# Reducing the UK's carbon footprint and managing competitiveness risks

Committee on Climate Change I April 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.

## Progress meeting carbon budgets

The Climate Change Act requires that we report annually to Parliament on progress meeting carbon budgets. We have published four progress reports in October 2009, June 2010, June 2011 and June 2012.

## 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 and July 2012, we published advice on adaptation, assessing how well prepared the UK is to deal with the impacts of climate change.

# Acknowledgements


The Committee would like to thank:

**The core team that prepared the analysis for this report**. This was led by Ute Collier, David Kennedy and Ewa Kmietowicz and included: Owen Bellamy, Adrian Gault, Hanane Hafraoui, Jenny Hill, Alex Kazaglis, Nina Meddings, Kavita Srinivasan and Indra Thillainathan.

**Other members of the Secretariat that contributed to the report**: Alice Barrs, Tara Barker, David Joffe, Swati Khare-Zodgekar, Jo McMenamin, Laura McNaught and Joanna Ptak.

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**A wide range of stakeholders** who engaged with us, provided advice, attended our expert workshops, or met with the Committee bilaterally.

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# Foreword

I have now been the Chairman of the Committee on Climate Change for seven months. Production of this report has enabled me to participate in the rigorous and objective process by which the Committee's reports are compiled, in line with the meticulous standards instituted by Lord Turner, my predecessor. Those standards will be fully maintained on my watch.

Although we will not publish our review of the fourth carbon budget until the end of this year, the present document forms an important element in its compilation. Britain's determination to meet the challenge of climate change will best be achieved within a global agreement to limit harmful emissions. The report notes some of the encouraging steps towards emission reduction which have recently been taken by countries as far apart as China and Mexico, and the United States and South Korea. In the meantime, we must gain the advantages of green growth while protecting ourselves against any significant impact upon our competitiveness from our transition to a low-carbon economy, including decarbonised electricity generation.

The report is a reply to questions asked of us by the Government. We have considered the issue of the UK's carbon footprint and shown that it has increased over recent years, largely because of the growth in our imports. We have investigated whether the concurrent reduction in our home produced emissions could be explained by relocation of manufacturing industry. Our firm conclusion is that very little, if any, of that reduction results from offshoring as a result of low-carbon policies. Nonetheless, the size of our footprint is worrying and will need to be diminished. We have concluded, however, that as a basis for a global deal and in the working of UK carbon budgets the present approach – measuring our emissions on a production-basis remains appropriate. It provides a more accessible comparator, with fewer uncertainties and – for carbon budgets – relates to matters which are largely under our own control.

We have identified those industries which may be particularly affected by the relatively small addition to energy costs which derive from moving to a low-carbon economy. We are satisfied that for the period to 2020 there are sufficient resources already committed by the Government to compensate for this effect. In addition, we have considered the implications of the lifecycle emissions associated with the key technologies for the fourth carbon budget and we consider that the present proposals remain appropriate.

None of these considered responses have been reached without very considerable work by our excellent research team and the detailed contribution of all the members of the Committee. I would like to thank them all and I look forward to presenting our full assessment of the fourth carbon budget before the end of the year.

**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.

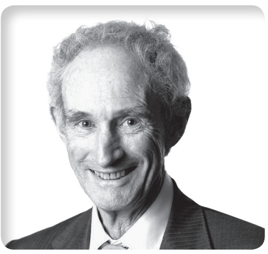
**Professor Samuel Fankhauser**
Professor Samuel Fankhauser is Co-Director of the Grantham Research Institute on Climate Change at the London School of Economics and a Director at Vivid Economics. He is a former Deputy Chief Economist of the European Bank for Reconstruction and Development.

**Sir Brian Hoskins**
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.

**Lord John Krebs**
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 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.

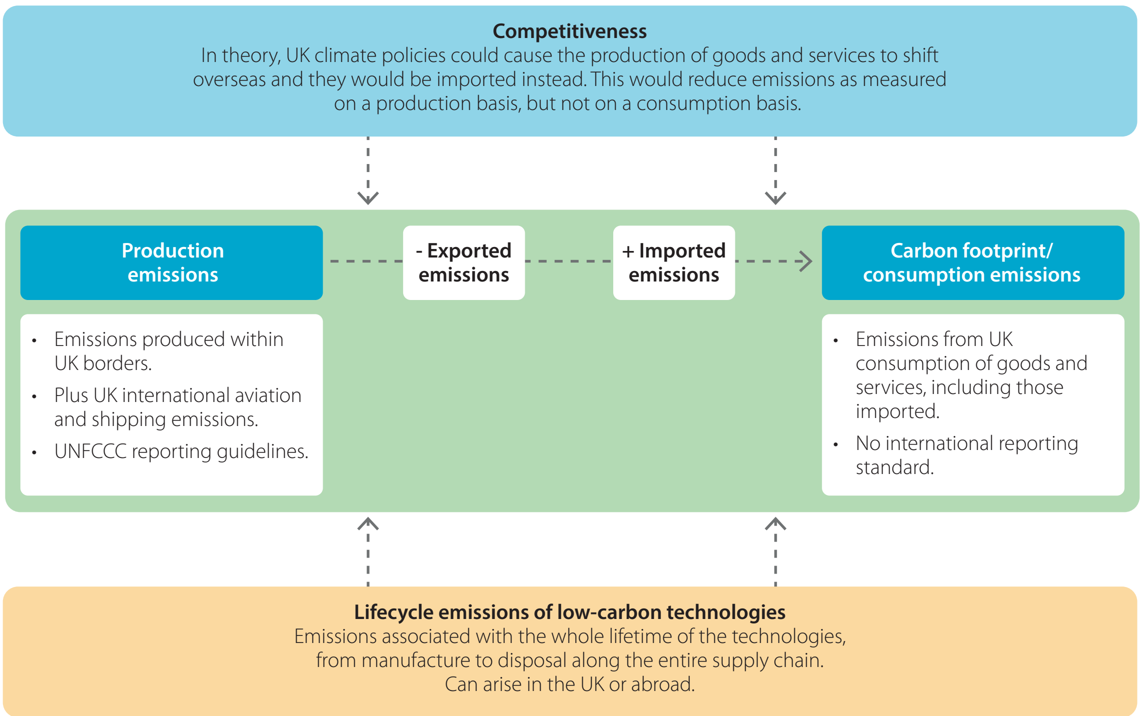
# Executive summary and key messages

This report responds to a request by the Government for us to look at the role of consumption-based emissions (i.e. the UK's carbon footprint, including imported emissions). In it, we cover past trends and set out future scenarios for UK consumption emissions. We also consider lifecycle emissions of low-carbon technologies in order to understand how their deployment would impact the UK's carbon footprint.

In providing this advice, we address the related issue as to whether offshoring of industry in response to low-carbon policies has been or could be a significant contributory factor to reductions in production emissions. This would not have any benefits for the UK's carbon footprint and therefore global emission reductions, and would not be desirable from a wider economic perspective.

It is important that these competitiveness risks are assessed and managed when designing approaches to reduce emissions. This is clear in the Climate Change Act, which requires us to consider international circumstances and competitiveness impacts when advising on carbon budgets.

**Figure 1:** Framework for the report



The broader context for the report is our review of the fourth carbon budget. The analysis in the report will help to inform us whether the level at which the fourth budget is currently legislated remains appropriate, based on consideration of the UK's carbon footprint, lifecycle emissions of low-carbon options, and the extent to which any competitiveness risks are manageable.

Our key conclusions are:

- **Trends in the UK's carbon footprint**. The UK's carbon footprint has increased over the past two decades, as growth in imported emissions has more than offset reductions in production emissions. However, our analysis shows that offshoring of industry in response to low-carbon policies has had at most a minor impact in reducing production emissions, and the carbon footprint would have increased more had production emissions not been reduced.
  - Although estimates are uncertain, there is a consistent finding across studies that the UK's carbon footprint has increased over the past two decades.
  - Our analysis suggests that the UK's carbon footprint has increased by around 10% since 1993, as growth in imported emissions more than offset the 19% reduction in production emissions. As a result, the UK is now one of the world's largest net importers of emissions[1], with a carbon footprint that is around 80% larger than its production emissions, reflecting the relatively small share of manufacturing in UK GDP.
  - The increase in imported emissions was largely a result of rising incomes which increased demand for manufactured goods; these are, due to globalisation, now mostly produced elsewhere.
  - The fall in production emissions was not due to significant offshoring in response to low-carbon policies. Rather, production emissions fell due to reductions in emissions from power generation and non-$CO_2$ gases (e.g. methane from waste). There has also been a reduction in industry emissions which reflects a falling carbon intensity of production due to energy efficiency improvement and fuel switching, industrial restructuring related to broader processes of globalisation, and more recently the impact of recession. If production emissions had not been reduced, the increase in carbon footprint would have been greater.
- **The UK's future carbon footprint**. To achieve the climate objective[2], there is a need for a global deal to substantially cut global emissions over the next decades. A consequence of this would be that the UK's carbon footprint would fall.
  - An ambitious and comprehensive global deal driving new policies will be *essential* so that global emissions are reduced in a manner consistent with the climate objective (e.g. such that deep cuts in global emissions are achieved by 2030), as a consequence of which UK imported emissions would fall.

1 Both in absolute terms and on a per capita basis.
2 To keep central estimates of global mean temperature as close to 2°C above pre-industrial levels as possible, and to limit the likelihood of temperature change above 4°C to very low levels (e.g. 1%). This is the climate objective that underpins all our advice.

- Our analysis suggests a reduction in the UK's carbon footprint of around 70% on current levels in 2050 is broadly consistent with global emissions pathways to achieve the climate objective underpinning the Climate Change Act.
- Achieving this reduction will require a step change in the pace of UK production emissions reduction – now needed urgently – and a reversal of the increase in global and imported emissions over time.
- Border carbon adjustments are not an alternative to a global deal but should not be ruled out as a possible transitional measure if there were to be slow progress agreeing a global deal. Policies to encourage resource efficiency and sustainable consumption (e.g. business carbon footprinting to reduce supply chain emissions, consumer information provision, regulation, and measures to promote reuse and recycling) could help to reduce the UK's carbon footprint.

- **Competitiveness risks of carbon budgets**. These risks exist for energy-intensive industries where low-carbon policies could have a disproportionate effect on costs, impacting on profits, location and investment decisions. However, our analysis suggests that policies already announced by the Government should be sufficient to address competitiveness risks for energy-intensive industries to 2020. These would continue to be manageable beyond 2020 in a carbon-constrained world where other countries commit to and deliver the emissions cuts required to achieve the climate objective. If other countries were to depart significantly from this course, an assessment of global ambition and therefore ambition in UK carbon budgets would be required, rather than of competitiveness risks per se.
  - **Direct emissions**. Costs and therefore competitiveness risks associated with measures to reduce direct emissions (i.e. related to the burning of fossil fuels by industry) in currently legislated carbon budgets are limited, including the incremental costs and risks associated with the fourth carbon budget. However, continued support in the EU Emission Trading System for industries subject to international competition may be required through the 2020s, dependent on progress towards a global deal and the carbon prices that this implies for other countries.
  - **Electricity price impacts to 2020**. Fossil fuel prices and low-carbon policies to support investment in low-carbon generation will be key drivers of future electricity prices. The component of rising electricity prices due to low-carbon policies carries competitiveness risks for some electro-intensive industries. Risks to 2020 relate to current Government policies funded under the levy control framework. We estimate that possible profit impacts are commensurate with support under already announced policies to address these impacts. This could increase energy bills by around £5 for the typical household in 2020, which is part of the insurance cost for households supporting investment in low-carbon technologies to avoid higher costs and risks in the future.
  - **Electricity price impacts from 2020 to 2030**. These are more uncertain than impacts to 2020, particularly due to uncertainty about low-carbon policies in other countries. However, in a carbon-constrained world our analysis suggests that required support would decline over time as carbon prices increase in other countries.

- **Agriculture**. While risks associated with direct on-farm abatement are expected to be low, rising electricity prices could impact the competitive position of some farming activities with high electricity consumption (e.g. pigs, poultry and dairy). Opportunities to offset the impact of rising electricity prices through energy efficiency improvement, use of renewable energy and other innovations should be further assessed.

- **Lifecycle emissions of low-carbon technologies**. Our assessment suggests that the key low-carbon technologies (i.e. in power, heat and surface transport) offer significant savings over fossil-fuel technologies even when accounting for lifecycle as well as operating emissions.

  - **Nuclear and wind power generation**. These technologies have a very low carbon footprint and offer very significant emissions reduction relative to conventional alternatives which have particularly high operating emissions.

  - **Carbon capture and storage (CCS)**. Emissions from fossil fuel power generation with CCS are higher than for nuclear and renewable generation, and considerably more so for coal than gas. Given these relatively high emissions, CCS with fossil fuels should only be used as part of a portfolio approach (i.e. together with nuclear and renewables), and with gas rather than coal where possible.

  - Lifecycle emissions of **electric vehicles** are significantly lower than those of conventional alternatives when using low-carbon power generation, and could be further reduced through the recycling of batteries.

  - **Shale gas**, like other forms of gas, cannot be regarded as a low-carbon fuel source. It can, however, have lower emissions than imported liquefied natural gas (LNG), if regulatory arrangements are in place to manage methane released during its production. If wider social and environmental issues can also be addressed (e.g. local water supply impacts), **UK shale gas** may therefore play a useful role substituting for imported gas in meeting demand for heat, and for gas-fired generation to balance the system or in conjunction with CCS. This does not alter the Committee's previous recommendation that, over the next two decades, it will be appropriate to invest in a range of low-carbon power generation technologies rather than to have a "dash for gas".

  - Lifecycle emissions of **heat pumps** are significantly lower than those associated with gas boilers when operated with low-carbon electricity. They could be reduced significantly through the use of low-carbon refrigerants, the uptake of which might require appropriate regulation.

  - **Bioenergy** can result in emissions reductions on a lifecycle basis, but stringent sustainability criteria are required to ensure that this is the case. In this respect, and noting the forthcoming Government announcement in this area, we repeat our recommendation that biomass used in power generation should come from sustainably managed forests (i.e. where carbon stocks are maintained or increased over time), and by 2020 should have lifecycle emissions of less than 200 $gCO_2e$/kWh.

Our findings highlight the importance of achieving an ambitious and comprehensive global deal for driving down global emissions and meeting the climate objective, for reducing the UK's carbon footprint and managing competitiveness risks.

We considered progress towards a global deal as part of our advice on the fourth carbon budget in 2010. Our conclusion at this time was that the climate objective remained achievable given commitments in the Copenhagen Accord, but that further commitments would be needed, particularly on deep emissions cuts through the 2020s, together with action to deliver these cuts.

There have been some positive developments since 2010:

- The United States has continued to reduce emissions through a combination of coal to gas switching in power generation, energy efficiency improvement in buildings, and fuel efficiency improvement in new vehicles. US emissions in 2010 were 6% below 2005 levels, and there is evidence to suggest that the US could deliver its Copenhagen commitment to reduce emissions in 2020 by 17% on 2005 levels without the need for new federal legislation[3].
- China has committed to reduce its carbon intensity by 45% in 2020; this compares to a 30% reduction in carbon intensity implicit in the UK's third carbon budget. Emissions trading pilot schemes in 7 major Chinese cities (including Beijing and Shanghai) will start operating in 2013 and 2014.
- Important climate change legislation has been passed in a number of countries, both in the developed and developing world (e.g. Mexico and South Korea)[4].
- The EU has started early negotiations on a package of measures to further reduce emissions through the 2020s.
- The UN process is moving towards a global deal in 2015 and could embody commitments on deep cuts in global emissions to 2030.

Our fourth carbon budget review will include an assessment of progress towards a global deal. In particular, it will consider the United Nations climate change process, and action being taken in key emitting countries. It will include analysis of alternative pathways for future global emissions and any implications that this might have for the fourth carbon budget, reducing the UK's carbon footprint, and managing competitiveness risks.

In the meantime, it is important that the Government should support proposals for an ambitious EU 2030 greenhouse gas target and supporting package, and develop approaches to help get agreement on a similarly ambitious global deal, given the significant economic, environmental and social benefits that this would bring.

3 World Resources Institute (2013) *Can The U.S. Get There From Here?* http://www.wri.org/publication/can-us-get-there-from-here. Burtraw, D. and Woerman, M. (2012) *US status on climate change mitigation*. Resources for the Future. http://www.rff.org/RFF/Documents/RFF-DP-12-48.pdf
4 *Globe 3rd climate legislation study*, http://www.globeinternational.org/index.php/climate-study-home

### Specific implications for the fourth carbon budget review

Our findings also have four specific implications for the review of the fourth carbon budget:

- **Carbon accounting**. It remains appropriate to account for carbon budgets on the basis of production emissions given accounting conventions and available policy levers. However, consumption emissions should be monitored to check whether these are falling in line with global action required to achieve the climate objective, or whether further action is required.
  - Moving to a consumption-based accounting methodology would be disruptive and impractical given international accounting conventions (which are based on territorial emissions and aim to avoid double counting) and uncertainties over measuring and projecting consumption emissions.
  - Production emissions account for more than half of the UK's carbon footprint and we have the levers to reduce them; there is less scope for reduction of imported emissions through UK levers.
  - If monitoring of consumption emissions were to reveal that these are falling too slowly, this may suggest the need for further action.
- **Domestic abatement**. We have said previously that there will be limited longer-term availability of offset credits at low cost if all countries are on a strong downward emissions path consistent with achieving the climate objective. In particular, this will require per capita emissions to reduce to around 2 $tCO_2e$, which our earlier analysis of UK emissions has suggested will be very challenging. Analysis in this report highlights the fact that the UK has a relatively small manufacturing base, while industry emissions are relatively high in other countries, making it more challenging for these countries to meet targets. This reinforces our previous recommendation that the UK should aim to meet the 2050 target largely through domestic emissions reduction and not through the purchase of expensive credits, and to reflect this in the design of the fourth carbon budget.
- **Competitiveness risks**. Competitiveness impacts associated with measures in the fourth carbon budget to reduce direct and indirect emissions are small and can be addressed within levels of financial support already committed. They would not therefore provide a basis for changing ambition in the fourth carbon budget.
  - The fourth carbon budget reflects implementation of measures to reduce direct emissions that are low cost, and therefore entail limited competitiveness risk.
  - Electricity price impacts for electro-intensive industries are due mainly to the Government's current policies for investment in the period to 2020, and within the range of support associated with policies already announced by the Government.
  - Our analysis suggests that incremental impacts due to the fourth carbon budget are limited given the expected reduction in costs of low-carbon technologies in this period, and rising carbon/electricity prices in other countries.

- **Lifecycle emissions**. Additional lifecycle emissions associated with low-carbon technologies in our fourth carbon budget scenario are likely to be limited, and the proposed technology portfolio to meet the budget remains appropriate.

We will publish our review of the fourth carbon budget at the end of 2013, with a Government assessment due early in 2014.

We will also report periodically on consumption emissions as part of our reporting to Parliament on progress reducing emissions and as part of broader monitoring of progress towards design and implementation of a global deal, identifying any need for further action as appropriate.

## Structure of the report

We set out the analysis in this report in four sections:

1. The UK's carbon footprint
2. Competitiveness risks and opportunities associated with the fourth carbon budget
3. Lifecycle emissions of low-carbon and conventional technologies
4. Implications for the fourth carbon budget

More detailed analysis is set out in two technical reports available on our website[5]:

1. Reducing the UK's carbon footprint
2. Managing competitiveness risks of low-carbon policies

**Box ES1:** Key terms

**Climate objective:** To keep central estimates of global mean temperature as close to 2°C above pre-industrial levels as possible, and to limit the likelihood of temperature change above 4°C to very low levels (e.g. 1%).

**Territorial emissions:** Greenhouse gas emissions occurring within a country's borders (e.g. from burning fossil fuels for electricity generation, in transport and industrial production, direct emissions from heating in households and businesses, as well as emissions related to a number of other activities such as agricultural, forestry, and waste management activities). These are the current basis of UK carbon budgets and accounting under the United Nations Framework Convention on Climate Change.

**Production emissions:** Territorial emissions plus emissions from international aviation and shipping on the basis of bunker fuels.

**Consumption emissions:** Production emissions minus emissions embedded in export of goods and services, plus emissions embedded in imports of goods and services.

**Carbon Footprint:** Total amount of greenhouse gas emissions caused directly or indirectly by a nation (equivalent to consumption emissions), a business, a product (equivalent to lifecycle emissions) or a person.

**Lifecycle emissions:** Emissions associated with all the stages of a product's life from cradle-to-grave.

**Competitiveness:** The ability of firms to sell and increase market share and profitability in international markets.

**Offshoring:** The relocation of a firm's business or processes to a foreign country.

5 http://www.theccc.org.uk/publication/carbon-footprint-and-competitiveness/

# Chapter 1: The UK's carbon footprint

The Climate Change Act requires us to assess progress towards carbon budgets and the target to reduce emissions by 80% in 2050 on 1990 levels. To date, our assessment has focused on territorial emissions (i.e. those occurring only within the UK's borders) which are the basis of carbon budgets. However, with the Government's recent publication of consumption-based emission statistics and a rapidly growing evidence base, it has become possible to look at the UK's broader carbon footprint, including emissions embedded in imports, and trends over time.

Our work on this responds to a request by the Government for us to look at the role of consumption-based emissions in future policy making, following a report by the House of Commons Energy and Climate Change Committee on consumption-based accounting in 2012. This argued that the Government should incorporate consumption-based emissions data into the policy making process. It recommended that options should be explored for monitoring trends in the UK's carbon footprint and setting emission targets on a consumption basis at the national level.

In this chapter, we examine methodologies for estimating the UK's carbon footprint, we present new estimates of recent trends in consumption emissions and we analyse key drivers. We then set out some possible scenarios for the UK's footprint to 2050, exploring whether the UK is likely to remain a net importer of emissions over time.

Based on the scenario results, we then turn to the options available for reducing the UK's footprint, highlighting the importance of a comprehensive global deal for emissions reduction. We also explore a range of complementary policy options. Finally, we set out the reasons why a production-based emissions approach is still the most appropriate basis for carbon budgets.

The key messages in this chapter are:

- **UK's carbon footprint**. This has increased over the past two decades, as growth in imported emissions has more than offset reductions in production emissions. However, our analysis shows that offshoring of industry in response to low-carbon policies has had at most a minor impact in reducing production emissions, and that the carbon footprint would have increased more had production emissions not been reduced.
- **Global deal**. There is a need for a global deal to substantially cut global emissions over the next decades and achieve the climate objective, as a consequence of which the UK's carbon footprint would fall. Complementary policies promoting resource efficiency and sustainable consumption could also help reduce the UK's carbon footprint.
- **Carbon accounting**. It remains appropriate to account for carbon budgets on the basis of production emissions given accounting conventions and available policy levers. However, consumption emissions should be monitored to check whether these are falling in line with global action required to achieve the climate objective, or whether further action is required.

We set our analysis in three sections:

1. Consumption emissions accounting approaches and estimates of the UK's carbon footprint
2. Scenarios for the UK's carbon footprint to 2050
3. Options to reduce consumption emissions

## 1. Consumption emissions accounting approaches and estimates of the UK's carbon footprint

### Alternative methodologies for estimating emissions and uncertainties

UK carbon budgets are defined on the basis of territorial emissions, or those occurring only within the UK's borders, in accordance with the United Nations Framework Convention on Climate Change (UNFCCC). These include emissions from burning fossil fuels for electricity generation and industrial production, direct emissions from heating in households and businesses, emissions from burning petrol and diesel in cars and other vehicles, and emissions arising from other activities, including agriculture, waste management, and land use, land use change and forestry (LULUCF). Territorial emissions are estimated in the National Atmospheric Emissions Inventory (NAEI) and are used as the basis for the UK's reporting on emissions reduction targets to the European Union (EU) and the UNFCCC.

The UK's national emissions inventory also includes emissions associated with international aviation and shipping. We envisage that international aviation and shipping emissions will be included in carbon budgets following agreement on a global approach to regulating these emissions. In this report, we refer to the UK's territorial emissions plus international aviation and shipping emissions as the UK's 'production emissions'.

However, these accounting approaches do not include emissions embedded in (or associated directly and indirectly with the production of) the goods and services we import, nor exclude the emissions embedded in goods and services that are exported. The UK's carbon footprint (or consumption emissions) allows for these emissions, and therefore covers all emissions related to the final consumption of goods and services in the UK. It is calculated by adding estimates of emissions associated with imports to production emissions, and subtracting emissions due to exports.

While UK production emissions are relatively straightforward to estimate, this is not the case for consumption emissions. Estimating consumption emissions can be done through a high level analysis of trade flows ('production plus' approaches) or through more sophisticated input-output analysis (e.g. multi-regional input-output analysis 'MRIO') which tracks monetary flows and associated emissions across sectors and regions (Box 1.1).

Different methodologies and datasets can produce very different estimates. For example, estimates of the UK's $CO_2$ carbon footprint in 2004[1] vary as much as 250 $MtCO_2$ (Figure 1.1), although all studies show that UK consumption emissions have increased over time. The much greater uncertainty for consumption emissions accounting compared to production accounting has implications for its usefulness in policy (see section 3).

1 Most studies have focused on estimating the UK's carbon footprint in 2004, which until recently, was the most recent year with complete data available in GTAP, a global database used for input-output analysis.

## Box 1.1: Methods for estimating consumption emissions

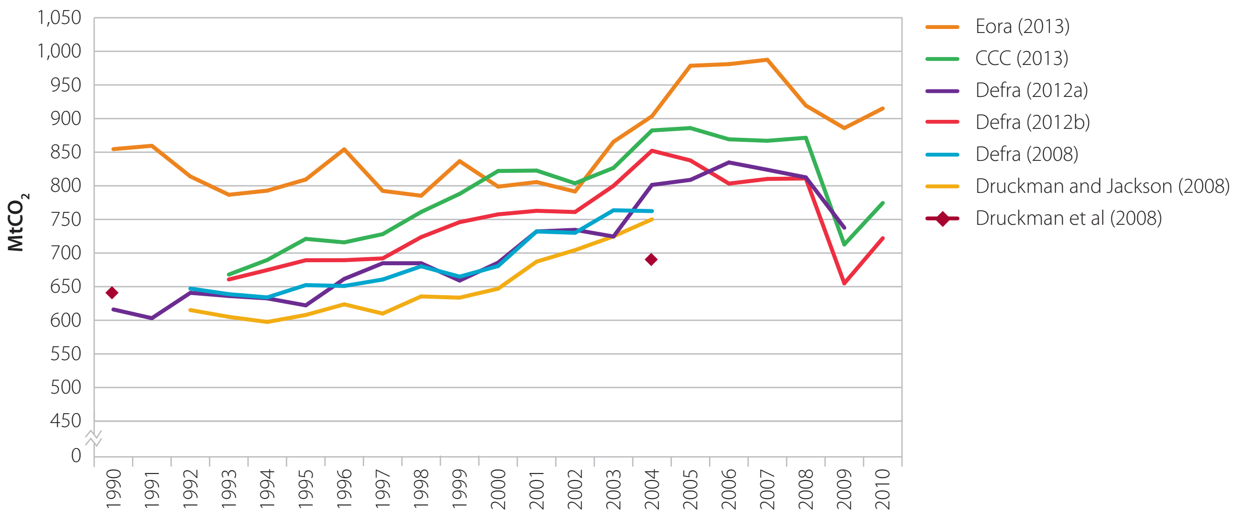
Consumption emissions are more complex to estimate than production emissions. They require estimates of emissions occurring along international supply chains, and there are no agreed international standards for reporting.

A range of methods have therefore been developed to estimate consumption emissions:

- **Production plus.** These add estimates of net imports of emissions to existing production emission figures, using bilateral trade data and economy-wide and/or sector emission intensities (defined as total emissions divided by total economic output). This approach is less data intensive but it cannot track activity and emissions through international supply chains.
- **Input-output models.** These use very detailed data within input-output tables, which are compiled and published by countries in order to track monetary flows across sectors and regions. Multi-regional input-output (MRIO) analysis enables tracking of UK purchases to emissions arising in interconnected supply chains across the globe. For example, under MRIO analysis, in purchasing a German car the UK would be responsible not only for German car manufacturing emissions, but also for emissions associated with inputs shipped to Germany to manufacture that car (e.g. steel from China, and any inputs used in China to manufacture that steel). Input-output analysis, in particular MRIO, produces potentially the most accurate estimates of consumption emissions but is complex and subject to a number of data limitations and uncertainties:
  - **Transparency.** Input-output data tables are very complex and require information on how economic sectors link together and trade with each other.
  - **Timing.** Economic and emissions data are often infrequently published by national authorities, and are sometimes years out of date.
  - **Alignment.** With no agreed international standard, economic and emissions data differ across countries in terms of quality and sectors/years represented, and must be aligned to create a consistent dataset.
  - **Emissions.** These have to be matched to economic sectors which are often classified on a different basis and scope than emissions data.

Consumption emissions are an area of significant ongoing research, which should help narrow the range of uncertainty.

**Figure 1.1:** Range of estimates for UK consumption emissions (1990-2010)




**Source:** Various authors and sources.
**Notes:** Figures are for $CO_2$ only. This figure provides a representative but not exhaustive summary of UK consumption emission estimates in the literature. All studies use multi-regional input-output analysis with the exception of Druckman et al. (2008) which used a single-region input-output model and Druckman and Jackson (2008) which used a quasi-multi-region input-output model. All studies, with the exception of Eora (2013), Defra (2012b) and CCC (2013) rely on GTAP (a global database) for trade, emissions, and economic output data. Defra (2012b) refers to the latest official Defra estimates published in December 2012.

## Trends in the UK's carbon footprint

The UK Government has reported on UK consumption emissions since 2008 and in 2012 produced a time series of consumption emissions going back to 1993[2], estimated using multi-regional input-output analysis.

We have commissioned the University of Leeds to rerun the model used by the Government to estimate the UK's carbon footprint with a greater disaggregation of regions. Our estimates exhibit a similar trend to the Government's figures[3] and show that while UK production emissions have fallen, imported emissions have more than offset this, such that the UK's carbon footprint has increased since 1993 (by an estimated 10% according to our analysis, Figure 1.2).

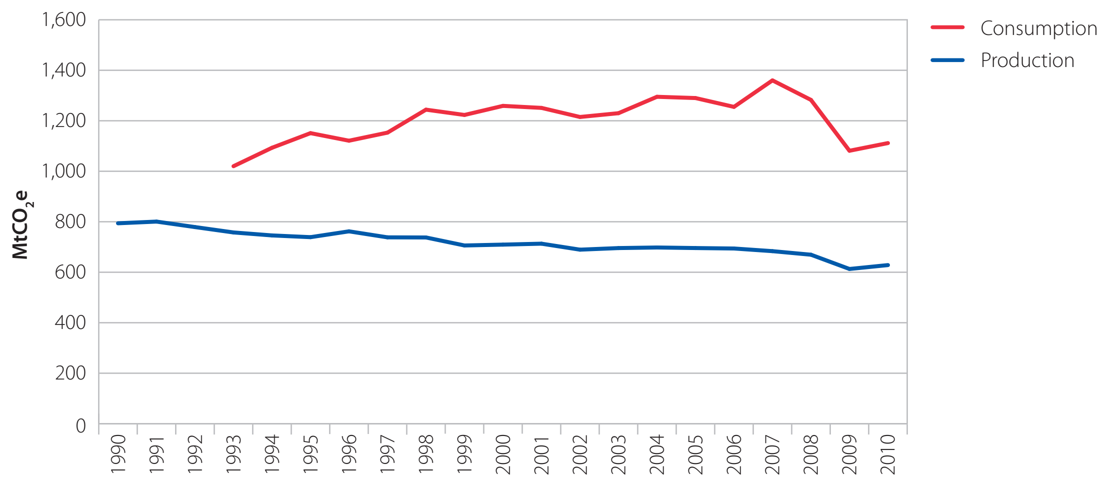
- **Production emissions**. Production emissions fell by 21% between 1990 and 2010 (19% since 1993), mainly due to switching from coal to gas in power generation and reductions in non-$CO_2$ gases such as waste methane emissions in response to EU landfill policies. Additionally, in industry there have been reductions due to switching to less carbon-intensive fossil fuels, energy efficiency improvement and industrial restructuring (Figure 1.3). More recently emissions have fallen as a result of the recession.
- **Imported emissions**. These are emissions that occur abroad to support final UK demand for goods and services (e.g. supply chain emissions associated with producing imported consumer electronics such as smart phones, including emissions associated with material extraction, manufacturing, and transport). GHG emissions embodied in imports are estimated to have increased by 40% between 1993 and 2010 (Figure 1.4), over which period imports increased by over 90%.
  - *Geographical composition*. There are significant imported emissions from the rest of Europe (15% of total imported emissions) and the rest of the OECD (15%). Imports from developing Asian economies account for about 30% of imported emissions (half of which come from China) and for the majority of the recent growth in imported $CO_2e$ emissions (Figure 1.5).
  - *Sectoral composition*. The UK's demand for goods and services results in significant emissions occurring in various economic production sectors overseas, including agriculture (accounting for around a third of imported emissions in 2010), electricity generation (e.g. embedded in manufactured products we import), and direct emissions occurring in the manufacturing of petroleum, chemicals, and non-metallic mineral (e.g. cement and glass) products. Together with overseas transport emissions (e.g. road, sea, and air freight emissions), these account for the majority of the UK's imported carbon footprint (over 80% in 2010) and growth in imported emissions from 1993 to 2010 (Figure 1.6).

2 Defra (2012) *UK's Carbon Footprint – Carbon dioxide emissions relating to UK consumption*, prepared by University of Leeds, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/85869/release-carbon-footprint-dec2012.pdf

3 While the trend is similar, our estimate is 13% higher than the Government's. This demonstrates that estimates can vary considerably depending on methodology (e.g. here the level of regional disaggregation), even when using the same dataset.

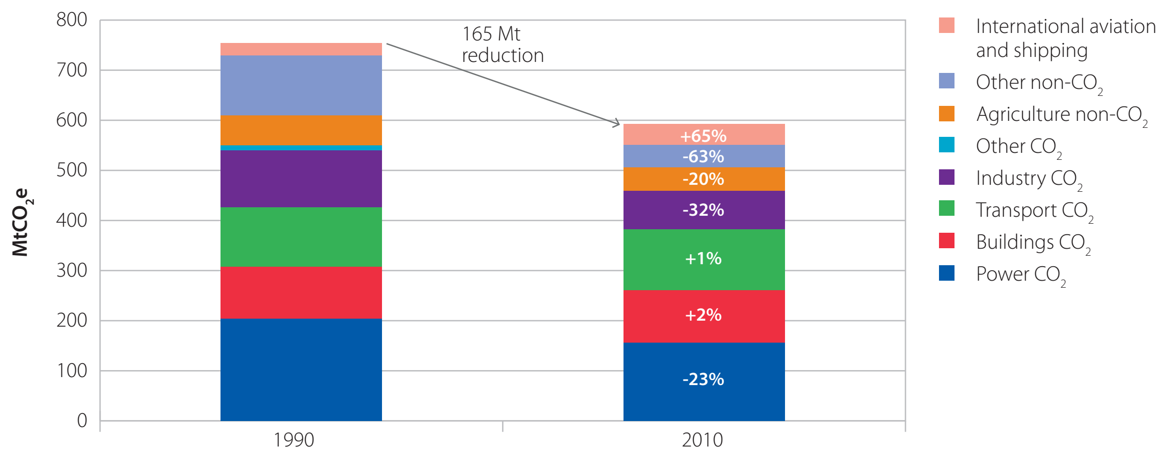
- **Exported emissions**. These are production emissions embedded in goods and services that are produced in the UK but exported for final consumption overseas. Exported emissions have fluctuated since 1993 but have decreased by 13% overall. Exported emissions related to the UK's petroleum, chemicals and non-metallic minerals, power generation, and mining sectors have fallen significantly, while emissions occurring in agriculture, transport, and retail trade activities have increased.
- **Consumption emissions**. UK consumption emissions increased by an estimated 26% from 1993 to 2008, over a period when the UK's population increased by 6% and GDP grew by 50%. However, due to the recession, both production and imported emissions have fallen, such that growth in consumption emissions from 1993 to 2010 was around 10%.

**Figure 1.2:** Greenhouse gas emissions associated with UK production and consumption (1990-2010)



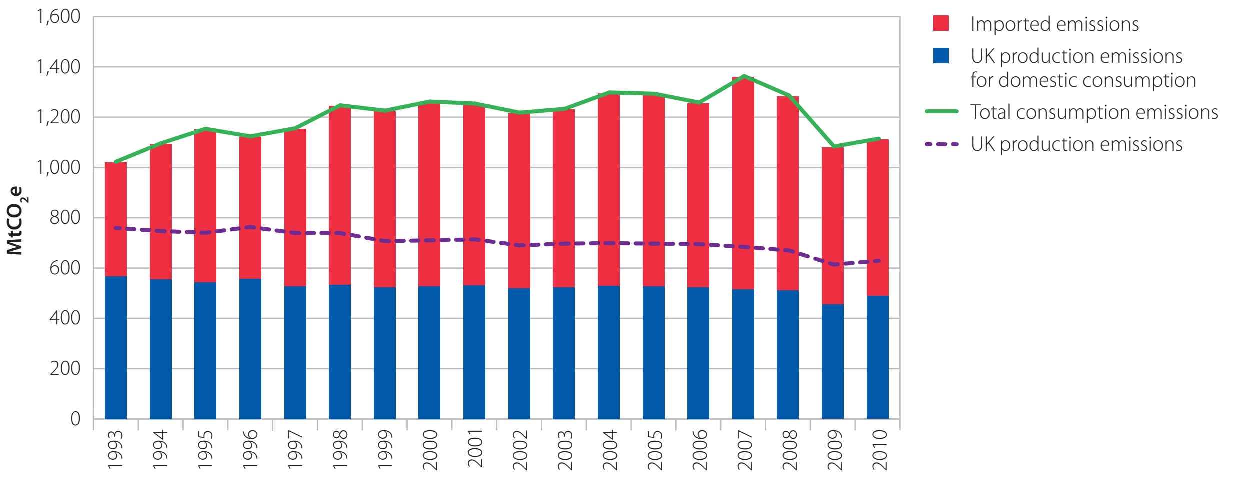

**Source:** CCC consumption estimates developed by the University of Leeds (2013); NAEI (2012).
**Notes:** Production emissions include emissions from international aviation and shipping. Due to data limitations, consumption emissions estimates are not available pre-1993.

**Figure 1.3:** UK greenhouse gas production emissions by sector (1990 and 2010)



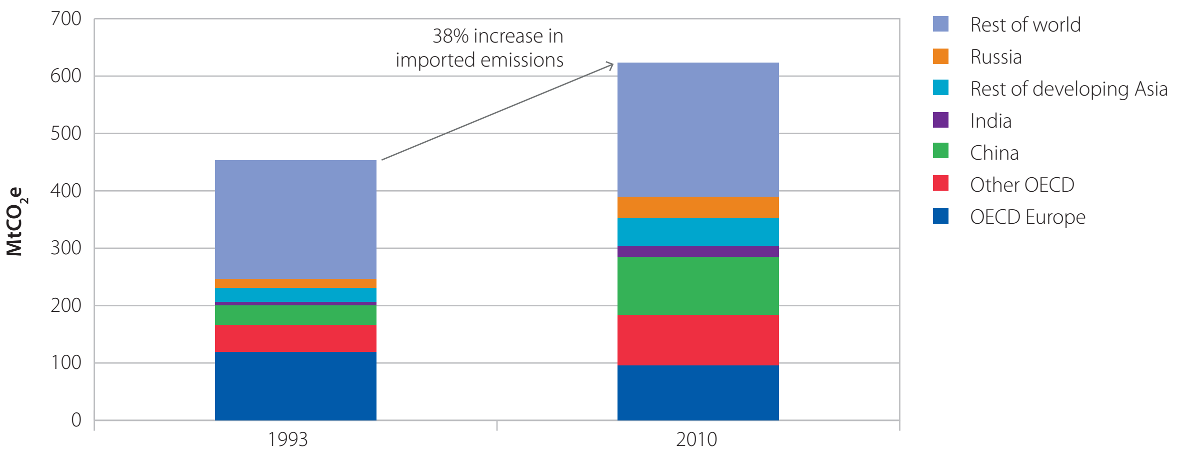

**Source:** NAEI (2012).
**Notes:** Other $CO_2$ include $CO_2$ emissions from domestic and military aviation, agricultural energy use and LULUCF. Due to negative LULUCF emissions, other $CO_2$ emissions were close to zero in 2010 on a net basis. Other non-$CO_2$ includes non-$CO_2$ emissions from waste, buildings, industry, energy supply and transport.

**Figure 1.4:** Greenhouse gas emissions associated with UK consumption – imported and domestic emissions (1993-2010)



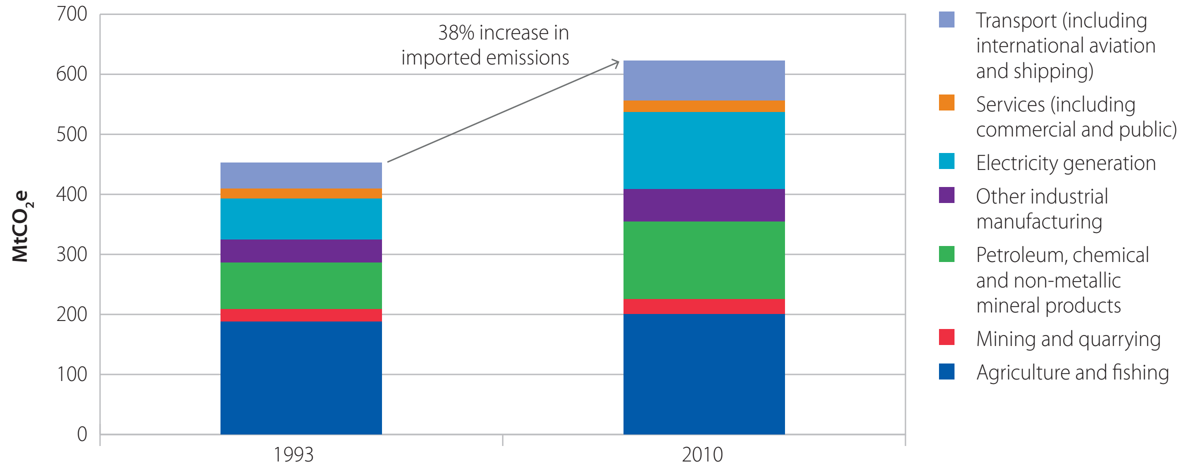

**Source:** CCC estimates developed by the University of Leeds (2013); NAEI (2012).
**Notes:** The green line shows estimates of total UK consumption emissions and the red and blue bars break down consumption emissions by goods and services produced and consumed within the UK versus imported goods and services. Domestic consumption emissions are estimated to have decreased over time while imported emissions are increasing. The dotted purple line shows trends in UK production emissions (including international aviation & shipping emissions), which have decreased over time. The gap between the dotted purple line and blue bar represents UK production emissions in goods and services for export.

**Figure 1.5:** UK imported greenhouse gas emissions by region (1993 and 2010)




**Source:** CCC estimates developed by the University of Leeds (2013).

**Figure 1.6:** UK imported greenhouse gas emissions by sector (1993 and 2010)




**Source:** CCC estimates developed by the University of Leeds (2013).
**Notes:** Imported emissions are production emissions occurring abroad associated with producing and transporting goods and services to the UK for consumption.

As a result of the decline in production emissions, reductions in exported emissions, and growth in imported emissions, the gap between the UK's carbon footprint and production emissions has increased, from an estimated 35% in 1993 to around 80% in 2010 (i.e. in 2010, consumption emissions were nearly 80% higher than production emissions, Figure 1.4)[4].

The UK is currently estimated to have one of the highest carbon footprints in the world and is one of the largest net importers of carbon (both in absolute terms and on a per capita basis). This reflects a smaller manufacturing sector and higher levels of imports of goods than most other countries and higher levels of exports of services, which have lower emissions intensities (Box 1.2).

While, as discussed above, there is a high degree of uncertainty around imported emissions given different methodologies, data sources and gaps; the broad message that the UK's carbon footprint has increased over the past two decades and is higher than production emissions appears to be robust.

4 More detail on trends in the UK's carbon footprint and key drivers of changes is provided in our Carbon Footprint technical report, http://www.theccc.org.uk/publication/carbon-footprint-and-competitiveness/

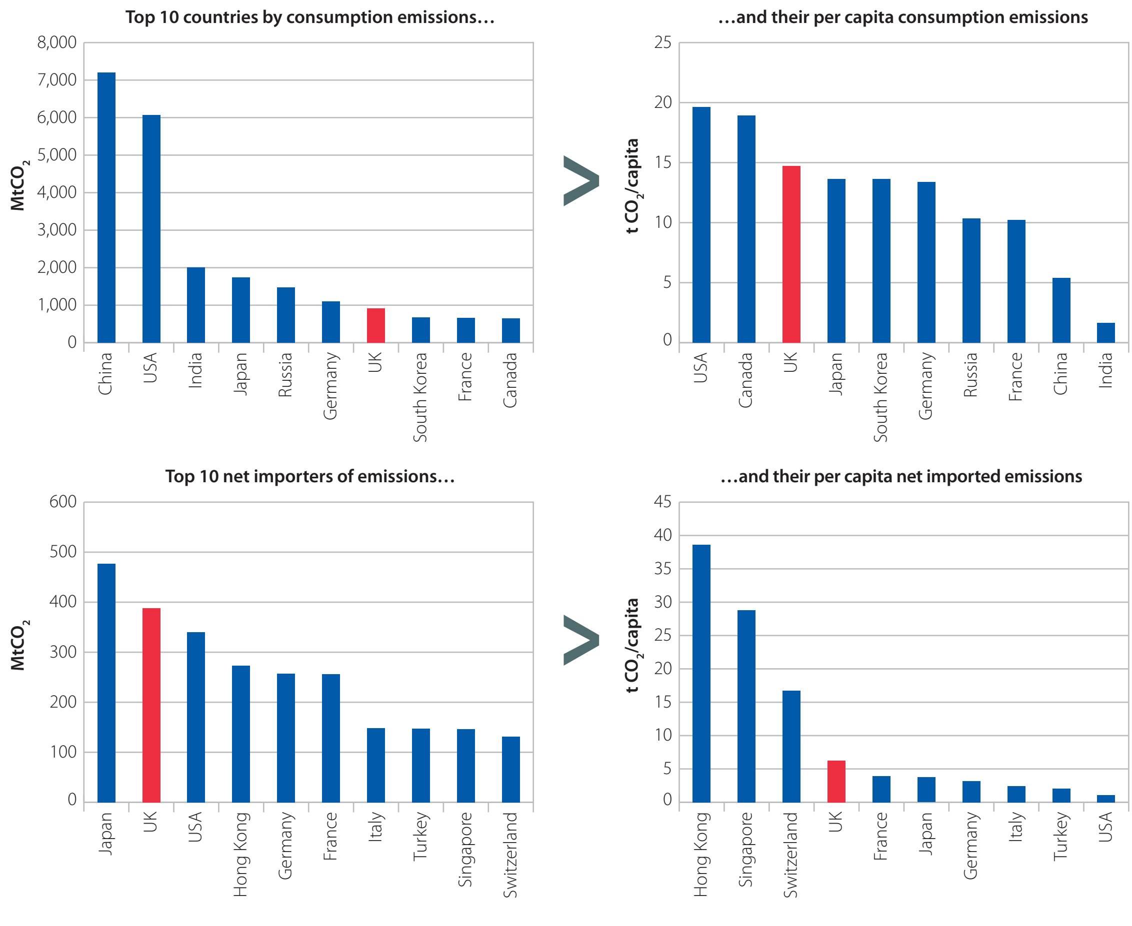
## Box 1.2: How UK consumption emissions compare to other countries

The UK is one of very few countries that publish detailed consumption emission estimates. Comparing the UK with other countries requires the use of global databases, each with their own uncertainties depending on the methodology used.

Latest data from Eora, a multi-region input-output model and database (which the UK Government consumption estimates partially rely upon) suggest the UK ranks among the top ten countries in consumption emissions and is also one of the largest net importers of emissions (the difference between consumption and production emissions) (Figure B1.2):

- In 2010, the UK was estimated to have the seventh highest $CO_2$ consumption emissions in the world. Amongst countries with the highest consumption emissions, the UK ranks third in terms of per capita consumption emissions.
- The UK is the second largest net importer of $CO_2$ emissions. In 2010, the UK's net emission imports were a third higher than those of Germany and France. On a per capita basis, the UK's net emission imports are 6.2 $tCO_2$ versus 3.1 $tCO_2$ and 3.9 $tCO_2$ for Germany and France respectively.
- The UK was the fifth largest importer of Chinese emissions after the U.S., Japan, Hong Kong and Germany.

### Figure B1.2: UK and other countries consumption emissions (2010)




**Source:** Eora (2013); World Bank.
**Notes:** Figures are for $CO_2$ only, excluding LULUCF. The Eora multi-region input-output database covers 187 countries and is hosted by the University of Sydney. Estimates for the UK's and other countries carbon footprint and net imported emissions in Figure B1.2 are obtained from Eora, and differ from the CCC and Defra estimates, which use updated and more accurate UK national and emissions account data provided by ONS, as well as and different levels of geographical aggregation of UK trading results (e.g. Defra analyses four regions, the CCC analysis includes eight regions, and Eora analyses all 187 countries). As a result, Eora estimates of UK consumption emissions of $CO_2$ in 2010 were estimated to be 18% higher than CCC estimates.

## Drivers and changes of consumption and production emissions

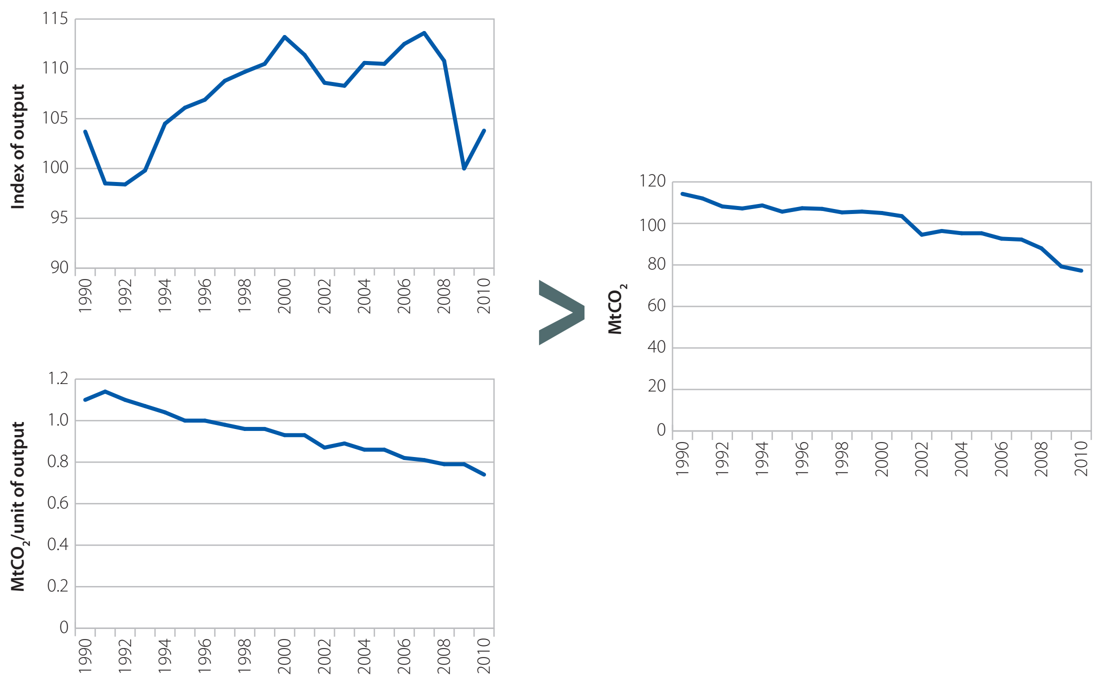
The fact that the UK's carbon footprint has grown as production emissions have been reduced raises the question of whether there should be more emphasis on addressing imported emissions, and less on production emissions.

Production emissions, however, are clearly important as they total more than half of the UK's carbon footprint (Figure 1.4). Had production emissions not been reduced, then the footprint would be around 7% higher than it currently is. Further reductions of production emissions will be required, as legislated by the Climate Change Act.

A related question is whether offshoring of industry in response to low-carbon policies has contributed to the fall in production emissions, to be replaced with imported goods and services, reallocating emissions within the UK's carbon footprint but not reducing it overall.

However, this cannot be the primary cause of production emission reductions since industry emission reductions only accounted for 22% of total reductions in production emissions between 1990 and 2010. Within this, reductions in industry emissions reflect falling carbon intensity due to energy efficiency improvement and fuel switching, restructuring, and more recently the impact of the recession (Figure 1.7).

**Figure 1.7:** UK industry output, carbon intensity and emissions (1990-2010)




**Source:** ONS (2013) Index of manufacturing production; NAEI (2012); CCC calculations.

Although in principle falling carbon intensity could also reflect restructuring of energy-intensive industry in response to low-carbon policies, this has had a minor, if any, impact in practice because:

- The impact of low-carbon policies has been limited to date (e.g. carbon price impacts have been limited given the allocation of free allowances to energy-intensive industry under the EU ETS, a low carbon price, and exemption from the Climate Change Levy through Climate Change Agreements).
- The overall output of energy-intensive industries increased between 1990 and the start of the recession, although specific industries such as iron and steel experienced a decline in output due to restructuring.
- Where there are specific examples of restructuring, this is likely to be part of a broader process of globalisation (e.g. based on labour cost differentials).
- More generally, restructuring due to globalisation and a UK focus on service industries has limited industry output growth rather than resulted in reduced output (services now account for 77% of total UK output, growing from 69% in 1997).

Growth in the UK's carbon footprint reflects import growth due to rising incomes, a growing population and shifts in the UK and global economies (i.e. the UK moving to a more service-based economy), with more manufacturing in countries with higher carbon intensities, especially in the power sector (e.g. China's power sector is estimated to emit almost seven times as much $CO_2$ per unit of economic output as the UK)[5].

Going forward, we do not expect any offshoring specifically as a result of low-carbon policies if measures are put in place to mitigate competitiveness risks (see chapter 2).

## 2. Scenarios for the UK's carbon footprint to 2050

Our analysis to date has focused on long-term scenarios for reducing production emissions in a manner compatible with achieving the 2050 target in the Climate Change Act (i.e. to reduce 2050 production emissions by 80% on 1990 levels).

For this report we have developed future scenarios for the UK's carbon footprint compatible with achieving the climate objective, which is to keep central estimates of global temperature rise by 2100 close to 2°C above pre-industrial levels, and limit the likelihood of a 4°C rise to very low levels (e.g. 1%). To meet this objective, global emissions need to peak before 2020 and halve by 2050 (2DS scenario).

As a sensitivity check, we have also analysed the UK's consumption emissions in a world where international actions would not go beyond the pledges made at the United Nations Climate Change Conference at Copenhagen in 2009. This scenario is projected by the International Energy Agency (IEA) to lead to a long-term temperature rise of 4°C (4DS scenario).

5 Eora Global MRIO database (2013)

Our scenarios for the UK's carbon footprint incorporate scenarios for UK production emissions, together with scenarios for demand, imports and emissions intensity in other countries:

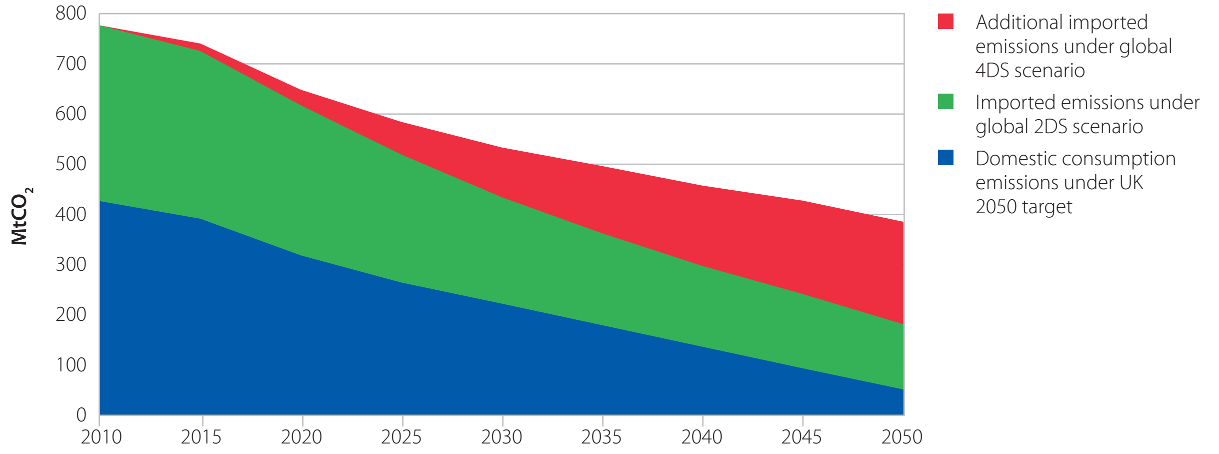
- **UK production emissions**. We have based these on our 80% reduction scenarios for 2050, published in our International Aviation and Shipping advice in 2012[6]. These identified a range of abatement options across the economy, reflecting a combination of improved energy efficiency and behaviour change to reduce demand for emitting activities, as well as increasing use of low-carbon sources of energy supply in place of unabated fossil fuels. They also reflect the UK's expected growth in population from around 63 million now to 75 million in 2050 (+19%).
- **Demand/imports**. Future UK consumption emissions will depend on final demand for domestic and imported goods and services. The UK's demand for imported goods and services has increased on average by 3.25% per year in real terms between 1975 and 2011. Applying this import growth rate forward may not be sustainable in the long run as it would reflect an increase in imports' share of GDP from 34% today to 50% in 2050. We have therefore explored a central demand scenario reflecting a lower growth of 2.75% per year, as well as a low (2.25%) and high (3.25%) growth scenario.
- **Emissions intensity in other countries**. Our assumptions about emissions intensities in the UK's trading partners are as follows:
  - **$CO_2$ emissions intensities**. We derive sectoral emission intensities using the IEA's *Energy Technology Perspectives* (2012)[7] scenarios for meeting the 2°C limit (2DS), as well as their scenario based on the Copenhagen pledges (4DS).
  - **Non-$CO_2$ emissions intensities**. As the IEA covers reductions in energy-related $CO_2$ emissions only, we explore scenarios for non-$CO_2$ emission reductions based on the climate modelling work described in our 2008 report on setting a 2050 target. Due to greater uncertainties about non-$CO_2$ emissions (particularly around imported agricultural emissions) and abatement options for them, there is less confidence in future estimates of the UK's carbon footprint when including these greenhouse gases.

We commissioned the University of Leeds[8], who currently produce the Government's UK carbon footprint estimates, to translate these scenarios into new projections of the UK's carbon footprint using an input-output model (Figure 1.8). The main results suggest that:

- **2DS scenario**. Under a scenario where the UK meets its 2050 target and global emissions fall in line with the CCC's climate objective, the UK's carbon footprint ($CO_2$ only) could fall up to 80% below current levels, or to around 2.4 $tCO_2$/capita, compared to 1.5 $tCO_2$/capita production emissions under the existing 2050 target (or when including all greenhouse gases, where there is less confidence in estimates, a 70% reduction in consumption emissions to around 4 $tCO_2e$/capita compared to around 2 $tCO_2$/capita production emissions under the existing 2050 target).

6 CCC (2012) *The 2050 target – achieving an 80% reduction including emissions from international aviation and shipping*, http://www.theccc.org.uk/publication/international-aviation-shipping-review/
7 IEA (2012) Energy Technology Perspectives, http://www.iea.org/etp/
8 Scott, K., Owen, A. and Barrett, J. (2013), *Estimating emissions associated with future UK consumption patterns*, http://www.theccc.org.uk/publication/carbon-footprint-and-competitiveness/

**Figure 1.8:** Scenarios for UK consumption emissions to 2050 ($CO_2$)




**Source:** CCC modelling (2012); University of Leeds (2013); IEA (2012) *Energy Technology Perspectives*.
**Notes:** Figures are for $CO_2$ only. Future consumption emissions estimated by using production emission scenarios developed for CCC's 2012 advice on IAS and IEA emissions scenarios. A linear trend in UK emissions is applied between 2030 and 2050.

- **4DS scenario**. Under a scenario where the UK meets its 2050 target but the rest of the world does not go beyond current pledges, the UK's carbon footprint ($CO_2$ only) could be reduced by only 50% from current levels, or to around 5 $tCO_2$/capita (or when including all greenhouse gases, where there is even less confidence in estimates under a 4DS scenario, 9.5 $tCO_2$/capita).

More detailed analysis of our assumptions and the model results is set out in a technical report available on our website[9].

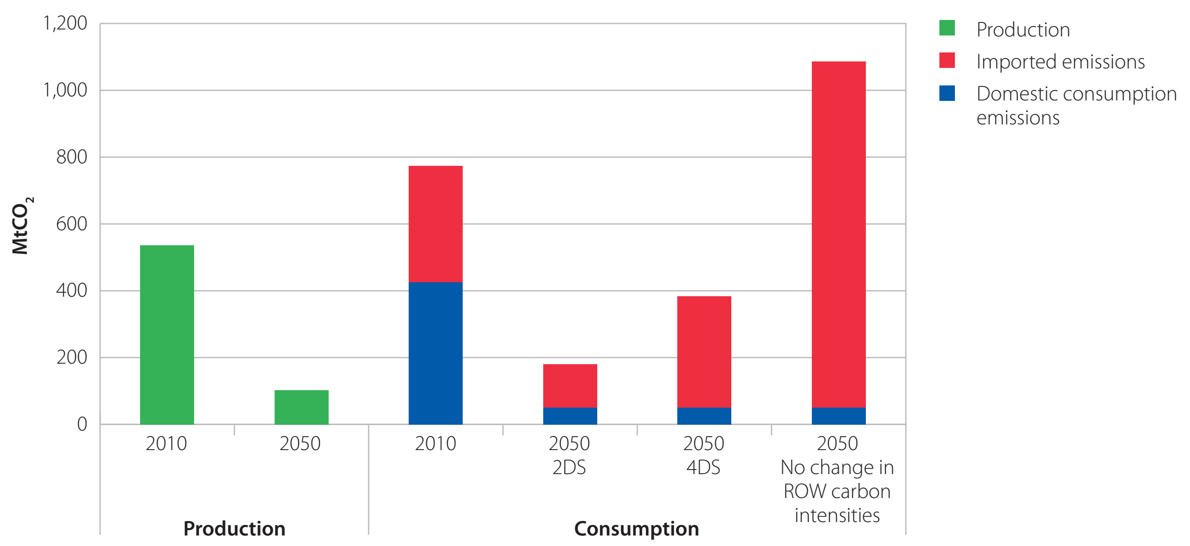
## Key finding 1: the need to reduce both production and imported emissions, and to monitor the UK's carbon footprint

Our analysis suggests that under a global agreement for achieving the global climate objective, the UK's carbon footprint could be reduced by up to 70% in 2050 compared to current levels. With production emissions currently accounting for more than half of the UK's carbon footprint, the reduction in these emissions by 80% (as legislated in the Climate Change Act) is essential.

However, even with an 80% reduction in production emissions, if the carbon intensity of imports were not reduced, emissions embedded in UK imports in 2050 could account for nine times as much as production emissions. Under the current pledges (4DS) global scenario, UK imports would still account for three times as much as production $CO_2$ emissions (Figure 1.9).

9 CCC (2013) *Reducing the UK's carbon footprint*, http://www.theccc.org.uk/publication/carbon-footprint-and-competitiveness/

**Figure 1.9:** UK production emissions and scenarios for UK consumption emissions to 2050 ($CO_2$)




**Source:** CCC modelling (2012); University of Leeds and Centre for Sustainable Accounting (2013); IEA (2012) *Energy Technology Perspectives*.
**Notes:** Figures are for $CO_2$ only. Future consumption emissions estimated by using production emission scenarios developed for CCC's 2012 advice on IAS and IEA emissions scenarios. Linear trend in UK emissions applied between 2030 and 2050. Production emissions include emissions associated with exports.

Therefore our analysis highlights the crucial importance of reducing the UK's imported emissions in addition to production emissions, as part of global emission reductions to achieve the climate objective. It implies the need to monitor the UK's carbon footprint together with production emissions, in order to check that this is being reduced in a way that is compatible with achieving the climate objective, or whether further action is required.

### Key finding 2: the need for action beyond current global policies

The modelling shows that in a world where global carbon intensity is reduced based on the Copenhagen pledges only (and the climate objective not being achieved), then the UK's carbon footprint could be of the order of five times as much as production emissions per capita allowed under the existing 2050 target. In a world where the climate objective is achieved, the UK's carbon footprint could be up to two times that of production emissions per capita allowed under the existing 2050 target.

We have previously highlighted the need for a step change in the pace at which UK territorial emissions are reduced in order to meet carbon budgets. The analysis in this report highlights the need for further action globally in order that the climate objective is achieved, and as a consequence of which the UK's carbon footprint would be reduced.

In particular, there is a need to reverse the upward trend in the UK's imported carbon emissions in the medium term (e.g. by 2030). UK policies to encourage resource efficiency and sustainable consumption are also important (see below).

We consider a range of policies which could ensure global emissions reductions in Section 3 below.

**Key finding 3: the UK is likely to remain a net importer of carbon**

In all scenarios, the modelling suggests that the UK will remain a net importer of carbon. Even under a scenario of ambitious global emission reductions, the UK could have a carbon footprint that is twice as large as its production emissions, reflecting the fact that it is likely to remain a net importer of manufactured goods (Figure 1.9).

Based on global modelling of emission trajectories[10], we recommended in our 2008 report that the UK should aim to reduce production emissions to around 2 $tCO_2e$/capita in 2050 (i.e. the basis for the 2050 target in the Climate Change Act) in a context where there are both flows of carbon in traded goods and a market for offset credits.

If the UK and some other countries are to continue to be net importers of carbon, this has implications for how we should plan to meet the 2050 target as defined in the Climate Change Act:

- We have said previously that there will be limited longer-term availability of offset credits at low cost if all countries are on a strong downward emissions path consistent with achieving the climate objective. In particular, this will require per capita emissions to reduce to around 2 $tCO_2e$, which our earlier analysis of UK emissions has suggested will be very challenging.
- Analysis in this report highlights the fact that the UK has a relatively small manufacturing base, while industry emissions are relatively high in other countries, making it more challenging for these countries to meet targets.
- Such countries would have even less scope to sell offset credits into the global carbon market and may need to purchase credits, thus further restricting what is already likely to be limited availability of credits in the market.

This reinforces our previous recommendation that the UK should aim to meet the 2050 target largely through domestic emissions reduction, and not through the purchase of expensive credits, and to reflect this in the design of the fourth carbon budget.

## 3. Options to reduce consumption emissions

### A global deal and supporting policies

The most effective option to achieve the climate objective is for all nations to agree a comprehensive new deal for reducing global emissions, with production-based accounting of all global emissions. Implementation of the deal would also result in a reduction of the UK's imported emissions. There are a number of other ways to reduce global emissions, but on their own they are unlikely to yield sufficient emissions reductions (e.g. sectoral agreements, carbon

10 CCC and Met Office Hadley Centre analysis for CCC (2008), *Building a low-carbon economy – the UK's contribution to tackling climate change*, Chapter 1 Technical Appendix: Projecting global emissions, concentrations, and temperatures.

footprinting, consumer information, and regulation). Border carbon adjustments have also been suggested as an alternative to a new global agreement[11].

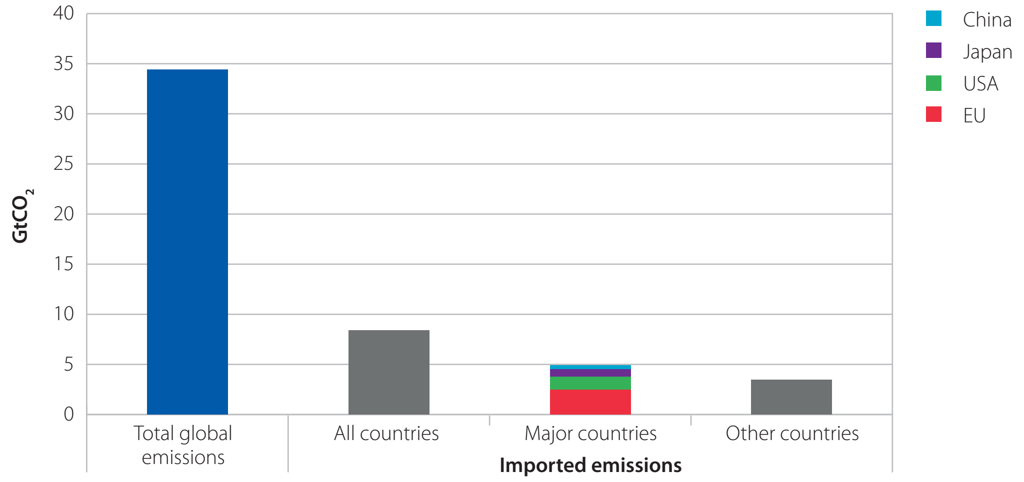
- **Global deal**. The key to meeting the climate objective is to get agreement on a strong global deal. This would ensure that all nations implement effective policies to reduce their carbon intensities, which would result in lower embedded emissions in their exports (and hence the UK's imports). This deal should be based on production-based accounting, as moving to a consumption accounting basis for this deal would be unnecessary and difficult to implement:
  - If all nations make commitments under a global deal and fully account for their production emissions, there is no need to further account for consumption emissions, given that these emissions will already have been covered (with some countries likely to continue as net emission exporters, while others will be net importers).
  - It is important that all countries follow the same accounting approach so that all emissions are covered and none are double counted.
  - Individual countries have policy levers to reduce production emissions, but less scope to reduce imported emissions, short of introducing border carbon adjustments (see below).
  - There is substantial uncertainty in consumption emissions data and it is not feasible to produce robust and up-to-date annual estimates, as would be required under a global deal with mandatory targets.
  - Introducing a new accounting basis into the on-going negotiations on the global deal would create unnecessary complications.
- There are also a number of polices which could support the implementation of a global deal.
  - **Sectoral agreements**. These would limit emissions at a sector level, for example through the introduction of sectoral cap-and-trade schemes, by setting sector efficiency targets, or by getting global agreement across sectors on adoption of best available technologies. However, progress towards sector agreements has been mixed: designing them is technically difficult, and incentives to enter into them on a voluntary basis are weak. Most progress has been made in sectors which are international in nature (e.g. the International Maritime Organisation has agreed a global fuel efficiency standard for new ships). Although it is possible that barriers could be overcome, it is unlikely that sectoral agreements would have extensive coverage. Therefore these could support the implementation of a global deal but not substitute for it.
  - **International climate finance**. Support for developing countries to implement mitigation and adaptation measures is an important aspect of the emerging global deal. Low-carbon power and industrial energy efficiency projects are priority areas for international climate finance and such projects can contribute to reducing carbon intensities in the UK's trading partners.

11 E.g. Helm, D., Hepburn, C. and Ruta, G. (2012) *Trade, climate change and the political game theory of border carbon adjustment*

- **Carbon footprinting**. To address carbon emissions embedded in goods and services (including imports), many companies have made attempts to carbon footprint their supply chains. While carbon footprinting methodologies have to deal with large uncertainties and a lack of data, they can be a valuable tool, especially for identifying carbon 'hotspots' and reducing costs. Businesses can play an important role by reducing the emissions within their control and using their influence in the value chain, by working with government to standardise approaches, by removing the most carbon-intensive products from their shelves, and by promoting lower carbon options.
- **Consumer information**. Provision of consumer information can provide a useful complement to other policies. For example, this has been helpful in the context of implementing regulations on the energy efficiency of new appliances and fuel efficiency of new cars in the EU. Evidence from the labelling of food aimed at improving health suggests that there can be a positive impact on consumer choices. However, there is also evidence that consumers find it difficult to grasp the more abstract concept of carbon embedded in products. Drawing on these experiences, there may be a benefit in labelling the carbon footprint of a targeted range of products which are carbon-intensive and where low-carbon alternatives are available.
- **Regulation.** For products where there is a high degree of variation in the carbon footprint, setting minimum standards could be helpful. This would build on the current EU approach, which regulates against the least carbon-efficient products on an operating basis (e.g. energy efficiency of appliances), and could in the future be extended to cover the carbon footprint of selected carbon-intensive products.
- **Reuse, recycling and resource efficiency**. For many products, lifecycle emissions can be reduced through increased reuse and recycling, as well as resource-efficient product design, as promoted by various EU directives. There is further scope for more effective implementation of these directives, in particular in terms of resource efficiency.

• **Border carbon adjustments**. These aim to create a level playing field for trade by charging imports the cost of their carbon (e.g. through a carbon tax on imports or the purchase of emission allowances by importers), combined with refunds for exporters' carbon costs. This therefore addresses competitiveness risks (i.e. it would address the current situation, where firms in a country which has unilaterally adopted a carbon constraint are at a disadvantage). Putting a price on imported carbon emissions would provide incentives for the reduction of part but not all of consumption emissions. Given limited coverage (e.g. traded emissions account for less than 25% of global emissions, Figure 1.10), together with the need for other polices in addition to a carbon price, border carbon adjustments are not an alternative to a global deal. However, they should not be ruled out for further consideration as a possible transitional measure, and any move towards border carbon adjustments would have to be considered in light of a full analysis of possible trade ramifications and associated costs.

**Figure 1.10:** Coverage of traded emissions compared to global emissions (2010)




**Source:** Eora (2013).
**Notes:** Traded emissions shown on an import basis for country breakdown. On an export basis the total traded emissions are the same (since imports and exports are equal at the global level) but country breakdown differs in line with trade patterns. Figures are for $CO_2$ only.

We considered progress towards a global deal as part of our advice on the fourth carbon budget in 2010. Our conclusion at this time was that the climate objective remained in play given commitments in the Copenhagen Accord, but that further commitments would be needed, particular on deep emissions cuts through the 2020s, together with action to deliver these cuts.

There have been some positive developments since 2010:

- The United States has continued to reduce emissions through a combination of coal to gas switching in power generation, energy efficiency improvement in buildings, and fuel efficiency improvement in new vehicles. US emissions in 2010 were 6% below 2005 levels, and there is evidence to suggest that the US could deliver its Copenhagen commitment to reduce emissions in 2020 by 17% on 2005 levels without the need for new federal legislation. [12]
- China has committed to reduce its emissions intensity by 45% in 2020; this compares to a 30% reduction in emissions intensity implicit in the UK's third carbon budget. Emissions trading pilot schemes in 7 major Chinese cities (including Beijing and Shanghai) will start operating in 2013 and 2014.
- Important climate change legislation has been passed in a number of countries, both in the developed and developing world (e.g. South Korea and Mexico).[13]
- The EU has started early negotiations on a package of measures to further reduce emissions through the 2020s.
- The UN process is moving towards a global deal in 2015 and could embody commitments on deep cuts in global emissions to 2030.

12 World Resources Institute (2013) *Can The U.S. Get There From Here?;* Burtraw, D. and Woerman, M. (2012) *US status on climate change mitigation*. Resources for the Future.
13 Globe 3rd Climate Legislation study, http://www.globeinternational.org/index.php/climate-study-home

Our fourth carbon budget review will include an assessment of progress towards a global deal. In particular, it will consider the United Nations climate change negotiation process, and action being taken in key emitting countries. It will include analysis of alternative pathways for future global emissions and any implications that this might have for the fourth carbon budget, reducing the UK's carbon footprint, and managing competitiveness risks.

In the meantime, it is important that the Government should support proposals for an ambitious EU 2030 greenhouse gas target and supporting package, and develop approaches to help get agreement on a similarly ambitious global deal, given the significant economic, environmental and social benefits that this would bring.

### Carbon budget accounting

It remains appropriate to account for carbon budgets on the basis of production emissions given accounting conventions and available policy levers. However, consumption emissions should be monitored to check whether these are falling in line with global action required to achieve the climate objective, or whether further action is required.

- Moving to a consumption-based accounting methodology would be disruptive and impractical given international accounting conventions (which are based on production emissions and aim to avoid double counting) and uncertainties over measuring and projecting consumption emissions.
- Production emissions account for more than half of the UK's carbon footprint and we have the levers to reduce them; there is less scope for reduction of imported emissions through UK levers.
- If monitoring of consumption emissions were to reveal that these are falling too slowly, this may suggest the need for further action.

We will report periodically on consumption emissions as part of our broader reporting to Parliament on progress in reducing emissions.

# Chapter 2: Competitiveness risks and opportunities associated with fourth carbon budget measures

Chapter 1 showed that although the UK's carbon footprint has increased over the last two decades, this was not due to significant offshoring of industry as a result of carbon-reduction policies in the UK. Going forward, it is important to reduce both production and imported emissions.

In order to ensure that this can be achieved in an economically sensible way, it is important to identify competitiveness risks associated with low-carbon policies. Such risks could, if not addressed, disadvantage UK firms with little or no environmental benefit due to carbon leakage elsewhere.

To prevent this happening mitigating measures should be identified, such that production emission reductions translate to reductions in carbon footprint.

These mitigating measures may involve some form of support to offset impacts of low-carbon policies. They can be justified to preserve profits or wages in energy-intensive companies relating to investments made before policies were introduced; to stop existing industry relocating to other countries; and to encourage new investment in energy-intensive industries.

It is important to note that mitigating measures could undermine consumer price signals that encourage a shift away from high-carbon goods, essential in the move to a low-carbon economy. The supporting measures should therefore be transitional on the path to a global deal which would over time ensure a level playing field and reduce the need for support. Furthermore, there are opportunities as well as competitiveness risks associated with the move to a low-carbon economy (e.g. new markets for low-carbon technologies).

The key messages from our analysis are:

- Costs and competitiveness risks associated with measures to reduce direct emissions to 2030 are manageable. Continued support in the EU Emission Trading System (EU ETS) for industries subject to international competition may be required through the 2020s, dependent on progress towards a global deal.
- Competitiveness risks to electro-intensive industries to 2020 of policies to decarbonise the power sector relate to current Government policies funded under the levy control framework. We estimate that possible profit impacts are commensurate with support under already announced policies to address these impacts. This could increase energy bills by around £5 for the typical household in 2020. They continue to be manageable in a carbon-constrained world to 2030.

- Electricity price impacts from 2020 to 2030 are more uncertain than impacts to 2020, particularly due to uncertainty about low-carbon policies in other countries. However, in a carbon-constrained world our analysis suggests that required support would decline over time as carbon policies increase in other countries.
- Higher electricity prices could impact on the competitive position of some farming activities (pigs, poultry and dairy). Opportunities to offset the impact of rising electricity prices should be further assessed.

We set out our analysis in five sections:

1. Competitiveness benefits from being on the least-cost path to meeting the 2050 target
2. Industries most impacted by low-carbon policies
3. Competitiveness impacts for energy-intensive industries associated with measures to reduce direct emissions
4. Competitiveness impacts for energy-intensive industries associated with measures to reduce indirect emissions
5. Competitiveness risks for agriculture associated with the fourth carbon budget

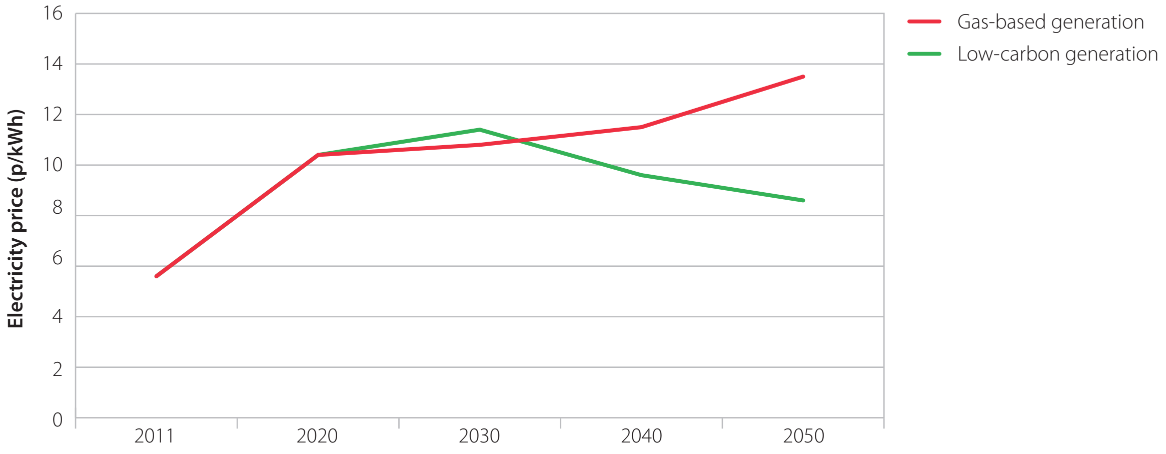
## 1. Competitiveness benefits from being on the least-cost path to meeting the 2050 target

There are opportunities for energy-intensive industries to benefit from the early transition to a low-carbon economy[1].

- **Lower medium to long-term electricity prices**. Early investment to decarbonise the power sector results in higher electricity prices in the 2020s, with limited price rises thereafter given falling costs of low-carbon technologies. We project relatively low prices for a low-carbon power system in the medium and longer-term compared to the alternative conventional fossil fuel based system subject to a rising carbon price (Figure 2.1). Therefore, early investment to decarbonise the power sector results in a competitiveness gain for UK industry in the medium and longer-term compared with investment in predominantly gas-based generation.

1 It is important to note that these benefits mainly ensue in a carbon-constrained world; as noted in Chapter 1, there is a need to closely monitor progress towards a global deal.

**Figure 2.1:** Industrial electricity prices in a low-carbon world versus a 'dash for gas' in the 2020s



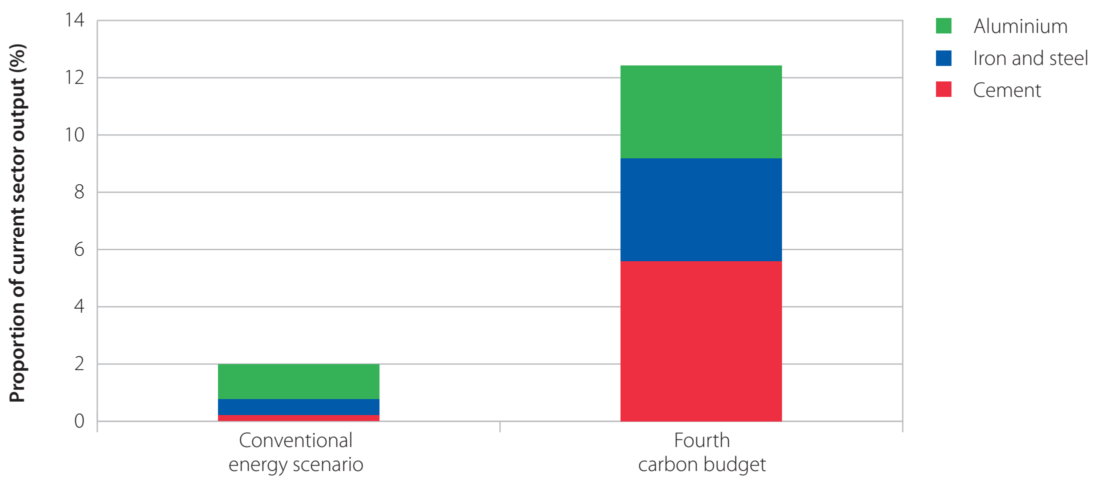

**Source:** Ofgem and CCC calculations.
**Notes:** Chart shows wholesale electricity price, including transfer payments to fund low-carbon generation via the Renewables Obligation and Contracts for Difference, and wider systems costs associated with intermittent renewables (where relevant). The retail price faced by industrial users will depend on ability to negotiate lower wholesale prices through bargaining power, direct contracts with generators and economies of scale in supply.

- **New markets**. A move to a low-carbon economy will create opportunities for energy-intensive industries in meeting demand for low-carbon technologies in domestic and export markets:
  - Our analysis suggests that, compared with a conventional energy scenario, there could be higher UK demand for some energy-intensive products supplied to the power and heat sectors over the period 2013-2030. Most of this stems from additional demand for on- and off-shore wind turbines, nuclear and CCS, which contain more embodied iron, steel, cement and aluminium compared to conventional gas power plants (Figure 2.2).
  - Our 2010 Innovation Review identified key areas where the UK had developed significant capability and potential to develop a leadership role in international markets. The UK was well placed to take on a 'develop and deploy'[2] strategy in offshore wind, marine, CCS for power, smart grids, aviation and electric vehicle technologies. Our analysis suggests that some energy-intensive sectors in the UK such as parts of chemicals, articles of concrete and cement and some non-metallic minerals, as well as aerospace, electronics and parts of heavy engineering and construction have a comparative advantage compared with key competitors[3]. These sectors are well placed to contribute to the supply chain of these technologies.
- **Innovative new technologies and processes**. The move to a low-carbon economy will involve innovative processes and technologies across a wide range of sectors and applications. Some UK energy-intensive sectors are well placed to compete in low-carbon innovation compared with key competitors (Figure 2.3). Sectors that already have a head start in green patenting activity[4] include basic non-ferrous metals, refineries and parts of rubber and chemicals. There is a role for energy-intensive industries in developing new innovative low-carbon products such as low-temperature detergents, low-resistance tyres and lightweight materials in aircraft and cars.

2 That is, investment and deployment of these technologies in the UK would accelerate learning and bring down costs.
3 Further detail is in a technical report available on our website. Available at http://www.theccc.org.uk/publication/carbon-footprint-and-competitiveness/
4 Where the Green Innovation Index (GII)>1. See Fankhauser et. al.(2012) 'Who will win the green race? In search of environmental competitiveness and innovation' available at http://www2.lse.ac.uk/GranthamInstitute/publications/WorkingPapers/Papers/90-99/WP94-green-race-environmental-competitiveness-and-innovation.pdf

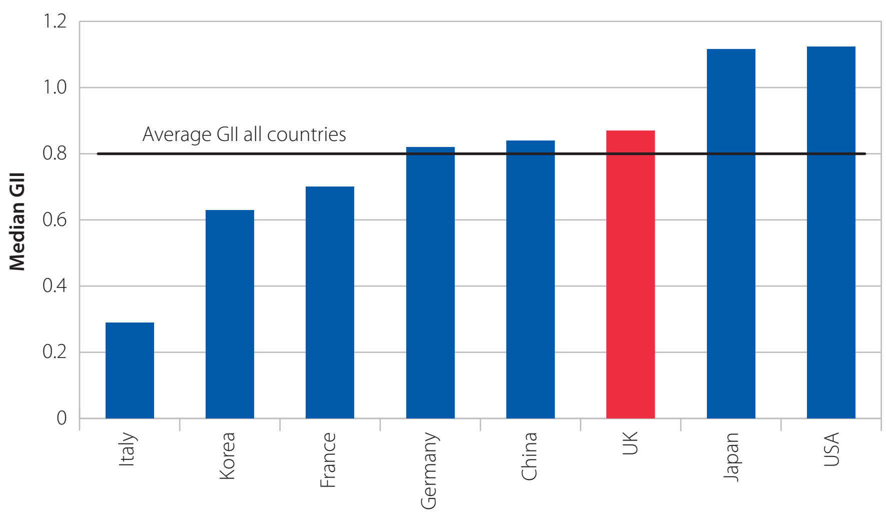
The challenge is to design policy in a way that allows industry to benefit, while mitigating potential competitiveness risks in the near to medium-term due to the fact that some countries will have a less stringent near to medium-term carbon constraint.

**Figure 2.2:** Annual material requirements for the power sector (2013-2030)




**Source:** CCC calculations based on model developed by Ricardo-AEA.
**Notes:** We compared material requirements for the power sector between 2013 and 2030 under a conventional energy scenario and under our scenarios for the fourth carbon budget. The conventional energy scenario reflects a gas-based system; the fourth carbon budget scenario reflects a portfolio of low-carbon technologies (i.e. on- and off-shore wind, nuclear, CCS, and some unabated gas). We combined these scenarios with data on embodied materials in different technologies (from our analysis of life-cycle emissions in Chapter 3). The chart shows the implied annual material requirements for each sector as a proportion of their current output (i.e. the cement requirement under a conventional energy scenario is less than 1% of current cement output; this rises to around 6% in a low-carbon scenario reflecting the additional cement needed for low-carbon technologies).

**Figure 2.3:** Median Green Innovation Index in energy-intensive industries




**Source:** CCC calculations based on data provided in Fankhauser et al (2012) et al op.cit

## 2. Industries most impacted by low-carbon policies

Manufacturing industry is an important source of carbon emissions. In 2011, industry accounted for 164 $MtCO_2$ or 36% of UK $CO_2$ emissions, covering both direct and indirect sources. Emissions in this sector are concentrated among energy-intensive sectors, which together accounted for 50% of industrial emissions in 2011.

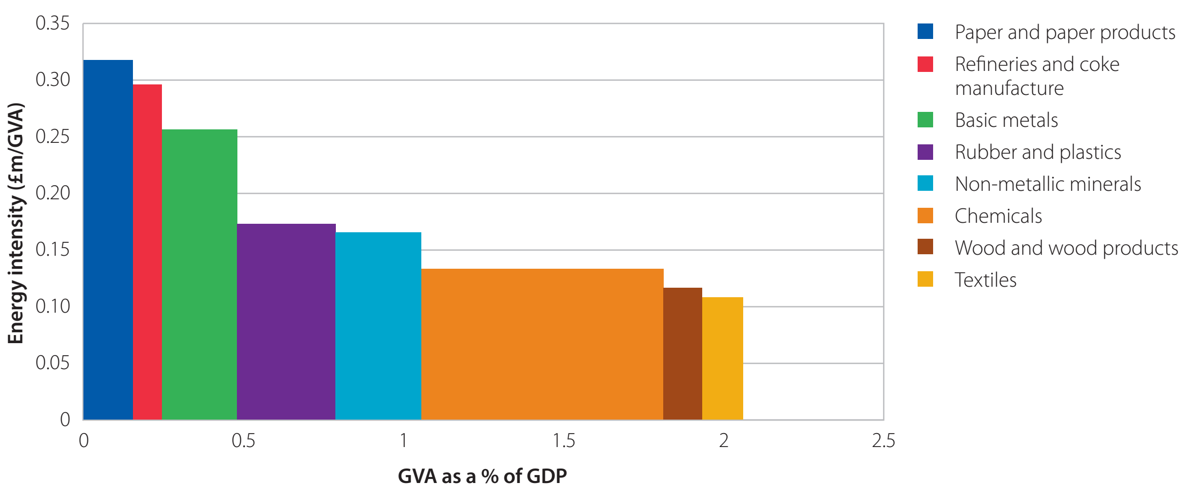
Across industry as a whole, energy costs account for around 3% of total costs. Given that this is the case, it is unlikely that low-carbon policies will have significant impacts for most industry.

- In our December 2012 Energy Prices and Bills report, we estimated that energy costs due to low-carbon policies would rise by 20-25% from 2011 to 2020 for industrial users.
- Assuming a 3% share in total costs, this will result in total cost increases of around 0.6%.
- If this were passed through to higher prices, then it would add 6p to every £10 spent on manufactured goods.

There is a higher risk of competitiveness impacts for energy-intensive firms, defined as spending more than 10% of their Gross Value Added (GVA) on energy. The risk is that these energy-intensive industries that are also subject to international competition facing higher relative energy costs will see a squeeze on profits which could potentially drive output and jobs overseas.

The key energy-intensive industries are paper, basic metals, non-metallic minerals, coke manufacture and refineries, chemicals, rubber and plastics, wood and wood products and textiles (Figure 2.4). In these sectors, energy costs range from 5-30%[5] of total costs.

**Figure 2.4:** Energy intensive industries energy costs and GVA




**Source:** CCC calculations based on ONS and DECC data.

5 Energy costs are defined here as gas and electricity costs. This range excludes petroleum products and solid and manufactured fuels.

Together the energy-intensive industries account for around 2% of UK GDP (or 2.5% of GVA) and 2% of total UK employment (around 600,000 jobs). Only a portion of these jobs, around 160,000 in some estimates[6], are in the energy- intensive parts of these industries. The sectors are of particular importance from a local economic perspective (e.g. accounting for 7% of Welsh GVA and 4%[7] of employment, with a concentration of industry around Port Talbot).

## 3. Competitiveness impacts for energy-intensive industries associated with measures to reduce direct emissions

### Measures to reduce direct emissions to 2020

We assessed the impact of measures to reduce direct emissions to 2020 in our 2008 report *Building a Low-Carbon Economy*. This report contained analysis of carbon price impacts on the costs of energy-intensive industries concluding that these could entail competitiveness risks.

Since 2008, the EU has developed an approach to giving free EU ETS allowances to energy-intensive industries regarded as at risk of global competition: for sectors deemed at risk of leakage, 100% free allowances are granted[8] and other sectors receive less (80%, declining to 30% in 2020). This will fully address cost impacts of the EU ETS for industries at risk, with evidence to suggest that it may actually result in windfall profits in some cases (Box 2.1).

**Box 2.1:** Surplus EU ETS allowances

Surplus allowances reflect over-allocation in Phase I and II of the EU ETS (in part due to recession-related falls in output) and the implementation of low-carbon measures.

We commissioned Cambridge Econometrics to assess the extent of surplus allowances to 2020, based on projections of industrial output and consumption consistent with our first three carbon budgets. The results suggest that allowances exceed emissions across energy-intensive industry until beyond 2020.

This confirms an assessment by DECC which indicated that the surplus of allowances would remain significant until 2020, with the implication that competitiveness risks from direct costs are mitigated during this period.

To the extent that surplus allowances are a result of over-allocation (i.e. rather than genuine emissions reductions through the implementation of low-carbon measures) this could also imply windfall profits for some firms.

This is particularly the case in basic metals (including iron and steel) which has surplus allowances of £450m in 2020, rising to £500m if low-carbon measures are implemented.

The implication is that some businesses may be more than fully compensated by the current regime.

The refineries sector has a shortfall of allowances in 2020 as a greater share of allowances from this sectors are auctioned (i.e. they have a larger proportion of onsite power generation which does not receive free allowances). Analysis conducted for the fourth carbon budget suggests that there is potential for low-cost abatement in this sector (e.g. around 4 $MtCO_2$ by 2030), which could help offset these additional costs.

This approach therefore mitigates competitiveness risks associated with direct emissions; we consider below risks related to indirect emissions, including those associated with the EU ETS.

6 TUC/EIUG, (2012). Building our low-carbon industries, available at http://www.tuc.org.uk/tucfiles/352/Buildingourlowcarboninds.pdf and Environmental Audit Committee, (2012) Energy-intensive industries compensation scheme available at http://www.publications.parliament.uk/pa/cm201213/cmselect/cmenvaud/669/669.pdf

7 This excludes SIC 13 and 16 due to lack of data.

8 Free allowances are granted up to a level of emissions consistent with the average greenhouse gas emission performance of the 10% best performing installations in the EU producing that product.

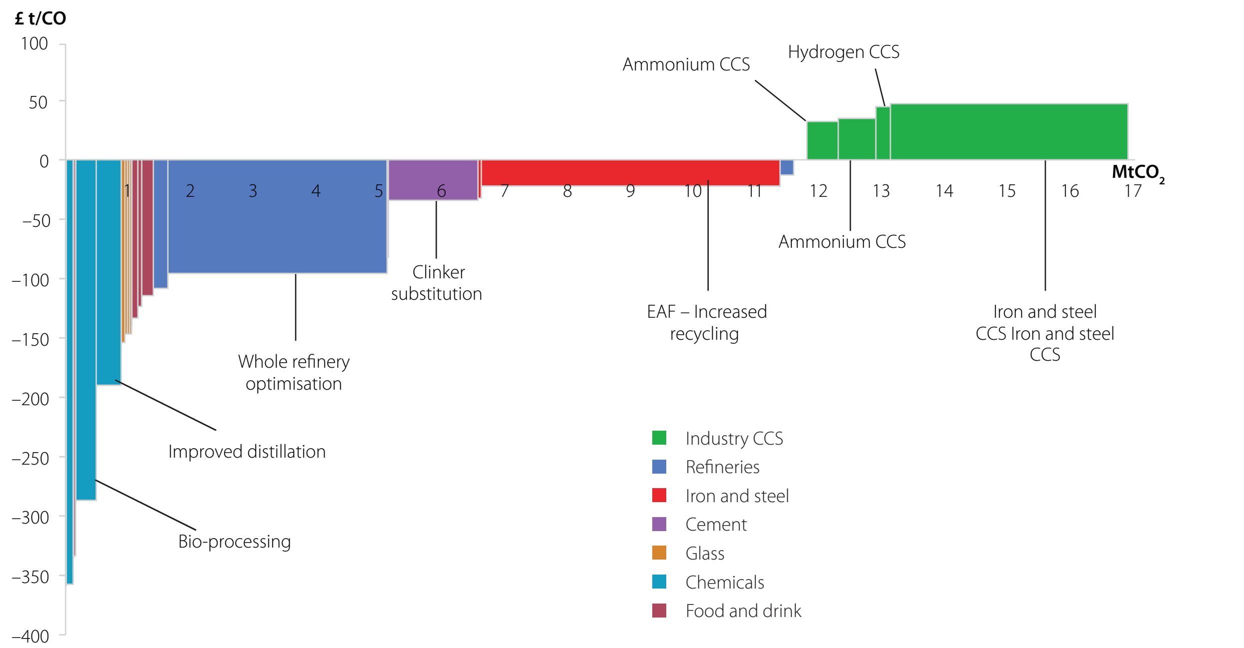
## Measures to reduce direct emissions in the fourth carbon budget

The fourth carbon budget is based on analysis which assumes further reduction in emissions from energy-intensive industries in the 2020s:

- The budget reflects scope to reduce emissions from energy-intensive industry by around 26% through the 2020s.
- This potential arises from the use of biomass for heat, energy efficiency and some CCS.

In considering competitiveness risks related to implementation of these measures, it is important to consider their cost. All of the energy-intensive industry measures underpinning the fourth carbon budget are relatively low cost. Specifically, they are cost-effective, falling well within carbon price projections for 2020 and beyond, both by the UK Government and the European Commission (EC) in its 2050 low-carbon roadmap[9] (Figure 2.5).

**Figure 2.5:** 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 broad implication is that competitiveness risks are manageable as long as the world is carbon-constrained:

- As long as energy-intensive industries remain within the EU ETS, and as long as the carbon price in the EU ETS continues to increase, then there should be no intra-EU competitiveness risks associated with the fourth carbon budget.
- Current trade among the energy-intensive industries is predominantly with countries in the EU. Although there may be risks between the EU and the rest of the world, any mechanisms required to address these risks will depend on the nature of a global agreement and the carbon constraint that this implies for EU versus non-EU countries through the 2020s.

9 Available at ec.europa.eu

- Options to address any risks include continuing the current approach of granting free allowances in the EU ETS, and/or sector agreements and border carbon adjustments. Sector agreements and border carbon adjustment could provide stronger incentives for reducing emissions than allocation of free allowances, but are likely to be both technically and politically difficult to agree and implement (see Chapter 1 above).

We will continue to monitor progress towards an EU 2030 package and a global agreement closely, and consider implications for design of carbon budgets and competitiveness risks.

## 4. Competitiveness impacts for energy-intensive industries associated with measures to reduce indirect emissions

Competitiveness risks arise not just through direct costs but through measures to decarbonise the power sector which add to electricity prices and raise costs to users. In this section we set out the following blocks of analysis:

- We identify industries most open to competitiveness risks associated with rising electricity prices and their key trading partners.
- We develop scenarios for electricity price increases due to low-carbon policies in the UK, EU and internationally.
- We identify uncertainty over current and future electricity consumption, reflecting differences in estimates of current consumption across data sets, and uncertainty over scope for energy efficiency improvement.
- We consider the evidence on scope for pass-through of rising electricity costs.
- We model the impact of rising electricity prices on profits under various assumptions about electricity costs in other countries, energy efficiency improvement, and scope for cost pass-through.
- We consider levers for addressing impacts, including approaches in place in the UK and other countries.

### Identifying at risk industries and key competitors

Our analysis focuses on electro-intensive industries most at risk of competitiveness impacts. These are the sectors with high electricity bills as a proportion of GVA (i.e. around 10% and above), which are trade-intensive[10] and which are relatively large electricity consumers. The specific industries considered are paper, iron and steel, rubber and plastics, chemicals (specifically nitrogenous fertilizers and chlor-alkali) and non-metallic minerals (specifically cement, lime and glass) [11].

10 Trade intensity is defined as (imports+exports)/(output+imports).
11 Further sectors are considered by ICF and Cambridge (2013) 'Assessment of Competitiveness Impacts of Carbon Budgets on Electro-intensive sectors to 2030' available at www.theccc.org.uk

Identification of sectors for consideration is not straightforward due to lack of up-to-date electricity consumption data at a disaggregated level[12].

Where such gaps exist we have included the whole sector for analysis, even when only a part would strictly be classified as electro-intensive (e.g. rubber and plastics).

While this list may not be exhaustive, we are confident we have captured most electro-intensive and trade-intensive sectors, and therefore our approach has been cautious with regard to overall impacts. Further targeting of specific parts of the sectors affected should be considered as part of any policy to address competitiveness risks.

In order to assess the competitiveness impacts, we need to identify key trading partners of the sectors most at risk. This was based on an assessment of the UK's current trading partners (both importers and exporters), key global producers regardless of whether they currently traded with the UK (as they could present a future risk), and a consideration of imminent changes to trade or other policy. The most significant trading partners were identified for each sector and the results combined to produce a final list to take forward for more detailed analysis. These were: Belgium, China, France, Germany, The Netherlands, Turkey, Russia and the US.

For each of these as well as for the UK, we developed electricity price scenarios.

## Electricity price scenarios

Electricity prices in the UK and competitor countries were based on an assessment of existing and future energy and climate change policies that are likely to affect prices to 2030. Our electricity price scenarios for the UK reflect the analysis in our December 2012 Energy Prices and Bills report[13]. For competitor countries, we commissioned ICF and Cambridge Econometrics[14] to conduct a study of the impact of current and future planned low-carbon policy on electricity prices (Box 2.2).

**Box 2.2:** International electricity prices

The ICF and CE study looked at the following key measures in the quantitative development of electricity price estimates:

- Greenhouse gas trading policies. This covers the EU ETS, the US-state emissions trading schemes, the pilot Chinese Emissions Trading Schemes and emerging US regulations
- Energy efficiency policies and targets
- Renewable energy policies. All countries apart from Russia have renewable energy policies in place or planned shortly. Where the impacts of these are reduced for the electro-intensive sectors (e.g. in Germany and the Netherlands) this is taken into account.
- Energy taxes

Wider energy policies are also considered, for example the Amendment of the Atomic Power Action (nuclear phase out) in Germany and the Law on New Organisation of Electricity Markets (ending regulated tariffs) in France.

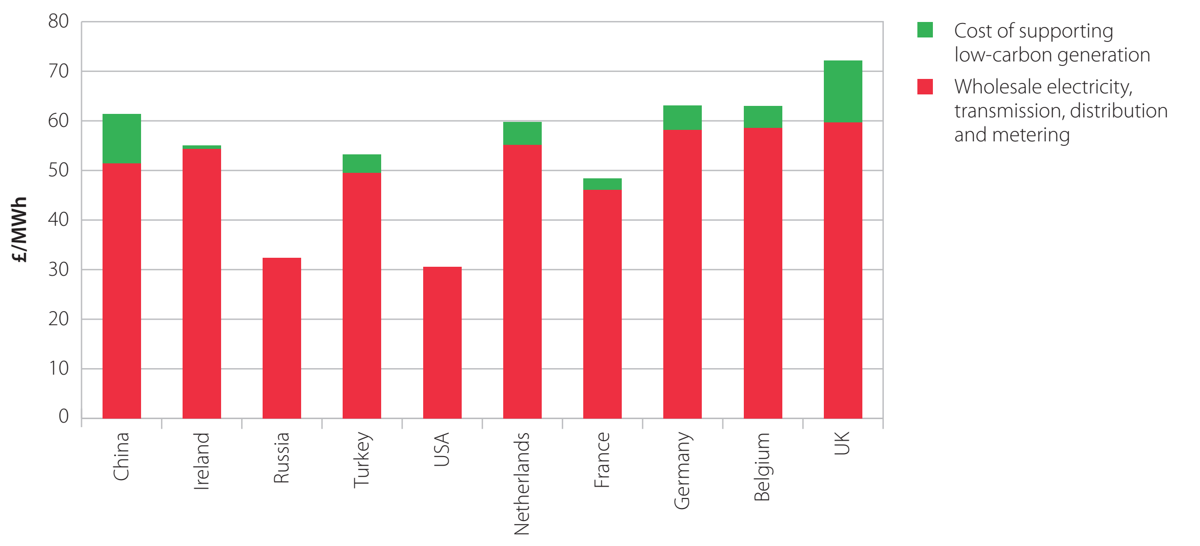
12 Current electricity consumption is only published by DECC at a relatively aggregate level (Standard Industrial Classification 2) which is too broad to assess competitiveness impacts. This is discussed further in the technical report available on our website.
13 CCC (2012) Energy prices and bills – impacts of meeting carbon budgets available at www.theccc.org.uk
14 ICF and Cambridge Econometrics (2013) Op..cit.

The analysis shows that current electricity prices for industrial users in the UK are high relative to those in the rest of the EU and internationally (Figure 2.6), most of which is due to higher base prices (wholesale plus network costs), with low-carbon costs adding around £12/MWh.

We project these prices forward based on an assessment of the impact of current and proposed energy and low-carbon policies and different scenarios for future carbon prices. Given the uncertainty both in future carbon price trajectories and the scope of future carbon markets, we developed two scenarios to test a range of competitiveness impacts compatible with achieving the climate objective (Box 2.3, Figure 2.7).

It is important to note that our focus in this report is on scenarios where the world is carbon-constrained, with variation according to how quickly this constraint binds different countries. If other countries were to significantly diverge from this course, this would raise more fundamental questions about the appropriate pace of emissions reduction, rather than competitiveness impacts per se. We will consider a wider range of global emissions pathways and carbon price scenarios in our review of the fourth carbon budget, drawing out implications for appropriate ambition in the fourth carbon budget.

**Figure 2.6:** Electricity prices in the UK and internationally (2011)



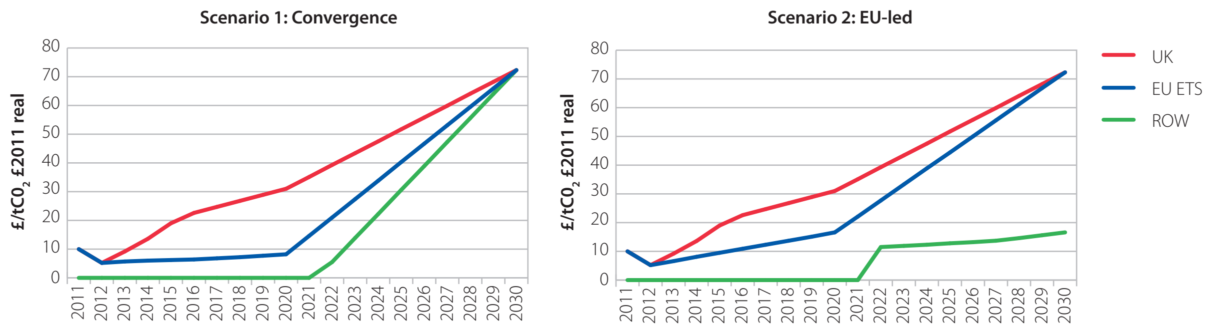

**Source:** CCC (UK prices), ICF (international prices).
**Notes:** German costs of supporting low-carbon generation includes exemptions for energy-intensive industries.

## Box 2.3: Carbon price scenarios

**Scenario 1: 'Convergence'.** There is a global carbon price by 2030. The EU ETS carbon price is based on DECC central estimates, reflecting futures contracts to 2020, with a move to prices needed to achieve stabilisation goals by 2030. The UK faces a carbon price floor (CPF) which is higher than this up to 2030, but converges with EU ETS prices in 2030. The rest of the world (ROW) is assumed to introduce a carbon market in 2022, with prices increasing rapidly to converge with other countries at around £70/t$CO_2$ by 2030.

**Scenario 2: 'EU-led'.** This is a stretching scenario for UK competitiveness impacts as UK and EU carbon prices converge as in Scenario 1, but ROW is on a slower track with no convergence in the forecast period. The EU ETS price is consistent with DECC's higher values used for modelling, reflecting higher demand conditions for allowances, consistent with tighter caps, faster growth and low prices of coal relative to gas. A global carbon price is assumed in the ROW by 2022, and prices are assumed to lag the EU ETS prices by 10 years. This scenario can be consistent with longer term stabilisation goals, but tests more challenging EU-ROW competitiveness conditions.

## Figure 2.7: Carbon price scenarios




**Source:** CCC calculations, DECC projections available at https://www.gov.uk/carbon-valuation

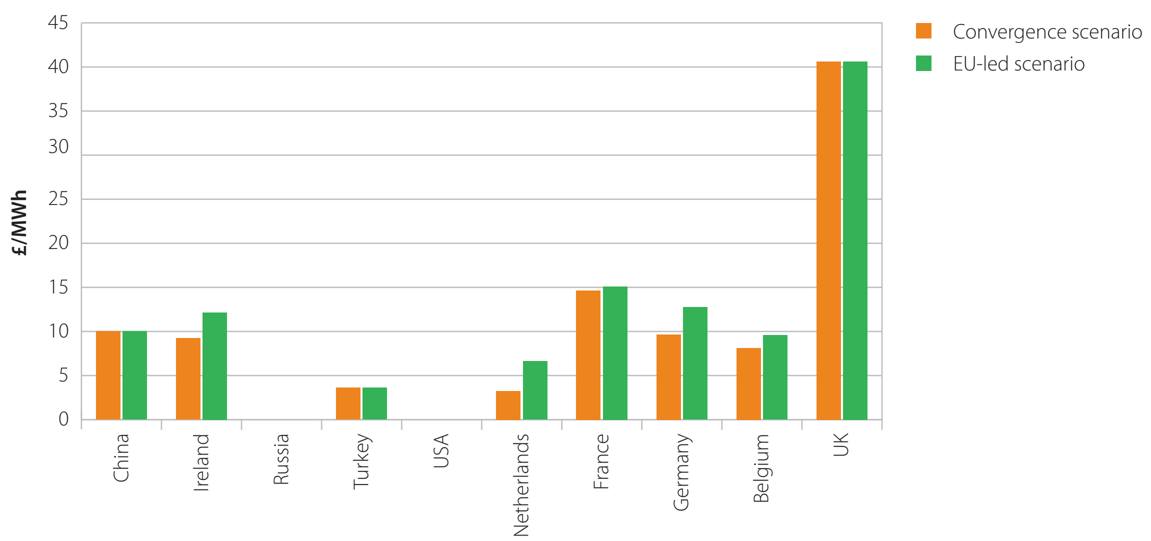
Our projections show significantly higher prices in the UK than other countries in 2020, with convergence through the 2020s, the extent of which depends on the carbon price scenario (Figures 2.8; 2.9):

- **UK electricity prices**. UK electricity price projections are the same under both carbon price scenarios. We project an increase in the component of the electricity price due to low-carbon policies from 1.2 p/kWh in 2011 to 4.1 p/kWh in 2020 and 5.0 p/kWh in 2030. These estimates take account of the impacts of the carbon price underpin, support for investment in renewable power generation under the Renewables Obligation, the Climate Change Levy (CCL) and costs associated with the Contracts for Difference (CFD). Impacts are lower for industries with autogeneration (e.g. CHP in the chemicals sector).

- **EU and international electricity prices.** We consider low-carbon policies in the UK's key trading partners, and project these forward under the carbon price scenarios above. In the 'Convergence' scenario, we find that the low-carbon component of electricity prices increases from 0-1p/kWh currently to 0-1.5p/kWh in 2020 and 1.8-5.5p/kWh in 2030. The largest differential compared with the UK is 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 electricity price differentials remain with non-EU countries, so that by 2030, UK low-carbon costs are 3-4.5p/kWh higher than countries outside the ETS.

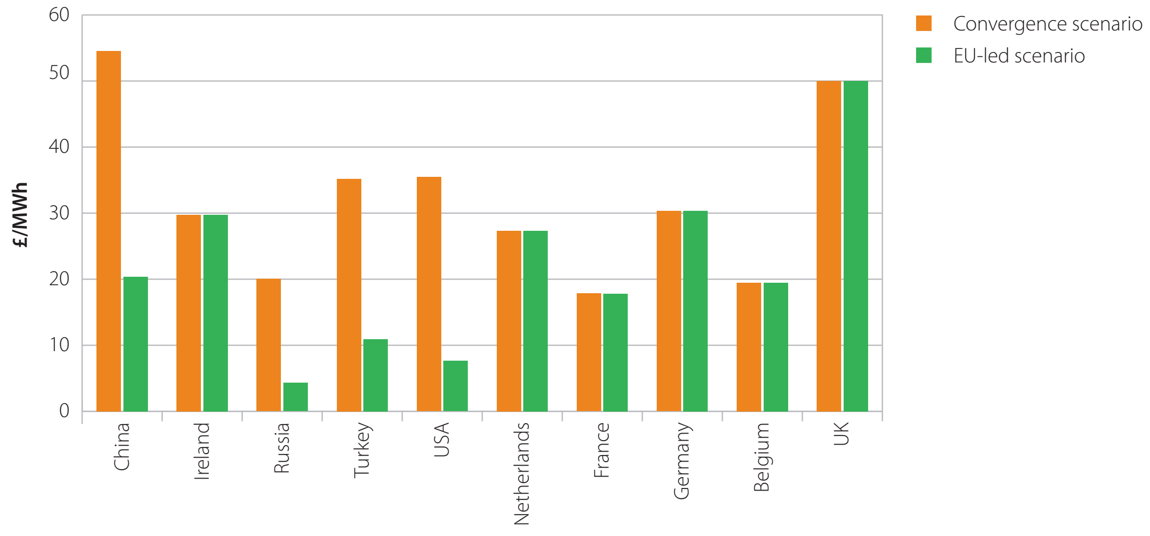
Given electricity price projections, the impact of low-carbon policies on costs and profits of electro-intensive industries depends on electricity consumption, and the nature of the markets in which firms operate (specifically their ability to pass-through higher costs to higher product prices). We now consider each of these in turn.

**Figure 2.8:** Impact of low carbon policies on electricity prices (2020)




**Source:** CCC (UK prices), ICF (international prices).
**Notes:** Projected UK costs for low-carbon policies are set out in detail in CCC's 2012 report *Energy prices and bills – impacts of meeting carbon budgets*.

**Figure 2.9:** Impact of low carbon policies on electricity prices (2030)




**Source:** CCC (UK prices), ICF (international prices).
**Notes:** Projected UK costs for low-carbon policies are set out in detail in CCC's 2012 report *Energy prices and bills – impacts of meeting carbon budgets*.

## Current and future electricity consumption

Electricity consumption of electro-intensive industries is uncertain given different estimates of current consumption across data sources, and uncertainty over scope for energy efficiency improvement.

- **Differences in estimates of current consumption.** There are two key data sets that can be used to derive industry electricity consumption[15], both of which are uncertain. Variation between these data sets is substantial in the case of some sectors. For example, in rubber and plastics, consumption derived from DECC sources is around 11 TWh in 2011, compared with around 6 TWh from the ONS data.
- **Scope for energy efficiency improvement.** Where there is scope for energy efficiency improvement, this offers potential to reduce the burden of carbon policies, which impose a cost for each unit of electricity consumed. Energy efficiency improvement will also provide a buffer against electricity price increases more generally, given that associated cost reductions go beyond avoided costs due to carbon policies. Our analysis suggests that there may be scope, depending on the industry, for around a 5–10% reduction in electricity consumption from energy efficiency improvement in electro-intensive industries in the UK, and a 0–20% reduction elsewhere. However, these estimates are highly uncertain given data limitations (e.g. about the current industry capital stock here and in other countries).
  - Electricity energy efficiency opportunities in the industrial sector include efficient motors and pumps, compressed air systems and lighting.

15 DECC (2012). Digest of United Kingdom Energy Statistics available at https://www.gov.uk/government/organisations/department-of-energy-climate-change/ and ONS (2011) Annual Business Survey available at http://www.ons.gov.uk

– In the UK, we developed an evidence base on electrical energy efficiency potential for our 2008 report, *Building a Low-Carbon Economy*. We have updated these estimates using evidence submitted to us by industry sectors on electricity energy efficiency potential by 2020. Due to long lead times in the turnover of capital stock, further efficiency potential may be possible beyond 2020 as equipment reaches the end of its lifetime.

– We commissioned consultants ICF and CE to estimate electricity energy-efficiency in competitor countries[16]. These estimates are highly uncertain due to data gaps on current capital stock, and uncertainty around assumptions regarding future consumption and technological improvements in competitor countries.

Our modelling of cost and profit impacts for electro-intensive industries includes various scenarios for electricity consumption to allow for these uncertainties.

**Scope for cost pass-through**

The ability of firms to pass on higher costs in higher product prices is key to determining the impact on their profitability and future market share. The characteristics of the market in which firms operate shape their ability to pass-through higher costs. At the extreme, in an internationally competitive market where foreign and domestically produced goods are perfect substitutes, there is no scope for industry to pass-through differential electricity price increases. In this case, electricity price increases would have to be absorbed and would be a direct hit on profits.[17]

However, in many cases foreign and domestically produced goods are not perfect substitutes, for example, because there are benefits to being located close to market, there are high transport costs or there are barriers to trade. There may then be scope to pass-through higher electricity costs, and less concern about competitiveness risks. To the extent that firms can pass on some costs, they will benefit from higher prices, partly offset by lower consumer demand. The overall impact on firms' profits will be lower than under the case of no pass-through.

Although the issue of scope for cost pass-through is highly controversial, there is evidence available which can inform this debate. We commissioned ICF and CE to advise us, and they have suggested a range for cost pass-through specific to each sector. These vary from a low range of 10-40% to a high range of 20-75% for the different sectors (Table 2.1). Further empirical work on pass-through rates is required to provide a sufficiently robust estimate for policy design. To inform such an analysis, an assessment of how firms have responded to low-carbon policy costs to date in the UK could provide a good grounding for understanding cost increases in future.

16 For some sectors (e.g. cement sector and parts of the chemicals sector) reliable estimates of current electro-intensity are reported by sector associations. Where this was not available, estimates were based on countries where the sector was thought to be similar so should be considered a reasonable proxy (e.g. chlorine industry in Belgium similar to Netherlands). Projected efficiency improvements are based on the International Energy Outlook (IEO, 2011), which publishes international energy consumption and industrial output projections for industry sectors based on projected technology demographic trends.

17 In the longer term this could lead to other adjustments such as lower wages or returns to shareholders.

**Table 2.1:** Pass-through rates

| Sector | Pass-through rate |
|---|---|
| Paper | 20-40% |
| Cement | 30-75% |
| Glass | 10-45% |
| Basic inorganic chemicals | 30-75% |
| Fertilizer and nitrogen | 10-20% |
| Iron and steel | 25-75% |
| Rubber and plastics | 40-75% |

**Source:** ICF and CE
**Notes:** The estimates were peer reviewed which suggests that while the ranges encompass the spectrum of possibilities, for some sectors pass-through is likely to be towards the higher end of the range (e.g. cement, due to high transport costs). The peer review can be found at Karsten Neuhoff (2013), available at http://www.theccc.org.uk/publication/carbon-footprint-and-competitiveness/

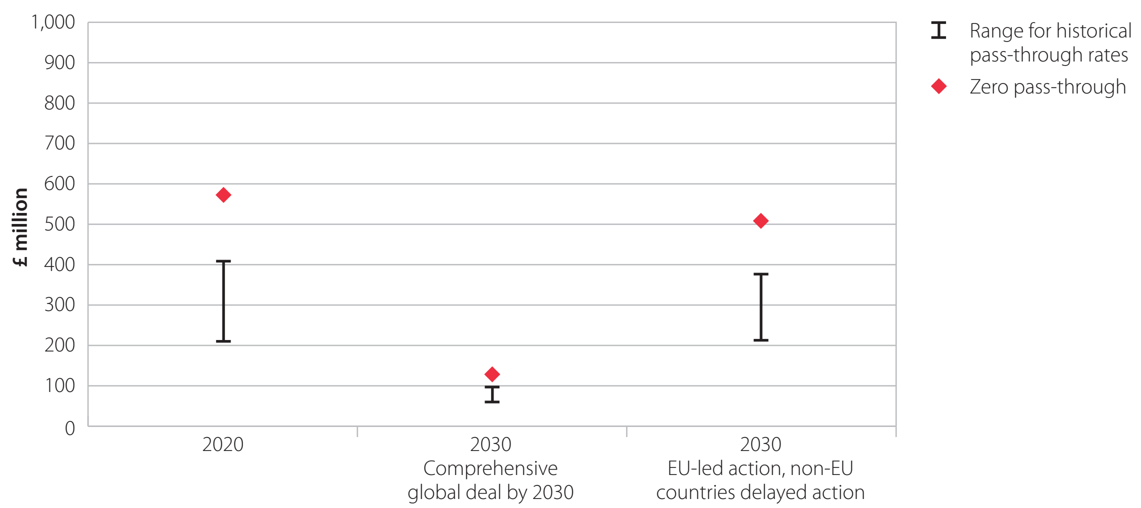
Given the uncertainty regarding pass-through rates and potential for these to change overtime, our scenarios for impacts of electricity price increases on profits reflect assumptions ranging from zero (an internationally competitive market) to the high end of the range suggested by ICF and CE.

## Impact of electricity price increases on profits

We now turn to electricity price impact on profits, which reflect electricity price impacts on costs and cost pass-through.

We estimate that higher electricity prices due to currently legislated carbon budgets could reduce profits of electro-intensive firms by £150-£400 million in 2020, reflecting the range of evidence on scope for cost pass-through, and estimates of consumption in different data sets. In the extreme case of zero cost pass-through, profit impacts could increase to £600m in 2020. Projected impacts in 2030 are lower (e.g. £50-150 million assuming a global carbon price by 2030, and up to £500 million if there is delayed action outside the EU) (Figure 2.10).

**Figure 2.10:** Profit reductions due to low-carbon policy




**Source:** CCC calculations, ICF and Cambridge Econometrics.
**Note:** Chart uses consumption estimates derived from DECC data. ONS data brings lower end of range to around £150 million in 2020.

- **Profit impacts due to higher electricity prices associated with carbon budgets in 2020**
  - The total profit of electro-intensive industries considered in our analysis was around £6 billion in 2011.
  - The profit impact under assumptions of low current consumption and high cost pass-through is £150 million in 2020.
  - This increases to £200 million if DECC data on current consumption are used rather than ONS estimates.
  - At the low end of the range for cost pass-through, projected profit impacts are around £400 million in 2020.
  - In the extreme case of zero scope for cost pass-through, projected profit impacts are £600 million.
  - The projected impact of rising electricity prices on costs is around £700 million in 2020 (with lower impacts on profits due to projected increases in electricity prices in other countries, and cost pass- through).
  - These figures assume energy efficiency improvement in the UK and elsewhere in the world. If the UK were to outperform other countries on energy efficiency improvement, lower profit impacts would ensue. Conversely, of other countries were to deliver the potential that we have identified and the UK were to fail to deliver, profit impacts would be higher.
- **Profit impacts in 2030**. Assuming a global carbon price that has converged across countries in 2030, but where the impact of carbon policies (including but going beyond the carbon price) is still relatively high in the UK, profit impacts fall to £50–£150 million reflecting the range of evidence on scope of cost pass-through.
- **Profit impacts with lower carbon prices in the rest of the world**. Impacts in 2030 could rise to £200–£500 million under the 'EU-led' carbon price scenario which has lower carbon prices in the rest of the world.

This analysis can inform design of polices aimed at offsetting electricity price impacts and limiting competitiveness impacts for electro-intensive industries.

## Policy levers for addressing competitiveness impacts

Other countries have acted to address competitiveness risks due to rising electricity prices:

- The German Government offers exemptions from costs of renewables and other taxes for energy-intensive users that amount to around £6.8 billion on average annually.[18]

18 TUC (2012) submission to the Environmental Audit Committee inquiry into the Energy-intensive Industries' compensation scheme available at http://www.tuc.org.uk

- Other European governments have offered similar exemptions (e.g. Netherlands). This is consistent with State Aid rules, as noted by the European Commission in its recent Green Paper[19]: "State Aid rules related to the ETS allow Member States, as from 2013 to provide compensation for parts of the indirect ETS costs for the most electricity intensive sectors. Furthermore, environmental state aid rules currently allow targeted exemptions for industry from energy related taxes".
- The Australian Government has offered around £2 billion average annual assistance to emissions-intensive and trade-exposed industries. This is designed to cover both direct and indirect impacts (i.e. is comparable to the value of UK support mechanisms for electricity price rises and free allocation of allowances in the EU ETS).

The UK Government has recognised competitiveness risks associated with rising electricity prices and put in place arrangements to limit competitiveness risks:

- In the 2011 Autumn Statement the Government committed £250 million for the period 2013-2015 to offset the impact of rising electricity prices for electro-intensive industries.
  - Up to £100 million is compensation for impacts from the Carbon Price Floor pass-through. The Government is currently consulting on eligibility criteria, with a view to making this available from 2013, subject to state aid approval.
  - Up to £110 million is compensation for indirect impacts of the EU ETS on electricity prices, in line with European Commission state aid guidelines. EU rules for eligibility were set in 2012 and compensation will be available from 2013.
  - A £40 million uplift on relief from the Climate Change Levy (from 65% to 90%) is to be introduced from April 2013.
- In November 2012, exemptions were announced to offset the additional costs arising under Electricity Market Reform as part of the 2012-13 Energy Bill. Although the value of these exemptions has not currently been specified by Government, we estimate they would amount to around £350 million in 2020 if extended to the at-risk electro-intensive industries identified above[20].
- In the 2013 Budget, further exemptions were announced to the metallurgical and mineralogical process sectors regarding the CCL, to be introduced in 2014.

The value of all these measures is at the high end of the range of modelled profit impacts for electricity-intensive sectors in 2020 (up to around £475 million annually, before the addition of the CCL exemptions, compared to profit impacts of £150-600 million).

In determining where on this range to provide support, the key drivers are electricity price increases in other countries, current and future electricity consumption, and scope for cost pass-through. It is also important to understand the extent to which rising electricity prices could change firm location and investment decisions, to inform political judgments about how far to offset profit impacts.

19 A 2030 framework for climate and energy policies, Green Paper, European Commission, March 2013.

20 We have assumed all new contracts issued are covered under Contracts For Difference (CFD) from 2016/17. In practice, there could be a mix of CFD and Renewables Obligation (RO) contracts around this period. CFDs will be available from 2014 onwards, along with the RO which is available until 2016/17.

If it is the case that the same firms requiring support for indirect impacts have received surplus free allowances, in excess of those generated through implementation of low-carbon measures, the Government could consider if these should be taken into account in judgements regarding the appropriate level of compensation (Box 2.1).

Given current uncertainties, the Government will have to develop the evidence base on future increases in UK electricity prices relative to other countries, current and future electricity consumption, scope for cost pass-through, and materiality of electricity price impacts for firm location and investment decisions.

Trade patterns should be closely monitored in order to check for evidence of switching from intra-EU to non-EU trade, in which case higher levels of support might be justified.

Related to this, it will be important to closely monitor progress towards a new deal to reduce global emissions, both as regards UK ambition generally to reduce emissions, and as regards specific implications for approaches to decarbonising and supporting energy-intensive industries.

For purposes of the fourth carbon budget review there are two key points:

- The largest impacts occur due to electricity price increases to 2020 from policies to which the Government is already fully committed; incremental impacts due to electricity price increases in the 2020s are relatively small.
- Rising electricity prices to 2030 are likely to have relatively small profit impacts, for example, compared to revenue expected from carbon policies (e.g. £3bn in 2020 from the carbon price underpin), and affordability impacts that would ensue from allocating costs associated with low-carbon policies away from electricity-intensive industries to other electricity consumers (e.g. adding around £5 to the typical household bill in 2020).

Competitiveness risks associated with rising electricity prices are therefore manageable, and should not be regarded as prohibitive in the context of ambition currently legislated in the fourth carbon budget.

## 5. Competitiveness risks for agriculture associated with the fourth carbon budget

In this section, we consider the competitiveness risks for agriculture associated with legislated carbon budgets. Agriculture accounts for 0.7% of UK GVA and agricultural products are relatively highly traded, therefore subject to international competition. We address two issues:

- Direct costs associated with on-farm abatement in the 2020s to meet the fourth carbon budget
- Indirect costs arising from higher electricity prices due to low-carbon policies.

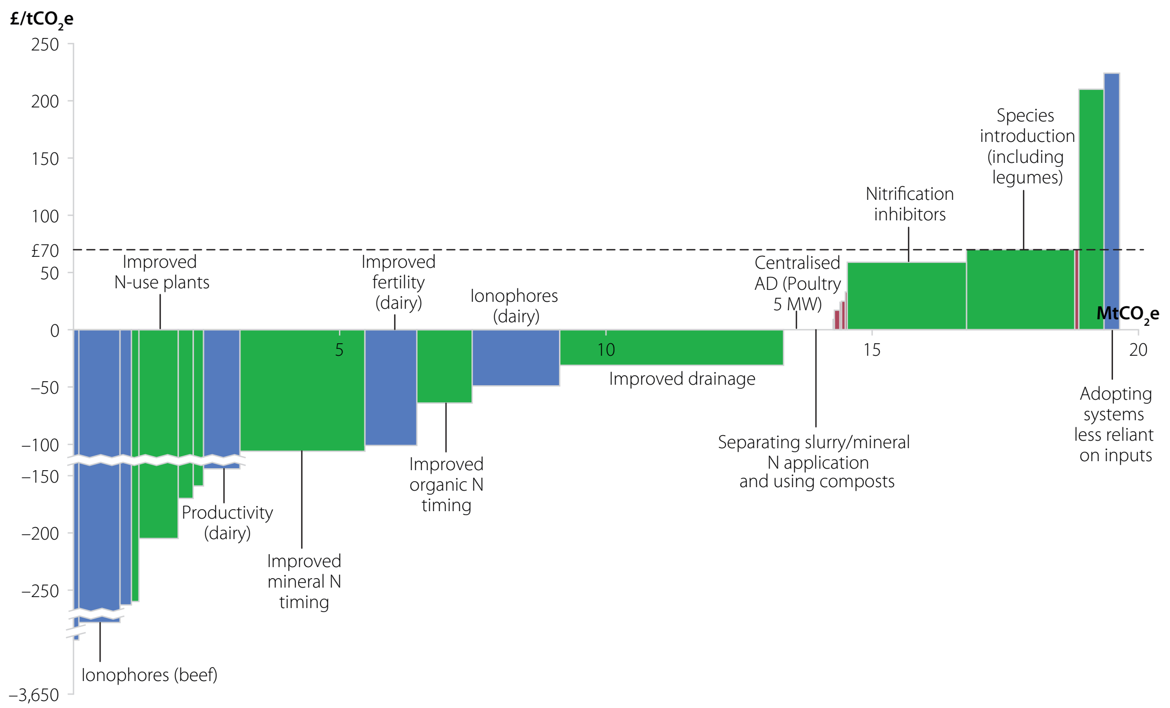
## Costs associated with measures to reduce direct emissions from agriculture

Emissions from agriculture account for 9% of total UK emissions. They largely comprise nitrous oxide emissions due to the application of fertiliser to soils (53% of agricultural emissions), and enteric emissions from sheep and cows (30%), with just 8% coming from combustion emissions.

Analysis underpinning the first three carbon budgets suggested scope to reduce agriculture emissions by up to 39% from 1990 levels through cost-saving measures related to soils and livestock (Figure 2.11). In response to the setting of these carbon budgets, the agriculture industry agreed an action plan with ambition to reduce emissions commensurate with about 38% of the maximum potential that we had identified (equivalent to savings of 4.5 $MtCO_2e$ for the UK by 2020).

Analysis underpinning the fourth carbon budget suggested scope to more than double emissions reduction to 10 $MtCO_2e$ in the 2020s, mostly through cost-saving measures. A small proportion of abatement identified as part of the analysis for the fourth carbon budget is more expensive (Box 2.4), but when considered as a package, this would not increase overall costs to the sector.

**Figure 2.11:** Agriculture MACC maximum technical potential, optimistic case (2022)




**Source:** Scottish Agricultural College, 2010.
**Notes:** The optimistic MACC assumes greater applicability uptake, abatement rates and lower costs of abatement for various measures. It also includes measures that would require substantive changes in policies and investment in research and development to support uptake. N = nitrogen; AD = Anaerobic digestion; propionate precursors are feed additives that reduce the production of methane in ruminants; ionophores are feed additives that can improve the performance of cattle and are at present banned in the EU. More details and a full measure list is available in the technical annex on the CCC website.

**Box 2.4:** Cost positive on-farm abatement measures by 2030

Analysis for the fourth carbon budget indicated that the following three abatement measures would entail positive costs:

- **New species of nitrogen fixing plants:** applicable for use on a certain proportion of cropland and pasture to fix nitrogen in the soil. This includes varieties not used commonly in the UK at present such as legumes. Combined costs associated with learning, consultancy advice, planting and reduced yields are not fully offset by reduced use of inorganic fertiliser. This particular measure accounted for the bulk of the abatement potential and the costs of the three measures.
- **Anaerobic digestion (AD) on pig farms:** costs are associated with capital investment and delivering less methane savings compared to beef and dairy AD, although costs are likely to be partially offset through reduced fertiliser use arising from digestate use.
- **Slurry tank and lagoon covers on beef and dairy farms:** costs are associated with installing new tanks and lagoons with covers due to the difficulty of retrofitting existing storage units.

## Design of policies to reduce direct emissions from agriculture

While the abatement measures associated with the carbon budgets to 2030 are cost-saving or low-cost, when designing policies to deliver these it is important to take account of competitiveness risks. In particular, given the highly traded nature of many agricultural products, policies should aim to minimise unilateral cost increases.

Fertiliser costs are significant for the agriculture industry in the UK. These have a direct impact on costs for arable and livestock farmers, and an indirect impact for livestock farmers through feed costs. Therefore policies which impact on fertiliser costs unilaterally (e.g. a fertiliser tax) should be avoided.

This suggests an approach based on the provision of information to farmers about cost-saving measures, possible cost-neutral schemes with stronger incentives at the UK level (e.g. cap and trade with revenue recycling, regulation) and EU level policies (linking CAP support to implementation of measures to reduce emissions).

## Costs and risks associated with rising electricity prices

For large parts of agriculture, electricity costs are not large as a proportion of GVA (e.g. around 3% for the cereals sector). However, there are parts of the agriculture industry where electricity costs account for 10% or more of GVA, namely intensively-reared poultry, and pigs and dairy:

- **Poultry farming** accounted for around 11% of UK agriculture output value in 2011. Electricity is used for ventilation, cooling and lighting and costs account for around 15% of GVA from poultry farming.
- **Pig farming** accounted for around 5% of UK agriculture output value in 2011. Electricity is used for heat, ventilation and lighting. Costs account for around 13% of GVA from pig farming (higher for indoor-raised pigs).

- **Dairy farming** accounted for around 18% of UK agriculture output value in 2011. Electricity is used to power milking machinery and on-farm refrigeration for cooling and storage of the milk. Electricity costs account for around 10% of sector GVA.
- The proportion of electricity costs to GVA for pigs and poultry is comparable to electricity-intensive industries such as paper (18%), rubber (15%) and glass (11%).

Electricity prices faced by farmers will rise in line with prices for commercial users. Low-carbon policies will account for 65% of the rise in the electricity price by 2020 for commercial users and 70% by 2030 according to projections in our December 2012 report[21] (Figure 2.12).

Electricity price increases of this order could erode profits for these three farming activities in England by around £30 million by 2030, which equates to less than 5% of the combined GVA of these farm types in England[22] in 2011 (Figure 2.13).

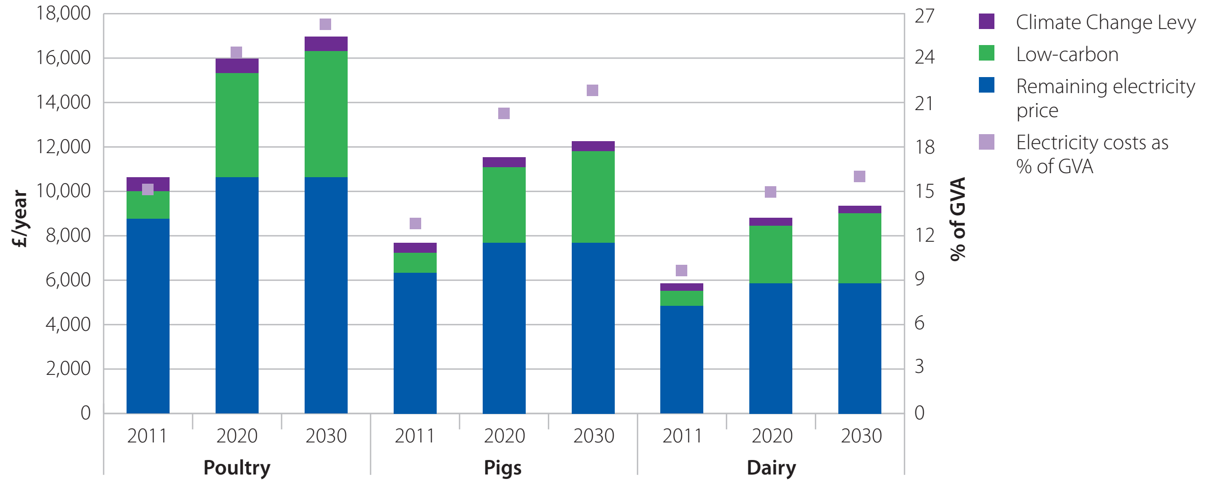
Whether this would ensue in practice depends on scope for cost pass-through, which in large part is dependent on the degree of trade and the structure of product markets.

- Poultry farming. More than 80% of the market for poultry and poultry meat are met by domestic supplies.
- Pig farming. The pig market in the UK is already highly exposed to imports, which now account for around 60% of domestic consumption. Main sources are Denmark and the Netherlands which accounted for 63% of pig meat imports in 2011.
- Dairy. Although liquid milk is not traded, the UK is a large net importer of dairy products with imports of milk powder, cheese and butter each accounting for more than half of domestic consumption.

There are also opportunities to offset electricity price increases through energy efficiency improvement, use of renewable technologies and other innovations (as illustrated in Box 2.5) although industry-wide potential is currently uncertain. The focus in addressing potential competitiveness impacts should be a further assessment of these opportunities.

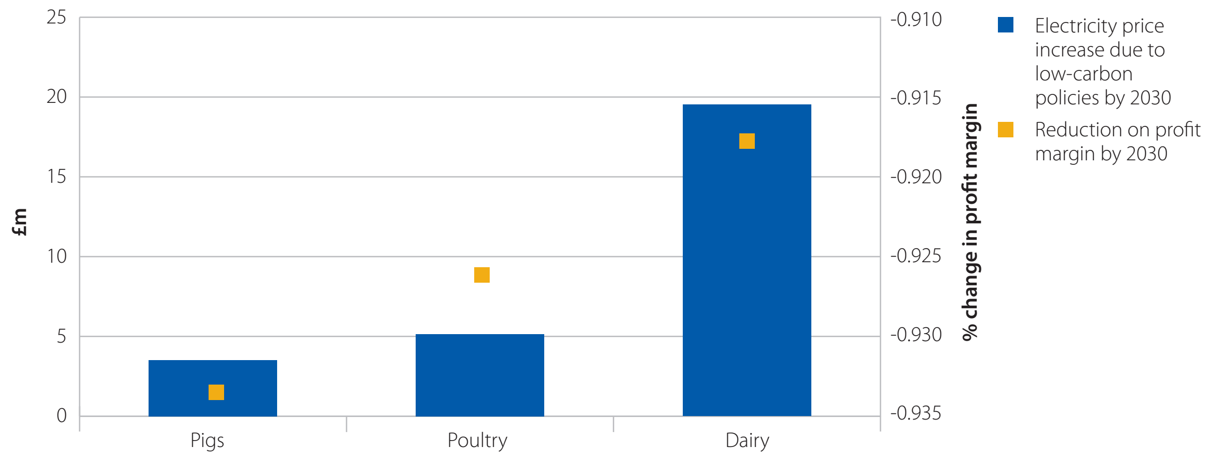
21 *'Energy prices and bills – impacts of meeting carbon budgets'* (2012), CCC.
22 Based on results that only cover those farms with at least 25,000 Euros of standard output in England.

## Figure 2.12: Change in average electricity costs per farm type to 2030




**Source:** England Farm Business Survey (Defra), Quarterly Energy Prices (DECC) & CCC .
**Notes:** Assumes no change in value of output over the period. Prices based on average-sized commercial consumer. 2011 average electricity costs based on results that only cover those farms with at least 25,000 euros of standard output in England, which captures 95% of total output in England.

## Figure 2.13: Impact of rising electricity prices on profit by farm type by 2030




**Source:** England Farm Business Survey (Defra), Quarterly Energy Prices (DECC) & CCC.
**Notes:** GVA as a % of output value is a proxy for profit margin; assumes no change in output value over the period; assume electricity price increase is absorbed by profits thus zero pass-through of costs.

**Box 2.5:** Case studies on reducing on-grid electricity demand

**The poultry sector**

Noble Foods is the UK's largest egg producer. Electricity use is mainly focused on lighting and ventilation for the egg layers and blast freezing and chilling of chicken meat. In terms of lighting, the company has been rolling out, across its sites and those of their contractors, the replacement of compact fluorescent lamps (CFLs) with LEDs specifically designed for poultry. The replacement of every two CFLs, each of 14 watts with one 7 watt LED light has delivered a 75% saving in electricity consumption. With such a large order, Noble were able to negotiate a sizeable discount on the LED price, slashing the payback period to one year. Additional benefits are reduced maintenance costs due to the significantly longer lifespan of LEDs, and reduced ventilation requirements due to the new lights emitting less heat. Further measures to reduce on-grid electricity use include the installation of small wind turbines, voltage optimisation, PIR sensors and the possibility of using poultry litter in Anaerobic Digestion in the future.

**The indoor pig sector**

The stock of buildings used to house pigs is relatively old (on average more than 22 years) which has implications for the thermal efficiency. Leaky and draughty buildings imply wasted heat, thus action to refurbish or rebuild can significantly cut electricity demand. One Suffolk pig farmer has done both, by refurbishing an existing building (only the steel structures were retained) for its herd of finishing pigs and replacing a 35-year-old building with a new one for its herd of five-week-old pigs. In both buildings, four-inch thick styrofoam was used to insulate the walls and the roofs, which had the effect of reducing electricity use by a quarter in the refurbished building. By having such well-insulated buildings, the farmer has been able to do without electrical heating as the heat generated by the pigs alone is sufficient to warm the animals. Additional electricity savings were made by having all-white plastic surfaces which reduced the need for artificial light while halving the time to pressure wash the building's interior.

**The dairy sector**

Since September last year, a Wiltshire based dairy farm has been generating its own electricity from an anaerobic digester capable of producing 4.1 million kWh/year, using animal waste mainly sourced from its herd of 500 dairy cows mixed in with farm-grown silage. In addition to electricity for its own use, the farm will earn an annual income of around £750,000 by selling the surplus to the grid under the Feed in Tariff. Additional savings will also come from use of the surplus heat on farm and sale to neighbouring facilities in the community, while the digestate is being used to displace about 400 tonnes of inorganic fertiliser each year.

# Chapter 3: Lifecycle emissions of low-carbon and conventional technologies

We have previously discussed lifecycle emissions for certain technologies in our 2011 Renewable Energy and Bioenergy Reviews. However, we have not made a comprehensive assessment of lifecycle emissions for the full range of low-carbon technologies and their conventional counterparts, focusing instead on operating emissions.

This leaves open the possibility that emissions from deployment of low-carbon technologies could be higher than we assumed in our analysis for the fourth carbon budget because of their non-operating lifecycle emissions. It is important therefore to assess full lifecycle emissions and their potential impacts on the UK's carbon footprint to establish whether the approach embodied in the fourth carbon budget remains appropriate or should be modified. For example, if it were the case that there are significant lifecycle emissions associated with technologies required to meet the budget, this might suggest a need to develop alternative technologies, and/or a need for additional abatement to offset lifecycle emissions.

In this chapter we assess lifecycle emissions of conventional fossil fuel and key low-carbon technologies in power, heat and surface transport; these sectors together account for the vast majority of emissions reductions required to meet the fourth carbon budget, and need to be largely decarbonised in order to meet the 2050 target.

We assess current lifecycle emissions, together with scope for reducing them through, for example, decarbonisation of electricity and use of different materials. We examine to what extent these emissions occur in the UK (and are therefore already covered by carbon budgets) or outside of the UK (and therefore impact on our overall carbon footprint). Given our assessment of individual technologies, we consider implications of our analysis for approaches to meeting carbon budgets and targets.

Our key messages in this chapter are:

- The key low-carbon technologies (i.e. in power, heat and surface transport) offer significant savings over fossil-fuel technologies even when accounting for lifecycle as well as operating emissions.
- Nuclear and wind power generation have a very low carbon footprint relative to conventional alternatives.
- Compared to nuclear and wind, fossil fuel generation with carbon capture and storage (CCS) has relatively high lifecycle emissions, particularly coal CCS. Therefore CCS with fossil fuels should only be used as part of a portfolio approach (i.e. together with nuclear and renewables), and with gas rather than coal where possible.
- Lifecycle emissions of electric vehicles are significantly lower than those of conventional alternatives when using low-carbon power generation, and could be further reduced through the recycling of batteries.

- Shale gas, like other forms of gas, cannot be regarded as a low-carbon fuel source. It can, however, have lower lifecycle emissions than imported liquefied natural gas (LNG), given appropriate measures to manage methane released during production.
- Lifecycle emissions of heat pumps are significantly lower than those associated with gas boilers when operated with low-carbon electricity, and could be further reduced through the use of low-carbon refrigerants.
- Bioenergy can result in emissions reductions on a lifecycle basis, but stringent sustainability criteria are required to ensure that this is the case. We repeat our recommendation that biomass used in power generation should by 2020 have lifecycle emissions of less than 200 $gCO_2e$/kWh.

We set out our analysis in three sections:

1. Current and future lifecycle emissions of low-carbon and conventional technologies and fuels

2. Implications of lifecycle emissions for meeting carbon budgets and for the UK's carbon footprint

3. Policies for reducing lifecycle emissions

## 1. Current and future lifecycle emissions of low-carbon and conventional technologies and fuels

This section sets out our analysis of current and future lifecycle emissions associated with key technologies in power, heat, and surface transport (see Box 3.1 for an outline of our methodology). It covers the following specific technologies (more detailed technology specifications are available in the supporting report[1]):

- **Power**. Onshore and offshore wind, nuclear, gas CCS, coal CCS (pre- and post-combustion) and combined cycle gas turbine (CCGT).
- **Heat**. Solid wall insulation, air and ground source heat pumps, and gas boilers in residential applications
- **Surface transport**. Conventional (petrol), plug-in hybrid and battery electric cars, conventional and hydrogen fuel cell heavy goods vehicles (HGVs).

We also recap in this section the analysis of bioenergy lifecycle emissions from our Bioenergy Review.

1 http://www.theccc.org.uk/publication/carbon-footprint-and-competitiveness/

**Box 3.1:** Methodology for assessing lifecycle emissions of low-carbon and conventional technologies

Our assessment of lifecycle emissions of low-carbon and conventional technologies was designed to answer the following questions:

- What are the lifecycle emissions associated with key low-carbon technologies, and their conventional alternatives?
- Will these emissions arise in the UK (i.e. we account for them already) or be imported?
- How might they change in the future?
- How could they be reduced?

We commissioned Ricardo-AEA Ltd to undertake the following tasks for a range of technologies:

- Establish the range of lifecycle emissions in the literature for technologies deployed or likely to be deployed in the UK under current/near-term conditions
- Identify the key sources of emissions over the technology lifecycle
- Identify the locations of these emissions, through consideration of the supply chains
- Develop scenarios for potential changes in lifecycle emissions to 2050, by developing simple parametric models in which the impact of different factors could be tested.

Given estimates of lifecycle emissions, we then assessed their implications for carbon budgets and the UK's carbon footprint, and considered policy options that could be used to minimise them.

## Low-carbon power generation technologies

Decarbonising the power sector is key to economy-wide decarbonisation. This is because power is currently a major source of emissions, low-cost low-carbon technologies are or are likely to be available, and low-carbon power can be used as a route to the decarbonisation of other sectors.

Power sector $CO_2$ emissions were 144 $MtCO_2$ in 2011 (24% of total UK GHG production emissions[2]). We proposed a scenario in our advice on the fourth carbon budget where these emissions fell to 16 $MtCO_2$ in 2030, through reducing the carbon intensity of power generation from 500g $CO_2$/kWh currently to around 50g $CO_2$/kWh.

We showed that this is achievable through deployment of a portfolio of low-carbon technologies which are, or are likely in future to become, cost-effective (i.e. cheaper than fossil fuel generation facing a carbon price[3]).

In our 2011 review of renewable energy, we considered the generation mix in 2030 in more detail and illustrated a possible mix comprising around 40% nuclear, 40% renewable (mainly wind), 15% CCS and 5% unabated gas-fired generation for balancing the system.

We now consider lifecycle emissions associated with each of these technologies[4]. Our analysis suggests that low-carbon technology lifecycle emissions are currently in the range 6 – 230 $gCO_2e$/kWh, with nuclear and wind at the low end of the range and coal CCS at the high end; all these technologies offer significant savings over conventional alternatives:

2 Including international aviation and shipping.
3 Based on DECC's central gas price and carbon price projections.
4 We have also assessed lifecycle emissions from solar PV, which while not playing a key role in our scenarios, has seen rising uptake in recent years. We estimate that current emissions are around 30 – 55 g/kWh depending on the technology, and could fall to around 15 – 45 g/kWh in 2030. This is discussed in more detail in the Carbon Footprint technical report.

- **Nuclear**. We estimate emissions for plants deployed in the UK in the near term of around 6 g/kWh, of which around 50% arise in the UK.
- **Wind**. We estimate emissions of around 9 g/kWh for onshore, and 6 g/kWh for offshore, with around 45 – 55% of these emissions arising in the UK.
- **CCS**. We estimate emissions of around 75 g/kWh for gas CCS (of which around 80% arise in the UK) and 210 – 230 g/kWh for coal CCS, depending on the technology (around 60% in the UK).
- **CCGT**. We estimate emissions of around 370 g/kWh, the majority of which (around 95%) arise in the UK.

Assessment of the composition of lifecycle emissions suggests that this varies by technology, and is largely due to fuel supply for nuclear generation, operation and fuel supply for CCS and CCGT, and manufacture for wind generation:

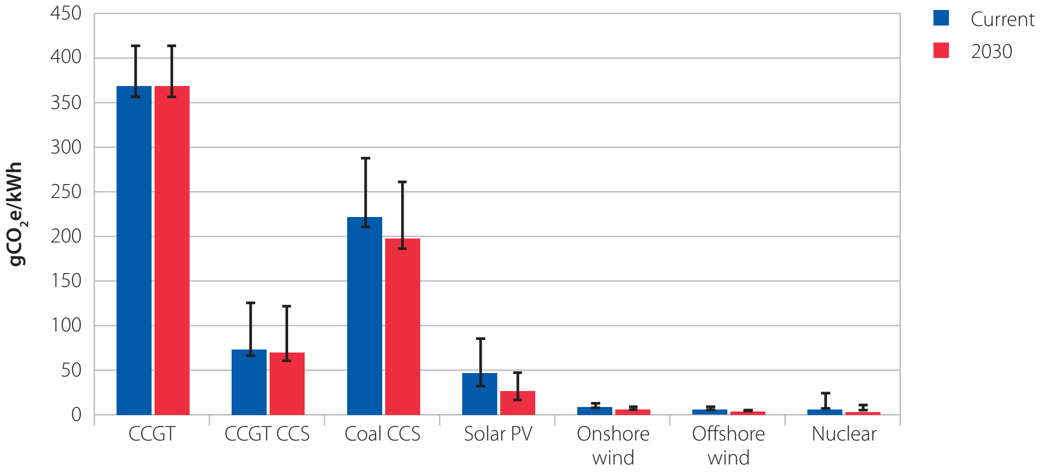
- **Nuclear**. Fuel supply emissions account for around 60% of total lifecycle emissions. Of these, around a quarter are from mining, and around half from milling, of uranium ore.
- **CCS.** Direct emissions from combustion are around 40 $gCO_2e$/kWh for gas CCS and 120 $gCO_2e$/kWh for coal CCS (i.e. much lower than CCGT, but higher than other low-carbon technologies). Remaining lifecycle emissions relate mainly to fuel supply; these account for around 40% of the total for gas CCS and 40 – 50% for coal CCS. The energy penalty associated with $CO_2$ capture means that around 15 – 30% more fuel is required per kWh of electricity generated than for unabated plant, and fuel supply emissions are therefore higher.
- **Wind**. Emissions stem from manufacture, installation, maintenance and disposal of turbines and supporting infrastructure[5]. Materials are the primary source of emissions, in particular steel, the embedded emissions from which account for around 35% of onshore and 50% of offshore wind lifecycle emissions.
- **CCGT**. Emissions from CCGT are dominated by combustion emissions, which account for almost 95% of the total.

For all types of generation, there is scope for emissions to be reduced over time, if the carbon intensity of materials and energy used across technology lifecycles is reduced. There is also a risk that, for a given technology, emissions could increase if the carbon intensity of supply chains (for materials, components and fuels) is not managed effectively.

Our estimates of lifecycle emissions in 2030 suggest a range across low-carbon technologies of 3 – 205 $gCO_2e$/kWh in a central case (a reduction of up to 45% relative to current levels) (Figure 3.1):

5 i.e. the wind farm. The transmission and distribution grid is not included in scope, nor have we reflected the potential need for back-up generation.

**Figure 3.1:** Estimated current lifecycle emissions of power technologies deployed in the UK, now and in 2030




**Source:** CCC analysis based on estimates developed by Ricardo-AEA.
**Notes:** Coal CCS and solar PV base case values are averages across technologies considered.

- **Nuclear**. Emissions could be around 3 g/kWh by 2030, with a range up to 10 g/kWh, depending, in particular, on assumptions for uranium ore grade and enrichment method. As materials and electricity (for construction and fuel supply) account for a high share of total emissions, the falling carbon intensity of these inputs over time has a relatively strong impact.
- **CCS**. Gas CCS emissions could remain at around 70 g/kWh by 2030, with a range between 60-120 g/kWh, depending in particular on generation and capture efficiency, and on methane leakage associated with gas supply. For coal CCS, emissions by 2030 could be around 190 g/kWh for pre- and 205 g/kWh for post-combustion capture, with ranges between 190 – 250 g/kWh and 195 – 265 g/kWh respectively.
- **Wind**. By 2030, emissions could be around 6 g/kWh for onshore and 4 g/kWh for offshore wind, with ranges between 4 – 7 g/kWh and 3 – 5 g/kWh respectively, depending on assumptions for turbine size, load factor and carbon intensity of materials and energy used in manufacture. Decarbonisation of materials over time has a strong impact for wind given the high share of their emissions in the total.
- **CGGT**. In comparison, emissions from CCGT could remain at around 370 g/kWh by 2030, with a range between 355 – 410 g/kWh, depending mainly on emissions from gas supply – this is discussed in more detail below.

Given current lifecycle emissions and scope for these to be reduced, each of the low-carbon technologies can still be regarded as low-carbon on a lifecycle basis, although emissions from CCS with fossil fuels will remain relatively high, suggesting limits on its use (see Section 2 below).

## Gas use and supply chains

There has been much recent debate about the role of shale gas in meeting the UK's energy requirements under emissions constraints.

Our analysis suggests that there is a very strong case for early power sector decarbonisation; this is robust across a wide range of scenarios for gas and carbon prices.

By 2030, we envisage that unabated gas generation should be limited to balancing the system. However, gas CCS could have a role operating at higher load factors, as part of a portfolio of low-carbon technologies. Moreover, there will continue to be significant demand for gas for heating in residential and industrial sectors.

This raises a question over whether UK-produced shale gas could play a role in meeting energy demand, for example, substituting for imported natural gas or LNG. In answering this question, it is important to understand the lifecycle emissions associated with shale gas relative to alternative gas sources.

These emissions comprise both methane and $CO_2$:

- Methane emissions at the well site, processing losses, and losses during transport, storage and distribution
- $CO_2$ emissions from fossil fuels used to extract, develop and transport the gas, as well as those arising from the use phase i.e. combustion of the gas to produce heat or electricity.

Processing, transport and use-phase emissions are generally considered to be similar for both conventional and shale gas, with the debate around shale gas relating to methane emissions from the well site released after fracking (Box 3.2).

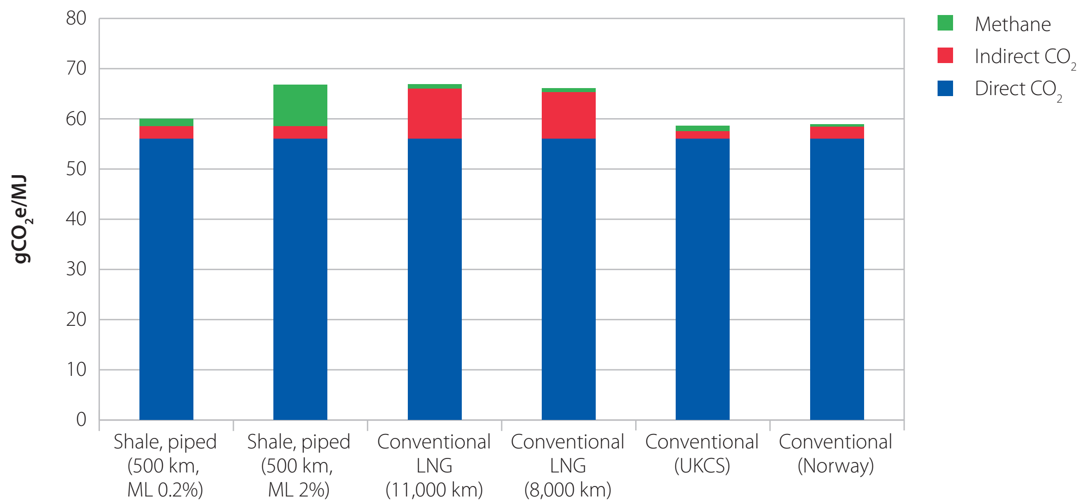
The key determinant of lifecycle emissions for shale gas compared to conventional gas is the extent to which the methane emissions from the well site can be limited:

- **Technical options**. 'Reduced Emission Completions' involve the temporary installation of equipment designed to handle the high initial flow of liquid during well completion. This separates the gas, which can be sent to a sales pipeline (if in place), to storage or to a temporary flare, and can reduce methane emissions at well completion by around 90%. Controls are also available for other sources of emissions which are common to conventional gas extraction (e.g. from storage tanks, dehydrators and compressors). A range of monitoring techniques at different production stages and locations can help to manage the risk of methane leakage.

- **Regulatory options**. Several EU/UK regulations, while not specific to shale gas operations, could in principle cover methane emissions from well completion operations in the UK. For example, it is likely that, under the Environmental Permitting (England and Wales) Regulations 2010, an operator will need a permit for managing flow-back fluid and waste gases, which will be considered mining wastes.

If methane emissions from well completion can be controlled, then piped shale gas is comparable to conventional pipeline gas on a lifecycle basis and may have lower emissions than LNG (Figure 3.2). Therefore, provided appropriate regulations are in place, and other social and environmental considerations can be addressed (e.g. local water supply impacts), well-regulated shale gas may have a useful role to play in meeting heat demand and, to a limited extent, electricity demand.

**Figure 3.2:** Illustrative lifecycle emissions of natural gas




**Source:** CCC analysis based on estimates developed by Ricardo-AEA.
**Notes:** Emissions per unit energy of gas delivered. Includes transmission but excludes UK distribution. ML = methane leakage from well completion.

**Box 3.2:** Hydraulic fracturing ('fracking')

Hydraulic fracturing is the process by which a liquid under pressure causes a geological formation to crack open. It is used to extract gas from shale formations: continuous deposits over large areas, which have very low permeability and low natural production capacities.

Typically, horizontal wells are drilled in order to maximise access to the gas reserves, following which fluids are injected under high pressure to generate fractures in the rock. Fracturing fluids consist of water and a range of additives including 'proppants', which keep the fractures open after the pressure is released, allowing the natural gas to flow from the pores and fractures in the rock into the well for subsequent extraction.

After fracking is completed, a proportion of the injected fracturing fluid rises to the surface, containing a mix of water, sand, hydrocarbon liquids and natural gas.

Estimates in the literature based on data from US shale gas operations suggest that, if unmitigated, methane emissions released during well completion could be around 2% of total methane produced, equivalent to 7.5 $gCO_2e/MJ$ (using a 100-year global warming potential for methane of 21).

## Low-carbon heat technologies

Direct $CO_2$ emissions from residential buildings were 66 $MtCO_2$ in 2011 (11% of total UK GHG production emissions). In previous reports we have identified two main opportunities for reducing direct building emissions. These are energy efficiency improvements and the deployment of low-carbon heat, in particular heat pumps. Our core scenario for meeting the fourth carbon budget included insulating 45% (3.5 million) of solid wall properties[6] and deployment of heat pumps to meet 25% of residential heat demand, largely replacing gas boilers. As a result, direct emissions in 2030 could fall to 41 $MtCO_2$ (a reduction of 38%).

### Solid wall insulation

Lifecycle emissions from solid wall insulation stem almost entirely from manufacture. We estimate current values of around 8 $kgCO_2e/m^2$ for rockwool and 10 $kgCO_2e/m^2$ for polystyrene foam insulation.

However, there is scope for emissions to fall in future as manufacturing processes become less carbon-intense (e.g. through improved efficiency and reduced carbon intensity of energy used). By 2030, emissions could be around 7 $kgCO_2e/m^2$ for rockwool and 8 $kgCO_2e/m^2$ for polystyrene foam.

Given a surface area of around 80 $m^2$, emissions associated with insulating a typical house would be around 550 – 655 $kgCO_2e$. This compares with total emissions savings of around 20 $tCO_2e$ over the life of the insulation.

Solid wall insulation therefore saves significantly more emissions than are produced during its manufacture and installation and remains an appropriate measure for inclusion in emissions reduction scenarios.

### Heat pumps and gas boilers

We estimate current lifecycle emissions of around 270 $gCO_2e/kWh$ for air source heat pumps (with a range between 225 – 300 g/kWh, depending mainly on assumptions for efficiency and refrigerant used) and around 215 $gCO_2e/kWh$ (190 – 290 g/kWh) for ground source heat pumps. The majority (95% or more) of these emissions are indirect emissions from electricity generation and therefore arise in the UK.

These estimates assume no change in the emissions intensity of electricity used for charging over the lifetime of the heat pump. However, given decarbonisation of the power sector, these emissions estimates can be expected to reduce:

- Given falling grid intensity, reaching $50gCO_2/kWh_e$ in 2030, emissions from air source heat pumps installed today would be reduced to around 165 g/kWh (135 g/kWh for ground source).

6 We envisage most lofts and cavity walls to be insulated already by the fourth budget period.

- Emissions from heat pumps installed in 2030 would be even lower (around 50 g/kWh for air source and 45 g/kWh for ground source) as a result of further reductions in grid intensity post-2030 (e.g. to around 10 g/kWh by 2050, as set out in our International Aviation and Shipping advice[7]).

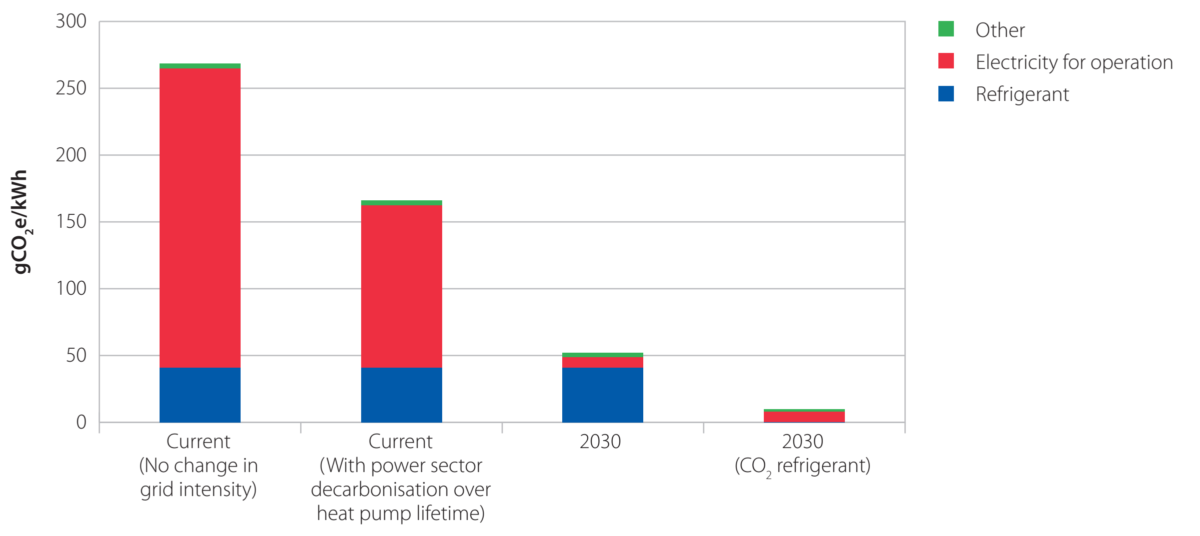
For heat pumps installed in 2030, emissions from other parts of the lifecycle then become much more important (Figure 3.3):

- In particular, emissions associated with the refrigerant could account for up to 80% of the total in 2030 if HFCs continue to be used and leakage rates (during manufacture, operation and disposal) remain at current levels.
- However, with a switch to $CO_2$ or other low-GWP refrigerant, emissions could be further reduced to around 10 g/kWh for air source heat pumps (16 g/kWh for ground source).

In contrast, there is more limited scope for reducing the lifecycle emissions of gas boilers from their current level of around 255 $gCO_2e/kWh$:

- Lifecycle emissions from gas boilers are dominated by those from the combustion of gas during operation, which accounts for around 90% of the total. Combustion emissions are determined by boiler efficiency which is already approaching maximum achievable levels[8].
- Upstream emissions from gas supply and boiler manufacture account for around 10% of the total. Measures such as reduced leakage rates during gas distribution and lower carbon intensity of materials and energy used in manufacture will therefore have a relatively limited impact on total lifecycle emissions.

**Figure 3.3:** Estimated lifecycle emisions of air source heat pumps, now and in 2030




**Source:** CCC analysis based on estimates developed by Ricardo-AEA.
**Notes:** Base scenario.

7 http://www.theccc.org.uk/publication/international-aviation-shipping-review/
8 Use of biogas would also reduce combustion emissions under current emissions accounting frameworks. However, biomethane will only be a fraction of gas supply even in the longer term, therefore the marginal source of gas will always be fossil natural gas.

With power decarbonisation, heat pumps therefore offer significant carbon savings relative to gas boilers, even after accounting for lifecycle emissions, and remain an appropriate means for reducing emissions from heat.

**Low-carbon surface transport technologies**

Direct $CO_2$ emissions from surface transport were 110 $MtCO_2$ in 2011 (19% of total UK GHG production emissions). Our analysis for the fourth carbon budget envisaged a 39% reduction by 2030.

- In the near to medium term, direct emissions can be reduced through improved efficiency of conventional (internal combustion engine) vehicles, some use of biofuels, as well as demand-side measures.
- In the longer term, wide-spread deployment of ultra-low carbon vehicles will be required to achieve deeper emissions cuts with minimal reliance on scarce bioenergy (see below). In our advice on the fourth carbon budget, we included a scenario in which 60% of new cars and vans are battery electric (BEV) or plug-in hybrid electric (PHEV) by 2030, and there is some deployment of hydrogen fuel cell buses (as a precursor to HGVs), in preparation for a fully electric (battery or fuel cell) vehicle fleet by 2050.

Our estimates of current lifecycle emissions[9] for different car technologies are around 250 – 295 $gCO_2e$/km for petrol cars, 175 – 235 $gCO_2e$/km for PHEVs and 140 – 235 $gCO_2e$/km for BEVs, depending on individual assumptions[10] for lifetime mileage, carbon intensity of materials/manufacturing processes, and for electric vehicles, need for battery replacement during the vehicle lifetime.

For HGVs, we estimate current lifecycle emissions of around 1275 $gCO_2e$/km for diesel HGVs, while emissions from near-term hydrogen fuel cell HGVs could be similar to this.

Operational emissions currently dominate the picture for all car technologies, and even more so for HGVs due to the large number of kilometres travelled, although the precise share in the total varies:

- For conventional vehicles, tailpipe emissions account for the vast majority of emissions. Emissions associated with manufacture, maintenance and disposal of the vehicle are a relatively small share (around 10% for cars and 2% for HGVs).
- For BEV cars, emissions from electricity generation currently account for the largest share of the total, given current carbon intensity in the power sector. However, emissions associated with manufacture are more significant than for petrol cars. In particular, emissions associated with battery production could account for around 25% of total emissions for BEVs.

9 Assuming, for EVs, no change in carbon intensity of electricity used for charging over the vehicle lifetime.
10 Combining all best (worst) case assumptions ***simultaneously*** leads to emissions of around 250 (310) g/km for petrol cars, 175 (290) g/km for PHEVs and 140 (465) g/km for BEVs.

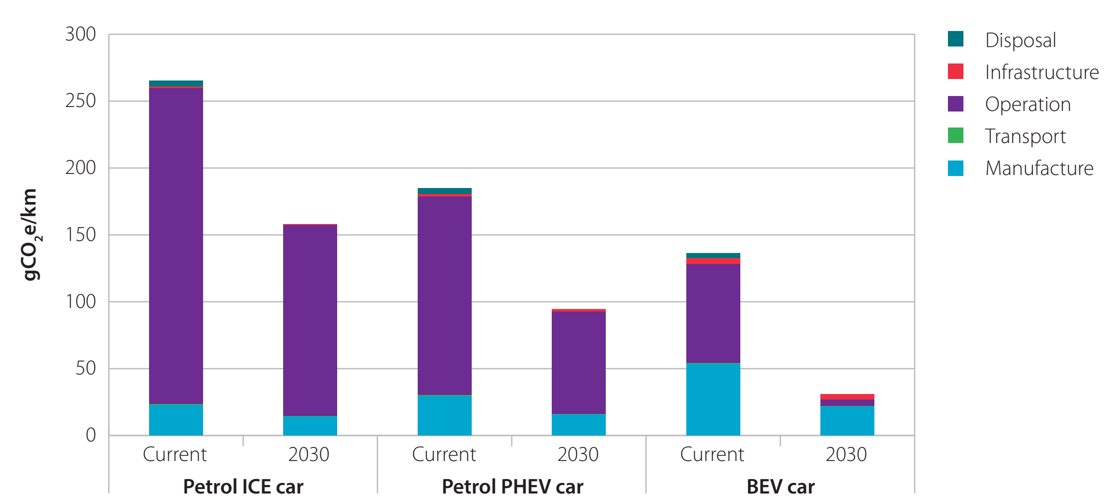
- For PHEV cars, tailpipe emissions and indirect emissions from electricity generation together account for the majority of overall lifecycle emissions, with the relative share of each dependent on the proportion of miles travelled in electric mode. Manufacturing emissions are a bigger share of total lifecycle emissions than for petrol cars, but smaller than for BEVs.
- For hydrogen fuel cell HGVs, emissions from hydrogen production account for 95% of our estimated emissions (assuming steam methane reforming). Emissions associated with both the vehicle and the hydrogen refuelling infrastructure are small on a per-km basis.

While, given current carbon intensity of electricity, emissions from electric cars are broadly comparable to those from conventional cars, in future there is scope for emissions from electric cars to fall significantly (Figure 3.4).

- Given our trajectory for power sector decarbonisation alone, emissions in our base case would be 20% lower, (135 g/km) for BEVs taken up today, and 60% lower (70 g/km) if the same vehicles were taken up in 2030.
- Further reductions are also expected through improvements in vehicle efficiencies and less carbon-intense manufacture. These include higher battery energy densities (meaning less material required for a given range), increased (closed-loop) recycling of batteries and lower carbon intensity of energy used in manufacture (which currently accounts for around 30% of the battery's embedded emissions)[11]. Given these improvements, total emissions from BEVs could fall to around 30 g/km in 2030 in the base case.

There is also scope for emissions from conventional cars to fall, through improvements in vehicle efficiency, carbon intensity of materials and energy used in manufacture, and limited use of sustainable biofuels. However, without major use of biofuels, it is unlikely that conventional (petrol) car emissions could fall below around 155 g/km.

**Figure 3.4:** Estimated lifecycle emissions of different car technologies, now and in 2030




**Source:** CCC analysis based on estimates developed by Ricardo-AEA.
**Notes:** Base scenario. Reflects power sector decarbonisation over vehicle lifetimes. Assumes biofuels at their 2012 average levels for public refuelling stations.

11 Second-life battery applications (e.g. for stationary energy storage) could also offer lifecycle emissions reductions; further work would be required to explore these.

Similarly emissions from hydrogen fuel cell HGVs could be reduced significantly in future, with a shift to hydrogen production via electrolysis using low-carbon electricity. We estimate fuel cell HGV emissions could fall to around 300 – 590 g/km in 2030, compared to around 850 g/km for diesel trucks.

Therefore, electric and hydrogen vehicles remain an appropriate means for decarbonising surface transport when lifecycle emissions are accounted for.

### Lifecycle emissions of bioenergy

Bioenergy currently meets around 2% of UK energy demand. In our 2011 Bioenergy Review[12] we assumed that this could increase to around 10% of primary energy demand in 2050. This would be through using bioenergy to generate heat for industry and – if CCS is available – using it in power generation and/or to produce hydrogen. Without CCS, aviation biofuels are likely to be a better option.

Whilst bioenergy could in principle be zero carbon, as carbon is absorbed in the growth phase of feedstocks and released when these are combusted, in practice this is not the case. This reflects emissions associated with cultivation, processing and transportation of biomass feedstocks and products, and emissions linked to possible direct and indirect changes in land use. These can be significant and lifecycle emissions of some feedstocks exceed emissions of fossil fuels:

- GHG savings for different liquid biofuels range widely. In the best case (e.g. when made from waste or growing a dedicated energy crop on previously degraded land), savings can be 80% or more compared to fossil fuels, while in the worst cases lifecycle emissions are actually higher than for petrol or diesel.
- Emissions associated with indirect land-use change (i.e. when a bioenergy crop displaces another crop which is then grown on newly converted land) can erode savings significantly but are difficult to calculate. Modelling for the European Commission suggests that nearly half of the potential gains of switching from fossil fuels to biofuels vanish due to indirect land-use emissions, with some feedstocks (soybean and rapeseed) even increasing emissions compared to fossil fuels.
- For forest biomass (used in power and heat), there is also a large variation in lifecycle emissions between feedstocks, with waste feedstocks and thinnings from managed or neglected woodlands offering emissions savings of more than 60% compared to natural gas per unit of energy, while biomass from whole trees (which would be best used for timber) or old-growth forests risks emissions higher than those from gas or even coal. Indirect land-use change and its associated emissions is also a potential problem if feedstock production causes deforestation elsewhere.

In our Bioenergy Review, we assumed that in the future low-lifecycle emission feedstocks would be available provided feedstock production was restricted to degraded or abandoned agricultural land, sustainable forestry, agricultural residues, and the use of wastes.

12 http://www.theccc.org.uk/publication/bioenergy-review/

## 2. Implications of lifecycle emissions for meeting carbon budgets and for the UK's carbon footprint

We estimate that total lifecycle emissions from deployment of the key low-carbon technologies in our scenarios for meeting carbon budgets are around 260 $MtCO_2e$ over the period to 2030 in our base case, of which around 40% are energy-related operational emissions and around 60% arise in the UK.

- Lifecycle emissions from low-carbon power generation technologies are estimated to be around 90 $MtCO_2e$ over the period to 2030, of which around 30% are operational emissions (i.e. combustion emissions from fossil fuel generation with CCS), and around 60% arise in the UK.
- Lifecycle emissions from low-carbon residential heat technologies are estimated to be around 45 $MtCO_2e$ over the period to 2030, of which around 40% are operational emissions, and around 80% arise in the UK
- Lifecycle emissions from low-carbon transport technologies are estimated to be around 125 $MtCO_2e$ over the period to 2030, of which around 45% are operational emissions, and around 55% arise in the UK

It is important to understand whether these emissions have already been accounted for in our modelling. If they had not, then extra abatement would be required to meet the carbon budgets and emissions targets that we have recommended.

Our modelling of both UK and global emissions has already substantially allowed for lifecycle emissions of low-carbon technologies:

- Our UK modelling to 2030 and 2050 explicitly includes energy-related operational emissions from all technologies, including residual emissions from CCS. Additional emissions, arising in the UK, from key-low carbon technologies are around 55 $MtCO_2e$ over the period to 2030 (around 0.5% of allowed emissions under carbon budgets[13]).
- Our modelling also includes ongoing industry emissions. While these are not explicitly linked to the demand for industrial products (e.g. steel and cement) created by deploying different technologies, the additional demand from key technologies in a low-carbon versus reference scenario is small compared to total projected output (e.g. 5%).
- The global models used in our analysis (e.g. TIAM[14]) also include energy-related operational emissions from all technologies as well as emissions from industrial sectors producing both materials and fuels. As these emissions are based on exogenous demand assumptions, this may lead to underestimates in some sectors (e.g. nuclear fuel supply) relative to an estimate explicitly linked to technology deployment. However these are likely to be offset by overestimates in other sectors (e.g. refineries).

Therefore, we can be confident that no significant additional abatement is required to meet carbon budgets, as long as lifecycle emissions from the key technologies in our scenarios are reduced from current levels, and provided CCS applied to fossil fuel power generation is used as part of a portfolio approach alongside other low-carbon technologies with lower lifecycle emissions.

13 Excluding international aviation and shipping, and assuming a 2030 target of a 50% reduction in emissions on 1990 levels.
14 See http://archive.theccc.org.uk/aws/IA&S/UCL%20(2012)%20Modelling%20carbon%20price%20impacts%20of%20global%20energy%20scenarios.pdf

## 3. Policies for reducing lifecycle emissions

There are a number of policies which will or could provide incentives for reduction of lifecycle emissions:

- **CCS**. Demonstration of CCS is important to verify and improve technology performance at commercial scale. It is important that both residual combustion emissions and fuel supply emissions are minimised, through optimised capture efficiency and minimised energy penalty. However, lifecycle emissions of CCS are likely to remain high relative to other low-carbon power technologies. This suggests CCS should only be used as part of a portfolio approach (i.e. together with nuclear and renewables).
- **Shale gas**. The Environment Agency is the environmental regulator for unconventional gas operations in England and Wales. Similar to landfill permitting, their permitting regulations for shale gas exploration require use or flaring of methane emissions from fracking (which can be interpreted as a waste under the Mining Waste Directive). Additional requirements (e.g. for fenceline monitoring) could further help to ensure fugitive methane emissions from shale gas exploration in the UK are minimised to very low levels, especially when scale-up from exploration to commercial production is considered.
- **Heat pumps**. Leakage of HFC refrigerants during use and end-of-life is covered by the existing EU F-Gas Regulation. Beyond this, the European Commission is considering options to further reduce F-gas emissions in future, including both a phase-down mechanism and an outright ban for placing F-gases on the market in sectors where appropriate alternatives are available. Use of $CO_2$ or other low-GWP refrigerants in heat pumps could be considered one such alternative and Government should support this where cost-effective.
- **Vehicles**. Support for R&D and for EVs more generally will help drive improvements in battery energy density, reducing the size of battery required for a given range. Battery recycling is mandated under the European Waste Battery and Accumulator Directive; however requirements for material recovery (50% for the Lithium-ion batteries used in EVs) are not based on emissions considerations. In future, improved recycling efficiency, including use of less energy-intensive recycling processes, could further reduce the lifecycle emissions of EV batteries.
- **Bioenergy**. Policies should incentivise the development and use of low-lifecycle feedstocks, e.g. through progressively tightening the greenhouse gas thresholds for the support of biomass under the Renewables Obligation (we have previously recommended 200 $gCO_2e$/kWh by 2020, compared to the current threshold of 285 $gCO_2e$/kWh). Consideration should also be given to introducing a sustainability standard for all wood to avoid indirect deforestation.

More generally, our analysis highlights the need for an economy-wide approach to emissions reduction in order that lifecycle emissions are reduced. It also emphasises the need for a comprehensive policy framework to cover emissions arising in both the UK and abroad. A global deal to reduce emissions would be the most effective means for achieving this. Meanwhile, many lifecycle emissions of low-carbon technologies will be covered by UK carbon budgets and/or the EU ETS, while others (e.g. those arising outside of the EU) would require additional policies (e.g. sectoral agreements, see Chapter 1) to ensure they are minimised.

With supporting policies and economy-wide approaches in place, the fourth carbon budget and the means we have recommended to meet it remain appropriate in light of our assessment of lifecycle emissions.

# Chapter 4: Implications for the fourth carbon budget

The broader context for this report is our review of the fourth carbon budget. The fourth carbon budget (covering the period 2023-2027) was legislated in 2011 and commits the UK to a 50% reduction in greenhouse gas emissions on 1990 levels by 2025, on the path to a an 80% reduction in 2050. When adopting the budget in line with our recommendations, the Government also committed to carrying out a review in early 2014. Prior to that, we will publish our review.

The analysis in this report on carbon footprint and competitiveness will help to inform us whether the level at which the fourth budget is currently legislated remains appropriate, based on consideration of the UK's carbon footprint, lifecycle emissions of low-carbon options, and the extent to which any competitiveness risks are manageable.

Our findings have four specific implications for the review of the fourth carbon budget:

## 1. Carbon accounting

We have highlighted that there is a need for a global deal to substantially cut global emissions over the next decades and achieve the climate objective. This would ensure that all nations implement effective policies to reduce their carbon intensities, which would result in lower embedded emissions in their exports (and hence the UK's imports). Moving to a consumption accounting basis for this deal would be difficult to implement and is unnecessary, provided all nations comprehensively account for their production emissions.

Production emissions also remain the most appropriate basis for UK carbon budgets:

- They currently account for over half of the UK's carbon footprint and we have the levers to reduce them. By 2030, with the implementation of fourth carbon budget measures, we expect production emissions to reduce to just below 50% of the UK's carbon footprint. This reflects faster emission reductions in the UK and EU trading partners, compared to developing country trading partners in line with achieving the climate objective.
- Estimating consumption emissions is inherently difficult and subject to much larger uncertainties than estimating production emissions. For example, in the model used by us and the Government to estimate consumption emissions, we have shown that by simply using a different regional disaggregation, the footprint estimate increases by 13%. Therefore, while useful as an investigative tool, consumption emissions are not suitable as a basis for our legally-binding carbon budget framework.

However, the Government should continue to regularly report on consumption emissions and monitor whether these are falling in line with global action required to achieve the climate objective. If this reveals that these are falling too slowly, this may suggest the need for further action.

We will periodically report on consumption emissions as part of our annual progress reports to Parliament, and as part of broader monitoring of progress towards the design and implementation of a global deal, identifying any need for further action as appropriate.

## 2. Domestic abatement

The Climate Change Act contains a provision to credit international carbon units to the UK's carbon account but requires the Secretary of State to set a limit on the use of these units. We have previously advised the Secretary of State that for the first two carbon budget periods, credit purchase should be limited.

Looking forward to the fourth budget period and beyond, we have said previously that there will be limited longer-term availability of offset credits at low cost if all countries are on a strong downward emissions path consistent with achieving the climate objective. In particular, this will require per capita emissions to reduce to around 2 $tCO_2e$, which our earlier analysis of UK emissions has suggested will be very challenging.

Analysis in this report highlights the fact that the UK has a relatively small manufacturing base, while industry emissions are relatively high in other countries, making it more challenging for these countries to meet targets. This reinforces our previous recommendation that the UK should aim to meet the 2050 target largely through domestic emissions reduction rather than through the purchase of expensive credits, and this should be reflected in the design of the fourth carbon budget (i.e. the fourth carbon budget needs to set the UK on the path for ambitious decarbonisation in most sectors).

## 3. Competitiveness

Competitiveness impacts associated with measures to reduce direct emissions are limited and manageable. Electricity price impacts for electricity-intensive industries are due mainly to policies already committed to by the Government for investment in the period to 2020, and within the range of support associated with policies already announced by the Government. Incremental impacts due to the fourth carbon budget are limited given the expected reduction in costs of low-carbon technologies in this period and rising carbon/electricity prices in other countries.

Competitiveness risks are focussed on the most electricity-intensive sectors and those most exposed to international competition. It is important to continue to take account of these risks on the path to a global deal

- It will be important to monitor trading patterns and market developments in these sectors to ensure continued competitiveness risks are mitigated.
- Some parts of agriculture (pigs, poultry and dairy) are electricity-intensive and face a competitiveness risk from higher electricity prices. The extent of this risk will depend on the ability of farmers to pass on costs to higher prices. Opportunities to offset the impact of rising electricity prices through energy efficiency improvement, use of renewable energy and other innovations should be further assessed.

## 4. Lifecycle emissions

Our fourth carbon budget scenarios imply a major shift to low-carbon technologies in the power, heat and transport sectors. Previously we have focused on use-phase emissions from these technologies: our analysis for the fourth budget explicitly includes energy-related operational emissions from all technologies, including residual emissions from CCS (which in any case accounts for less than 15% of power sector capacity by 2030).

In terms of emissions from other lifecycle stages of the low-carbon technologies in our fourth budget scenario, our analysis shows that these are likely to be limited relative to economy-wide emissions on a production basis (i.e. 55 $MtCO_2e$ non-operational lifecycle emissions versus 10 $GtCO_2e$ economy-wide emissions between now and 2030). Beyond 2030, these emissions would reduce further as carbon intensities in the UK and other countries fall in accordance with a global deal.

Moreover, the approach we have used in our fourth budget analysis has already allowed for most of these emissions:

- Our UK modelling includes ongoing industry emissions. While these are not explicitly linked to the demand for industrial products (e.g. steel and cement) created by the deployment of different technologies, the additional demand in a low-carbon versus a reference scenario is small compared to total projected output (e.g. <5%).
- The same applies to our global modelling, which includes direct emissions from all technologies, as well as emissions from industrial sectors producing both materials and fuels.

While our fourth budget scenario includes the use of natural gas in heating (serving more than 60% of heat demand) and to a lesser extent in the power sector, we did not include the possibility of meeting this demand from UK-produced shale gas. This could result in additional UK-based lifecycle emissions. It is therefore essential that methane emissions from shale gas production are controlled.

Overall, our proposed technology portfolio to meet the fourth carbon budget remains appropriate.

We will publish our review of the fourth carbon budget at the end of 2013, with a Government assessment due in early 2014.

# Glossary

**Anaerobic digestion (AD)**
A treatment process breaking down biodegradable material, particularly wastes, in the absence of oxygen. Produces a methane-rich biogas substitute for fossil fuels.

**Battery electric vehicle (BEV)**
A vehicle that receives all motive power from a battery.

**Border carbon adjustment**
Policy to create a level playing field for trade by putting a price on imported emissions and/or refunding carbon costs to exporters.

**Carbon accounting**
The process undertaken to measure and make an inventory of the amount of greenhouse gases emitted.

**Carbon budget**
The Climate Change Act established a system of five-yearly carbon budgets, currently stretching to 2023-27. They restrict the amount of carbon that can be emitted in the UK during these five year periods.

**Carbon capture and storage (CCS)**
Set of technologies to capture the carbon dioxide emitted from industrial processes or from burning fossil fuels or biomass, transport it, and store it in secure spaces such as geological formations, including old oil and gas fields and aquifers under the seabed.

**Carbon dioxide equivalent ($CO_2e$) emission**
The mass of carbon dioxide emission that would give rise to the same level of radiative forcing, integrated over a 100-year time period, as a given mixture of greenhouse gas emissions.

**Carbon footprint**
Total amount of greenhouse gas emissions caused directly and indirectly by a nation (equivalent to consumption emissions), a business, a product (equivalent to lifecycle emissions) or a person.

**Carbon-intense**
Activities or goods that have a high emissions intensity (see below).

**Carbon intensity**
See 'emissions intensity'.

**Carbon price**
The price at which 1 $tCO_2e$ can be purchased. We use projections for the carbon price as a comparator for judging cost-effectiveness of potential emissions reduction measures.

**Climate Change Levy (CCL)**
CCL is a tax on the supply of specified energy products (e.g. electricity and gas) for use as fuels that is for lighting, heating and power by business consumers.

**Climate objective**
To keep central estimates of global mean temperatures as close to 2°C as possible, and to limit the likelihood of temperature change above 4°C to very low levels.

**Combined cycle gas turbine (CCGT)**
A gas turbine generator that generates electricity. Waste heat is used to make steam to generate additional electricity via a steam turbine, thereby increasing the efficiency of the plant.

**Competitiveness**
The ability of firms to sell and increase market share and profitability in international markets.

**Consumption emissions**
Production emissions minus emissions embedded in export of goods and services, plus emissions embedded in imports of goods and services.

**Contracts for Difference (CfD)**
Form of hedging on the future price of a commodity in which a strike price is pre-specified. Payments are made between counterparties depending on the difference between the strike price and the market price at the time.

**Conventional gas**
Natural gas from conventional reserves.

**Direct emissions**
Emissions from sources that are owned or controlled by the installation.

**Electric vehicle**
Vehicle capable of full electric operation fuelled by battery power driven by an electric motor.

These include battery electric (BEV), plug-in hybrid electric (PHEV) and hydrogen fuel-cell vehicles.

**Electro-intensive**
In this report, taken to be a sector or firm where electricity costs are around 10% or more of gross value added.

**Emissions intensity**
A measure of total emissions generated per unit of activity. In consumption emissions accounting, typically defined as total emissions per unit of monetary output.

**Energy-intensive**
In this report, taken to be a sector or firm where energy costs are around 10% or more of gross value added.

**European Commission**
Executive arm of the European Union.

**European Union Allowances (EUAs)**
Emissions credits traded within the EU ETS.

**European Union Emissions Trading System (EU ETS)**
Cap and trade system within the EU covering the power sector, energy intensive industry, and from the start of 2012 all domestic and international aviation.

**Feed in Tariff**
A type of support scheme for electricity generators, whereby generators obtain a long-term guaranteed price for the output they generate.

**Fuel cell**
A device that converts a fuel into electrical energy through a chemical reaction. For example, a hydrogen fuel cell produces electrical energy from hydrogen, which can be used to power an electric vehicle.

**Fugitive emissions**
Emissions of gases from pressurised equipment due to leaks, e.g. from gas wells or gas pipelines.

**Heat pumps**
Working like a 'fridge in reverse', heat pumps use compression and expansion of gases or liquid to draw heat from the natural energy stored in the ground or air. Both air source and ground source heat pumps can provide heating for buildings.

**Heavy goods vehicle (HGV)**
A truck over 3.5 tonnes (articulated or rigid).

**Hybrid vehicle**
A vehicle powered by an internal combustion engine and electric motor that can provide drive train power individually or together e.g. Toyota Prius.

**Gross Domestic Product (GDP)**
Key indicator of the output of the whole UK economy including taxes and subsidies, such that: GDP = GVA + taxes on products – subsidies on products.

**Gross Value Added (GVA)**
Measure of the contribution to the economy of each individual producer, industry or sector.

**Indirect emissions**
Emissions that are a consequence of the activities of the installation or firm but occur at sources owned or controlled by another entity.

**Input-output analysis**
An economic technique that records the flows of goods and services using the transaction values between industrial sectors and nations. Methodological basis for estimating consumption-based emissions.

**Joule**
The standard international unit of energy. Related units are: Kilojoule (kJ) = 1000 Joules, Megajoule (MJ) = 1 million Joules, and Gigajoule (GJ) = 1 billion Joules.

**Kilowatt-hour (kWh)**
A unit of energy, equal to the total energy consumed at a rate of 1,000 watts for one hour.

Related units are: Megawatt-hour (MWh) = 1,000 kWh, Gigawatt-hour (GWh) = 1,000 MWh and Terawatt-hour (TWh) = 1,000 GWh. The kilowatt-hour is equal to 3.6 million Joules.

**Lifecycle analysis**
Methodology used to quantitatively assess the environmental performance (e.g. emissions) of a product or service from its cradle to grave (i.e. including emissions during production and disposal).

**Lifecycle emissions**
The emissions generated for a product system or service from its cradle to grave (i.e. over its entire life-time).

**Liquefied natural gas (LNG)**
Natural gas cooled to a low temperature so it becomes a liquid occupying a much smaller volume (1/600), which can then be transported over long distances without the need for fixed infrastructure.

**LULUCF emissions**
Emissions occurring in the land use, land use change and forestry sector with croplands the single largest source of emissions. Emissions in this sector are offset by carbon sequestered by forestry and grasslands.

**Marginal abatement cost curve (MACC)**
Graph showing costs and potential for emissions reduction from different measures or technologies, ranking these from the cheapest to most expensive to represent the costs of achieving incremental levels of emissions reduction.

**Methane ($CH_4$)**
Greenhouse gas with a global warming potential of 21 (1 tonne of methane emission corresponds to 21 tonnes $CO_2e$). Arises in the agriculture sector as a result of enteric fermentation in the digestive systems of ruminant animals (e.g. cattle and sheep) as well as in manures. Arises in the waste sector as biodegradable waste decomposes in landfill sites in the absence of oxygen.

**Mitigation**
Action to reduce the sources (or enhance the sinks) of factors causing climate change, such as greenhouse gases.

**National Atmospheric Emissions Inventory (NAEI)**
Data source compiling estimates of the UK's emissions to the atmosphere of various (particularly greenhouse) gases.

**Nitrous oxide ($N_2O$)**
Greenhouse gas with a global warming potential of 310 (1 tonne of nitrous oxide emission corresponds to 310 tonnes of $CO_2e$). Arises naturally in agricultural soils through biological processes and is influenced by a variety of soil and nutrient management practices and activities (e.g. synthetic fertiliser application).

**Offshoring**
The relocation of a firm's business or processes to a foreign country.

**Pass-through rate**
The extent to which a rise in firms' costs are passed on to higher product prices.

**Plug-in hybrid electric vehicle (PHEV)**
A vehicle that receives motive power from both a battery and a secondary source (e.g. an internal combustion engine). The battery will generally be charged in the same way as that in a BEV, but all electric range will be more limited (e.g. 40 rather than 100 miles).

**Production emissions**
Territorial emissions plus emissions from international aviation and shipping on the basis of bunker fuels.

**Renewables**
Energy resources, where energy is derived from natural processes that are replenished constantly. They include geothermal, solar, wind, tide, wave, hydropower, biomass and biofuels.

**Shale gas**
A type of unconventional gas, extracted using hydraulic fracturing ('fracking') i.e. the pumping of fracturing fluids (water, chemicals and proppants) at high pressure to crack open the rock and release the gas trapped inside.

**Standard Industrial Classification (SIC)**
System for categorising economic activities in the UK by type of activity. At the highest level there are 21 classifications (A-U), for example Manufacturing (C). These sections are further broken down into divisions, groups, classes and subclasses which are represented in a two-five digit hierarchy.

**Territorial emissions**
Greenhouse gas emissions occurring within a country's borders e.g. from burning fossil fuels for electricity generation, in transport and industrial production, direct emissions from heating in households and businesses, as well as emissions related to a number of other activities such as agricultural, forestry, and waste management activities.

**Trade intensity**
(Imports+exports)/(output+imports).

**United Nations Framework Convention on Climate Change (UNFCCC)**
International environmental treaty, signed in 1992, with the objective of stabilising greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

**2DS scenario**
Global emissions trajectories developed by the International Energy Agency in its 2012 Energy Technology Perspectives to meet a global 2°C climate objective (see 'Climate objective').

**4DS scenario**
Global emissions trajectories to 2050 developed by the International Energy Agency in its 2012 Energy Technology Perspectives reflecting a world where international actions would not go beyond the pledges made at the United Nations Climate Change Conference at Copenhagen in 2009. This scenario is projected by the International Energy Agency (IEA) to lead to a long-term temperature rise of 4°C.

# Abbreviations

| | |
|---|---|
| **AD** | Anaerobic Digestion |
| **ASHP** | Air source heat pumps |
| **BEV** | Battery electric vehicle |
| **CCC** | Committee on Climate Change |
| **CCGT** | Combined cycle gas turbine |
| **CCL** | Climate Change Levy |
| **CCS** | Carbon capture and storage |
| **$CH_4$** | Methane |
| **$CO_2$** | Carbon dioxide |
| **$CO_2e$** | Carbon dioxide equivalent |
| **DECC** | Department for Energy and Climate Change |
| **Defra** | Department for Environment, Food and Rural Affairs |
| **EC** | European Commission |
| **EPR** | Environmental Permitting Regulations |
| **EU** | European Union |
| **EU ETS** | European Union Emissions Trading System |
| **EUA** | European Union Allowance |
| **EV** | Electrical vehicle |
| **GDP** | Gross Domestic Product |
| **GHG** | Greenhouse gas |
| **GSHP** | Ground source heat pumps |
| **Gt** | Giga tonnes |
| **GVA** | Gross value added |
| **GWP** | Global warming potential |
| **HFC** | Hydrochlorofluorocarbons |
| **HGV** | Heavy goods vehicle |

| | |
|---|---|
| **ICE** | Internal combustion engine |
| **IEA** | International Energy Agency |
| **kWh** | Kilowatt hour |
| **LNG** | Liquefied natural gas |
| **LULUCF** | Land use, land use change and forestry |
| **MACC** | Marginal abatement cost curve |
| **MJ** | Million Joules |
| **MRIO** | Multi-region input-output |
| **Mt** | Million tonnes |
| **$N_2O$** | Nitrous oxide |
| **NAEI** | National Atmospheric Emissions Inventory |
| **OECD** | Organisation for Economic Cooperation and Development |
| **ONS** | Office for National Statistics |
| **PHEV** | Plug-in hybrid electric vehicle |
| **PV** | Photovoltaic |
| **ROW** | Rest of the world |
| **2DS** | Two degrees scenario |
| **4DS** | Four degrees scenario |

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