Fourth Carbon Budget Review – part 2

The cost-effective path to the 2050 target

Committee on Climate Change | December 2013

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 May 2009. In December 2010, we set out our advice on the fourth carbon budget, covering the period 2023-27, as required under Section 4 of the Climate Change Act. The fourth carbon budget was legislated in June 2011 at the level that we recommended.

In April 2013 we published advice on reducing the UK's carbon footprint and managing competitiveness risks. In November 2013 we published the first part of our review of the fourth carbon budget, covering climate science, international and EU circumstances.

Progress meeting carbon budgets

The Climate Change Act requires that we report annually to Parliament on progress meeting carbon budgets. We have published five progress reports in October 2009, June 2010, June 2011, June 2012 and June 2013. Our next annual report is due in July 2014 and will include a backward look at how the first carbon budget (2008-12) was met.

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, renewable energy ambition, bioenergy, and the role of local authorities. In September 2010, July 2011, July 2012 and July 2013 we published advice on adaptation, assessing how well prepared the UK is to deal with the impacts of climate change.

Acknowledgements

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The team that prepared the analysis for the report: This was led by David Kennedy, Adrian Gault and Mike Thompson and included Andrew Beacom, Owen Bellamy, Ute Collier, Hanane Hafraoui, Taro Hallworth, Jenny Hill, David Joffe, Ewa Kmietowicz, Sarah Leck, Eric Ling, Nina Meddings, Clare Pinder, Stephen Smith, Kavita Srinivasan and Indra Thillainathan.

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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

The fourth carbon budget, covering the years 2023-27, was set in 2011 at the level of 1,950 $MtCO_2e$. The budget was passed in line with the advice of this Committee, to reflect the cost-effective path to meeting the 2050 target in the Climate Change Act (i.e. to reduce emissions by at least 80% relative to 1990). On this pathway, it commits the UK to reduce greenhouse gas emissions in the mid-2020s by 50% on 1990 levels.

When it set the budget, the Government also committed to a Review, for which it must again obtain Committee advice. The budget can then only be changed if there has been a significant change affecting the basis upon which it was set, with the relevant circumstances clearly specified in the Climate Change Act.

Last month we provided the first part of that advice, in which we considered the evidence on climate science and international and EU circumstances.

We concluded that there had been no significant change in relation to these issues since we provided our original advice in December 2010. Based on those criteria, therefore, there is no legal or economic basis for a change in the budget at this time.

We now come to the second part of our advice. This is to review the latest evidence on how the budget can be met and the impacts this could have for the other criteria specified in the Climate Change Act.

When the Climate Change Committee first recommended the level of the fourth carbon budget it identified a set of measures that could meet the proposed budget, which were feasible and economically sensible on the path to meeting the statutory 2050 target.

Our updated assessment confirms this finding – that the legislated budget can be met by a set of changes that are desirable in a carbon-constrained world. Indeed if anything, the risk now is that the budget could be met too easily and without preparing sufficiently for 2050.

We have therefore considered whether the budget should be tightened. However, we have concluded that this would go too far at the present time, given the inherent uncertainties in projecting future emissions and the potential for important further changes in coming years, not least relating to the EU negotiations over a 2030 energy and climate package. This may be something to which we have to return as these issues are resolved.

We have also considered possible impacts of the budget, including on fuel poverty and competitiveness. These are hugely important issues and ones that we have a statutory duty to consider. As in our original advice, we find that to the extent that the budget has negative impacts these can be managed given an appropriate policy response. Government has a number of suitable policies in place, but will need to extend and clarify these to ensure they are fully effective. However, there is no reason to change the budget in this regard.

In the long run, the report shows a clear benefit to reducing emissions through the 2020s. This will help develop technologies needed in the context of the statutory 2050 target and will avoid costs associated with burning fossil fuels and releasing carbon emissions. The detailed analysis shows that meeting the fourth carbon budget offers a cost saving of over £100 billion versus a scenario that delays actions beyond the 2020s. It could also improve the UK's energy sovereignty and offer wider health and environmental benefits, such as improved air quality.

The context for our review is one where the evidence on climate risks is as stark as ever, but where the pressure to reduce impacts on consumer bills is also at an all-time high. Given these apparently conflicting challenges there is a danger that businesses are caught in the middle and receive mixed signals over policy intent.

The Government has rightly recognised that there are ways of limiting the impacts for hard-pressed bill-payers while maintaining its climate ambition. No doubt it will want to signal this very clearly to business. An early decision to continue with the fourth carbon budget at its current level could help to achieve that. This would be in line with both the letter and the intent of the Climate Change Act to create a long-term stable framework for climate policy.

We will report on specific existing policies and requirements for the future in our 2014 progress report to Parliament, as part of our statutory assessment of the first carbon budget period.

In 2013 we have produced substantive reports on a number of important issues – Next steps on EMR, Reducing emissions in Wales and in Scotland, the UK's carbon footprint and competitiveness, our annual progress report to Parliament, and now the two parts of our advice on the fourth carbon budget – as well as providing advice on other issues. I am extremely grateful for the insight, advice and support of the Committee members. In turn and on behalf of the Committee, I thank the Secretariat for their hard work in producing this and all the other reports.

Lord Deben

Chairman, Committee on Climate Change

The Committee

The Rt. Hon John Gummer, Lord Deben, Chairman
The Rt. Hon John Gummer, Lord Deben established and chairs Sancroft, a Corporate Responsibility consultancy working with blue-chip companies around the world on environmental, social and ethical issues. He was the longest serving Secretary of State for the Environment the UK has ever had. His experience as an international negotiator has earned him worldwide respect both in the business community and among environmentalists. He has consistently championed an identity between environmental concerns and business sense.

David Kennedy (Chief Executive)
David Kennedy is the Chief Executive of the Committee on Climate Change. Previously he worked on energy strategy and investment at the World Bank, and the design of infrastructure investment projects at the European Bank for Reconstruction and Development. He has a PhD in economics from the London School of Economics.

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

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Professor Sir Brian Hoskins, CBE, FRS is the Director of the Grantham Institute for Climate Change at Imperial College 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 is the director of the Institute for Fiscal Studies. He has worked on the economics of public policy throughout his career. Paul has been chief economist at the Department for Education and director of public spending in HM Treasury, where he had particular responsibility for environment (including climate change), transport and public sector pay and pensions. Between 2004 and 2007 Paul was deputy head of the Government Economic Service. He has also served on the council of the Economic and Social Research Council.

Professor Dame Julia King
Professor Dame Julia King DBE FREng Vice-Chancellor of Aston University. She led the 'King Review' for HM Treasury in 2007-8 on decarbonising road transport. She was formerly Director of Advanced Engineering for the Rolls-Royce industrial businesses, as well as holding senior posts in the marine and aerospace businesses. Julia is one of the UK's Business Ambassadors, supporting UK companies and inward investment in low-carbon technologies. She is an NED of the Green Investment Bank, and a member of the Airports Commission.

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Professor Lord Krebs Kt FRS, is currently Principal of Jesus College Oxford. 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 is chairman of the House of Lords Science & Technology Select Committee.

Lord Robert May
Professor Lord May of Oxford, OM AC FRS holds a Professorship jointly at Oxford University and Imperial College. 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 & Technology.

Professor Jim Skea
Professor Jim Skea, CBE, is Research Councils UK Energy Strategy Fellow and Professor of Sustainable Energy at Imperial College London. He was previously Research Director at the UK Energy Research Centre (UKERC) and Director of the Policy Studies Institute (PSI). He led the launch of the Low Carbon Vehicle Partnership and was Director of the Economic and Social Research Council's Global Environmental Change Programme.

Executive summary

The fourth carbon budget was legislated in June 2011. It covers the period 2023-27, and commits the UK to reduce greenhouse gas emissions by 32% in 2025 on 2012 levels (50% on 1990 levels). It reflects our best estimate of the cost-effective path to meeting the 2050 target in the Climate Change Act (i.e. to reduce emissions by at least 80% relative to 1990), taking into account the criteria in the Act. These include impacts on energy affordability and fuel poverty, competitiveness, energy security, the public finances and circumstances in the devolved administrations.

As part of the agreement to set the budget, the Government scheduled a review for 2014. The Act sets out the basis for the review: it must be based on advice from the Committee and the budget can only be changed if "there have been significant changes affecting the basis on which the previous decision was made" (i.e. something has happened such that the budget is no longer cost-effective, or the impacts from meeting it have become prohibitive).

Our overall advice is that there has been no significant change in circumstances as specified in the Climate Change Act and therefore the budget should not and cannot be changed under the terms of the Act.

We published the first part of our advice in November 2013[1]. This covered climate science, international action, and developments in the EU. We concluded:

- **Climate science.** If global emissions were to continue to increase throughout the century it is likely that global temperature would rise by 4°C or more. In order to limit risks of dangerous climate change and preserve close to a 50% chance of keeping temperature rise below 2°C, it is necessary that global emissions peak around 2020, with deep cuts through the 2020s and in the following decades. The currently legislated budget is a minimum UK contribution to this global emissions pathway.
- **International action.** The UK is not acting alone. While the UN process is moving slowly and there have been backward steps in some countries (e.g. Australia), many countries around the world have made commitments comparable to the UK and are acting to reduce emissions. These include the largest emitters (i.e. China, the US and the EU, accounting for 57% of global emissions). Required global emissions cuts consistent with limiting warming to 2°C are still feasible if very challenging, and remain an appropriate basis for UK policy.
- **EU developments.** The fourth carbon budget is at the low end of the range of ambition currently being discussed by the EU for emissions pathways through the 2020s. If the UK Government is successful in achieving its stated objectives in these EU discussions, the budget would have to be tightened significantly.

1 CCC (November 2013) *Fourth Carbon Budget Review – part 1: Assessment of climate risk and the international response.* Available at www.theccc.org.uk

This report completes our advice. It includes an updated assessment of the cost-effective path to meeting the 2050 target (i.e. the lowest cost path to the target, which formed the basis for the legislated budget) and the wider social and economic impacts associated with this path.

Our conclusion is that the budget remains feasible and economically sensible, and continues to have manageable impacts. This reinforces the conclusion from the first part of our advice that there is no legal or economic basis to change the budget at this time.

- **Feasibility of the budget**. The budget can be met based on more prudent assumptions on implementation of measures than in our original advice (e.g. lower assumed uptake of heat pumps and more limited contribution from solid wall insulation). This is because official projections of energy demand have been revised down to reflect updated evidence on key demand drivers and improved approaches to projecting emissions in line with previous Committee advice.
- **Cost savings of early action.** The budget provides insurance against risks of dangerous climate change and rising energy bills. It offers significant cost savings relative to a path where action to reduce emissions is delayed until the 2030s. We estimate that the saving could be over £100 billion in present value terms under central assumptions about fossil fuel and carbon prices, allowing for expected impacts of shale gas; in a world of high fossil fuel prices, the benefit could be as high as £200 billion. Even with low fossil fuel or carbon prices, the budget would offer a cost saving compared to an alternative path where action to reduce emissions is delayed.
- **Social and economic impacts from meeting the budget.** Our assessment of the budget's impacts on the circumstances specified in the Climate Change Act is broadly unchanged from our original advice. Impacts on energy affordability, fuel poverty, competitiveness and the public finances are important but manageable. For example, incremental affordability and fuel poverty impacts are small, with scope to offset these through energy efficiency improvement; competitiveness impacts can be addressed under current policies for energy-intensive industries, provided these are clarified and extended. In the long run (e.g. after 2030) the budget offers benefits in terms of lower electricity and energy prices than would ensue without early decarbonisation.
- **Keeping the budget at its current level.** Our updated best estimate of the cost-effective path to the 2050 target implies a larger reduction in emissions in the 2020s than required by the budget. This could imply that a tighter budget (i.e. requiring a larger emissions reduction) is appropriate. However, it would be premature to tighten the budget now, given uncertainties over: the cost-effective path, EU emissions targets for the 2020s and the precise path for UK power sector decarbonisation under the Electricity Market Reform. Any change now would require a further change later, once these issues are resolved, and frequent budget changes would undermine the certainty that they are meant to provide.

The Government has rightly considered it essential that the UK continues to push for an ambitious EU 2030 package. The UK has an important role in these discussions and an ambitious package is required as part of an effective global response to climate change.

If the UK Government is successful in achieving its objectives in the EU, then the fourth carbon budget would have to be tightened under the current accounting rules of the Climate Change Act. Under these rules, UK emissions for those sectors covered by the EU Emissions Trading System (i.e. power generation and energy-intensive industry) are defined by the UK's share of the EU ETS cap.

Such a tightening would have the consequence of aligning the budget with our central expectation of the cost-effective path to meeting the 2050 target.

On the domestic front, an early confirmation of the fourth carbon budget at its current level would help to improve the currently poor conditions for low-carbon investment and to overcome the manifest uncertainties which have arisen in the energy sector. It would allow UK firms to position themselves to compete and prosper in growing markets for low-carbon goods and services.

It is appropriate to aim to implement the full set of cost-effective measures. In particular, it is important to implement the Electricity Market Reform to achieve deep decarbonisation of the power sector through ongoing investment in a portfolio of low-carbon generation technologies through the 2020s, given the significant economic benefit that this offers.

This aim could then be reflected in the fourth and fifth carbon budgets when uncertainties about EU ambition are resolved, and when a target for power sector decarbonisation is set in 2016 as provided for in the Energy Bill.

The cost-effective path to the 2050 target

The cost-effective path to meeting the 2050 target in the Climate Change Act embodies deep emissions cuts through the 2020s – following this path offers cost savings and other benefits in a carbon-constrained world.

- **The cost-effective path.** Our updated assessment is that the cost-effective path embodies lower emissions than in our original advice, even though we now make more prudent assumptions on the uptake and effectiveness of some low-carbon measures. This provides more confidence that the budget can be met.
  - Our original advice suggested that the budget could be met through deep decarbonisation of the power sector, energy efficiency improvement in buildings and in vehicles, some electrification of heat and transport and some efficiency measures in industry and agriculture.
  - Our updated assessment of abatement potential is more prudent than our original advice, reflecting barriers to uptake and factors which affect the economics of low-carbon measures. For example, we now assume lower numbers of heat pumps in the residential sector and lower emissions cuts from solid wall insulation.
  - New official projections suggest lower energy demand and emissions than previously expected, given slow economic growth since 2010 and improvements in projection methodologies to reflect current data and historic trends more robustly.

- – Taken together these new assumptions imply a lower level of emissions in the 2020s than in our original advice, providing more confidence that the budget can be met.

- **Cost savings relative to delayed action.** Following the cost-effective path for emissions reduction through the 2020s offers significant long-run savings relative to an alternative path where action to reduce emissions is delayed until the 2030s; this conclusion is robust across a wide range of plausible scenarios. It does not add to costs in the period prior to 2020.
  - – Cutting emissions through the 2020s rather than delaying this to the 2030s offers cost savings of over £100 billion in present value terms under central case assumptions about fossil fuel and carbon prices, with much higher savings in a high fossil fuel or high carbon price world (e.g. up to £200 billion).
  - – Only if there were a significant departure from the climate objective *and* fossil fuel prices are much lower than current levels would the budget entail significant costs over a delayed action path. A departure from the climate objective would be contrary to the agreed UN position and much lower fossil fuel prices would be counter to expectations.
  - – In the near term, specifically in the period prior to 2020, cutting emissions in line with the cost-effective path implies no additional costs over and above those associated with policies to which the Government has already committed, and which are independent of the fourth carbon budget.

- **Security of supply.** As North Sea reserves become depleted, the UK is becoming more reliant on imported fossil fuels, in some cases from countries with geopolitical risks to supply. Investment in low-carbon technologies will reduce this reliance and increase energy sovereignty. This would complement any security of supply benefit from UK shale gas. In the power sector, increased reliance on intermittent sources of generation like wind power is manageable at low cost through a combination of demand flexibility, energy storage, interconnection and balancing generation.

- **Quality of life.** There are various broader benefits associated with cutting emissions in the 2020s. For example, our scenario for meeting the fourth carbon budget implies: improved air quality from reduced burning of fossil fuels; reduced noise pollution resulting from improved glazing, electric vehicle use and reduced traffic; improved health and reduced congestion from rationalisation of car journeys and more active travel (i.e. walking and cycling). These benefits are likely to be much greater than potential negative impacts, such as the visual impact of wind turbines.

Impacts of the fourth carbon budget

Wider social and economic impacts associated with the cost-effective path for emissions reduction remain manageable and have not significantly changed since the budget was legislated.

- **Affordability.** The evidence shows that support for low-carbon technologies have contributed only a small proportion of the large energy bill increases since 2004. While there will be some further increases in future, incremental impacts associated with the fourth carbon budget are small.
  - Annual energy bills for the average dual-fuel household included support for low-carbon technologies of £35 in 2012, with an additional £50 to support energy efficiency improvement, often in fuel poor households. The overall rise in energy bills since 2004 has been much larger at £500 per household, mainly due to increases in the international price of gas.
  - Further bill increases announced for 2013/14 include only around £10 for support of investment in low-carbon power generation (i.e. this now costs £45 per household). Given recent announcements by the Government aimed at limiting the bill impact of energy efficiency funding, other factors are driving the much larger announced bill increases for this year.
  - Support for low-carbon technologies will add a further £85 to bills by 2020 (through the EU Emissions Trading System and UK Carbon Price Floor, the Renewables Obligation, Feed-In Tariffs and Electricity Market Reform). This would bring the total cost to £130 per household, alongside the £50 funding for energy efficiency. £30 of this cost reflects the carbon price, which will raise around £2-3 billion in tax revenue.
  - We estimate that the further cost of power sector decarbonisation through the 2020s would be small compared to the wider uncertainties – around £20 over and above policies to which the Government is already committed. Delivering it offers the opportunity for falling bills thereafter.
- **Fuel poverty.** Potential negative impacts of carbon budgets can be offset by appropriate targeting of energy efficiency policies. However, additional policies are needed for the Government to achieve its targets for reducing the number of households in fuel poverty. There is a particular issue for electrically-heated households, where further Government action is urgently needed given the disproportionate impacts of support for low-carbon power generation on this group.
- **Competitiveness.** The Committee has done extensive work to assess the impact of low-carbon policies on competitiveness. Our conclusion is that there has been no significant industry relocation to date as a result of low-carbon policies and there is no reason to expect this in future, given policies currently in place to limit competitiveness risks. Further detail on policy implementation, and extension of compensation policies to 2020 and beyond, is desirable in order to ensure this remains the case and to provide confidence to investors. Although there may be restructuring and relocation of industry in future, there is no evidence to support arguments that this is the result of the UK's low-carbon policies.

- **Fiscal.** Impacts of the carbon budget on the public finances are foreseeable and manageable. Some measures will bring increased revenues (e.g. the EU Emissions Trading System and the Carbon Price Floor), offsetting others which will erode the current tax base (e.g. improved energy efficiency of cars reducing receipts of road fuel duty). Others will require adjustments in current bands to preserve revenues (e.g. Vehicle Excise Duty).
- **Scotland, Wales and Northern Ireland.** The devolved administrations have introduced policy measures and targets that will support delivery of the fourth carbon budget. To deliver their own targets, which for Scotland are more stretching than the fourth carbon budget, it will be important that the UK does not weaken ambition in the currently legislated budget.

Conclusions

We conclude that there is no legal or economic case to loosen the budget. This would run counter to our updated assessment of the likely cost-effective path to the 2050 target in the Climate Change Act, which involves larger emissions reductions than required to meet the budget. Neither could a case be justified by impacts in relation to the criteria listed in the Act, which continue to be manageable, nor by EU developments, given that the budget is at the low end of EU ambition currently being discussed. Furthermore, any proposal to loosen the budget would undermine credibility of the UK in EU and international negotiations and further undermine already fragile investment conditions, particularly as such a proposal would be counter to the available evidence.

Whilst there could be some value in tightening the budget, we have concluded that the evidence is not sufficient to justify this at the current time and that keeping it at the current level will improve the currently poor conditions for investment in low-carbon technologies.

- **Non-traded sector** (i.e. emissions outside the EU Emissions Trading System – transport, buildings, agriculture and non-CO_2 greenhouse gases). If all cost-effective measures were to be implemented, our best estimate is that this would result in outperformance of this part of the budget by around 4%. However, this is within the likely margin of error and could provide flexibility to deal with uncertainties including the pace and cost at which low-carbon measures can be delivered, how the UK population and economy will grow and how these will translate to energy demand and emissions.
- **Traded sector** (i.e. emissions from those sectors of the economy covered by the EU ETS – power generation and energy-intensive industry). The current accounting rules of the Climate Change Act require that this part of the budget should be aligned with the EU ETS path through the 2020s, once this is agreed. While current discussions in the EU suggest a tightening of the budget may be required, the negotiations are ongoing and further decisions are required before the budget can be aligned. From a domestic perspective, a judgement on any budget revision should be taken together with setting a target for power sector decarbonisation; the Government and Parliament have decided that any power sector decarbonisation target should be set in 2016 alongside the fifth carbon budget (covering 2028-32).

- **Investor confidence.** We have received the clear message from a wide range of business stakeholders that there is a benefit in sticking with the currently legislated budget, and that any change to this could undermine the certainty that the budget provides.

We therefore recommend that the budget is kept at the currently legislated level, and that the Government should aim for full implementation of cost-effective measures in the 2020s, including power sector decarbonisation, improved energy efficiency and early electrification of heat and transport.

An early confirmation of the budget at its current level would help to improve currently poor conditions for low-carbon investment and to reduce present uncertainties in the energy sector. It would provide a positive signal to UK firms and support the transition of existing industries employing large numbers of people to compete in markets for low-carbon goods and services, thereby helping to avoid potential structural costs.

It remains necessary to monitor all of the factors upon which the budget was determined. Of particular importance will be progress towards EU and international agreements over the next two years.

- If the Government achieves its objective in negotiations over the EU package for 2030 (i.e. if the EU adopts a target for a 50% cut relative to 1990 in the context of a global agreement) then the fourth carbon budget will need to be tightened.
- If there were to be a complete failure in the EU negotiations, then the default trajectory for the EU ETS from the 2009 EU ETS Directive would be adopted as the EU path for the 2020s. This could require a small change in the fourth carbon budget or could be managed within existing budget flexibilities.
- The United Nations process is aiming to agree a global deal in Paris at the end of 2015 to reduce emissions consistent with limiting global temperature rise to 2°C. If this is to be effective it is likely to require a higher emissions reduction from the UK than currently legislated under the fourth carbon budget.

It is also necessary to develop approaches more generally for managing uncertainty about the feasibility and costs of low-carbon measures.

- Our assessment of the cost-effective path to meeting the 2050 target is our best estimate at this time. As such, it is an appropriate basis for current policy.
- The analysis in the report highlights uncertainties related to emissions projections and feasibility and costs associated with low-carbon measures. As we get new information in these respects, it may be appropriate to aim for a different balance between measures.
- This uncertainty should be reflected in approaches to meeting carbon budgets. For example, it will be important to consider under what circumstances it would be appropriate to meet carbon budgets through the purchase of carbon credits rather than by reducing emissions in the UK, or through banking outperformance from earlier budgets. It may also be appropriate to aim to outperform budgets.

- Uncertainty should also be reflected in policy design. The level of ambition in policies should reflect the best understanding of the cost-effective path, while allowing some flexibility to adjust ambition should this understanding change.

The Committee will continue to monitor all the circumstances relevant to carbon budgets as part of our ongoing statutory work and will draw out implications as appropriate for existing budgets and how they are met. If not before, we will publish an assessment of these factors in 2015, when we provide advice on the fifth carbon budget (2028-32) and the 2030 target for power sector decarbonisation.

In the meantime the Government should continue developing its policies to build a low-carbon economy. In particular it should ensure that the Electricity Market Reform is implemented such that it achieves deep decarbonisation of the power sector by 2030, that policies to drive energy efficiency improvement are effective, and that policies to support uptake of renewable heat and low-carbon vehicles are extended into the 2020s.

We will report on existing policies and requirements for the future in our 2014 progress report to Parliament, as part of our statutory assessment of the first carbon budget period.

We set out the analysis that underpins our conclusions in four chapters:

1. Approach to the fourth carbon budget review
2. Climate science, international and EU circumstances
3. The cost-effective path to the 2050 target
4. Impacts of the fourth carbon budget

Chapter 1: Approach to the fourth carbon budget review

Carbon budgets: the cost-effective path to the 2050 target, subject to costs and impacts being manageable

The Climate Change Act sets out the criteria that guide setting of carbon budgets (Box 1.1). Together these imply that carbon budgets should at a minimum reflect the cost-effective path to achieving the 2050 target (i.e. to reduce emissions by at least 80% relative to 1990) subject to wider costs and impacts being manageable. Additional emissions reductions may be appropriate as a UK contribution to EU and global emissions reductions required to tackle dangerous climate change.

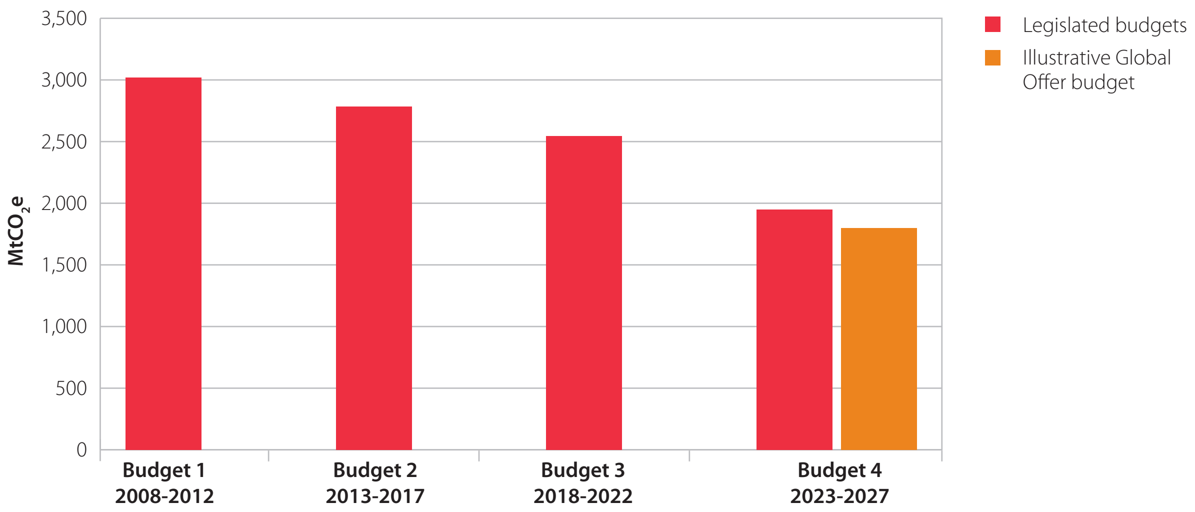
In advising on the fourth carbon budget[1] (covering the period 2023-2027) we recommended a Domestic Action budget, designed to reflect the cost-effective path to meeting the 2050 target; we also suggested a more ambitious Global Offer budget to illustrate what might be appropriate in the context of a new global deal to reduce emissions (Figure 1.1).

- The Domestic Action budget was designed to reflect cost-effective abatement measures in the context of the 2050 target. It requires an emissions reduction of 50% in 2025 on 1990 levels (32% on 2012 levels). We recommended that this budget should be implemented as a minimum in the first instance, with an intention to deliver it through emissions reductions in the UK (i.e. without recourse to purchase of carbon credits or allowances in international trading markets). Our analysis showed that it can be met through a range of measures across the economy; notably power sector decarbonisation, efficiency improvements, electrification of transport and heat, and development of carbon capture and storage (CCS).
- We also suggested a more ambitious Global Offer budget. This was designed to reflect a possible UK contribution to global emissions reduction through the 2020s consistent with our climate objective: to limit expected warming to close to 2°C and keep the risk of a 4°C rise to very low levels. It was more ambitious than the Domestic Action budget, with an illustrative limit of 1,800 $MtCO_2e$ over the period 2023-2027 compared to 1,950 $MtCO_2e$ under the Domestic Action budget. We recommended that the Government should be prepared to commit to this more ambitious budget if and when a global deal covering action in the 2020s is agreed. The additional effort can be met through further domestic effort, plus possible purchase of international credits.

The Government accepted our advice and legislated the Domestic Action budget in June 2011, stating its intention to meet this budget through domestic action[2]. This limits UK emissions of greenhouse gases to 1,950 $MtCO_2e$ over the period 2023-27.

1 CCC (2013) *Fourth Carbon Budget Review – part 1: Assessment of climate risk and the international response* http://www.theccc.org.uk/publication/fourth-carbon-budget-review-part-1
2 HM Government (2011) *Implementing the Climate Change Act 2008: The Government's proposal for setting the fourth carbon budget*, Policy Statement.

Figure 1.1: Carbon budget levels and the illustrative Global Offer budget



Source: CCC.

Box 1.1: Criteria for setting carbon budgets in the Climate Change Act

The Climate Change Act sets out the matters to be taken into account in setting carbon budgets in sections 8 and 10:

- **8** (2) The carbon budget must be set with a view to meeting –
  - a) the target in section 1 (the target for 2050)
- **10** (2) The matters to be taken into account are –
  - a) scientific knowledge about climate change;
  - b) technology relevant to climate change;
  - c) economic circumstances, and in particular the likely impact of the decision on the economy and on the competitiveness of particular sectors of the economy;
  - d) fiscal circumstances, and in particular the likely impact of the decision on taxation, public spending and public borrowing;
  - e) social circumstances, and in particular the likely impact of the decision on fuel poverty;
  - f) energy policy, and in particular the likely impact of the decision on energy supplies and the carbon and energy intensity of the economy;
  - g) differences in circumstances between England, Wales, Scotland and Northern Ireland;
  - h) circumstances at European and international level;
  - i) the estimated amount of reportable emissions from international aviation and international shipping for the budgetary period or periods in question.

Source: Climate Change Act (2008).

Reviewing the fourth carbon budget: is it still cost-effective, and are the costs and impacts manageable?

In accepting our advice and legislating the fourth carbon budget, the Government announced that it would review the level of the budget in 2014.

The Climate Change Act states that a carbon budget can only be changed if "*there have been significant changes affecting the circumstances on which the previous decision was made*"[3]. In changing a budget, the Secretary of State must *"obtain, and take into account, the advice of the Committee on Climate Change"*[4] before proposing it to Parliament for affirmative resolution.

We published the first part of our advice in November[5], concluding that with regard to climate science, European and international circumstances there has been no significant change that would support a change to the budget. The basis for this conclusion is summarised again in Chapter 2.

Given that the budget was set to be cost-effective with manageable costs and impacts, the other key question for the review is: has anything changed significantly since the budget was set such that it is no longer cost-effective, or that the costs and impacts of meeting it are now prohibitive?

Chapter 3 of this report focuses on whether the cost-effective path to the 2050 target has changed significantly given the latest energy and emissions projections, fossil fuel and carbon price projections, updated technology cost estimates, and new evidence on the feasible pace of implementing measures.

Chapter 4 considers the impacts of meeting the budget on energy affordability, security of supply, competitiveness, fiscal circumstances, wider health and environment issues, and considerations for Scotland, Wales and Northern Ireland.

In doing so, this report draws on recent reports we have published assessing affordability and competitiveness impacts of the fourth carbon budget[6] and the implications of latest evidence for the approach to power sector decarbonisation[7].

Given our assessment of all these factors – climate science, international and EU circumstances, cost-effectiveness and wider impacts – we consider whether the level of the fourth carbon budget should remain the same, or whether an increase or decrease in the budget is justified. Our conclusion is that there has been no significant change in circumstances, therefore the budget should not and cannot be changed at this time under the terms of the Climate Change Act.

3 Climate Change Act (2008) 21 (2).
4 Climate Change Act (2008) 22 (1).
5 CCC (2013) *Fourth Carbon Budget Review – part 1: Assessment of climate risk and the international response* http://www.theccc.org.uk/publication/fourth-carbon-budget-review-part-1
6 CCC (2012) *Energy prices and bills – impacts of meeting carbon budgets* http://www.theccc.org.uk/publication/energy-prices-and-bills-impacts-of-meeting-carbon-budgets; CCC (2013) *Reducing the UK's carbon footprint and managing competitiveness risks* http://www.theccc.org.uk/publication/carbon-footprint-and-competitiveness
7 CCC (2013) *Next steps on Electricity Market Reform – securing the benefits of low-carbon investment* http://www.theccc.org.uk/publication/next-steps-on-electricity-market-reform-23-may-2013/

Chapter 2: Climate science, international and EU circumstances

Introduction

The Climate Change Act requires the Committee to consider a range of factors when advising on carbon budgets (see Box 1.1 in Chapter 1).

In the first part of our fourth carbon budget review, published in November 2013[1], we assessed changes in climate science, international and EU circumstances.

We concluded that there has been no significant change in circumstances upon which the fourth carbon budget was set. In these respects there is therefore no basis to support a change in the budget.

This chapter recaps how we reflect climate science, international and EU circumstances in designing carbon budgets and our latest assessment of these criteria, as set out in part one of the review.

1 CCC (2013) *Fourth Carbon Budget Review – part 1: Assessment of climate risk and the international response* http://www.theccc.org.uk/publication/fourth-carbon-budget-review-part-1

Approach to designing carbon budgets

Climate science, international circumstances and EU pathways are reflected in the design of the fourth carbon budget as follows:

Climate science

- Our advice reflects a climate objective: to limit central estimates of 21st Century global temperature rise to as close to 2°C above pre-industrial levels as possible, and to keep the probability of an extremely dangerous 4°C rise at very low levels.
- Global pathways which meet this objective embody peaking of emissions around 2020, followed by rapid reductions, such that they are halved by 2050 and further reduced thereafter.
- The UK's 2050 target reflects global average per capita emissions consistent with these pathways, and an assumption that it is unlikely a future global deal would be agreed in which the UK and other developed countries have per capita emissions above this level. This requires at least an 80% reduction in UK emissions relative to 1990.
- The carbon budgets are designed to reflect the cost-effective path to the statutory 2050 target (see Chapter 3).

International circumstances

- We consider actions other countries are taking and therefore if the UK's fourth carbon budget puts it out of step with the rest of the world, including any implications for competitiveness risks (see Section 2 in Chapter 4).
- Given these actions and progress in the UN talks, we assess the feasibility of global emissions pathways required to deliver our climate objective, and whether this is a suitable basis for policy.

EU pathways

- EU ambition through the 2020s helps shape the cost-effective path to the UK's 2050 target, given the relationship between EU ambition and the carbon price used to design carbon budgets.
- Under the current accounting rules of the Climate Change Act, the contribution of the traded sector, covering power generation and the energy-intensive sectors, to meeting carbon budgets is determined by the UK's share of the cap in the EU Emissions Trading System (EU ETS) (see Box 2.1).
- We take account of possible intra-EU competitiveness risks associated with any difference in the pace of emissions reductions in the UK and elsewhere in the EU.

Box 2.1: How carbon budgets are accounted for under the Climate Change Act

The Climate Change Act sets limits on the UK's 'net carbon account' for 2050 and each carbon budget period.

The net carbon account is calculated by adjusting UK emissions of greenhouse gases for any carbon credits bought or sold in international markets by UK firms or the government.

This means that the Act takes into account that a large proportion of UK emissions are covered by the EU's Emission Trading System (EU ETS), and that these emissions are traded internationally.

UK emissions can therefore be separated into those that are traded internationally (the 'traded sector'), and those that are not traded internationally (the 'non-traded sector').

- Non-traded sector. Emissions in the non-traded sector (i.e. transport, buildings, agriculture, non-CO_2 greenhouse gases) are, for the purposes of carbon budgets, counted equal to those sectors' actual emissions. There is no automatic adjustment for international trading since these sectors are not currently covered by any international trading systems.
- Traded sector. Emissions in the traded sector are those that are covered by the EU ETS (i.e. power generation, energy-intensive industry and domestic aviation). These emissions are adjusted to take account of any trading of emission permits across the EU.
  - The UK has a share of the EU ETS cap. This is defined by the UK's share of each of the three elements of the cap (i.e. freely allocated allowances, auctioned allowances and allowances allocated from the new entrant reserve). This cap determines the traded sector part of the carbon budget.
  - If UK emissions in the traded sector are above the level of the UK's cap, then UK firms must purchase EU ETS permits to cover the difference between actual emissions and the cap. Similarly, if emissions are below the level of the cap then UK firms can sell this difference in permits to firms in other countries.

By definition, after accounting for buying/selling of permits, UK *net* emissions are therefore always equal to the UK's cap. The traded sector part of the budget will always be exactly met, whatever the actual level of UK emissions, so long as the budget is aligned to the cap.

A key question for the review is therefore whether the currently legislated budget is aligned to the possible EU ETS cap for the 2020s. As we set out below, this cap is yet to be agreed, with the current budget aligned to the low end of ambition being discussed.

It remains important to reduce emissions in the traded sector, given the value of these reductions as reflected in the carbon price and the importance of a decarbonised power sector to meeting the 2050 target.

Whether the budget is met overall will be determined by the combination of the UK's share of the EU ETS cap for the traded part of the economy, and actual UK emissions in the non-traded part of the economy.

Latest assessment of climate science, international and EU circumstances

In the first part of our fourth carbon budget review, published in November 2013[2], we assessed changes in climate science, international and EU circumstances.

We concluded that there has been no significant change in circumstances upon which the fourth carbon budget was set. In these respects there is therefore no basis to support a change in the budget.

2 CCC (2013) *Fourth Carbon Budget Review – part 1: Assessment of climate risk and the international response* http://www.theccc.org.uk/publication/fourth-carbon-budget-review-part-1

Climate science

- The latest evidence generally gives more confidence in the reality of climate change, in its cause and in projections for the future. For example, the IPCC's Fifth Assessment concludes that warming of the climate system since the mid-20th Century is unequivocal, and it is extremely likely that human activity is the dominant cause.
- The recent slowdown in surface temperature rise can be explained in terms of short-term fluctuations and cooling from other natural factors. Similar periods occurred in the 20th Century, and they are consistent with longer-term warming.
- Recent assessments of the likely temperature change in response to greenhouse gas concentrations confirm previous ones. In particular, the IPCC provides the same likely range for climate sensitivity as in its first three assessments in 1990, 1995 and 2001, with a slight revision from the fourth assessment in 2007.
- In a scenario where global greenhouse gas emissions were to continue to increase throughout the century, it is likely that global temperature will increase by 4°C or more above pre-industrial levels.
- The latest evidence on risks and damages reinforces our climate objective: to limit central estimates of warming to as close to 2°C as possible, and keep the probability of an extremely dangerous rise of around 4°C to very low levels. To achieve this, global emissions should peak around 2020 followed by rapid cuts, such that emissions are halved by 2050 and fall further thereafter. Delaying peaking to 2030 would raise the costs and risks of achieving the objective, and probably make it unattainable.

International circumstances

- Progress towards a global deal has been slow but broadly as expected when the fourth carbon budget was set. Since 2010 the UN has formally adopted an objective to limit warming to 2°C, and is working towards an agreement aimed at peaking and reducing emissions consistent with this goal. The agreed aim is to resolve that process in Paris at the end of 2015.
- The UK is not acting alone. Many countries have made ambitious commitments to reduce emissions, and are beginning to deliver against these commitments. While there have been backward steps in some countries, there is now widespread coverage by low-carbon policies of major emitting sectors around the world. This provides a good basis for agreeing and implementing an ambitious global deal.
  - Amongst the major emitters, China (29% of global CO_2 emissions) has made significant progress on low-carbon investment. It has made commitments to reduce carbon intensity by 40-45% from 2005 to 2020, and introduced policies to deliver this as part of the 12th five-year plan. With ongoing action, China's emissions could peak in the early-to-mid 2020s.

- The United States (16% of global CO_2 emissions) has a good chance of delivering its Copenhagen Accord commitment to reduce 2020 emissions by 17% on 2005 levels. Going beyond this, there is a major challenge to develop and implement approaches to drive further cuts required through the 2020s.
- Commitments comparable to the UK's have been made by a range of developed and developing countries: Germany in terms of medium-term emissions reduction; China and the US against a 2005 baseline on the basis of carbon-intensity; the US, Japan, the EU and Mexico in terms of 2050 commitments.
- Some countries have made backward steps (e.g. Canada, Australia, Japan), albeit often with ongoing progress behind headline developments. For example, Canada has withdrawn from the Kyoto Protocol but has adopted stretching vehicle fuel efficiency standards and regional carbon trading systems/taxes.
- Coverage of low-carbon laws and policies has increased internationally. Legally-binding legislation requiring emissions reduction has been passed in South Korea and Mexico; global coverage of carbon pricing is now 20% of non-transport emissions and rising (e.g. this has been introduced in parts of China and the US); vehicle standards now cover around 80% of global emissions from road transport.

• Our climate objective and the global emissions reduction required to achieve it remain feasible, but challenging. These remain an appropriate basis for policy, both because of the very significant risks associated with dangerous climate change and the costs of delayed-action pathways. An ambitious fourth carbon budget is important to the global process because of the key role of the UK in securing an effective global agreement.

EU circumstances

• EU ambition for both 2020 and 2030 are relevant for the path through the 2020s and therefore to the fourth carbon budget.

• In relation to 2020, the fourth carbon budget is consistent with the current EU target for a 20% reduction relative to 1990. If a 30% target were to be agreed, which is the UK Government's objective, tightening of the budget might be justified.

• In relation to 2030, negotiations are ongoing, with various options being considered; the legislated budget is towards the low end of ambition being discussed.

- The EC's Low-Carbon Roadmap, published in 2011, identifies cost-effective decarbonisation pathways, and suggests at least a 40% reduction in EU emissions in 2030 relative to 1990. These pathways broadly match the ambition in the fourth carbon budget, both in terms of the underlying cost-effective UK path and the UK's share of a resulting EU ETS cap.

- The range currently being discussed for EU ambition in 2030 goes beyond this. For example, the Government has stated a negotiating position to secure an EU emissions reduction of 30% in 2020 and 50% in 2030 relative to 1990 in the context of an effective global deal; this would require a tightening of the fourth carbon budget.

- There is a default trajectory for the EU ETS cap. This applies should the negotiations fail to agree a new package, and continues the slow rate of decline from the pre-2020 phase. A strategy of aligning to this now and then realigning later once an EU package is agreed would not be legal, practical or sensible:
  - It would amount to a change in the budget without a corresponding change in circumstances and would represent a significant departure from the cost-effective path to the 2050 target. As such, it would not meet the criteria under the Climate Change Act.
  - The precise level of carbon budget implied by the default trajectory is unclear, given that the detailed rules for calculating the UK share of the EU ETS cap in the 2020s are not yet known.
  - Such a strategy and the frequent changes in the budget that it entails would undermine investor confidence. Moreover, it would undermine credibility of the UK in EU negotiations.
  - It would not offer any benefits for competitiveness or a more favourable share for the UK when negotiating how EU-wide targets are split across countries.
- The Government has rightly considered it essential that the UK continues to push for an ambitious EU 2030 package. The UK has an important role in these discussions and an ambitious package is required as part of an effective global response to climate change.

Next steps and implications for designing the fourth carbon budget

We will continue to monitor climate science, international circumstances and EU pathways as part of our ongoing statutory work and draw out any implications for carbon budgets as appropriate.

In the particular case of the EU, this should be regarded as our advice on current circumstances. If and when there are developments, we will provide further advice, consistent with the Climate Change Act, on whether this constitutes a significant change in the circumstances upon which the budget was set and if a change in the budget to tighten or loosen it would be appropriate.

Our assessment of the cost-effectiveness of the fourth carbon budget depends on assumptions over the international carbon price, which in turn depends on uncertain international and EU action to reduce emissions.

In this report we use DECC's long-term carbon values, which are consistent with a range of scenarios for global and EU emissions (see Box 3.1 in Chapter 3), to assess the cost-effective pathway for UK emissions through the 2020s, to which we now turn.

Chapter 3: The cost-effective path to the 2050 target

Introduction and key messages

This chapter sets out our updated assessment of the cost-effective path to meeting the 2050 target.

The updated assessment allows for new evidence on: emissions projections; the feasible pace at which measures can be implemented; and whether these measures are cost effective, depending on technology costs, fossil fuel prices and carbon prices.

We compare our updated assessment with the path reflected in the legislated fourth carbon budget.

Our key conclusion is that there is no rationale to change the budget based on our updated assessment of the cost-effective path to meeting the 2050 target.

- **Feasibility of the budget**. The budget can be met based on more prudent assumptions on implementation of measures than in our original advice (e.g. lower assumed uptake of heat pumps and more limited contribution from solid wall insulation). This is because official projections of energy demand have been revised down to reflect updated evidence on key demand drivers and improved approaches to projecting emissions in line with previous Committee advice.
- **Cost savings of early action.** The budget provides insurance against risks of dangerous climate change and rising energy bills. It offers significant cost savings relative to a path where action to meet the 2050 target is delayed until the 2030s. We estimate that the saving could be over £100 billion in present value terms under central assumptions about fossil fuel and carbon prices, allowing for expected impacts of shale gas; in a world of high fossil fuel prices, the benefit could be as high as £200 billion. Even with low fossil fuel or carbon prices, the budget would offer a cost saving compared to an alternative path where action to reduce emissions is delayed.
- **Keeping the budget at its current level.** Our updated best estimate of the cost-effective path to the 2050 target implies a larger reduction in emissions in the 2020s than required by the budget. This could imply that a tighter budget (i.e. requiring a larger emissions reduction) is appropriate. However, it would be premature to tighten the budget now, given uncertainties over the cost-effective path, EU emissions targets for the 2020s and the precise path for UK power sector decarbonisation under the Electricity Market Reform. Any change now would require a further change later, once these issues are resolved, and frequent budget changes would undermine the certainty that they are meant to provide.

– **Non-traded sector** (i.e. emissions outside the EU Emissions Trading System – transport, buildings, agriculture and non-CO_2 greenhouse gases). If all cost-effective measures were to be implemented, our best estimate is that this would result in outperformance of this part of the budget by around 4%. However, this is within the likely margin of error and could provide flexibility to deal with uncertainties including the pace and cost at which low-carbon measures can be delivered, how the UK population and economy will grow and how these will translate to energy demand and emissions.

– **Traded sector** (i.e. emissions from those sectors of the economy covered by the EU ETS – power generation and energy-intensive industry). The current accounting rules of the Climate Change Act require that this part of the budget should be aligned with the EU ETS path through the 2020s, once this is agreed. While current discussions in the EU suggest a tightening of the budget may be required, the negotiations are ongoing and further decisions are required before the budget can be aligned. From a domestic perspective, a judgement on any budget revision should be taken together with setting a target for power sector decarbonisation; the Government and Parliament have decided that any power sector decarbonisation target should be set in 2016 alongside the fifth carbon budget (covering 2028-32).

– **Investor confidence.** We have received the clear message from a wide range of business stakeholders that there is a benefit in sticking with the currently legislated budget, and that any change to this could undermine the certainty that the budget provides.

– Our updated analysis shows that there should be no lowering of ambition in the budget. This would imply a further departure from the cost-effective path to meeting the 2050 target, which could not be justified in terms of any change in the impacts associated with meeting the budget (e.g. affordability or competitiveness, see Chapter 4). Furthermore, any proposal to loosen the budget would undermine credibility of the UK in EU and international negotiations and further undermine already fragile investment conditions, particularly as such a proposal would be counter to the available evidence.

Taken together with our assessment of the impacts from meeting the budget, which remain unchanged (see Chapter 4), and our assessment of climate science, international and EU circumstances (see Chapter 2), there is therefore no legal or economic basis to change the budget at the current time.

Given the short lead-time to the 2020s, the focus now should be on putting in place policies to support implementation of cost-effective measures, including early decarbonisation of the power sector.

- **Power.** Implement the Electricity Market Reform such that this supports portfolio investment in low-carbon technologies and supply-chain investment, thereby ensuring early decarbonisation of the power sector with significant consumer benefit. Key challenges include setting strike prices at the right level, and providing confidence to investors that there will be sufficient and ongoing volume to 2020 and beyond.

- **Buildings energy efficiency.** Put in place incentives for uptake of the full range of cost-effective measures in residential and non-residential buildings. Monitor the effectiveness of these policies, responding as necessary if uptake is low, while ensuring that there are safeguards in place to prevent cost escalation.
- **Low-carbon heat.** Put in place approaches to address financial and non-financial barriers to support very significantly increased levels of investment in heat pumps; and to carry out detailed feasibility studies and move forward with investments in district heating infrastructure.
- **Transport.** Continue to press for stretching efficiency standards for new vehicles at the EU level, out to 2030. Continue to support market development for electric vehicles through purchase subsidy and investment in charging infrastructure.
- **Industry.** Develop approaches to demonstration and then deployment of carbon capture and storage (CCS) in industry. Continue to develop the evidence base on potential for improved energy efficiency. Ensure that policies to address potential competitiveness effects of low-carbon are clear and extend sufficiently into the future to cover investment cycles (see Chapter 4).

We will set out a detailed assessment of these challenges in our sixth report to Parliament on progress reducing emissions, to be published in July 2014.

We will continue to monitor closely all the relevant factors in budget design. We will report on the fifth carbon budget and the power sector decarbonisation target together with any possible adjustment to the fourth carbon budget in 2015, by which time we expect better information to be available about the EU and international contexts for emissions reduction.

1. Recap of approach in the fourth carbon budget: the cost-effective path to the 2050 target

Principles upon which the fourth carbon budget was designed

The fourth carbon budget was designed to embody the cost-effective path to the 2050 target legislated in the Climate Change Act (i.e. to reduce emissions by at least 80% relative to 1990), subject to the wider economic and social impacts being manageable (see Chapter 4).

We define the cost-effective path as comprising measures that cost less than the projected carbon price across their lifetimes (Box 3.1), together with measures that may cost more than the projected carbon price, but are necessary in order to manage costs and risks of meeting the 2050 target.

- **Measures that cost less than the projected carbon price.** The implication of constraining emissions is that there is a value to emissions reduction. This may be explicit, for example a carbon tax or a carbon price generated in a cap-and-trade scheme, or implicit, for example in meeting a regulation or emissions constraint. There is then a clear economic benefit in abatement measures that reduce emissions at a cost below the carbon price, either through avoiding emitting activities like energy use or delivering them through low-carbon means. Examples of abatement options which our previous analysis has suggested are or are likely to become cost-effective in this way for investment to 2030 include avoided waste in energy use, energy efficiency improvement in buildings, fuel efficiency improvement in vehicles, nuclear and some renewable power generation technologies.
- **Measures that are cost-effective in the context of the 2050 target.** Many abatement options that may be required to meet the 2050 target are not yet fully developed. It is important to invest in these options in the near-to-medium term given the need to drive technology innovation and market development, prior to widespread uptake in the 2030s and 2040s. In the short term, this may cost more than investment in conventional fossil fuel alternatives, even when a projected carbon price is included. However, this additional cost can be justified in terms of option development and long-term reductions in cost and risk. Our previous analysis has suggested that investment in electric vehicles, offshore wind and CCS can be justified on this basis.

Recent decisions and analysis reinforce the need to prepare for deep emissions cuts by 2050:

- The Government confirmed in December 2012 that emissions from international aviation and shipping are included in the 80% emissions reduction target for 2050. Given the difficulty in delivering deep reductions in emissions from international aviation and shipping (e.g. due to limited opportunities for low-carbon fuels and projected aviation demand growth), this reinforces the need to develop options that could reduce emissions in other sectors to very low levels.
- The Committee's 2012 report on *The 2050 target* reinforced the finding from our first report[1], when we argued that the UK should put itself in a position to meet the 2050 target through domestic (i.e. UK) action, with a potential role for credits to reduce costs at the margin. This is because reducing global emissions to an average of 2 tCO_2e per capita by 2050 is sufficiently stretching that extensive volumes of credits are unlikely to be available in the long term at reasonable cost.
- The Committee's April 2013 report on the UK's carbon footprint[2] concluded that the UK is likely to continue being a net importer of emissions embodied in industrial products out to 2050 and beyond. This will make emissions targets in other countries relatively harder to meet, and emphasises the need for the UK to prepare to meet the 2050 target through domestic action, rather than through purchasing emissions credits.

1 CCC (2008). *Building a low-carbon economy.* Available at http://www.theccc.org.uk/publication/building-a-low-carbon-economy-the-uks-contribution-to-tackling-climate-change-2/
2 CCC (April 2013). *Reducing the UK's carbon footprint and managing competitiveness risks.* Available at http://www.theccc.org.uk/publication/carbon-footprint-and-competitiveness/

Box 3.1: Carbon prices used in our analysis

Carbon price projections have an important role in our analysis, in the identification of cost-effective abatement options and emissions pathways in the UK through the 2020s. Our budgets are based on pathways that are cost-effective relative to the carbon price and required on the path to meeting the 2050 target.

We judge the cost-effectiveness of measures by reference to carbon price projections across the asset lives of low-carbon investments (e.g. the carbon savings from an electric vehicle purchased in 2025 will accrue from that year until the vehicle is replaced in the late 2030s).

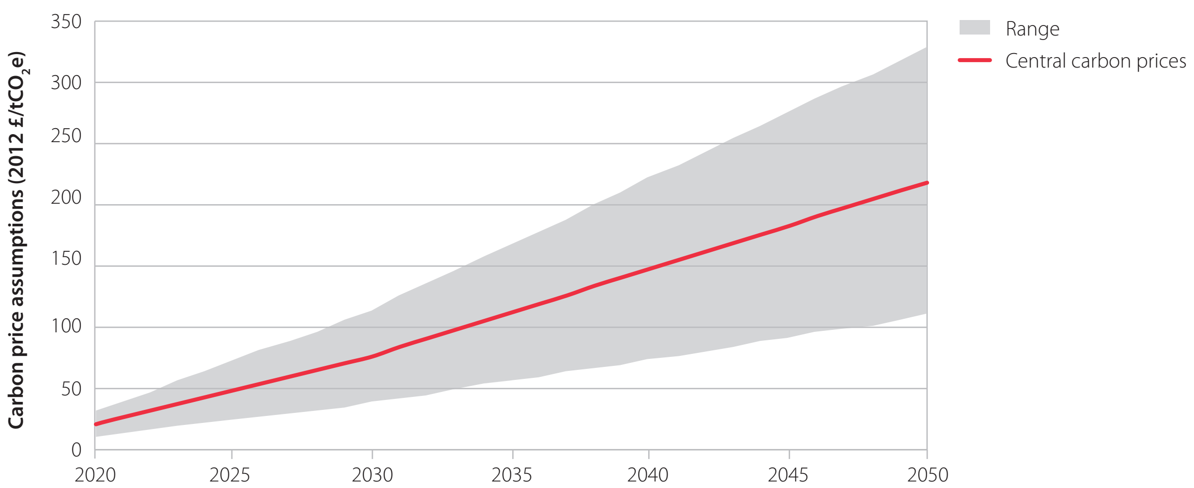
As set out in more detail in the first part of our review[3], our updated assessment of the cost-effective abatement path uses carbon values based mainly on the Government's projected values (Figure B3.1):

- For 2030 to 2050, we use the full range of DECC carbon appraisal values. These have central levels of £76/tonne in 2030 and £216/tonne in 2050 (2012 prices), with low and high values 50% below and above the central levels.
- For the period prior to 2030, we use the European Commission's value of €25/tonne (£21/tonne) in 2020, rising linearly through the 2020s and reaching DECC's appraisal value of £76/tonne for 2030. The EC value for 2020 represents a projection of the EU carbon price on a cost-effective trajectory towards an emissions reduction of at least 80% in 2050, going through 25% in 2020. We again use low and high values 50% below and above this central assumption (i.e. as in the Government's values post-2030) for sensitivity analysis.
- These assumptions are similar to those that we used in our original advice on the fourth carbon budget, when we assumed carbon prices of £29/tonne in 2020, £76/tonne in 2030 and £216/tonne in 2050 (£27, £70 and £200 respectively in 2009 prices).

Sensitivity analysis across the range of possible carbon prices allows us to test the robustness of the fourth carbon budget across the uncertainties that we have identified, and the extent to which flexibility may be required in approaches to meeting the budget.

Although lower prices are possible if the world fails to act sufficiently (e.g. a combination of low ambition and the economic slowdown has resulted in very low carbon prices in the European trading scheme currently), this would not be consistent with keeping expected global temperature increase close to 2°C or with the UK 2050 target to reduce emissions by 80%. Lower prices would therefore not be an appropriate basis for the carbon budget analysis.

Figure B3.1: Carbon prices used for the Fourth Carbon Budget Review analysis



Source: DECC (2009) Carbon Valuation in UK Policy Appraisal: A Revised Approach; EC (2011) Low-Carbon Roadmap.
Notes: Linear interpolation assumed between the EC point for 2020 and the DECC point for 2030, as in DECC methodology post-2030.

3 CCC (November 2013) *Fourth Carbon Budget Review – part 1: Assessment of climate risk and the international response.* Available at www.theccc.org.uk/publications

The level of the fourth carbon budget – and how to meet it

Our previous analysis led us to recommend a fourth carbon budget involving a 50% cut in emissions in 2025 relative to 1990 levels (32% on 2012 levels).

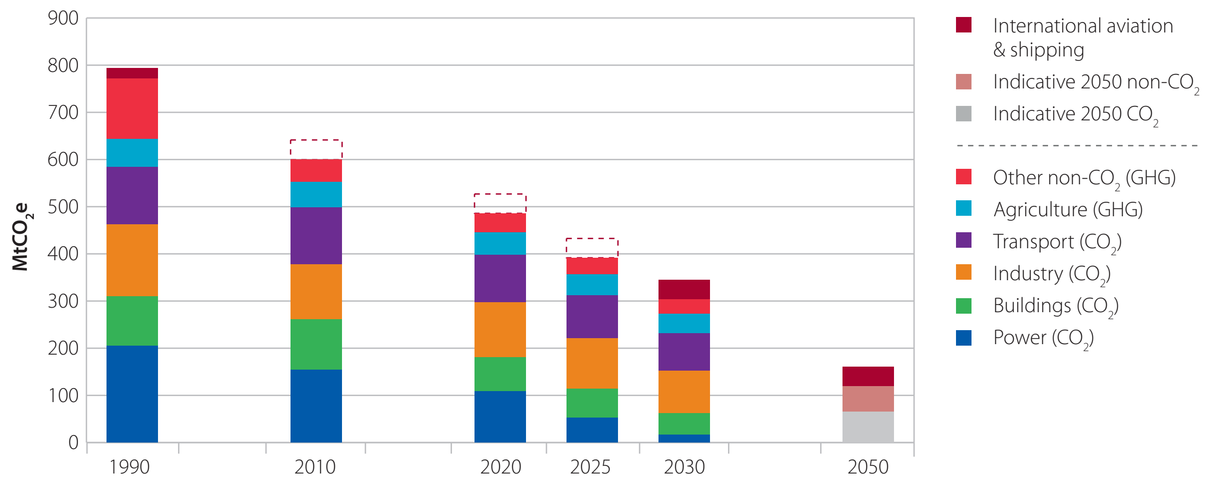
Meeting the budget requires investment in each of energy efficiency improvement, fuel efficiency improvement, power sector decarbonisation, some electrification of surface transport and heat, and use of sustainable bioenergy (Figure 3.1). Our original fourth budget advice included an illustrative scenario which would achieve the budget, including the following measures:

- **Power sector decarbonisation.** Investment focused on low-carbon capacity through the 2020s, resulting in a reduction in carbon intensity from around 300 gCO_2/kWh in 2020 to around 50 gCO_2/kWh in 2030. The aim should be to achieve these kinds of emissions reduction through investment in a technology portfolio including renewables, nuclear and carbon capture and storage (CCS) applied to coal and gas. The scenario included a 30% demand increase from 2020 to 2030, reflecting increased uptake of electric vehicles and heat pumps.
- **Energy efficiency improvement.** Continued improvements in energy efficiency, following on from substantial roll-out during the first three carbon budget periods.
  - **Buildings.** Ongoing energy efficiency improvement through the 2020s, including cumulative insulation of 3.5 million solid walls by 2030 in the residential sector.
  - **Transport.** Further improvement of new conventional vehicle efficiency, to 80 gCO_2/km for conventional cars and 120 gCO_2/km for conventional vans in 2030.
  - **Industry.** We did not assume any further improvements in industrial energy efficiency during the 2020s, reflecting the weakness of the evidence base on the potential for such measures.
- **Electrification of surface transport.** A 60% penetration of electric vehicles in new car sales by 2030, the majority of which were assumed to be plug-in hybrids rather than pure electric, reflecting ongoing concerns around range constraints. We assumed some role for hydrogen vehicles in niche sectors (e.g. 50% of new buses in 2030), with the possibility of broader penetration.
- **Electrification of heat.** The key option for supply-side decarbonisation in our scenario was deployment of heat pumps. These reached a penetration rate of 25% of heat demand in the residential sector, and around 60% in the non-residential sector by 2030. We assumed a limited role for district heating, reflecting uncertainties around technical and economic aspects of this option, with the possibility of deeper penetration as uncertainties are resolved.
- **Use of sustainable bioenergy.**
  - **Biofuels in transport.** We took a cautious approach to sustainable biofuels, assuming no growth in the 2020s from the level recommended for 2020 in the Gallagher Review.

- – **Bioenergy in heat.** Bioenergy provides a particularly useful option in the industrial sector, given the lack of low-carbon alternatives for industry decarbonisation. A limited deployment of biomass and biogas for buildings heat was assumed.
- – **Biomass in power.** We assumed limited use of biomass in the power sector, given available alternatives for sector decarbonisation and the scarce resource of sustainable bioenergy.

- **Agriculture non-CO_2.** Continuation of progress during the 2010s implementing soils and livestock measures. The scenario recognised the possibility of, but does not require, consumer behaviour change, both as regards reducing waste and rebalancing diet to less carbon-intensive foods. It included emissions reduction potential from increasing afforestation in the 2020s.

Figure 3.1: UK Greenhouse gas emissions scenarios (1990-2050) from the CCC's 2010 advice on the Fourth Carbon Budget



Source: NAEI (2010); CCC modelling.
Notes: Emissions from international aviation and shipping are not currently included in carbon budget accounting, but Government have confirmed that they are included in the 80% emissions reduction target for 2050.

These measures led to emissions of 690 $MtCO_2e$ in the traded sector of the economy (i.e. for those sectors covered by the EU ETS – power generation and energy-intensive industry) and 1,260 $MtCO_2e$ in the rest of the economy – the non-traded sector. Together they formed the basis for the legislated budget of 1,950 $MtCO_2e$ (i.e. 690 plus 1,260). This implies a reduction of 50% in emissions by 2025 relative to 1990, which we suggested should be regarded as a minimum level of effort given the need to prepare for the 2050 target and to contribute to global emissions reduction.

2. Update of cost-effective abatement options and scenarios

This section summarises the updated evidence on baseline emissions and abatement potential, and the implications for the cost-effective path to meeting the 2050 target. We also set out this evidence in full in a technical report published on our website alongside this report.

a) New evidence that we consider in this report

Our updated assessment looks at new evidence on the cost-effective path to the 2050 target, including: emissions projections; the feasible pace at which measures can be implemented; and whether these measures are cost effective, depending on technology costs, fossil fuel prices and carbon prices.

- **Baseline emissions projections.** The emissions scenarios underpinning the fourth carbon budget were developed from DECC's official baseline projections assuming no further low-carbon investment beyond 2020, which were then adjusted to reflect uptake of abatement options. Updated baseline projections of emissions reflect the latest economic data and expectations for fossil fuel prices, as well as improved approaches to forecasting. They have been reduced significantly since the fourth budget was set, particularly for industry and electricity sectors. Other things equal, this could suggest that a tightening of the budget is appropriate.
- **Feasibility of abatement options.** The analysis for the fourth carbon budget made assumptions about the pace at which abatement options could be implemented. In turn, these reflected assumptions on capital stock turnover, consumer acceptability, and supply chain development. In this report, we consider new evidence on the pace of feasible investment in low-carbon technologies. A faster or slower pace of feasible investment could suggest the need to adjust the budget.
- **Cost-effectiveness of abatement options.** The cost of reducing emissions depends on the relative costs of the low-carbon solutions compared to the cost of continuing to consume fossil fuels as currently. Whether these are cost-effective depends on the carbon price that the UK faces.
  - **Low-carbon technology costs.** Future costs of abatement options are inherently uncertain, reflecting uncertainty over current costs and scope for cost reduction. In this report we review cost assumptions underpinning the fourth carbon budget, and update these based on latest evidence. Significantly higher or lower costs than previously assumed could suggest that a different level of uptake is appropriate on the cost-effective path.

- **Fossil fuel price projections.** These are important in estimating the cost of conventional fossil fuel investments, against which cost effectiveness of investments in energy efficiency and low-carbon technologies can be assessed. We consider latest fossil fuel price projections, including potential impacts of shale gas on gas prices (Box 3.2). Higher or lower fossil fuel prices could suggest a different set of cost-effective investments in low-carbon technologies.
- **Carbon price projections.** These are a key driver of whether low-carbon investments are cost effective compared to conventional fossil fuel alternatives. For example, a higher carbon price would suggest more investment in low-carbon technologies is appropriate, while a lower price would point to less. We consider a set of carbon price projections consistent with our updated assessment of climate science, international and EU contexts, and which reflect the range of uncertainty for each (see Box 3.1 above).

Subject to other impacts remaining manageable (see Chapter 4), and other relevant circumstances remaining unchanged (see Chapter 2), only if there were a substantive change in the assessment of the cost-effective path to meeting the 2050 target would a change in the fourth carbon budget be justified, and allowed under the Climate Change Act.

We now summarise the latest evidence on emissions projections and our updated assessment of feasibility and costs of abatement measures.

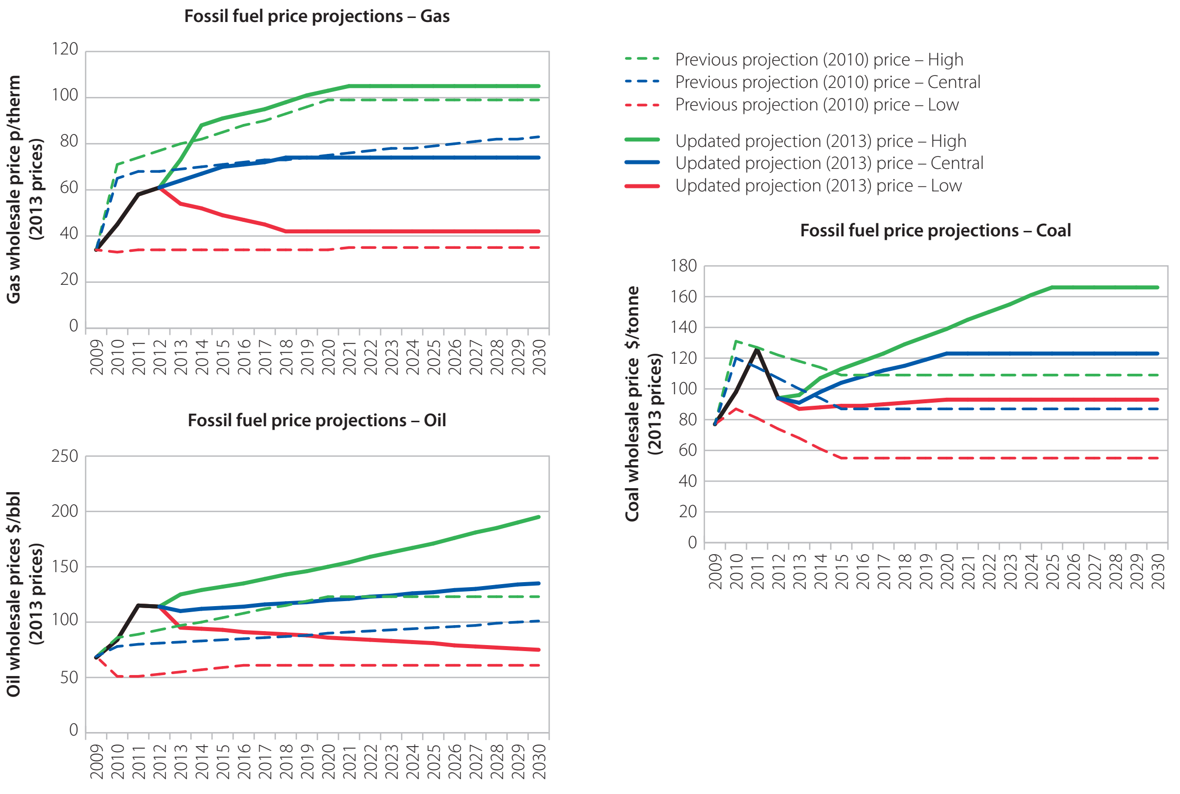
Box 3.2: Changes to DECC's fossil fuel price scenarios since 2010

In our 2010 advice on the level of the fourth carbon budget we used DECC fossil fuel price scenarios from June 2010. These scenarios have since been updated. In this report, we use the latest fossil fuel price projections from DECC's 2013 Updated Energy Projections (UEP). The changes to the fossil fuel price projections (Figure B3.2) are as follows (all data in 2013 prices):

- **Gas.** In 2010, DECC's central gas price scenario anticipated an increase from 75p/therm in 2020, to 79p/therm in 2025 and 83p/therm in 2030. The latest central price assumption has now decreased slightly to 74p/therm in 2020 and then remains constant at that level to 2030. In 2010 DECC's range for gas prices in 2030 was 39-108p/therm, whereas in 2013 the assumed range for 2030 is 42-105p/therm.
- **Oil.** In 2010 central oil prices were projected to increase from 90$/bbl in 2020, to 95$/bbl in 2025 and 101$/bbl in 2030. The central price has now increased to 120$/bbl in 2020, 127$/bbl in 2025 and 135$/bbl in 2030. In 2010 DECC's range for oil prices was 67-134$/bbl in 2030, whereas in 2013 the assumed range for 2030 is 75-195$/bbl.
- **Coal.** In 2010 central coal prices were projected to reach 87$/tonne in 2020 and remain there until 2030. In the latest projections, the central price reaches 123$/tonne in 2020 and remains there until 2030. In 2010 DECC's range for coal prices was 55-109$/tonne in 2030, whereas in 2013 the assumed range for 2030 is 93-166$/tonne.

DECC's latest scenarios take account of the potential for shale gas production in the UK and elsewhere. This has only a minor impact on gas prices in the central scenario, given the interconnectedness of the European gas network, constraints on shale gas production in Europe (e.g. due to high population density and environmental regulation) and the context of declining conventional natural gas production.

Figure B3.2: UK fossil fuel price projections (2010-2030)



Source: DECC (2010) *Energy and emissions projections*; DECC (2013) Energy and emissions projections.

b) New projections for baseline emissions

Since our original advice, assumptions for the drivers of energy demand have changed, with lower expected GDP in the 2020s, higher population numbers and changes in fossil fuel prices (see Box 3.2 above). DECC have also improved their modelling approach for projecting emissions.

- **GDP.** In the 2013 updated projections, GDP is projected to grow by 35% to 2025, at which time it will be 6% lower than was projected in 2010.
- **Population.** Under updated 2011 Office of National Statistics projections, the UK population is projected to grow by 10% from 2010 to 2025. This gives a population around 1.3% higher in 2025 than the projection published in 2009.
- **Modelling approach.** In 2011 the Committee commissioned a review of the DECC energy demand model, which made a number of recommendations for how this could be improved. Subsequently, the DECC model has been updated to include a new model of electricity supply, and energy demand equations have been improved, especially for the industrial sector, where the equations now better reflect historic trends and current structure.

There have also been changes in how the UK emissions inventory is defined and calculated. This has specifically affected shipping emissions, where an improved estimate has reduced the share allocated to domestic shipping and increased that for international shipping (which is not currently covered by carbon budgets), and waste emissions, where an improved methodology has been adopted for calculating methane emissions from landfill.

As a result, DECC's projections for emissions within the scope of carbon budgets have been reduced for the 2020s. In a baseline scenario that includes measures which we have previously recommended should be implemented to 2020 (and which the Government has largely already implemented or committed to, e.g. deployment of renewables, efficiency standards for new vehicles, insulation in buildings), but no further measures beyond 2020:

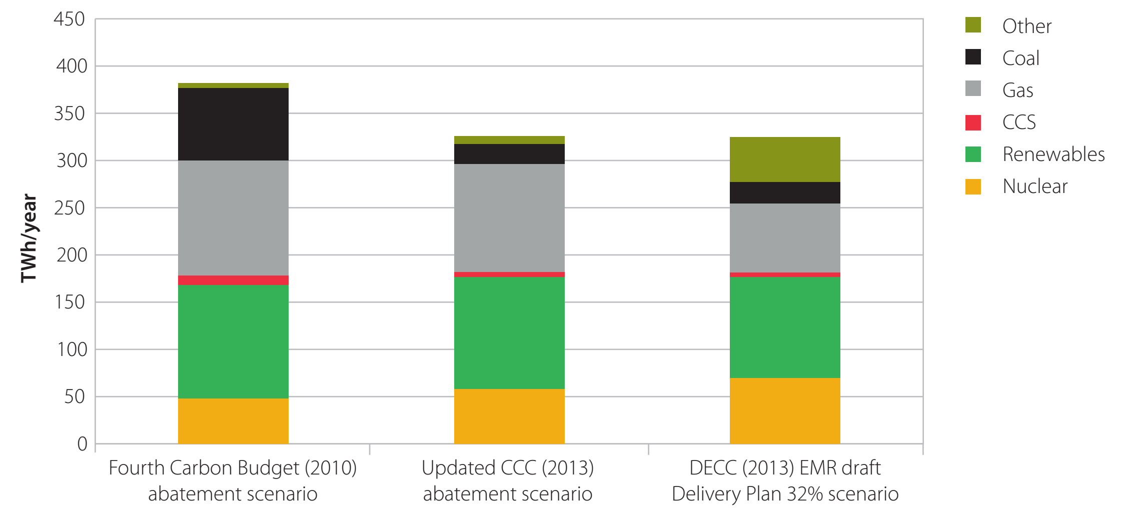
- Greenhouse gas emissions outside the power sector are now projected to fall by 6.3% from 2010 to reach 408 $MtCO_2e$ in 2030. Relative to our previous assessment, this is a substantial reduction in projected emissions before abatement action (220 $MtCO_2e$ less across the five-year fourth budget period). It reflects lower projections of both CO_2 and non-CO_2 emissions.
  - CO_2 emissions (excluding power emissions) are projected to fall by 1.8% from 2010 to reach 335 $MtCO_2$ in 2030 in our baseline projection. Across the fourth budget period CO_2 emissions are now projected to be 183 $MtCO_2$ lower than previously expected. The biggest change is in the industry sector, reflecting the latest economic data and DECC's improved projection methodology, where emissions are now expected to be 130 $MtCO_2$ lower than previously assumed across the carbon budget period.
  - Non-CO_2 emissions projections have also been revised down, primarily due to an improved methodology for measuring and projecting waste emissions. The latest projections are for a fall of 23% from 2010 to reach 73 $MtCO_2e$ in 2030 in our baseline scenario. Projected emissions across the fourth budget period are now 37 $MtCO_2e$ lower than previously expected.

- In the power sector, we use DECC's baseline projection of demand for electricity and undertake our own modelling of supply
  - Electricity demand in the baseline projection is expected to increase by 22% (previously 25%) from 2010 to reach 400 TWh in 2030. Projected electricity demand during the fourth carbon budget period is now expected to average 370 TWh/year if there is no additional abatement effort; this is 2% lower than previously expected.
  - Projected power sector emissions have decreased significantly since our advice in 2010, mainly due to a more rapid assumed fall in coal-fired generation. The amount of unabated coal-fired generation assumed for 2020 has reduced by 72% to 21 TWh (Figure 3.2). This is due to a combination of: reduced overall demand reducing the need for coal generation; greater assumed generation from existing nuclear plants due to announced life extensions; plans to convert existing coal units to biomass; an assumption that any coal CCS demonstrations would have CO_2 capture applied to all units; and latest assumptions relating to the impact of the Industrial Emissions Directive on coal-fired capacity. These new assumptions are also reflected in DECC's latest analysis for the EMR Delivery Plan.

Taken together these updated projections suggest that the legislated budget could be met with less abatement effort than we previously expected in both the traded and non-traded sectors of the economy (Figure 3.3).

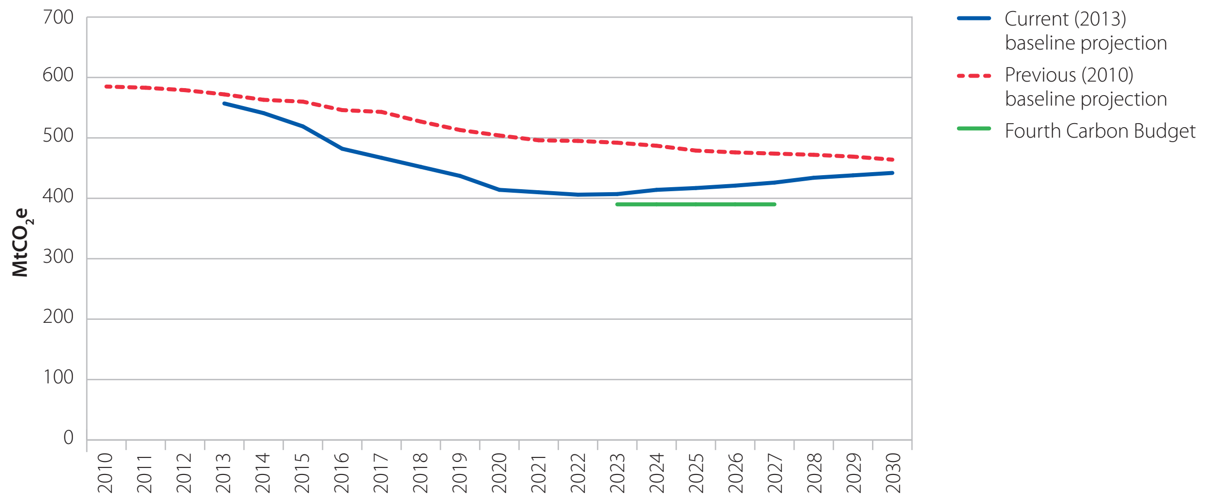
However, the new projections still imply that meeting the fourth carbon budget will need a significant reduction in emissions against the baseline scenario. We now turn to the latest evidence on the potential to make these reductions.

Figure 3.2: UK power generation in 2020



Source: CCC (December 2010) The Fourth Carbon Budget – Reducing emissions through the 2020s; DECC (July 2013) Draft EMR Delivery Plan; CCC calculations based on Redpoint (2012) and (2013) modelling.
Notes: Generation from major power producers only; renewable generation from all generators. DECC scenario reflects generation mix in 32% scenario in draft EMR Delivery Plan (July 2013). Other category includes pumped storage, gas CHP, oil, and imports. CCC updated abatement scenario assumes no imports in 2020 (instead generation is supplied by gas CCGT) while DECC EMR scenario includes imports. Renewables includes onshore and offshore wind, solar PV, marine. biomass and hydro as well as other renewables identified in DECC's 2013 draft EMR Delivery Plan. Nuclear generation in updated CCC (2013) abatement scenario is lower than DECC (2013) EMR draft Delivery Plan to reflect recently announced (October 2013) delay in Hinkley Point C timeline.

Figure 3.3: Projections for UK greenhouse gas emissions covered by carbon budgets with committed ambition to 2020 and no further measures in the 2020s



Source: DECC (2013) Energy and emissions projections; CCC modelling.

c) Updated evidence on cost-effective abatement potential

Options for reducing emissions in the power sector

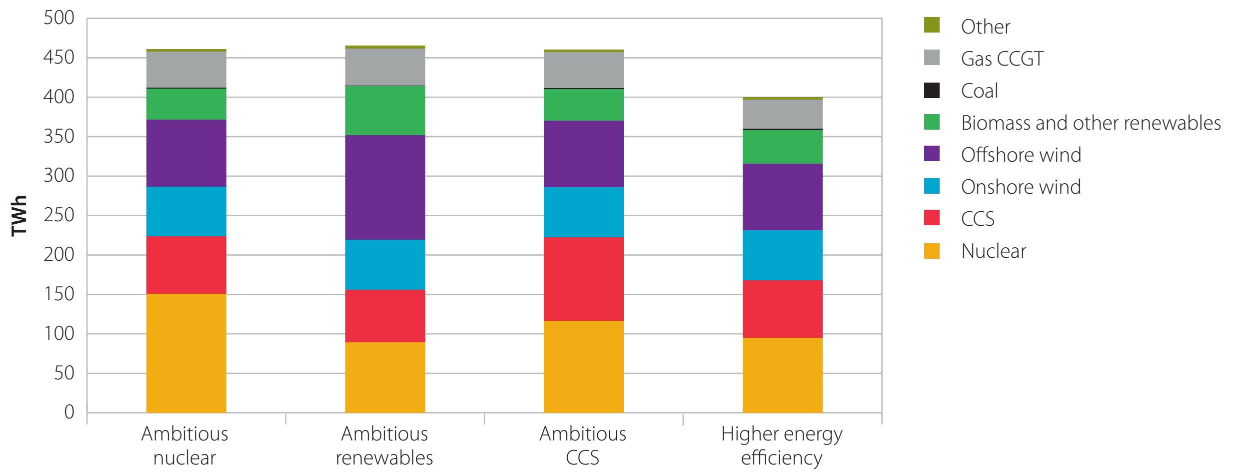
We reviewed the latest evidence on low-carbon power technologies (nuclear, renewables and carbon capture and storage – CCS) in our report *Next steps on Electricity Market Reform*, published in May 2013. In that report, we concluded that the pace of investment in low-carbon technologies assumed when designing the fourth carbon budget remains feasible, and that there is potential for each of the key technologies to become cost-effective through investment in the period to 2030.

- There are various investment pathways that remain feasible to achieve carbon-intensity of around 50 gCO_2/kWh in 2030, as reflected in the fourth carbon budget. These pathways embody a different balance of investment between renewables, nuclear and CCS or more success in reducing electricity demand (Figures 3.4 and 3.5).

- Our updated assessment of low-carbon technology costs reinforced our previous conclusions, which are also consistent with recent announcements on strike prices (Figures 3.6 and 3.7).
  - Nuclear and onshore wind are likely to have broadly comparable costs to new unabated gas-fired generation under projected carbon prices (which at around £50/tonne in 2025 implies a cost of gas generation of £80/MWh in that year, and an average of £100/MWh over a 15-year lifetime, given rising carbon prices). Investing in these technologies in preference to unabated gas can therefore offer a cost saving over plant lifetimes.
  - Projected costs of offshore wind and CCS in the 2020s are currently relatively high. This reflects the fact that these technologies are less mature. There is scope for significant cost reduction such that offshore wind and CCS become cost-effective compared to gas generation under central carbon prices during the 2020s or soon after. These technologies are potentially important in the long run, suggesting that deployment to drive down costs is desirable.
  - Recent announcements on strike prices are in line with these conclusions, noting that these are not directly comparable to costs. At £92.50/MWh the price for the first nuclear plant is in line with our assumptions of £85-100/MWh, and the contract terms explicitly recognise the scope for costs to fall for future projects. The strike prices proposed in the Government's draft delivery plan for onshore and offshore wind (£100/MWh and £150/MWh for contracts signed this year) are broadly comparable to the prices that we suggested would be required in our May 2013 report.

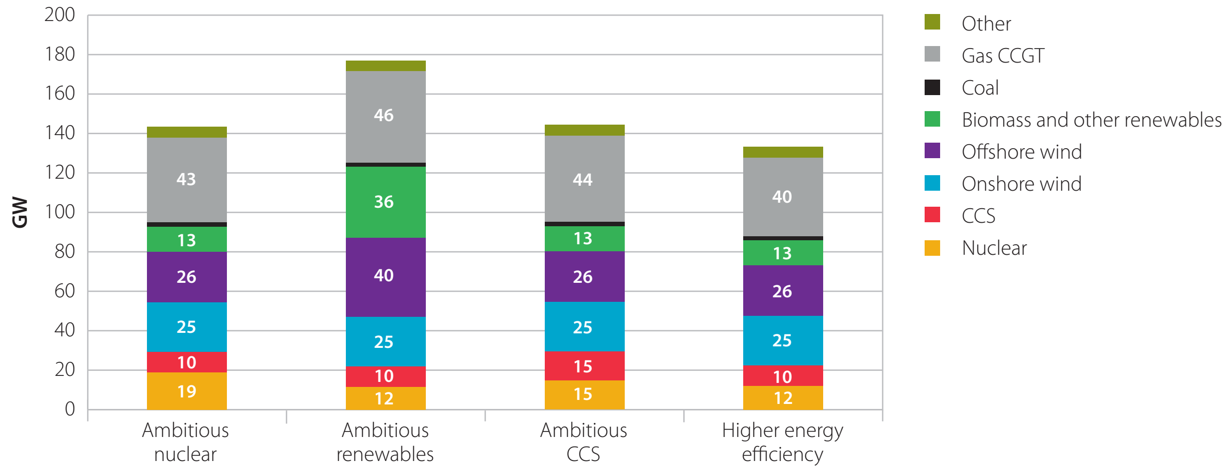
This updated assessment of the feasible pace of investment and costs informs our updated core emissions scenario. We also consider a sensitivity where deployment is slightly slower.

Figure 3.4: Power sector scenarios reaching 50gCO_2/kWh by 2030 – generation (TWh)



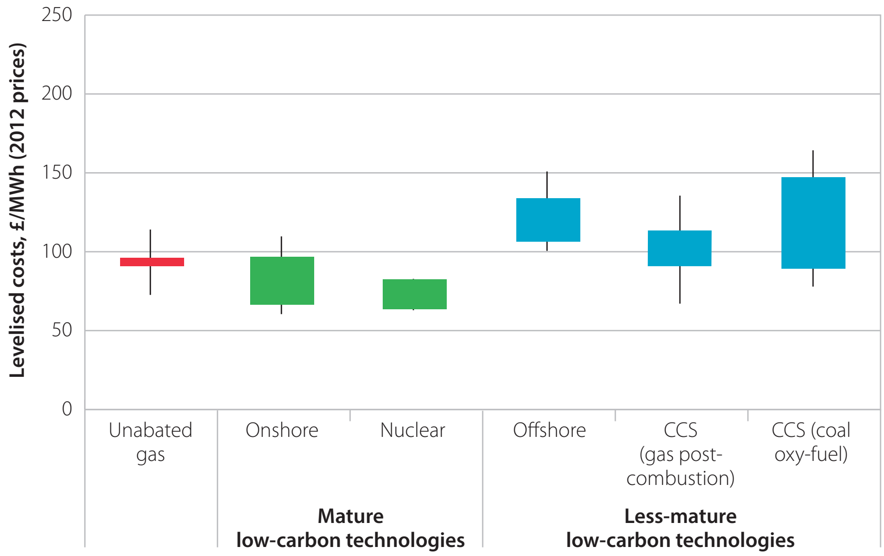
Source: Redpoint, CCC calculations.
Notes: Other includes Pumped Storage and Gas CHP. Other renewables include solar PV, marine and hydro. Excludes autogeneration consumed onsite. CCGT: Combined Cycle Gas Turbine. All the scenario data are presented at UK level, including a small adjustment to add Northern Ireland to the GB-level outputs of the Redpoint modelling.

Figure 3.5: Power sector scenarios reaching 50gCO_2/kWh by 2030 – installed capacity (GW)



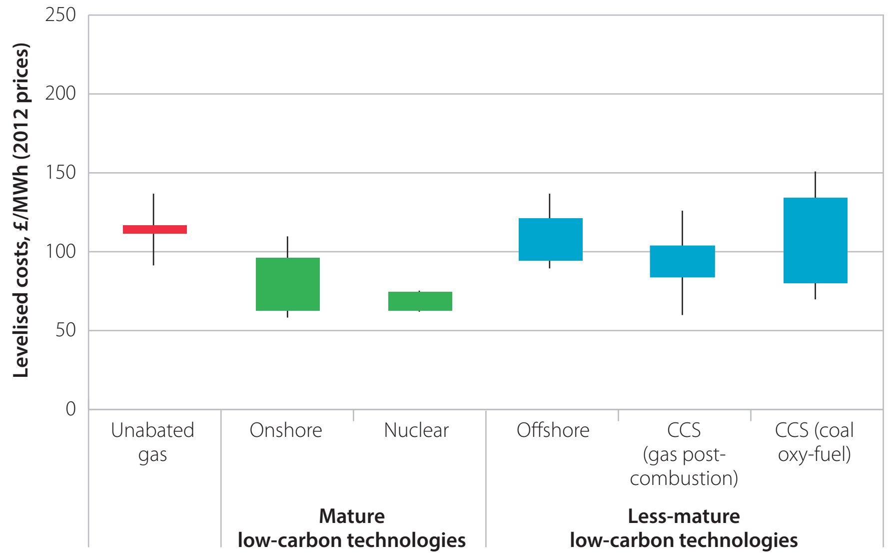
Source: Redpoint, CCC calculations.
Notes: Other includes Pumped Storage and Gas CHP. Other renewables include solar PV, marine and hydro. Excludes autogeneration consumed onsite. CCGT: Combined Cycle Gas Turbine. Nameplate capacity (not derated for availability).

Figure 3.6: Projected costs of low-carbon technologies (2020) relative to unabated gas



Source: CCC calculations based on Poyry, Parsons Brinckerhoff.
Notes: Costs for projects starting construction in 2020. Excludes conversion of existing coal plants to biomass, which comes on in 2010s. Fuel price assumption consistent with DECC projections (October 2012). Carbon price rises in line with Carbon Price Floor, to £32/t in 2020 and £76/t in 2030. Beyond 2030 rises in line with Government 'central' carbon price values (£147/t in 2040 and £217/t in 2050). Cost over project lifetime assuming pre-tax real rate of return of 9% for unabated gas, 9.1% onshore, 9.1% offshore, 9.2-10.2% nuclear, 13% CCS. Solid boxes represent range for high/low capex and central fuel prices (central load factor for wind); thin extending lines show sensitivity to combined high/low capex and high/low fuel prices (high/low load factor for wind).

Figure 3.7: Projected costs of low-carbon technologies (2030) relative to unabated gas



Source: CCC calculations based on Poyry, Parsons Brinckerhoff.
Notes: Costs for projects starting construction in 2020. Excludes conversion of existing coal plants to biomass, which comes on in 2010s. Fuel price assumption consistent with DECC projections (October 2012). Carbon price rises in line with Carbon Price Floor, to £32/t in 2020 and £76/t in 2030. Beyond 2030 rises in line with Government 'central' carbon price values (£147/t in 2040 and £217/t in 2050). Cost over project lifetime assuming pre-tax real rate of return of 9% for unabated gas, 9.1% onshore, 9.1% offshore, 9.2% nuclear, 10% CCS. Solid boxes represent range for high/low capex and central fuel prices (central load factor for wind); thin extending lines show sensitivity to combined high/low capex and high/low fuel prices (high/low load factor for wind).

Opportunities for improving energy efficiency in buildings

The evidence base on energy efficiency potential in buildings has developed significantly since our 2010 advice. We therefore commissioned Element Energy to inform us in updating our assumptions in this area in light of the new evidence.

Our updated assessment suggests that for certain measures there has been a change in the remaining technical potential and/or reduced energy/carbon savings. Reduced energy/carbon savings will mean that some measures are now less cost-effective than we previously assumed in reducing emissions:

- **Thermal insulation**. New evidence based on actual experiences of installed measures on the level of energy savings from solid wall, loft and cavity wall insulation suggests these may be roughly half as effective at cutting energy use as previously assumed. As a result, our assessment of feasible potential from these measures has roughly halved based on the same level of uptake. Reduced effectiveness also implies that much solid wall insulation is no longer cost-effective, potentially costing several hundred pounds per tonne of CO_2 abated, raising questions over its desirability.
- **Lights and appliances**. We now have better disaggregation of the types of efficient lighting, which suggests that switching from halogens to LEDs (a process that has begun) offers the greatest abatement potential from lighting. We now expect the efficiency of cold and wet appliances (e.g. fridges and dishwashers) to continue improving from 2020 to 2030, suggesting greater feasible abatement than we previously assumed.

The implications of this analysis are that cost-effective abatement potential from improving energy efficiency in buildings is lower than we previously assumed. We reflect this in our updated abatement scenario and consider sensitivities with reduced uptake of measures that are now judged to be less cost-effective (i.e. insulation of solid walls and hard-to-treat cavity walls).

Electrifying heat and transport

In our original advice on the fourth carbon budget we included scenarios with significant penetration of electric vehicles and heat pumps, as a route to increasing the share of low-carbon fuels for the transport and buildings sectors.

However, progress deploying these important long-term technologies has been slow since 2010. We therefore commissioned Element Energy and Frontier Economics to reassess the feasible levels of uptake of these technologies to 2030, focusing on the barriers to consumer uptake and policy options to overcome these. We also commissioned Element Energy and Imperial College London to assess the network infrastructure requirements of large-scale electrification alongside deep decarbonisation of the power sector.

These projects reinforce the view that a major roll-out of electric vehicles is possible and desirable, but raise a question over how far heat pump deployment can and should go by 2030:

- Achieving a 60% market share of electric vehicles (EVs) by 2030 is possible provided manufacturers continue to bring new models to market and that industry and Government extend the package of measures to address current financial and non-financial barriers. These measures could include battery leasing to reduce purchase price premiums, a modest national rapid charging network to complement overnight home/depot-based charging, marketing to improve consumer awareness and acceptance, and provision of financial and/or non-financial 'cost-equivalent' support (Box 3.3).
- Although heat pumps remain a cost-effective abatement option for some types of dwelling for the 2020s, our new evidence on capital costs, performance and durability suggest lower deployment is desirable than in our previous scenario. This is offset to a degree by higher assumed uptake of district heating, given greater long-term potential identified (Box 3.4).
- The additional electricity distribution infrastructure required in a scenario with extensive deployment of heat pumps and electric vehicles represents a small (2%) part of the cost of decarbonising the power sector and is not expected to present serious technical challenges (Box 3.5).

We reflect these findings in our updated core scenario, in which we assume a lower level of uptake of heat pumps than previously. We also consider a sensitivity in which heat pump uptake is reduced further for the 2020s.

Box 3.3: New evidence on electric vehicle uptake

We commissioned Element Energy, with Ecolane Consultancy and Dr Jillian Anable from the University of Aberdeen, to review our uptake scenarios for electric vehicles. The key findings were:

- Costs. Capital costs are likely to remain a key barrier in the period to 2030. The lower running costs of electric vehicles (EVs) are not sufficient to offset higher purchase costs over required consumer pay-back periods (which are much shorter than vehicle lifetimes). However battery leasing could be used to spread the purchase cost premium of EVs.
- Supply. A good supply of EV models and brands across vehicle segments is key to delivering high uptake. Automotive manufacturer announcements on planned releases and production capacity give confidence that this is achievable by 2030.
- Consumer acceptability. Consumer awareness and acceptance of EVs is currently low. A well-designed marketing campaign, complemented with direct exposure to EVs (e.g. through test drives), is needed to ensure all consumers understand EV capabilities. The 'neighbour effect' should also reduce bias against EVs among some consumer segments, as the technology becomes more familiar with increased sales.
- Overnight charging. Certainty of access to charging is a pre-requisite for EV purchase, and best delivered overnight at home/depot. Around 70% of vehicle buyers have access to off-street parking where this could take place.
- Public charging infrastructure. Despite overnight charging being likely to dominate, a public rapid-charging network would offer a number of benefits: it would increase the proportion of fleet vehicles for which pure battery electric vehicles are range-compatible (i.e. rather than only plug-in hybrid EVs), address the perceived need for public charging among private buyers and reduce minimum charging times, which currently act as a barrier to EV deployment.

These interventions can help deliver a high uptake of EVs. Nevertheless, it is possible that 'cost-equivalent' support for EVs may be required to 2030. This could be financial (e.g. the Plug-In Car Grant) and/or non-financial (e.g. preferential access to parking etc). We will return to policy options for EVs in the 2014 progress report.

While we maintain our previous assumption for EVs to comprise 60% of new car sales in 2030, we scale back our assumption for 2020 to reflect the likely share of projected overall EU production that the UK would access.

Source: Element Energy et al (2013). *Pathways to high penetration of electric vehicles*. This report will be published at www.theccc.org.uk.

Box 3.4: New evidence on low-carbon heat

Heat pumps

We commissioned Frontier Economics and Element Energy to review our uptake scenarios for heat pumps. The key findings were:

- Financial barriers and cost-effectiveness.
  - Additional costs. The study reviewed the evidence on cost data and provided revised assumptions. These include additional costs for upgrading radiators and underfloor heating to account for the lower flow temperatures of heat pumps. There is also evidence that the potential for capital costs to decrease over time is limited, with cost savings to be found mainly in the installation costs.
  - Lower performance. Performance measurements from field trials suggest that the potential for improvements over time may be limited, in part by the low efficiency of the UK housing stock. This particularly affects the uptake of air source heat pumps (ASHPs), which are less efficient than ground source heat pumps (GSHPs).
  - Durability of air-source heat pumps (ASHPs). The evidence on the life expectancy of heat pumps is weak, with a range of 15-20 years commonly given for ASHPs. As heat pumps have similar costs to gas boilers in the 2020s, estimates of the cost-effective level of uptake are strongly affected by this assumption.
- Non-financial barriers. The most significant barriers relate to consumer confidence and awareness, the suitability of the housing stock and a lack of installer capacity.

The study suggests that the barriers can largely be addressed by a set of cost-effective policy options, and that a significant level of uptake is still likely to be desirable in the long run. We will return to the policy options in our 2014 progress report to Parliament.

District heating

Since 2010, the evidence base on the potential for district heating to contribute to low-carbon heat supply has been strengthened.

- In 2012 we commissioned AEA and Element Energy to look at scenarios for low-carbon heat to 2050 for our report on the 2050 Target, published alongside our advice on inclusion of international aviation and shipping in carbon budgets. This project identified greater potential for district heating deployment, at 160 TWh/year by 2050, and showed that a mix of district heat and heat pumps would have similar emissions and overall cost to a scenario with a very high level of heat pump uptake.
- DECC's Heat Strategy has also identified a greater role for district heating than we had previously allowed for, drawing on heat from a range of low-carbon sources including a potentially important contribution from larger-scale heat pumps.

Keeping in play this potential long-term deployment is likely to require a greater level of roll-out to 2030 than we had previously envisaged, which we reflect in our scenarios in section (d).

Source: Frontier Economics et al (2013). *Pathways to high penetration of heat pumps*. This report will be published at www.theccc.org.uk.

Box 3.5: New evidence on the infrastructure required to support our scenario

We commissioned Element Energy, with Imperial College London and Grid Scientific, to characterise and cost the infrastructure required to support our abatement scenarios to 2030 and to identify barriers to its delivery. The project identified the type, scale, and cost of three types of required infrastructure:

- Electricity transmission and distribution infrastructure (including interconnection with other countries).
- Carbon capture and storage (CCS) infrastructure.
- "Smart grid" infrastructure required to achieve demand-side response (e.g. electric vehicles charging off-peak, and/or in response to real-time price signals).

The project confirms that expected costs of the required electricity transmission and distribution and CCS infrastructure are broadly similar to high-level estimates we used in our original advice on the fourth carbon budget.

Relative to a baseline with no climate action (i.e. with limited take-up of electric vehicles and heat pumps, lower energy efficiency improvement and continued reliance on unabated gas and coal for power generation):

- Additional costs of electricity transmission and interconnection infrastructure are estimated to be around £0.8 billion in 2030 (around 5% of the cost of decarbonising the power sector);
- Costs of electricity distribution infrastructure are estimated to be around £350 million in 2030 (for a scenario with several million heat pumps and electric vehicles);
- Costs of CCS infrastructure in power and industry are estimated to be around £350 million in 2030.

The costs of implementing a smart grid are worth paying in order to secure wider benefits in grid management, with additional costs to meet low-carbon requirements expected to be negligible.

While there remains some uncertainty over the technical feasibility of CCS, the political, regulatory and commercial challenges are manageable, given appropriate actions from government and industry. Similarly, we find that barriers to deployment of the other required infrastructure can be overcome with an appropriate response. We will set out more detail on the challenges and policy responses required in our 2014 progress report to Parliament.

Source: Element Energy et al (2013). *Infrastructure in a low-carbon energy system to 2030.* This report will be published at www.theccc.org.uk.

Other abatement options

Other evidence on costs and feasibility of low-carbon measures has generally reinforced our previous assumptions, or suggested only small changes:

- **Transport.** We commissioned AEA to review our assumptions for vehicle technologies and costs[4] for our report on *The 2050 target*, published alongside our advice on whether emissions from international aviation and shipping should be included in budgets. We use the results of that work here, and have also updated our modelling to better reflect real-world driving conditions and the higher annual mileages of large cars.
- **Industry.** For this report, we commissioned Ricardo-AEA to review abatement potential and associated costs[5]. The review identified a few small abatement options (e.g. impulse drying) that have not achieved, in demonstration, the energy efficiency improvement previously assumed. Updated modelling also suggests slightly less low-carbon heat uptake is likely to be cost-effective.

4 AEA (2012). *A Review of the Efficiency and Cost Assumptions for Road Transport Vehicles to 2050.* Available at http://www.theccc.org.uk/publication/international-aviation-shipping-review/
5 Ricardo-AEA (2013). *Updating and extending carbon budget trajectories: A review of the evidence.* This report will be published at www.theccc.org.uk

- **Agriculture.** There have been minimal developments in the evidence base on low-carbon measures on farms since our 2010 advice. Defra is currently developing a 'Farmscoper' tool which could potentially improve estimates of abatement from new and existing mitigation methods. We will consider the outputs of this tool in our 2014 progress report, by which time they should be available.
- **Bioenergy.** In December 2011 we published our *Bioenergy Review*. We identified a valuable role for bioenergy in meeting carbon budgets and the 2050 target, but also concluded that the amount of global bioenergy resource available sustainably is uncertain and likely to be limited. We therefore recommended that bioenergy should be used only where it can contribute most effectively to reducing emissions and should be strictly limited to available sustainable supply. Bioenergy use in the abatement scenarios in our fourth budget advice were within the constraint estimated in the Bioenergy Review; we use a similar bioenergy penetration in this report (260 TWh in 2030).

We reflect these findings in our updated abatement scenario, in which we assume a slightly lower level of abatement than previously in industry.

d) Update of our abatement scenario to 2030

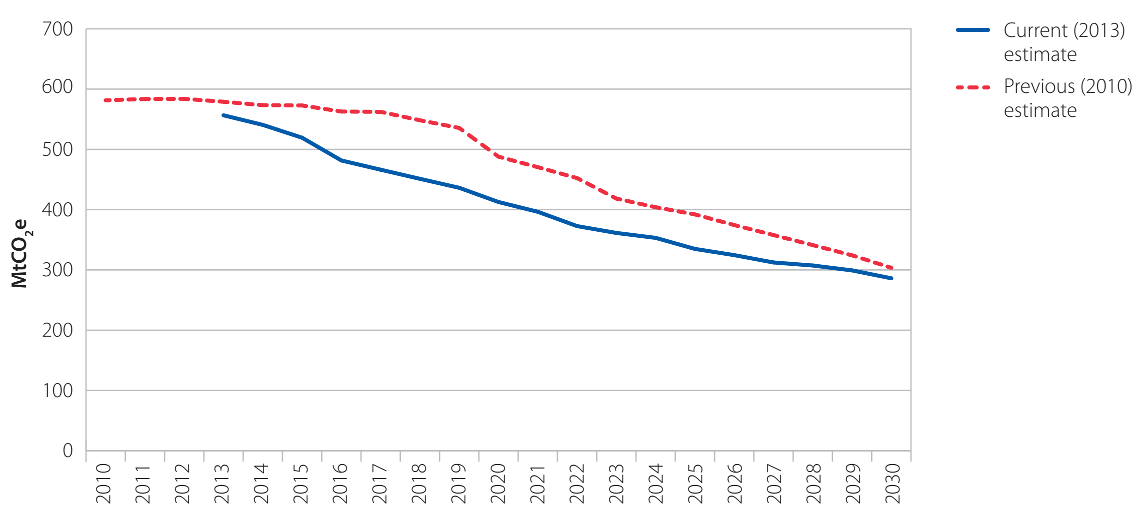
Our economy-wide scenarios reflect the updated evidence in Sections 2(b) and 2(c) above. Our updated abatement scenario results in emissions cuts of 56% in 2025 and 63% in 2030 on 1990 levels, compared to the scenario underpinning the budget which resulted in a 50% cut in 2025 and a 60% cut in 2030 on 1990 levels (Figures 3.8 and 3.9).

- **Power**. The updated abatement scenario includes portfolio investment in low-carbon technologies through the 2020s resulting in carbon-intensity of around 50 gCO_2/kWh in 2030. Estimated emissions in the 2020s are lower than we previously assumed due to the lower starting point in 2020 and lower demand projection.
- **Buildings.** The updated abatement scenario involves changes in the assumed abatement across a range of measures.
  - We have reflected the reduced estimates for effectiveness of insulation measures, but retain previous assumptions on uptake (i.e. all lofts and cavities and 3.5 million solid walls are insulated by 2030), given the importance of these measures to other goals, such as tackling fuel poverty. We will revisit this assumption in our 2014 progress report to consider the appropriate level of ambition allowing for the full set of objectives.
  - We have revised our uptake down from 7 million heat pumps in homes to 4 million by 2030 (i.e. 13% of homes have heat pumps in 2030, rather than 21%), along with lower deployment in non-residential and industrial buildings.
  - This is offset to a degree by higher uptake of district heating – increased from 10 TWh to 30 TWh (i.e. from 2% to 6% of buildings heat) in 2030.

- **Transport**. The updated core scenario reflects lower baseline emissions and changes to the assumed mix of pure battery and plug-in hybrid electric vehicles with lower assumed range, informed by our new consumer choice modelling (see Box 3.3).
- **Industry**. Changes in the baseline scenario, reflecting lower projected output of carbon-intensive industry in the 2020s, have a significant net downward effect on industry emissions in the 2020s, which is only slightly offset by the reduction in assumed abatement potential. The updated core scenario includes slightly less abatement from energy efficiency improvements to reflect the conclusions of our review of potential and costs.
- **Agriculture.** As in our original advice we assume a slower pace of reduction in emissions from agriculture than other sectors. We continue to build in around half of the technical potential to reduce emissions through the uptake of best practices and technologies to reduce N_2O emissions from soils and CH_4 emissions from livestock and manures. Together with the latest projections this implies a 19% fall in emissions from 2012 to 2025, to an emissions level 2% lower than we previously assumed.

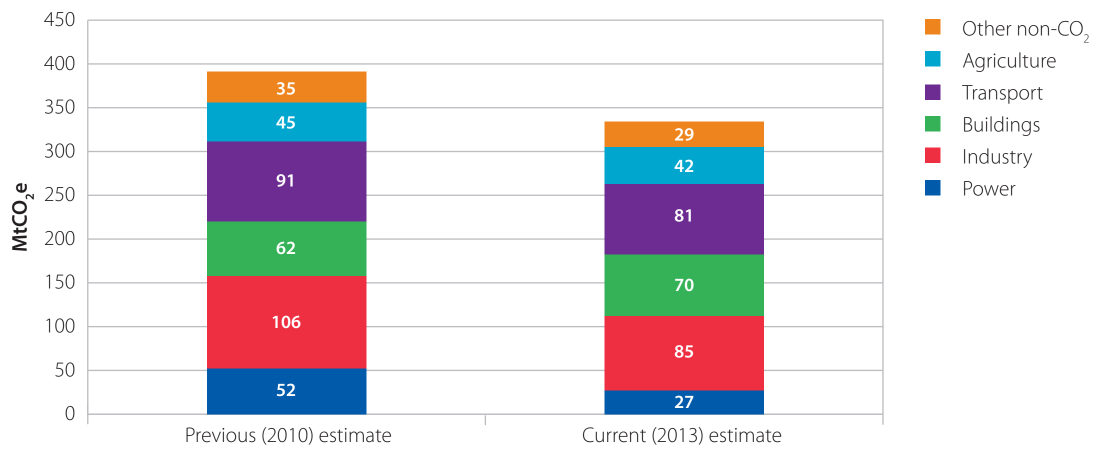
We consider departures from this scenario under different assumptions about the feasible pace of investment, technology costs, fossil fuel and carbon prices in the following sub-section.

Figure 3.8: Estimates of the cost-effective path to 2030 (total GHG)



Source: CCC modelling.

Figure 3.9: Estimates of the cost-effective level of emissions in 2025 (GHG by sector)



Source: CCC modelling.

e) Sensitivities for abatement measures to 2030 and resulting emissions

Notwithstanding potential benefits from the core scenario, departures from it could be justified if the feasible pace of investment were shown to be limited, if cost reductions were to occur more slowly than assumed, or if low fossil fuel and/or carbon prices were to make the higher carbon alternative relatively more attractive.

We have developed a number of sensitivities to model these contingencies, including:

- **Power.** Carbon-intensity of emissions is reduced to 100 gCO_2/kWh in 2030 rather than 50 gCO_2/kWh, increasing emissions by around 65 $MtCO_2$ (3-4%) across the fourth budget period. This could reflect a failure of CCS, limited reduction in costs of emerging renewable technologies, or slow progress on nuclear and CCS deployment.
- **Heat pumps.** Residential heat pump deployment is limited to 2.5 million by 2030 rather than 4 million, increasing emissions by around 25 $MtCO_2$ (1-2%) across the fourth budget period. This could be an appropriate course of action if technology performance is poor or gas prices are low. It would reduce costs while still keeping open the option of meeting the 2050 target through extensive deployment of heat pumps – any lower level of deployment would risk closing off this option.
- **Solid wall insulation.** If no solid wall insulation is installed during the 2020s then emissions would be around 6 $MtCO_2$ (<1%) higher across the fourth budget period. This could save money given the high cost of carbon savings implied by our latest evidence, but would also raise questions over how to deal with fuel poverty given the prevalence of this in solid wall homes (see Chapter 4).

- **Electric vehicles.** If the market share of electric vehicles grows more slowly, reaching 30% of car and van sales in 2030 rather than 60%, then emissions would be 14 $MtCO_2e$ (<1%) higher across the fourth carbon budget period. Furthermore, this would make it more difficult to meet the 2050 target, as it would very likely push back beyond 2035 the point at which ultra-low emission vehicles could comprise 100% of sales.

Even where measures are implemented as in our updated abatement scenario, resulting emissions could be different to the level we have modelled. For example, if population, GDP or energy prices turn out differently to our assumptions then emissions could be higher or lower:

- If population were to increase faster than our central assumptions (e.g. according to the Office of National Statistics (ONS) "High Migration" projection), emissions could be around 3% higher; if population were to increase more slowly (e.g. according to the ONS "Low Population" projection), emissions could be around 2.5% lower.
- If GDP were to increase faster than our central assumptions (e.g. growth one quarter of a percentage point higher in each year than assumed in DECC's baseline emissions projection), emissions could be around 1.3% higher; if GDP were to increase more slowly (one quarter of a percentage point lower in each year), emissions could be around 1% lower.[6]

Alternatively, it may be desirable to go further than assumed in our scenario if measures prove cheaper than we have assumed, or if fossil fuel and/or carbon prices turn out to be high. This could lead to more rapid reductions in emissions than we have assumed or compensate for some of the other sensitivities listed above. For example, there could be: higher uptake of hydrogen vehicles or district heating; greater improvements in efficiency of vehicles, buildings or appliances; more behaviour change including in energy use and in diets; deeper reductions in non-CO_2 emissions than we have assumed. We demonstrated in our original advice that together these options could deliver a further 64 $MtCO_2e$ (20%) reduction in 2030 emissions compared to our central scenario.

We use these alternative scenarios in assessing approaches to meeting the fourth carbon budget, and in particular, the extent to which the budget offers appropriate flexibility given the current set of uncertainties.

3. Implications for the fourth carbon budget

The budget should not be tightened at the current time

Our updated abatement scenario suggests emissions of 1,690 $MtCO_2e$ across the fourth budget period, compared to the currently legislated limit of 1,950 $MtCO_2e$. This is our best estimate, based on the latest evidence. It implies that if all measures that we have identified as being cost-effective were to be implemented, then emissions across the economy would be 260 $MtCO_2e$ (13%) below the level of the budget.

6 These estimates are based on assumptions in the DECC energy model. We have previously questioned the responsiveness of projected emissions in the DECC model to GDP assumptions, implying that the full range of uncertainty attached to GDP is likely to be higher.

Emissions in our abatement scenario would be below the budget in both the traded sector (i.e. in those sectors of the economy covered by the EU ETS: power generation and energy-intensive industry) and the non-traded sector (i.e. outside the EU ETS, including buildings and surface transport).

- **Non-traded sector.** If all cost-effective measures were to be implemented in the non-traded sector, this would reduce emissions to around 1,210 $MtCO_2e$ across the budget period. This would be around 50 $MtCO_2e$ (4%) lower than assumed in the budget (1,260 Mt).
- **Traded sector.** If all cost-effective measures were to be implemented in the traded sector, this would reduce emissions to around 480 $MtCO_2e$ across the budget period. This would be around 210 $MtCO_2e$ (30%) lower than assumed in the budget (690 Mt).

Given these gaps there is the question of whether the budget should be tightened, thereby committing to full implementation of cost-effective measures, or whether to maintain the budget at the present level (with the possibility to outperform by full implementation of measures). In answering this question, it is important to recognise the inherent uncertainties and the flexibility that exists in the budget:

- **Evidence base**. In a number of areas, the evidence base is limited. For example, there is considerable uncertainty over the current level of emissions in agriculture and over future opportunities to reduce emissions in industry. It is important that work continues to improve this evidence base; in so doing, the expectation is that these improvements will change estimates of the suitable path for emissions across the budget period.
- **Uncertainty in projections**. It is inevitable that in making projections there will be uncertainty across a range of factors and that a later updated assessment would result in some changes to projected emissions across the budget period.
- **Possible further changes in circumstances**. Budget recommendations are made in the context of an expectation of future circumstances. Our new assessment is based on the latest expectations, which have changed since our original advice. However, it is likely that they will change again in the future.
- **Flexibilities**. The Climate Change Act allows for flexibilities in both directions. It is perfectly possible to outperform a budget by reducing emissions to below the legislated level (e.g. the Government is aiming and expecting to do this in each of the first three budgets, following the large emissions reduction during the recession). It is also possible to accommodate higher emissions than the legislated budget with purchase of carbon credits, by banking outperformance from previous budget periods or, to a limited extent, by borrowing from future periods.
- An important question for any review is whether the legislated budget sufficiently requires effort to reduce emissions, while managing the many uncertainties, given available flexibilities and interaction with EU and international objectives.

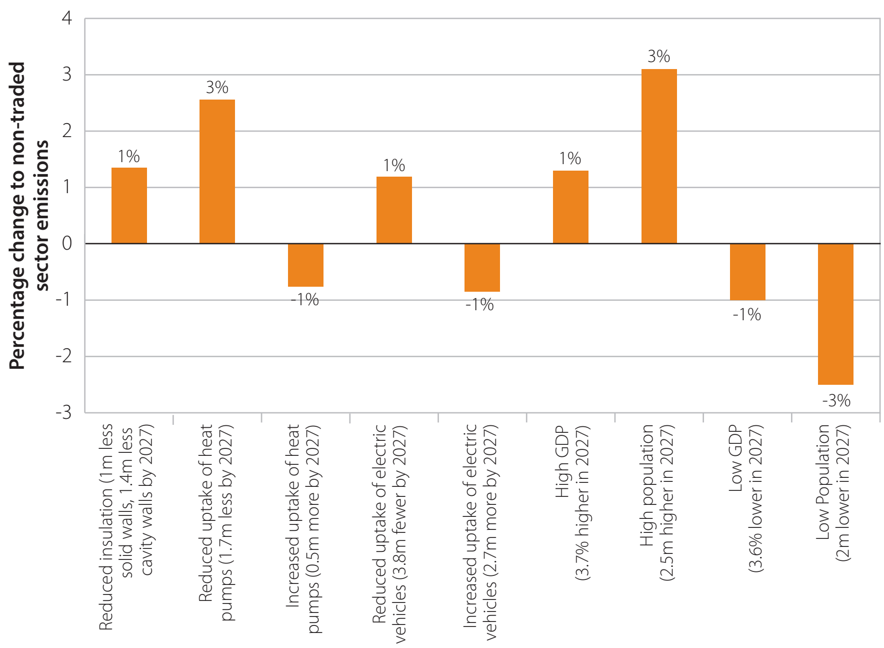
We have concluded that the evidence is not sufficient to justify a tightening at the current time. In the non-traded sector, the potential outperformance is within the likely margin of error and could provide useful flexibility. In the traded sector, while the implied contingency is larger than required, it would be premature to tighten the budget now given uncertainties about EU emissions reduction through the 2020s, and the ambition of any future target to reduce carbon-intensity of power generation to be set under the Energy Bill. Furthermore, keeping the budget at its current level would provide a degree of certainty that would be welcomed by investors.

- **Non-traded sector.** The 50 $MtCO_2e$ (4%) potential outperformance in the non-traded sector if all cost-effective measures were to be implemented is small compared to the uncertainties relating to the feasibility and cost of the various measures, and over the future growth of energy demand and emissions (Figure 3.10). It could provide some increased flexibility in how the budget is met and some useful contingency against the key risks that we have identified, for example, faster than expected population growth, or reduced implementation of some measures where these are more expensive or more constrained than we have assumed.
- **Traded sector.** The current accounting rules of the Climate Change Act require that this part of the budget should be aligned with the EU ETS path through the 2020s, once this is agreed. While current discussions in the EU suggest a tightening of the budget may be required, the negotiations are ongoing and further decisions are required before the budget can be aligned. From a domestic perspective, a judgement on any budget revision should be taken together with setting a target for power sector decarbonisation; the Government and Parliament have decided that any power sector decarbonisation target should be set in 2016 alongside the fifth carbon budget (covering 2028-32).
  - **EU ambition**. Under the current accounting rules of the Climate Change Act, performance against the budget in the traded sector will be determined by the UK's share of the EU ETS cap. As we set out in Chapter 2, this could end up broadly in line with assumptions underpinning the legislated budget (i.e. at 690 $MtCO_2e$) if the EU adopts ambition at the low end of current discussions. In this case the UK would be a net seller of allowances under the cost-effective path, but the budget would not necessarily need to be changed. Although a tightening of the budget may be required if the EU adopts a higher level of ambition, this would be premature at this time, since it remains unclear exactly what the outcome of the EU process will be (see Chapter 2).
  - **The decarbonisation target**. From a domestic perspective, the Government has included a provision to set a power sector decarbonisation target for 2030 in the Energy Bill, with a decision to be taken on this in 2016. The direction for the UK power sector, and specifically for investments contracted under the Electricity Market Reform, will largely be determined by a combination of the carbon budgets and the decarbonisation target. To the extent that the carbon budgets and EU ETS do not reflect the cost-effective path, it will be even more important to signal the Government's intention to follow this by setting a suitable carbon-intensity target for 2030 (e.g. at 50 gCO_2/kWh, with some flexibility to adjust this in the light of new information).

– **Medium-term objective**. In the meantime it remains appropriate to plan for early decarbonisation of the power sector. This is the cost-effective path in a carbon-constrained world and should be reflected in any revised fourth carbon budget, together with the fifth carbon budget and the power sector decarbonisation target to be set in 2016.

- **Investor confidence.** When there is a change to projected emissions across a budget period, there is a tension over whether to maintain the level of required policy effort (implying a change to the budget level) or to maintain the level of the budget. However, we have received the very clear message from a wide range of business stakeholders that there is a benefit in sticking with the currently legislated budget, even though this could imply a different level of required policy effort, and that changing this to reflect changes in emissions projections or other assumptions, which remain inherently uncertain, would undermine the certainty that the budget is intended to provide[7].

Figure 3.10: Uncertainties in non-traded sector emissions



Source: CCC modelling, DECC (2013) Energy and emissions projections, ONS (2011) 2010-based population projections.

Given these considerations, on the basis of our reassessment of the cost-effective path, we conclude that the budget should be kept at the current level rather than tightened, and that the aim should still be to achieve early decarbonisation of the power sector. This is economically sensible and offers significant cost savings relative to an alternative approach which delays investment in low-carbon power generation technologies from the 2020s to the 2030s. A decision on the traded sector part of the fourth carbon budget and on the power sector decarbonisation target should be taken together, alongside the fifth carbon budget decision in 2016.

7 As part of the evidence gathering for this report, we issued a Call for Evidence and held workshops with key stakeholders. The outputs will be published alongside this report, at www.theccc.org.uk.

There is no rationale to loosen the budget

While there could be a case to tighten the budget, there is no case to loosen it, and we strongly recommend against doing so. This would be neither economically sensible, nor allowed under the Climate Change Act, given that other impacts remain manageable (see Chapter 4), and other relevant circumstances remain unchanged (see Chapter 2). It would further undermine investor confidence and the UK's role in international negotiations.

- Loosening the budget would allow it to be met with a significant departure from implementation of cost-effective abatement measures. Proceeding in this way would raise the costs and risks of meeting the 2050 target. In particular, it would prolong use of conventional fossil fuel technologies that will become increasing expensive as carbon costs increase. These would then have to be replaced with immature and expensive low-carbon technologies deployed at very high build rates.
- A loosening of the budget might be allowed under the Climate Change Act if the cost-effective pathway to meeting the 2050 target were to imply emissions above the currently legislated level; the evidence in this report suggests that the opposite is the case. Alternatively, the budget could be changed if wider costs and impacts had become prohibitive; this is also not the case (Chapter 4).
- Only if there were a significant departure from the climate objective *and* fossil fuel prices are much lower than current levels would the budget entail significant costs over a delayed action path (see section 4). A departure from the climate objective would be contrary to the agreed UN position and much lower fossil fuel prices would be counter to expectations.
- Furthermore, any proposal to loosen the budget would undermine credibility of the UK in EU and international negotiations and further undermine already fragile investment conditions, particularly as such a proposal would be counter to the available evidence.

We will continue to monitor technology costs, fossil fuel prices and carbon prices and draw out any implications for approaches to meeting carbon budgets.

Uncertainties relating to EU ambition through the 2020s

Another justification for loosening the budget could be a view that the budget is not sufficiently aligned to the EU ETS, given the accounting rules in the Climate Change Act.

Our assessment is that if the UK is successful in achieving its goals in the European negotiations (i.e. at least a 40% reduction in EU 2030 emissions relative to 1990, rising to a 50% reduction under an ambitious global agreement), then the fourth budget would need to be tightened to align to the EU ETS.

In the event that there is total failure to agree an EU 2030 emissions reduction target, the analysis in this chapter suggests that there may be enough flexibility in the budget to allow for this.

- In Part One of the review, we estimated that the default trajectory would imply a UK share of the EU ETS cap that is 50 $MtCO_2e$ above that assumed when setting the budget for the period 2023-27. If the budget is not changed then the allowable emissions in the non-traded sector would be 50 $MtCO_2e$ lower as a result. This would align to our updated best estimate of the cost-effective path for emissions in the non-traded sector.
- The other flexibilities for carbon budgets built into the Climate Change Act could be used to meet the legislated budget under the EU default trajectory:
  - **Banking and borrowing.** Subject to the advice of the Committee on Climate Change and consultation with other national authorities, outperformance of a carbon budget may be carried forward to the subsequent budget period, while a small amount may be borrowed from a later period in order to address underperformance, limited to 1% of the size of the later budget.
  - **Credit purchase.** Performance against carbon budgets is judged on the net carbon account, after allowing for purchase of carbon credits. The budget could therefore still be met under the default EU ETS trajectory without increased effort in the non-traded sector with the purchase of 50 $MtCO_2e$ across the fourth budget period. At our central carbon values, this would cost around £0.5 billion per year.

We will continue to monitor the EU process and identify any implications for carbon budgets as this is resolved, for example in 2015 when we provide advice on the fifth carbon budget, if not before.

Policies to cut emissions through the 2020s

There is a short lead-time to the 2020s in terms of policy development, supply-chain investment, project development and consumer behaviour change. Given that this is the case, it is important to focus now on putting in place policies which provide incentives for cost-effective measures to be delivered.

Major challenges remain in each of the key policy areas to deliver cost-effective abatement measures:

- **Power.** Implement the Electricity Market Reform such that this supports portfolio investment in low-carbon technologies and supply-chain investment, thereby ensuring early decarbonisation of the power sector with significant consumer benefit. Key challenges include setting strike prices at the right level, and providing confidence to investors that there will be sufficient and ongoing volume to 2020 and beyond.
- **Buildings energy efficiency.** Put in place incentives for uptake of the full range of cost-effective measures in residential and non-residential buildings. Monitor the effectiveness of these policies, responding as necessary if uptake is low, while ensuring that there are safeguards in place to prevent cost escalation.

- **Low-carbon heat.** Put in place approaches to address financial and non-financial barriers to support very significantly increased levels of investment in heat pumps; and to carry out detailed feasibility studies and move forward with investments in district heating infrastructure.
- **Transport.** Continue to press for stretching efficiency standards for new vehicles at the EU level, out to 2030. Continue to support market development for electric vehicles through purchase subsidy and investment in charging infrastructure.
- **Industry.** Develop approaches to demonstration and then deployment of carbon capture and storage (CCS) in industry. Continue to develop the evidence base on potential for improved energy efficiency. Ensure that policies to address potential competitiveness effects of low-carbon are clear and extend sufficiently into the future to cover investment cycles (see Chapter 4).

We will provide a full assessment of these challenges in our sixth report to Parliament on progress reducing emissions, to be published in July 2014.

4. Costs and benefits of meeting the budget

Economic benefits of the core emissions scenario

When we recommended the fourth carbon budget we set out analysis demonstrating that this could be achieved at a cost of less than 1% of GDP. This was the cost of all measures implemented to 2030 to reduce emissions compared to a scenario with no carbon constraint[8]. We argued that this cost is worth paying given the much higher costs and risks associated with dangerous climate change. We estimated that the cost of the additional measures required in the 2020s would be around 0.5% of GDP in 2030, with limited implication for GDP before 2020. Our updated assessment of the cost-effectiveness of low-carbon measures gives a broadly unchanged estimate.

Given that the budget is based on the cost-effective pathway to the 2050 emissions reduction target in the Climate Change Act, the implication is that a departure from this pathway would increase costs and risks. However, in our advice in 2010 we did not attempt to value this relative to a path with more delayed action.

In carrying out its Impact Assessment for the fourth carbon budget, the Government adopted a methodology which suggested that the budget would cost more than a less ambitious path for emissions reduction through the 2020s. This reflected a limited treatment of the value of carbon reductions required to meet the climate objective and of the dynamics of the energy system.

8 Our analysis is based on a 'resource cost' methodology (i.e. it sums the direct additional costs of implementing measures in our scenarios to reduce emissions). As in our original advice on the fourth carbon budget, we have not undertaken detailed macroeconomic modelling for this report. This reflects the finding of our previous work using HMRC's general equilibrium model and Cambridge Econometrics' macroeconometric model that a resource cost estimate is likely to capture the most important elements of the GDP cost (see CCC (2008) *Building a low-carbon economy*).

- The headline figures in the Impact Assessment reflect the costs of undertaking measures within the fourth carbon budget period, but no value was ascribed to having lower UK emissions. Therefore only a handful of measures were presented as having a net benefit, on the basis that they save money even without consideration of climate change.
- Furthermore, no value was placed on emissions savings post-2027, as a result of measures undertaken within the fourth carbon budget period. As much of the economic benefit of these measures derives from a lower emissions path following the budget period, this approach considerably understated the long-term value of action during the 2020s in meeting long-term emissions targets in a carbon-constrained world.
- As a result the Impact Assessment suggested that a looser budget would have lower costs as it ignored the benefits of measures that reduce emissions at a cost below the carbon price, both within the budget period and over the period to 2050.

In order to reflect full costs and benefits of action to cut emissions in the 2020s, it is necessary to attach value to carbon as implied by the climate objective, and to consider dynamics of the energy system over time, including path dependency associated with investment choices in the 2020s.

For example, while a reduction in ambition could reduce costs of abatement a full analysis must reflect that higher emissions also increase climate risk and associated costs, and that in a carbon-constrained world this will translate to a value of carbon reductions. It should also allow for the likelihood that lower implementation of measures in the medium term would limit options for later emissions reduction, implying higher costs may be incurred in the long term.

Therefore, in this report we include an analysis of cost savings where carbon is valued as implied by our climate objective, and where we consider system costs to 2050 under the requirement that the 2050 target to reduce emissions by 80% relative to 1990 is met.

We now set out that assessment based on a comparison of measures to meet the fourth carbon budget versus an alternative scenario where implementation of measures is delayed until 2030 and beyond.

- **Power sector.** The cost-effective path involves ongoing portfolio investment in low-carbon technologies through the 2020s, such that the carbon intensity of power generation is reduced to 50 gCO_2/kWh in 2030. We compare this with a situation where the focus in the 2020s is on investment in unabated gas-fired generation, followed by rapid roll-out of low-carbon technologies in the 2030s, without the benefits of cost reduction from earlier deployment. Our assessment here reflects analysis in our May 2013 report Next steps on Electricity Market Reform.
- **Heat.** We consider the impact of delaying deployment of heat pumps and district heating by ten years, with no uptake in the 2020s. This amounts to a scenario of 0.7 million heat pumps in homes in 2030, compared to 4 million in our abatement scenario. District heating capacity remains constant at 6 TWh/year throughout the 2020s. After 2030, we assume that uptake of low-carbon heat grows at a rate constrained by the pace at which the supply chain can be expanded.

- **Transport.** We consider the impact of delayed uptake of electric vehicles, assuming no further policy intervention beyond 2020 (but assuming costs continue to fall with global deployment). This results in a 26% market share for car sales (22% for vans) by 2030, against 60% in our core scenario. We also assume no improvement in conventional vehicle efficiency between 2020 and 2030, and that biofuels penetration falls to 5%. However after 2030, we assume that uptake of electric vehicles and improvement to new conventional vehicle efficiency can be accelerated to 'catch' up with our core scenario by 2050, in terms of vehicles sales; however, emissions in 2050 are higher under the delayed scenario, as the stock still contains high-carbon vehicles purchased in the 2030s and early 2040s.
- **CCS with bioenergy and on industrial installations.** We consider timely development of carbon capture and storage (CCS) in the power sector, which could have spillover benefits for application to industrial and bioenergy installations. CCS deployment at scale in the power sector during the 2020s would drive the development of CO_2 infrastructure clusters, creating opportunities for industrial/bioenergy CCS projects to connect with low risks and at relatively low cost. Such CCS applications would not otherwise be feasible, due to the high risks and costs of infrastructure development specifically for individual projects producing relatively small volumes of CO_2. The greater deployability of CCS in these sectors during the 2030s enables greater cumulative deployment by 2050, given slow refurbishment cycles in relevant industries (e.g. 20 years) and the potential for bioenergy resources to be locked in to use in facilities without CCS.

Our analysis suggests that delivering our abatement scenario to 2030 rather than delaying action beyond 2030 offers a saving of over £100 billion in present value terms under central case assumptions for technology costs, fossil fuel prices and carbon prices. Further benefits upwards of £15 billion could be associated with development of CCS in the 2020s.

- A substantial part of the cost saving associated with the abatement scenario under central assumptions comes from the power sector. In our report *Next steps on Electricity Market Reform*, published in May 2013, we estimated this at £25-45 billion. This reflects the benefits of investing in nuclear power generation and onshore wind rather than gas-fired generation subject to a carbon price, and the option value associated with developing less mature technologies such as offshore wind and CCS
  - Under central assumptions, deployment during the 2020s of 18 GW of nuclear and 10 GW of onshore wind (generating the equivalent of 3 GW of baseload capacity) would save around £25 billion over their lifetimes. This is relative to gas-fired generation subject to a rising carbon price in line with the Government's carbon price underpin reaching £76/tCO_2 in 2030 and continuing to rise thereafter (see Box 3.1).
  - Deployment of offshore wind and CCS in power generation during the 2020s creates options for further deployment post-2030, at lower costs and at faster rates if required. This investment saves up to £40 billion over the lifetime of investments, relative to unabated gas-fired generation with a rising carbon price and depending on the availability of mature alternatives like nuclear (i.e. up to £20 billion if nuclear is available and £40 billion if not).

- Roll-out of heat pumps, district heating and electric vehicles during the 2020s develops markets that will be important for further deployment between 2030 and 2050. These measures are cost-effective against a rising carbon price when considering the entire timeframe to 2050, offering a potential present value saving of around £55 billion versus a scenario where their deployment is delayed (Box 3.6).
- Other measures, like energy efficiency improvement in cars and buildings, are generally cost-effective compared to the carbon price. Together these offer a potential saving of around £35 billion compared to a scenario that does not roll them out through the 2020s.
- Deployment of CCS in the 2020s, primarily in the power sector, provides the necessary scale to develop CO_2 infrastructure clusters and drive down the cost of capital associated with CCS in all sectors. In addition to the benefits of developing CCS for deployment in the power sector, this also enables CCS applications in industry and on bioenergy, both of which are likely to be important in meeting the 2050 target. Assuming that a delay to CCS roll-out would reduce the deployability of CCS for industry and bioenergy by 25% to 2050, investment in CCS would reduce the costs of meeting long-term emissions targets by £15 billion in addition to the benefits for power sector decarbonisation (Box 3.7).

Box 3.6: Benefits of 2020s deployment of electric vehicles and low-carbon heat for the path to 2050

The 2020s is likely to be an important decade for developing options that are important for meeting long-term emissions targets. This is true both on the supply side, where low-carbon generation technologies need to be proven and improved, and on the demand side, where markets for end-use technologies such as electric vehicles and heat pumps need to be developed.

Therefore the value of deploying low-carbon heat and electric vehicles in the 2020s derives not only from the emissions avoided in that decade, but also from the increase in the possible deployment rates in subsequent decades resulting from market development. Given that these technologies are projected to become cost-effective during the 2020s, there is an economic benefit in the opportunity to deploy them at greater scale in subsequent decades, when they will save money against high-carbon technologies:

- Low-carbon heat. Deployment of heat pumps in the 2020s is cost-effective in some building types, and has a benefit in market development, enabling heat pumps to be deployed at a greater rate in the 2030s, when they have a significant saving versus gas boilers at our assumed carbon prices. Over the period to 2050, the benefit relative to the delayed scenario has a net present value of £16 billion under central assumptions. Delaying roll-out of district heating would add a further £13 billion.
- Electric vehicles. Electric vehicles are projected to become cost-effective during the 2020s, and deployment during this decade also has a market development benefit, enabling greater uptake in the 2030s and early 2040s. Over the period to 2050, the benefit relative to the delayed scenario has a net present value of £27 billion under central assumptions.

Box 3.7: Value of CCS in meeting long-term emissions targets

Carbon capture and storage (CCS) has a large value in meeting long-term emissions targets, due to the possibility to deploy it not just in the power sector, but also on carbon-intensive industry, bioenergy facilities and for hydrogen production.

While in principle its use for power generation and hydrogen production could be substituted by other low-carbon energy sources (i.e. renewable and nuclear), its application to industry and bioenergy provides abatement that cannot be provided by other technologies:

- Industry. In a range of carbon-intensive industries, notably the cement, iron and steel, chemicals and refinery sectors, CO_2 is produced via chemical reactions as well as the use of fossil fuels for energy. While in principle the energy could be decarbonised using renewables or nuclear energy, the only way to abate the emissions from chemical reactions is with CCS.
- Bioenergy. Sustainable supplies of bioenergy are likely to be scarce, and therefore it will be important to maximise the amount of emissions reduction achieved from the available resource. As we set out in our 2011 *Bioenergy Review*, the use of bioenergy with CCS can achieve around twice the abatement per tonne of solid biomass compared to producing liquid fuels for transport without CCS.

Analysis for our 2012 report *The 2050 target* suggested that having CCS available as an option could reduce the resource cost of meeting the 2050 target by 0.4% of GDP in 2050, suggesting a very high value to its development as an option.

For this report we have used the Energy Technology Institute's ESME (Energy Systems Modelling Environment) cost-optimising model to examine the impact that a delay in CCS development would have on the cost of reducing UK emissions through to 2050. This modelling indicated that a failure to develop CCS in the 2020s, leading to a reduction of 25% in its deployment in industry and on bioenergy by 2050, would increase costs by around £15 billion at DECC's central carbon prices. To the extent that potential deployment in 2050 could be reduced further by a delay in development, the cost increase would be larger.

The total cost saving from delivering our abatement scenario increases to around £200 billion in present value terms under assumptions of high fossil fuel or carbon prices. Under low fossil fuel prices or low carbon prices, the cost saving is eroded, but does not become negative. Only if there is the combination of low fossil fuel prices and low carbon prices might the core scenario have significant additional costs compared to a more back-ended approach to meeting the 2050 target.

- The cost savings increase under assumptions of high fossil fuel or carbon prices, both of which improve the cost effectiveness of low-carbon technologies. A faster pace of investment in low-carbon technologies may be appropriate with high fossil fuel or carbon prices, which could lead to an outperformance of the budget, and larger cost savings.
- Although cost savings are eroded under assumptions of low fossil fuel or carbon prices, both of which make low-carbon investment relatively more expensive, the core scenario still offers a potential cost saving relative to a more back-ended emissions reduction path to the 2050 target. A slightly slower pace of investment in low-carbon technologies may be an appropriate response to either low fossil fuel or low carbon prices provided it still prepares sufficiently for the 2050 target, and as set out in section 3 could still be consistent with the legislated budget.

- There could be significant additional costs associated with the core scenario under assumptions of both low fossil fuel prices and low carbon prices. In these circumstances, significantly delaying investment in low-carbon technologies could reduce costs, but this would be inconsistent with UN-agreed climate objectives and counter to expectations for fossil fuel prices.

This analysis assumes that delayed action can be compensated for by faster deployment of low-carbon technologies in the 2030s and 2040s than under the core emissions scenario, so partially catching up with the path to meeting the 80% target in 2050. It also assumes that any shortfall in abatement can be made up by purchase of international credits at a cost in line with the Government's carbon values. Both of these assumptions may be optimistic:

- In reality, a back-ended path would entail a very rapid transformation of the system. This would be likely to raise the costs and risks of meeting the 2050 target, given the need for consumer acceptance of new technologies to grow very quickly, high build rates across a wide range of low-carbon technologies and the need for scrappage of high-carbon technologies in some areas (Box 3.8).
- Such a path would therefore most likely imply the need for the UK to purchase international emissions credits to meet the 2050 target. The Government assumes that the cost of carbon credits will rise strongly to 2050 (e.g. to reach £110-325/tCO_2e), while our previous analysis has identified significant risks that carbon prices could be even higher (e.g. if sustainable bioenergy is limited or if the world follows a back-ended path to meeting the climate objective)[9]. Furthermore, were this shortfall to be replicated internationally, this would jeopardise meeting of the climate objective.

This analysis suggests that investment in low-carbon technologies as in our abatement scenario and as reflected in the fourth carbon budget is low-regrets with potentially significant benefits across plausible scenarios. While it is possible that fossil fuel prices will turn out to be low, this would imply that carbon prices would need to be correspondingly higher in order to drive emissions reduction. A combination of low fossil fuel prices and low carbon prices would therefore imply a lowering of ambition in the climate objective and is not a suitable basis on which to plan.

9 See Chapter 4 of CCC (November 2013) *Fourth Carbon Budget Review – part 1: Assessment of climate risk and the international response.* Available at www.theccc.org.uk/publications

Box 3.8: Evidence on transitions and the potential role of scrappage

In order to achieve the UK's legally binding target of an 80% reduction in emissions by 2050, the UK will have to make transitions to low-carbon in several sectors simultaneously. Some insights on how these transitions could succeed can be drawn from the extensive academic literature that considers how technology and energy system transitions occur. Looking across a wide variety of transitions both in the UK and internationally, some key themes emerge:

- Energy system transitions generally take at least 40 years, and often considerably longer (e.g. up to 130 years). This suggests that the transitions required will happen over a relatively short timescale by historical standards and therefore immediate action is needed to drive them forward.
  - For example the transition in the UK from traditional renewable energy sources (e.g. wind and water mills, biomass for heat) to coal took around 130 years,
  - the shift from a coal-dominated energy system to one with major roles for oil, gas and electricity took around 80 years
- In general, larger transitions that require a lot of new infrastructure, and which will interact with other systems, will take longer to complete. Given the challenges involved in some of the transitions required by 2050 (e.g. introduction of electric vehicles, low-carbon heat and CCS), it is likely that most of these will be slower than rapid transitions such as the 'dash for gas' in the power sector during the 1990s.
- There is potential for faster transitions to occur when new technologies have an immediate advantage over previous technologies, or where they have had a chance to develop in niche markets prior to wider deployment.
  - Without a carbon price, many of the technologies required for a low-carbon transition will remain more expensive than incumbents, which also have the advantage of established infrastructure.
  - Targeted support may be required to drive uptake of new technologies in niche markets, ahead of mass-market roll-out.
  - As transitions will be driven primarily by the social need to reduce emissions, a switch to low-carbon technologies may not involve significant private benefits to end-users, making the transition more challenging.

Overall this indicates that our approach of allowing long lead-times in key markets such as electric vehicles, and keeping options open for a portfolio of technologies in 2050, is appropriate. It also suggests that, given the comparatively short period for this transition to occur, reductions in shorter-term ambition for key technologies may make it extremely challenging/expensive to meet the 2050 target domestically.

If markets for key technologies are not developed sufficiently early, they may not reach the levels of uptake required by 2050 to meet the 80% target. Under these circumstances, scrappage policies may be required in the 2040s to accelerate introduction of low-carbon technologies at a faster pace than could be achieved simply via end-of-life replacement of high-carbon capital, even though this would entail higher costs:

- **Heat pumps.** Scrapping a gas boiler in the mid-2040s to replace it with a heat pump would have an effective cost of between £75-220/tCO_2, depending on the type of building. While this is more expensive than installing a heat pump instead of a gas boiler under the natural replacement cycle, and therefore should not be planned for, in most cases it is less than the level of the 2045 carbon price of £180/tCO_2.
- **Ultra-low emission vehicles.** Scrapping an internal combustion engine vehicle to replace it with an electric vehicle would have an effective cost of over £1200/tCO_2, well in excess of the carbon price.

This suggests that failure to create a market for ultra-low emission vehicles will lead to higher emissions in the transport sector by 2050, but that failure to deploy low-carbon heat in a timely fashion could be partially mitigated through scrapping gas boilers in the 2040s.

Broader economic benefits of the core emissions scenario – opportunities for UK industries

The analysis above is focused on the resource cost of the fourth carbon budget, based on summing the direct additional costs of implementing measures to reduce emissions. Decarbonising the energy system will also have broader economic impacts, relating to redeployment of resources towards building a low-carbon economy.

Production and supply of low-carbon goods and services already makes up a significant part of the UK economy, and are set to increase:

- The CBI estimate that the UK 'low-carbon economy' was worth £122 billion in 2010/11 (7% of GDP) and involved close to a million jobs. They also estimate that these sectors grew by 2.3% in 2012, contributing over a third of the total GDP growth in the economy[10].
- New markets associated with the measures in our abatement scenario (i.e. investment in low-carbon power generation, installation of energy efficiency measures and heat pumps, roll-out of electric vehicles, etc) provide scope for this part of the economy to grow considerably. For example, BIS project that the low-carbon economy could grow by over 5% per year.
- Globally, the market for low-carbon technologies is already worth over £3 trillion/year and is expected to grow by 2015/16 to around £4 trillion/year[11]. This suggests that firms in low-carbon supply chains could also have markets for their products and services beyond the UK.

UK companies are well-placed to take advantage of these opportunities:

- Some of the low-carbon measures, such as installation of insulation in buildings inherently require local supply chains and jobs. For example, over 110,000 people in the UK are currently employed in the low-carbon building technologies industry (insulation and heat-retention materials, double-glazing, etc).
- UK firms have skills and expertise and are well-placed to compete and prosper in low-carbon markets (e.g. heavy and offshore engineering, vehicle and engine manufacture).

In the long run there is no reason to think employment will be any higher or lower in a low-carbon versus a high-carbon world. There may be structural costs associated with the transition however, if it is not well managed. In the near to medium term there may also be a net addition of jobs to the extent that the economy is currently operating below capacity.

An appropriate goal for policy is to ensure that the transition to a low-carbon economy involves as little disruption as possible. Keeping the fourth carbon budget could send a useful signal to businesses that the UK is planning for a low-carbon world and is a suitable location for low-carbon investments. By contrast, a weakening of ambition in the budget could put off investors and require greater and more rapid structural change in later years, with associated economic cost.

10 CBI (2012), *The colour of growth*.
11 Low Carbon Environmental Goods and Services (LCEGS) Report for 2011/12.

Chapter 4: Impacts of the fourth carbon budget

Introduction and key messages

The Climate Change Act requires that we consider the following additional matters in our advice:

- social circumstances, and in particular the likely impact on fuel poverty;
- economic circumstances, and in particular the likely impact on the economy and the competitiveness of particular sectors of the economy;
- fiscal circumstances, and in particular the likely impact on taxation, public spending and public borrowing;
- energy policy, and in particular the likely impact on energy supplies and the carbon and energy intensity of the economy;
- differences in circumstances between England, Wales, Scotland and Northern Ireland.

This chapter updates our 2010 findings in these areas, and summarises analysis on energy affordability and competitiveness which we have since published[1].

Our overall conclusion is that the impacts of the budget are manageable across the range of legislated criteria given appropriate policy responses; and that the circumstances with respect to these criteria have not significantly changed since the budget was legislated. Therefore the budget should not and cannot be changed on the basis of impacts across these matters.

Our conclusions on the specific matters are:

- **Social circumstances – energy affordability and fuel poverty:** The circumstances under which the budget was set with regard to energy affordability and fuel poverty remain unchanged, and therefore there is no basis to change the budget in these respects. Specific impacts related to the fourth budget (i.e. rather than impacts related to existing policies to 2020) are very small. If anything, the additional flexibility in the budget that we identify in Chapter 3 provides more opportunity to address these impacts.

1 CCC (2013) *Reducing the UK's carbon footprint and managing competitiveness risks* available at http://www.theccc.org.uk/publication/carbon-footprint-and-competitiveness/
CCC (2013) *Energy prices and bills – impacts of meeting carbon budgets* available at http://www.theccc.org.uk/publication/energy-prices-and-bills-impacts-of-meeting-carbon-budgets/

- **Competitiveness:** Our assessment of the competitiveness risks to energy-intensive sectors suggests there is no evidence of significant industry relocation due to low-carbon policies to date and no reason to expect this in the future. Costs continue to be manageable given policies currently in place to limit competitiveness risks. Further detail on policy implementation to 2020 and beyond is desirable to ensure this remains the case and to provide confidence to investors. The circumstances relating to competitiveness have not changed since the fourth carbon budget, and there is no rationale to change the budget on this basis.
- **Security of supply:** There has been no change in the expected impact of the fourth carbon budget on security of supply. Low-carbon investment offers benefits for security of supply through reduced reliance on imported fuels, while intermittency in power generation can be managed. This is unchanged in the light of developments in shale gas, which offers additional security of supply benefits, but should not be seen as an alternative to low-carbon technologies in this respect. In the power sector, increased reliance on intermittent sources of generation like wind power is manageable at low cost through a combination of demand flexibility, energy storage, interconnection and balancing generation.
- **Fiscal:** There has been no change in the fiscal implications of meeting the fourth carbon budget. Our conclusion remains that fiscal impacts from meeting the fourth carbon budget are likely to be small and manageable, particularly given scope for rebalancing in the tax system over the longer-term.
- **National circumstances:** Strengthened targets and policy commitments in the devolved administrations will help to deliver the fourth carbon budget. Furthermore, the devolved administrations continue to be heavily reliant on the fourth carbon budget and associated policies to deliver their own targets.

We also include in this chapter an assessment of the wider impacts of the budget including on health and the environment. We conclude that there are wider net benefits from actions to meet carbon budgets, such as improved air quality, health and reduced noise. Recognising these impacts strengthens the case for ambitious action to reduce emissions over the next two decades.

We assess each area in turn across six sections:

1. Energy affordability and fuel poverty
2. Competitiveness
3. Security of supply
4 Fiscal impacts
5. Differences in national circumstances within the UK
6. Wider health and environmental impacts

1. Energy affordability and fuel poverty

In this section, we set out the implications of the fourth carbon budget for energy affordability and fuel poverty. We assess impacts of policies to date, likely impacts in the future and scope for offsetting these impacts.

Box 4.1 provides a summary of our conclusions and Table 4.1 outlines the bill impacts over time.

Box 4.1: Conclusions on affordability and fuel poverty

- Low-carbon policies account for a small part of energy bill increases to date.
- They are likely to lead to a further bill increase of around £85 for the typical dual-fuel household in 2020 compared to now. This will pay for investment in low-carbon power generation technologies which offer significant benefits and will lead to lower electricity prices in the future.
- During the 2020s, we expect a further £50 increase in bills as the carbon price rises. Decarbonising the power sector to around 50 gCO_2/kWh would add a further £20.
- There is scope to offset energy bill increases through energy efficiency improvement. Strengthening of policies will be required if this is to be achieved in practice.
- Impacts of policies to meet the fourth carbon budget (including energy efficiency programmes) are likely to leave the number of households in fuel poverty broadly unchanged but additional polices are required in order to reduce the number of households in fuel poverty form currently high levels.
- The circumstances under which the budget was set with regard to energy affordability and fuel poverty remain unchanged, and therefore there is no basis to change the budget in these respects. If anything, the additional flexibility in the budget identified in Chapter 3 provides increased opportunity to address these impacts.

Table 4.1: Summary – energy bills impacts of low-carbon policies

2011 prices	2010s	2020s impacts of carbon price	2020s additional impact fourth carbon budget
With Carbon Price Floor	£100[2]	£50	£20
Without Carbon Price Floor	£70+	Up to £75 (depending on EU ETS)	£20+

Residential energy bill increases in recent years

There have been significant increases to household energy bills in the last decade. The total annual energy bill for the typical dual-fuel household (i.e. a household using gas for heating and electricity for its lights and appliances) increased by £520 (around 85% in nominal terms) between 2004 and 2012. The majority of this increase was due to the rising price of gas in the international market. Network investment and low-carbon policies each accounted for a small part of the increase.

- The annual energy bill for the typical dual-fuel household was around £610 in 2004.
- This increased to around £1130[3] by 2012, the latest year for which comprehensive data is available.

2 From 2011 to 2020. Around £85 from 2014.
3 When calculating the average dual fuel bill, we exclude homes that use electricity for heating. This is different from DECC's approach whose 2012 average bill estimate is higher at £1279.

- The increase of £520 between 2004 and 2012 was primarily due to a rise in international gas prices, with only £20 of additional funding for policies to support decarbonisation of power generation (specifically renewables), around £10 for the carbon price in the EU Emissions Trading System and £45 to support energy efficiency improvement, without which bills would have increased further for some groups, including those in fuel poverty.
- In 2012, total support for low-carbon generation and the carbon price accounted for only around 3% (£35) of the typical household energy bill, while energy efficiency policies amounted to another 4% (£50).

Significant further bill increases were announced by suppliers towards the end of 2013. However, low-carbon policies account for only a small part of these increases.

- We estimate that they include only around £10 for support of investment in low-carbon power generation (£5 to support increased renewables capacity and a similar amount for the new Carbon Price Floor).
- Given recent announcements by the Government aimed at limiting the bill impact of energy efficiency funding, other factors are driving the much larger announced bill increases.

Therefore, the story to date is one where low-carbon policies are responsible for only a very small part of energy bill increases in recent years.

Residential energy bill increases under current policies to 2020

Future energy bill increases due to low-carbon policies will occur because of the increasing carbon price and increased investment in low-carbon power generation technologies. The Government's intention is that funding for energy efficiency policies will stay broadly constant, therefore requiring no energy bill increase, and resulting in bill reductions for those groups benefiting from these policies.

Our analysis suggests that low-carbon policies should add around £100 (in real terms, before general price inflation) to the annual bill for the typical dual-fuel household from 2012 to 2020:

- £70 would pay for the increase in investment for renewables, Carbon Capture and Storage demonstration, upgrading the electricity grid and providing back-up generation to support more intermittent generation.
- £30 would be needed to pay for the Carbon Price Floor which the Government expects to rise to £32 t/CO_2 in 2020. This would raise around £2-3 billion revenue for the Exchequer in 2020, creating an opportunity for offsetting tax reductions or public spending to mitigate energy bill impacts.
- We assume that funding for energy efficiency measures would stay constant, so that there would be no further bill increases.

There is the opportunity to more than offset this impact through energy efficiency improvement (e.g. boiler replacement, insulation measures, more efficient appliances and lighting). Whether this opportunity is addressed will depend on policies to encourage energy efficiency improvement; we will return to these in our 2014 Parliament report.

Residential energy bill increases between 2020 and 2030

As in the period to 2020, energy bill increases due to low-carbon policies are expected to occur via electricity bills, due to investment in low-carbon power generation, and not via increased gas bills.

The Government has suggested that the Carbon Price Floor will double from 2020 to 2030 to around £76/tCO_2. This would add around £50 to the typical household electricity and energy bill in 2030 relative to 2020.

Whether the Carbon Price Floor will be above the carbon price in the EU Emissions Trading System (EU ETS) at this time will depend on the level of ambition in EU ETS (see Chapter 2 for a summary discussion of EU ambition, and Part 1 of our advice on the fourth carbon budget, published in November 2013).

Our analysis suggests that investment in low-carbon power generation through the 2020s to achieve an average carbon-intensity of power generation of 50 gCO_2/kWh in 2030 (i.e. as in the cost-effective path to the 2050 target, see Chapter 3) entails a further cost of up to £20 per household in 2030 compared to 2020:

- The need for funding would increase from around £8 billion in 2020 to £11.5 billion in 2025, before falling to around £10 billion in 2030. If, as at present, this was to be recovered through energy bills, a further £20 would have to be added to the typical household bill from 2020 to 2030.
- The smaller increase than in the 2010s reflects that the cost of adding low-carbon technologies is expected to be lower as these benefit from learning and cost reduction, while the alternative avoided cost of adding gas generation would be higher given the rising carbon price.
- There is some flexibility to adjust the 50 gCO_2/kWh ambition and still meet the fourth carbon budget (see Chapter 3). We will return to the question of whether and when lower ambition might be appropriate when advising on the appropriate level of the 2030 decarbonisation target, expected to be in 2015.
- There is scope to reduce energy bills through the 2020s by improving energy efficiency, for example by purchasing more efficient appliances when old appliances reach the end of their life.

Therefore, the incremental affordability impacts associated with cost-effective investment through the 2020s are small relative to those under current policies (with or without the Carbon Price Floor), and are worth paying in order to access cheaper bills in the long run.

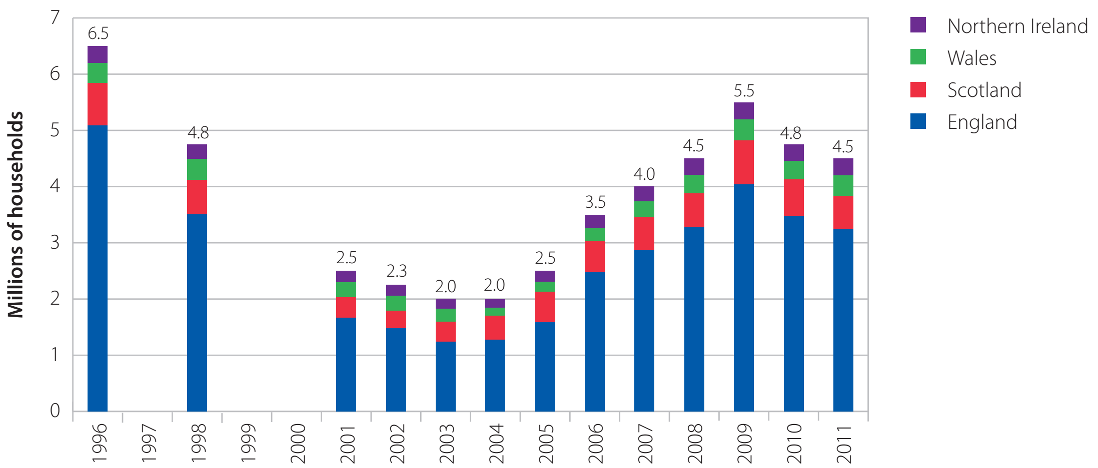
Fuel poverty impacts due to energy bill increases

Definition and number of households in fuel poverty

Affordability impacts are a particular concern for the large number of households already affected by fuel poverty (i.e. those who face high costs to maintain a warm home and often cannot afford to heat their home to an adequate level).

Fuel poverty was an issue long before investment in low-carbon measures began. Government fuel poverty statistics go back to 1996 and recorded particularly high levels for that year (6.5 million for the UK). The Warm Homes and Energy Conservation Act 2000 places a duty on government to have a strategy for making sure no person lives in fuel poverty, as far as is reasonably practicable, by 2016. Fuel poverty levels did drop in the early 2000s (Figure 4.1), mainly due to energy efficiency improvements and rising incomes, but subsequently increased again with rising energy prices.

Figure 4.1: Fuel poverty in the UK (1996-2011)



Source: DECC (2013) annual report on fuel poverty statistics.
Notes: Fuel poverty figures have been estimated for: Northern Ireland for 2010; Wales for 2009, 2010 and 2011. No data available for 1997, 1999 and 2000.

Until recently, a household was defined as fuel poor if it needed to spend more than 10% of its income on fuel to maintain an adequate level of warmth. The Hills Review, published in 2012, suggested that the definition of fuel poverty should be changed to measure the problem more accurately and distinguish the problem from poverty in general:

- The Hills Review proposed that households should only be regarded as being in fuel poverty when facing a combination of low incomes and higher than typical energy costs (i.e. excluding low-income households with low energy costs in energy efficient homes).
- The Hills Review also introduced the concept of a fuel poverty gap, defined as the fuel bill reduction that would be required to take fuel poor households out of poverty.

The Hills definition of fuel poverty has now been adopted for England. However, fuel poverty is a partially devolved matter, and the devolved administrations are continuing to use the old definition[4].

The latest estimate of the number of fuel poor households on the old definition is broadly the same as the 2008 level we reported in our 2010 advice on the fourth carbon budget (Figure 4.1). The proportion of fuel poor households in the devolved administrations is higher than the UK average:

- Based on the old '10%' definition, in our advice on the fourth carbon budget we reported 4.5 million households were living in fuel poverty in 2008.
- The latest data available now is for 2011 and also estimates 4.5 million UK households in fuel poverty (with a similar number projected for 2012). England had the lowest percentage of households in fuel poverty (15%, 3.2 million), whereas in Northern Ireland fuel poverty levels reached 42%, in Wales 29% and in Scotland 25%.
- Under the new 'low-income/high-cost measure', 2.4 million households were fuel poor in England in 2011, with an average fuel poverty gap of £438. As with the old measure, levels are likely to be higher in the devolved nations.

Under either definition, it is clear that fuel poverty remains a major problem.

Impacts of low-carbon policies on fuel poverty

Low-carbon policies will impact fuel poverty in two ways – negatively through rising prices and positively through energy efficiency improvements:

- Rising electricity prices will increase energy bills and push more households into fuel poverty. As with the assessment of energy affordability above, incremental impacts associated with electricity price increases in the 2020s are expected to be relatively small compared to those in the 2010s.
- Subsidised energy efficiency improvement, for example under the Energy Company Obligation, will reduce the number of households in fuel poverty. There is a particular opportunity here given that the low energy efficiency of dwellings is a key driver of fuel poverty (Box 4.2).

In our original 2010 advice on the fourth carbon budget, we argued that there are opportunities for meeting carbon budgets without exacerbating fuel poverty, for example through effective targeting of energy efficiency. New analysis since 2010 reinforces this finding:

- The Hills Review, which only looked at impacts to 2016, found that the current climate change and energy policy package is likely to have a small but downward impact on the aggregate level of fuel poverty.
- DECC's most recent analysis suggests that the impact of current policies is likely to be broadly neutral for fuel poverty to 2027, although electricity price impacts in this analysis are slightly smaller than those associated with the higher level of investment that we have recommended.

4 The exact methodology differs slightly between the devolved administrations. Fuel poverty estimates are thus not strictly comparable.

Slightly higher levels of support for the fuel poor may in future be required than in current policies if fuel poverty impacts are to be fully offset. In particular, policy strengthening is required if the issue of fuel poverty in electrically-heated households is to be addressed, and currently high numbers of fuel poor households are to be reduced.

Box 4.2: Fuel poverty and energy efficiency

Energy performance and type of heating fuel are key indicators of fuel poverty:

- Fuel poor households on average live in less energy efficient homes (in 2011, fuel poor households averaged SAP 48.4 versus 57.8 for non-fuel poor households. SAP rating is expressed on a scale of 1 to 100, the higher the number the lower the running costs).
- One third of households who live in the worst (G-rated on the energy performance scale) properties are fuel poor.
- The average fuel poverty gap is four times higher in G rated properties compared to A-C rated properties (with an average fuel poverty gap of around £1,406 vs. £339 in 2011).
- Many of the most severely fuel poor households live in larger dwellings with solid walls.
- A greater proportion of non-gas properties are in fuel poverty (15% versus 10% for gas properties).

The Hills review suggested that policies that improve the thermal efficiency of dwellings tend to be more cost-effective compared to policies that subsidise energy costs or increase incomes.

Source: DECC (2013) *Fuel poverty: a framework for future action*, findings apply to England only and use the 'low-income/high-cost' fuel poverty measure.

Strengthening of policies to address fuel poverty

Low-income households using electric heating will experience disproportionate impacts of policies to support investment in low-carbon power generation, given that associated costs are added to electricity bills:

- Around 9% of UK households have electricity as their primary heating source, consuming around three to four times as much electricity as the average dual-fuel household.
- While they are often on tariffs with lower unit prices than dual-fuel households (e.g. Economy 7), they still face much higher bills and will be more vulnerable to fuel poverty and particularly to the effect of policies that increase the cost of electricity.

Policies to address these impacts include supporting insulation measures in these homes (especially solid wall insulation), switching electrically-heated households to more efficient forms of heating and spreading costs of funding investments across electricity and heat bills:

- **Insulation.** Around 600,000 electrically-heated homes have solid walls, most of which could be insulated at negative or low cost per tonne of carbon. DECC analysis shows that insulation of these homes is a particularly effective way to address fuel poverty.
- **Switching heating system.** There is scope for many electrically-heated households to switch away from electric heating to gas, district heating or renewable heat.
  - For electrically-heated homes in areas on the gas network a shift to gas heating could reduce energy bills and exposure to increasing electricity costs.

– However, many electrically-heated homes are in high-rise blocks of flats, where gas heating is not possible because of health and safety regulations. District heating can provide a good solution for these buildings.

– The Renewable Heat Incentive will provide support for electrically-heated households to switch to more efficient forms of heating (e.g. heat pumps), thereby reducing electricity consumption and bill impacts of higher electricity prices. However, the high upfront costs of renewable options are a problem for low-income households and additional support may be needed (e.g. through the ECO Home Heating Cost Reduction Obligation).

- **Tariffs.** Bill impacts would be equalised across different groups of consumers through spreading the impact of low-carbon policies across electricity and gas bills. This would make a significant difference for the relatively small number of electrically-heated households and a small difference for the relatively large number of dual fuel households.

In addition, other options for targeting fuel poverty and neutralising the impacts of low-carbon policies include:

- New exchequer-funded policies, similar to those in the devolved administrations.
- Increasing the proportion of funding targeted at the fuel poor under the Energy Company Obligation (as suggested by the Hills Review), including under the Carbon Emission Reduction sub-obligation which subsidises solid wall insulation.
- Providing support for electricity-focused measures (e.g. appliance & lighting replacement programmes).
- Reinforcing incentives for energy efficiency improvement for the fuel poor through setting ambitious standards for the private rented sector, and possibly for the owner occupied/ social sectors.
- Targeting funding currently provided through the Winter Fuel Payment (a tax-free payment of between £100 and £300 currently paid to everyone born on or before 5 January 1952) to the fuel poor so as to limit impacts prior to energy efficiency improvements being made.

The Government published a 'Fuel Poverty Framework for Future Action' in July 2013 and has committed to setting a new fuel poverty target that focuses on improving the energy efficiency of the homes of the fuel poor. This is a step forward but needs to be accompanied by some adjustment to current policies, as well as possibly new measures.

Incremental energy affordability and fuel poverty impacts associated with the fourth carbon budget are relatively small compared to those under current policies. They are manageable, particularly with policy strengthening, for example, to increase uptake of energy efficiency measures generally and in fuel poor households.

Summary: Energy affordability and fuel poverty impacts have not changed since the budget was set. In particular, underlying investments, costs and price impacts remain the same, together with potential to offset these impacts through energy efficiency improvement. Given that this is the case, there is no justification to change the budget on the basis of its energy affordability or fuel poverty impacts.

2. Competitiveness

Competitiveness risks relate to the possibility that energy-intensive firms subject to costs of carbon policies might relocate or transfer investment to other countries where these costs are lower. The Committee has done extensive work on the impact of low-carbon policies on competitiveness[5]. We found there is no evidence of significant relocation due to low-carbon policies to date given a low carbon price, allocation of free allowances and exemption from the Climate Change Levy for sectors at risk.

In this section we consider competitiveness risks for energy-intensive industries to 2030, together with opportunities for mitigating risks. We first consider impacts on energy-intensive industries and then impacts on electricity-intensive industries.

We draw on our detailed report on competitiveness impacts published in April 2013. Box 4.3 sets out the key conclusions from our analysis.

Box 4.3: Conclusions on competitiveness

- Direct emissions – measures in the fourth carbon budget are low-cost and cost-effective at the carbon price. Sectors at risk of competitiveness impacts are allocated free allowances in the EU ETS. Our analysis suggests some have surplus allowances to bank to 2020, particularly if they undertake cost-effective abatement. There may be a need for continued support to 2030 depending on progress towards a global deal.
- Indirect emissions – higher electricity prices from low-carbon measures in the power sector pose a risk to electricity-intensive sectors. Government has a package of measures to support at-risk sectors, which is broadly in line with the amount needed to compensate these sectors in 2020. They could add up to £5 to household bills.
- The required support is expected to decline through the 2020s as there will be only a small increase in the low-carbon component of UK electricity prices, with larger increases in prices elsewhere as countries adopt low-carbon measures. It is important to keep this under review.
- A statement now from the Government about continued support would help improve investment conditions for energy-intensive industries.
- The fourth carbon budget does not preclude any price benefits that may ensue from shale gas impacts on the gas price, although the expectation is that these will be very small.
- There is no change in circumstances on which budget was set with respect to competitiveness, therefore there is no rationale to change the budget on this basis.

a) Impacts on energy-intensive industries

Impacts to 2020

Industries subject to competitiveness risks due to low-carbon policies are energy-intensive with 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 regarded as being subject to international competition if they trade extensively with other countries (particularly with countries outside the EU with no climate policies).

5 CCC (2013) *Reducing the UK's carbon footprint and managing competitiveness risks.*

UK energy-intensive industries account for around 2% of GDP, 2% of employment (600,000 jobs), and are particularly important in some local contexts (e.g. in Wales energy-intensive industries account for 7% of GVA and 4% of employment, with a concentration of industry around Port Talbot; one-sixth of the UK's chemical industry is located in Scotland).

Key energy-intensive industries are paper, basic metals, non-metallic minerals, coke manufacture and refineries, chemicals, rubber and plastics, wood, wood products and textiles. Energy costs for these sectors represent 10 to 30% of GVA. (Figure 4.2).

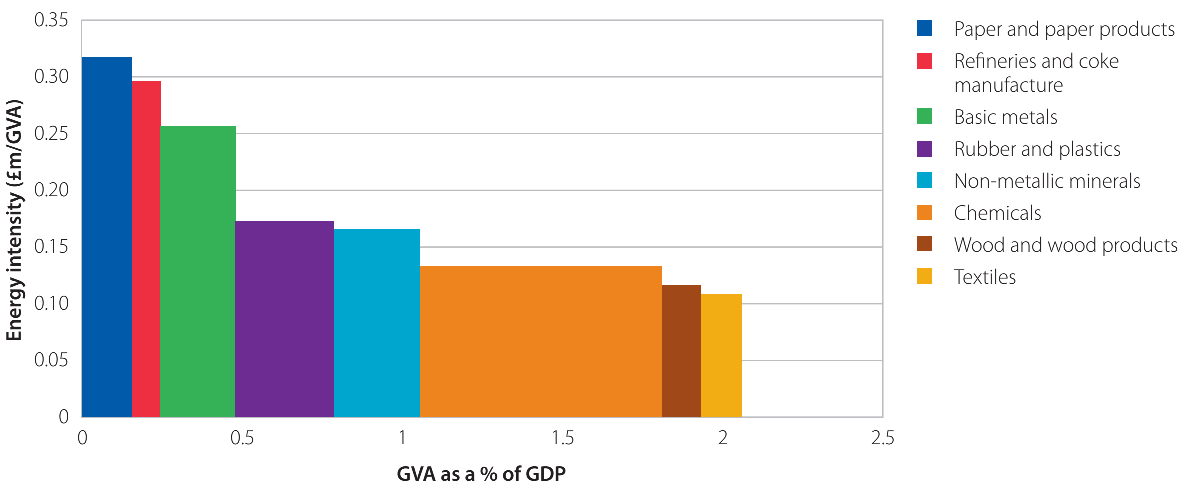
Energy-intensive industries are included in the EU ETS, requiring them to surrender allowances to cover carbon emissions associated with their energy consumption. Paying for such allowances would raise the costs of energy-intensive industries relative to competitors outside the EU, resulting in competitiveness risks.

In order to mitigate competitiveness risks, the EU agreed that free allowances would be 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). This effectively makes the EU ETS neutral for energy-intensive firms.

In practice some sectors have surplus allowances due to over-allocation in phases I and II of the EU ETS (covering 2005-07 and 2008-12) and implementation of abatement measures. To the extent that there has been over-allocation, windfall profits could result and could persist through phase III (2013-20) given allowed banking of allowances between phases.

Therefore competitiveness risks arising from direct measures to reduce emissions to 2020 are limited under the current EU approach to energy-intensive industries.

Figure 4.2: Energy intensive industries energy costs and GVA (2011)



Source: CCC calculations based on ONS and DECC data.

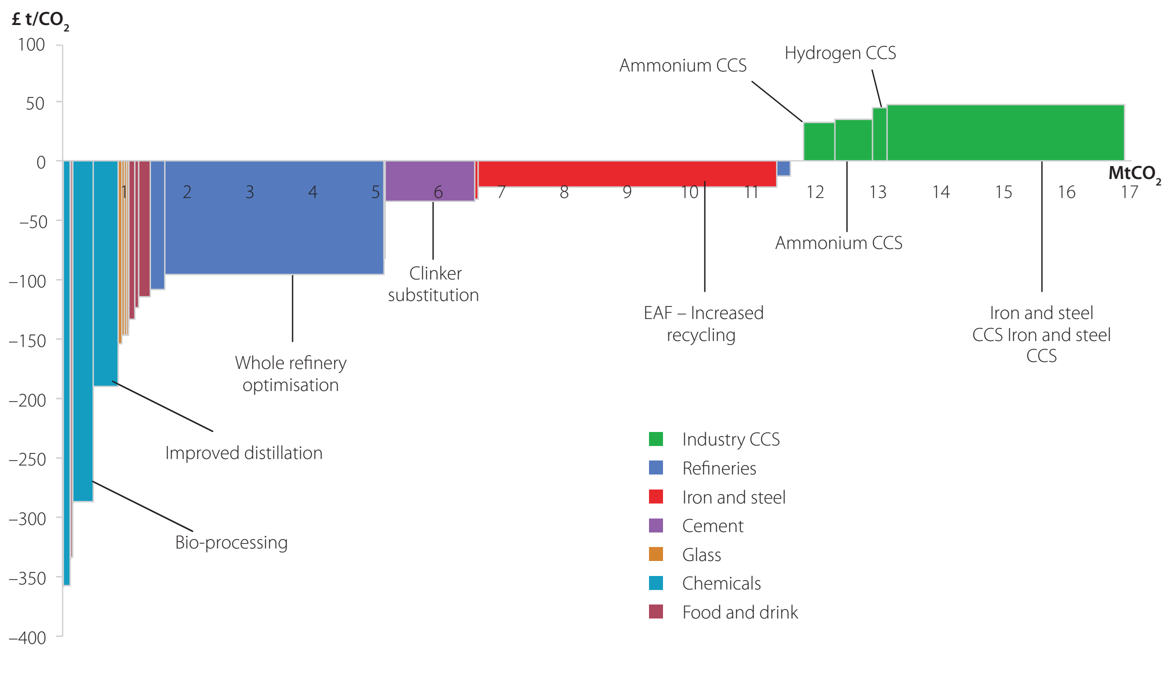
Impacts through the 2020s

In designing the fourth carbon budget, we assessed the cost-effective path for industry emissions through the 2020s, and identified significant scope to reduce emissions at low cost in 2030 (Figure 4.3). The fourth carbon budget reflects implementation of measures on the relevant part of the path through the 2020s.

Our updated assessment for this report identifies similar cost-effective abatement measures as our previous assessment. Our analysis in Chapter 3 shows that this level of abatement in industry, alongside other cost-effective measures in the rest of the economy, would be more than enough to meet the legislated fourth carbon budget.

- Our latest assessment suggests potential from energy efficiency measures, such as improvements in blast furnace operation and clinker substitution in cement production, could contribute around an 11% emissions reduction in the 2020s, compared with 10% assumed in our previous advice. Much of this is negative cost and implies savings to operators.
- We find potential for biomass and biogas to reduce fossil fuel heating applications in industry by around 11%, compared with 12% identified previously.
- We continue to assume the potential for installation of four carbon capture and storage plants in these sectors by 2030.

Figure 4.3: Measures to reduce emissions in energy-intensive industry in the Fourth Carbon Budget



Source: CCC modelling; AEA (2010).
Notes: Chart shows measures that apply to carbon intensive industry. There are further measures for industry in the fourth carbon budget that do not appear in this chart (e.g. renewable heat and short payback efficiency measures). For a full list of technologies see supporting data on the CCC website.

The key point in understanding the potential competitiveness impacts of this reduction in emissions is that the associated cost is low relative to plausible EU carbon prices for the 2020s and in many cases would reduce costs even without a carbon price. The implication is that implementing these measures could improve the competitive position of UK firms. Therefore, intra-EU competitiveness impacts should be very limited whatever the EU approach to protection of energy-intensive industries.

Turning to impacts versus the rest of the world, Part 1 of our advice on the review of the fourth carbon budget[6] showed that the UK was not acting alone in implementing measures to meet climate change targets and that many countries have made progress delivering their Copenhagen commitments.

Nevertheless, EU carbon prices may remain relatively high compared to those in other regions through the 2020s. To the extent that this continues, the risk to competitiveness should be addressed in order to prevent relocation of production away from the EU, which would be damaging from an economic perspective and offer no environmental benefit.

We will continue to monitor progress towards an EU 2030 package and a global agreement closely, and consider implications for options to address competitiveness impacts through the 2020s. These include: continued granting of free allowances; border price adjustments; and sector agreements. The UK should ensure that measures to mitigate competitiveness risks are included as part of the new EU 2030 package.

Use of shale gas by energy-intensive industries

In 2012, industry accounted for around 13% of UK gas consumption over half of which was by energy-intensive industries. The most gas-intensive sectors are glass, chemicals, ceramics, textiles, plastics and parts of food manufacturing where gas costs represent 10-30% of GVA. However, total expenditure on gas is around one third of that on electricity for the energy-intensive sectors.

In the US, development of shale gas has reduced gas prices. The main effect of this has been to incentivise a switch from coal to gas in electricity generation. Direct impacts on energy-intensive sectors have not been apparent at the macroeconomic level; latest economic data suggests energy-intensive industries have not grown faster than manufacturing as a whole in recent years, which in turn has grown slower than the overall economy.

If sustained, significantly lower shale gas costs in the US could present a direct competitiveness risk to UK gas-intensive firms trading with the US, and risks production from UK-based gas-intensive industries relocating to the US.

- Currently around 12% of trade by energy-intensive industries is with the US, ranging from 0.3% in the cement sector to 14% in chemicals. A worsening terms of trade could see UK export markets eroded and higher import penetration by US firms.

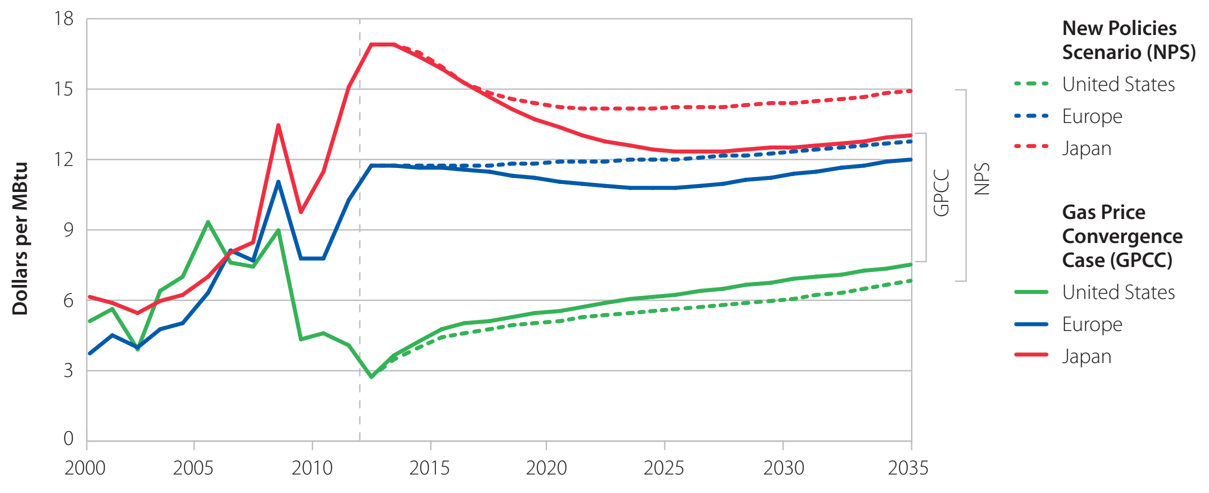
6 CCC (2013) *Fourth Carbon Budget Review – part 1 – Assessment of climate risk and the international response.*

- In the longer-term there is a risk that investment and jobs could re-locate to the US. This will depend on access to markets, transport costs from the US and other factors (e.g. labour costs, exchange rates).

These risks will continue as long as a gas price differential persists between the UK/EU and the US. This is something that is likely to be the case, given the high cost of transporting and storing gas, and the limited US trade with the EU.

- Gas price differentials between the US and EU markets are currently around $9/MBtu – with gas prices in the EU around 3 times higher than those in the US. The IEA expects price differentials to narrow slightly in the 2020s and beyond but projects EU prices that are still 1.5 to 2 times higher than those in the US in 2030 (Figure 4.4).
- US gas trade with the EU is likely to be limited going forward. Four LNG (i.e. liquefied natural gas) projects at existing terminals have received conditional approval in the US. Scope to increase projects beyond this is likely to be limited given they are on greenfield sites and face higher costs of both liquefaction and construction of terminals. These projects are expected to fill Asian gas demand rather than European markets, given the higher current and projected prices in Asia.

Figure 4.4: Regional gas price differentials (2000-2035)



Source: IEA 2013 World Energy Outlook.

However, this gas price differential reflects energy market fundamentals rather than carbon polices:

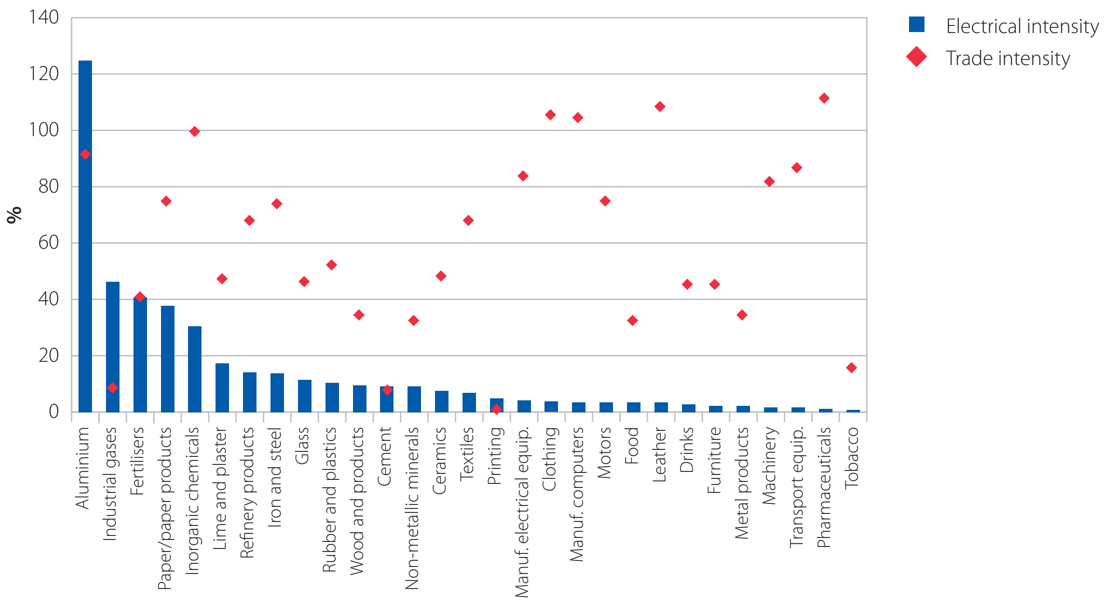
- There is more shale gas relative to demand in the US than the EU.
- The cost of shale gas supply is lower in the US than the estimated cost in the EU – reflecting more favourable geological, regulatory and market conditions.
- There is limited US export capacity relative to EU demand.
- Low-carbon polices do not add to gas prices faced by energy-intensive industries under current UK and EU approaches.

The fourth carbon budget analysis suggests that while energy efficiency measures will reduce gas demand to 2030, there will still be significant gas use in energy-intensive industries. Therefore the fourth carbon budget does not preclude any price benefits that may ensue from shale gas impacts on the gas price, although the expectation is that these will be very small.

b) Impacts on electricity-intensive industries

The sectors most at risk of competitiveness impacts from low-carbon policies levied on electricity bills are those which are both electricity and trade intensive. Sectors most at risk are aluminium, chemicals, paper and paper products, non-metallic minerals, refinery products, iron and steel and rubber and plastics (Figure 4.5).

Figure 4.5: Electricity and Trade Intensity of UK manufacturing sectors



Source: CCC calculations, ONS and DECC data.
Notes: Electricity intensity is £electricity bill/GVA. Trade-intensity is (imports+exports)/(output+imports). Trade intensity can be over 100% due to different data sources used for trade and GDP data.

In our April 2013 report[7] we showed that low-carbon policies have had no more than a minor impact on relocation of energy-intensive industry to date, given their limited impact and measures in place to protect those most at risk. Going forward, electricity prices are expected to increase to 2020 under the Government's current policies to support investment in a portfolio of low-carbon power generation technologies (i.e. renewables, nuclear and CCS).

Analysis in our April 2013 report showed that this price increase could increase costs of electricity-intensive industry by around £700 million in 2020. This would be £600 million more than costs would increase in other countries and profits would be reduced by £150-400 million, depending on scope to pass through higher costs to consumers.

7 CCC (2013) *Reducing the UK's carbon footprint and managing competitiveness risks.*

Based on this we suggested that compensation of £150-400 million could be required to offset electricity price impacts, rising to £600 million in the extreme case where there is no scope for cost pass through.

The Government is putting in place arrangements to offset these impacts:

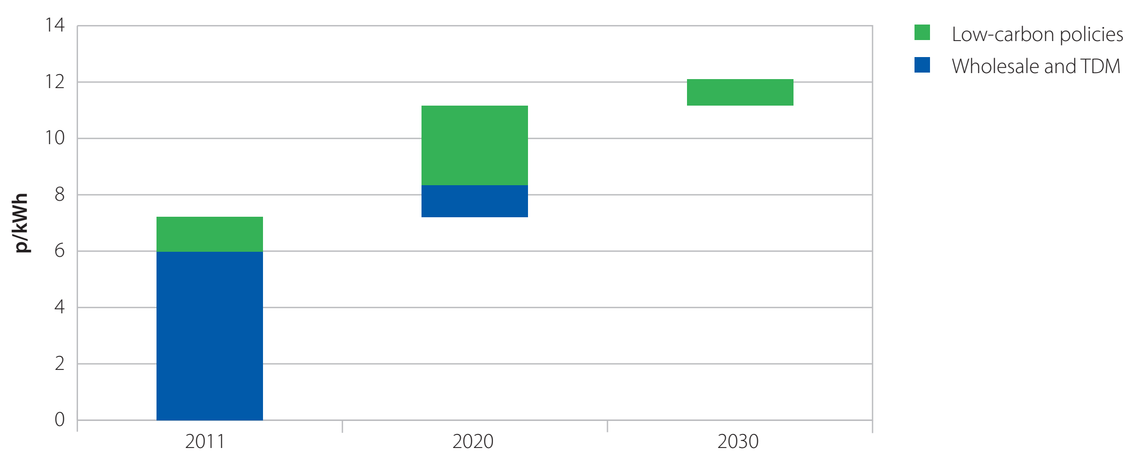
- A scheme to compensate for the indirect impacts of the EU ETS on electricity prices is in place, and open to applicants.
- A scheme to help firms with the impacts of the Carbon Price Floor is being designed and awaiting State Aid approval from the European Commission.
- Energy-intensive sectors will also be eligible to receive up to 90% compensation from the Climate Change Levy (CCL) from April 2014, subject to meeting industry energy efficiency benchmarks.
- A consultation on industry compensation for the costs of supporting low-carbon generation under the Electricity Market Reform was held in the summer, with the detailed scheme design currently being finalised. The draft methodology suggests that the implied level of support should be sufficient to offset higher industry costs.

The support proposed by the Government is at the top end of the range that we recommended and should offset the impacts of electricity price increases due to low-carbon policies to 2020.

Impacts through the 2020s

We have identified a clear benefit from portfolio investment in low-carbon technologies over the next decade (see Chapter 3, and our May 2013 report 'Next steps on Electricity Market Reform'). While there are further electricity price increases associated with this investment, these are relatively small compared to projected increases over the next decade (Figure 4.6). The competitiveness impact of these further increases will be limited depending on the extent to which other countries adopt carbon policies.

Figure 4.6: Impact of low-carbon measures on industrial electricity prices



Source: CCC calculations for our April 2013 report *Managing competitiveness risks of low-carbon policies.*

Our assessment is that the combination of these effects (i.e. small increases in UK electricity prices with more rapidly rising prices elsewhere) will reduce the extent of support required in 2030 compared to 2020 (Box 4.4).

Box 4.4: Industrial electricity prices in the UK and key trading partners

- Electricity prices for industrial users in the UK were high in 2011 relative to the rest of the EU and internationally, reflecting higher base prices (wholesale plus network costs), with low-carbon costs adding just over 1.2 p/kWh (around 17%).
- Key low-carbon measures adding to industry costs are the relatively high costs of meeting the 2020 EU renewable target in the UK, the Carbon Price Floor and the Climate Change Levy.
- These measures continue in the 2020s, adding around 4.1 p/kWh to industrial prices in 2020 (i.e. 2.8 p/kWh more than in 2011) and 5.0 p/kWh in 2030 (i.e. 0.9 p/kWh more than in 2020). Impacts are lower for industries with autogeneration (i.e. industries generating their own electricity, rather than sourcing this from the grid).
- We also expect future prices in key trading partners to increase as they adopt low-carbon measures. Key to the competitiveness impact will be how quickly we expect carbon prices to converge.
  - Scenario 1: 'Convergence'. There is a carbon price by 2030, based on DECC central estimates. The UK Carbon Price Floor is higher than this up to 2030 but converges with the rest of the EU to 2030. Outside the EU, countries introduce carbon markets in the early 2020s with prices converging by 2030.
  - Scenario 2: 'EU-led'. A stretching scenario for UK competitiveness impacts, assumes countries outside the EU ETS are on a slower track with no carbon price convergence by 2030.
- Under the 'Convergence' scenario price differentials between the UK and other countries are highest in 2020. By 2030, the gap narrows leading to a more even spread of low-carbon costs, with some countries having higher overall electricity prices than the UK. Under the 'EU-led' scenario, significant price differentials remain with non-EU countries.

Source: CCC (April 2013), *Reducing the UK's carbon footprint and managing competitiveness risks.*

Support for the sectors at risk could be achieved by extending current policies to 2020 and beyond, and linking these to the pace of adoption of low-carbon measures in other countries. The Government should seriously consider clarifying its intent to continue support as necessary, in order to provide confidence for investors in electricity-intensive industries making decisions about assets that will be here for decades to come.

We conclude that impacts of low-carbon policies on electricity-intensive industries relative to those in other countries should fall in the 2020s. This reinforces our conclusion when first recommending the fourth carbon budget that competitiveness impacts are manageable. The challenge now is to signal and implement required policy to make it clear to industry that any potential impacts will be managed.

The underlying drivers of competitiveness remain unchanged (e.g. electricity price impacts in the UK and other countries). Therefore the circumstances relating to competitiveness have not changed, and there is no rationale to change the budget on this basis. If anything, the rationale for the currently legislated budget is stronger, given that other countries have now made commitments to reduce emissions; and that the UK Government has put in place approaches to limit risks for electricity-intensive industries.

Summary: Our assessment of the competitiveness risks to energy-intensive sectors suggests there is no evidence of significant industry relocation due to low-carbon policies to date or reason to expect this in the future. Costs continue to be manageable and measures are in place to protect industries at risk of both direct and indirect impacts of low-carbon policies, albeit that these measures need to be extended. The circumstances relating to competitiveness have not changed since the fourth carbon budget, and there is no rationale to change the budget on this basis.

3. Security of supply

Box 4.5: Conclusions on security of supply

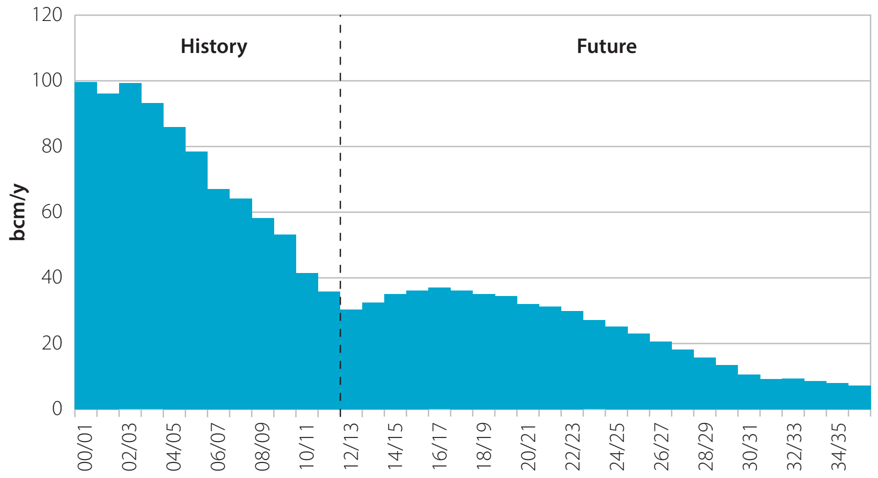
- Meeting the fourth carbon budget offers a security of supply benefit in reducing dependence on imported fossil fuels.
- Use of UK shale gas would provide an additional benefit, but is not a substitute for low-carbon technologies in this respect.
- Intermittency of low-carbon sources of power generation is manageable while maintaining security of supply.

Benefits associated with reduced dependence on imported gas and oil

The UK would be exposed to increasing security of supply risk in an energy system that is based on fossil fuels. This is because reduced production of oil and gas from the North Sea would require increasing energy imports, with which there would be associated geopolitical risk.

- Britain has benefitted since the late 1960s due to low-cost oil and gas from the North Sea.
- However, production has declined as North Sea fields are exhausted. For example, gas from the UK continental shelf fell by 65% in the last decade.
- Supplies from the North Sea are expected to fall further in future (Figure 4.7).
- A fossil-fuel based energy system would require increasing energy imports over time, in some cases from countries where there is geopolitical risk.

Figure 4.7: Current and projected gas supply from the UK continental shelf



Source: National Grid (2013), Future Energy Scenarios.

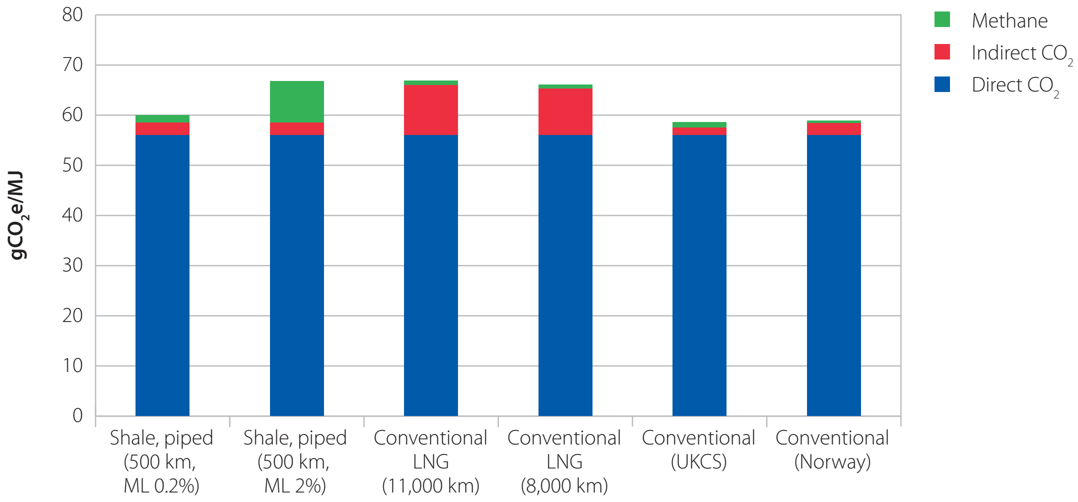
Investment in low-carbon technologies would reduce dependence on imported fossil fuels, therefore improving security of supply. In particular, this would reduce the likelihood and impact of fuel supply interruption, and would provide a hedge against the risk of high fossil fuel prices in international markets.

- Compared to a business as usual path with rising demand, the abatement scenario we set out in Chapter 3 would reduce 2030 gas demand by around 60% and oil demand by around 50%. The UK would be less reliant on imports – more so if domestic supply of shale gas can be brought to market (see below) – therefore reducing the likelihood and impact of fuel supply interruptions.
- There is a risk of high fossil fuel prices which would pass through to higher consumer prices in an energy system which has not been decarbonised. A low-carbon energy system is considerably less exposed to the risk of high fossil fuel prices, and to volatility in prices more generally, which can have a destabilising macroeconomic effect.

The use of low-carbon technologies and of domestic shale gas are not substitutes in providing security of supply. Rather, use of shale gas offers additional security of supply benefits, substituting for imported gas in meeting residual gas demand in a carbon-constrained world. Improved security of supply, rather than lower prices, is likely to be the main benefit of developing domestic shale gas supply.

- Abundant resources of shale gas have been identified in the UK, although there remains considerable uncertainty about the scope to bring these to market.
- Provided methane emissions from well completion can be controlled, local shale gas can have emissions comparable with natural gas imported by pipeline and lower than imports of liquefied natural gas (LNG) (Figure 4.8).

Figure 4.8: Illustrative lifecycle emissions of gas



Source: CCC analysis.
Notes: Emissions per unit energy of gas delivered. Includes transmission but excludes UK distribution. ML = methane leakage from well completion.

- If environmental and other impacts can be addressed, use of shale gas rather than imported gas in meeting residual gas demand in a decarbonising energy system could enhance security of supply.
- This benefit is additional to that provided by low-carbon technologies, given that the expected supply from shale gas is lower than the residual gas demand in a decarbonisation scenario. For example, National Grid consider a 'Shale Sensitivity' in which shale gas supply rises rapidly through the 2020s to provide around 10 bcm/year by 2030. This would be sufficient to meet around 15-20% of gas demand in a decarbonisation scenario, but still leave a significant import dependency (e.g. the increased shale gas supply would reduce the proportion of gas demand met by imports from 75% to 60% in Grid's 'Gone Green' decarbonisation scenario).[8]
- This is likely to be the main benefit, together with increased tax revenues and benefits for UK industry and jobs. Any impact on prices faced by gas consumers is expected to be small. (see Box 3.2 in Chapter 3).

We conclude that there is a potentially complementary role for investment in low-carbon technologies and shale gas in improving security of supply. Shale gas does not change the conclusion that a transition to a low-carbon economy would reduce import dependency given that the potential contribution from shale gas is lower than the UK import requirement for gas even in a decarbonising system.

8 National Grid (July 2013) *UK Future Energy Scenarios*

Managing an intermittent power generation system

Although it is sometimes argued that there would be a security of supply risk associated with intermittent power generation (i.e. that the lights will go out when the wind is not blowing), even high levels of intermittency are manageable through a combination of demand flexibility, energy storage, interconnection, and balancing generation.

In previous reports we identified and assessed these options for managing intermittency:

- **Demand-side response.** Active management of demand (e.g. charging electric vehicles or running washing machines overnight when other demand is low) can help smooth the profile of demand and reduce the requirement for capacity during peak periods. Widespread deployment and use of smart technologies (such as smart meters) will facilitate increases in demand-side response given sufficient consumer engagement.
- **Interconnection.** Interconnection already provides a valuable source of flexibility to the UK, with around 4 GW of capacity with Ireland, France and the Netherlands. Flows are price-driven according to relative demand and supply, and to the extent that these persist, will continue to be an important source of flexibility.
- **Storage.** Bulk storage, such as pumped storage, can be used both to provide fast response and to help provide flexibility over several days (providing supply at times of peak daily demand rather than continuously over a whole period). Other storage options could emerge in future.
- **Flexible generation.** Gas-fired capacity offers the potential to meet demand when output from intermittent technologies is low, and can be operated reasonably flexibly. There may also be some scope for using low-carbon capacity flexibly – for example scheduling maintenance outages for summer when demand is low, or running CCS at slightly reduced load factors.

Given these options, previous work that we commissioned from Pöyry found that high shares of intermittent renewables could be managed (i.e. up to around 60% of generation in 2030 and over 75% in 2050).[9] The scenarios that we set out in Chapter 3 of this report involve much lower penetration of intermittent renewables (e.g. around 40%), and significant increases in interconnection, flexible demand and gas-fired capacity, such that security of supply is maintained and peak demand can still be met by total despatchable capacity.

Summary: There has been no change in the expected impact of the fourth carbon budget on security of supply. Low-carbon investment offers benefits for security of supply through reduced reliance on imported fuels, while intermittency in power generation can be managed. This is unchanged in the light of developments in shale gas, which offers additional security of supply benefits, but should not be seen as an alternative to low-carbon technologies in this respect.

9 Pöyry (2010) *Options for low-carbon power sector flexibility to 2050*. CCC (2011) *Renewable Energy Review*. CCC (2012) *The 2050 target*. Available at www.theccc.org.uk.

4. Fiscal impacts

In our 2010 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, even without any rebalancing in the tax system, fiscal impacts from meeting the fourth carbon budget are likely to be small and manageable relative to total revenues.

- Additional revenues from auctioning of allowances in the EU Emissions Trading System (EU ETS) would largely offset losses from fuel duty and vehicle excise duty.
- However, scope for fiscal rebalancing (e.g. by adjusting banding for vehicle excise duty in line with vehicle efficiency improvement) means that impacts could be neutral or even positive.

We have reconsidered these factors in light of developments since 2010, and conclude that fiscal impacts remain small and manageable overall, particularly given scope for fiscal rebalancing to maintain revenues in the period to 2030.

- **EU ETS auctioning revenues.** UK revenues from auctioning of EU ETS allowances could increase to around £4-6 billion by 2030 in a central price scenario, rising to around £11 billion with full auctioning. This reflects a rising carbon price – and Carbon Price Floor for the power sector – which more than outweighs a falling EU ETS cap.
- **Transport revenues.**
  - Current fuel duty and vehicle excise duty (VED) receipts are around £27 billion and £6 billion respectively.
  - With an unchanged fiscal regime, our scenarios for meeting the fourth carbon budget would result in reduced revenues as efficiency of conventional vehicles improves and electric vehicles penetrate the fleet. For example, we assume that average efficiency of the car fleet improves from 108 gCO_2/km in 2020 to 66 gCO_2/km in 2030, and electric vehicles represent 31% of the fleet in 2030.
  - Fuel duty revenues would fall by up to around £4 billion relative to our reference emissions projection (which also assumes significant efficiency improvement from current levels). While VED revenues would fall very substantially relative to current levels, the incremental impacts of the fourth carbon budget would be smaller. This is because most new cars, and the fleet average, would be below the current threshold for zero-rating (100 gCO_2/km) under both a current policy baseline and the fourth carbon budget scenario. Furthermore, VED impacts could be offset by adjusting banding as vehicle efficiency changes over time.

- **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. the Renewable Heat Incentive). We do not assess these in detail, given their small size and/or uncertainty about policy design in the 2020s. However, the scale of these measures in the current spending period is generally as expected in our original advice in 2010. We consider the impact of spending covered by the Levy Control Framework (i.e. costs associated with supporting low-carbon generation in the power sector) in our affordability analysis in section 1, since this is funded through energy bills rather than public spending.
- **Overall magnitude of net fiscal impacts.** This is likely to be small relative to total revenues (e.g. around 1%), and with scope for rebalancing could even be positive.

Summary: There has been no significant change in the fiscal implications of meeting the fourth carbon budget. Our conclusion remains that fiscal impacts from meeting the fourth carbon budget are likely to be small and manageable, particularly given scope for rebalancing in the tax system to 2030.

5. Differences in national circumstances within the UK

Scotland, Wales and Northern Ireland together account for just over 20% of UK greenhouse gas emissions. Since our 2010 advice, all three nations have made or are considering increased commitments and there has been some good progress on policy development and the implementation of measures.

a) Scotland

The Scottish Parliament passed legislation in 2011 to set annual emissions reduction targets for 2023-27, based on our advice to the Scottish Government and comparable with the fourth carbon budget. 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 in the fourth carbon budget. The Scottish Government published its report on proposals and policies (which sets out how it intends to meet these targets) in 2013.

In recent years, Scotland has made some good progress reducing emissions in key sectors. For example, it has been leading the UK in renewable energy deployment, both in terms of installed capacity and the pipeline of potential capacity. However, delivery of future targets will be reliant at least in part on UK-wide policies and requires continued commitment to the fourth carbon budget at UK level.

b) Wales

Wales published its Climate Change Strategy in 2010 and aims to meet two targets: (1) to reduce emissions within devolved competence by 3% each year from 2011 (compared to a 2006-2010 baseline) and (2) to reduce all Welsh emissions by 40% by 2020 from 1990 levels. These commitments go beyond UK commitments and are compatible with a path to the level of ambition in the fourth carbon budget. Wales has made good progress in some policy areas, for example implementing ambitious residential energy efficiency programmes.

Currently, the Welsh government is reviewing its climate change strategy and policies, as well as considering the scope of an upcoming Environment Bill. We provided advice to the Welsh Government in early 2013, suggesting that a statutory underpinning to Wales' climate change targets could help to provide certainty to policy-makers, businesses, investors, and wider society in Wales and strengthen incentives to reduce emissions.

c) Northern Ireland

The Northern Ireland Executive has increased Northern Ireland's emissions reduction target from 25% to 35% by 2025 (relative to 1990 levels). The Executive's Greenhouse Gas Action Plan was agreed and published in February 2011, outlining how each department in the Executive will contribute towards meeting the 2025 emissions reduction target. Northern Ireland has greater devolved responsibilities than Scotland and Wales (e.g. the Energy Company Obligation does not apply to Northern Ireland) but delivery of its target still partially depends on UK-level policy and the fourth carbon budget.

Summary: Overall, since 2010 there has been progress in the devolved administrations in terms of targets and policies. Much remains to be done but achievements to date (where the devolved administrations have led the UK in key areas) provide confidence that these challenges can be addressed. It is important that the UK remains committed to the currently legislated fourth carbon budget in order to support the devolved administrations in the delivery of emissions reduction against ambitious targets.

6. Wider health and environmental impacts

Box 4.6: Conclusions on wider health and environmental impacts

- There are likely to be significant additional net benefits from taking action to reduce emissions.
- Fossil fuel combustion and inefficient buildings are closely linked to air and noise pollution. Our abatement scenario therefore leads to significant benefits in these areas.
- Additional significant opportunities arise to reduce traffic congestion and road accidents, and to improve health through more active forms of travel.
- There are some costs, notably in air pollution from increased use of biomass in heat, the landscape impact of new installations (especially renewables) and potential hazards from increased nuclear power. These negatives can often be reduced through appropriate mitigation actions.

Many low-carbon measures have significant impacts (positive and negative) beyond those specified by the Climate Change Act as factors in setting carbon budgets. These impacts are, however, covered implicitly by the broad requirement to consider economic and social circumstances. In particular, many measures directly affect human health and the environment, aside from the long-term indirect benefits from avoided climate change.

In the impact assessment accompanying the Climate Change Act, the Government estimated additional health benefits from improved air quality totalling £32 billion (net present value)[10]. A further assessment was made by DECC in its 2011 Low Carbon Plan[11] which identified a number of health and environmental benefits, and some trade-offs, in meeting the first four carbon budgets.

We have commissioned a more comprehensive survey[12] of the various impacts likely to arise from following our main abatement scenario, relative to a scenario of no action to reduce emissions (Box 4.7). A number of significant impacts have been identified:

- **Improved air quality** will follow from economy-wide measures which reduce or replace fossil fuel use. There are some air quality trade-offs in using biomass, especially as a replacement for fossil gas in heating, and in using coal with carbon capture and storage (CCS) for electricity. Overall, however, our scenarios show a large air quality benefit.
- **Reduced noise** is an additional benefit arising from measures such as improved glazing, electric vehicles and reduced traffic.
- **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.
- **Potential trade-offs** 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 our analysis suggests there are likely to be large additional net benefits from decarbonisation. The total of the impacts we were able to monetise provides a significant further rationale for meeting carbon budgets to 2030, additional to the cost savings identified in Chapter 3. There are some trade-offs between low-carbon measures and other health or environmental goals, but these can be minimised by good design and practice.

10 DECC (2009) *Climate Change Act 2008 Impact Assessment*, http://www.climatedatabase.eu/sites/default/files/eia_climatechangeact.pdf
11 DECC (2011) *The Carbon Plan: Delivering our low-carbon future, Annex B.*
12 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 accompanying this report – see CCC website).*

Box 4.7: Identifying and quantifying impacts on human health and the environment

In collaboration with Ricardo-AEA, Imperial College London and Defra we have surveyed the wider impacts (externalities) associated with low-carbon measures, beyond those included in standard cost-benefit calculations.

Externalities were classified using HM Treasury Green Book methods, and where possible they were valued in accordance with Government guidelines. We then applied these to the central abatement scenario from our 2010 report on the fourth carbon budget, relative to a scenario of no abatement. In this way we identified additional costs and benefits by 2030 from meeting the first four carbon budgets.

A range of externalities emerge, both positive and negative. Some are well understood and readily quantified and monetised. Others are less well understood or quantifiable. Our work is not comprehensive, and some impacts will be large at local levels, however the work gives a good national-level indication of the most important impacts.

Of the significant benefits, air quality and noise are both improved by many measures across the economy. Further large health (and time) benefits are provided by a small subset of measures – reduced vehicle use and increased walking and cycling – which contribute a relatively small amount to overall carbon abatement.

- Air quality. Air pollution causes heart and lung damage, damage to buildings, and ecosystem acidification. Both CO_2 and air pollutants are emitted by fossil fuel burning. Air quality benefits therefore come from many low-carbon measures such as greater efficiency, renewables and electrification of heat and vehicles. Monetising these impacts using Government methods we find an annual net benefit by 2030 on the order of £1 billion (i.e.10% of the total resource cost for our scenario), relative to a future of unabated gas and coal use to meet energy demand. This benefit is probably an underestimate: it excludes impacts outside the UK (a large fraction of pollution is blown across national boundaries) and the reduction in damage from ozone. It also excludes the benefits from less use of manure and fertiliser, which can overload ecosystems with nutrients. The overall air quality benefit is therefore likely to be substantial. Other studies suggest it is enough by itself to offset the entire costs of carbon abatement.[13]
- Noise. Impacts of noise include heart problems, sleep disturbance, slower learning and annoyance, as well as disrupting the natural environment. These are reduced through improved insulation and glazing in buildings, reduced traffic and more electric vehicles. Using Government methods to monetise these impacts leads to a benefit in 2030 of around £0.5 billion (i.e. offsetting around 4% of the total scenario resource cost). Although not included in this analysis, further noise benefits would come from more efficient aircraft and less growth in air travel.
- Active lifestyle. Lack of exercise is clearly linked to diabetes, dementia, depression, heart disease and some cancers. This is reduced by greater use of active transport (e.g. walking and cycling). Our scenario avoids 5% of projected car journeys by 2020, broadly in line with the potential identified by the Government's Smarter Choice Programmes. These avoided journeys are compensated by a combination of increased public transport, active travel and avoided journeys. If active travel were to account for one third of this (roughly equivalent to a doubling of current active travel) there would be a significant benefit, worth over £2 billion a year, or 20% of the scenario resource cost in monetary terms.
- Road accidents. Death and injury from road accidents arise at least in part from increased traffic on the roads. Analysis of our abatement scenario shows an increase in accident risk from greater numbers of pedestrians and cyclists, offset by a larger reduction in risk due to avoided travel in cars and HGVs. The estimated net benefits in monetary terms could be about 2% of the scenario cost, although the number of accidents will also depend ultimately on other factors such as road design and driving habits.

Source: 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 accompanying this report – see CCC website). CCC (2011) *Bioenergy Review*

13 West et al. (2013) *Co-benefits of mitigating global greenhouse gas emissions for future air quality and human health.*

Box 4.7: Identifying and quantifying impacts on human health and the environment

- Congestion. Reduced congestion leads to time savings for drivers, arising in our scenario from a both improved HGV logistics and modal shift away from cars. Applying DfT's national average value to monetise this effect suggests a large benefit, over £8 billion annually by 2030, or 60% of the total scenario resource cost. In practice the savings will depend on the distribution of congestion change in terms of location and time of day. Further analysis would be required to refine this estimate.
- Diet. High levels of red meat consumption lead to heart disease. We have not assumed reduced consumption as part of our scenarios. We have however previously assessed an illustrative 50% reduction, replaced by the same level of nutrition from plant products. This would lead to moderate greenhouse gas savings and large health benefits, equivalent in monetary terms to around £11 billion in 2030, or 80% of total scenario costs.

Some negative wider impacts were also identified for our scenario. In many cases actions can be taken to mitigate these impacts.

- Accident risk and pollution from coal CCS. Our scenario contains some coal burning coupled to carbon capture and storage (CCS). There are external costs to mining and burning coal, particularly in terms of accident risk, noise and pollution. Monetised estimates of these effects suggest they add roughly 0.5% to the scenario cost. Using gas CCS would reduce, but not eliminate, these costs.
- Accident risk from nuclear. Costs of waste disposal are (at least partially) accounted for in resource costs for nuclear. There are however further risks attached to the possibility of nuclear accidents. It is very difficult to characterise the costs associated with such events, which are rare but would have major consequences. Safeguards are in place, and a review following the Fukushima incident in Japan found no gaps in the UK nuclear safety regime.
- Impacts of bioenergy. Our scenarios employ bioenergy to levels consistent with our 2011 Bioenergy Review, which sought to minimise global impacts on biodiversity, water and food security. Beyond these wider impacts considered in the Review, biomass and biofuel burning gives rise to air pollution. Whether or not this is a net cost depends on the technology it replaces. Use of biomass for heat in buildings and industry can cause a net cost (although it is more than offset by the other air quality benefits noted above). Ways of limiting this cost include emissions standards for boilers, and targeting rural off-grid coal and oil-burning buildings rather than on-grid, densely-populated locations.
- Landscape impacts of renewables. Public attitudes to windfarms and other installations can vary widely and depend on a range of factors. Although studies in the UK and elsewhere have found limited concern over the visual impact of windfarms, there are notable instances of strong local opposition. The planning process has a key role to play in responding to these concerns.

Overall, there are a range of effects from well understood and easily quantifiable to less well understood and unquantified. But the overall impact is likely to be a net benefit, offsetting a substantial fraction of the total resource cost for meeting carbon budgets. If future fossil fuel prices turn out to be high and costs of low-carbon measures low, there could be a net benefit regardless of the carbon price.

Source: 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 accompanying this report – see CCC website). CCC (2011) *Bioenergy Review.*

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 or localised areas. Accounting for them strengthens the case for ambitious action to reduce emissions over the next two decades.

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