The scientific and international context for the fifth carbon budget

October 2015

Acknowledgements

The Committee would like to thank:

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Contents

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

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

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

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

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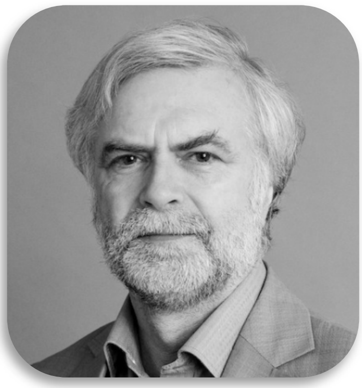


Professor Jim Skea

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

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

Executive summary

Under the Climate Change Act (2008) the Committee is required to advise the Government, by the end of 2015, on the level of the UK's fifth carbon budget. The budget will set the limit on the amount of greenhouse gases that can be emitted by the UK between 2028 and 2032.

The fifth budget marks the halfway point from the first budget (2008-12) to the UK's 2050 target to reduce greenhouse gas emissions by at least 80% below 1990 levels. It follows on from the first four legislated carbon budgets, which were set on the basis that UK emissions are reduced by at least 50% in 2025 relative to 1990 (25% relative to 2014).

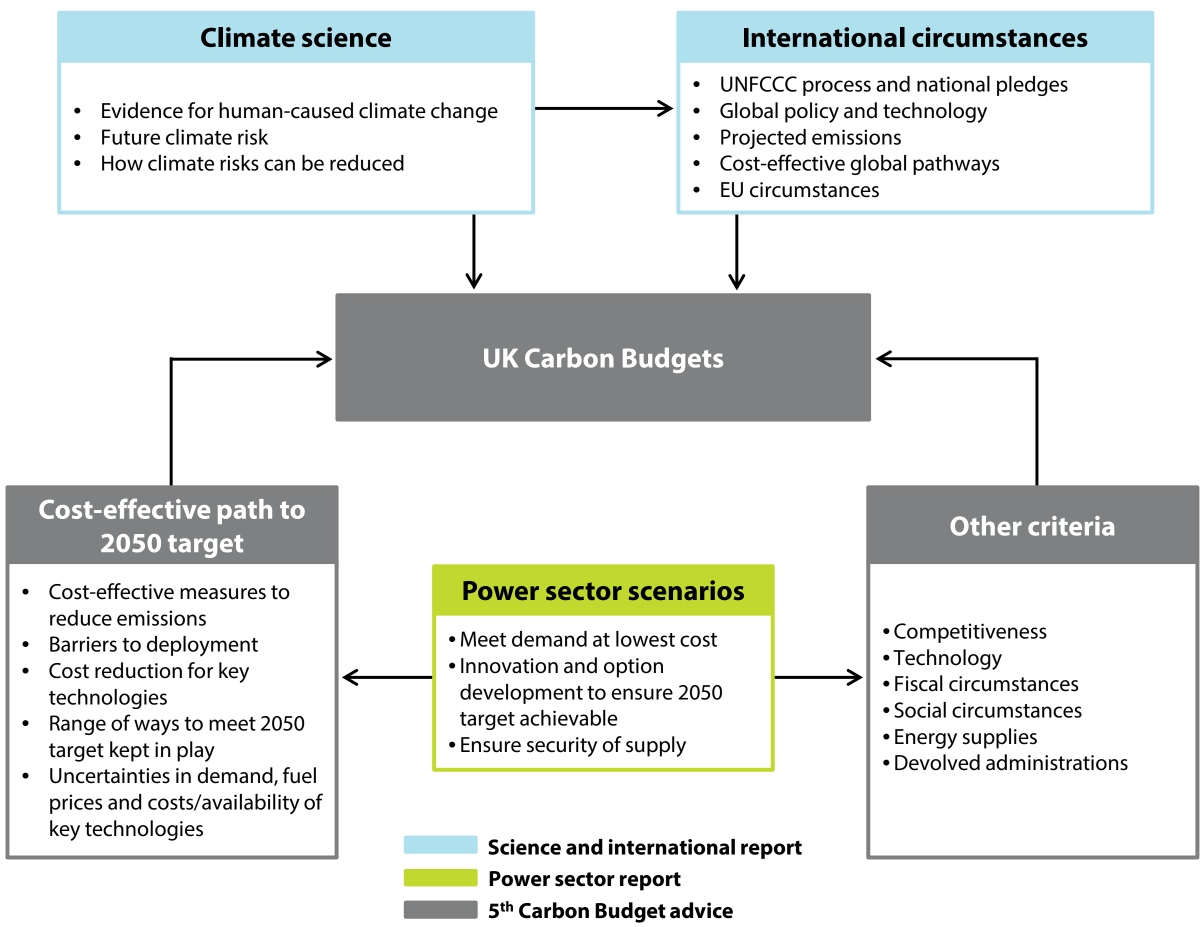
The advice must take into account criteria set out in the Act. These criteria include climate science, international circumstances, and the impact of the budget on the economy, the government's fiscal position, affordability of energy for households, security of supply and the competitiveness of businesses.

We will deliver our fifth carbon budget recommendation, reflecting the full set of criteria, in a report to be published towards the end of November. In developing our advice we are publishing in advance:

- Our assessment of the state of climate science and international circumstances. The UN conference in Paris at the end of 2015 makes these criteria particularly pertinent. This is the subject of this report.
- Scenarios for development of the power sector through the 2020s, setting out approaches to increasing the availability of low-carbon power whilst minimising costs and ensuring a secure electricity supply. The report on this will be published later in October.

Figure 1 provides a representation of how these reports fit together in providing our advice.

Figure 1: Framework for the Committee's advice



Key findings from this report[1]

1. The science of climate change

- It is clear that the climate is changing as a result of greenhouse gas emissions. This is leading to rising temperatures and sea levels, retreating ice and other changes to the natural environment. Global average temperature has risen around 0.9°C and sea level around 20cm since the late 19th Century.
- Many impacts are already being detected across the world, from changes in extreme weather and ecosystems, to a slowdown in productivity gains for some key crops.
- Further emissions will lead to further warming and change. With rapid global action to cut emissions, total human-induced warming could be held below 2°C. Under baselines assuming no action, warming could exceed 6°C.

[1] We provide full supporting evidence for these findings in the main chapters of the report.

- There is no simple threshold beyond which climate change moves from safe to dangerous. Some disruption and irreversible losses are expected at 2°C. Losses accelerate with warming, and very severe damage is expected in a world reaching 4°C. The impacts will be unevenly distributed and there are currently wide uncertainties about their magnitude.
- The increase in global temperature is determined mainly by total carbon dioxide emissions over time, which must fall to near zero in order to limit warming. The allowable total for a likely[2] chance of staying below 2°C will be exceeded in the mid-2030s if global emissions continue at the current rate.

2. International action to limit climate change

- The UK's carbon budgets are domestic commitments, but set in the context of efforts worldwide to reduce greenhouse gas emissions.
- The UN has formally adopted an objective to limit global temperature rise to 2°C, and countries are submitting pledges to reduce emissions post-2020. The aim is to adopt a new agreement, with legal status, in Paris at the end of 2015.
- Many countries and sub-national bodies have made commitments for deep emissions reduction and are now delivering against these. Penetration of low-carbon technologies around the world is increasing, although these still account for a relatively small share of global energy production.
- Lowest-cost paths with a likely chance of staying below 2°C require global emissions to peak around 2020 with steep reductions thereafter (e.g. to 40-70% below 2010 levels in 2050). UN pledges made so far are not on this path. There is scope to reduce the gap through remaining pledges, increases in existing ambition and further commitments to reduce emissions beyond 2030.
- Both the UK and EU have objectives to reduce their greenhouse gas emissions in 2050 to at least 80% below 1990 levels. These objectives remain appropriate in the light of the latest evidence regarding global emissions pathways consistent with 2°C.

3. The EU and UK share of international climate action

- The EU's Member States have agreed a 2030 target for EU emissions of at least 40% below 1990 levels. This is also the EU's collective pledge for 2030 as part of the UN process towards a global deal. It is currently one of the more ambitious pledges.
- Our best estimate is that the EU 2030 agreement could mean a reduction in UK emissions over the fifth carbon budget period of 54% below 1990 levels. The precise UK share cannot be known with certainty until final rules governing Member States' shares are agreed. Reflecting these uncertainties suggests the UK will contribute emissions reductions within a range of 51-57% (Box 1).

[2] Our original advice on the UK 2050 target, which predated international agreement on the 2°C limit, proposed that the world should keep a 50% likelihood of staying close to 2°C by 2100 (and keep the likelihood of a 4°C rise to very low levels). From this we inferred global emissions in 2050 should be 51-59% below 2010 levels. This is within the range for at least a 66% likelihood of 2°C (defined as "likely") according to IPCC AR5.

- The EU's agreed 2030 target is at the lower end of ambition compared to the cost-effective path to its 2050 objective. It is below estimates for a 'fair' EU share of a global 2°C pathway, and the UK's likely contribution is at the low end of ambition compared to its global 'fair' share.
- The EU should be prepared to raise its ambition as a contribution to closing a global emissions gap in 2030, provided other countries make similar commitments.

Box 1: UK share of EU effort to 2030

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

- It has been agreed that the EU-wide cap on emissions under the EU ETS will be 43% lower than 2005 levels by 2030. The UK share of allowances under this cap depends on rules yet to be finalised. Our best estimate is that it could imply a 49% reduction in the UK's traded sector allocation from 2005 to 2030, within a range of 44-53%.
- It has been agreed that EU-wide emissions in sectors not covered by the EU ETS will be 30% below 2005 levels by 2030. It has also been agreed that the maximum required reduction from any Member State will be 40% below 2005 emissions. Our analysis for the UK's likely reduction under the EU agreement suggests a best estimate of 37.5%, within a range 35-40%.

Compared to 1990 levels, our overall best estimate for the UK's share of the EU 2030 pledge is for a 54% reduction in emissions in 2030. Reflecting the uncertainties gives a range of 51-57%.

Source: Further detail of the assumptions for these estimates is set out in Chapter 3.

Implications for the fifth carbon budget

Our findings in this report suggest that a fifth carbon budget reflecting current international circumstances and EU commitments requires, on a best estimate, a reduction in UK emissions by 2030 of around 54% on 1990 levels:

- **International action.** The world is acting to tackle climate change. The agreement in December 2015, under the UN process, could provide the legal basis for international action beyond 2020. The 2°C limit requires substantial global emission cuts by 2030. The UK should continue to play its part.
- **The EU 2030 pledge.** The EU's Member States have agreed to reduce EU emissions by at least 40% below 1990 levels in 2030. The UK has supported rules for dividing reductions between Member States which imply higher effort from richer countries like the UK, Germany and France. This is a fair, sensible and practical approach. For the current EU agreed pledge our best estimate is that this means a UK reduction of 54% below 1990 levels in 2030, within the range 51-57%.

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

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

We will consider further the implications for the level of the fifth carbon budget when we provide our advice in November, taking into account the full range of factors required under the Climate Change Act.

While the process of submitting pledges in advance of Paris means important information is already available, more continues to arrive and there is scope for the Paris conference to produce significant new developments. We will send a letter to the Secretary of State after the Conference to set out if and how this affects our published advice.

Chapter 1: The science of climate change

Introduction and key messages

In this chapter we consider the scientific understanding that underpins the rationale for reducing greenhouse gas emissions. While we note some recent research developments, much of the material was covered in our previous carbon budget advice (in 2008, 2010 and 2013). This reflects the fact that the evidence linking greenhouse gas emissions to climate risk is robust and widely agreed by experts.

We briefly revisit the key observations that show the world has been warming for several decades, and that this is mainly due to human activities rather than natural fluctuations. We then focus on impacts on human and natural systems: those already being observed, and potential future impacts which will depend significantly on the path of human activity. Finally we set out the implications for global emissions from setting a limit to global temperature change.

Our key messages are:

- It is clear that the climate is changing as a result of greenhouse gas emissions. This is leading to rising temperatures and sea levels, retreating ice and other changes to the natural environment. Global average temperature has risen around 0.9°C and sea level around 20cm since the late 19th Century.
- Many impacts are already being detected across the world, from changes in extreme weather and ecosystems, to a slowdown in productivity gains for some key crops.
- Further emissions will lead to further warming and change. With rapid global action to cut emissions, total human-induced warming could be held below 2°C. Under baselines assuming no action, warming could exceed 6°C.

- There is no simple threshold beyond which climate change moves from safe to dangerous. Some disruption and irreversible losses are expected at 2°C. Losses accelerate with warming, and very severe damage is expected in a world reaching 4°C. The impacts will be unevenly distributed and there are wide uncertainties about their magnitude.
- The increase in global temperature is determined mainly by total carbon dioxide emissions over time, which must fall to near zero in order to limit warming. The allowable total for a likely chance of staying below 2°C will be exceeded in the mid-2030s if global emissions continue at the current rate.

We set out the analysis underpinning these key messages in five sections:

1. Evidence for human-caused climate change
2. Impacts already occurring around the world
3. Potential future climate change
4. Climate risks
5. Implications for the fifth carbon budget

Much of the information presented here is covered at length in the latest assessment of the Intergovernmental Panel on Climate Change (IPCC AR5)[3]. The fundamental points – that global warming is happening, driven by human activity and with large potential impacts – are agreed by the world's leading scientific bodies[4].

1. Evidence for human-caused climate change

The Earth is gaining energy and hence warming, driven principally by greenhouse gas emissions from human activity:

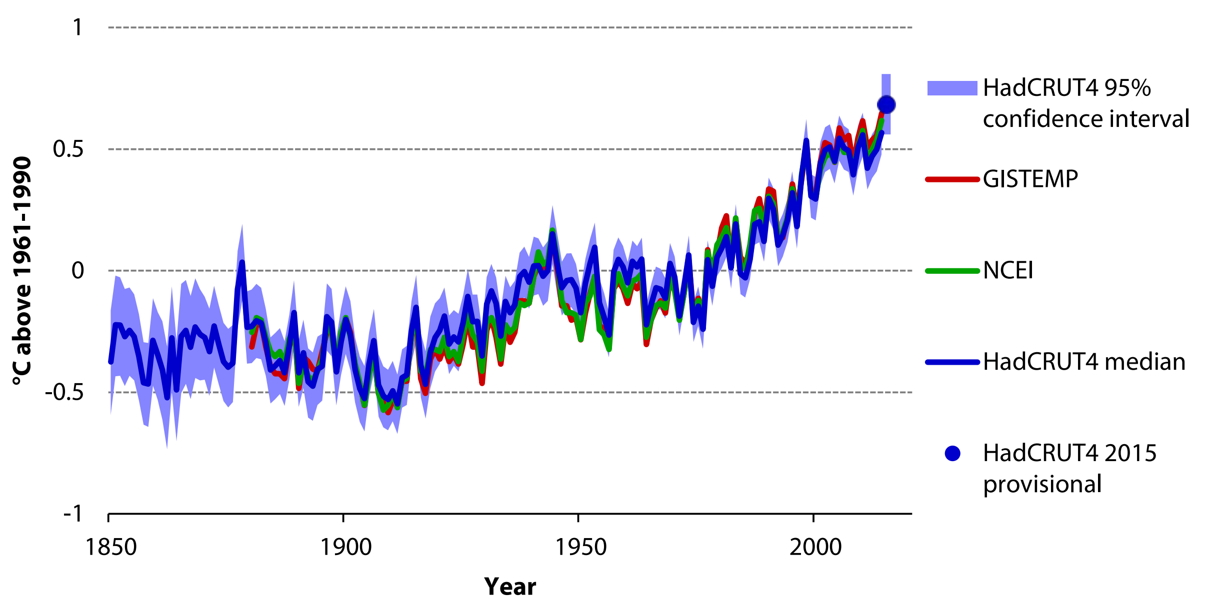
- Warming is seen at the surface and in the atmosphere and oceans as measured by several different scientific institutions. Global average surface temperature is now about 0.9°C above late-19th Century levels (Figure 1.1).
- The basic fact that greenhouse gases in the air warm the surface of the Earth has been understood for over a century and is well-established.
- Greenhouse gases are being emitted by human activities (principally carbon dioxide from fossil fuel burning) at an increasing rate and are accumulating in the atmosphere. Emissions of other air pollutants have a net cooling influence, partially offsetting greenhouse warming to date.
- Trends in climate are also influenced by natural factors. Solar variations and volcanic eruptions affect the global energy balance. Natural cycles within the climate system (such as El Niño) move energy between the surface, air and oceans. These cycles are known to have a strong influence in some regions on timescales from a year up to a few decades.

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

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

- The pattern of global warming over the 20th Century matches that expected from natural and human factors combined, and not that from natural factors alone. Human activity has clearly been the dominant driver of global temperature rise since at least the 1950s.

Figure 1.1: Global average surface temperature change during 1880-2015 as measured by three different research groups

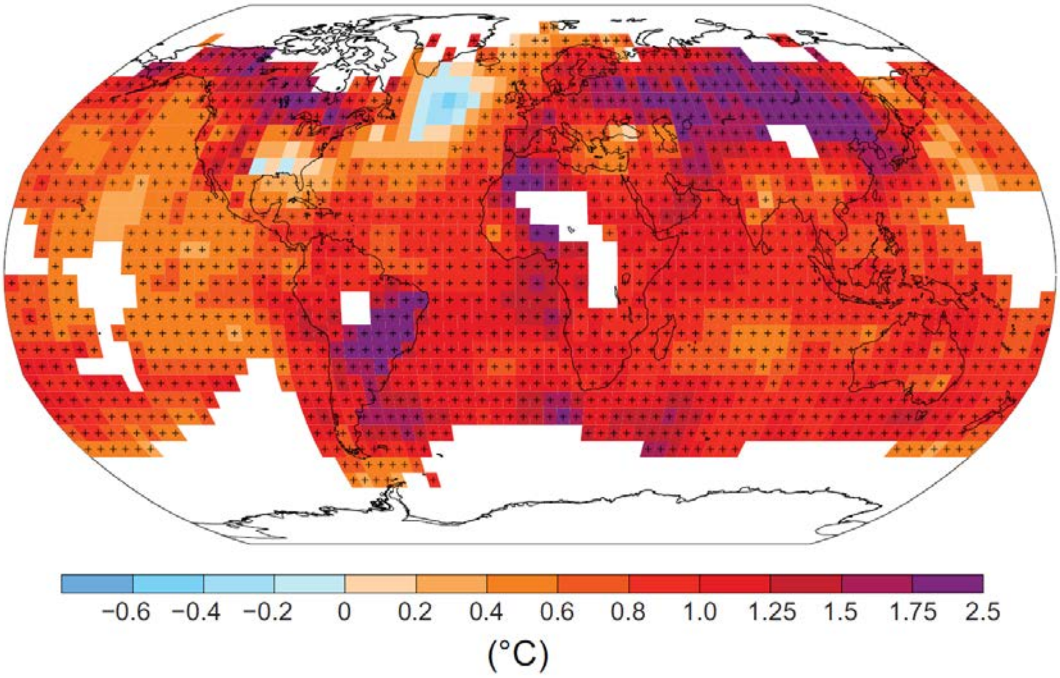


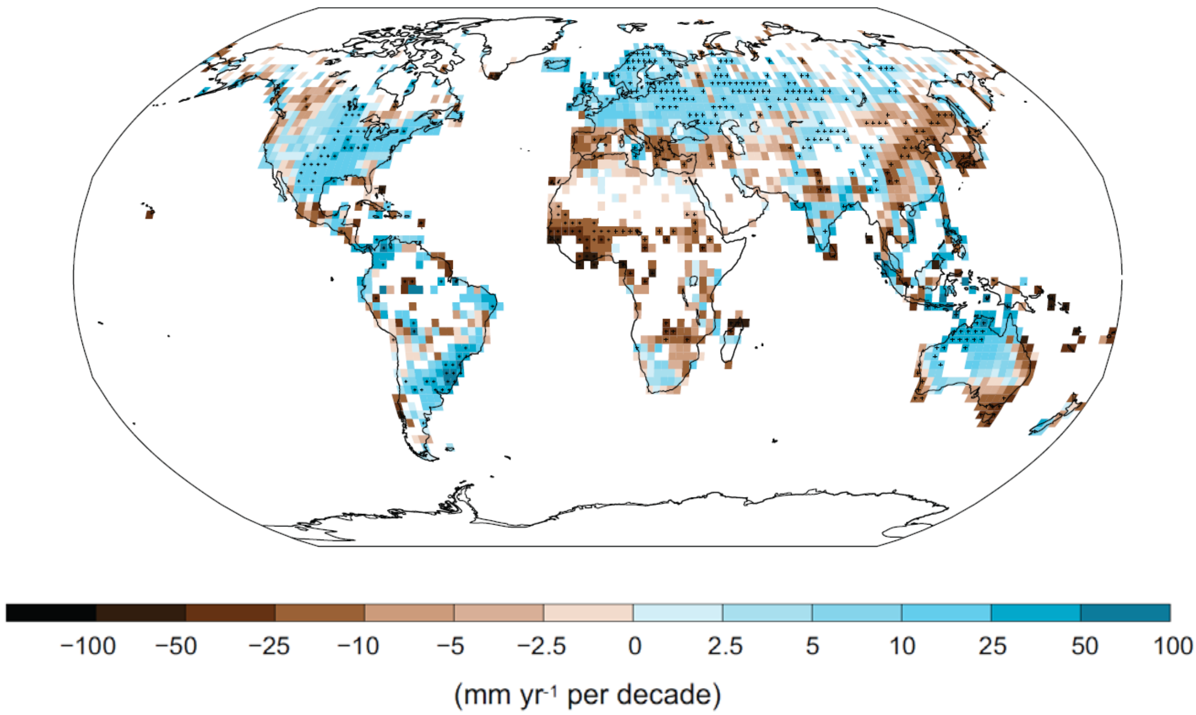
Source: Met Office (http://www.metoffice.gov.uk/hadobs/hadcrut4/data/current/download.html), NASA (http://data.giss.nasa.gov/gistemp/), NOAA (http://www.ncdc.noaa.gov/monitoring-references/faq/anomalies.php).
Notes: Provisional data from the HadCRUT4 dataset for 2015 so far (downloaded September 2015) are shown as a circle with 95% confidence interval.

The observed warming is not uniform and has led to many changes beyond rising temperatures (Figure 1.2):

- Land areas are warming faster than ocean areas, and the Arctic appears to be warming much faster than the global average.
- Global sea level has risen around 20cm since 1900. Also, ocean surface pH has declined by 0.1 (i.e. become more acidic) as it has absorbed more carbon dioxide from the air.
- Across the temperate Northern Hemisphere, where we have the most reliable measurements, precipitation has increased.
- In recent decades sea ice in the Arctic has retreated. The extent of Antarctic ice has varied around the continent but has increased overall, probably associated with increased westerly winds.

Figure 1.2: Observed patterns of change in surface temperature (top) and precipitation (bottom)





Source: IPCC AR5

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

- The ice sheets over Greenland and Antarctica are losing mass. New observations show faster ice loss than reported in IPCC AR5, especially along the West Antarctic coast[5]. The structure of the ice sheet here makes it vulnerable to collapse, potentially adding 3.5-5m to sea level over several centuries even without further warming. New modelling suggests collapse may already be under way, but more detailed models are needed to support this[6].

The global climate has therefore undergone substantial change in recent decades. Global average temperature is only one indicator of this change. A wealth of theory and observations points clearly to human activity, and greenhouse gases in particular, being the principal cause.

2. Impacts already occurring around the world

Impacts from climate change are being seen on all continents and across the oceans. This is detectable even in the presence of other, confounding drivers such as population growth and development, pollution and land use change[7]:

- Many hundreds of published studies find links between recent climate change and impacts on the natural world and human society.
- For instance, scientists are highly confident that climate change is bleaching coral on reefs worldwide; greening and fruiting trees earlier in the year across Europe; reducing river flows across South Western Australia; forcing plant and animal species towards the poles and to higher elevations around the world; and negatively impacting those living in the Arctic.
- There has been a negative effect on the global growth in productivity of some key crops, with a reduction of 2 %/decade (0-5 %/decade[8]) for wheat, and 1 %/decade (0-3 %/decade) for maize. Some crops in Europe and southern South America have experienced gains due to climate change, while South Asia and wheat in Europe have incurred losses.

The warming is having a measurable influence on individual weather events such as heat waves in Europe and hurricanes in the US:

- It has been estimated that high-precipitation events (i.e. those expected once every three years in pre-industrial times) are already around 20% more likely, and high-temperature events four times more likely[9].
- European heat waves as strong as in 2003 (when crop yields fell, power stations were shut down due to overheating and the heat-related death toll ran into tens of thousands) are estimated to have been made at least twice as likely by human activity. A recent update suggests the warming since 2003 now makes it ten times more likely to occur again[10].

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[5] McMillan et al. (2014) *Increased ice losses from Antarctica detected by CryoSat-2*, Geophysical Research Letters; Rignot et al. (2014) *Widespread, rapid grounding line retreat of Pine Island, Thwaites, Smith, and Kohler glaciers, West Antarctica, from 1992 to 2011*, Geophysical Research Letters.

[6] Joughin et al. (2014) *Marine Ice Sheet Collapse Potentially Under Way for the Thwaites Glacier Basin, West Antarctica*, Science

[7] IPCC WG2 AR5 Technical Summary

[8] Brackets indicate 10-90% confidence ranges.

[9] Fischer & Knutti (2015) *Anthropogenic contribution to global occurrence of heavy-precipitation and high-temperature extremes*, Nature Climate Change

[10] Christidis et al. (2015) *Dramatically increasing chance of extremely hot summers since the 2003 European heatwave*, Nature Climate Change

- The coastal surge brought to Manhattan by Hurricane Sandy in 2012 was made 20cm higher by sea level rise, increasing losses in New York by 30%[11]. In addition, the above-average sea surface temperatures at the time increased its wind speeds and rainfall[12].

These impacts give an indication of the widespread and pervasive nature of climate risk. As emissions continue these risks would be expected to increase.

3. Potential future climate change

Continuing greenhouse gas emissions will lead to further warming and change. In relation to global temperature, it remains possible that rapid emissions reduction could limit human-induced warming to less than 2°C above late 19th Century levels. If emissions grow unabated, this warming rises to potentially more than 6°C:

- Under baseline scenarios in which no action is taken, energy system models predict a continued increase in global emissions. As a result global temperature in 2100 would be 2.5-7.8°C (5-95% confidence range) above late 19th Century levels and rising[13].
- Under an ambitious mitigation scenario considered by the IPCC, in which emissions peak now and decline to zero or further before 2100, global temperature rise would be 0.9-2.3°C.
- Natural cycles will continue to affect trends, especially on regional scales. However, the recent "pause" or "slowdown" in global temperature rise does not substantially affect long-term projections of warming (Box 1.1).
- Large volcanic eruptions, when they occur, will lower global temperature for a year or two. A major downswing in solar activity over several decades, considered possible but unlikely, would also lower global temperature by a few tenths of a degree[14].

Box 1.1: Has there been a pause in global warming and does it affect future projections?

Although the world has clearly warmed since the 1950s, global average surface temperature has risen relatively slowly in recent years. Periods of slower (and faster) temperature rise are to be expected, and this "pause" does not substantially affect long-term projections.

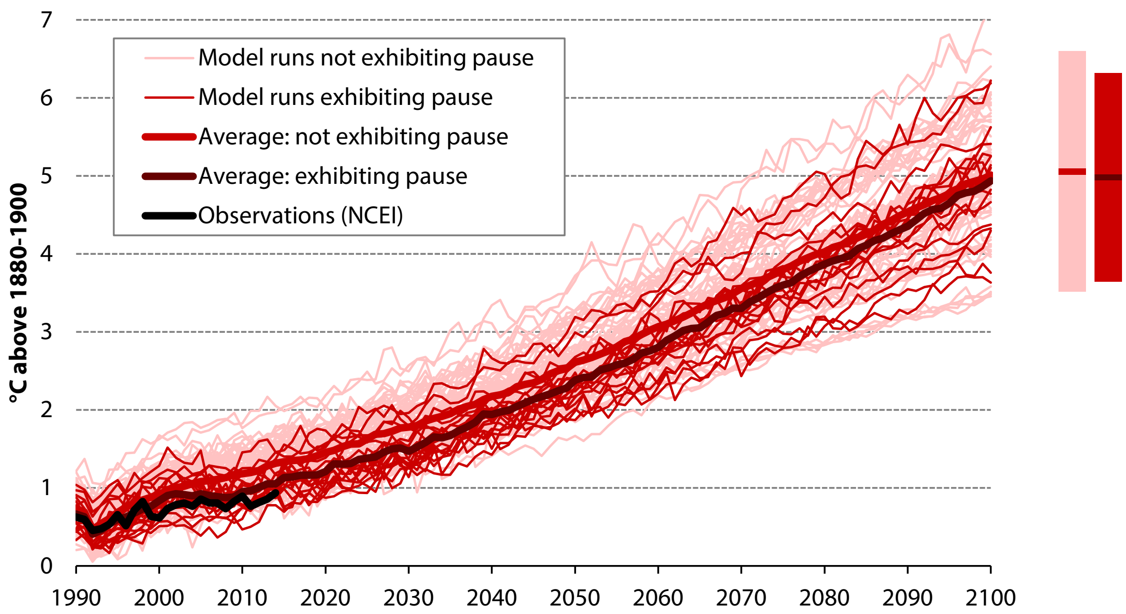
- The pause has no agreed start date, but most estimates of global surface temperature show a slower rise during 2000-14 than the average since the 1950s.
- Nevertheless, the last 15 years are the warmest on record stretching back to the 1850s, and 2015 is extremely likely to set a new high (Figure 1.1).
- Average surface temperature is only one indicator of climate change. Others, such as sea level rise and Arctic sea ice decline, have not paused during this time.
- Short-term fluctuations in global temperature are to be expected, and can be seen from year to year and decade to decade in the observations. They are caused by two factors:

[11] Lloyd's (2014) *Catastrophe Modelling and Climate Change*
[12] Magnusson et al. (2014) *Evaluation of Medium-Range Forecasts for Hurricane Sandy*, Monthly Weather Review
[13] IPCC WG3 AR5 Technical Summary; see also further discussion in Chapter 2
[14] Ineson et al. (2015) *Regional climate impacts of a possible grand solar minimum*, Nature Communications

Box 1.1 (cont.): Has there been a pause in global warming and does it affect future projections?

  - Changes in the rate of energy going into the climate system (e.g. from greenhouse gases, the Sun's activity, volcanoes and air pollutants).
  - "Internal variability", or natural cycles within the climate system, moving heat between the surface, air and oceans. These are generally difficult to forecast.
- Scientists think a mix of factors have driven the pause: transfer of more surface heat to the deeper oceans by internal variability; cooling from volcanoes and air pollution; and a dip in the Sun's cycle of activity. A lack of sufficient observations (especially in the oceans) makes it hard to quantify each of these very precisely.
- Climate models also show fluctuations in global temperature, but do not forecast the exact timings of internal variability and so may not accurately predict short-term trends.
- Scientists are confident the temperature will rise more quickly again, as greenhouse gas emissions continue and current cooling influences subside. The pause does not substantially affect long-term projections (Figure B1.1).

Figure B1.1: Global temperature projected by multiple climate model runs



Source: England et al. (2015) *Robust warming projections despite the recent hiatus*, Nature Climate Change

Notes: Each line shows a climate model run using a high-emission future scenario (RCP8.5). Dark lines denote runs which, through internal variability, exhibit a pause in the early part of the century. Light lines denote runs which do not. "Pause" is defined here as a trend of no more than 0.096°C per decade for a 14-year period during 1995-2015. Thick lines show the average for each case, while right-hand bars show the means and 95-percentile ranges in 2100.

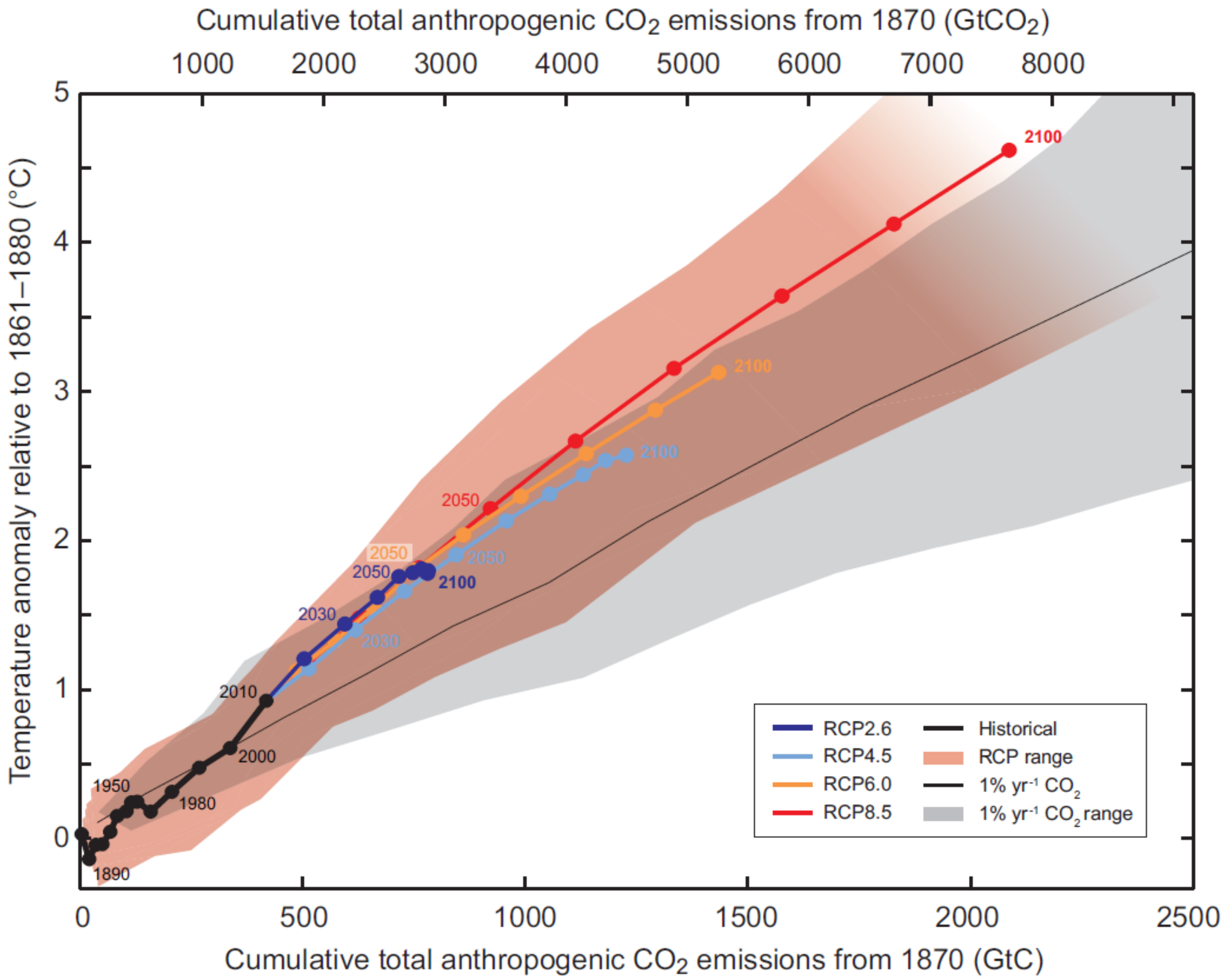
Warming will lead to changes across all parts of the climate system, with very long-term implications:

- Sea level rise will accelerate over the coming decades, reaching about 0.5-1m above 1900 levels by the end of the century. An increasing contribution will come from the Greenland Ice Sheet. Larger rises would occur if the Antarctic Ice Sheet were to collapse.
- Though with some exceptions, the contrast between wet and dry regions of the world will generally increase, and heavy rainfall events will tend to become more intense.
- Ocean pH will continue to decline as the concentration of carbon dioxide increases.
- Some evidence – especially from warmer climates deep in Earth's past – suggests more fundamental shifts are possible, particularly at high levels of warming. These include changes to circulation patterns in the atmosphere and ocean (including the Gulf Stream which feeds mild weather to the UK), changes to monsoons, dieback of the Amazon forests and further feedbacks from release of carbon in thawing permafrost.
- The long-lived nature of raised carbon dioxide concentrations means that, even if emissions were to cease, temperatures would remain high, ice sheets would recede, sea level would continue rising, and other changes would persist for several centuries.

The increase in global temperature will be determined mainly by total carbon dioxide emissions over time. These emissions must fall to near zero (or, in the case of delayed action, go negative) in order to limit warming:

- IPCC AR5 estimated the total carbon dioxide emissions over time consistent with staying below specific global temperature limits. To preserve a 50% likelihood of keeping warming below 2˚C, the total remaining allowable emissions from 2011 is around 1100 $GtCO_2$. For at least a 66% (i.e. "likely") chance, this total decreases to around 1000 $GtCO_2$.
- These totals accounts for projected emissions of other greenhouse gases and particles but apply to global emissions of carbon dioxide only (Figure 1.3).
- If global emissions continue at the current rate, the total for a likely chance of staying below 2°C will be exceeded in the mid-2030s, and for a medium chance by the late 2030s

Figure 1.3: Relationship between global temperature rise and cumulative carbon dioxide emissions



Source: IPCC AR5

Notes: Black line shows observations, coloured lines show results for the main IPCC future scenarios (RCPs). Grey shaded region is the relationship for CO_2 only, not including the influence from other greenhouse gases and air pollutants.

The range in projected warming for any given emissions scenario reflects the difficulty in accounting precisely for all the processes and feedbacks in the climate system. Research is ongoing to narrow this range, but it remains wide:

- One metric of projected warming is the Transient Climate Response (TCR), which is the global temperature rise immediately after ramping up carbon dioxide concentration to double previous levels.
- Based on a range of studies using different lines of evidence, IPCC AR5 concluded that the TCR is 66% likely to be in the range 1-2.5°C and 95% likely to be less than 3°C.

- Since IPCC AR5 there have been several more studies on TCR and the processes that control it. Some support the lower end of the IPCC range while others support the upper end[15].
- In our Fourth Carbon Budget Review (2013) we noted that the probability of exceeding global temperature thresholds depends strongly on assumed TCR. Nevertheless, even under a pathway of rapid emissions reductions and with the lowest distribution of TCR cited in IPCC AR5, the likelihood of crossing 2°C is over 10% (Table 1.1).
- Furthermore, there are feedbacks not currently in climate models but beginning to be quantified (such as further carbon release from thawing permafrost). For the medium TCR assumption in Table 1.1, we estimated in our 2013 Review that these feedbacks could add just under 10% (with a range of -20% to 30%) to the likelihood of exceeding 2°C.

Table 1.1: Likelihood of exceeding global temperature thresholds for a rapid emissions reduction pathway, using different assumptions for Transient Climate Response (TCR)

Likelihood of exceedance in 2100 (global temperature above pre-industrial)	**Transient Climate Response (TCR) assumption**		
	Low (Otto et al., 2013)	**Medium (Forster et al., 2013)**	**High (Stott & Forest, 2007)**
2°C	11%	57%	81%
3°C	1%	14%	27%
4°C	0%	4%	7%

Source: CCC (2013) *Fourth Carbon Budget Review – part 1: assessment of climate risk and the international response.*
Notes: Results are for global emissions peaking in 2020, 50% below 2007 levels in 2050 and 85% below in 2100. Low, medium and high assumptions are taken from the range of TCR studies cited in IPCC AR5.

The potential size and rate of global warming is very large compared to previous changes during human history:

- Some regional climate change has been experienced by human populations in the past (e.g. US megadroughts, monsoon changes) but the best available evidence suggests global temperature has not varied by more than several tenths of a degree during the course of human civilisation (i.e. the last 6,000 years or so). It is partly this lack of historical precedent that creates uncertainty in future impacts.
- In the deeper past we do know that Earth's climate has been very different. For instance during the peak of the last "ice age" (around 20,000 years ago) global average temperature was in the region of 3-8°C below pre-industrial levels.

[15] See for instance Lewis & Curry (2015) *The implications for climate sensitivity of AR5 forcing and heat uptake estimates*, Climate Dynamics; Qu et al (2014) *On the spread of changes in marine low cloud cover in climate model simulations of the 21st century*, Climate Dynamics.

- During this time there were kilometres-thick ice sheets over North America and Northern Europe, large-scale weather patterns were substantially different to now, there was much less rainfall, more dust and fewer rainforests.

These points suggest we should expect dramatic changes for 4°C or more warming this century.

4. Climate risks

Future climate change will have many implications around the world, increasing various risks to people and the environment while reducing some others. This section focusses on key climate risks at the global scale which can inform thinking about global ambition to reduce emissions.

Existing emissions targets stem from objectives to keep a substantial chance of staying below a 2°C rise in global temperature above pre-industrial levels:

- There is international agreement that global temperature should not rise more than 2°C above pre-industrial levels (see Chapter 2).
- In previous CCC advice on the 2050 target and carbon budgets (which predates international agreement on 2°C) we have proposed the world should seek to keep central (i.e. 50%) estimates of global temperature in 2100 close to 2°C above pre-industrial levels, and keep the probability of a 4°C rise to very low levels (e.g. 1%).

There is no simple threshold beyond which climate change moves from safe to dangerous, but global aggregate damages will accelerate with warming. There may be benefits in some locations, although some disruption and irreversible losses are expected even at the low end of projected warming. Impacts will not be distributed evenly, with damages falling disproportionately on the poor and vulnerable in both developed and developing regions[16]. For instance:

- Crop yields will decline further in parts of Africa, Asia and Latin America, where many rely on subsistence farming. Meanwhile the UK may see greater agricultural potential (barring other constraints, notably soil fertility and water[17]). Around the world, yields are expected to decrease and become more variable, impacting on food security[18].
- Sea level rise will cause coastal flooding and saline intrusion into freshwater resources. Low-lying islands may face a long-term existential threat. Especially large risks to people and assets are found in major coastal cities such as Mumbai, Shanghai, New Orleans, New York, Amsterdam and London[19].
- Extreme weather has major impacts on the elderly and vulnerable even in the developed world, as heat waves in Paris[20] and Chicago[21] have shown. In tropical regions extreme heat events may start to exceed the survival limits of fully-fit people. In temperate parts of the world (including the UK) there will also be a reduction in the impacts from cold snaps.

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[16] IPCC WG2 AR5 Technical Summary

[17] Defra (2012) UK Climate Change Risk Assessment: Government report

[18] Challinor et al (2014) *A meta-analysis of crop yield under climate change and adaptation*, Nature Climate Change; Rosenzweig et al. (2014) *Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison*, Proceedings of the National Academy of Sciences

[19] Nicholls et al. (2008) *Ranking port cities with high exposure and vulnerability to climate extremes*, OECD Environment Working Papers No. 1

[20] Robine, et al. (2008) *Death toll exceeded 70,000 in Europe during the summer of 2003*, Comptes Rendus

- In the Arctic, where snow and ice are retreating, access to new routes and resources will open up. At the same time this retreat puts local cultures and ecosystems in existential risk.
- Coral reefs (home to a quarter of all fish species and a key source of food, coastal protection and income) will suffer widespread losses from ocean warming and acidification. Other ecosystems are at risk, including on mountains (where species must move to higher, smaller zones of habitability) and in the tropics (where species already live near their thermal limits).

There are deep uncertainties in quantifying future impacts because they depend not only on projections of future climate but also of future society (i.e. how many people there are, where they live, what they do, and the resources they have to cope and adapt). However, there is wide-ranging agreement climate change will have far-reaching and systemic consequences. Holding global temperature rise to 2°C does not eliminate climate risks but does reduce many of them substantially.

- IPCC AR5 concluded warming of 1.5°C above late 19th Century levels leads to high risk of damage from extreme weather and of losing sensitive ecosystems. Warming of around 2.5°C brings high risk of large-scale singularities (such as irreversible ice sheet melting leading to more sea level rise) and severe global impacts on the economy and environment. Warming of around 4.5°C puts global food security in doubt.
- Both the US Department of Defense[22] and the UK Ministry of Defence[23] identify climate change as presenting risks to their operations and to global security. They consider it to be a "threat multiplier" which can trigger or amplify existing social instabilities.
- The 2015 Lancet Commission on Health and Climate Change concluded it could be the biggest global health threat of the century, primarily through indirect effects from water, food security and extreme weather. It also noted that measures to reduce emissions often provide health co-benefits[24].
- The World Bank focussed on possible impacts in a 4°C world, concluding they would be "devastating" and need to be avoided[25].

In order to illustrate the scale of the risks we commissioned[26] a consortium of scientists to estimate impacts at 2°C, 3°C and 4°C above pre-industrial levels by the end of the century, assuming a "middle of the road" socio-economic future (Box 1.2). They found the following:

- Relative to no change in climate, global wheat and maize yields could be 20-30% and 25-50% lower at 4°C, respectively, even assuming farmers adapt their planting times and crop varieties. (Together with rice these crops provide 60% of world food energy intake[27] and without climate change, yield projections to 2050 roughly match rising global demand[28]).

Biologies

[21] Klinenberg (2003) *Heat Wave: A Social Autopsy of Disaster in Chicago*

[22] Department of Defense (2014) *Quadrennial Defense Review*

[23] MoD (2014) *Global Strategic Trends out to 2045*

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

[25] World Bank (2012) *Turn Down the Heat: Why a 4°C warmer world must be avoided.*

[26] AVOID 2 (2015) *The global impacts of climate change under pathways that reach 2, 3 and 4°C above pre-industrial levels*

[27] http://www.fao.org/docrep/u8480e/u8480e07.htm

[28] Alexandratos and Bruinsma (2012) *World agriculture towards 2030/2050: the 2012 revision*. ESA Working paper No. 12-0, FAO

- Roughly 3-30 million additional people could suffer coastal flooding each year due to 4°C warming, even assuming defences continue to improve with rising population and wealth. Further protection can bring these numbers down to about 125,000 per year, at an annual average capital cost of around $10bn.
- Impacts from flooding of major rivers will also increase. 4°C warming could expose 80-350 million more people per year, in addition to around 60 million more exposed due to growth and development. This assumes flood defences stay fixed over time; as with coastal flooding, further investment could help lower damages.
- The total number of people exposed to water stress will not change significantly with climate change, but this masks large regional differences. Access to freshwater may rise in East Africa, India, northern Russia and Alaska. But at 4°C, 1-3.5 billion people may face enhanced water stress in places such as South Europe, North Africa and the Middle East.
- Combined heat and humidity (captured by the Wet Bulb Globe Temperature, WBGT) limits peoples' ability to function. WBGTs above 32°C risk death even for healthy people at rest, but almost never occur currently and would still be very rare for 2°C global warming. By 4°C, however, exposure in parts of South Asian and Africa would rise dramatically.
- At 4°C around 50-65% of plant and amphibian species, and around 25-40% of bird and mammal species, are expected to lose at least half of their suitable climatic range.

These estimates are incomplete. They are based on models which do not capture potentially important climate shifts (see Section 3); they do not consider the compound effects of impacts occurring together; and they only sample a subset of all potential impacts (not considered here for example are wider implications for health, supply chains, finance, and national security).

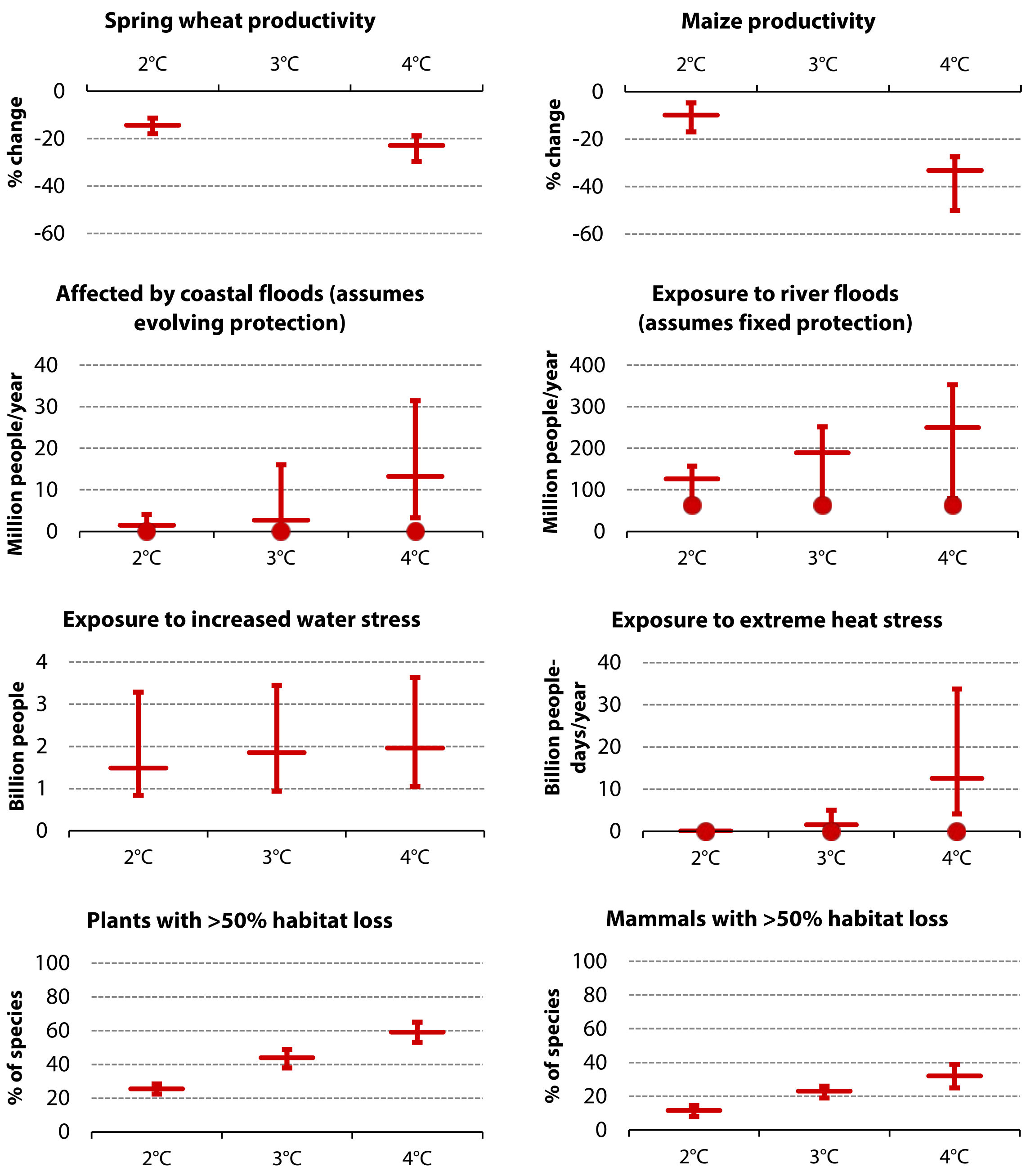
Box 1.2: Estimate of changes in global impacts with increasing global temperature

We commissioned the AVOID2 consortium to quantify future global impacts across a range of sectors. They used an existing set of impact models that have already been used in peer-reviewed literature. The models are applied here to a fixed scenario of population and wealth, but with 2, 3 and 4°C warming above pre-industrial levels in 2100. Impact ranges at each temperature level come from using different climate models as inputs, reflecting uncertainty in the future pattern of regional temperature and rainfall.

The estimates mainly represent exposure to impact, which may be reduced by adaptation. Some adaptations are included, however: coastal flooding data assumes flood defences evolve with population and wealth; crop productivity assumes crop varieties and time of planting are adjusted to optimise yields; plants and animals are assumed to disperse to new areas at historically-observed rates. Crop productivity numbers do not include expected gains from improved breeding and farming practices, while habitat loss numbers exclude direct (non-climatic) losses expected from human activity.

Box 1.2 (cont.): Estimate of changes in global impacts with increasing global temperature

Figure B1.2: Potential global impacts from climate change at the end of the century



Source: AVOID 2 (2015) *The global impacts of climate change under pathways that reach 2, 3 and 4°C above pre-industrial levels*

Notes: Plots shows estimates as a function of global temperature in 2100 relative to pre-industrial levels. Bars denote median and whiskers the 10-90% range of outputs due to climate model differences in projected regional temperature and precipitation. For productivity and habitat loss whiskers denote the full range from a more limited set of climate models. Where shown, circles show impacts in a 1961-1990 climate, i.e. the impacts in 2100 from population and wealth growth.

According to the assessment in Box 1.2, limiting warming to 2°C rather than 4°C this century leads to reductions in global total impacts across all indicators (Table 1.2).

Table 1.2: Differences in impact indicators at 2°C above pre-industrial global average surface temperature in 2100, relative to 4°C

Impact	**Reduction (2°C relative to 4°C)**
People with increased exposure to water stress	280 (150-580) million
People-days exposure to extreme heat stress	12 (4-34) billion/yr
People exposed to major river floods (assuming fixed protection over time)	120 (25-195) million/yr
People affected by coastal flooding (assuming protection improves with population and wealth)	12 (3-27) million/yr
Spring wheat, maize crop productivity	-8 (-12 to -7)%, -24 (-33 to -23)%
Plant, mammal species losing at least half of climatic habitat	34 (31-37)%, 21 (17-25)%

Source: AVOID 2 (2015) *The global impacts of climate change under pathways that reach 2, 3 and 4°C above pre-industrial levels*

These results show that adaptation (i.e. preparing for future impacts) is a necessary complement to mitigation (i.e. reducing emissions to limit future warming). This is true for the UK which, although unlikely to be worst affected by climate change, still faces risks:

- Looking across the risks to the UK, the CCC's Adaptation Sub-Committee (ASC) has identified four key areas where progress has been made but further steps are necessary: water scarcity; flooding; heat stress in the built environment; and impacts on natural assets and agriculture.
- In 2016 the ASC will publish its advice to the Government on the second national Climate Change Risk Assessment. In the interim it is publishing updated projections of water availability, flooding, natural assets and extreme events[29].

[29] See CCC website for further details: www.theccc.org.uk/publications/

5. Implications for the fifth carbon budget

The nature of climate change risks and the many unknowns make a simple cost-benefit approach to climate action untenable:

- In setting a level of ambition for climate policy, global climate risks from greenhouse gas emissions need to be weighed against the challenges and opportunities arising from decarbonising society.
- Quantitative projections of future climate impacts are subject to deep uncertainty and cover only on a limited subset of all potential impacts.
- Aggregating impacts relies on subjective assumptions about the value of future impacts versus those in the present, of impacts on the rich versus the poor, and of non-monetary impacts such as those on human health and the natural world.

The internationally-agreed limit to warming, and the UK's own emissions targets, are based on an approach which seeks to minimise the largest risks. On the basis of the latest climate science we judge that this level of ambition remains broadly appropriate for now:

- The CCC's past advice has been based on an objective to keep central estimates of warming by 2100 close to 2°C above pre-industrial levels, and also keep the chance of a 4°C rise to very low levels (e.g. 1%).
- There is now international agreement on limiting global temperature to no more than 2°C above pre-industrial levels (see Chapter 2). Compared to the CCC objective this is less explicit on the acceptable likelihood of crossing 2°C, but is arguably more ambitious.
- Our recommendation was based on a broadly similar assessment of climate risk to the latest understanding.
- Given the link between peak temperature and cumulative carbon dioxide emissions, the ultimate aim (beyond 2050) should be to get to zero net carbon dioxide emissions globally.

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

Chapter 2:
International action to limit climate change

Introduction and key messages

The Climate Change Act requires us to take account of international circumstances when developing our recommendations for carbon budgets. In considering appropriate UK action it is important to assess the feasibility of global emissions pathways consistent with meeting climate goals, and the developments in low-carbon technologies and measures compatible with that.

Our key messages are:

- The UK's carbon budgets are domestic commitments, but set in the context of efforts worldwide to reduce greenhouse gas emissions.
- The UN has formally adopted an objective to limit global temperature rise to 2°C and countries are submitting pledges ('Intended Nationally Determined Contributions' - INDCs) to reduce emissions post-2020. The aim is to adopt a new agreement, with legal status, in Paris at the end of 2015.
- Many countries and sub-national bodies have made commitments for deep emissions reduction and are now delivering against these. Penetration of low-carbon technologies and measures around the world is increasing, although these still account for a relatively small share of global energy production:
  – 75% of global emissions are covered by economy-wide reduction targets. There is increased action at sub-national, city and business levels.
  – In 2013, 18% of global emissions were covered by some form of carbon pricing scheme and 76% of global transport emissions were covered by legislated fuel efficiency standards in 2015.

– Deployment of low-carbon technologies (notably renewables and low-carbon vehicles) is increasing and more large-scale Carbon Capture and Storage (CCS) plants are in development. High deployment rates have led to large cost reductions for some technologies (e.g. solar PV module prices fell 70% between 2009 and 2015), such that they are cost-competitive with fossil fuel generation in many applications and parts of the world.

- Lowest-cost paths with a likely chance of staying below 2°C require global emissions to peak around 2020 with steep reductions thereafter (e.g. to 40-70% below 2010 levels in 2050). UN pledges made so far are not on this path. There is scope to reduce the gap through remaining pledges, increases in existing ambition and further commitments to reduce emissions beyond 2030.
- Both the UK and EU have objectives to reduce their greenhouse gas emissions in 2050 to at least 80% below 1990 levels. These objectives remain appropriate in the light of the latest evidence regarding global emissions pathways consistent with 2°C.

We set out the analysis underpinning these conclusions in five sections:

1. International negotiations and national pledges
2. Global developments in policy and technology
3. Consistency of UN pledges with global emissions paths to 2°C
4. EU and UK 2050 objectives
5. Implications for the fifth carbon budget

1. International negotiations and national pledges

International negotiations on climate change are governed through the United Nations Framework Convention on Climate Change (UNFCCC), to which 195 countries plus the EU are party. Under this process countries have agreed to limit global temperature rise to 2°C above pre-industrial levels, and many countries have made emission pledges for 2020. At the Conference of Parties (COP) in Paris this year the aim is to reach a comprehensive and binding agreement going beyond 2020.

In this section we set out latest developments in the UN process and progress towards agreeing post-2020 pledges at the Paris conference.

The UN process and the agreed 2°C limit

In 1992 the UNFCCC set out the goal of "preventing dangerous anthropogenic interference with the climate system". Countries have formally agreed this to mean limiting the increase in global temperature to below 2°C[30] (Box 2.1), to work towards deep cuts in emissions and to assess progress towards meeting this objective:

[30] A limit of 1.5°C above pre-industrial levels has also been proposed and has been the subject of a UNFCCC review. Further details at http://unfccc.int/science/workstreams/the_2013-2015_review/items/6998.php.

- Under the 2009 Copenhagen Accord countries agreed to come forward with pledges to limit or reduce emissions covering the period to 2020. 86 countries plus the EU subsequently made pledges, including all major emitters and covering the bulk of global emissions.
- At the Durban negotiations in 2011 it was agreed to deliver a new and universal greenhouse gas reduction agreement 'with legal force' by 2015, for the period beyond 2020. The aim is that this new deal will govern post-2020 emissions pledges, financing and adaptation to the impacts of climate change (Box 2.2).

A key element under discussion for the Paris negotiations is a forward-looking regime of commitment periods with a mechanism to enhance ambition over time.

Box 2.1: Interpreting the 2°C limit

The implication of the 2°C limit for global emissions depends on a judgment about acceptable risk:

- There is some uncertainty in the sensitivity of the climate to emissions. We cannot therefore be sure a given emissions path will keep the world below a given global temperature. Instead paths have likelihoods of crossing different temperature thresholds (see Chapter 1).
- UNFCCC parties have not specified an acceptable likelihood for staying below 2°C. However, key analyses feeding into the international negotiations (such as those by the Intergovernmental Panel on Climate Change (IPCC) and United Nations Environment Programme (UNEP)) tend to provide estimates of emissions limits consistent with a 'likely' (i.e. at least 66%) or 'medium' (i.e. 50-66%) chance of staying below 2°C this century.
- The IPCC's Fifth Assessment Report (AR5) concluded that pathways likely to stay below 2°C show global greenhouse gas emissions in 2050 of 15-29 $GtCO_2e$ (see Section 3). G7 leaders recently endorsed the lower end of this range and 'decarbonisation of the global economy over the course of this century' as policy goals[31].
- CCC advice (predating the UNFCCC agreement on 2°C) assumed the world should seek to keep central (i.e. 50%) probabilities of global temperature in 2100 close to 2°C above pre-industrial levels, and keep the probability of a 4°C rise to very low levels (e.g. 1%).
- Although this CCC goal appears to leave only a 'medium' chance of 2°C, the UK 2050 target was based on global emissions in 2050 (20-24 $GtCO_2e$) in the middle of the IPCC range for 'likely' pathways. The difference is due partly to assumptions around climate sensitivity and emissions before and after 2050.

[31] Leaders' Declaration, G7 Summit (2015) https://www.g7germany.de/Content/DE/_Anlagen/G8_G20/2015-06-08-g7-abschluss-eng.pdf

Box 2.2: Aims for Paris agreement

Key elements of a successful agreement at the Paris COP are likely to include the following:

- Ambitious national plans from 2020 onwards to limit global greenhouse gas (GHG) emissions to a level consistent with the 2°C climate objective. This may involve accelerated action pre-2020 such that cumulative emissions levels to 2°C are easier to meet.
- A strong legal basis with clear rules, underpinned by a governance framework with powers to review and strengthen ambition in regular time periods.
- Strong action plans and investment strategies to ensure the commitments are credible and deliverable.
- It should build on and extend existing support for mitigation as well as climate resilience and adaptation efforts.

Post-2020 pledges

Ahead of the Paris conference in December 2015, countries agreed to submit their post-2020 pledges to the UN. These are typically for 2025 or 2030.

By 2 October 146 countries had submitted their 'Intended Nationally Determined Contribution' (INDC) to the UNFCCC, covering 87% of global emissions. This includes all developed countries and 70% of developing countries, and includes the major emitters (e.g. China, the US, the EU and India) (Table 2.1):

- **China** has pledged to peak emissions by 2030, to reduce the carbon intensity of GDP by 60-65% below 2005 levels in 2030, increase the share of non-fossil fuels in primary energy generation to around 20% by 2030 and to take significant action on afforestation.
- **The US** has pledged to reduce its emissions by 26-28% below 2005 levels by 2025.
- **The EU** has pledged to reduce its emissions by at least 40% below 1990 levels by 2030 (see Chapter 3).
- **India** pledged by 2030 to lower its emission intensity of GDP by 33-35% below 2005 levels, to increase the share of non-fossil fuel based power generation capacity to 40% of capacity, and to create an additional cumulative carbon sink of 2.5-3 $GtCO_2e$ through forest and tree cover**.**
- **Mexico** plans to reduce GHG emissions by 22% below business as usual in 2030, increasing to 36% conditional on a global agreement. This is on track towards its legislated 2050 target of a 50% reduction below 2005 levels.

In addition to these pledges, international aviation and shipping emissions are regulated through their respective international agencies, the International Civil Aviation Organisation (ICAO) and the International Maritime Organisation (IMO). The ICAO and the IMO have made some progress developing and implementing emission reduction policies, but have not made official UN pledges (Box 2.3).

Table 2.1: Summary of INDCs from selected countries

Country	Reference year	Metric	Reduction by 2030 (see notes)
China	2005	Emissions intensity of GDP	60-65%
EU (28)*	1990	Emissions	40%
USA†*	2005	Emissions	26-28%
India	2005	Emissions intensity of GDP	33-35%
Brazil†	2005	Emissions	37%
Australia	2005	Emissions	26-28%
Canada	2005	Emissions	30%
Russian Federation	1990	Emissions	25-30%
Mexico	2030	Business as usual	25-40%
Japan	2013	Emissions	26%
New Zealand*	2005	Emissions	30%
Switzerland	1990	Emissions	50%
South Korea*	2030	Business as usual	37%
Norway	1990	Emissions	40%
Ethiopia	2030	Business as usual	64%

Source: Climate Action Tracker and UNFCCC.
Notes: INDCs are for 2030 except for 2025 denoted with †, and include emissions from Land Use, Land Use Change and Forestry except where denoted with *.

Box 2.3: Progress reducing global international aviation and shipping emissions

International aviation and shipping (IAS) contribute 3% of current global CO_2 emissions, and are projected to grow significantly unless further measures are taken[32]. These emissions are not accounted for in any single country's national accounting. The Kyoto Protocol delegated responsibility to limit and reduce emissions from IAS sectors to their relevant UN regulatory bodies, the International Civil Aviation Organisation (ICAO) and the International Maritime Organisation (IMO). Progress towards reducing these emissions has so far been slow.

- **Aviation.** The ICAO is aiming to agree a global market-based measure in 2016, for implementation from 2020. The EU has already taken steps to include intra-EU flights in the EU Emissions Trading System and the US Environment Protection Agency (EPA) has recently classified emissions from aviation as contributing to air pollution that causes climate change. These developments could encourage the eventual implementation of an international agreement to curb emissions from aviation. In 2010 the ICAO also set a goal of improving fuel efficiency by 2% per year up to 2020, an aspirational goal to continue this rate to 2050 and an aspirational goal to keep net carbon emissions flat from 2020[33]. Progress on the first of these has been around half the target rate on a fuel/passenger km basis[34]. Additionally the aviation industry has pledged to reduce net emissions in 2050 to 50% below 2005 levels[35].
- **Shipping.** In 2011 the IMO agreed the Energy Efficiency Design Index (EEDI), a standard which aims to improve fuel efficiency of new ships by up to 30% by 2025. This was introduced in 2013. In 2015 the EU adopted regulations establishing a system for monitoring and reporting of emissions from ships using EU ports. This will apply from 1 January 2018.

2. Global developments in policy and technology

As well as progress towards a global agreement, it is important to monitor progress implementing low-carbon policies and measures in order to provide confidence that the path towards 2°C can be met. In this section we consider the key drivers of global emissions and set out global developments in low-carbon laws, policies and technologies.

We conclude that there is evidence of increased implementation of low-carbon laws and pledges. Global coverage of low-carbon measures such as carbon trading and vehicle standards is widening, as is deployment of low-carbon technologies, although these will need to ramp up rapidly to be on a pathway consistent with 2°C.

Key drivers of global emissions

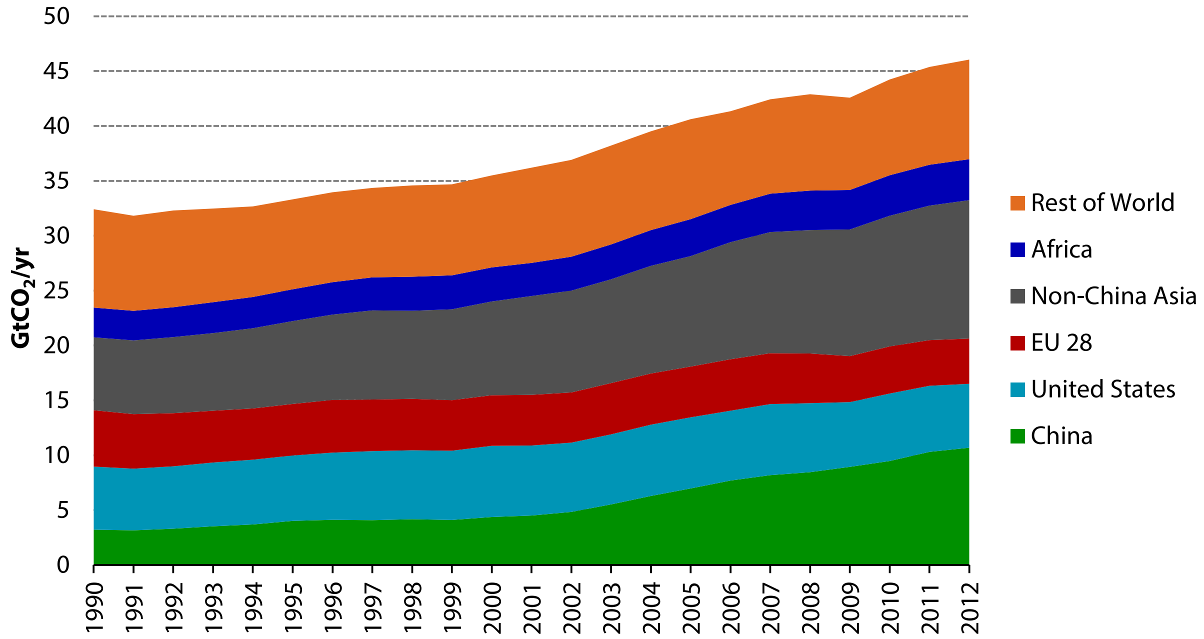
Between 1990 and 2012 global greenhouse gas emissions grew by 42 % (Figure 2.1), made up

[32] New Climate Economy (2015) *Raising Ambition to Reduce International Aviation and Maritime Emissions*
[33] ICAO (2010) *Resolutions adopted by the Assembly – 38th Session*
[34] The International Council on Clean Transportation (2015) *Fuel efficiency trends for new commercial jet aircraft: 1960 to 2014*
[35] Air Transport Action Group (2012) *A Sustainable Flightpath Towards Reducing Emissions*

largely of carbon dioxide from fossil fuel burning and industry. Population increased by 33% and GDP by 79% over the period meaning that, although emissions continued to increase, the amount of greenhouse gases produced per unit of GDP fell by around 20%.

- The largest contribution to the growth in emissions came from developing countries, in particular China which is now the world's largest emitting country.
- CO_2 emissions from fossil fuels and industry grew 55% during 1990-2012. In 2012 they constituted 70% of all long-lived greenhouse gas emissions.
- Around 60% of the growth in global energy-related CO_2 emissions since 2000 has come from increased use of coal, which by 2012 was responsible for 43% of global CO_2 emissions from fossil fuel combustion[36].
- In 2014 global CO_2 emissions are estimated to have been the same as in 2013. As global GDP rose by around 2.5% this is the first time emissions have not increased in a period of economic growth.

Figure 2.1: Global CO_2 emissions (1990-2012)



Source: World Resources Institute CAIT database.
Notes: Includes Land Use, Land Use Change and Forestry (LULUCF) emissions.

The future path for global emissions will be determined by a number of factors, including demographic trends, the structure and rate of economic growth and the mix of high- and low-carbon technologies in use. The global energy system is largely fossil-fuel based and in the absence of further policies and measures, global emissions are projected to continue growing

[36] CCC calculations based on BP (2015) *Statistical Review of World Energy*.

(Box 2.4). For example, the International Energy Agency (IEA)[37] estimates that with no change in current or planned policy, global CO_2 emissions from fossil-fuel burning and industry will rise by 20% above today's level by 2040, leading to a long-term rise in global average temperature of around 3.5°C.

The transition will require a strong legislative framework across countries and sectors and an acceleration of investment in low-carbon technologies. We now turn to consider latest developments in these areas.

Box 2.4: Outlook for incumbent technologies

In the absence of new policies global primary energy use is expected to grow with a continued reliance on fossil fuels.

The IEA's 'New Policies' scenario forecasts energy demand and emissions to 2040 based on policies in place, planned or announced by mid-2014. Under this scenario, primary energy demand is projected to grow 37% between 2012 and 2040.

The scenario considers the global outlook for the electricity, transport and industry and building sectors:

- **Electricity.** The majority of electricity is expected to be generated from coal and natural gas in 2040. However, the overall share of total fossil fuels decreases from 68% in 2012 to 55% in 2040; most of this decrease in share is absorbed by renewables which comprise 35% of the total investment in the power sector out to 2040.
- **Transport.** The transport sector is heavily reliant on fossil fuels, with around 95% of road transport energy from oil in 2012. Under the New Policies scenario this reliance is expected to continue, with alternative road fuels taking only a minor share. The number of vehicles in the global fleet is forecast to double to 2040, mostly from non-OECD countries, but due to the uptake of fuel efficiency standards energy consumption is projected to increase only 40%.
- **Industry & Buildings**. Energy demand in industry is expected to increase an average 1.4% per year and in buildings an average of 1% per year to 2040. Most of the growth in both sectors is expected from non-OECD countries – for example, nearly 50% of industrial energy growth is expected from China and India.

Overall, the implication is that global emissions are projected to grow 20% to 2040, consistent with a long-term global average temperature increase of 3.6°C.

Source: IEA (2014) *World Energy Outlook 2014*

[37] IEA (2014) *World Energy Outlook*

Global coverage of low-carbon laws and pledges

Alongside the UN process of agreeing global emission reductions, country-level laws and targets will be required in order to deliver national pledges. Commitments to reduce emissions are being developed and put in place at national, sub-national and city and business levels:

- **National climate change laws and policies.** Climate change legislation is becoming more prevalent. Over 75% of global emissions are covered by some form of economy-wide reduction target, across 98 countries plus the EU[38]. Of these, 75 countries plus the EU have framework laws (statute or regulation equivalent), providing greater credibility for the development of policy to support low-carbon technology and markets. Some countries, including Mexico, France, Denmark and Finland have also passed Climate Change Acts in recent years that legislate emissions reduction targets, including reductions in emissions by 2050 of up to 80%.
- **Sub-national pledges and policies.** Action at the sub-national level can be significant given the size of some regional economies. Action is most prevalent in some US states and Canadian provinces, including joint initiatives on carbon pricing and zero-emission vehicles.
  - In the US, 12 states have legislated emissions targets and five have 2050 targets. For example, California – the largest US state by GDP – has pledged to reduce emissions by 40% below 1990 levels in 2030 and 80% by 2050. California's cap-and-trade scheme now covers 85% of state emissions and was linked to Quebec's scheme in 2014.
  - In Canada, four provinces have emission reduction targets for 2020: British Columbia, Vancouver, Ontario and Quebec. Ontario also has a target to reduce emissions by 37% on 1990 levels by 2030.
  - Cross-state initiatives to reduce emissions include the Regional Greenhouse Gas Initiative (a cap-and-trade system covering power sector emissions in nine Eastern US states) and the Western Climate Change Initiative (a market-based system between seven US states covering around 20% of US GDP, and four Canadian provinces covering 76% of Canadian GDP).
  - In the US, eight states have agreed a joint target for at least 3.3 million zero-emission vehicles on the road by 2025 and have developed an action plan to deliver this.
- **Other pledges.** Cities and businesses can have a significant impact on emissions; the top 1,000 GHG emitting companies produce one-fifth of global emissions[39]. Other pledges and collaborative measures have grown in recent years.
  - The Covenant of Mayors, covering around 6,300 cities, was set up to support the deployment of sustainable energy policies by local authorities.
  - As part of the Science Based Targets initiative, a range of leading companies have pledged ambitious science-based emissions targets. For example, Coca Cola Enterprises aims to reduce its emissions from operations by 50% below 2007 levels by 2020.
  - UNEP estimate the reduction from non-national pledges to be approximately 2.9 $GtCO_2e$ (5% of global emissions) in 2020. This includes regions, cities, companies and sectors and excludes overlapping emission reductions from national pledges[40].

[38] Nachmany, M. et al (2015) *The 2015 Global Climate Legislation Study*
[39] UNEP (2015) *Climate commitments of sub-national actors and business*
[40] UNEP (2015) *Climate commitments of sub-national actors and business*

Climate legislation and pledges can be effective at providing a framework for long-term objectives and stability to investors. Development of low-carbon policies and regulation is then necessary to deliver these targets.

Action in individual countries and sectors

The range of emissions reduction pledges now in place has led to increased global coverage of low-carbon policy measures including carbon pricing and vehicle standards. There has also been some limited reform of fossil fuel subsidies. China and the US, the world's highest carbon-emitting countries, are implementing measures to deliver their emission reduction goals (Box 2.5).

- **Carbon pricing.** In 2013 18% of global emissions[41] were covered by carbon pricing in the form of emission trading systems or carbon taxes (Figure 2.2). However, there is a wide disparity in carbon prices. The major emission trading systems (e.g. the EU ETS, pilot systems in China, the North American linked markets and the newly introduced South Korean ETS) trade at carbon prices up to around €10/tCO_2, whilst there are a range of carbon taxes across Europe at varying levels (e.g. €14.50/tCO_2 in France rising to €56/tCO_2 in 2020 and €100/tCO_2 in 2030; €55/tCO_2 in Switzerland[42]).
- **Vehicle emission/fuel efficiency standards.** In 2015, 76% of global transport emissions were covered by legislated fuel efficiency standards (Figure 2.3). These standards are set to become increasingly stringent over time (Figure 2.4) and will require increasing use of ultra-low emission vehicles.
- **Fossil fuel subsidy reform.** In 2014, 13% of CO_2 emissions were linked to fossil-fuel consumption subsidies, at an implicit subsidy of $115/t$CO_2$[43]. This represents around four-times the value of subsidies to global renewable energy. Subsidies encourage inefficient allocation of resources, increase emissions due to inefficient energy use and increase government spending. The major oil and gas exporting countries in the Middle East and North Africa account for around half of global fossil fuel spending. Some countries, including India, Indonesia, and Malaysia have abolished subsidies on some fuels and are reforming others, helped by lower oil prices, whilst others including Iran, Kuwait and Venezuela are considering them.

[41] Non-surface transport combustion emissions
[42] World Bank (2015) *State and Trends of Carbon Pricing*
[43] IEA (2015) *Energy and Climate Change, World Energy Outlook Special Report*

Box 2.5: Action in China and the US

China is the world's highest emitter of CO_2 and the second largest economy. In 2012 it was responsible for 28% (9.3 $GtCO_2$) of global CO_2 emissions, and in 2014 accounted for 9% of global GDP and 19% of the world's population.

In the Copenhagen Accord, China pledged to reduce its carbon intensity by 40-45% by 2020 and set out a five-year plan to achieve this. Other key actions in China include:

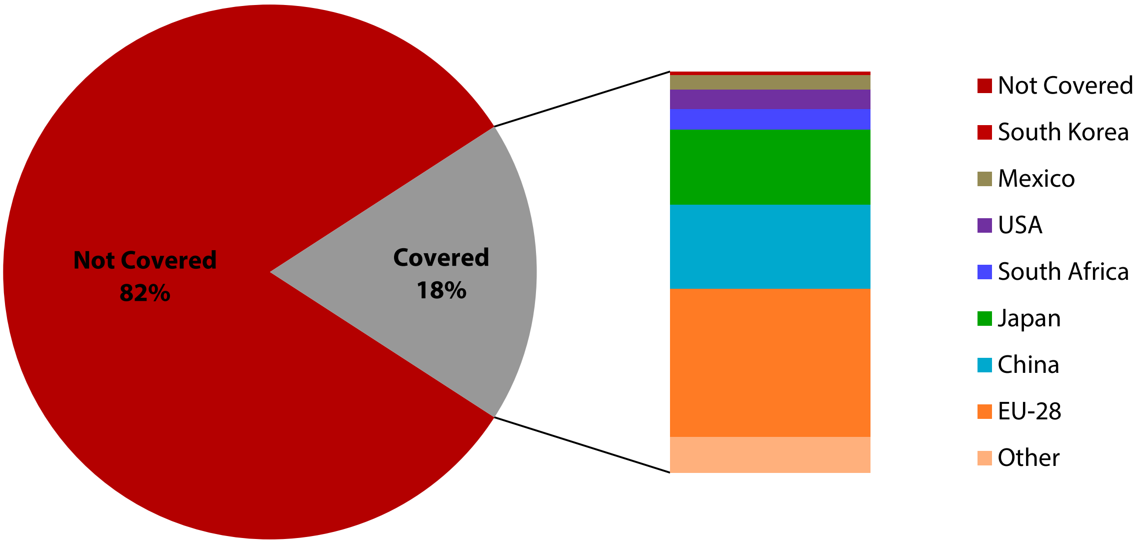
- **Renewables:** Renewable generation capacity in China nearly tripled between 2005 and 2013, and represented 30% of capacity (380 GW) in 2015. It aims to install at least 700 GW of renewable capacity by 2020 and has targets for specific technologies to achieve this.
- **Coal:** In 2012 coal supplied 66% of total energy consumption. There is a target to reduce this to 62% by 2020. In March 2015 the government set out an action plan which limits coal consumption on a decreasing scale to 2020.
- **Carbon pricing:** Carbon trading in China has been in development since 2008. Seven mandatory schemes for emission trading have been introduced, ahead of a national scheme expected to be launched in 2018. The pilot schemes have a coverage of around 1 $GtCO_2e$, which is twice that of total UK emissions.
- **Transport:** China has a target for fuel efficiency of new passenger cars of 117gCO_2/km by 2020 (an improvement of around 4.2% per annum), and for five million electric vehicles on the road by 2020. It is also only one of four countries worldwide to have a target to improve the carbon intensity of heavy duty vehicles and buses, by 11% between 2011 and 2015.

The US is the world's highest per capita emitter of CO_2 emissions and the largest economy. In 2012 the US was responsible for 15% (5.1 $GtCO_2$) of global CO_2 emissions, and in 2014 accounted for 25% of global GDP and 4% of world population.

- **Recent climate policy developments:** In 2015 the US EPA announced plans for a number of key climate regulations. These included publication of the Clean Power Plan outlining measures to reduce emissions from power plants by 30% below 2005 levels by 2030, and a change to the legal classification of emissions from planes to bring them in scope of climate regulation.
- **Transport:** The US has a fuel efficiency standard for new cars of 93 gCO_2/km for 2025 (requiring a 6.8% annual improvement). In 2014 it also introduced fuel efficiency standards covering HGVs, which are expected to save 76 $MtCO_2$ per year by 2030.
- **Energy consumption:** New energy efficiency standards have been set for household and industry products (e.g. the phasing out of incandescent light bulbs), which are cumulatively expected to save at least 3 $GtCO_2$ by 2030

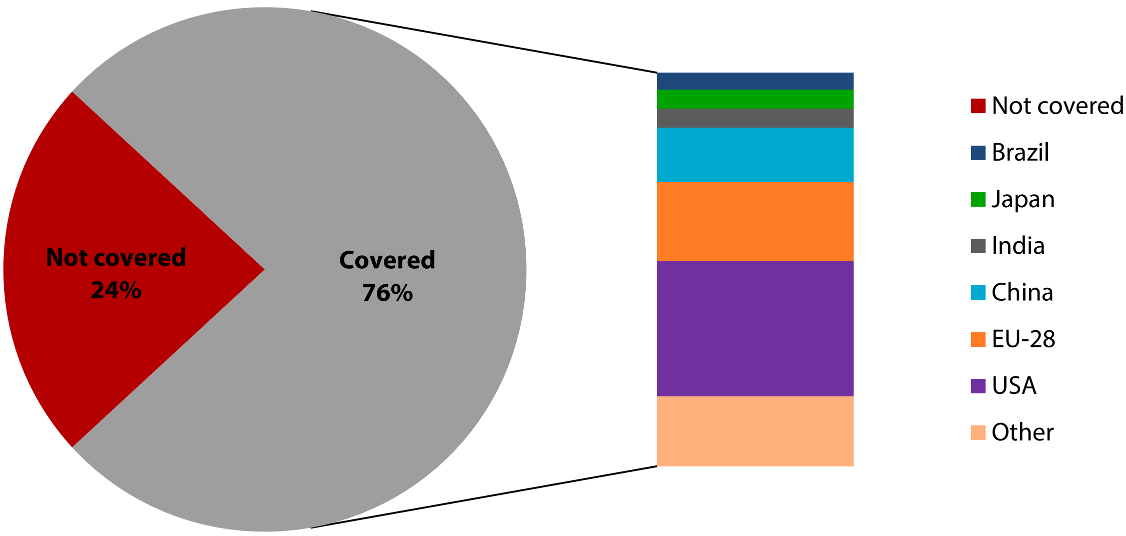
Source: IRENA (2014) *Renewable Energy Prospects in China*; ICCT (2014) *The State of Clean Transport Policy*

Figure 2.2: Proportion of global emissions covered by a carbon price (2013)



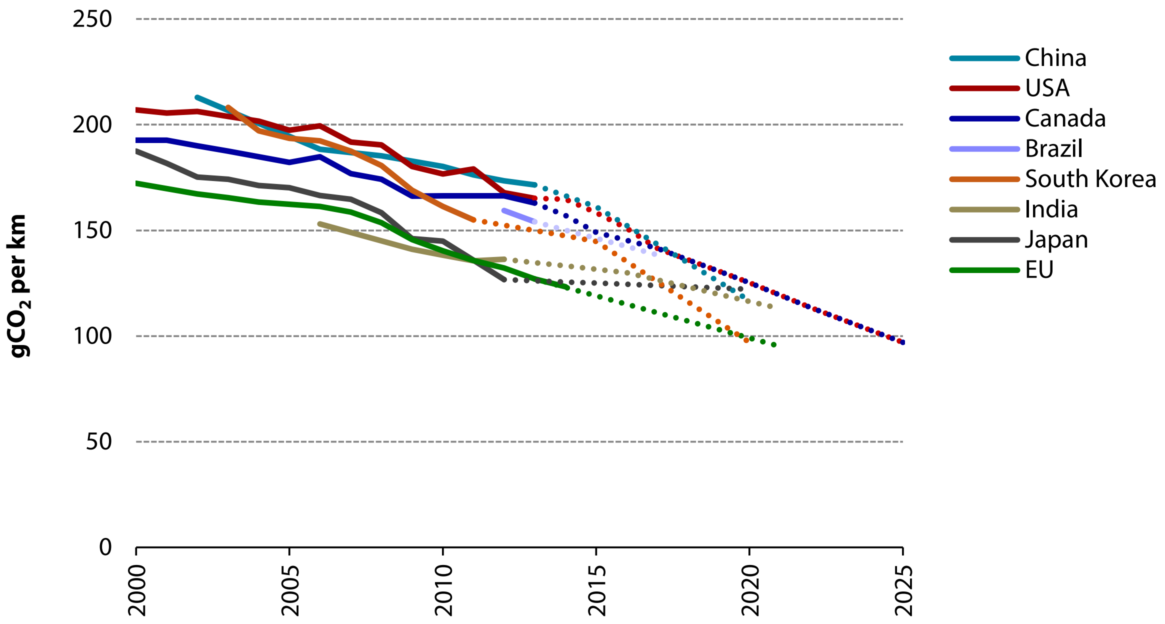
Source: CCC calculations based on World Bank (2014) and various national sources
Notes: Proportion of global emissions excludes surface transport emissions. Excludes expansion of scope of Californian ETS in 2015; proportion covered would be higher taking this into account.

Figure 2.3: Proportion of global surface transport emissions covered by emission/fuel efficiency standards (2015)



Source: CCC calculation based on www.transportpolicy.net and IEA emissions data.

Figure 2.4: Fuel efficiency/emission standards for cars in selected countries (2000-2025)



Source: The International Council on Clean Transportation (www.theicct.org/info-tools/global-passenger-vehicle-standards)
Notes: Solid lines reflect historical standards, dashed lines reflect future enacted or proposed targets.

Developments in low-carbon technologies

As the coverage of low-carbon policy continues to widen, deployment of low-carbon technologies has increased at the global level. As a result, costs of key low-carbon technologies have fallen substantially in recent years:

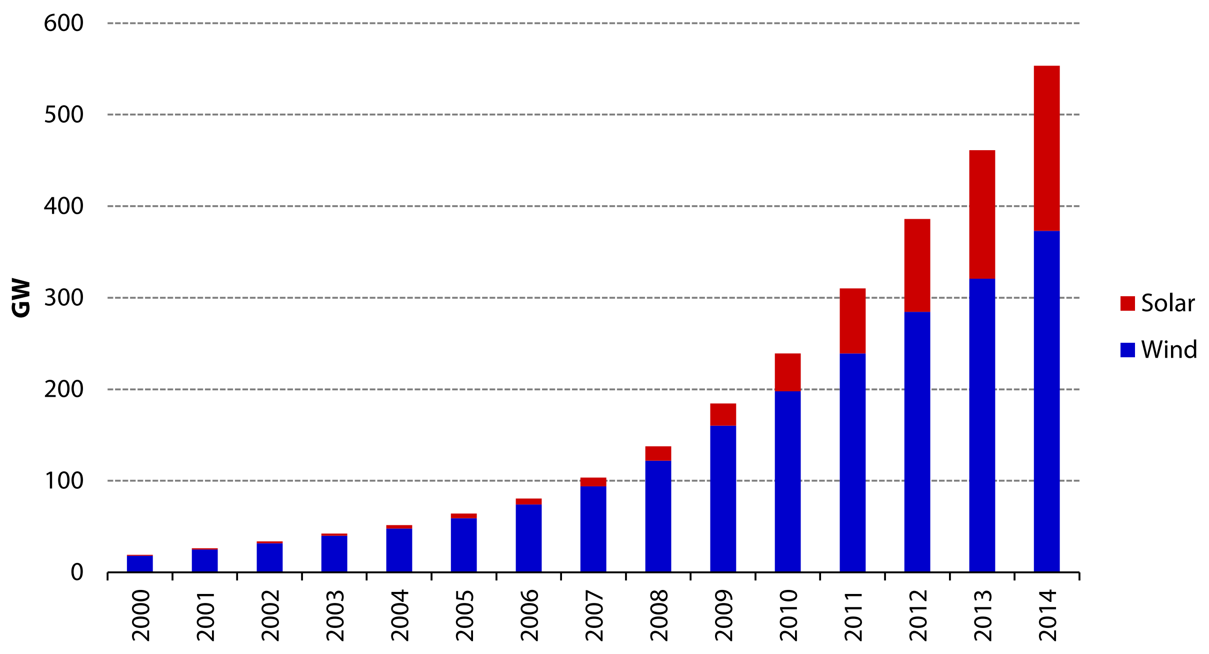
- **Renewables deployment.** In 2014, 28% of all globally installed electricity capacity was made up of renewables, with a slightly lower proportion of generation - 23% - given the lower load factors associated with intermittent renewable generation. Recent growth in deployment of solar and wind has been strong.
  - Globally installed solar and wind capacity has increased over 130% since 2010, from 239 GW to 553 GW in 2014 (Figure 2.5).
  - In the past four years there has been over a four-fold increase in global solar capacity, reaching 180 GW in 2014. One quarter of the additional capacity was in Europe, nearly a fifth in China and a tenth in the US.
  - Global wind capacity was 373 GW in 2014, nearly double the level in 2010. China, the US and Germany remain the top markets for installed wind power with 31%, 18% and 11% of global capacity respectively.
  - Overall, wind and solar accounted for 3.8% of electricity generation in 2014, an increase from 1.7% in 2010[44]. In comparison, fossil fuels generated the majority of electricity (67%),

[44] BP (2015) *Statistical Review of World Energy 2015*

with the remaining 29% supplied by nuclear and other renewables, mainly hydropower.

– IEA analysis[45] suggests that the annual installation rate of wind and solar capacity will need to almost double by 2020, from nearly 80 GW per year between 2010 and 2014 to 145 GW per year to 2050, in order to be on a 2°C consistent path.

Figure 2.5: Installed global wind and solar capacity (2000-2014)



Source: BP (2015) *Statistical Review of World Energy 2015*

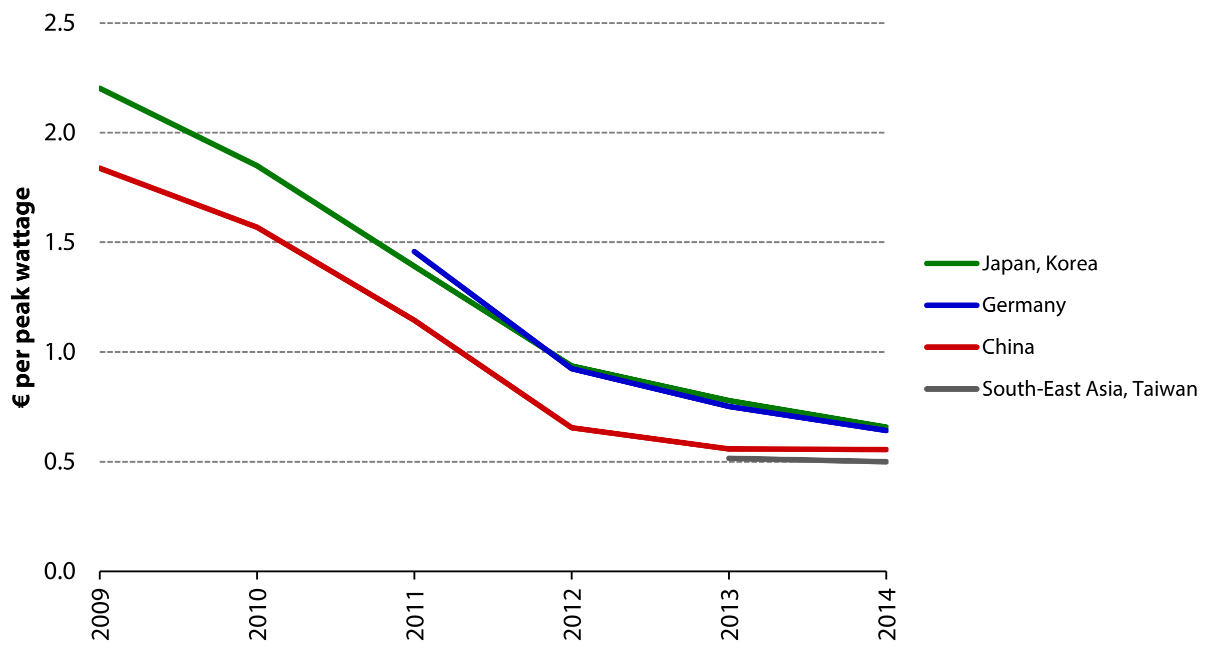
- **Electric vehicles.** Global sales of electric vehicles (battery electric and plug-in hybrid) reached 300,000 in 2014, an increase of 53% over 2013. This is only 0.4% of global car sales, but reflects a very early market. Norway had the highest share of electric vehicles in new car sales, at 12.5% (compared with 0.6% in the UK).
- **Carbon Capture and Storage (CCS).** There are 14 large-scale CCS projects in operation and eight under construction, with a total capture capacity of 40 $MtCO_2$ per year. The first large-scale power sector project, at Boundary Dam in Canada, became operational in 2014. A further eight large-scale power CCS projects, mainly in North America, are expected to be operational by 2020. However, there have been problems in some projects, and questions remain whether the flow of projects is sufficient.
- **Technology costs.** Costs of key low-carbon technologies, including renewables and batteries, have fallen substantially in recent years (Figures 2.6 and 2.7). As a result, costs of electricity from onshore wind and solar PV are in the range of fossil fuel-power generation costs in many places.

[45] IEA (2015) *Energy Technology Perspectives 2015*

- Between 2009 and 2014, solar PV module prices are estimated to have fallen by around 70%. As a result, the generation cost of utility-scale solar PV is now competitive with fossil generation in some regions (e.g. Dubai and Chile).
- Costs of onshore wind continue to fall, though more slowly than for solar PV. Many projects are cost-competitive with fossil fuel generation, with the best projects generating at $50/MWh compared with global fossil-based generation costs of $40-120/MWh in 2014.[46]
- A comprehensive study of battery costs estimated costs of lithium-ion batteries to have fallen by 14% per year between 2007 and 2014[47]. Since battery costs make up the bulk of the cost difference between electric and conventional vehicles, these reductions bring electric vehicles closer to the cost-competitive level. However, reductions are dependent on increasing demand for electric vehicles, which will require continued government support.

In the next section we consider whether countries' pledges on emissions reduction are consistent with global emission pathways to achieve 2°C.

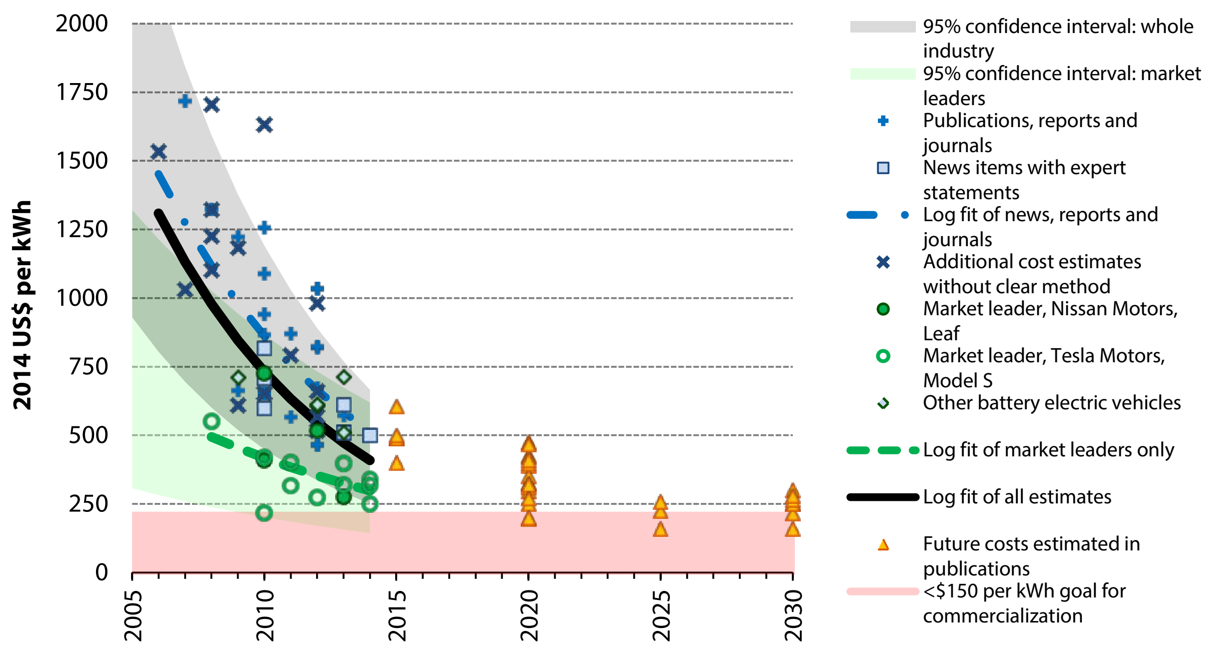
Figure 2.6: Developments in solar PV module prices



Source: www.pvxchange.com

[46] International Renewable Energy Agency (2015) *Renewable Power Generation Costs in 2014*
[47] Nykvist, B. & Nilsson, M (2015) Rapidly falling costs of battery packs for electric vehicles, Nature Climate Change 5, 329-332

Figure 2.7: Costs of battery packs in Battery Electric Vehicles



Source: Nykvist, B. & Nilsson, M. (2015) Rapidly falling costs of battery packs for electric vehicles, *Nature Climate Change*
Notes: Reflects costs of Lithium-ion batteries.

3. Consistency of UN pledges with global emissions paths to 2°C

The aim of this section is to assess whether current actions and pledges are consistent with global emissions pathways to 2°C. We start by looking at emission pathways on track to meet this objective and go on to compare these with global emissions implied by countries' emissions reduction pledges.

Our conclusion is that current pledges are not on a cost-effective path to 2°C, but that this gap can be reduced through remaining pledges, by increasing ambition in pledges and through further commitments to reduce emissions beyond 2030.

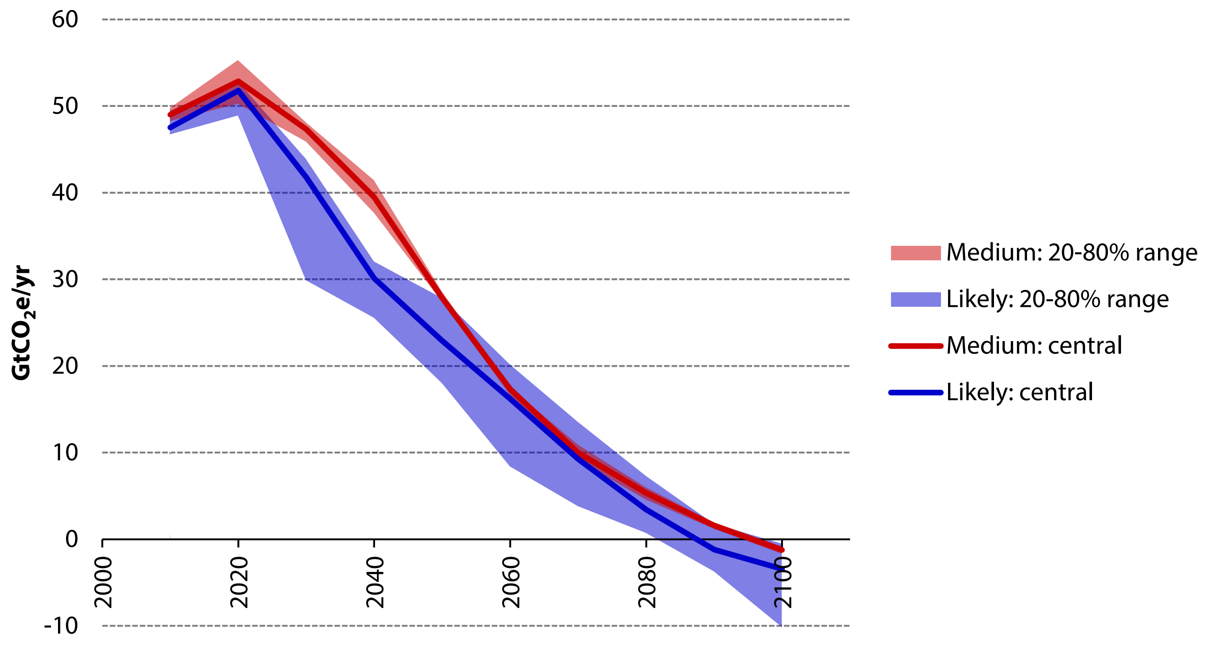
Cost-effective global emissions paths to 2°C

Lowest-cost pathways with a substantial likelihood of staying below 2°C require peaking around 2020 and then entail steep reductions towards net zero or even negative emissions by the end of the century (Figure 2.8).

- The IPCC's Fifth Assessment Report concluded that pathways that are likely (i.e. with at a least a 66% chance) to stay below 2°C show a 40-70% reduction in global greenhouse gas emissions by 2050, relative to the 2010 level of 49 $GtCO_2e$, and have emissions near zero or below by 2100.

- These conclusions are derived from runs of several different models which simulate global energy and emissions using different methods and levels of detail (Box 2.6).
- Studies by the IEA[48] and the recent Deep Decarbonization Pathways Project[49] confirm such pathways remain technically feasible without changing global economic and development prospects.
- In the IEA's '2 degree' scenario, consumption of coal peaks before 2020 and falls 42% between 2012 and 2035. The share of power generation coming from unabated coal falls from 40% in 2012 to 0.5% in 2050, while the share for unabated gas falls from 22% to 7% and low-carbon increases from 32% to 93% of electricity generation over the same period.

Figure 2.8: Global emission pathways consistent with 2°C



Source: IPCC AR5 WG3 database
Notes: Chart shows global emission pathways consistent with a 'likely' (i.e. at least 66%) and 'medium' (i.e. 50-66%) chance of staying below 2°C in 2100. 10 model scenarios are available in the IPCC database for a likely chance and four for a medium chance. Shaded areas give the range within which 60% of the model scenarios lie, while central lines give the median emissions.

[48] IEA (2015) *Energy and climate change: World Energy Outlook Special Report*
[49] Deep Decarbonization Pathways Project (2015) *Pathways to deep decarbonization 2015 report*

Box 2.6: Integrated Assessment Models and scenarios of future global emissions

Quantitative estimates of future global emissions consistent with different levels of warming come from Integrated Assessment Models (IAMs). The IPCC's most recent assessment (and the most recent UNEP Gap Report) used 1,184 scenarios produced by 31 IAMs. Each IAM simulates (at a minimum) the global energy system, but they have important differences in scope, detail and numerical methods:

- Models differ dramatically in the level of detail they contain. Some attempt to include all sectors of the economy and even have a simple representation of how emissions translate into climate change. Some have much more disaggregation of different technology options and regions of the world than others.
- Some assume perfect foresight (i.e. they optimise at each point in time as if they know future demand, targets, options and costs precisely). Others are myopic and optimise based only on information at that point in time in the simulation.
- They take very different economic approaches: for example, trade may be assumed to operate perfectly with a single global price for energy commodities and carbon permits. In other models trade is not modelled explicitly or is more limited.
- Individual simulations are driven by different parameters or restrictions on the future. For instance, some are driven by a single global carbon price or emissions target, others by a more fragmented development of climate action. Some apply limits on certain options to reduce emissions (such as nuclear power or bioenergy).

All IAM scenarios are simplifications, and these differences mean they are not all equally likely visions of the future. They help to give insights into costs and technology deployment under specific assumptions, but they have an approach to socio-economic behaviour and innovation that is highly simplified. There is always scope for unpredicted economic shocks, new technologies, and changes in behaviour to affect the future. Care should be taken therefore in judging the feasibility of different futures on the basis of these model results.

Delayed action such that global emissions peak after 2020 will raise the costs of achieving climate goals and introduce heavier dependence on technologies which are currently unproven at scale. Ultimately, continued delay will lead to likely warming above 2°C:

- Peak temperature depends largely on cumulative emissions over time (see Chapter 1). This means paths with delayed peaking require more rapid reductions post-peak and have a stronger emphasis on negative emissions in the second half of the century to maintain the same level of warming.
- Deeper and more rapid post-peak reductions lead to higher costs.
  - According to IPCC AR5, delaying action until 2030, even with only moderate emissions growth, leads to a 14-50% increase in costs relative to immediate action.
  - IEA analysis[50] also considered a delay scenario where global emissions rise in line with current policies to 2020, but need to be cut more sharply thereafter to get back on a

[50] IEA (2013) *Redrawing the Energy-Climate Map*

trajectory compatible with the 2°C scenario. In this scenario investment costs of $1.5 trillion are avoided in the period to 2020, but an additional $5 trillion of investments are required between 2020 and 2035, through the early scrappage of assets and foregoing early learning and development opportunities.

- Many 2°C scenarios already assume large-scale use of bioenergy with Carbon Capture and Storage to provide negative emissions. There are questions about availability of sustainable bioenergy resource to levels assumed. Other negative emission technologies could play a role but are currently speculative (Box 2.7).
- If global emissions are allowed to grow to 55 $GtCO_2e$ or more in 2030, many energy system models are unable to find a low enough path for emissions to keep a 50% chance of 2°C, even with optimistic assumptions about technology deployment and global co-operation.

Box 2.7: The role of negative emissions

There are several ways to remove CO_2 from the atmosphere - negative emission technologies - including afforestation and other land-use measures (AFOLU), bioenergy with carbon capture and storage (Bio CCS or BECCS), and direct air capture. These are at different stages of development, but most models of future emissions currently include AFOLU and BECCS as potentially cost-effective options.

For pathways that keep a high chance of 2°C, many models choose to deploy BECCS within the next couple of decades. By the latter half of the century AFOLU and BECCS play an extensive role such that net global CO_2 emissions become zero or negative.

To the extent both CCS and sustainable bioenergy are both available, combining them is a sensible way to maximise emissions reduction. There are however issues with BECCS, and negative emissions technologies more widely, that are not captured well in models:

- BECCS and other industrial negative emissions technologies are untested at scale. Their future costs and public acceptability are uncertain. The example of CCS has so far shown that development may not occur as fast as initially expected.
- Very high use of bioenergy brings with it risks over environmental sustainability. Bioenergy grown on agricultural land involves trade-offs with food security, and not all bioenergy crops produce carbon savings relative to fossil fuels. There can also be trade-offs (or benefits) to water availability and biodiversity.

Estimates of the global sustainable bioenergy resource vary greatly, but we concluded in our 2011 Bioenergy Review that a sensible planning assumption was up to around 110 Exajoules by 2050[51]. Many model scenarios for 2°C considered by the IPCC exceed this limit (Figure B2.7).

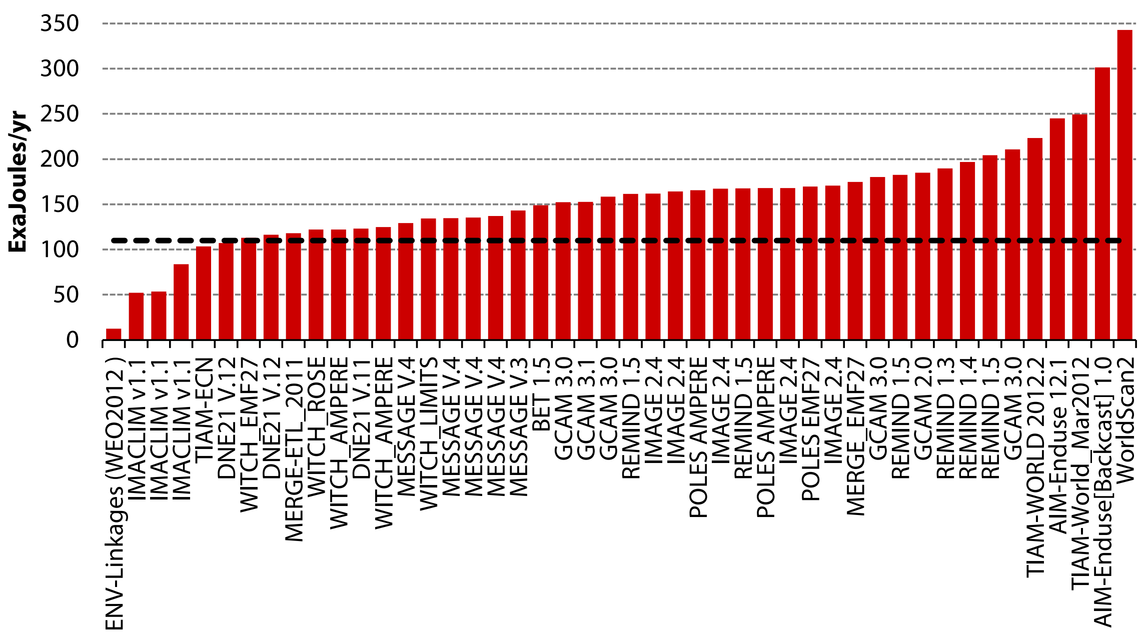
[51] CCC (2011) *Bioenergy Review*

Box 2.7 (cont.): The role of negative emissions

Model scenarios do exist which achieve a high chance of 2°C without BECCS but they require radical emissions reductions over the next 10-20 years through efficiency and other low-carbon sources[52].

To make a substantial contribution, negative emission technologies will require international effort to scale them up and reduce costs. While potentially key options, they may well not be deployed to the levels suggested in these models. This underlines the need for near-term emissions cuts to keep within a sensible global carbon budget over the 21st Century.

Figure B2.7: Global 2050 bioenergy use assumed by models in 2°C pathways



Source: IPCC AR5 WG3 database; CCC (2011) *Bioenergy review*.
Notes: Black line indicates sustainable upper limit identified in CCC Bioenergy Review. Scenarios included are those designed to stabilise at 450ppm concentration and with full technology deployment.

Current forecast of global emissions under UN pledges

In Section 1 we set out the latest UN pledges made in advance of the Paris conference. As of 2 October 146 countries had made submissions, representing 87% of global emissions.

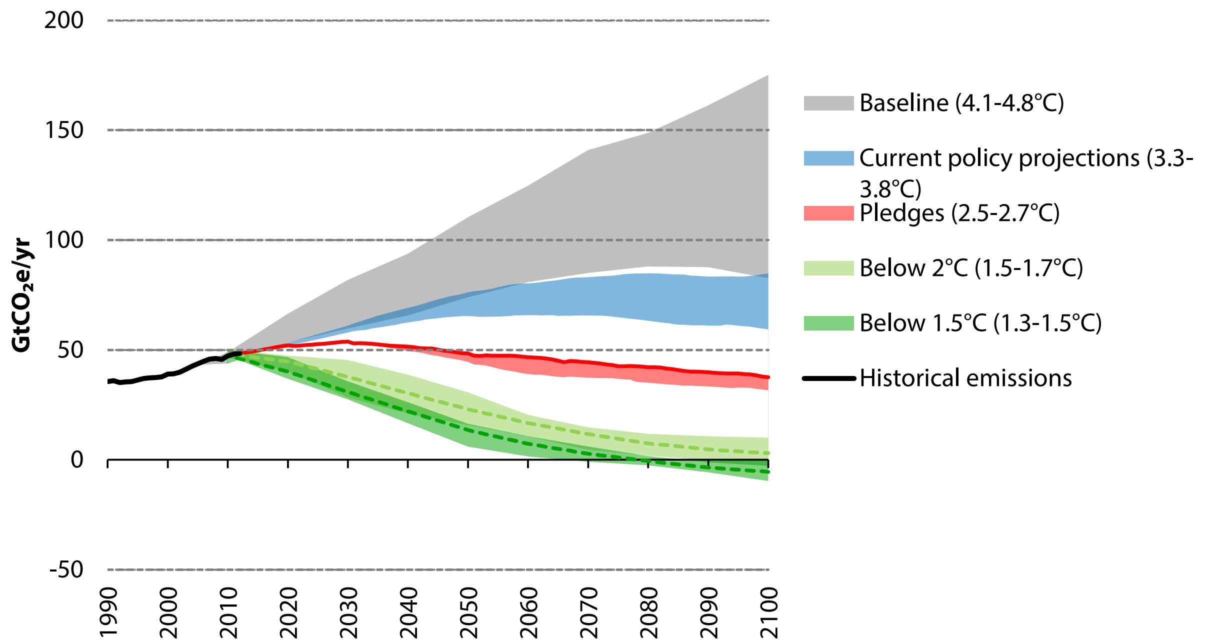
Analysis of the main UN pledges made so far suggests that, if successfully implemented, these would substantially reduce future global emissions and therefore expected future global temperature increases (Figure 2.9). However, they leave the level of emissions in 2030 above the

[52] Riahi et al. (2012) Chapter 17 - Energy Pathways for Sustainable Development; IIASA Global Energy Assessment - Toward a Sustainable Future

level consistent with a cost-effective 2°C pathway.

- Median estimates of business-as-usual global emissions in 2030 are 68 $GtCO_2e$.
- Analysis[53] of the INDCs suggests that global emissions are on track to reach 53-55 $GtCO_2e$ in 2030.
- Pledges would therefore deliver substantial emission reductions and could lower expected warming in 2100 from around 4°C to around 2.7°C, with the potential to reach 2.5°C under more stringent conditions[54].
- Current pledges are not on a lowest-cost track to 2°C. Lowest-cost pathways from 2020 that give at least a 50% likelihood require global emissions of 42-47 $GtCO_2e$ or less by 2030. This implies a gap of 6-13 $GtCO_2e$ compared with the INDCs in this analysis.

Figure 2.9: Effect of the UN pledges on long-term global emissions pathways



Source: Climate Action Tracker (2015) *INDCs lower projected warming to 2.7°C: significant progress but still above 2°C*

[53] Climate Action Tracker (2015) *INDCs lower projected warming to 2.7°C: significant progress but still above 2°C*. This analysis covers 19 INDCs, covering 71% of global emissions and an estimate for India to bring this to 77%.

[54] The 2.7°C estimate is based unconditional or lower-end pledges being delivered, and the 2.5°C estimate is based on conditional or upper-end pledges being met.

The gap between pledges and cost-effective 2°C pathways can be reduced through remainingpledges, by increasing ambition in existing commitments, and further commitments to reduce emissions beyond 2030:

- INDCs are yet to come from around 50 countries, and 23% of global emissions are not covered in the above analysis. This includes contributions from the international aviation and shipping sectors, which together represent 3% of global emissions but are expected to grow rapidly in coming decades.
- Analysis by Climate Action Tracker (CAT) suggests that the ambition of INDCs vary, with some countries not being in line with a 'fair' contribution to limit warming to 2°C; others have put forward INDCs inconsistent with their national 2050 targets.
- Many INDCs are backed up with some form of climate legislation or executive policies with detailed plans of how these will be delivered. This provides credibility that their INDC target will be met and an opportunity to strengthen existing commitments.
- Many countries now have longer term emission reduction targets. For some, current pledges are incompatible with these, and all countries will need to raise post-2030 ambition in order to meet these.

Reducing the gap is challenging and will require effort to increase ambition across nations and sectors. A key way to achieve this will be creation of a review mechanism at the Paris conference to increase ambition to 2030 and beyond.

4. EU and UK 2050 objectives

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

- When advising on the UK 2050 target in 2008, we stated it was difficult to envisage a global climate deal which does not involve the UK reducing its emissions to a per person level consistent with the global average needed to meet the climate objective. This is because it will be hard to find other nations much below the average, especially in a world of substantially-declining emissions.
- On the basis of a world population around 9.7 billion in 2050[55], a 40-70% global cut in greenhouse gas emissions below 2010 levels is equivalent to emissions per person of 1.5-3 tCO_2e in 2050.
- Applying this per person average to a projected UK 2050 population of around 74 million[56] equates to domestic emissions in 2050 of 107-225 $MtCO_2e$, a 73-87% reduction below 1990 levels[57]. The UK's 2050 target of at least an 80% reduction is at the centre of this range. This would apply to all emitting sectors including international aviation and shipping.
- Applying the same logic to the EU28 as a whole leads to a 74-87% reduction below its 1990 level (again, including international aviation and shipping).

[55] Medium variant from UN (2015) World Population Prospects, 2015 Revision
[56] Low migration variant from Office of National Statistics (2013) 2012-based National Population Projections
[57] 1990 carbon budget baseline plus international aviation and shipping bunker emissions, DECC (2015) *Final UK greenhouse gas emissions national statistics: 1990-2013*

5. Implications for the fifth carbon budget

Our advice on the fifth carbon budget must take into account international circumstances. In this chapter we have shown that the internationally agreed climate objective and the global emission pathways to achieve this are still feasible but increasingly challenging:

- There are significant climate change risks and costs involved in delaying action.
- Implementation of low-carbon technologies, laws, measures and pledges has progressed, giving higher confidence that a global deal can be delivered once agreed. The UK is acting in a context of increasing moves towards decarbonisation globally.
- Countries are delivering emissions reduction pledges ahead of the Paris conference in 2015. Current pledges are not on the lowest-cost path to the climate objective, and ambition needs to be ramped up to bridge this gap.
- The UK is an important player in driving forward EU and international ambition. Both the UK and EU have objectives to reduce their greenhouse gas emissions in 2050 to at least 80% below 1990 levels. These objectives remain appropriate in light of the latest evidence regarding global emissions pathways consistent with 2°C,.

We will continue to monitor closely further progress towards a global deal, in particular outcomes from the Paris conference and progress to review and increase ambition post-2030.

Chapter 3:
The EU and UK share of international action

Introduction and key messages

The Climate Change Act requires us to assess European circumstances when advising on carbon budgets. Current and planned EU climate policy is important because it sets targets for Member States and provides some of the main policy instruments for reducing emissions.

In this chapter we set out the EU emissions target for 2030 agreed by the EU's Member States, the implications of this for UK action to 2030 (which is the middle of the fifth carbon budget period), and consider the role of the EU in contributing to closing the global emissions gap for 2030 identified in Chapter 2.

Our key messages are:

- The EU's Member States have agreed a 2030 target for EU emissions of at least 40% below 1990 levels. This is also the EU's collective pledge for 2030 as part of the UN process towards a global deal. It is currently one of the more ambitious pledges.
- Our best estimate is that the EU 2030 agreement could mean a reduction in UK emissions over the fifth carbon budget period of 54% below 1990 levels. The precise UK share cannot be known with certainty until final rules governing Member States' shares are agreed. Reflecting these uncertainties suggests the UK will contribute emission reductions within a range of 51-57%.
- The EU's agreed 2030 target is at the lower end of ambition compared to the cost-effective path to its 2050 objective of an 80-95% reduction below 1990 levels. It is below estimates for a 'fair' EU share of a global 2°C pathway, and the UK's likely contribution is at the low end of ambition compared to its global 'fair' share.

- The EU should be prepared to raise its ambition as a contribution to closing a global emissions gap in 2030, provided other countries make similar commitments. The UK Government has previously argued for a 50% reduction in EU emissions in 2030 below 1990 levels.

We set out the analysis underpinning these conclusions in four sections:

1. The EU's 2030 target and its UN pledge
2. UK share of EU action to 2030
3. EU contributions to closing a 2030 global emissions gap
4. Implications for the fifth carbon budget

1. The EU's 2030 target and its UN pledge

The EU's Member States have agreed a 2030 emissions target, and this also forms the basis for the EU's collective pledge under the international UN negotiations (Chapter 2). In this section we outline the EU's agreed 2030 target, timelines for its implementation, and implications for the pace of EU action.

The emissions target Member States agreed for the EU in 2030 is for at least a 40% reduction below 1990 levels[58]. The EU has formally submitted this as their pledge, collectively covering all the 28 countries in the EU, to the UN process leading to Paris[59]. A greater proportion of the reduction is to be achieved in sectors covered by the EU's Emission Trading System (EU ETS):

- The agreement for at least a 40% reduction in emissions by 2030 compared to 1990 levels (equivalent to 35% below 2005 and 25% below 2012) specifically leaves open the possibility of increasing ambition beyond 40% in light of developments in Paris.
- The target is to be achieved domestically, without purchase of international offset credits.
- Sectors covered by the EU ETS will reduce their emissions by 43% compared to 2005 levels. This means tightening the rate of reduction in the EU ETS cap, from 38 $MtCO_2e$ per year in Phase III (i.e. 1.74% of the average level of the EU ETS cap over 2008-12) to 48 $MtCO_2e$ per year in Phase IV (i.e. 2.2% of the 2008-12 average).
- Sectors not covered by the EU ETS (the 'non-ETS' sectors) will reduce their emissions by 30% compared to 2005 levels.

The EU has also agreed a wider set of measures as part of the 2030 framework, including targets for renewable energy and energy efficiency, and significant structural reform of the EU ETS:

- **Renewable energy.** The agreement is for an EU-wide renewable energy target of at least 27% by 2030. This is to be binding at the EU level but not translated into national targets.
- **Energy efficiency.** The agreement endorsed an indicative and non-binding energy efficiency improvement of at least 27% by 2030. This will be reviewed in 2020, with reference to a 30% target.

[58] European Council Conclusions October 2014 (EUCO 169/14)
[59] http://www4.unfccc.int/submissions/INDC/Published%20Documents/Latvia/1/LV-03-06-EU%20INDC.pdf

- **Reform of EU ETS.** The European Parliament approved legislation in 2015 to introduce a 'Market Stability Reserve' for the EU ETS (Box 3.1). The purpose of this is to address the current surplus of allowances within the system, and to improve the resilience of the system to major shocks.

Box 3.1: The EU ETS Market Stability Reserve

Since the start of Phase III of the EU ETS (2013-20) there has been a large imbalance between supply and demand for allowances. A significant surplus of allowances has resulted in a low price of carbon under the system.

The surplus arose because demand weakened, largely but not exclusively as a result of the recession, whereas the annual supply of allowances was fixed.

In an attempt to provide a long-term solution, the EU has agreed to implement a 'Market Stability Reserve' (MSR)[60]. The aim of this is to address the current surplus of allowances and to improve the system's resilience to major shocks:

- The MSR operates according to a set of pre-defined rules, which adjust the supply of allowances depending on market conditions.
- When the pool of surplus allowances is large, new allowances are put into the MSR rather than auctioned. If the surplus shrinks below a certain level then allowances are released from the MSR.

The result is that supply and demand for allowances should be more closely aligned, with more stable incentives for emissions reduction.

While the 2030 framework was agreed by the European Council in October 2014, it is likely to take several years to implement and the final implications may not be known until around 2020:

- The agreement by the European Council reflects a high-level agreement on targets for emissions, renewables and energy efficiency.
- Implementation of the 2030 framework is being undertaken in a staged approach.
  - The first stage covers the EU ETS: in 2015 the European Commission published a legislative proposal for the rules covering Phase IV of the scheme, and legislation establishing the Market Stability Reserve was approved.
  - The second stage covers the non-ETS sectors, and more information on the approach to these is expected in 2016.
- The experience of implementing the EU's 2020 targets suggests it is likely to be several years until final legislation is passed and the full implications of this are known (i.e. potentially not until around 2020 - Box 3.2)

[60] http://ec.europa.eu/clima/policies/ets/reform/index_en.htm

Box 3.2: The EU's 2030 agreement and timelines for implementation

The EU Council, which comprises the heads of all 28 Member State Governments, agreed the EU's 2030 emissions target in October 2014. This was a high-level agreement with details of the implementation to be worked up and agreed over the coming years[61]:

- The agreement in 2014 was for a 2030 emissions reduction of at least 40% below 1990 levels. The reduction is 43% below 2005 levels for those sectors covered by the EU ETS, and 30% below 2005 in other sectors.
- The agreement also set out some implementation details. For the EU ETS this includes an increase in the annual rate at which the cap is reduced, confirmation that free allocation to protect against competitiveness risks will continue, and the creation of new modernisation and innovation funds. For the non-ETS sectors it was specified that the maximum Member State reduction would be 40% below 2005 levels by 2030.
- In July 2015 the European Commission published a proposal for revised EU ETS legislation reflecting the 2014 Council agreement. A proposal for the non-ETS sectors is expected in 2016. Both of these proposals will need to be agreed by the Parliament and Council.

Experience with the EU's 2020 targets suggests that the final implications of the 2030 agreement for individual Member States may not be known for several years and possibly not until around 2020:

- The EU Council agreed the EU's high-level 2020 targets in March 2007.
- In January 2008 the European Commission proposed legislation to support meeting these targets. These were agreed and passed into law in April 2009.
- The final details of implementation were not agreed until 2013. For example, this reflected detailed consideration of rules governing free allocation of allowances to industry under the EU ETS (including which sectors were considered exposed to carbon leakage).

Therefore, the process from agreeing the EU's 2020 targets until final implementation took around six years. Applying this to the EU's agreement in 2014 for a 2030 target suggests the final implications may not be known until around 2020.

Overall, the implication is that the pace of EU-wide decarbonisation will increase during the 2020s and will need to increase further after 2030 in order to be on track to 2050:

- To meet the EU's 2020 target of a 20% reduction in emissions below 1990 levels a reduction of 0.1% per year is required from 2012 (the latest year for which data is available). In practice, EU emissions are expected to outperform the 2020 target and fall at least 24% below 1990 levels, implying an annual reduction of 0.7% per year from 2012 levels.
- The EU's 40% target for 2030 would require a 2.8% reduction per year from the 2020 target, or 2.3% per year taking into account the expected 2020 over-performance (and even less if the 2020 reduction is greater than 24%).
- After 2030 a further increase in effort will be necessary, to around 5% per year, in order to reach the 2050 goal of at least an 80% reduction below 1990 levels.

[61] European Council Conclusions October 2014 (EUCO 169/14)

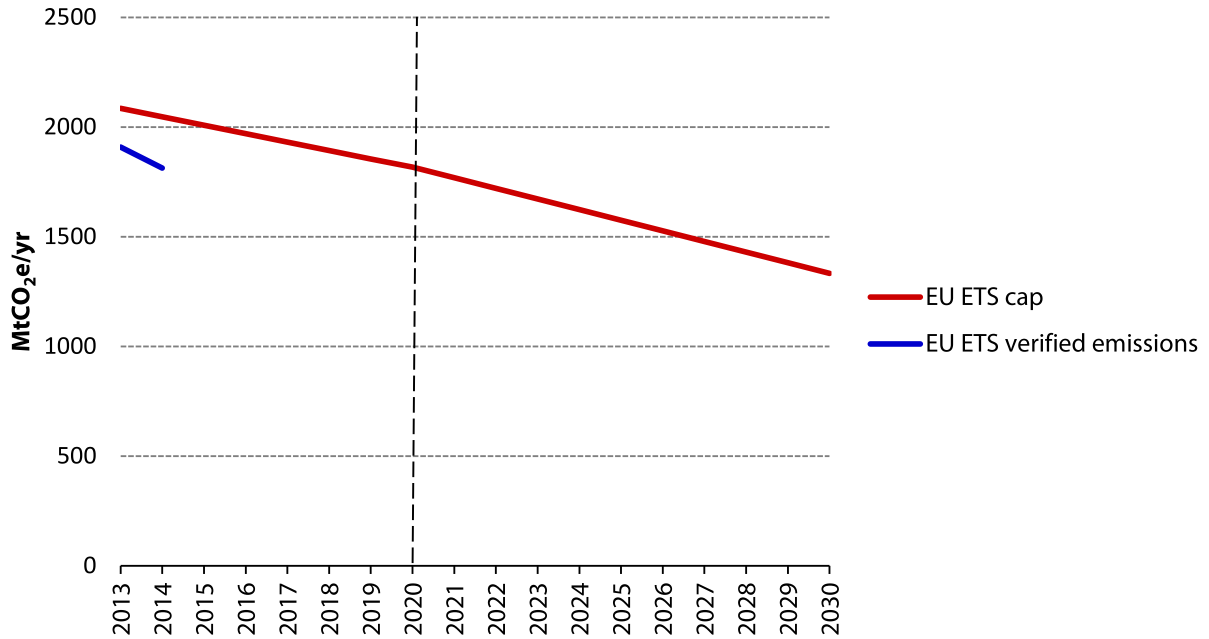
2. UK share of EU action to 2030

Under the Climate Change Act we are required to assess the contribution towards meeting carbon budgets by sectors covered, and not covered, by the EU ETS. In this section we set out the UK's likely share of reductions under the EU's 2030 agreement, for both the EU ETS and non-ETS sectors over the fifth carbon budget period.

The UK's share of the EU ETS cap to 2030

Under the 2030 agreement made by EU Member States, the EU-wide ETS cap will tighten by 2.2% per year[62] after 2020 (i.e. by 48 $MtCO_2e$ per year). This is an increase from the 1.74% (38 $MtCO_2e$) annual decline before 2020. The result is that the EU-wide cap will be 43% lower than 2005 levels by 2030 (Figure 3.1).

Figure 3.1: EU ETS cap to 2030



Source: Consolidated EU ETS Directive (2003/87/EC); European Commission COM(2015) 337 - Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC to enhance cost-effective emission reductions and low-carbon investments; European Environment Agency EU ETS data viewer

Notes: Cap covers stationary installations only and falls at 1.74% (38.3 $MtCO_2e$ per year) to 2020, and 2.2% (48.4 $MtCO_2e$ per year) post-2020.

[62] This is a linear annual reduction, calculated as 2.2% of the average level of the EU ETS cap between 2008 and 2012.

There are complexities in identifying the UK's share of the EU-wide cap (Box 3.3). Based on the European Commission's draft legislation published in 2015, our best estimate of the UK's share of the EU ETS cap over the fifth carbon budget period is 610 $MtCO_2e$[63].

- There are a range of uncertainties given that the final rules for the EU ETS after 2020 have not yet been agreed. Reflecting these uncertainties suggests the range for the UK share of the EU ETS cap could be 555-670 $MtCO_2e$ over the fifth carbon budget period.
- Our estimates assume the impact of the Market Stability Reserve (MSR) is neutral over the budget period. To the extent that allowances are placed in or released from the MSR, the UK's share of the cap could differ in specific years (Box 3.4).

Box 3.3: Calculating the UK's share of the EU ETS cap

The UK's share of the EU ETS cap – which defines net emissions for the traded sector – is determined by two factors:

- The level of the EU ETS cap
- The proportion of the cap attributable to the UK.

For Phase III of the EU ETS (covering the period to 2020), these two factors can be accurately assessed in advance, given that they are determined by rules published in the legislation governing the EU ETS.

For Phase IV of the EU ETS (covering 2021-2030) the European Commission proposed, in July 2015, a revised set of rules reflecting the EU Council's agreement on a 2030 EU emissions target[64]. This will affect the UK's share of the EU ETS cap, as both the level of the EU cap and the proportion attributable to the UK could differ compared to Phase III:

- **EU ETS cap.** In Phase IV the EU cap will tighten at a faster rate compared to Phase III. The cap falls by a fixed linear amount per year. In Phase III this was 1.74% of the average level of the EU cap between 2008-12, which equates to a reduction of 38.3 $MtCO_2e$ per year. In Phase IV the EU Council has agreed this rate of reduction will increase to 2.2%, equating to an annual linear reduction of 48.4 $MtCO_2e$. The result is that the EU cap, excluding aviation, will reduce from 2,084 $MtCO_2e$ in 2013 to 1,816 $MtCO_2e$ in 2020 and 1,333 $MtCO_2e$ in 2030 (Figure 3.1). As the fifth carbon budget covers the period to 2032, we assume the same rate of reduction continues for those two additional years.

- **The proportion of the cap attributable to the UK** will reflect the UK's share of each of the four elements which make up the cap in Phase IV: auctioned allowances, freely allocated allowances, the Innovation Fund and the Modernisation Fund. The UK will also have a share of the separate aviation cap:

[63] All our estimates covering the fifth carbon budget period in this report are presented to the nearest 5 $MtCO_2e$.
[64] European Commission, Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC to enhance cost-effective emission reductions and low-carbon investments, 15th July 2015, COM (2015) 337 final.

Box 3.3 (cont.): Calculating the UK's share of the EU ETS cap

– **Auctioned allowances.** The majority of allowances are sold by auction by Member States. In Phase III these represented 55% of the cap on average. Under the rules of the EU ETS Directive the UK received 10.0% of these allowances to auction. In Phase IV the share of auctioning at the EU level is proposed to stay constant at the same proportion as Phase III. Reflecting minor changes in the proposed auctioning rules that remove a Kyoto Protocol adjustment, the UK is expected to receive 10.3% of these allowances to auction.

– **Freely allocated allowances.** In Phase III energy-intensive industries at risk of carbon leakage were allocated allowances for free. A complex set of rules in the EU ETS Directive govern how these are allocated. For Phase IV free allocation will continue, using the same broad framework for allocation, with the detailed rules updated to better target sectors at risk of carbon leakage. The expectation is that the new rules will not materially change the approach to free allocation, so the UK share will be close to that in Phase III. Our assumption for Phase IV is therefore to continue the UK's share from Phase III (7.9%), but with a range of ±25% to reflect the uncertainty in the new rules.

– **Innovation Fund.** In Phase IV 400m allowances (3% of the cap over Phase IV) will be auctioned centrally to provide finance for innovative projects across all sectors in the EU ETS. Given Fund finance is available to all EU ETS sectors and all Member States, we assume the UK receives a share based on its share of verified emissions in 2005 (12.0%), with a range of ±25% around this. We assume the 400m allowances are auctioned equally across the opening four years of Phase IV, mirroring the approach to a similar fund in Phase III (the NER300). If these allowances were auctioned equally across Phase IV as a whole it would not materially change our central estimate, given the relatively small size of the Fund.

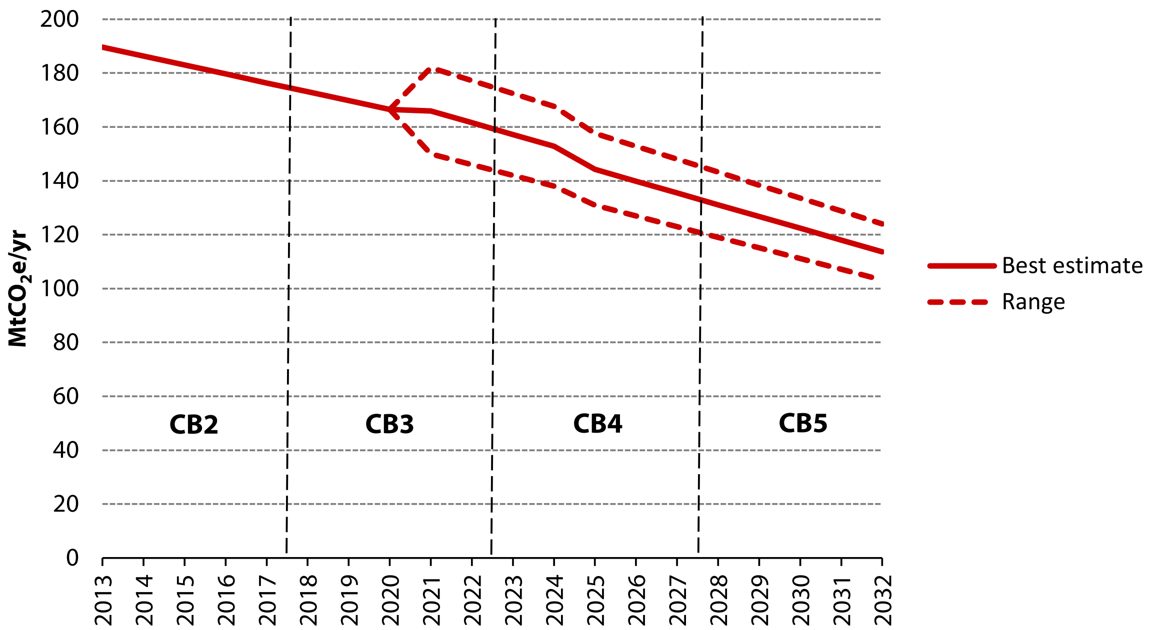
– **Modernisation Fund.** This makes up 2% of the EU cap in Phase IV. Access to the Modernisation Fund is reserved for lower income EU Member States. The UK is therefore not eligible for these allowances.

– **Aviation.** Emissions from flights within the EU are covered by the EU ETS, under a separate cap which is semi-tradable with the main EU ETS. This includes domestic UK flights and UK flights to EU countries. Emissions from UK flights to non-EU countries are not included. Carbon budgets only cover domestic aviation emissions, so we estimate the UK's share of the aviation emissions cap for domestic emissions, and add this to our estimate of the UK's share of the main EU ETS cap. We assume the approach for Phase III continues in Phase IV. That is, the cap is flat at 95% of 2004-06 average emissions (18.1 $MtCO_2$ for domestic aviation emissions across the EU), and the share is allocated on the basis of the UK share in 2010 emissions (9.7%). We therefore add 1.7 $MtCO_2$ per year to reflect that UK domestic aviation emissions are covered by the EU ETS.

Box 3.3 (cont.): Calculating the UK's share of the EU ETS cap

Overall, our best estimate is that the UK's share of the EU ETS cap will fall out to 2030, from 190 $MtCO_2e$ in 2013 to 167 $MtCO_2e$ in 2020 and 122 $MtCO_2e$ in 2030 (Figure B3.3). This primarily reflects a tightening EU-wide ETS cap, with the proportion of the stationary cap attributable to the UK increasing slightly in our central scenario from 9.0% in Phase III to 9.1% in Phase IV. This assumes a neutral effect of the Market Stability Reserve (Box 3.4). It implies a level for the traded sector over the five year fifth carbon budget period of 610 $MtCO_2e$[65], within a range of 555-670 $MtCO_2e$.

Figure B3.3: Range for UK share of EU ETS cap under EU 2030 agreement



Source: CCC analysis based on European Council Conclusions October 2014 (EUCO 169/14)
Notes: Includes UK stationary sources and UK domestic aviation. Assumes effect of Market Stability Reserve is neutral (Box 3.4). Outturn pre-2020 may differ from best estimate depending on level of closures, cessations and new entrants.

[65] To the nearest 5 $MtCO_2e$.

Box 3.4: Relationship between the EU ETS Market Stability Reserve and carbon budgets

The EU has agreed a 'Market Stability Reserve' (MSR) to improve the resilience of the system to major shocks (Box 3.1). The MSR operates by altering the supply of auctioned allowances according to pre-defined rules.

Under the accounting rules of the Climate Change Act[66], the UK's carbon budgets are measured against the 'net carbon account':

- The net carbon account comprises the UK's share of the EU ETS cap plus UK emissions in the non-ETS sectors.
- If the UK's share of the EU ETS cap significantly differs in practice from the level assumed when setting the budget then this could have implications for the room available for non-ETS sectors (e.g. for a given level of budget, if the UK's actual share of the EU ETS cap is lower than assumed then the room for non-ETS sectors is increased, thus weakening ambition).

The operation of the MSR could therefore present an issue for carbon budget management, since we do not know in advance when, and to what extent, it will operate.

However, in principle the impact of the MSR can be managed through flexibility mechanisms in the Climate Change Act:

- The Climate Change Act provides for banking and borrowing between carbon budgets[67].
- If, within a carbon budget period, UK allowances are withheld from auctioning and placed into the MSR then we assume the equivalent amount of carbon budget units are banked.
- If these allowances are released from the MSR at a later date, then we assume the equivalent units are released for carbon budgets.

Our analysis therefore assumes carbon budgets are set on a neutral basis, with no operation of the MSR.

[66] The Carbon Accounting (2013-2017 Budgetary Period) Regulations 2015
[67] Climate Change Act 17

The UK's share of the EU non-ETS reduction to 2030

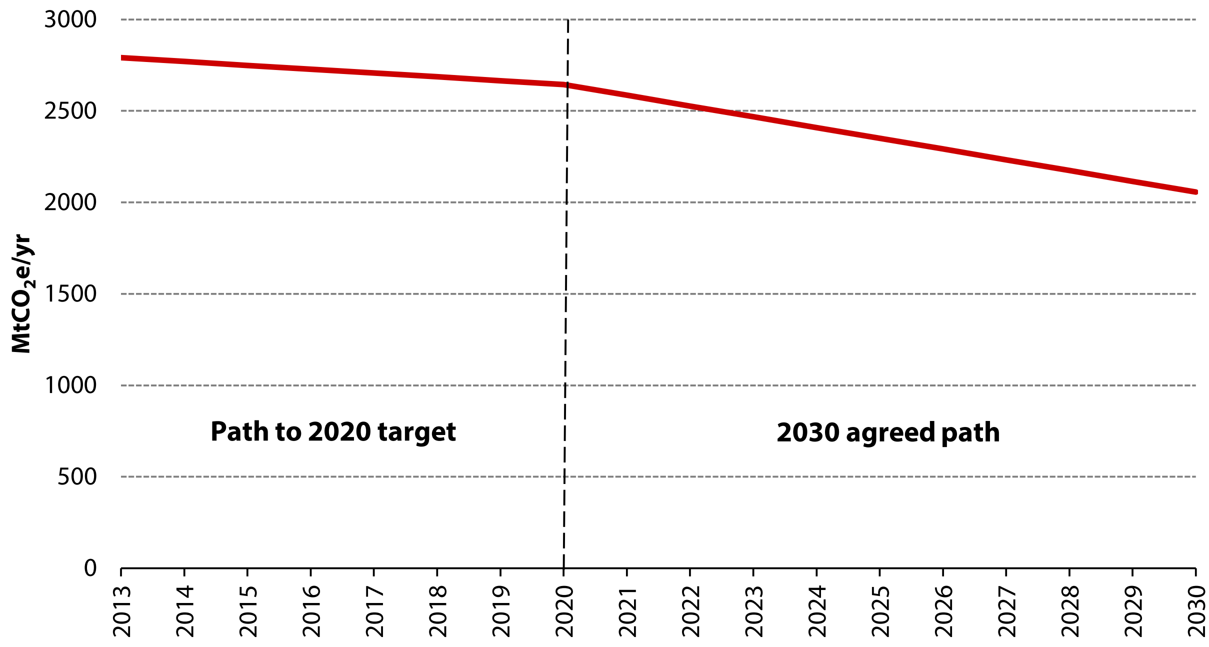
Under the 2030 agreement made by EU Member States, EU-wide emissions in sectors not covered by the EU ETS will be 30% below 2005 levels by 2030 (Figure 3.2).

This EU-wide reduction will be translated to annual targets for each country, broadly following the approach already in place for the period to 2020.

For the fifth carbon budget period, our best estimate of the UK's share of the non-ETS reduction under the EU agreement is 1,250 $MtCO_2e$ (Box 3.5).

- There are a number of uncertainties given the European Commission has not yet published their proposed specific legislation for these sectors. Taking these into account suggests a range for the UK's non-ETS sector target of 1,195-1,300 $MtCO_2e$ over the fifth budget.
- More specific details are expected to be published in 2016, but EU Member States have agreed the maximum required reduction for any country will be 40% below 2005 emissions. Countries are free to go further than this should they deem that to be cost-effective.

Figure 3.2: Agreed EU trajectory for non-ETS emissions to 2030



Source: CCC analysis based on: EU Decision No 406/2009/EC and Commission Decisions of 26 March 2013 and 31 October 2013; European Council Conclusions October 2014 (EUCO 169/14)
Notes: Excludes LULUCF emissions.

Box 3.5: Calculating the UK share of the EU's non-ETS 2030 target

Under the EU's 2030 agreement sectors not covered by the EU ETS (the 'non-ETS' sectors) will reduce their emissions by 30% below 2005 levels. Each Member State will have annual targets to reduce their non-ETS emissions consistent with this, continuing the approach in place for the period to 2020. These set a floor for ambition in the non-ETS sectors, and Member States are free to go beyond this should they deem that cost-effective.

The UK's share of the EU's non-ETS reduction in 2030 will be determined by the 2020 non-ETS target, the agreed 2030 reduction, and the level of 2005 emissions:

- **2020 target.** Under the EU's 2020 package the UK has agreed to reduce its non-ETS emissions by 16% below 2005 levels by 2020. This has been converted into binding annual targets covering the period 2013-20.[68,69,70]
- **2030 target.** The UK's final agreed 2030 non-ETS target will be between 35% and 40% below 2005 levels.
  - Under the EU's 2030 target the EU Council has agreed that the maximum reduction by any single Member State will be 40% below 2005 levels[71].
  - The European Commission has assessed the cost-effective UK reduction in 2030 as 35% below 2005 levels[72]; the final target is likely to be higher than this since there will be a further adjustment to reflect relative GDP per capita.
  - For our central assessment we assume a 2030 reduction of 37.5%. We link this linearly to the existing agreed 2020 point.
- **2005 emissions.** Both the 2020 and 2030 targets are set relative to 2005 emissions. However, there is uncertainty about the level of 2005 emissions which will be used. Current 2020 targets were set using a version of the UK emissions inventory which has since been updated to reflect methodological developments (e.g. revised CO_2-equivalence factors from the IPCC's 4th Assessment Report). Given there is provision in the existing non-ETS legislation to review this, we assume that the latest version of the inventory is incorporated in both the 2020 and 2030 target setting.

To be consistent with carbon budgets we add emissions from Land Use, Land Use Change and Forestry (LULUCF, which are not covered by the EU's target), and extend the analysis to cover the fifth carbon budget period:

[68] Decision No 406/2009/EC of the European Parliament and of the Council of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020

[69] Commission Decision of 26 March 2013 on determining Member States' annual emission allocations for the period from 2013 to 2020 pursuant to Decision No 406/2009/EC of the European Parliament and of the Council

[70] Commission Implementing Decision of 31 October 2013 on the adjustments to Member States' annual emission allocation for the period from 2013 to 2020 pursuant to Decision No 406/2009/EC of the European Parliament and of the Council

[71] European Council Conclusions October 2014 (EUCO 169/14)

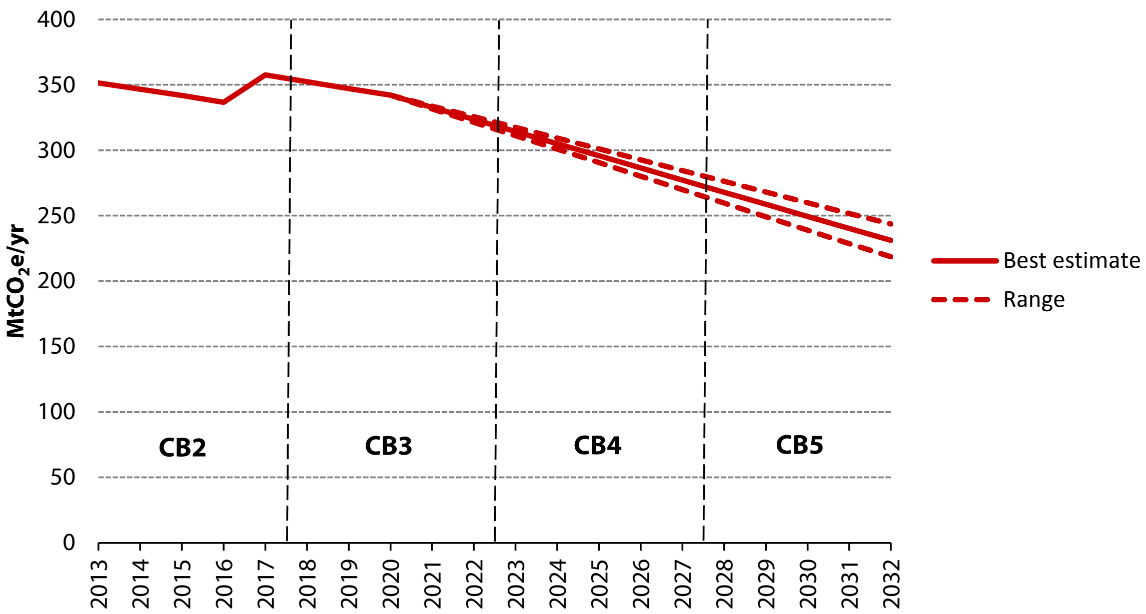
[72] Commission Staff Working Document, Impact Assessment Accompanying the document Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A policy framework for climate and energy in the period from 2020 up to 2030, SWD (2014) 15 final

Box 3.5: Calculating the UK share of the EU's non-ETS 2030 target

- **LULUCF.** The EU's non-ETS target does not include emissions from LULUCF. To be consistent with coverage of carbon budgets we therefore add projected baseline LULUCF emissions to our estimates of the UK's non-ETS share, based on DECC projections[73].
- **Fifth carbon budget period.** The fifth carbon budget extends to 2032 which is beyond the EU's 2030 agreement. For 2031-32 we therefore assume the trajectory continues to decline at the same rate as through the 2020s.

Overall, our best estimate is that the UK's share of the EU's non-ETS reduction will fall, from 342 $MtCO_2e$ in 2020 to 249 $MtCO_2e$ in 2030, within a 2030 range of 239-260 $MtCO_2e$ (Figure B3.5). This implies a level for the non-traded sector over the fifth carbon budget period of 1,250 $MtCO_2e$[74], within a range of 1,195-1,300 $MtCO_2e$.

Figure B3.5: Range for UK share of non-ETS reduction under EU 2030 agreement



Source: CCC analysis based on European Council Conclusions October 2014 (EUCO 169/14) and DECC (2014) *Updated energy and emissions projections 2014*
Notes: Includes projected LULUCF emissions. Step up in 2017 reflects assumed adjustment for inventory revisions.

[73] Department of Energy and Climate Change (2014) *Updated energy and emissions projections 2014*
[74] To the nearest 5 $MtCO_2e$.

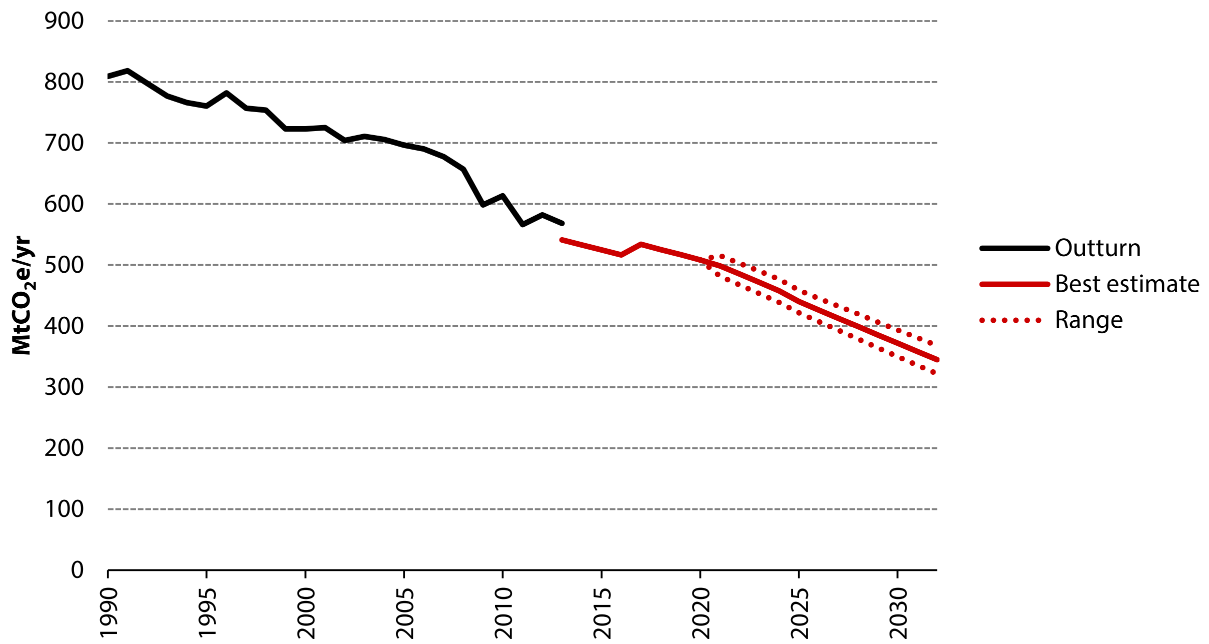
Implications of the EU 2030 target for the fifth carbon budget

The UK's overall required reduction in emissions under the EU's 2030 framework will reflect reductions in its share of the EU ETS cap and its share of the non-ETS reduction.

Our best estimate of the combination of the UK's share of the EU 2030 target in the EU ETS and non-ETS sectors suggests a reduction of 54% below 1990 levels on average over the fifth carbon budget period, within a range of 51-57% (Figure 3.3).

In comparison, the legislated fourth carbon budget is 52% below 1990 levels in 2025[75]. Our best estimate of the UK's reduction under the EU's 2030 agreement is that this therefore could imply a 2 percentage point reduction in average emissions from the fourth to fifth carbon budget (i.e. 18 $MtCO_2e$). This compares to a 6.6 percentage point (54 $MtCO_2e$) reduction per budget on average required to meet the UK's 2050 target from the fourth carbon budget in 2025.

Figure 3.3: Range for UK emissions pathway under the EU's 2030 agreement



Source: DECC (2015) *2013 UK Greenhouse Gas Emissions, Final Figures*; CCC analysis
Notes: Reflects sum of the UK's share of the EU ETS cap (Figure B3.3) and EU non-ETS reduction (Figure B3.5). Excludes international aviation and shipping emissions. Discontinuity in 2013 due to inventory revisions; we assume this is reflected in EU targets from 2017 onwards.

[75] When the fourth carbon budget was legislated it reflected a 50% reduction on 1990 levels. Subsequent inventory revisions mean it now reflects a 52% reduction.

3. EU contributions to closing a 2030 global emissions gap

We concluded in Chapter 2 that the EU and UK's 2050 commitments to reduce domestic emissions by at least 80% on 1990 levels remain appropriate but that, globally, there is a gap between UN pledges for 2030 and the cost-effective path to 2°C.

The gap to the cost-effective path could be closed through remaining pledges, by increasing ambition in pledges, and by further commitments beyond 2030. While the EU's pledge is one of the more ambitious made so far (Chapter 2), in this section we consider what further EU and UK contributions to closing a global gap could be. We consider what a 'fair' share of a 2°C pathway implies under various equity criteria, and whether an EU reduction of 40% is on the cost-effective path to a 2050 reduction of 80-95% below 1990 levels.

Our conclusion is that the EU should be prepared go further than a 40% reduction below 1990 levels as a contribution to closing a 2030 global emissions gap, provided other countries make similar commitments.

Fair shares of global pathways to 2°C

There is no agreed approach for estimating what a 'fair' share of a global 2°C pathway would be for individual countries or regions in 2030. A range of methods reflecting different judgements over fairness and equity suggest the EU's current 2030 target is below the required level of ambition on a range of metrics:

- A range of methods have been proposed for dividing a global 2°C pathway between individual countries and regions. We have considered the implications of seven methods which reflect different dimensions of fairness, based on economic factors, convergence of emissions and historic responsibility (Box 3.6).
- We use results from GLOCAF modelling to assess the implications of different methods for EU and UK emissions reduction in 2030. All methods show steep cuts for both the EU and UK, reflecting relative wealth and high historical emissions. For the EU we find a range between 45-71% below 1990 levels in 2030, and for the UK we find a range of 53-80% (Figure 3.4).
  - GLOCAF is a global model, developed by the Department of Energy and Climate Change, which represents emissions reduction potential across world regions and sectors, and which can assess the implications of different fairness metrics. We have used a global emissions level in 2030 consistent with a likely chance of staying below 2°C (i.e. at least 66%, 42 $GtCO_2e$ – see Chapter 2).
  - The modelling suggests an indicative range for EU emissions in 2030 of 45-71% below 1990 levels, and 53-80% for the UK. The UK takes on a slightly higher reduction than the EU as a whole, given its status as one of the wealthiest EU nations.
  - The results are not evenly distributed across the range. Methods focussing on economic factors and convergence of emissions by 2050 allocate smaller reductions, whereas methods focussing on historical responsibility are outliers suggesting much higher reductions.

The EU's agreed target for 2030 of at least a 40% reduction below 1990 levels is therefore below the estimated levels of ambition on this basis.

Box 3.6: 'Fair' shares of global emission pathways

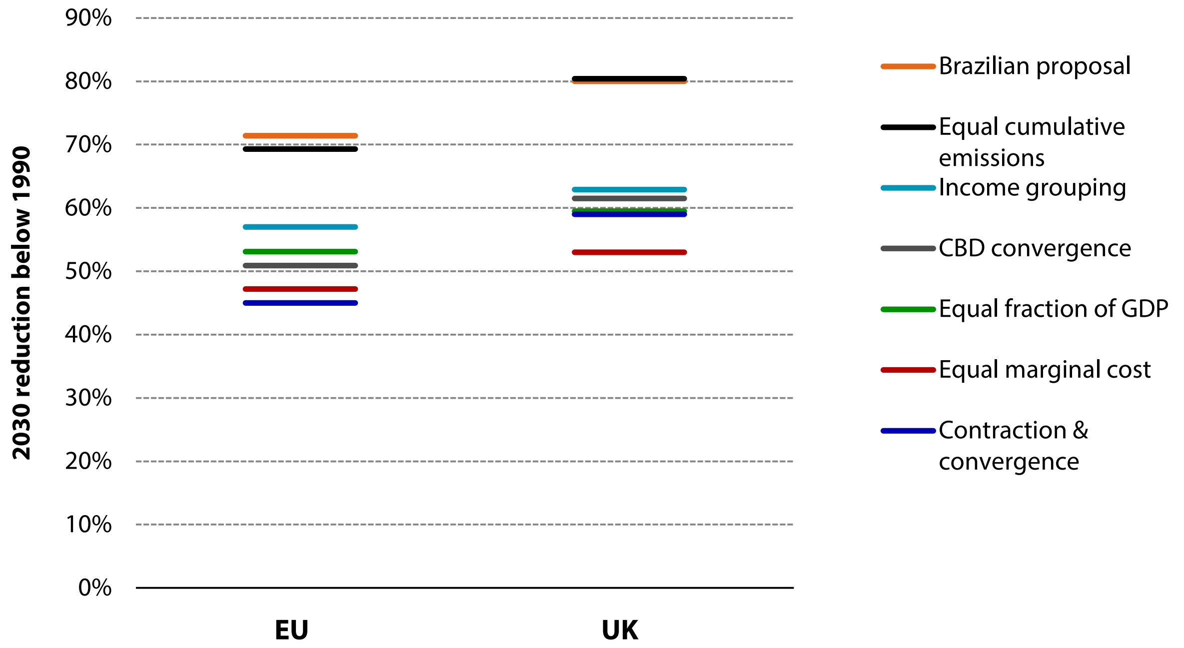
Several different methods have been proposed for determining a 'fair' share of global emissions between nations. They focus on different aspects of fairness, with some hybrid approaches combining the different aspects. The resulting allowances of emissions (or effort) could be made up through a combination of domestic action, trading and other forms of co-operation between nations.

The following 'fair' share methods are considered in this analysis and come from the GLOCAF model using the same methods described in Averchenkova et al (2014)[76]:

- **Equal cumulative emissions**: nations are allocated an emissions budget over a period of time on the basis of their share of global population over the same period. For this analysis we use the period 1990-2050.
- **Brazilian proposal (or "index-based approach")**: the share of emissions reduction (relative to a path of no climate action) is determined by contributions to historical emissions. In this analysis we define this contribution as the nation's share of cumulative emissions during 1990-2020.
- **Contraction and convergence**: all nations converge towards equal per capita emissions by a given year (in this case 2050).
- **Common but differentiated (CBD) convergence**: as above, but using a staged approach in which low emitters can continue to increase emissions until they reach a specific level (in this case global average per-capita emissions).
- **Equal fraction of GDP**: each nation faces the same mitigation cost as a fraction of national GDP.
- **Income grouping**: the amount paid by nations on mitigation is indexed by their GDP, such that wealthier countries pay a greater fraction than poorer ones. In this analysis "high income" nations (as identified by the World Bank) are allocated double the fraction of their GDP compared to others.
- **Equal marginal cost**: the marginal cost of mitigation (i.e. the carbon price) is set to be the same across all nations.

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

Figure 3.4: Range for EU and UK 'fair' 2030 reduction under a global 2°C pathway



Source: GLOCAF modelling
Notes: Compared to 1990 levels. Excludes international aviation and shipping emissions. Global emissions in 2030 assumed to be 42 $GtCO_2e$.

The EU's cost-effective path to its 2050 goal

The EU's Member States have agreed a goal of reducing EU emissions by 80-95% below 1990 levels by 2050[77]. Analysis of the cost-effective path to that objective suggests that the EU's agreement for at least a 40% reduction in emissions below 1990 levels by 2030 is at the low end of ambition:

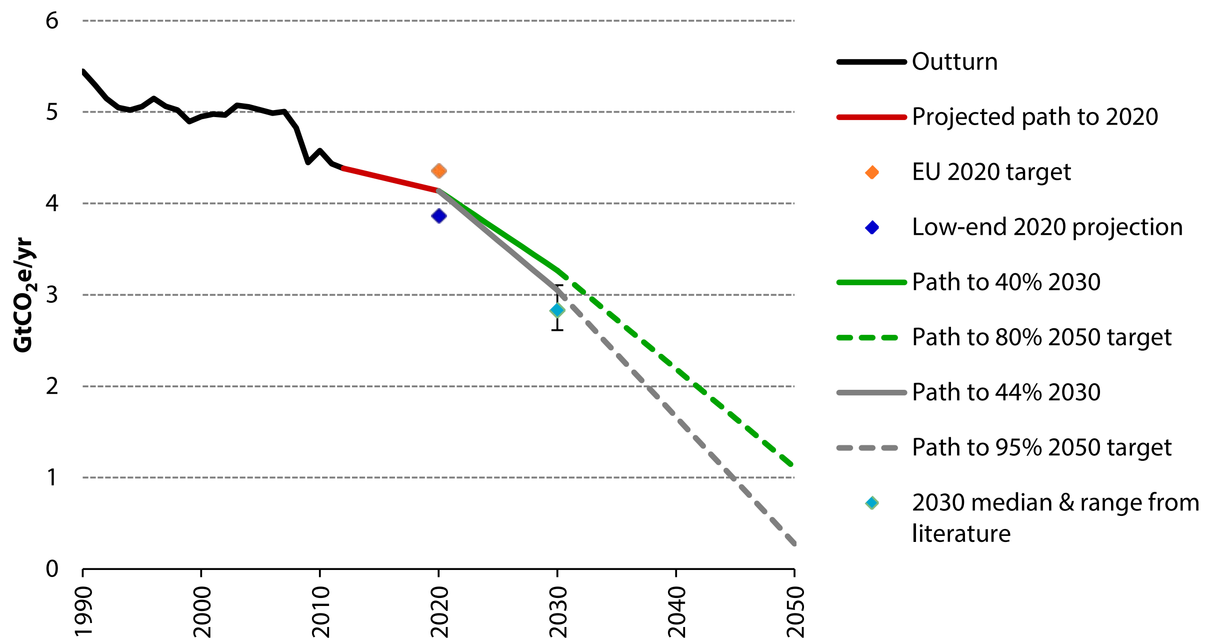
- In 2011 the European Commission published its Low-Carbon Roadmap, which set out their assessment of the cost-effective path to the EU's 2050 goal[78]. This concluded that the aim should be to achieve a 25% reduction in EU emissions in 2020 below 1990 levels, and a 40-44% reduction in 2030 (Figure 3.5).
  - The Roadmap specified these reductions should be achieved on a *domestic* basis, and therefore without relying on purchase of international credits or offsets.
  - A domestic reduction of 40-44% in 2030 could be achieved through a significant reduction in power sector emissions, roll-out of electric vehicles, substantial improvements in energy efficiency, penetration of low-carbon heating technologies as well as contributions from industry and non-CO_2 greenhouse gases.

[77] European Council Conclusions on EU position for the Copenhagen Climate Conference, 2968th Environment Council meeting, Luxembourg, 21 October 2009.
[78] European Commission, *A Roadmap for moving to a competitive low carbon economy in 2050*, COM (2011) 112 final

- Analysis published since the Roadmap indicates that the cost-effective EU path is more ambitious than the 40-44% range identified in the Roadmap.
  - EU emissions are now likely to substantially outperform the EU's 2020 target of a 20% reduction below 1990 levels. Recent projections suggest EU emissions could fall 24% below 1990 levels by 2020, and possibly close to 30%[79], thus bringing into play deeper reductions in 2030 for the same level of currently committed effort.
  - A recent review of energy modelling studies[80] implied that the median cost-effective path for EU emissions in 2030 is 48% below 1990 levels, within a range of 43-52%[81].

In the long-term, costs could therefore be reduced by increasing EU ambition in 2030.

Figure 3.5: Cost-effective pathway for EU emissions to 2050



Source: European Environment Agency data viewer; European Environment Agency (2014) *Trends and projections in Europe 2014*; Sandbag (2014) *Is Europe's new climate target a walk in the park?*; Knopf et al (2013) Beyond 2020 – Strategies and costs for transforming the European energy system, *Climate Change Economics*
Notes: Excludes international shipping emissions.

[79] European Environment Agency (2014) *Trends and projections in Europe 2014: Tracking progress towards Europe's climate and energy targets for 2020*; Sandbag (2014) *Is Europe's new climate target a walk in the park?*
[80] Knopf, B. et al (2013) *Beyond 2020 – Strategies and costs for transforming the European energy system*, Climate Change Economics
[81] This covers all greenhouse gases. Knopf et al (2013) presents estimates for CO_2 reduction (a median of 47% with a range of 40-51%); we add projections of EU non-CO_2 emissions from the EC Low-carbon Roadmap (SEC(2011) 288 final) in order to be comparable to the EU's 2030 40% target which covers all greenhouse gases.

Implications for closing a global emissions gap in 2030

UN pledges made so far put the world on a pathway likely to go beyond 2°C. One way to reduce this gap is by increasing ambition in pledges.

Analysis of both the cost-effective path to the EU's 2050 objective and estimates of the EU's 'fair' share of a 2°C pathway suggest the EU should be prepared to go further than a 40% reduction below 1990 levels as a contribution to closing a 2030 emissions gap, provided other countries make similar commitments.

That a greater than 40% reduction may be required has been recognised by both the EU (in its formulation of the target as 'at least' a 40% reduction with a review mechanism post-Paris) and by the EU Committee of the Regions and the UK Government (which have both previously formally argued for a 50% reduction[82]).

4. Implications for the fifth carbon budget

The key points from our assessment are summarised in Table 3.1 and are that:

- The EU's Member States have agreed a 2030 target for EU emissions of at least 40% below 1990 levels. This is also the EU's collective pledge for 2030 as part of the UN process towards a global deal. It is currently one of the more ambitious pledges.
- Our best estimate is that the UK's share of the EU 2030 agreement could mean a reduction in UK emissions over the fifth carbon budget period of 54% below 1990 levels. The precise UK share cannot be known with certainty until final rules governing Member States' shares are agreed. Reflecting these uncertainties suggests the UK will contribute emission reductions within a range of 51-57%.
- The EU's agreed 2030 target is at the lower end of ambition compared to the cost-effective path to its 2050 objective of an 80-95% reduction below 1990 levels. It is below estimates for a 'fair' EU share of a global 2°C pathway, and the UK's likely contribution is at the low end of ambition compared to its global 'fair' share.
- The EU should be prepared to raise its ambition as a contribution to closing a global emissions gap in 2030, provided other countries make similar commitments.

The implications of the EU's 2030 agreement for the UK should therefore be monitored and kept under review, given that the final implications are not yet known and that the EU may need to increase its ambition as a contribution to closing a global emissions gap. The UK Government has previously argued for a 50% reduction in EU emissions in 2030 below 1990 levels.

[82] Department of Energy & Climate Change (2013) *A 2030 framework for climate and energy policies: UK Government Response to Commission Green Paper COM(2013) 169 final;* Opinion of the Committee of the Regions – Green Paper on Framing 2030 Climate and Energy Policy, *Official Journal of the European Union* (2014/C 126/04).

Table 3.1: EU and UK emission reductions in 2030 under the EU's agreement compared to other criteria

	EU in 2030	UK in 2030
EU 2030 pledge vs. 1990	≥40%	54% (51-57%)
EU ETS reduction vs. 2005	43%	48.7% (43.9-53.4%)
Non-ETS reduction vs. 2005	30%	37.5% (35.0-40.0%)
Cost-effective path to 2050 target vs. 1990	40-44% (EC Roadmap) 48% (43-52%) (Literature)	See fifth carbon budget advice Nov 2015
'Fair' share of global 2°C pathway vs. 1990	45-71%*	53-80%*

Notes: *Range for 'fair' share not evenly distributed: upper end (reflecting historical responsibility criteria) are outliers.

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Under the Climate Change Act (2008), the Committee is required to advise the Government, by the end of 2015, on the level of the UK's fifth carbon budget (the limit on the amount of greenhouse gases that can be emitted by the UK between 2028 and 2032).

This report has examined the scientific and international circumstances we are required to consider under the Climate Change Act when advising the Government and Parliament on carbon budgets.

The final advice on the fifth carbon budget must take into account other criteria in the Act, including: the impact of the budget on the economy, the government's fiscal position, affordability of energy for households, security of supply, the devolved administrations and the competitiveness of businesses. The budget must also be on a path to the UK's 2050 target of at least an 80% reduction in emissions below 1990 levels.

We will deliver our fifth carbon budget recommendation, reflecting the full set of criteria, in a report to be published towards the end of November. This will set out our assessment of the cost-effective path for UK emissions to the 2050 target and the appropriate level of the fifth carbon budget.

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