implement low-carbon measures in other countries.

Overall, net fiscal impacts under our fifth carbon budget scenarios are likely to be manageable, particularly with scope for rebalancing in the period to 2030. There is time between 2016 and 2028 to make suitable adjustments to the fiscal framework. Changes to current duty rates and bands could be used to preserve tax revenue from road transport – whilst this would increase the rate of tax on each litre of fuel it would not increase the annual or per mile cost to drivers, given higher fuel efficiency of vehicles.

Summary: We have considered the main fiscal impacts likely to arise as a result of our fifth carbon budget scenarios, both positive (e.g. EU ETS auction receipts) and negative (e.g. lower fuel duty receipts as vehicle fuel efficiency improves). Our conclusion is that the overall net impacts are likely to be manageable, given the time available from now to the fifth carbon budget period to make adjustments.

28 other than a supplement for the most expensive cars

29 CCC (2015) *Power sector scenarios for the fifth carbon budget*. Available at https://www.theccc.org.uk/publication/power-sector-scenarios-for-the-fifth-carbon-budget

6. Wider health and environmental impacts

UK action to reduce greenhouse gas emissions is one part of wider global action to tackle climate change. International action will lead to less severe climate impacts on human health and the environment around the world, and less need for adaptation[30]. The value of this is captured implicitly in setting emissions targets and putting a consistent price on carbon emissions.

The UK must adapt to the impacts of inevitable future climate change. There are, however, limits to how much adaptation is technically and economically feasible, so this cannot be a substitute for mitigation (i.e. reducing emissions).

Changes included in our scenarios in Chapter 3 to reduce UK emissions can be implemented alongside adaptation to a changing climate. In taking forward policies and plans to meet the fifth carbon budget, the synergies, costs and benefits for both adaptation and mitigation should be considered:

- Buildings can be made more thermally efficient and more resilient to extreme weather conditions, such as heatwaves and flooding.
- Low-carbon infrastructure can be designed from the outset to be more resilient to extreme weather.
- Adopting more sustainable land management practices, particularly in the case of peatland habitats, will safeguard agricultural productivity and other benefits provided by the natural environment, as well as protecting important carbon stores.

There will be more local and immediate health and environmental impacts from the various changes assumed in our carbon budget scenarios. While the Climate Change Act does not specify these explicitly as factors to consider in setting carbon budgets, they are part of the broad requirement to consider economic and social circumstances.

For our 2013 review of the fourth carbon budget we commissioned a survey of the estimated impacts to 2030 on health and the environment[31]. It found significant benefits and some costs from low-carbon measures:

- **Improved air quality** results from a range of measures that reduce burning of fossil fuels. As well as harming the environment, air pollution currently reduces average life expectancy by at least six months, according to government estimates. Reducing vehicle emissions will be essential to meet air quality requirements in many UK cities. A switch away from unabated coal-fired power generation also provides considerable co-benefits. There are trade-offs between reducing GHG emissions and air quality in burning biomass, especially as a replacement for gas in heating, and coal with carbon capture and storage (CCS) for electricity. Overall, however, our scenarios show a substantial air quality benefit.
- **Reduced noise** is an additional benefit arising from measures such as improved glazing, electric vehicles and reduced traffic. As well as being a nuisance, noise can lead to more serious health issues through stress and impaired sleep and concentration.
- **More active lifestyles** result from greater levels of cycling and walking, significantly improving human health and wellbeing while also reducing emissions from vehicle transport.
- **Reduced congestion**, as a result of avoided travel by cars and HGVs, could offer a further economic benefit in the form of less wasted time for transport users.

30 CCC (2015) *The scientific and international context for the fifth carbon budget*

31 Ricardo-AEA (2013) Review of the impacts of carbon budget measures on human health and the environment; ApSimon and Oxley (2013) *Analysis of the air quality impacts of potential CCC scenarios*. Both available at https://www.theccc.org.uk/publication/fourth-carbon-budget-review

- **Potential costs** include increases in road accidents from more walking and cycling (although this is more than offset by reductions from less traffic in our scenario), the landscape effects of new installations (especially renewables) and hazardous waste and accident risk from increased nuclear power.

Overall, for the impacts that could be quantified, the review showed substantial net benefits from following our low-carbon scenario. They were estimated to total around 0.1-0.6% of GDP in 2030 when monetised using recommended government methods (the range largely reflecting uncertainty in the monetary value of years lost through ill-health, and the extent to which the time saved by reduced congestion should be included).

Further work reinforces this conclusion and shows that the benefits may be even greater:

- In 2015 the Lancet Commission on Health and Climate Change published its review of impacts of, and responses to, climate change. It found that tackling climate change could be the greatest global health opportunity this century. For the UK in particular, it notes the health benefits of decarbonising the power sector, using cleaner vehicles and more active travel, and from well-ventilated, more efficient buildings[32].
- Since our review new evidence suggests a stronger link between air pollution and impacts on health. Government has revised its damage costs upwards, particularly for oxides of nitrogen, in light of this new evidence[33]. Hence the air-quality benefits of a low-carbon path are likely to be greater than we estimated in 2013.

Where there are possible costs of low-carbon measures to other health or environmental goals, many of the impacts, such as potential road accidents from walking and cycling, or impacts of new power sources on the landscape and habitats, can be reduced through appropriate design and operation.

Summary: There are wider benefits from actions to meet carbon budgets, in addition to the long-term global benefit in mitigating climate change. These benefits, such as improved air quality, health and reduced noise, accrue immediately and directly to individuals, communities and habitats. Accounting for them strengthens the case for ambitious action to reduce emissions over the next two decades. At the same time, measures can be put in place to reduce local costs from action, including allowing communities to choose which approaches meet their particular priorities. In taking forward policies and plans to meet the fifth carbon budget, the synergies, costs and benefits for both adaptation and mitigation should be considered.

32 Watts et al. (2015) *Health and climate change: policy responses to protect public health, The Lancet Commissions*

33 https://www.gov.uk/guidance/air-quality-economic-analysis

Chapter 5: Differences in national circumstances

1. Current and projected emissions
2. Abatement opportunities and challenges through the 2020s
3. Central scenario for emissions in the devolved administrations
4. Wider considerations
5. Summary

The devolved administrations have an important role to play in achieving the UK's carbon budgets. Scotland, Wales and Northern Ireland accounted for 22% of UK emissions in 2013, whilst accounting for 16% of the UK's population and 13% of GDP.

They have (fully or partially) devolved powers (Box 5.1) in a number of areas relevant to emissions reduction. These vary by nation, and are increasingly important as powers are further devolved. Key areas of devolved responsibilities include transport demand-side measures, energy efficiency, agriculture, land use and waste. The devolved administrations also have an important role in implementing UK policy (such as renewable energy deployment) through the provision of additional incentives and their approach in areas such as planning policy[1].

As part of their contribution to the UK's long-term emission reduction goal, the governments of the devolved administrations have adopted different emission reduction policies, as well as different strategies for monitoring their progress towards emissions targets. Scotland has passed its own Climate Change Act and has legislated annual targets, while in Wales and Northern Ireland targets have been set by the devolved governments. In Wales, the Environment Bill (2015) provides for the setting of reduction targets and carbon budgets.

This chapter explains how differences in national circumstances and devolved policies affect the recommended level for the fifth carbon budget. Our approach to assessing differences in national circumstances through the 2020s involves three steps:

1. Derive a baseline emissions projection to 2030 for each of the devolved administrations that takes into account, as far as possible, differences in current and projected trends across Scotland, Wales and Northern Ireland.
2. Present the results of analysis carried out for the 2020s on abatement opportunities across a range of sectors, highlighting where particular opportunities and challenges exist for the devolved administrations.
3. Put these together to provide an indicative Central scenario for 2030.

1 Energy policy is fully devolved to the Northern Ireland Executive.

Box 5.1: Overview of current devolved matters for key sectors

The balance of powers that are reserved (i.e. issues upon which only the UK Parliament can make laws) versus devolved varies to some extent by devolved administration:

- **Economic and fiscal**: Mostly reserved, although increased powers are being devolved to the Scottish Government (e.g. air passenger duty).
- **Energy**: In Scotland and Wales energy is mostly reserved with the exception of the Renewables Obligation in Scotland. Energy (apart from nuclear) is devolved to Northern Ireland.
- **Planning**: Mostly devolved, with the exception of nationally significant infrastructure in Wales being reserved.
- **Local government and housing**: Including domestic and public energy efficiency and fuel poverty is mostly devolved.
- **Industry**: Mostly reserved.
- **Transport**: Demand side measures are mostly devolved.
- **Agriculture and land use**: Mostly devolved.
- **Waste**: Fully devolved.

It is likely that legislation will be altered and affect what is devolved in the future. If any subsequent changes between now and 2028 affect how to achieve the fifth carbon budget we will discuss them in our annual progress reports.

1. Current and projected emissions

Current emissions

The latest greenhouse gas inventory for the devolved administrations is for 2013[2] and shows higher shares of emissions relative to population and GDP, due to high emissions from sectors such as industry and agriculture (Figure 5.1):

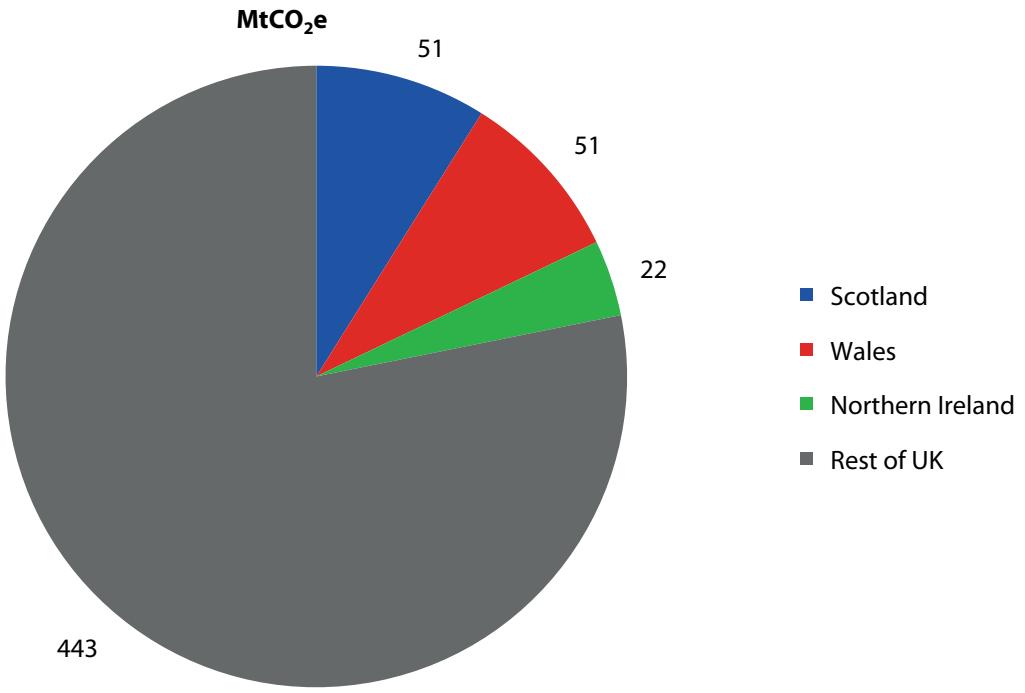
- Emissions in Scotland of 50.6 $MtCO_2e$ account for around 9% of total UK emissions, compared with an 8% share of UK population and 8% share of UK GDP.
- Emissions in Wales of 50.8 $MtCO_2e$ account for around 9% of total UK emissions, compared with a 5% share of UK population and 4% share of UK GDP. Higher emissions per person in Wales reflect the larger share of heavy industry in Wales.
- Emissions in Northern Ireland of 22.4 $MtCO_2e$ account for around 4% of total UK emissions, compared with a 3% share of UK population and 2% share of UK GDP.

The level of emissions reflects the distribution of production around the UK. Carbon budgets are set on the basis of where production – and emissions – take place. It may be that the devolved administrations have similar emissions to the UK as a whole when considered on a consumption basis (i.e. emissions embedded in the goods and services consumed in devolved administration)[3].

2 Emissions data for the devolved administrations are available almost a year after that of the UK. 2014 data for Scotland, Wales and Northern Ireland will be published in June 2016.

3 https://www.theccc.org.uk/publication/carbon-footprint-and-competitiveness/

Figure 5.1: Greenhouse gas emissions in the devolved administrations as proportion of UK total (2013)

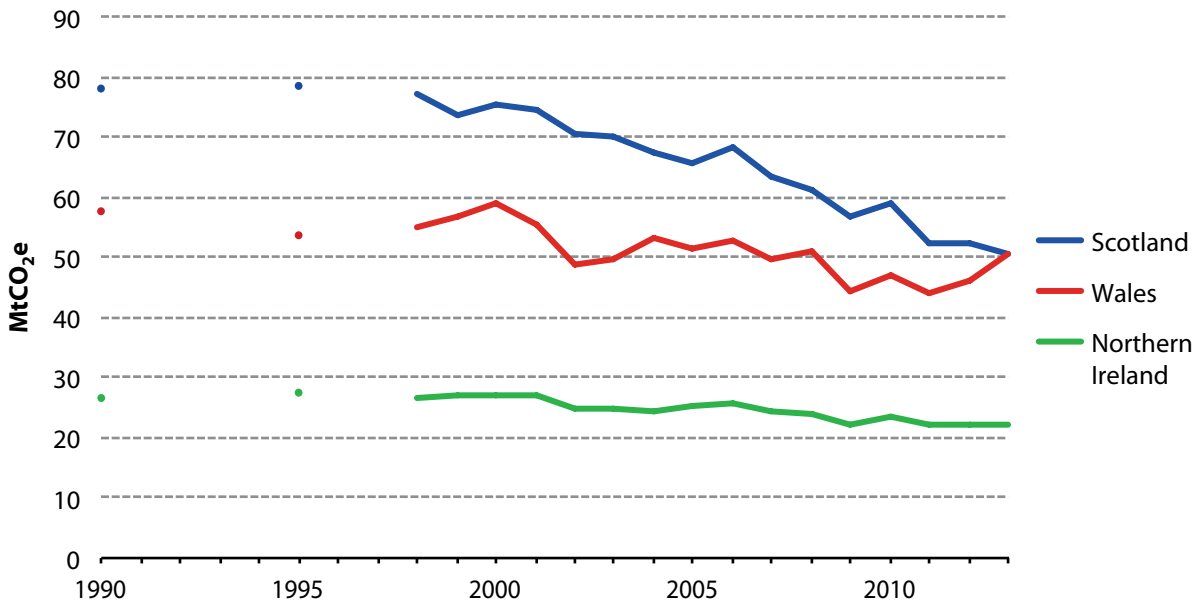


Source: National Atmospheric Emissions Inventory (2015).
Notes: Does not include international aviation and shipping emissions. Emissions presented are for 2013, as these are the most recent that have been disaggregated by devolved administration. Since their publication, the UK-wide emissions inventory has been revised, so data here are not consistent with UK-wide emissions data elsewhere in this report. It is expected that emissions estimates for 2013 will change for each devolved administration when 1990-2014 disaggregated data are published in June 2016.

Emissions trends since 1990 vary between the devolved administrations (Figure 5.2):

- Gross emissions have fallen since 1990 by 35% in Scotland, 12% in Wales and 16% in Northern Ireland.
- Emissions in 2013 in Scotland fell nearly 4% on 2012 levels, but rose 10% in Wales due to an increase in emissions from industry (primarily from Port Talbot steelworks). Emissions in Northern Ireland remained largely unchanged.
- Over the four years to 2013, emissions have fallen by an average 2% per annum in Scotland, have risen by an average 3% per annum in Wales and remained largely unchanged in Northern Ireland. This followed falls of 7%, 13% and 7% respectively between 2008 and 2009 due to the impact of the recession.

Figure 5.2: Greenhouse gas emissions in Scotland, Wales and Northern Ireland (1990-2013)



Source: NAEI (2015).
Notes: Includes CO_2 and non-CO_2 emissions from all sectors (power, buildings, industry, transport agriculture, LULUCF and waste). GHG emissions data are not available for the devolved administrations for 1991-1994, or 1996-1997. Does not include emissions from international aviation and shipping.

Baseline emission projections to 2030

Disaggregated projections to 2030 suggest that, without policy to reduce them, emissions could rise between 2013 and 2030 by 3% in Scotland and 12% in Northern Ireland, and fall 1% in Wales, compared to a 3% rise projected for England (Box 5.2). The slight fall in emissions in Wales is due to projected reductions in industrial emissions, in particular the iron and steel sector where DECC project a 20% drop in UK production by 2030. As industry emissions account for a higher proportion of Wales' total compared to elsewhere in the UK the impact of the drop in production is more pronounced.

The actual emissions to 2030 will in part depend on the actions and policies developed towards meeting devolved administration targets covering this period (Box 5.3), which include both traded and non-traded emissions:

- Scotland has missed its first four annual targets in large part due to inventory revisions. However, since 1990 gross emissions have reduced 35%, the most in the UK (UK wide emissions fell 30% in 2013), while net emissions in Scotland (including international aviation and shipping and adjusting for trading in the EU ETS) have fallen 38.4%. Scotland is therefore on track to meet its 42% reduction target by 2020. Scotland's strong performance is down to significant new entry of low-carbon electricity generation and some success improving the energy efficiency of homes.
- The Welsh Government has made good progress in some policy areas, for example implementing ambitious residential energy efficiency programmes. However, progress toward the 2020 target to reduce emissions to 34.6 $MtCO_2e$ (a 40% reduction from 1990, 32% from 2013) is currently falling short of the reductions required. Wales has a higher proportion of emissions covered by the EU ETS than the rest of the UK, meaning the 40% target is particularly sensitive to increases in traded sector emissions for which policy is not devolved. Wales' emissions are dominated by traded sector industrial emissions (34% of total emissions in 2013 from industry), mostly from Port Talbot steelworks. In 2013, gross emissions in Wales had fallen only 12% from 1990 levels due to high industrial emissions.

- Northern Ireland has greater devolved responsibilities than Scotland and Wales (e.g. its energy market is linked to that in the Republic of Ireland), but delivery of its target still partially depends on UK-level policy and future targets on the fifth carbon budget. The Northern Ireland Executive is behind their required progress to reduce emissions 35% from 1990 levels by 2025.

The delivery of future devolved administration targets will be reliant at least in part on UK-wide policies and targets and requires continued commitment to meeting UK carbon budgets.

Box 5.2: Deriving baseline emissions projections for the devolved administrations

Our methodology includes:

CO_2 emissions

Residential emissions are derived from a UK baseline from the National Household Model (NHM). Average nation-specific shares derived from emissions between 2009 and 2013 are applied to the UK projections.

Non-residential buildings and industry emissions are derived from DECC interim projections (October 2015). Average nation-specific shares derived from emissions between 2009 and 2013 are applied to the UK projections. This does not account for the potential of future variation in demand for energy or in the fuel mix (for example if the gas grid was extended in Northern Ireland) specific to the devolved administrations.

Road transport (cars, vans, HGVs, and buses) emission projections are produced from the Department for Transport (DfT) National Transport Model for Scotland and Wales, while Northern Ireland's emissions are estimated on the basis of road transport fuel consumption[4].

Emissions from land use, land use change and forestry are produced separately for each UK nation by the Centre for Ecology & Hydrology, currently projected to 2050.

Non-CO_2 emissions

Agriculture and Waste non-CO_2 emissions are derived from DECC's UK non-CO_2 forecasts. Average nation-specific shares derived from emissions between 2009 and 2013 are applied to the UK projections.

4 Rail transport and aviation and shipping are not included in the analysis as the emissions and abatement potential from the devolved administrations is relatively small.

Box 5.3: Devolved administration's emission reduction targets to 2020

Each of the devolved administrations has set their own targets for emissions reductions over the next decade:

- **Scotland**: The Climate Change (Scotland) Act 2009 sets the target of reducing emissions by 80% by 2050 compared to 1990 levels, with a target for 2020 of a 42% reduction in emissions, covering all greenhouse gas emissions (including international aviation and shipping). Additional targets include generating the equivalent of 100% of Scotland's gross annual electricity consumption through renewable sources by 2020 and for renewable sources to provide the equivalent of 11% of Scotland's heat demand. Secondary legislation in the Act sets annual targets for Scottish emissions. These have been set on an absolute basis up to 2027.
- The Scottish Parliament is due to pass legislation to set annual emission reduction targets for 2028-2032 in 2016. The fourth set of annual targets (2023-2027) are based on the Committee's advice to the Scottish Government in 2011 and originally embodied comparable ambition to the fourth carbon budget at UK level. However, since then there have been significant revisions to both historical emissions data and projections. As a result, these targets are now considerably more challenging and go beyond the ambition of the fourth carbon budget. The Scottish Government published its second report on policies and proposals in 2013 which sets out how it intends to meet these targets.
- **Wales**: has set a target to reduce all greenhouse gases by 40% by 2020 against a 1990 baseline. This goes beyond the UK-wide commitment and is compatible with a path to the level of ambition in the fourth carbon budget. Additionally, Wales has an annual target to reduce emission within devolved areas of competence by 3% per year. Wales' new Environment Bill due to be legislated in 2016 will include the provision for carbon budgets and interim targets to 2050.
- **Northern Ireland**: is aiming to reduce greenhouse gas emissions by 35% below 1990 levels by 2025 for all greenhouse gases and sectors. The Northern Ireland Executive have set out a Greenhouse Gas Action Plan in 2011 to outline how each department in the Executive will contribute towards meeting their 2025 reduction target.

Source: Scottish Government, Welsh Government, Northern Ireland Executive.

2. Abatement opportunities and challenges through the 2020s

The devolved administrations have different emission reduction opportunities and ambitions to the UK average, and from each other. While advice on UK carbon budgets needs to be consistent with these circumstances, the devolved governments also need to take into account UK commitments in deciding on their individual paths. As further powers are devolved the Governments and Executive should ensure that any new plans are also consistent with UK climate change targets.

In developing a central emission reduction scenario for the devolved administrations, we identify abatement opportunities across key emitting sectors and take these off the baseline projection.

This is a high-level assessment and we will analyse abatement opportunities in greater detail in Scotland and Wales in follow-up advice in 2016.[5]

5 Advice on the levels of the 2028-2032 Scottish annual targets will be published March 2016. Advice on carbon budgets for Wales is expected to be published in the summer of 2016.

We do not include emissions from the power sector in our baseline emissions projections. Our UK power scenarios involve reduced use of fossil-fired power stations (especially coal), but we are not able to predict the exact spatial distribution of these. Nevertheless, we briefly discuss the potential contribution to decarbonising the UK's power sector from the devolved administrations, given the significant resource potential in each area.

Buildings: Energy efficiency and low-carbon heat

There is potential in the devolved administrations for emission reductions from both energy efficiency and low-carbon heat in buildings through the 2020s:

- At the UK level, we have highlighted scope in the residential sector for ongoing insulation of solid walls through the 2020s. The opportunity exists also at the devolved level, particularly in Scotland where the proportion of households with solid walls is around 26% (compared to 23% across the UK).
- Existing building regulations are likely to make a useful contribution to emission reductions, although these will impact on only a small proportion of the total building stock in 2030.
- Energy efficiency measures in all buildings (residential and non-residential) could provide potential abatement of 1.3 $MtCO_2$, 0.6 $MtCO_2$ and 0.4 $MtCO_2$ in Scotland, Wales and Northern Ireland respectively in 2030[6].
- The devolved administrations also have high numbers of households in fuel poverty[7] (39% in Scotland, 30% in Wales and 42% in Northern Ireland compared to 12% in England), in part due to higher numbers of households not on the gas grid (50% in Scotland, 21% in Wales and 80% in Northern Ireland compared to 10% across the UK), lower incomes and inefficient housing.
- Our detailed analysis of the housing stock and of potential for low-carbon heat at the UK level (see Chapter 3 of our technical report – *Sectoral scenarios for the fifth carbon budget*)[8] also identifies opportunities at the level of the devolved administrations in residential buildings to 2030 (e.g. 0.3 $MtCO_2$, 0.4 $MtCO_2$, and 0.1 $MtCO_2$ of potential abatement in Scotland, Wales and Northern Ireland respectively). Low-carbon heat in non-residential buildings suggests further savings (e.g. 0.6 $MtCO_2$, 0.2 $MtCO_2$ and 0.1 $MtCO_2$ in Scotland, Wales and Northern Ireland respectively) in 2030.
- In particular Northern Ireland has a relatively high share of cost-effective low-carbon heat potential in the residential sector, reflecting the lack of a widespread gas grid and the high proportion of the population using oil for heating (68% compared to 4% in UK). There are plans to extend the gas grid in Northern Ireland to connect towns in the west to natural gas (approximately 4.5% of homes); however there will remain a large number of households (63%) who could potentially benefit from low-carbon heating.

There is therefore substantial scope for cost-effective emissions reductions from low-carbon heat across the devolved administrations.

Scotland and Northern Ireland both have targets and their own policies for low-carbon heat deployment. However, in our progress report in June 2015[9] we highlighted that current projects are not enough to meet the targets. Scotland relies in part on funding from the GB-wide Renewable Heat Incentive for investment in low-carbon heat; however, with uncertainty about the future of the scheme, longer-term commitment from the UK and Scottish Governments is needed to encourage further uptake.

6 These numbers have been derived from CCC's UK energy efficiency abatement potential calculations.

7 A fuel-poor household is defined here, in line with definitions in the devolved administrations, as one which needs to spend more than 10% of its income on fuel to maintain an adequate standard of warmth. In England, this is defined as 21°C in the living room and 18°C in other occupied rooms.

8 Available at https://www.theccc.org.uk/publications

9 https://www.theccc.org.uk/publication/reducing-emissions-and-preparing-for-climate-change-2015-progress-report-to-parliament/

Industry

Industry emissions in the devolved administrations are in part covered by the EU ETS, in different proportions to the UK average. The 2013 share of industry CO_2 emissions covered by the EU ETS in Scotland is around 38%, with a share of 58% in Wales and 21% in Northern Ireland, compared with 40% UK-wide.

In the 2020s, there are significant opportunities for additional abatement (traded and non-traded) (see Chapter 4 of our technical report) including:

- For low-carbon heat, there is emission reduction potential up to 0.9 $MtCO_2$, 0.4 $MtCO_2$ and 0.2 $MtCO_2$ in Scotland, Wales and Northern Ireland respectively from increased penetration of biomass and biogas in industry.
- For carbon capture and storage (CCS), there are opportunities for deployment in Scotland[10], first in power and then, utilising the CO_2 infrastructure developed for the power projects, for carbon-intensive industry. Deployment of industrial CCS in Scotland is not included in our Central scenario to 2030 (where deployment of industrial CCS is limited to England), but could be deployed by 2050. In practice, opportunities for deployment of industrial CCS will be determined by what happens with CCS power projects and the development of infrastructure clusters.

Our analysis of additional abatement options in the carbon-intensive industry sectors suggests there is potential by 2030 for:

- In Scotland an additional 0.3 $MtCO_2$ from the refining sector from waste heat and energy recovery, as well as increased energy efficiency.
- In Wales, a further 0.4 $MtCO_2$ from the refining sector and 0.3 $MtCO_2$ from the iron and steel sector. Industry in Wales accounted for 34% of total emissions in 2013, with nearly half of these from Port Talbot steelworks. The plant is not located near any planned CCS infrastructure. The abatement potential identified is from steam and power production system upgraders, reducing yield losses and from heat recovery and reuse.

There remain challenges in realising this potential for reducing emissions in the devolved administrations, particularly in Wales where industry emissions make up a large share of the total and have increased in recent years. Industry remains a reserved matter and to reduce emissions further as targets tighten through the 2020s devolved and UK governments need to work together on innovative solutions which can be implemented at a devolved level.

Transport

The main opportunities for reducing transport emissions through the 2020s are more efficient conventional vehicles, increased penetration of electric and plug-in hybrid vehicles and biofuels.

However, there are also important demand-side measures, such as the promotion of 'Smarter Choices' including use of public transport, eco-driving and developing cycling infrastructure, for which devolved administrations control the relevant policy levers.

The disaggregation of abatement potential for the devolved administrations from road transport in both reserved and devolved matters is split by distance travelled and suggests significant scope in 2030 of 5.4 $MtCO_2$, 3.4 $MtCO_2$ and 3.1 $MtCO_2$ in Scotland, Wales and Northern Ireland respectively.

10 A final investment decision will be made in early 2016 on the Peterhead gas CCS power plant, while there is also potential for a 570 MW CCS coal-gasification power station at Grangemouth, following £4.2 million industrial research and feasibility work.

We are not able to account for how geographic factors will affect uptake of abatement measures in transport for the purposes of the advice in this report given a lack of evidence. When we later provide specific advice to the devolved governments we will consider local options further.

Changing travel behaviour is the main lever to influence emission reductions from transport available to the devolved administrations, and they are often at the forefront of programmes and action. However, the devolved governments need to work with UK and EU policy to ensure that infrastructure facilitating sustainable behaviours, such as EV charging and cycling provisions, are in place and that any future targets are tailored to their specific nation's needs.

Agriculture and land use

Agriculture is particularly important in the economies of the devolved administrations compared to the UK as a whole, reflected in this sector's share of emissions of 29% in Northern Ireland, 16% in Scotland and 12% in Wales, compared to 9% for the UK as a whole.

Agriculture is a devolved policy matter and the devolved administrations, like England, have voluntary programmes to reduce emissions through a range of soils and livestock measures:

- The Scottish Government has outlined 1.5 $MtCO_2e$ abatement potential by the end of the 2020s from Farming for a Better Climate, a programme aimed at improving efficiency, optimising livestock management and developing renewable energy, and 0.2 $MtCO_2e$ from uptake of fertilizer efficiency measures[11].
- The Welsh Glastir programme supports farmers to develop sustainable land management approaches and encourages on-farm renewable energy generation.
- The Northern Ireland Executive has established the Greenhouse Gas Implementation Partnership (GHGIP), which encourages implementation of on-farm efficiency measures which will reduce the carbon intensity of local food intensity.

Beyond 2020, our Central scenario contains abatement in agriculture of around 8.5 $MtCO_2e$ for the UK as a whole in 2030 (see Chapter 6 of our technical report). Analysis of the potential at the devolved administration level suggests a Central scenario of around 1.2, 0.9, and 0.9 $MtCO_2e$ reductions in 2030 in Scotland, Wales and Northern Ireland respectively. This abatement potential forms a higher share of overall abatement in devolved nations compared to UK as a whole (e.g. 18% of total abatement potential from the sectors analysed in Northern Ireland being from agriculture, compared to 8% in UK, reflecting its high share of agriculture emissions).

In addition, there are opportunities for reducing emissions through devolved administration approaches to land use and forestry:

- Scotland has a significant proportion of the UK's carbon sinks in its peat soils (60%). The importance of protecting and managing this is highlighted in the Scottish Government's land-use strategy. Although peatland restoration is not included in our abatement scenarios, the Scottish Government have previously estimated 0.5 $MtCO_2e$ of potential abatement in 2027[12,13]. Targets in Scotland to increase forests require 100,000 hectares of woodland to be created by 2020 (approx. 10,000 per annum). Farmers in Scotland are also able, depending on the land's ongoing use, to receive funding for agro forestry under Pillar II of the EU CAP while still being able to receive Pillar I payments. These payments are greater than those available in England. Afforestation and agro-forestry could contribute 0.8 $MtCO_2e$ of potential abatement in 2030.

11 As reported in Scottish Government's second report on policies and proposals http://www.gov.scot/Publications/2013/06/6387/0

12 As reported in Scottish Government's second report on policies and proposals http://www.gov.scot/Publications/2013/06/6387/0

13 Emissions from upland peat and the savings potential from the restoration of degraded peat are not currently included in the LULUCF inventory.

- The Welsh Assembly Government has a target to plant 100,000 hectares of new woodland over 20 years. The Government has also set out a rural development plan to help prioritise areas for investment and emission reductions. Abatement potential from afforestation and agro-forestry in Wales is estimated at 0.4 $MtCO_2e$ in 2030.
- The Northern Ireland Executive has a longer-term planting target to double the area of forest from 2012 levels (6%) by 2056. Abatement potential from afforestation and agro-forestry is estimated at 0.1 $MtCO_2e$ in 2030. Northern Ireland has the lowest woodland cover in the UK.

Waste

Waste in the UK is fully devolved to the Scottish and Welsh Governments and Northern Ireland Executive. Their policies go further to reduce the amount of waste and waste emissions than those in England. These are discussed in greater detail in Chapter 7 of our technical report – *Sectoral scenarios for the fifth carbon budget*.

- Landfill taxation will become devolved to Scottish and Welsh Governments before 2020 and it is expected that the landfill tax will be set at a higher level than in England.
- Sending food waste to landfill will be banned in Wales under the planned Environment Bill and in Northern Ireland under the Food Waste Regulations (2015).

Our Central scenario for UK abatement includes the impact of devolved policies to divert biodegradable waste streams from landfill, and then across the UK by 2025. Abatement potential in 2030 has been identified as 0.5, 0.2 and 0.1 $MtCO_2e$ respectively in Scotland, Wales and Northern Ireland.

Power sector

Much of the UK's renewable electricity resource potential lies in the devolved administrations, especially Scotland, due to favourable geography for onshore and offshore wind. Alongside strong progress to date, there are significant investments in the pipeline and ambitious targets in place:

- Scotland's renewable electricity generation accounted for 29% of the UK's total, including 36% of total UK wind in 2014. This was generated from 7.2 GW of capacity. Planning has been granted for a further 4.1 GW of offshore wind at sites in Scottish Territorial Waters and for 4.4 GW of onshore wind. In addition, up to 150 MW of wave and tidal energy could be deployed by 2020. These projects could deliver the capacity required for the Scottish Government to meet its target for at least 100% of gross electricity consumption to be delivered from renewables by 2020 (nearly 50% was met in 2014). However, latest projections from Scottish Renewables[14] show that predicted capacity by 2020 will produce 87% of equivalent annual demand for power. This is because a number of the projects with planning permission may not have finance in place as they cannot meet the deadline for the closure of the Renewables Obligation and have not yet secured a Contract for Difference. There is also greater uncertainty in investment in Scottish renewables following the announcement of subsidy cuts for onshore wind energy from April 2016. With 66% of planned onshore wind farms in the UK located in Scotland, this could have a greater impact on future development than for other areas of the UK.

14 https://www.scottishrenewables.com/publications/update-scotlands-2020-renewable-energy-targets/

- In Wales, renewable electricity generation accounted for around 5% of the UK total. Planning decisions for large infrastructure projects are a reserved matter, with applications over 50 MW decided by the UK Planning Inspectorate. The Silk Commission in Wales recommended that powers over larger-scale energy consents (between 50 and 350 MW) become devolved by 2020. The world's second largest wind farm opened in 2015 off the coast of Wales delivering nearly 600 MW of capacity. In 2015, planning permission was granted for a tidal lagoon scheme in Swansea which would generate 500 GWh/year of electricity if built, although there is uncertainty over whether the project will be awarded a contract.
- Northern Ireland accounted for 3% of the UK's renewable electricity generation in 2014. The Northern Ireland Executive has set a target to generate 40% of electricity from renewable sources by 2020, although the current pipeline of projects is not enough to meet this target. Northern Ireland is not part of the GB small-scale feed-in-tariff at present although the Department for Enterprise, Trade and Investments (DETI) are in discussions with DECC on how they can be integrated into the scheme to help drive uptake in smaller-scale renewables.

Given their resource potential and ambitious targets, the devolved administrations, in particular Scotland, have an important role to play contributing to required UK power sector decarbonisation through the 2020s. For our Central power sector scenario in 2030[15], which has a carbon intensity below 100 gCO_2/kWh across GB, Scottish emissions from the power sector are projected to fall to 1.6 $MtCO_2$, a reduction of 86% from 2013 levels compared to a 69% fall for GB as a whole. However, the Scottish Government has a target to achieve a carbon intensity of 50 gCO_2/kWh or lower in the power sector. If reached this would give a fall in emissions of 90% from 2013 levels[16].

3. Central scenario for emissions in the devolved administrations

Table 5.1 and Figure 5.3 bring together our baseline emissions projections and our assessments of abatement potential to set out a central emissions scenario for the devolved administrations through the 2020s. Under our Central scenario for the fifth carbon budget (Chapter 3), direct emissions in the sectors analysed (i.e. excluding power)[17] would fall by around 54%, 39%, and 28% by 2030 in Scotland, Wales and Northern Ireland compared to 1990 levels.[18]

The different rates of reduction largely reflect the respective shares of emissions from different sectors. For example, our scenarios have a lower amount of reduction in emissions from agriculture compared to transport, leading to lower overall reductions in emissions in Northern Ireland, where agriculture has a larger share. The scenarios at devolved level are necessarily approximations; precise levels are hard to predict as changes in single emissions sources (e.g. a single power plant or industrial facility) can have a large effect.

We will use parts of this analysis to help inform our advice on targets on emissions reduction in Scotland and Wales in 2016.

15 The power sector model (Chapter 2 of our technical report) for Great Britain is split into geographical regions matched to Distribution Network Operator regions. Scotland is included as a region on its own. Wales is split between two and therefore cannot be separated. Northern Ireland is not included as the model is GB only.

16 However, given that Scotland is part of an integrated GB power system, calculating its carbon intensity is less meaningful, as it will share back-up capacity with the rest of the system.

17 Includes: buildings, industry, road transport, agriculture, LULUCF and waste. Power sector projections are not included in Scotland. If they were, Scottish emissions would be projected to fall by 61% form 1990 levels in our Central scenario.

18 Emissions would fall by around 27%, 23%, and 18% by 2030 in Scotland, Wales and Northern Ireland compared to emissions in 2013.

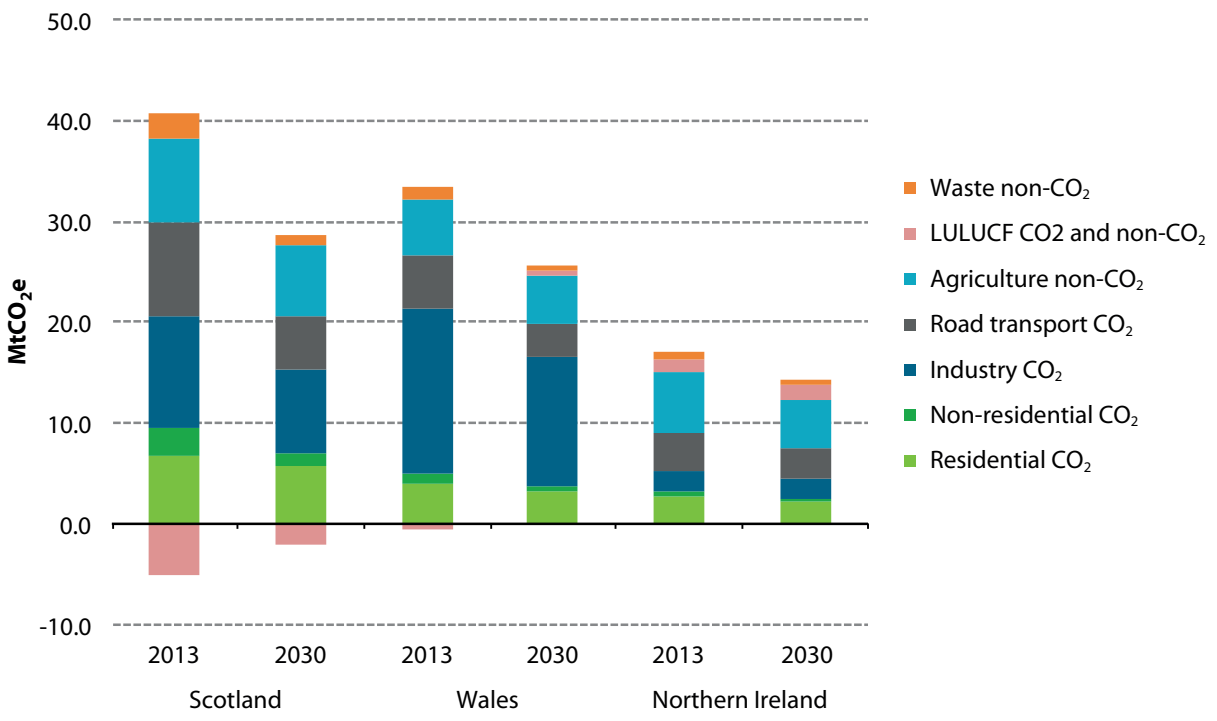
In 2050 the aim for the devolved administrations is similar to the UK as a whole. This will include energy efficient homes, very low emissions from waste and transport and decarbonised power and heat sectors. Scotland has legislated within the Climate Change (Scotland) Act, a target to reduce emissions by at least 80% in 2050 on 1990 levels, with a cumulative budget of 1,250 $MtCO_2e$ covering 2010 to 2050. Wales is also planning to introduce an 80% reduction target in its Environment Bill. Northern Ireland does not have any specific target for 2050, although all the devolved governments are covered by the UK-wide targets and carbon budget levels.

Table 5.1: Abatement potential in the devolved administrations in 2030 ($MtCO_2e$)

Sector	Scotland	Wales	Northern Ireland	Total abatement	2030 Central emissions	% reduction from 2013
Buildings	2.2	1.2	0.6	4.0	13.0	26%
Industry	1.2	1.1	0.2	2.5	23.4	20%
Transport	5.4	3.4	3.1	11.9	11.5	41%
Agriculture	1.2	0.9	0.9	3.0	16.5	17%
LULUCF	0.8	0.4	0.1	1.3	-0.2	n/a
Waste	0.5	0.2	0.1	0.8	2.0	56%
Total	11.7	7.4	5.3	24.4	66.2	22%

Source: CCC calculations, DECC, DEFRA, DfT, SRUC, CEH, ICL (2015).
Notes: Total abatement, 2030 Central emissions and % reduction from 2013 are combined across Scotland, Wales and Northern Ireland. For LULUCF, the emissions can be positive or negative, and so a percentage reduction is not an appropriate metric.

Figure 5.3: Scotland, Wales and Northern Ireland – 2013 emissions and 2030 Central scenario (selected sectors)



Source: DECC, DEFRA, DfT (2015), CCC calculations.
Notes: 2013 emissions do not match figure 5.2. This chart does not include emissions from the power sector, other transport, non-CO_2 from buildings, industry, and road transport, and CO_2 from agriculture and waste.

4. Wider considerations

Chapter 4 covered a range of considerations required under the Climate Change Act, at the UK level. Here we cover relevant issues specific to the devolved administrations.

Fuel Poverty

Rising carbon prices and support for investment in renewable electricity could result in higher energy bills. These costs could be disproportionate to those heating with electricity, especially in off-gas grid properties, often in rural or island communities, of which there is a greater number in the devolved administrations. This could exacerbate fuel poverty, which is already a significant problem.

However, fuel poverty and energy efficiency is a partially devolved matter. Each nation has its own targets and programmes to improve energy efficiency of homes, which are more comprehensive than those available in England (i.e. GB-wide Green Deal and Energy Company Obligation). These include area-based schemes in Wales and a new £224m scheme in Scotland which targets funds at installing energy efficiency measures in fuel-poor homes over the next 15-20 years.

We will consider fuel poverty in more detail when we advise the devolved administrations individually.

Competitiveness

There is a potential risk to the competitiveness of energy-intensive sectors in the devolved administrations, in particular Wales where these are a large part of the economy. These can occur if low-carbon policies disadvantage specific sectors or firms, potentially harming profits and driving location of production to other countries. The steel industry has seen some large changes globally and in the UK including the price of steel decreasing, the strengthening of the pound and an increase in electricity prices due to the wholesale cost of electricity increasing.

Climate change policies however, constitute a small proportion (around 2%) of total costs in the UK steel sector. For steel and other heavy industry, exemptions and compensations for climate policy costs are in place or planned. We have therefore concluded that competitiveness risks are manageable across the UK given the policies in place, and cost effective abatement opportunities to reduce emissions (Chapter 4).

There may also be positive impacts from the shift to a low-carbon economy given opportunities for the devolved administration to sell in new markets for low-carbon goods and services and opportunities for investments in renewables.

Energy Security

The devolved administrations, especially Scotland, have ambitious targets for renewable power generation. These pose challenges related to the intermittency of supply (i.e. wind power is only available when the wind is blowing). Our conclusion at the UK level also applies at the devolved level – these challenges are likely to be manageable with sufficient deployment, within the overall GB system, of back-up gas capacity, interconnection, storage and demand-side response (see Chapter 2 of our technical report). It is likely that, due to the locations of unabated gas power stations required for the GB system as a whole, some devolved administrations will appear to have less or more than their 'fair share' of emissions from gas generation required to balance the system at times of high demand or low renewables output.

Further planned interconnections between England, Scotland and Wales will also help to improve security of electricity supply in Great Britain.

Wider energy security is reserved in Scotland and Wales, and in Northern Ireland it is devolved to the Executive. Increasing the proportion of renewable generation would increase the diversity of the energy mix, while reduced reliance on fossil fuels would lessen the exposure to fossil fuel price volatility. The Northern Ireland gas supply relies on imports, so deployment of non-fossil generation will reduce this dependence.

Overall, security of electricity supply will depend on incorporating flexibilities that exist across the GB grid alongside the decarbonisation programmes of the devolved administrations. A transition to a low-carbon economy is likely to be beneficial for broader energy security.

5. Summary

There is a similar pattern of abatement potential in the devolved administrations as in the UK, but with the following key differences:

- There is potential for Scotland to contribute a greater share of low-carbon power, given the size of its renewable resources.
- The high share of energy-intensive industry in Wales is reflected in a relatively lower amount of abatement and a lesser overall projected fall in emissions compared to UK as a whole.
- Agriculture abatement is more pronounced, given the higher share of agriculture emissions in devolved nations. This is especially the case in Northern Ireland where the sector is relatively more important for emissions and the economy. This also contributes to a lower overall fall in emissions in Northern Ireland compared to the UK as a whole.

Devolved levers and policies are important to delivering the scenarios for reducing emissions set out in Chapter 3. In areas where devolved administrations have led so far there is increased scope to reduce emissions further. There is also potential for greater learning across the UK from the experience of each devolved administration.

The total potential abatement in the sectors analysed (excluding power) from the devolved administrations in 2030 is 23.5 $MtCO_2e$[19]. While they will deliver against their own targets, which may be more stretching than the fifth carbon budget, the potential abatement is 21% of the total UK abatement and therefore the devolved administrations will be important in delivering the emissions reductions needed to meet the fifth carbon budget.

Delivering these feasible emissions reductions through the 2020s will require action now to develop options and new policies, both at the UK and devolved levels, given the balance of reserved and devolved powers:

- New policies and commitments will be required to support energy efficiency improvements in the period to 2020 and beyond.
- UK and devolved government support and incentives will be required for development of markets for low-carbon heat and promotion of public transport and active travel.
- Development of land use strategies and local action plans across the nations including new policies to encourage farmers to reduce emissions.

19 This includes both traded and non-traded abatement potential in industry. This is therefore in part dependent on EU ETS allocation to 2030. Non-traded only potential abatement is 21.5 $MtCO_2e$.

- As further powers are devolved the governments and Executive should ensure that any new plans are consistent with climate change targets and reducing greenhouse gas emissions.
- UK Government financial and other support will be required if renewable electricity resource potential is to continue to be exploited.
- Devolved and UK governments need to work together on innovative solutions to reduce industrial emissions which can be implemented at a devolved level.

Chapter 6: Budget recommendation

1. Level of the fifth carbon budget
2. Inclusion of international aviation and shipping in carbon budgets
3. Role for purchase of offset credits
4. Costs and benefits of meeting the budget
5. Maintaining the integrity of the carbon budgets
6. Delivering the budget
7. Next steps

We recommend that the fifth carbon budget is set at 1,765 $MtCO_2e$, including emissions from international shipping, over the period 2028-2032. That would limit annual emissions to an average of 57% below 1990 levels, consistent with the cost-effective path to the 2050 target in the Climate Change Act. This balances the range of factors the Committee must consider and requires that the UK continues its historical rate of emissions reduction.

The Climate Change Act sets out how the Committee is legally required to advise on, and how the Government must set, carbon budgets. In particular the budgets:

- "must be set with a view to meeting … the target for 2050"; and
- must take into account
  - "scientific knowledge about climate change;
  - technology relevant to climate change;
  - economic circumstances, and in particular the likely impact of the decision on the economy and the competitiveness of particular sectors of the economy;
  - fiscal circumstances, and in particular the likely impact of the decision on taxation, public spending and public borrowing;
  - social circumstances, and in particular the likely impact of the decision on fuel poverty;
  - energy policy, and in particular the likely impact of the decision on energy supplies and the carbon and energy intensity of the economy;
  - differences in circumstances between England, Wales, Scotland and Northern Ireland;
  - circumstances at European and international level;
  - the estimated amount of reportable emissions from international aviation and international shipping for the budgetary period or periods in question".
- whilst "complying with the European and international obligations of the United Kingdom".

The preceding chapters have covered the relevant considerations: science and international circumstances (Chapter 2), technology and economics (Chapter 3); competitiveness, social circumstances (including fuel poverty and wider impacts on health), security of energy supplies and fiscal circumstances (Chapter 4); and the differences in circumstances between the devolved administrations (Chapter 5).

In this chapter, we bring those assessments together to recommend the level of the fifth carbon budget. The recommended budget is based on our best estimates of the UK's share of the cap in the EU Emissions Trading System (EU ETS), and the cost-effective path to 2050 for those sectors outside the EU ETS. On the current basis of carbon budget accounting (excluding international shipping) this leads to a budget recommendation of 1,725 $MtCO_2e$.

In addition to recommending the level of the carbon budget, the Committee also has duties under the Act to advise on:

- "the consequences of treating emissions of targeted greenhouse gases from international aviation, and international shipping, as emissions from sources in the United Kingdom" (i.e. inclusion of international aviation and shipping in carbon budgets);

- the "limit on the net amount of carbon units that may be credited" (i.e. the role of offset credits) in meeting the carbon budget.

We cover those in sections 2 and 3 respectively. We recommend that international shipping emissions are added into the budget (which would then increase from 1,725 to 1,765 $MtCO_2e$). International aviation should continue to be allowed for in the size of the budget for other sectors, but not formally included. We recommend that the budget should be met without recourse to carbon units (i.e. credits).

We set out the costs and benefits of meeting the budget in section 4. The budget is on the lowest-cost path to meeting the 2050 target. It implies a small cost increment compared to the legislated fourth carbon budget and a continuing cost of up to 1% of GDP in 2030 versus a hypothetical scenario with no action to tackle climate change (though we note that this is not an option given the requirements under the Climate Change Act, the international response to climate change and the UK's existing commitments to play a role in that international response).

In section 6 we outline the implications for policy required to meet the budget and the 2050 target. Existing policies mostly come to an end in 2020. They must be extended and built on if the proposed fifth carbon budget and the statutory 2050 target are to be met.

1. Level of the fifth carbon budget

There is a cost to tackling climate change. New low-carbon options currently cost more than their existing high-carbon alternatives, in part because the existing technologies and approaches do not face the full costs of their emissions.

The role of the Committee, as set out in the Climate Change Act, is to find a budget that keeps costs as low as possible now *and* into the future, balancing the range of factors set out above (competitiveness, fiscal circumstances, fuel poverty, international action, energy policy and technological progress).

We are therefore recommending a budget that balances effort to 2032 with effort required beyond 2032, that is on the path to meet the UK's statutory target for 2050 and that would position the UK to meet stronger international action that might be required in future.

Recommendation: On the current scope of carbon budgets (i.e. without formally including emissions from international aviation and shipping), we recommend a fifth carbon budget level of 1,725 $MtCO_2e$, implying emissions in 2030 57% below those in 1990.

This is the sum of our estimates for the appropriate limits for the traded and non-traded sectors (Table 6.1):

- **The 'traded' sector** refers to those sectors of the economy covered by the EU ETS, primarily electricity generation and energy-intensive industry. Emissions from these sectors have reduced by 44% since 1990, and are projected to be 60% below 1990 levels by 2020. Under the accounting rules of the Climate Change Act (Box 6.1), the contribution of those sectors to the carbon budget will be determined by the emissions allowances allocated to the UK in the EU ETS, which is currently uncertain. Our proposed budget is based on our current best estimate of 590 $MtCO_2e$ for the fifth budget period, an average of 66% below 1990.[1]

1 This estimate for the traded sector is an update from the estimate we published in our Ocober report on the scientific and international context for the fifth carbon budget. That change reflects the latest information on uncertain inputs, including the eligibility of UK installations for free permits allocated under the EU ETS. As when previous budgets have been set, we will continue to work with Government officials in the coming months to ensure that when the budget is legislated it reflects any further significant developments in the evidence.

- **The 'non-traded' sector** covers all emissions outside the EU ETS, including transport, heating in buildings, agriculture, waste and some industry. Emissions from these sectors have reduced by 29% since 1990, and are projected to be 35% below 1990 by 2020. For these sectors, performance against the budget is judged on actual emissions. Our proposed budget is based on our best estimate of the cost-effective path for emissions from today to the 2050 target in the Act. This implies emissions of 1,135 $MtCO_2e$ for the non-traded sector over the fifth budget period, an average of 51% below 1990.

The recommended budget is on a path for emissions that is consistent with progress to date and the effort required between the legislated fourth carbon budget – which remains in line with our estimated share of the EU ETS cap and the cost-effective path for the non-traded sector – and the 2050 target (Figure 6.1).

Whilst the recommended budget reflects our current best estimate of the cost-effective path for emissions, it does not automatically follow that a change to any of the individual inputs to that estimate (e.g. projected emissions in the absence of effort) would imply a different budget level. Other factors have to be considered in making our recommendation (e.g. the overall rate of emission reduction and the costs and opportunities for abatement).

Table 6.1: Budget recommendation

$MtCO_2e$	2030	The fifth budget period (2028-2032)
Non-traded sector	**227**	**1,135**
Traded sector (gross emissions)	87	450
Adjustment for the UK share of the EU ETS cap	+31	+140
Traded sector portion of net carbon account	**118**	**590**
Recommended budget		**1,725**

Notes: Adjustment for the UK share of the EU ETS cap is the difference between gross UK emissions and the UK share of the EU ETS cap. This adjustment essentially reflects net trading in the EU ETS, with the positive number reflecting net sales of allowances given that the share of the ETS cap is above our assessment of the traded sector cost-effective path. However, this difference could also reflect differences in the time profile of emissions within the EU ETS (e.g. companies holding onto allowances to use for future periods, use of previously retained allowances or the operation of the Market Stability Reserve). The 2030 level of gross traded sector emissions is not equal to the average emissions over 2028-32, due to the shape of the emissions trajectory in our Central scenario.

Box 6.1: Accounting rules in the Climate Change Act

Under the Climate Change Act, performance against carbon budgets is measured by the net UK carbon account. In practice, this means that the part of the budget for the power sector and energy-intensive industry, which is covered by the EU Emissions Trading System (EU ETS), is based on the UK's share of the EU ETS cap rather than the actual emissions in those sectors.

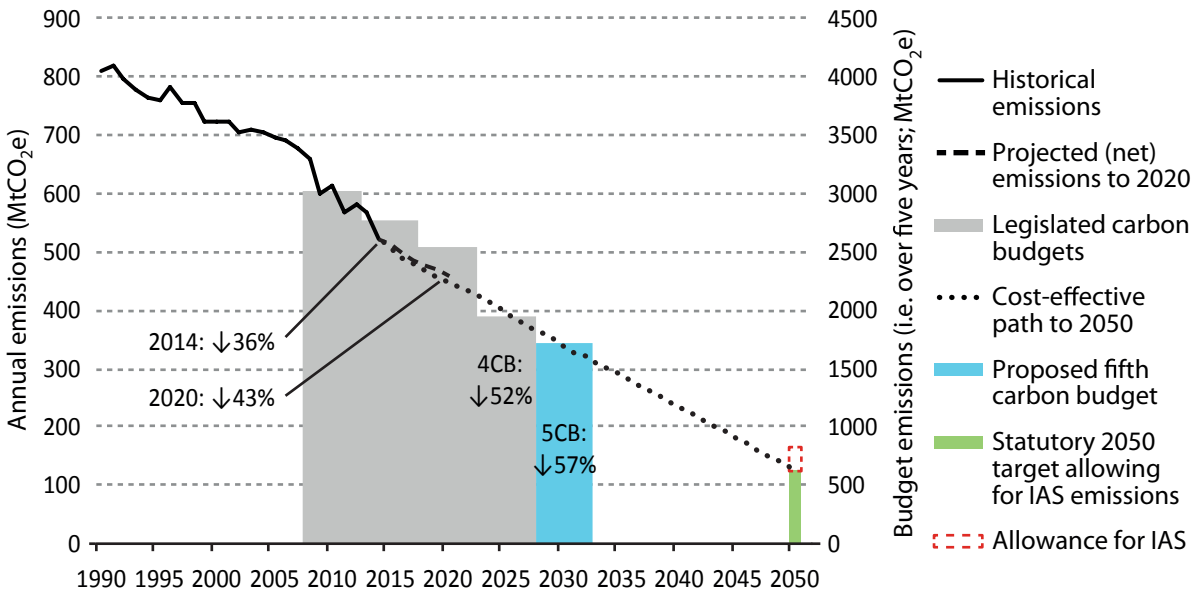
It is clear that in order to stay on track to the 2050 target in the Act, actual emissions must be reduced. The accounting rules should not be used to mask the real progress to the UK's legal commitment.

Our proposed budget implies a 57% reduction in emissions from 1990 to 2030 on the accounting basis in the Act. We also identify the cost-effective path for actual emissions across the UK economy (ignoring the allocation of emissions allowances in the EU ETS). For actual emissions the recommended budget requires a 61% reduction from 1990 to 2030. The larger reduction in actual emissions reflects our scenarios for the power sector. Under the cost-effective path the power sector should reach a carbon intensity of below 100 gCO_2/kWh in 2030. This would result in emissions in the traded sector of 450 $MtCO_2e$ across the fifth carbon budget period (a 75% reduction in 1990 levels), lower than the Committee's current best estimate of the allocation of emissions allowances to the UK.

Box 6.1: Accounting rules in the Climate Change Act

To stay on track to the 2050 target and to support emissions reductions elsewhere in the economy, the power sector will need to reduce emissions at around the rate in our estimate of the cost-effective path. In line with our approach to date, the Committee will continue to assess progress towards carbon budgets and the 2050 target on the basis of both the net carbon account and actual emissions across the economy.

Figure 6.1: The first five carbon budgets on the path to meeting the 2050 target



Source: DECC (2015) *Final UK greenhouse gas emissions national statistics: 1990-2013*; DECC (2015) Provisional UK greenhouse gas emissions national statistics; DECC interim projections (October 2015) CCC analysis.
Notes: Historical emissions are on a 'gross' basis (i.e. actual emissions). Projections and carbon budgets are on the current budget accounting basis: net carbon account excluding international aviation and shipping (IAS), but allowing for IAS to be included in the 2050 target.

Our proposed budget:

- Continues steady progress from the legislated fourth carbon budget towards the 2050 target, avoiding a more expensive 'stop-start' approach to meeting our obligations.
- Is achievable based on known options that are realistically deployable with some strengthening of policies, mainly for the 2020s (see Chapter 3).
- Meets the UK's current obligations under the EU 2030 package, while setting a foundation for effort consistent with a global 2°C target (see Chapter 2).
- Can be met without adversely affecting the competitiveness of existing UK industries, while also creating opportunities for innovation and growth in UK firms (see Chapter 4).
- Can be met with a small incremental cost for household energy bills and with a manageable impact on the public finances (see Chapter 4).
- Implies specific domestic effort in both the 'traded' and 'non-traded' sectors (see section 6).
- Allows for emissions from international aviation and international shipping, whether or not the government decides to include them formally in carbon budgets (see section 2).

Furthermore, in considering these impacts, the Committee also took into account that there is time to put in place suitable remedies should evidence emerge of greater impacts (e.g. competitiveness impacts or affordability concerns).

The Committee considered the evidence for both a looser budget and a tighter budget.

A looser budget would imply a lower cost in 2030, but it would store up higher costs for the future. It may meet the UK's existing international and EU commitments, but would not prepare sufficiently for the 2050 target. It would not provide a competitiveness benefit for UK firms, indeed it could lead to missed opportunities and increased costs as confidence in the low-carbon transition is undermined:

- As set out in Chapter 2, our best estimate of the UK's existing commitment under the EU's 2030 climate package would imply UK emissions in the non-traded sector of over 260 $MtCO_2e$ in 2030, whereas our proposed budget requires a reduction to 227 Mt. This means that the UK could meet the lower ambition implied by the EU package without any deployment of ultra-low-emission vehicles or low-carbon heat in the 2020s (Figure 6.2). As set out in Chapter 3, these are an important part of preparing for the 2050 target in the UK.
- Furthermore, were the UK to adopt this best estimate of UK commitment under the EU package, non-traded emissions would be allowed to rise relative to the level under the UK's fourth carbon budget (250 $MtCO_2e$ in 2025)[2], implying a stop-start approach that is likely to increase costs.
- The markets for low-carbon vehicles and heating are currently small and developing. Policy approaches, supply chains, infrastructure and consumer acceptance will all need to develop significantly before these become mass-market propositions. Those are challenges for the UK specifically, alongside the global challenge of developing technology (e.g. batteries for electric cars). Our proposed budget would clearly signal a commitment to meeting these challenges, increasing confidence for investors and thereby cutting risks and ultimately costs for consumers.
- We also note that the EU 2030 package appears at the low end of ambition on the EU's path to 2050 (see Chapter 2) and that the UK Government has argued for an increase in ambition at the EU level.

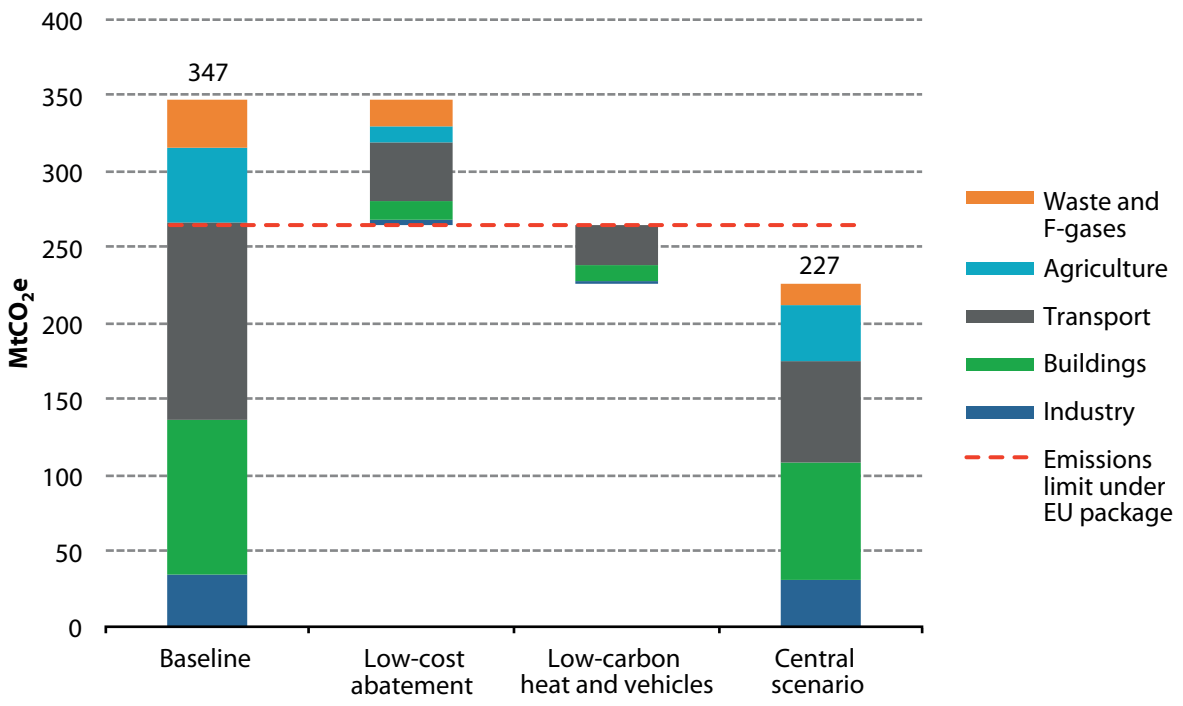
Considering all these factors, while the UK's commitments under the EU 2030 package represent the minimum level of effort under international obligations, this would not represent an appropriate basis for the UK carbon budget. It would be inconsistent with the Act's requirement to prepare for meeting the 2050 target, and would imply a stop-start approach to decarbonisation or a reneging on existing commitments.

A tighter budget could reflect a greater UK contribution to an international 2°C target[3], but would go beyond existing commitments in other comparable countries and beyond what is required to prepare sufficiently for the UK's 2050 target. A tighter budget could still be achieved in future if required through increased UK effort and/or the purchase of emissions credits – potentially as part of a ratcheting up process for global effort.

2 Our current estimate for allowed non-traded sector emissions under the fourth carbon budget is 1,245 $MtCO_2e$, calculated as the legislated level of the budget minus our latest estimate for the UK share of the EU ETS cap across the budget period of 705 $MtCO_2e$. This is very similar to allowed non-traded sector emissions when the budget was recommended (1,260 $MtCO_2e$).

3 For a detailed discussion of different shares for the UK and EU in meeting an international 2°C target, see our recent report on *The scientific and international context for the fifth carbon budget*, available at https://www.theccc.org.uk/publication/the-scientific-and-international-context-for-the-fifth-carbon-budget

Figure 6.2: Emissions reductions on the cost-effective path vs. those required by EU commitments (2030)



Source: CCC analysis.
Notes: Abatement in CCC cost-effective path divided into two categories: 'Low-carbon heat and vehicles' comprises ultra-low-emission vehicles, heat pumps and district heating, with 'low-cost abatement' containing all other measures. It should be noted that some of the 'low-carbon heat and vehicles' measures are also cost-effective in or before the fifth budget period, and that the large majority of the 'low-cost abatement' measures are likely to be required before 2050 (although their timing may be flexible).

2. Inclusion of international aviation and shipping in carbon budgets

When recommending a carbon budget, the Climate Change Act requires the Committee to recommend whether international aviation and/or international shipping (IAS) emissions should be included in carbon budgets. As we have previously recommended, in principle, these sectors should be included in carbon budgets unless there are strong practical considerations which prevent this. Where they cannot be included, budgets must be set to allow for their emissions, such that the 2050 target in the Act can be met including these – that has been the approach to date and is continued in this report.

Currently, inclusion of international aviation remains impractical, given the design of the EU ETS for aviation and ongoing uncertainty about how this will be treated in future:

- Given that aviation is included in the EU ETS, accounting rules for carbon budgets state that emissions should be included on the basis of UK allowances rather than on a gross basis (e.g. bunker fuels). However, the current design of the EU ETS for aviation means that only emissions from flights within Europe are covered. Inclusion on this basis would be unfavourable: it would leave a proportion of emissions outside carbon budgets, and the exact amount of UK emissions to add to carbon budgets and report annually would be unclear given the EU ETS is administered on an airline, rather than Member State, basis.
- In addition, the International Civil Aviation Organisation (ICAO) is currently negotiating a global market-based measure for international aviation emissions. These negotiations are expected to conclude in autumn 2016. At that point the implications for carbon budgets should be assessed, including whether it is practical to include international aviation emissions in carbon budgets or more sensible to continue to formally exclude, whilst making allowance for, these emissions.

However, there is no reason to continue to exclude international shipping from carbon budgets and there would be no additional costs or competitiveness concerns associated with inclusion. If international shipping is included, an additional 40 $MtCO_2e$ should be added to the fifth carbon budget, reflecting projected emissions on a bunker fuel basis and under currently agreed international policies (Box 6.2):

- Emissions from international shipping are not currently included in the EU ETS. They can therefore be included on the basis of bunker fuels as reported in the UK's national emission inventory. Should an alternative methodology be agreed internationally then carbon budgets can be adjusted to reflect this.
- On a bunker fuel basis emissions from international shipping were 8.7 $MtCO_2e$ in 2013, which is broadly the same as their 1990 level.
- Our projection for international shipping emissions incorporates the International Maritime Organisation's agreed policy for reducing shipping emissions (i.e. the Energy Efficiency Design Index). It does not assume any unilateral UK policy action but does reflect the impact of our economy-wide fifth carbon budget scenarios on demand for internationally shipped goods, specifically fossil fuels. Overall, we estimate emissions would fall by 5% to 2030 compared to 2013 levels.
- Over the five years of the budget period this implies emissions of 40 $MtCO_2e$ from international shipping in addition to the emissions from the other sectors of the economy.
- This does not involve any additional costs beyond those already committed to, and does not imply a unilateral UK approach to reducing emissions nor the competitiveness risks that could result from such an approach.

The recommended inclusion of international shipping does not affect the level of effort implied by the recommended budget. Whether or not it is included in budgets, our proposals are on a path to meeting the 2050 target with both international shipping and aviation included (Figure 6.1).

Recommendation: International shipping emissions should be included in the fifth and subsequent carbon budgets. This would imply a fifth carbon budget level, including international shipping, of 1,765 $MtCO_2e$ (Table 6.2). On international aviation, we recommend that it is not included at this stage; we will provide further advice following decisions expected at ICAO in 2016, and recommend that the Government revisit inclusion at that point.

Table 6.2: Fifth carbon budget recommendation including international shipping

$MtCO_2e$	**The fifth budget period (2028-2032)**
Non-traded sector	1,135
Traded sector portion of net carbon account	590
International shipping	40
Recommended budget including international shipping	**1,765**

Box 6.2: Basis for inclusion of international shipping emissions in carbon budgets

In our 2012 statutory advice on inclusion of international aviation and shipping in carbon budgets[4] we recommended that international shipping emissions should be included on the basis that they are reported in the national emissions inventory (i.e. bunker fuel sales).

This approach remains the appropriate basis for inclusion. International shipping emissions should therefore be added to the fifth carbon budget at a level of 40 $MtCO_2e$, reflecting projected emissions over the period. Uncertainties around the level of international shipping emissions are likely to be small relative to factors already accepted in legislated carbon budgets. There are no additional costs of inclusion beyond those already committed to, and no competitiveness risks.

- **Methodologies for inclusion of international shipping emissions.** In our 2012 advice we recommended that international shipping emissions be included in carbon budgets on the basis of bunker fuel sales. This is the convention used for reporting emissions to the UNFCCC and is used in the UK's emissions inventory. Alternative methods for measuring shipping emissions have been proposed (e.g. based on shipping activity) but have not yet been fully developed or agreed for annual reporting. Therefore inclusion should be initially on the basis of bunker fuels, moving to inclusion on an alternative approach once this is sufficiently developed and agreed internationally.
- **Uncertainty in international shipping emissions.** A potential concern is that changes in the agreed accounting methodology, or year-to-year fluctuations in reported bunker fuel sales, could imply unintended changes to the effort required from other sectors covered by carbon budgets. Our analysis suggests the impact of alternative methodologies and the uncertainty in bunker fuel estimates (both historical and projected) are small, particularly relative to factors already included in carbon budgets[5]. As a result, any consequences for carbon budget management would also be small and manageable under provisions set out in the Climate Change Act.
- **Projected international shipping emissions over the fifth carbon budget.** Our scenarios for international shipping emissions are based on current emissions as reported in the UK's emissions inventory, which we project forward using assumptions on future shipping demand and carbon intensity of ships (see our Technical Report[6], Chapter 5). Our demand scenarios are consistent with the reduction in fossil fuel imports under our economy-wide emission scenarios. Our carbon intensity scenarios are based on the International Maritime Organisation's (IMO) agreed policy for reducing emissions (i.e. the Energy Efficiency Design Index, EEDI). Overall, we project international shipping emissions would fall by 5% to 8.3 $MtCO_2e$ in 2030, compared to 2013 levels of 8.7 Mt.
- **Costs and competitiveness.** Our projection for international shipping emissions reflects the currently agreed international policy for reducing shipping emissions (i.e. the EEDI), which the UK Government has agreed to through the IMO. It does not assume any unilateral UK policy action. There are therefore no additional costs beyond those already committed to, nor the competitiveness risks that could result from a unilateral UK approach.

There is therefore no reason to continue to exclude international shipping emissions from carbon budgets, and they should be added to the fifth carbon budget at a level of 40 $MtCO_2e$.

4 CCC (2012) *Scope of carbon budgets – Statutory advice on inclusion of international aviation and shipping*, available at: https://www.theccc.org.uk/publication/international-aviation-shipping-review/

5 CCC (2012) *Scope of carbon budgets – Statutory advice on inclusion of international aviation and shipping*, p29-30

6 CCC (2015) *Sectoral scenarios for the fifth carbon budget*. Available at www.theccc.org.uk

3. Role for purchase of offset credits

Given a suitable level of global ambition, trading enables emissions reductions to take place in parts of the world where these are lowest cost and easiest to deliver. Credit purchase and the accompanying financial flows to developing countries might be part of an international agreement to tackle climate change.

The Committee's scenarios in Chapter 3 put the UK in a position to meet the 2050 target through domestic action, allowing for emissions from international aviation and shipping. As we have noted in previous reports, uncertainty over the availability and cost of offset credits in 2050 makes this an appropriate planning assumption at this stage.

If delivered, the scenarios in Chapter 3 would meet the proposed fifth carbon budget through domestic action, without recourse to purchased credits, on central expectations.

In recommending the fifth carbon budget, we are required by the Climate Change Act to recommend the appropriate role for international credits in meeting the budget. In doing so, it makes sense to treat the traded and non-traded sectors separately:

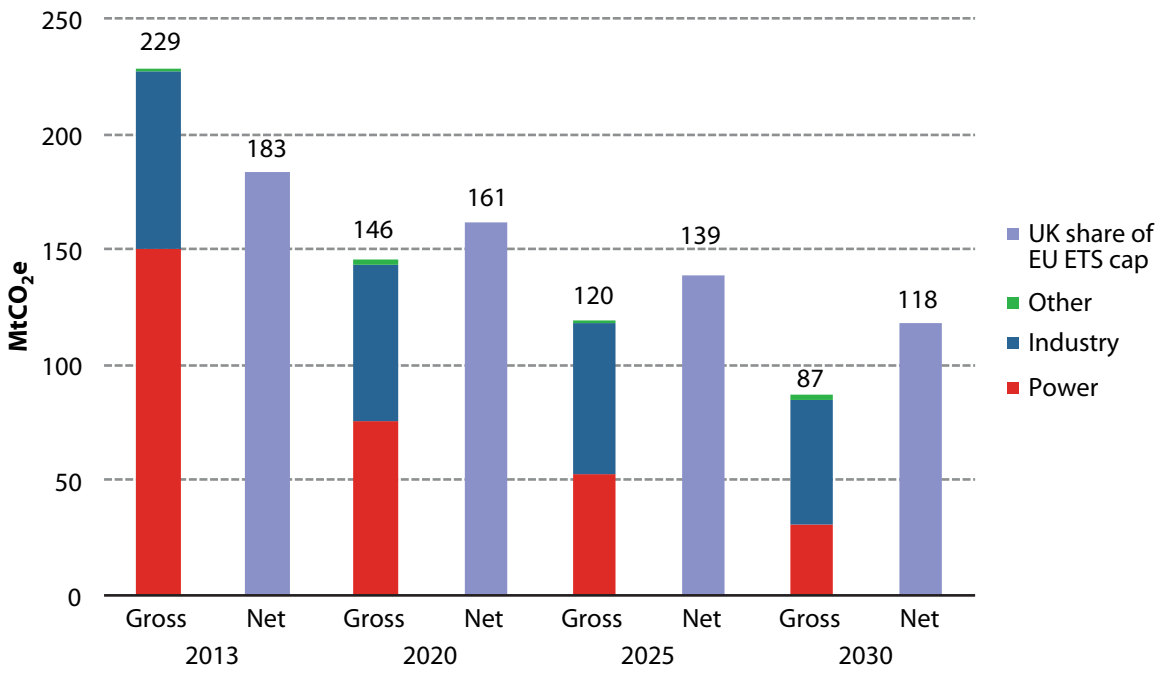
- **Traded sector**. Trading of EU Allowances (EUAs) under the EU ETS should not be limited, given the way that the traded sector is treated under carbon budget accounting. However, we note that the cost-effective path for the UK power sector means that we would expect actual traded sector emissions to be below the level of the UK share of the EU ETS cap (Figure 6.3).
- **Non-traded sector**. The part of the budget covering the non-traded sector has been recommended on the basis that it is our assessment of the set of measures that are cost-effective and/or required to prepare for meeting the 2050 target. The budget should therefore be met without the use of international carbon units (i.e. credits).

If unexpected circumstances mean the budget cannot be met cost-effectively without recourse to purchase of credits, the Committee would revisit this advice, including an assessment of the strength and validity of the credit market at that time.

As part of the potential ratcheting up of international effort beyond Paris there may be a role for international credits to support ambition globally. That should be additional to existing commitments and our proposed carbon budget for the UK. We would advise on this, as well as the appropriate level of the budget, should the EU commit to an increase in ambition.

Recommendation: The budget should be met without the use of international carbon units (i.e. credits). Credits could be used to go beyond the proposed budget to support international action to reduce emissions.

Figure 6.3: Cost-effective path for the traded sector (gross) and estimated UK share of the EU ETS cap (net) (2013-2030)



Source: CCC analysis; Tables 13 and 16 in DECC (2015) *Annual Statement of Emissions for 2013.*
Notes: Category 'Other' includes traded emissions in buildings, transport, agriculture and waste.

4. Costs and benefits of meeting the budget

The proposed budget is our best assessment of the lowest cost path to the UK's 2050 target. Meeting it will ensure costs are kept as low as possible in the long term. However, there is a financial cost to climate action since low-carbon technologies currently have higher costs than high-carbon alternatives which, amongst other things, do not face the full cost of their emissions:

- We estimate that meeting the proposed fifth carbon budget will involve an annual cost in 2030 that is up to £3 billion (around 0.1% of expected GDP) more than the cost of meeting the fourth carbon budget that has already been legislated. Costs would be lower to the extent that reduced carbon emissions mean UK firms can purchase fewer emissions allowances in the EU ETS.
- The total annual cost of meeting the fifth carbon budget in 2030 is therefore similar to our estimate of the cost of meeting the fourth carbon budget in 2025: less than 1% of GDP.
- Offsetting some of these costs, there are wider benefits to climate action through reduced air pollution and other health benefits. Using government valuation methods, we have previously estimated the monetary value of these to be around 0.1-0.6% of GDP in 2030 (see Chapter 4).

We are recommending setting the budget at this level because it is on the lowest cost path to the legislated 2050 target. Even in the absence of this target, not acting to tackle climate change is not an option given the much higher costs of unmitigated climate change and the international commitments in place. If the world is to stay credibly on track to the internationally-agreed objective to limit global temperature increase to 2°C, then the UK's share of the necessary global emissions reduction is likely to be at least as large as that required by our proposed budget.

The budget is therefore a low-regret course to follow.

The precise costs and benefits of meeting the budget depend on a range of uncertain factors. These include the pace of innovation (e.g. the path of technology costs and performance), fossil fuel prices, wider economic performance, the level of demand and behaviour of consumers and the mix of measures used to meet the budget:

- Across a range of assumptions about how the budget is met, technology costs, the level of demand in the economy and fossil fuel prices, our estimates for the annual cost remain under 1% of GDP (Table 6.3).
- The costs and risks from climate change need to be addressed regardless of the cost of fossil fuels or the rate of GDP growth. While lower fossil fuel prices and higher GDP would make meeting the budget more expensive, in such cases consumers and businesses would be more able to bear the cost (as costs associated with these inputs would be lower or incomes overall would be higher). For example, while lower fossil fuel prices make decarbonisation look relatively more expensive, total energy bills are still lower compared to a situation with higher fossil fuel prices. Conversely, higher fossil fuel prices and lower GDP would be expected to mean a lower cost of meeting the budget, in more testing times economically.
- The estimated cost of meeting the budget is consistent with our earlier estimates that meeting the UK's 2050 target might cost 1-2% of GDP.[7]

Based on this cost, which was deemed acceptable when the Climate Change Act was passed, the manageable impacts set out in Chapter 4 and the further steps that the budget makes towards meeting the 2050 target, the proposed budget level best meets the requirements of the Climate Change Act.

Table 6.3: Estimated costs of meeting the fifth carbon budget under a range of assumptions

Costs as % GDP	**Central estimate**	**High or low fossil fuel prices**	**Low or high technology costs**
Total costs	**0.5%**	**0.1% to 0.8%**	**0.2% to 0.9%**
Of which:			
Power	0.5%	0.3% to 0.7%	0.4% to 0.7%
Industry	0.0%	0.0%	0.0%
Buildings	0.0%	-0.1% to 0.0%	-0.1% to 0.0%
Transport	0.1%	-0.1% to 0.2%	-0.1% to 0.2%
Agriculture, waste and F-gases	0.0%	0.0%	0.0%

Source: CCC analysis.
Notes: The cost estimates presented are based on the resource costs of the measures in our scenarios to reduce emissions. They do not include quantified costs or benefits relating to changes in welfare (e.g. warmer homes or changes in demand for energy services), or impacts on health (e.g. due to improved air quality). We expect net abatement costs in agriculture to be negative; in these calculations we assume zero costs due to uncertainties around exact magnitudes. Numbers may not sum due to rounding.

7 See CCC (2008) *Interim advice by the Committee on Climate Change*, https://www.theccc.org.uk/publication/letter-interim-advice-from-the-committee-on-climate-change and CCC (2008) *Building a low-carbon economy – the UK's contribution to tackling climate change*, https://www.theccc.org.uk/publication/building-a-low-carbon-economy-the-uks-contribution-to-tackling-climate-change-2/

5. Maintaining the integrity of the carbon budgets

The Climate Change Act requires a carbon budget to be set as a single number 12 years in advance: in the present case, the limit for total emissions over the five-year period from 2028 to 2032. Our recommendation reflects the best estimates available of some uncertain factors.

Carbon budgets do not address actual UK emissions in the parts of the economy covered by the EU ETS (the 'traded sector'), but rather the UK share of the EU ETS cap. In recommending a budget, we make an estimate of the UK share of the EU ETS cap; however, it is not possible now to estimate what this share will be with complete accuracy – or indeed at any point in advance.

Under the Cimate Change Act's existing Carbon Accounting Regulations, any difference between the out-turn and the projected UK share of the EU ETS cap affects the level of emissions allowed in the non-traded sector, which is the residual from the total budget minus the share of the EU ETS cap. So far this has meant that carbon budgets require less action than originally envisaged, although in principle it is also possible for the approach set out in the Act to have the opposite effect.

Setting a clear level of ambition in the non-traded sector that is independent of changes in the UK share of the EU ETS cap provides a guide to policymakers and a signal to businesses and consumers.

Recommendation: The Government should use the Carbon Accounting Regulations to fix the net carbon account for the traded sector at the assumed level (i.e. 590 $MtCO_2e$ over 2028-2032), and not adjust for the out-turn UK share of the EU ETS cap. This would ensure that the implications of the budget for the non-traded sector are clear, limiting emissions to 1,135 $MtCO_2e$ over 2028-2032, and requiring annual reductions of 2% (6 $MtCO_2e$) through the 2020s.

As a way of providing a clear signal to businesses and consumers in the non-traded sector, this solution is preferable to future revisions to the budget in order to adjust for new estimates of the UK share of the EU ETS cap. We received a clear message from business stakeholders as part of the Review of the Fourth Carbon Budget[8] and during the course of preparing this advice that budgets should not be changed if this can be avoided.

Applying this same approach to the existing carbon budgets could also deal with the issue of 'phantom emissions' raised by the previous Secretary of State.[9] The changes to estimates of the UK share of the EU ETS cap for already legislated budgets have been large, making the second and third budgets much easier to meet than originally envisaged:

- Latest estimates of the UK share of the EU ETS cap are now over 300 $MtCO_2e$ lower over the second and third carbon budget periods than estimates when the budgets were set.
- That means that the second and third budgets could be met with very little effort in the non-traded sector. Or, if near-term effort is preserved and excess emissions are carried forward to future budgets, the integrity of the fourth and fifth carbon budgets would likely be undermined.
- In our response to the Secretary of State earlier in 2015 we reiterated the importance that carbon budgets be met through UK action consistent with achieving the 2050 target and not through accounting loopholes.
- We suggested that a revision to the Carbon Accounting Regulations could be used to deal with this issue, and if that were not possible then the second and third budgets should be tightened.

8 CCC (2013) *Fourth Carbon Budget Review – part 2: The cost-effective path to the 2050 target*, page 14. Available at: https://www.theccc.org.uk/publication/fourth-carbon-budget-review

9 Letter from DECC Secretary of State Ed Davey to Lord Deben, March 2015. Available at: https://www.theccc.org.uk/publication/letter-preserving-the-integrity-of-the-uks-climate-change-regime/

Recommendation: The recommended change to Carbon Accounting Regulations should also apply to the second, third and fourth carbon budgets, with the traded sector accounted for at the level estimated when the original budgets were set (Table 6.4).

Table 6.4: Levels of traded sector emissions assumed in the carbon budgets

	Budget 2 (2013-2017)	Budget 3 (2018-2022)	Budget 4 (2023-2027)	Budget 5 (2028-2032)
Assumed level of traded sector emissions across the budget	1,078	985	690	590

Source: HM Government (2009) *Building a low-carbon economy: implementing the Climate Change Act 2008*, Table 3.B: Proposed carbon budget levels p18-19; CCC (2010) *The Fourth Carbon Budget – reducing emissions through the 2020s*, https://www.theccc.org.uk/publication/the-fourth-carbon-budget-reducing-emissions-through-the-2020s-2/
Notes: Estimates of the UK share of the EU ETS cap for the second and third carbon budgets were adjusted slightly between the budgets being recommended by the CCC and being legislated by the Government.

Finally, we note that an amendment was recently passed in the House of Lords[10] that would affect accounting for the fifth carbon budget and those that follow. The amendment would effectively mean that the budget covers actual emissions in the traded sector as well as the non-traded sector. Should the basis of emissions accounting for the fifth carbon budget be changed in law, we would need to return to our recommendation to advise on the appropriate budget level. Our estimate of the cost-effective path in the traded sector is significantly below our estimate for the UK share of the EU ETS, implying that a tighter 'gross' budget would be required.

6. Delivering the budget

Our Central scenario sets out our current assessment of the cost-effective path on the way to meeting the 2050 target. However, this is indicative and only one way to meet the budget. Chapter 3 and our Technical Report on *Sectoral scenarios for the fifth carbon budget*[11] set out a range of scenarios for how the budget can be met, and outline the flexibilities available.

Meeting the carbon budgets will require Government leadership. The Climate Change Act requires the Government, as soon as is reasonably practicable after setting the budget, to set out proposals and policies for meeting it.

Policies are largely in place to continue reducing emissions to 2020. Policies will need to be extended and developed after 2020 to meet both the fourth and the fifth carbon budgets. This process should start now given the lead-time from policy development to actions which will reduce emissions: changes in behaviour, low-carbon investment decisions, technology innovation and development of markets for low-carbon products. The Government has recognised the need for policy development and committed to providing more detail on how this will be done once the fifth budget is set.

Particular priorities for policy development are:

- **Power.** Ensuring the power sector can invest with a 10-year lead-time by committing funding to 2025 consistent with reducing sector carbon intensity to below 100 gCO_2/kWh in 2030 and clarifying future plans for offering low-carbon contracts.

10 http://www.publications.parliament.uk/pa/bills/cbill/2015-2016/0092/15092.pdf
11 Available from our website, www.theccc.org.uk.

- **CCS.** Continuing commercialisation of carbon capture and storage. This needs a strategic approach to transport and storage infrastructure, a joined-up approach across power and industry, completion of the two proposed projects and contracts offered for at least two follow-on projects this Parliament.
- **Heat.** Putting in place measures to increase uptake of low-carbon heat (heat pumps and low-carbon heat networks supplying businesses and households) alongside energy efficiency improvement.
- **Buildings.** Setting out how energy efficiency improvements will be delivered and financed, following the end of the Green Deal and forthcoming end of the Energy Company Obligation in 2017; delivering an effective simplified package for improving energy efficiency in non-residential buildings.
- **Transport.** Pushing for clear, stretching 2030 targets at the EU level to reduce CO_2 from new vehicles, combined with robust testing approaches. Alongside stretching targets, early-stage support for the emerging electric vehicle market and funding for supporting infrastructure should continue.
- **Other sectors.** Policies will also be needed in other sectors, including agriculture, where it is likely that policy will need to go beyond the existing voluntary approach.

We will return to the policy challenges around delivering the emissions reduction to meet the fourth and fifth carbon budgets in our annual progress report to Parliament in June 2016.

7. Next steps

The Climate Change Act sets statutory deadlines that mean the Committee is giving its advice before the 21st Conference of the Parties (COP21) to the UNFCCC takes place in Paris in December 2015. The COP21 negotiations are due to end on 11 December 2015 and could produce significant new developments. The Committee will write to the Secretary of State for Energy and Climate Change in early 2016 to set out if and how the outcomes of Paris, or other significant changes, affect our published advice.

The Government must legislate the fifth carbon budget by the end of June 2016. If the level that is proposed to Parliament does not accord with the Committee's advice, the Climate Change Act requires the Secretary of State to explain why not.

As soon as is reasonably practicable after the budget is legislated, the Act requires the Government to set out proposals and policies for meeting the budget, and those preceding it. In their response to the Committee's June 2015 Progress Report the Government stated: *"After we set the fifth carbon budget (by the end of June 2016), we will be able to set out more detail about our expectation for how we intend to meet the targets. Our new emissions reduction plan towards the end of 2016 will set out our proposals in full."*

We will monitor progress developing the policy framework and provide advice in our annual report to Parliament on what this should cover.

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