Committee on Climate Change

Scottish emissions targets 2028-2032

The high ambition pathway towards a low-carbon economy

March 2016

Acknowledgements

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Foreword

In the strength of its ambition for reducing the emissions of greenhouse gases which lead to climate change, Scotland is leading the UK. It has legislated an interim target to reduce emissions by 42% in 2020, on 1990 levels. It has committed to a tightening of targets of at least 3% a year after 2020.

When we look at what is being achieved, we can also see that progress is being made. Actions are being taken – with most obvious effect in the power sector, but also elsewhere – which are reducing emissions. In 2013 the level of emissions was 38% below 1990. This is a greater reduction than for the UK as a whole and on track to the 2020 target. We will return to make a fuller assessment of this progress in a report later this year.

Under the Climate Change (Scotland) Act 2009, the Committee has now been asked for its advice on the level of Scotland's targets for the years 2028-2032. We provide our advice in this report, consistent with the requirements of the Act.

Our recommendation requires a 61% reduction in Scotland's emissions, as measured by the Net Scottish Emission Account, by 2030. In line with Scottish ambition, this goes further than the reduction we have recommended in our fifth carbon budget advice for the UK as a whole.

In coming to this advice, we also recommend revisions to Scotland's existing annual targets for the years 2017-2027. Since there is substantial value in a stable signal to investors provided by fixed targets, we do not make this recommendation lightly. However, for reasons covered in the report, we conclude that maintaining a credible signal of intent requires amendment to those targets now.

Following our advice will maintain the lead in emission reduction that Scotland has been setting. Aside from a reduction of 61% by 2030, it will require emissions to fall by about 47% on 1990 levels by 2020. Achievement will require a strengthening of existing measures. This will be stretching, but it meets the requirements of the Act, will be a suitable contribution to global ambition and will open up opportunities for Scotland in the transition to a low-carbon economy.

Our advice takes account of the budget-setting criteria in Scotland's Act, and specific circumstances relevant to Scotland. We have benefited from engagement with interested parties, including at our Committee meeting in Edinburgh in January and responses to our call for evidence. I am grateful for that engagement, for the contributions and guidance of members of the Committee in developing the advice, and to the small team within the secretariat who have been so instrumental in its delivery.

Lord Deben
Chairman, Committee on Climate Change

The Committee

The Rt. Hon John Gummer, Lord Deben, Chairman

The Rt. Hon John Gummer, Lord Deben, was the Minister for Agriculture, Fisheries and Food between 1989 and 1993 and was the longest serving Secretary of State for the Environment the UK has ever had. His sixteen years of top-level ministerial experience also include Minister for London, Employment Minister and Paymaster General in HM Treasury. He has consistently championed an identity between environmental concerns and business sense. To that end, he set up and now runs Sancroft, a Corporate Responsibility consultancy working with blue-chip companies around the world on environmental, social and ethical issues. Lord Deben is Chairman of the Committee on Climate Change, Valpak Limited, and the Association of Professional Financial Advisors.

Professor Samuel Fankhauser

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

Professor Sir Brian Hoskins

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

Paul Johnson

Paul has been director of the Institute for Fiscal Studies since January 2011 and is a visiting professor at UCL. He is widely published on the economics of public policy including tax, welfare, inequality and poverty, pensions, education, climate change and public finances. He is also one of the authors of the "Mirrlees review" of tax system design.

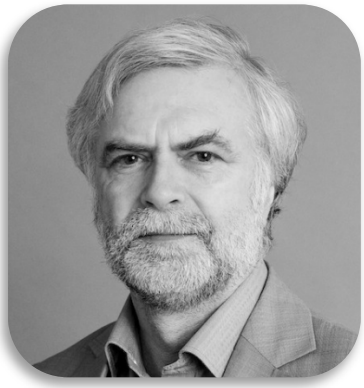
Paul has previously worked at the FSA and has been chief economist at the Department for Education and director of public spending in HM Treasury, as well as deputy head of the UK Government Economic Service. He is currently a member of the council and executive committee of the Royal Economic Society, a member of the Committee on Climate Change, a member of the banking standards board, and has just completed an independent review of consumer price inflation statistics for the UK Statistics Authority. Paul has previously served on the council of the Economic and Social Research Council. He was a founder council member of the Pensions Policy Institute and in 2010 he led a review of the policy of auto-enrolment into pensions for the new Government.

Julia King, The Baroness Brown of Cambridge

Julia King DBE FREng, The Baroness Brown of Cambridge, is the Vice-Chancellor and Chief Executive of Aston University. After an academic career at Cambridge University, Julia held senior business and engineering posts at Rolls-Royce for eight years. She returned to academia as Principal of the Engineering Faculty at Imperial College, London, becoming Vice-Chancellor of Aston University in 2006. Julia advises Government as a member of the Committee on Climate Change, the Science and Technology Honours Committee and as the UK's Low Carbon Business Ambassador. She is a member of the World Economic Forum Global Agenda Council on Decarbonizing Energy, and was an inaugural member of the European Institute of Innovation and Technology's Governing Board. She is Chair of the Sir Henry Royce Centre for Advanced Materials, a non-executive Director of the Green Investment Bank and Offshore Renewable Energy Catapult, and a member of the Engineering and Physical Sciences Research Council. In 2015 Julia was elevated to the peerage as a crossbench peer.

Lord John Krebs

Professor Lord Krebs Kt FRS FMedSci ML was Principal of Jesus College Oxford from 2005-2015. Previously, he held posts at the University of British Columbia, the University of Wales, and Oxford, where he was lecturer in Zoology, 1976-88, and Royal Society Research Professor, 1988-2005. From 1994-1999, he was Chief Executive of the Natural Environment Research Council and, from 2000-2005, founding Chairman of the UK Food Standards Agency. He is a member of the U.S. National Academy of Sciences, the American Philosophical Society, the American Academy of Arts and Sciences and the German National Academy of Sciences (Leopoldina). He was chairman of the House of Lords Science and Technology Select Committee from 2010 to 2014 and currently sits on the Energy and Environment Select Committee. He was President of the British Science Association in 2012.



Professor Jim Skea

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

Scotland has more ambitious climate targets than the UK as a whole. Consistent with this approach, the Committee recommends that annual emissions targets for 2028-2032 are set to require a 61% reduction in emissions by 2030 relative to 1990 (Figure 1).

Our recommended targets reflect the requirement in the Climate Change (Scotland) Act for targets from 2020 to fall by at least 3% each year. They are therefore more ambitious than our proposals for the UK's fifth carbon budget, requiring 2030 emissions to be 57% below 1990 levels.[1] This more front-loaded path reflects the statutory framework in Scotland. It may be appropriate for Scotland given the different structure of the Scottish economy – a higher share of emissions in sectors like agriculture means Scotland has a greater challenge to reach its long-term target to reduce emissions at least 80% by 2050 relative to 1990. Larger reductions in the period to 2032 should help to prepare for this greater challenge.

However, these are stretching targets. They require Scotland to deliver fully the high ambition scenarios that we identify in this report, and possibly to go beyond them in some areas. This will require a significant strengthening of existing policies, using devolved powers, as well as measures implemented at a UK and EU level to drive take-up of low-carbon technologies and behaviours. Scenarios that would meet the targets involve:

- **Low-carbon heat:** Heat pumps in about 18% of homes by 2030, compared to around 9% in the UK; significant roll-out of heat networks; insulation of all available cavity walls and lofts.
- **Electric (or other ultra-low emission) vehicles:** about 65% of new car and van sales by 2030, compared to about 60% for the UK.
- **Afforestation:** 16,000 hectares per year of new tree planting.
- **Electricity generation:** reducing emissions intensity from over 200g to 10-20 gCO_2/kWh by 2030, compared to around 100 gCO_2/kWh for the UK. This would also go beyond Scotland's legislated target of 50 gCO_2/kWh, but is achievable given the very large potential for expanding renewable power and the shutdown of coal-fired power.

In developing this advice, the Committee has also considered the existing carbon targets. Updated scientific information about the level of historical Scottish emissions recorded in the inventory and developments in the EU Emissions Trading System (EU ETS) have undermined the value of existing annual targets for the period to 2027.

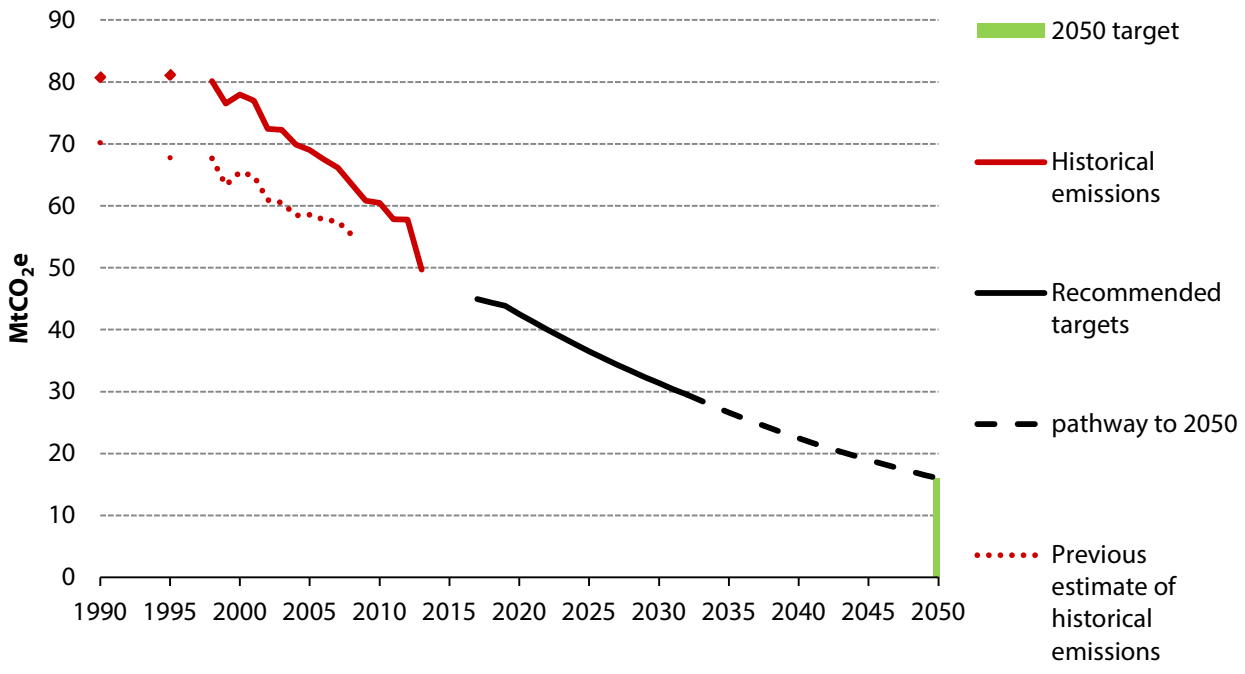
To preserve the value of the annual targets, and to restore their original intention of credibly driving high ambition in Scotland, we recommend that existing targets are aligned to this latest information (Box E1). That is the best way to ensure the targets are meaningful for monitoring progress and judging when policy effort needs to increase. The full set of

[1] Unlike Scottish targets, the UK budgets do not include international aviation. On a comparable basis, the UK reduction would be 53% by 2030.

recommended targets are set out in Table E1.

In setting these new targets Scotland would be raising ambition. For example, the new targets imply a 47% reduction in emissions by 2020 (compared to a 42% reduction required by the Act) and are on track to emissions reductions by 2050 of over 80%. This could help support the higher global ambition in the Paris Agreement and, as identified for the UK fifth carbon budget, could support an increase in pledged EU ambition for the period to 2030.

Figure E1: Recommended annual targets (2017-2032), historical emissions (1990-2013) and path to 2050



Source: CCC analysis
Note: Historical emissions are on a net basis, taking into account trading in the EU ETS.

Table E1: Recommended targets (2017-2032)

Year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
$MtCO_2e$	44.9	44.4	43.8	42.5	41.2	40.0	38.8	37.6	36.5	35.4	34.4	33.3	32.3	31.4	30.4	29.5
Reduction from 1990	44%	45%	46%	47%	49%	50%	52%	53%	55%	56%	57%	59%	60%	61%	62%	63%

Source: CCC analysis
Note: The Net Scottish Emissions Account was 80.8 $MtCO_2e$ in 1990 and 49.7 $MtCO_2e$ in 2013.

Box E1: Preserving the value of existing annual targets

Recent improvements to the measurement of greenhouse gas emissions in the UK have led to increases in the estimates of historical emissions contained in the Scottish inventory (Figure E1 shows this change – from the dotted red line to the solid line). That largely reflects changes in the waste and agriculture sectors, where the Committee has previously noted significant uncertainties and of which, for agriculture, Scotland has a high share.

These changes have been compounded by developments to the EU ETS since our previous advice, which have also made existing targets in the 2020s more stretching than was intended when they were set.

This poses a particular problem for Scotland as it has meant that targets that were already very challenging have been made infeasible. For example, the existing targets require a reduction of emissions by 2020 that is eight percentage points greater than envisaged when the targets were set.

Revisions to targets should be reserved for exceptional circumstances. The key purpose of setting targets in advance is to provide as much certainty to investors and other decision-makers as possible. However, for targets to provide that certainty they must remain credible and the actions they imply should remain broadly stable. The only option we see to preserve the value and credibility of the existing targets, and to ensure future targets can also be credible, is to revise them from the next full year, 2017.

We also note that the targets for 2010-2013 were missed by a cumulative level of 17.5 $MtCO_2e$. That was a result of the changes to the EU ETS and the inventory, as outlined above. Without these changes, emissions would have been below the targeted level. It is also possible that some or all of the shortfall will be made up in the years 2014-2016, when the rules for the EU ETS (specifically, 'backloading', see chapter 2) are likely to make the existing targets easier than intended. Since we have proposed resetting targets from 2017, and since the shortfall is a result of accounting changes not a lack of action, any shortfall or excess at that time should also be reset (with any shortfall in meeting the targets from that point tracked and addressed). That would ensure that the level of effort required by the targets for 2017-2032 is consistent with original intentions and is clear.

To ensure that the targets continue to drive genuine effort in a transparent and credible way we recommend that **offset credits** are not used to meet the targets, including for 2018-2022. Credits could be used to go beyond the proposed targets to support international action to reduce emissions. If the existing targets are not revised it may not be possible to meet them without a significant purchase of credits – this would imply a potential fiscal liability totalling over £500 million over the period to 2027.

As required in the Act we also identify the respective contributions of the 'traded' and 'non-traded' sources of emissions:

- **The traded sector** refers to those sectors of the economy covered by the EU ETS, primarily electricity generation and energy-intensive industry. Under accounting rules of the Climate Change (Scotland) Act, the contribution of those sectors to the annual targets is determined by the Scottish share of emissions allowances allocated to the UK in the EU ETS, rather than the actual level of emissions. This is currently estimated; however exact allowances through the

2020s may change. Our proposed targets are based on our current best estimate of the cap for Scotland: 12.1 $MtCO_2$ in 2030 (chapter 2). Under our scenarios for meeting the targets, actual Scottish emissions in the traded sector would be lower than this allocation, implying total (traded and non-traded) actual economy-wide emissions of 64-66% below 1990 levels in 2030.

- **The non-traded sector** covers all emissions outside the EU ETS, including transport, heating in buildings, agriculture, waste and some industry. For these sectors, performance against the targets is judged on actual emissions. Our proposed targets reflect the requirement in the Act for annual net reductions of at least 3% from 2020. This requires that emissions in the non-traded sector should fall at an average 0.8 $MtCO_2e$ annually to 2030. That is broadly in line with our highest ambition scenario for these sectors, which is likely to be appropriate on the path to the 2050 target.
- There is a risk that accounting rules for the EU ETS are changed further.[2] That could undermine the integrity of Scotland's targets by artificially increasing or decreasing the effort required from sectors outside the EU ETS. It is effort in these sectors that is most relevant for Scotland, since devolved powers are strongest here. Therefore, to preserve the intention of the targets we recommend that the Scottish Government consider using the **Carbon Accounting Regulation** provision in the Climate Change (Scotland) Act to fix the net emissions account for the traded sector at the level assumed when the targets are set (see chapter 2). This is consistent with our UK advice on the fifth carbon budget.

Our recommendations reflect the specific criteria in the Climate Change (Scotland) Act. These are discussed in the rest of this report, based on analysis that reflects Scottish circumstances:

- Chapter 1 sets out our approach.
- Chapter 2 considers the latest scientific knowledge about climate change, EU and international law and policy relating to climate change, including a fair and safe cumulative emissions budget for Scotland.
- Chapter 3 sets out a detailed assessment of how Scottish circumstances affect the potential to reduce emissions and the opportunities and challenges in doing so, including the impact on energy supplies, with sector-by-sector detail in the Annex at the end of the report.
- Chapter 4 considers economic and fiscal circumstances, social circumstances including fuel poverty, impacts on rural and island communities and environmental considerations including biodiversity.
- Chapter 5 sets out our recommendations.

Conclusion

These are very stretching targets for Scotland. They go beyond the ambition we have proposed at the UK level for 2030. That is in line with the requirements of the Climate Change (Scotland) Act. To best prepare for that challenge, annual targets must be credible and achievable. We therefore advise against keeping with the existing targets to 2027. Revising the targets to 2027 while also setting the new targets to 2032 is the best way to allow government and wider society to focus on developing Scottish policies to ensure that the transition to a low-carbon economy progresses as quickly as possible, guided by stretching but achievable annual emissions targets.

[2] CCC (2015) *The Fifth Carbon Budget (page 13)*: https://documents.theccc.org.uk/wp-content/uploads/2015/11/Committee-on-Climate-Change-Fifth-Carbon-Budget-Report.pdf

Chapter 1: Background and introduction

Introduction and key messages

This report provides the Committee's advice about the level of Scotland's annual targets for the years 2028-2032 as requested by Scottish Ministers under the Climate Change (Scotland) Act 2009.

Targets are already in place for 2010-2027 and must be set on track to Scotland's long-term target to reduce emissions by at least 80% by 2050 relative to 1990. The Act also sets out various criteria to be considered in setting targets, including the need for targets from 2020 to require annual reductions of at least 3%.

The Committee has engaged extensively in reaching its advice. This includes an open call for evidence, public hearings and individual discussions with stakeholders. The evidence from this engagement is further underpinned by the analysis set out in the rest of this report.

This chapter summarises the existing targets (Section 1), the requirements in the Act (Section 2) and the approach that the Committee has taken in reaching its advice (Section 3).

1. Scotland's targets

The Climate Change (Scotland) Act 2009 set a long-term target to reduce emissions of greenhouse gases (GHGs) by at least 80% in 2050 relative to 1990, with an interim target to reduce emissions by 42% in 2020. Secondary legislation passed in October 2010 and October 2011 also set a series of annual emission reduction targets for 2010 to 2022 and 2023 to 2027 respectively.[3]

Compared with UK legislation, the Scottish Act has the same long-term ambition (i.e. a reduction in emissions of at least 80% from 1990 to 2050) but with higher medium-term ambition towards that target. The faster progress reflects greater ambition by successive Scottish governments. It also reflects the different structure of the Scottish economy, such as a higher share of emissions in challenging sectors like agriculture. A more ambitious path to 2030 for Scotland will help it prepare to meet its 2050 target.

In 2013 Scotland missed its legislated annual target for the fourth consecutive year, with a Net Scottish Emission Account of 49.7 $MtCO_2e$ compared to a target of 47.976 $MtCO_2e$. Emissions as measured in the net account (which adjusts for emissions trading in the EU Emissions Trading System and is the basis for the annual targets) were 38% below 1990 levels in 2013, on track to

[3] Scotland's emission targets are set on a net basis. Net emissions in Scotland are calculated using the Net Scottish Emission Account (NSEA) which takes account of non-traded emissions, surrendered EU ETS units and Scotland's assigned EU ETS cap (known as the specified amount), which covers the power and energy intensive industry sectors and some of aviation.

the 42% target for 2020. Ignoring emissions trading, Scottish emissions have fallen 34% (compared to 27% in UK, 12% Wales and 15% in Northern Ireland).

2. Requirements of the Scottish Climate Change Act for 2028-2032 and considerations for setting targets

The Scottish Act places a number of requirements on Scottish Ministers to request advice from a "relevant body". The relevant body is the Committee on Climate Change ('the Committee'). The Act also sets out the obligations on the Comittee when it provides such advice.

The Scottish Ministers must, by order, set the annual targets for 2028-2032 no later than 31 October 2016. The Committee has therefore been requested to provide advice on the level of the annual targets which would allow the 80% 2050 target to be met, with reference to the Act's target setting criteria (Box 1.1). The advice includes the extent to which the annual targets should be met by taking action to reduce Scottish emissions and by the use of carbon units. We have considered domestic action in Scotland in the non-traded sector (i.e. outside of the EU ETS; emissions from international aviation and shipping (Annex) and the approach to the traded (EU ETS) sector of the Scottish economy (Chapter 2).

The targets must be set:

- For each year in the period 2011-2019, at an amount that is consistent with a reduction in the Net Scottish Emissions Account over that period which would allow the interim target and the 2050 target to be met;
- For each year in the period 2020-2050, at an amount that is:
  - Consistent with a reduction in the Net Scottish Emissions Account over that period which would allow the 2050 target to be met, and
  - At least 3% less than the target for the preceding year.

Our advice in this report reflects these criteria.

Box 1.1: Target setting criteria in the Climate Change (Scotland) Act 2009

The 'target setting criteria' are:

- The objective of not exceeding the fair and safe Scottish emissions budget[4].
- scientific knowledge about climate change.
- technology relevant to climate change.
- economic circumstances, in particular the likely impact of the target on:
  - the Scottish economy.
  - the competitiveness of particular sectors of the Scottish economy.
  - small and medium-sized enterprises.

[4] In the Act, the 'fair and safe emissions budget' is the aggregate amount of net Scottish emissions for the period 2010-2050 recommended by the relevant body as being consistent with Scotland contributing appropriately to stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

Box 1.1: Target setting criteria in the Climate Change (Scotland) Act 2009

  - jobs and employment opportunities.
- fiscal circumstances, in particular the likely impact of the target on taxation, public spending and public borrowing.
- social circumstances, in particular the likely impact of the target on those living in poorer or deprived communities.
- the likely impact of the target on those living in remote rural communities and island communities.
- energy policy, in particular the likely impact of the target on energy supplies, the renewable energy sector and the carbon and energy intensity of the Scottish economy.
- environmental considerations and, in particular, the likely impact of the target on biodiversity.
- European and international law and policy relating to climate change.

3. Approach and engagement

The Committee engages widely with businesses, governments, researchers, non-government organisations, representative bodies and other relevant parties throughout its work. The advice in this report reflects that broad engagement, including as part of the Committee's evidence gathering for its advice on the UK's fifth carbon budget.[5]

The Committee has gathered further evidence specifically for this advice:

- On 30 October 2015 we published a Call for Evidence, containing 12 questions on climate science, international circumstances, the annual targets and other considerations. It was open for a six week period and closed on 11 December 2015.
- We received six responses spanning power, buildings, agriculture from NGOs and academics. All responses will be published in full on our website.[6]
- To provide further input to the Scottish annual targets advice, we held public Committee hearings where evidence was provided by stakeholders within heat and energy efficiency, energy supply, agriculture and land use and transport. A full list of participants will be published on our website alongside the consultation responses.
- We have held meetings with individual stakeholders and Scottish Government departments covering the sectors and the targets in general.

Our engagement has been valuable in gathering evidence about the opportunities for emission reductions across the economy, the barriers to progress and the potential impacts of annual targets, and policies to meet them. We would like to thank all those who took the time to be involved.

[5] CCC (2015) *The Fifth Carbon Budget (figure 1)*: https://documents.theccc.org.uk/wp-content/uploads/2015/11/Committee-on-Climate-Change-Fifth-Carbon-Budget-Report.pdf

[6] See: www.theccc.org.uk

Chapter 2: Latest climate science and international circumstances

Introduction and key messages

The Climate Change (Scotland) Act requires that the Committee consider scientific knowledge about climate change and European and international law and policy relating to climate change when providing our advice. This chapter contains that assessment, drawing on our recent UK advice on the fifth carbon budget, updated in the light of the 2015 Paris Agreement and covering the specific issue of cumulative emissions (i.e. a fair and safe Scottish emissions budget), as required in the Act. Our key messages are:

- **Climate science.** It is clear that the climate is changing as a result of greenhouse gas emissions from human activity. This is resulting in detectable impacts on people and the natural environment, which will cause increasing disruption and costs as further emissions lead to further warming and change. To limit warming to 1.5°C to 2°C, annual global emissions will need to fall significantly and ultimately to near zero or negative.
- **International action.** The world is acting to tackle climate change. The Paris Agreement increases the agreed level of ambition while identifying the need for parties to increase efforts to deliver this. The Committee will assess later in the year further implications of the increased ambition in the Paris Agreement for the UK's long-term target (which is the same as Scotland, to reduce emissions at least 80% by 2050 on 1990 levels) drawing on new evidence as it becomes available.
- **Cumulative emissions.** The increase in global temperature is determined mainly by cumulative carbon dioxide emissions over time. The Scottish targets are based on emissions falling steadily to a level of around 2 tCO_2e per capita by 2050. This implies cumulative Scottish emissions of around 1,330 $MtCO_2e$ over the period 2010-2050, and if replicated globally would imply cumulative emissions consistent with limiting warming to 2°C.
- **Role of the EU ETS.** For the covered sources of emissions, the EU ETS defines the level of the Scottish net emissions account against which the annual targets are judged. Available rules for future phases of the EU ETS suggest that this will imply a reduction in Scottish net emissions in these sectors of 34% from 2013 to 2030. We include this level in our advice on the targets in chapter 5.

This chapter recaps our assessment of the latest climate science (Section 1) and international circumstances (Section 2). We then consider the implications for a 'fair and safe' cumulative emissions budget for Scotland (Section 3). Finally we set out the implications of the EU Emissions Trading System for setting the Scottish targets (Section 4).

1. The science of climate change

The evidence that global warming is happening, driven by human activity and with large potential impacts, is supported by many lines of research and agreed by the world's leading scientific bodies.[7] We reviewed the latest evidence in 2015 as part of our advice on the fifth UK carbon budget,[8] drawing extensively on the latest assessment by the Intergovernmental Panel on Climate Change (IPCC AR5).[9]

It is clear that the climate is changing as a result of greenhouse gas emissions. This is leading to rising temperatures and other changes, with detectable impacts on people and the natural environment:

- Global average temperature has risen around 0.9°C and sea level around 20cm since the late 19th Century. There have been changes in rainfall patterns and the loss of ice from Greenland and Antarctica. Carbon dioxide emissions are also acidifying the oceans.
- The pattern of global warming over the 20th Century matches that expected from natural and human factors combined, and not that from natural factors alone. Human activity has clearly been the dominant driver of global temperature rise since at least the 1950s.
- Many impacts are already being detected across the world, from changes in extreme weather and ecosystems, to a slowdown in productivity gains for some key crops.
- Natural variability and other factors continue to influence climate, especially on shorter timescales and at smaller spatial scales. Large volcanic eruptions can lower global temperature for a year or two. A major downswing in solar activity over several decades, considered possible but unlikely, could also lower global temperature by a few tenths of a degree.

Further emissions will lead to further warming and change. There is no known simple threshold beyond which climate change moves from safe to dangerous. Some disruption and irreversible losses are expected at 2°C. Losses accelerate with warming, and very severe damage is expected in a world reaching 4°C:

- Under baseline scenarios in which no action is taken, energy system models predict a continued increase in global emissions. As a result global temperature in 2100 would be 2.5-7.8°C (5-95% confidence range) above late 19th Century levels and rising.
- Under an ambitious mitigation scenario considered by the IPCC, in which emissions peak now and decline to zero or further before 2100, global temperature rise would be 0.9-2.3°C.
- Impacts will be unevenly distributed and there are currently wide uncertainties about their magnitude. It is clear however that greater warming will lead to larger risks.

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7 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

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

9 IPCC (2014) *AR5:* https://www.ipcc.ch/report/ar5

- IPCC AR5 concluded warming of 1.5°C above late 19th Century levels leads to high risk of damage from extreme weather and of losing sensitive ecosystems (such as those in the Arctic, on mountains and coral reefs). Warming of around 2.5°C brings high risk of large-scale singularities (such as irreversible ice sheet loss, leading to more sea level rise) and severe global impacts on the economy and environment. Warming of around 4.5°C puts global food security in doubt.

The increase in global temperature is determined mainly by cumulative carbon dioxide emissions over time. Annual emissions must therefore fall to near zero in order to limit warming. If annual global emissions stay at the current rate, let alone grow further, internationally-agreed targets will be exceeded by the mid-2030s:

- IPCC AR5 estimated the total carbon dioxide emissions over time consistent with staying below specific global temperature limits.
- To preserve a 50% likelihood of keeping warming below 2˚C, the total remaining allowable emissions from 2011 is around 1,300 $GtCO_2$.[10] For at least a 66% (i.e. "likely") chance, this total decreases to around 1,000 $GtCO_2$.
- To preserve a 50% likelihood of keeping warming below 1.5˚C, the total remaining allowable emissions from 2011 is around 550 $GtCO_2$. For at least a 66% (i.e. "likely") chance, this total decreases to around 400 $GtCO_2$.
- These totals account for projected emissions of other greenhouse gases and particles but apply to global emissions of carbon dioxide only.
- If global emissions continue at the current rate, the total for a likely chance of staying below 1.5°C will be exceeded by around 2020. The total for a medium chance of staying below 2°C will be exceeded around the late 2030s.

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

2. International aims and action to limit climate change

Scotland's emissions targets are domestic commitments, but set in the context of efforts worldwide to reduce greenhouse gas emissions.

Many countries, cities and businesses have made commitments to reduce emissions and are now delivering against these:

- As of January 2016, 189 nation states (including the 28 Member States who submitted as part of the EU) had submitted pledges to the United Nations Framework Convention on Climate Change (UNFCCC). These pledges cover over 99% of territorial emissions (excluding international aviation and shipping). The pledges set emissions limits for the period out to 2030 although they fall short of the action required to meet international objectives for tackling climate change.
- 18% of global emissions were covered by some form of carbon pricing scheme and 76% of global transport emissions were covered by legislated fuel efficiency/emission standards in 2015.

[10] This figure differs to that reported in our fifth carbon budget report. 1,300 $GtCO_2$ comes from IPCC AR5 SYN. The difference is due to assumptions around non-CO_2 forcings and use of scenarios that cross or stay below 2°C.

- The Covenant of Mayors, now joined by over 6,700 cities, is fostering emissions reduction targets and sustainable energy policies in major urban areas around the world.

Despite these developments, annual global emissions rose 42% between 1990 and 2012. Penetration of low-carbon technologies is increasing, but accounts for a relatively small share of global energy production. Fossil fuels are still expected to meet a large share of rising energy demand. Based on the continuation of current policies around the world, the International Energy Agency (IEA) predicts that emissions could grow a further 20% by 2040.[11]

The Paris Agreement,[12] reached in December 2015, creates a mechanism for reviewing and raising national pledges. It also set a more ambitious long-term goal for global temperature and emissions:

- Parties to the UNFCCC met in Paris during December 2015 and drafted the first truly global agreement to reduce emissions.
- The Agreement aims to hold the increase in global temperature to well below 2°C above pre-industrial levels, to pursue efforts to limit it to 1.5°C and to reach net zero global emissions of greenhouse gases in the second half of the century.
- The Agreement introduces a five-yearly system to review and raise ambition in a nationally-determined manner, recognising that current ambition in aggregate falls short of what would be required to limit global temperature increase to 2°C.

This language around limiting global temperature is more ambitious than previous UNFCCC statements. It is also more ambitious than the basis of the UK's and Scotland's statutory targets for 2050, which was a global path to hold the temperature rise close to 2°C.

Lowest-cost paths with a likely chance of staying below 2°C require global emissions to peak as soon as possible with steep reductions thereafter. UN pledges made so far have measurably reduced the forecast of global emissions, but fall short of this lowest-cost path (Figure 2.1). There is scope to reduce the gap through increased ambition to 2030 and further commitments to reduce emissions beyond:

- IPCC AR5 concluded that pathways likely (i.e. with at a least a 66% chance) to stay below 2°C show a 40-70% reduction in global greenhouse gas emissions by 2050, relative to the 2010 level of 49 $GtCO_2e$, and emissions near zero or below by 2100.
- Of the scenarios considered by the IPCC, those that were likely to stay below 2°C in 2100 but showed limited action to 2020 (consistent with current near-term projections) have emissions in 2030 of 42 (31-44) $GtCO_2e$.
- Studies by the IEA[13] and the recent Deep Decarbonization Pathways Project[14] confirm such pathways remain technically feasible without changing global economic and development prospects. They do however require very large and rapid changes in energy generation and patterns of investment.

[11] IEA (2014) *World Energy Outlook 2014.*
[12] FCCC/CP/2015/L.9/Rev.1: http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf
[13] IEA (2015) *Energy and climate change: World Energy Outlook Special Report.*
[14] Deep Decarbonization Pathways Project (2015) *Pathways to deep decarbonization 2015 report.*

- Separate analyses of the INDCs by Climate Action Tracker, the UNFCCC and the United Nations Environment Programme (UNEP) all suggest that global emissions are on track to reach 53-59 $GtCO_2e$ in 2030, compared to pre-INDC projections of around 68-72 $GtCO_2e$.[15] Climate Action Tracker estimates these pledges could help bring warming by 2100 down from 3.3-3.8°C to 2.2-3.4°C, with a central estimate of 2.7°C [16] if followed by accelerated effort after 2030.

There is much less information on cost-effective global paths to limit warming to 1.5°C, although it would clearly imply more ambitious reductions:

- One recent study[17] reviewed six scenarios with at least a 50% likelihood of reaching 1.5°C, from two independent modelling groups (a much smaller dataset than available for 2°C). These scenarios typically exceed 1.5°C at some point this century, before reversing the warming later in the century using substantial negative emissions.
- This smaller set of scenarios shows global emissions of around 39 $GtCO_2e$ in 2030 and around 8 $GtCO_2e$ in 2050.

Following the Paris Agreement we advised that the UK's current ambition to 2030 – as represented by our recommendation for the fifth carbon budget - remained an appropriate contribution to the international effort. The tighter global temperature goal does however raise questions as to whether the long-term UK ambition is currently enough. We will look at this in more detail over the coming year:

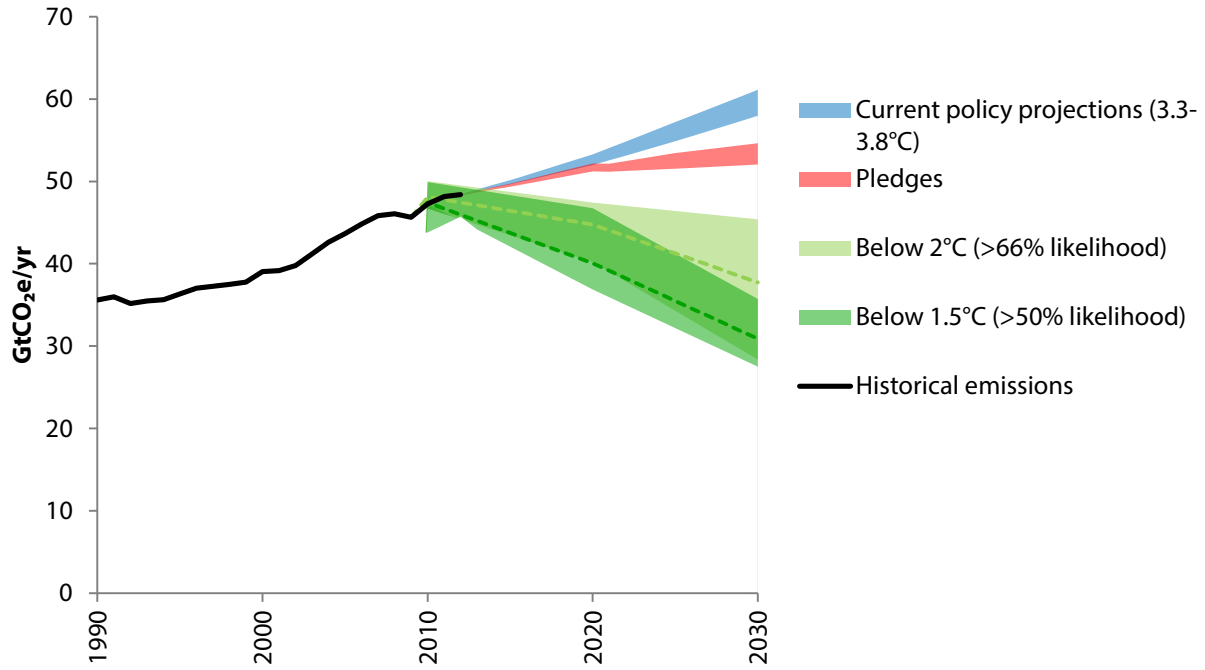
- The UK's statutory target for 2050 is based on a global path that keeps central (i.e. 50% likelihood) estimates of global temperature rise close to 2°C.
- The measures underpinning our proposed fifth UK carbon budget (covering 2028-32, see Chapter 3) are on the cost-effective path to the current 2050 target. They also keep open the possibility of deeper reductions by 2050 should these become appropriate.
- This path exceeds the UK's likely obligation under the current EU 2030 pledge, and therefore supports an increase in EU-wide ambition. The Scottish and UK governments should continue to push for a revised EU pledge, consistent with the need for all UNFCCC parties to increase ambition to deliver the goals of the Paris Agreement.
- We committed to assessing further the implications of the aims to stay well below 2°C, pursue efforts to reach 1.5°C and reach net zero emissions in the second half of the century.

[15] Climate Action Tracker (2015) *What do the CAT, UNFCCC Synthesis Report and the UNEP 2015 Emissions Gap report say about the prospects of limiting warming to below 2°C and 1.5°C from INDC levels for 2025 and 2030?*.

[16] Jeffery, L, R Alexander, B Hare, M Rocha, M Schaeffer, N Hohne, H Fekete, P van Breevoort, and K Bloc (2015) '*How close are INDCs to 2 and 1.5°C pathways?', Update,* vol. September. Potsdam: Climate Action Tracker.

[17] Rogelj et al. (2015) *Energy System transformations for limiting end-of-century warming to below 1.5°C*, Nature Climate Change.

Figure 2.1: Effect of the UN pledges on the global emission pathways



Source: Climate Action Tracker (2015)
Notes: Red shaded area reflects best estimate of impact of pledges. Green areas denote 10th to 90th percentile range of modelled cost-effective paths to meet temperature limits, with dashed lines reflecting median values.

3. A "fair and safe" cumulative emissions budget for Scotland

Section 1 above sets out the limits to cumulative emissions globally to limit warming to 2°C or 1.5°C with different levels of probability based on the latest scientific understanding. Section 2 set out possible global pathways consistent with those limits. This Section investigates the implications for Scotland.

Scotland, the UK and the EU all have objectives to reduce their greenhouse gas emissions in 2050 to at least 80% below 1990 levels. These objectives are consistent with the global emissions pathways designed to keep the world within 2°C of pre-industrial levels:

- 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,[18] the IPCC's 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.

[18] Medium variant from UN (2015) *World Population Prospects 2015 Revision.*

- Applying this per person average to a projected UK 2050 population of around 77 million[19] equates to a 72-86% reduction below 1990 levels. The UK's 2050 target of at least an 80% reduction is at the centre of this range. This would apply to all emitting sectors including international aviation and shipping.
- Applying the same logic to Scotland leads to a 78% - 89% reduction below its 1990 level in 2050 (again, including international aviation and shipping).

We advised in 2011 that an appropriate cumulative emissions budget for Scotland would involve steady reductions towards that long-term target, as required at the global level. At the time that implied a cumulative budget of 1,250 $MtCO_2e$ over the period 2010-2050. However, improved estimates for Scotland's current level of emissions in the latest inventory (see chapters 3 and 5) imply a higher starting point for emissions and potentially, therefore, a higher 2°C cumulative budget for Scotland. Reflecting that latest information, cumulative Scottish emissions would be around 1,330 $MtCO_2e$ from 2010-2050.

Pursuing efforts to limit warming to 1.5°C would require a tighter cumulative emissions budget, and hence would imply a more ambitious 2050 target.

4. Role of the EU Emissions Trading System

The EU's Member States have agreed a 2030 target for EU emissions reduction of at least 40% below 1990 levels (equivalent to 35% below 2005). This is the EU's collective pledge for 2030 under the Paris Agreement.

- Sectors covered by the EU ETS will reduce their emissions by 43% compared to 2005 levels, and sectors not covered by the EU ETS will reduce their emissions by 30%, on average.
- The target is to be achieved domestically, without purchase of international offset credits.
- A wider set of measures have also been agreed as part of the 2030 framework. These include increases in EU-wide renewable generation and energy efficiency, and introduction of a Market Stability Reserve for the EU ETS.

The share of the EU ETS cap attributable to Scotland is the basis on which participating sectors are currently accounted for under the Scottish Climate Change Act (rather than their actual emissions). Our best estimate is that the EU agreement implies a 34% reduction in the Scottish share of the cap by 2030 compared to 2013 (Box 2.1 and Table 2.1):

- The Scottish share of the EU ETS cap depends on several elements which make up the cap during the 2020s.
- Our best estimate for the Scottish share of the cap is 10.9 $MtCO_2e$ in 2030, which represents a 34% reduction below 2013 (excluding aviation).
- Emissions from flights within the EU are also currently covered by the EU ETS. Our estimate of the Scottish share of the cap for these emissions is 1.3 $MtCO_2e$ per year.
- 'Backloading' in 2014-2016 will temporarily reduce the cap and Scotland's share of it. That will artificially make Scotland's emission targets easier to meet in those years.

[19] Principal variant from Office of National Statistics (2013) 2012-based National Population Projections. Note that this is different from the Low Migration variant projection of 74m we used in our October 2015 report - CCC (2015), *The scientific and international context for the fifth carbon budget*: https://documents.theccc.org.uk/wp-content/uploads/2015/10/The-Scientific-and-International-Context-for-the-Fifth-Carbon-Budget.pdf

- Our estimates assume that the impact of the Market Stability Reserve (MSR), which aims to align demand and supply of allowances, is neutral from 2017. To the extent that allowances are placed in or released from the MSR, the UK and Scotland share of the cap could differ in specific years.

This estimate of the Scottish share of the ETS cap is our best estimate of the future level of the Net Scottish Emissions Account for those parts of the economy covered by the EU ETS (i.e. power generation and energy-intensive industries). It is therefore a direct input to our advice on the appropriate level for the Scottish annual targets, along with our scenarios for actual Scottish emissions set out in chapter 3.

Box 2.1: Scottish share of EU Emissions Trading System (ETS) cap to 2030

The Scottish share of the EU ETS cap to 2030 - which defines net emissions for the traded sector - will depend on the level of the cap and rules for apportionment that are unlikely to be known for several years. Our estimates reflect:

- **The EU ETS traded sectors.** The EU ETS cap covers emissions from power generation, energy-intensive industry and flights within Europe.
- **EU ETS cap.** As part of the agreement to reduce EU emissions by at least 40%, EU Member States have agreed the EU ETS cap will be 43% lower than 2005 levels by 2030. The cap will tighten at a faster rate after 2020 compared to before 2020 – at an annual linear rate of 2.2% of the average level of the Phase II cap, compared to 1.74% before 2020. The result is that the EU cap, excluding aviation, will reduce from 2,084 $MtCO_2e$ in 2013 to 1,816 $MtCO_2e$ in 2020 and 1,333 $MtCO_2e$ in 2030.
- **The proportion of the cap attributable to Scotland** will reflect the Scottish share of each of the four elements which make up the cap in Phase IV: auctioned allowances, freely allocated allowances, and the Innovation and Modernisation Funds. Scotland will also have a share of the separate aviation cap (which covers emissions from flights within Europe, Table 2.1).
  - Auctioned and freely allocated allowances will make up the vast majority of the Scottish allocation.[20] Based on the proposed Phase IV rules we assume the Scottish share of UK auctioning is 9.3% (i.e. the Scottish share of average 2005-07 UK emissions).
  - The largest uncertainty is around the level of free allocation as this depends on: the level of emissions in these sectors across the EU ETS, the efficiency of energy use in industry, and the final rules to allocate allowances. In line with our approach for the UK, we assume free allocation follows the latest Scottish National Implementation Measures to 2020, and then follows the EU ETS trajectory for free allocation to 2030.
  - We assume that Innovation Fund allowances are centrally auctioned equally across the opening four years of Phase IV, with the share of these based on Scottish verified emissions in 2005. The Modernisation Fund is reserved for lower income Member States and the UK and Scotland will therefore not be eligible for these allowances.

[20] Our analysis is based on our work for the fifth carbon budget, CCC (2015), *The scientific and international context for the fifth carbon budget* (chapter 3): https://documents.theccc.org.uk/wp-content/uploads/2015/10/The-Scientific-and-International-Context-for-the-Fifth-Carbon-Budget.pdf

Box 2.1: Scottish share of EU Emissions Trading System (ETS) cap to 2030

  - Our best estimate is that the Scottish share of the cap falls from 14.8 $MtCO_2e$ in 2020 to 10.9 $MtCO_2e$ in 2030.

- **Backloading and the Market Stability Reserve (MSR).** Backloading is an initiative at the EU level to withhold allowances from auctioning (by 400 million in 2014, 300 million in 2015 and 200 million in 2016). The implication of this is that the Scottish share of the EU ETS cap will also be correspondingly smaller in those years (by around 1% of the total amount withheld at the EU level). However, this is not a permanent reduction in the cap; these allowances are placed in the Market Stability Reserve (MSR) and could therefore return to the Scottish account in future. Our analysis assumes Scottish targets are set on a neutral basis, with no operation of the MSR. To the extent that allowances are placed in or released from the MSR the Scottish share of the cap could differ in specific years in future.

Table 2.1: Estimates for Scottish share of EU ETS cap (2014 -2032)

Year	Stationary installations ($MtCO_2e$)	Aviation ($MtCO_2$)	Total ($MtCO_2e$)
2014	12.51	1.29	13.80
2015	13.21	1.29	14.50
2016	13.91	1.29	15.20
2017	15.53	1.29	16.82
2018	15.29	1.29	16.58
2019	15.04	1.29	16.33
2020	14.80	1.29	16.09
2021	14.79	1.29	16.08
2022	14.39	1.29	15.68
2023	14.00	1.29	15.29
2024	13.60	1.29	14.90
2025	12.82	1.29	14.11
2026	12.43	1.29	13.72
2027	12.04	1.29	13.33
2028	11.64	1.29	12.93
2029	11.25	1.29	12.54

Table 2.1: Estimates for Scottish share of EU ETS cap (2014 -2032)			
Year	**Stationary installations ($MtCO_2e$)**	**Aviation ($MtCO_2$)**	**Total ($MtCO_2e$)**
2030	10.85	1.29	12.14
2031	10.46	1.29	11.75
2032	10.07	1.29	11.36
Source: CCC analysis			

Chapter 3: Scotland's cost-effective path

Introduction and key messages

The Climate Change (Scotland) Act requires that annual targets are set on track to meeting the 2050 target to reduce emissions by at least 80% relative to 1990 with 3% reductions each year from 2020. This chapter sets out our scenarios for potential paths to the 2050 target.

We base our assessment on an analysis of the potential future path of Scottish emissions and the opportunities to reduce those emissions through low-carbon technologies and behaviours. We include two scenarios: a Central scenario, based on the Central UK scenario from our fifth carbon budget advice, and a High Ambition scenario, based on the UK Max scenario. The scenarios are adapted in line with specific Scottish circumstances, such as the make-up of the Scottish building stock, existing industrial installations and power plants, agricultural activity and land use, Scottish driving patterns and more ambitious Scottish plans for forestry and waste disposal.

The High Ambition scenario is stretching and goes beyond what is required by the fifth carbon budget that we have recommended for the UK. This is consistent with the requirements under the Scottish Act and also likely to be appropriate given the higher share in Scotland of sectors, like agriculture, where emission reduction is harder to achieve. Larger reductions in the period to 2032 should help to prepare for this greater challenge.

The High Ambition scenario includes by 2030:

- **Electricity supply.** Emissions intensity of Scottish electricity generation is reduced to 10-20 gCO_2/kWh in 2030 compared to a current level of over 200 gCO_2/kWh. Much of the reduction results from the closure of the coal power station at Longannet in 2016. Continued expansion of renewable generation ensures that Scotland remains a net exporter of low-carbon power during a period when existing nuclear power stations are expected to close. Storage, demand-side response and interconnection play an important role in maintaining security of supply.
- **Heat in buildings.** Heat pumps are rolled out to 18% of homes by 2030, supplemented by significant roll-out (2.6 TWh) of heat networks, primarily in public and commercial buildings and around 1.5million more homes are properly insulated.
- **Industry.** Various opportunities to improve energy efficiency are taken up, including waste heat recovery and material efficiency. There is a switch away from fossil fuels to bioenergy and some electrification for space and process heating. A Scottish carbon capture and storage cluster is developed to reduce emissions from large point sources.
- **Transport.** Vehicle efficiency improves throughout the period to 2030 and the gap between test cycles and real-world performance is reduced (this requires action at the EU

level). Out of new cars and vans 65% are ultra-low emission (e.g. electric) vehicles by 2030. Further abatement is delivered from biofuels, a shift towards public and active transport (i.e. walking and cycling) and more efficient freight operations. Our scenarios reflect a detailed assessment of travel patterns in Scotland, where the average trip length is similar to the UK average. Aviation and shipping have improved efficiency.

- **Forestry and agriculture.** The rate of new tree planting increases to 16,000 hectares per year. Various measures are implemented to reduce emissions in agriculture, requiring stronger levers than the current voluntary approach including: on-farm efficiency measures, improved management of crops and soils and improved animal health.
- Further abatement is delivered from **waste disposal** and **F-gases.** That could largely be delivered through effective implementation of the existing waste policy plans and the new EU F-gas regulation.

The evidence on scenarios is summarised for the economy as a whole and set out on a sector by sector basis in the following sections and in the sectoral annex at the end of the report:

1. Overview of 2013 emissions and projections to 2035
2. The role of emissions scenarios in setting annual targets
3. Scenarios for annual targets
4. Emissions by sector of the economy
5. Further progress required from 2033-2050

1. Overview of 2013 emissions and projections to 2035

Current emissions

Scotland's emissions fell 8 $MtCO_2e$ (14%) from 2012 to 2013[21] on a net basis. On a gross basis (i.e. actual emissions before allowing for sales and purchase in the EU ETS) emissions fell 3.6% in 2013. This compares to a 2%[22] decrease for the UK as a whole. Gross emission decreases were driven primarily by a switch from coal to lower-carbon fuels in power generation (Figure 3.1).

The Net Scottish Emissions Account (NSEA) in 2013 was 49.7 $MtCO_2e$ which is 1.7 $MtCO_2e$ higher than the 48.0 $MtCO_2e$ target for the year. As a result, Scotland missed its legislated annual target for the fourth successive year (Figure 3.2).

The failure to achieve the target largely reflects an improved scientific understanding of the level of Scottish emissions in 1990, rather than a failure to reduce emissions (see our 2015 Progress Report for detail,[23] we discuss more below). In 2013 emissions were 38.4% below the re-estimated 1990 levels. At the time the targets were set, the 2013 target represented a 31.7%

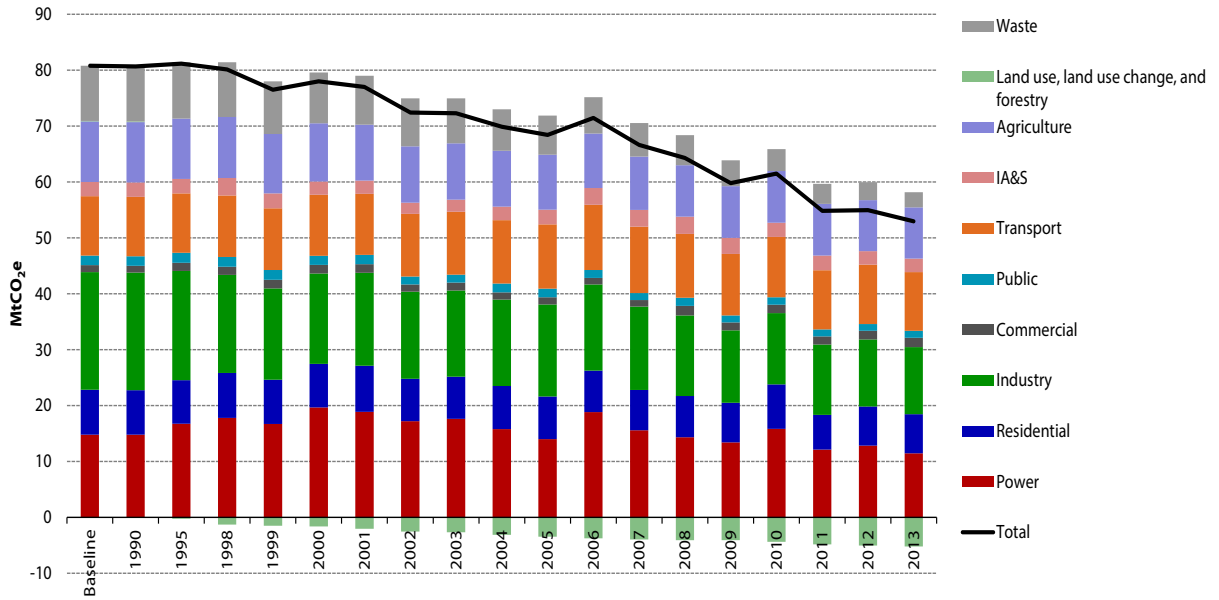
[21] Emission data for Scotland and the other devolved administrations are produced with a significant delay compared to UK wide emissions data, and comprehensive data are only available for 2013.

[22] This figure includes international aviation and shipping and therefore differs from what has been reported in other CCC reports.

[23] CCC (2015), *Reducing emissions in Scotland 2015 progress report:* https://www.theccc.org.uk/wp-content/uploads/2015/01/Scotland-report-v6-WEB.pdf

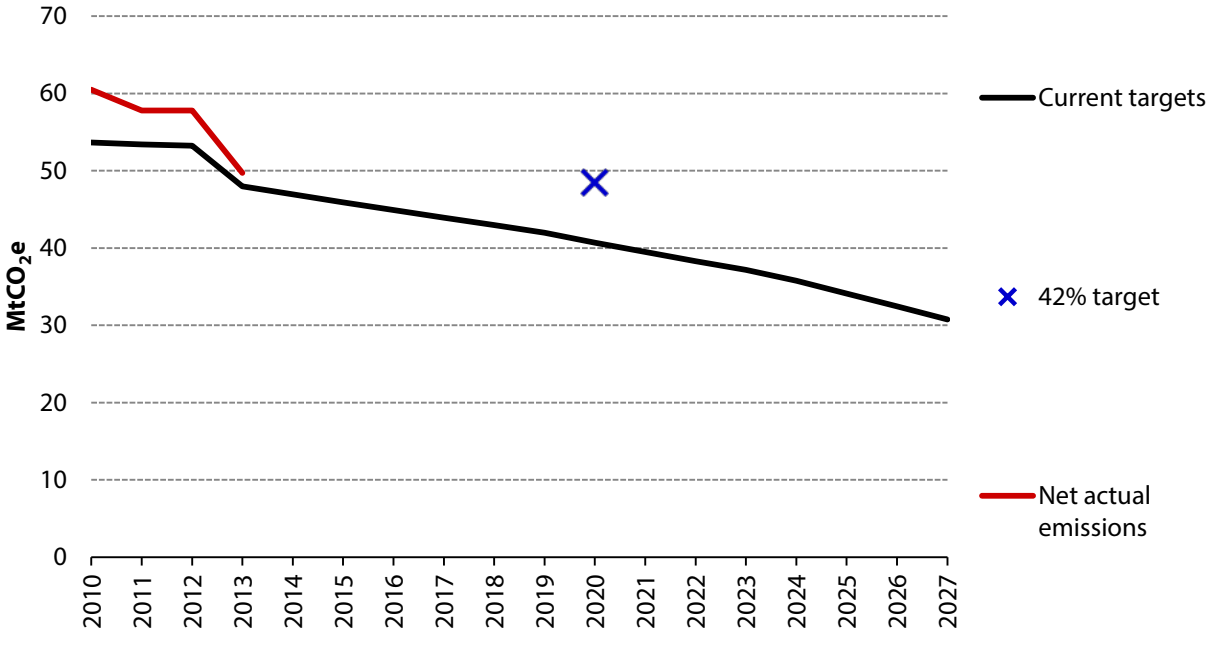
decrease from 1990 levels, indicating that if changes to the inventory had not occurred the 2013 target would have been met.

Figure 3.1: Scottish GHG emissions by sector (1990-2013)



Source: NAEI (2015)

Figure 3.2: Net Scottish Emissions Account (2010-2013): comparison against current targets to 2027



Source: NAEI (2015)

Business as usual projections to 2035

Emissions are likely to rise by about 7%[24] from 2013 to 2030 without any further action (Figure 3.3). These 'Business as usual' emission projections have been compiled from a number of sources (Box 3.1) and provide the baseline against which to judge the costs and benefits of additional action. The projections are based on a scenario where no further policies are enacted beyond those introduced by Scotland and the UK up to and including in the UK Low Carbon Transition Plan 2009.

Box 3.1: BAU projection sources

Business as usual projections are a baseline of reduction in emissions that would occur if no new policy to reduce emissions were implemented beyond those in the 2009 UK Low Carbon Transition Plan. The CCC drew on a number of sources to produce this baseline:

Cambridge Econometrics (CE) were commissioned to use their regional economic forecasts and estimated energy demand equations to determine the responsiveness of energy demand in Scotland to key inputs (including prices, output and air temperature)split between traded and non-traded CO_2 sectors**:**

- Agriculture CO_2
- Industry and industrial processes CO_2
- Non-residential (commercial and public buildings) CO_2
- Residential CO_2

The Scottish share of UK-wide emissions in CE's projections were then applied to DECC's UK baseline for agriculture, industry, industrial processes and non-residential sectors; and applied to projections from the National Household Model for the residential sector.

DECC UK projections / CCC calculations disaggregated for Scotland[25]:

- Industry (energy intensive) CO_2
- Agriculture Non-CO_2
- Waste and F-gases Non-CO_2
- Other sectors Non-CO_2

Modelling by Imperial College London for our UK fifth carbon budget advice was disaggregated to a Scottish level for power sector CO_2 emissions.

Centre for Ecology and Hydrology[26]:

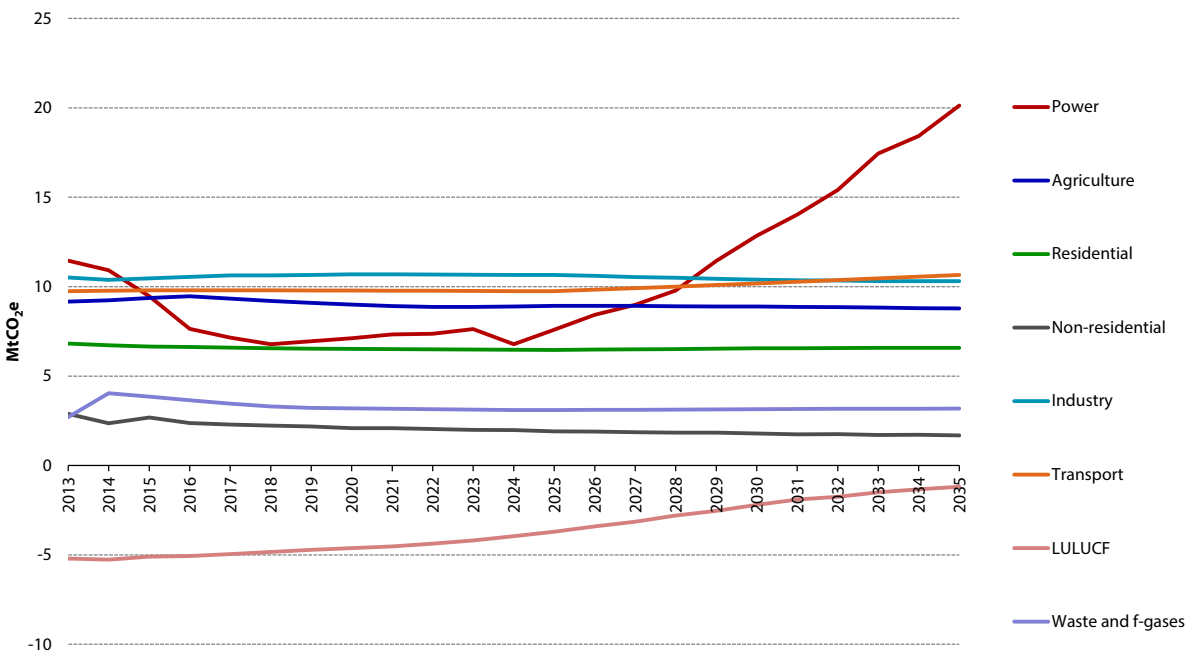
- LULUCF CO_2 and non CO_2

[24] It was not possible to calculate a business as usual projections for aviation and shipping emissions and as such these sectors are not included.

[25] DECC (2015), *Updated energy and emission projections 2014*: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/368021/Updated_energy_and_emissions_projections2014.pdf

[26] DECC (2015), *Projected emissions of non-CO_2 greenhouse gases:* *https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/453665/2015_Report_v1_6.pdf*

Figure 3.3: Business as usual projections, Scotland (2013-2035)



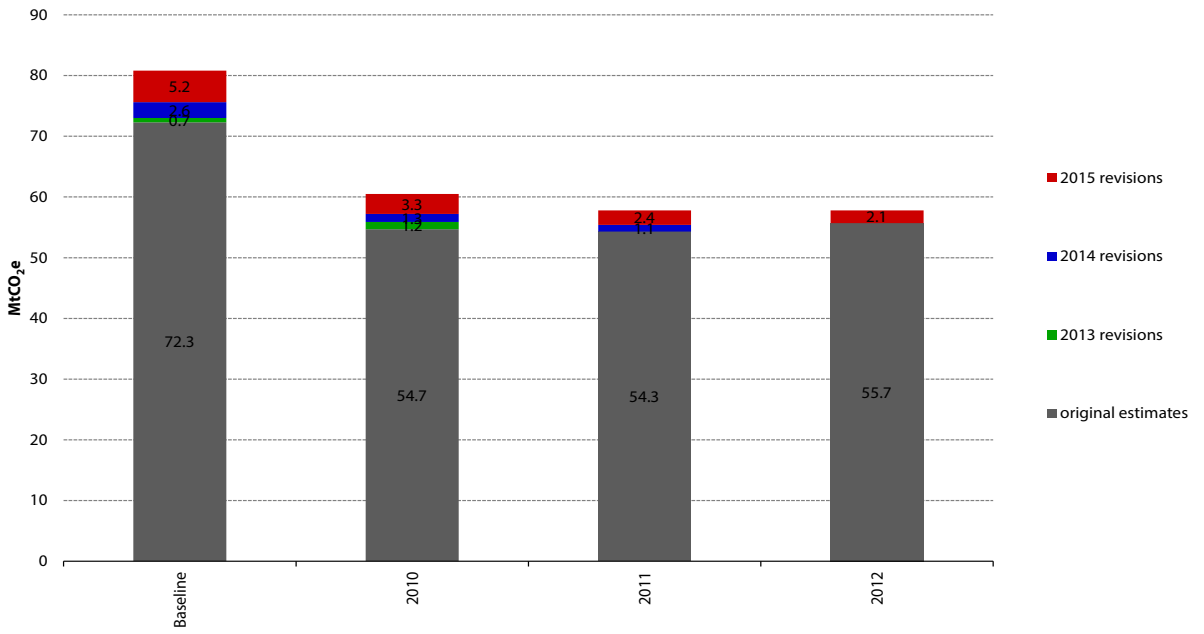
Source: CCC analysis
Notes: Not including international aviation and shipping. LULUCF = land use, land use change and forestry. The baseline power sector technology is unabated gas. Emissions initially therefore fall as this replaces the Longannet coal power station, and then rise as it replaces both assumed closure of nuclear plant and existing renewables coming to the end of their economic life.

Inventory changes

Since the annual targets were legislated in 2009 there have been several revisions to the Scottish greenhouse gas inventory. These changes reflect improvement in scientific understanding which led to changes in the methodology for estimating emissions. Such improvements are welcome but they have made the targets, which were set on an absolute basis, more difficult to achieve. The fact that targets since 2010 have been missed is largely a reflection of these revisions to the greenhouse gas inventory:

- The most recent revision added 2.1 $MtCO_2e$ to 2012 emissions estimates, and 5.2 $MtCO_2e$ to 1990 emission levels, bringing the total cumulative effect of revisions to the 1990 baseline to 8.5 $MtCO_2e$ (Figure 3.4).
- In the non-traded sector, inventory changes have added on average 2 $MtCO_2e$ per year to our most recent BAU projections for 2014-2027 compared to our 2011 projections which were based on the 2008 inventory. The largest revisions are in agriculture and waste.

Figure 3.4: Scottish inventory changes (1990 baseline, 2010-2012) from 2013 to 2015



Source: NAEI and Scottish Government (2015)

2. The role of emissions scenarios in setting annual targets

The role of the annual targets in the Scottish framework is to set a steady and realistic path from current emissions to the long-term 2050 target and the interim 2020 target. The targets ensure that Scotland takes action to remains on track from year-to-year and can be used to monitor progress and guide corrective action if progress appears to be off-track.

To be effective guides to action, the annual targets need to meet the criteria set out in the Act and, overall, they should balance ambition with achievability. They must be sufficiently ambitious to ensure they are genuinely on track to the long-term target, but also feasible in terms defined by the Act given what is known today.

The Committee uses scenarios to make these judgements. We construct scenarios on a bottom-up sector-by-sector basis, combining assumptions about new technology and investments (e.g. new vehicle purchases, heating system replacements, energy efficiency installations, power plant investments) and how consumers behave (e.g. how vehicles are driven, how buildings are heated). Our scenarios are informed by an assessment of the costs and barriers of different options (both technologies and behaviours), by the need to reduce emissions on the path to 2050 and by our projections for a business as usual scenario set out in Section 1.

The scenarios help to ensure that the Committee recommends targets that are consistent with the Act. They are not intended to prescribe the precise route that must be taken to achieve the targets.

For this report we have developed two specific scenarios for Scottish emissions. These are a Central and a High Ambition scenario:

- The **Central Scenario** uses our best assessment of the cost-effective path to the UK's 2050 target that meets the other criteria in the UK Climate Change Act and adapts it to specific circumstances in Scotland and under the Scottish Act. It represents a steady rate of decarbonisation, intended to give an even balance at the UK level between the challenges to 2030 and after 2030. If the UK adopts the fifth carbon budget recommended by the Committee, then the Central scenario gives an indication of the level of ambition that will need to be delivered for the UK. The Central scenario for Scotland is an estimated share of this path for Scotland to contribute to the UK's 2050 target. The share is estimated by taking Scottish specific projections, the criteria in the Scottish Act and its abatement potential.
- The **High Ambition Scenario** goes further in a number of areas where we judge that to be achievable. It is not an upper bound but demonstrates that there are areas with potential to go further than the Central scenario. It recognises this may be appropriate for Scotland given the higher medium-term ambition and the greater challenge in meeting the Scottish 2050 target (see Chapter 1).
- We have not developed a less ambitious **Barriers scenario** (as we did at the UK level), given that would be insufficient to meet existing Scottish ambition.

The scenarios are not intended to be prescriptive, but rather give an indication of the overall level of emission reduction that could be achieved and the sorts of changes that are likely to be appropriate to meet Scottish carbon targets. Scotland could pursue a different balance of effort consistent with the same levels of emissions, based on future developments that cannot be perfectly predicted and the priorities of the Scottish Government.

3. Scenarios for annual targets

Central scenario: summary of results and comparison with legislated targets

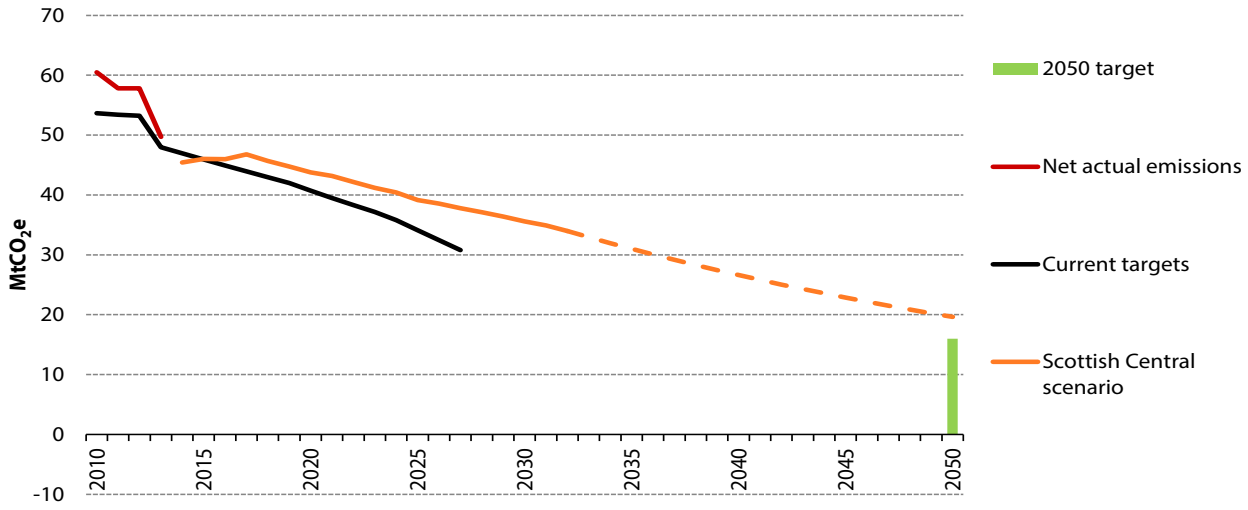
Our economy-wide Central scenario for Scotland implies emissions (on the basis of the net emissions account, i.e. allowing for trading in the EU ETS) in 2030 that are 56% below 1990 levels. This is similar to the Central scenario for the UK, which has a 57% reduction.

The Central scenario for Scotland has emissions of 37.8 $MtCO_2e$ in 2027, considerably above the legislated 2027 target of 30.8 $MtCO_2e$ (Figure 3.5). As in the UK case, the Central scenario implies steady progress for Scotland, with similar reductions required in the period after 2030 (0.76 $MtCO_2e$ each year) compared to before (0.74 $MtCO_2e$ each year). However, that may be insufficient for Scotland, given the higher share of hard-to-reduce sectors like agriculture. It is also inconsistent with the requirement in the Scottish Act for a minimum 3% annual reduction from 2020.

These differences reflect difference between the UK and Scotland:

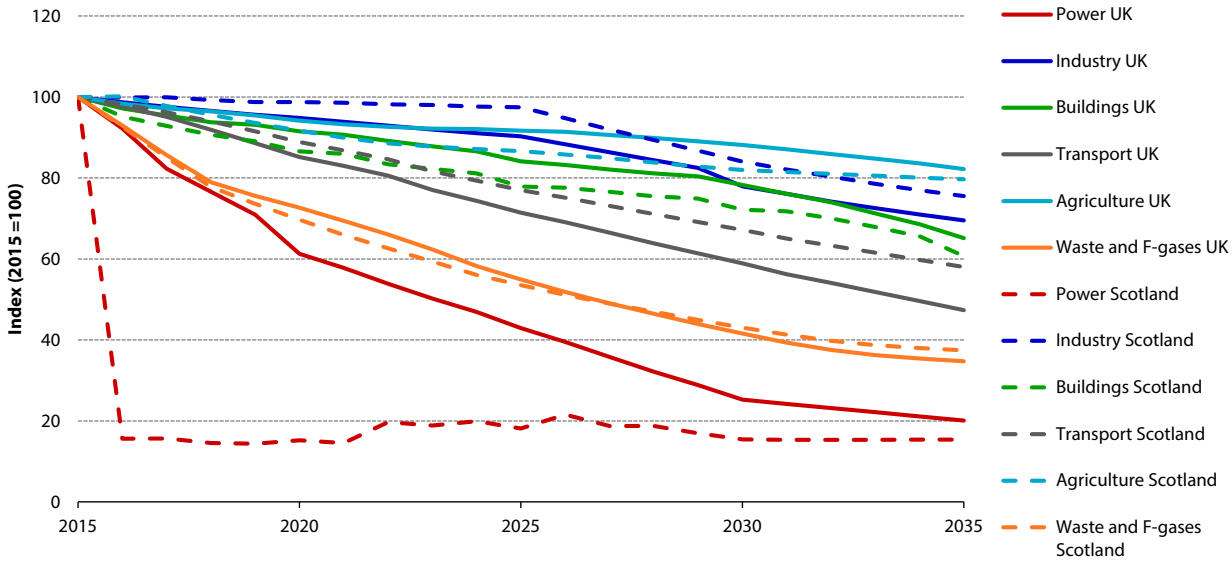
- Different starting points: in 2013 UK net emissions including international aviation and shipping were 27% below 1990 levels, in Scotland emissions were down 38%.
- Different scope: the Scottish projections include international aviation and shipping (as required by the Scottish Act), which are expected to increase from 1990 to 2030.
- Different potential in each sector: Scottish-specific characteristics imply more potential to reduce emissions than the UK average in some sectors and less in others (Figure 3.6).
- Different balance between sectors: greater shares of Scottish emissions currently are in sectors that are relatively harder to reduce (e.g. agriculture) (Figure 3.7).

Figure 3.5: The Scottish Central scenario would fall short of existing targets (2010-2050)



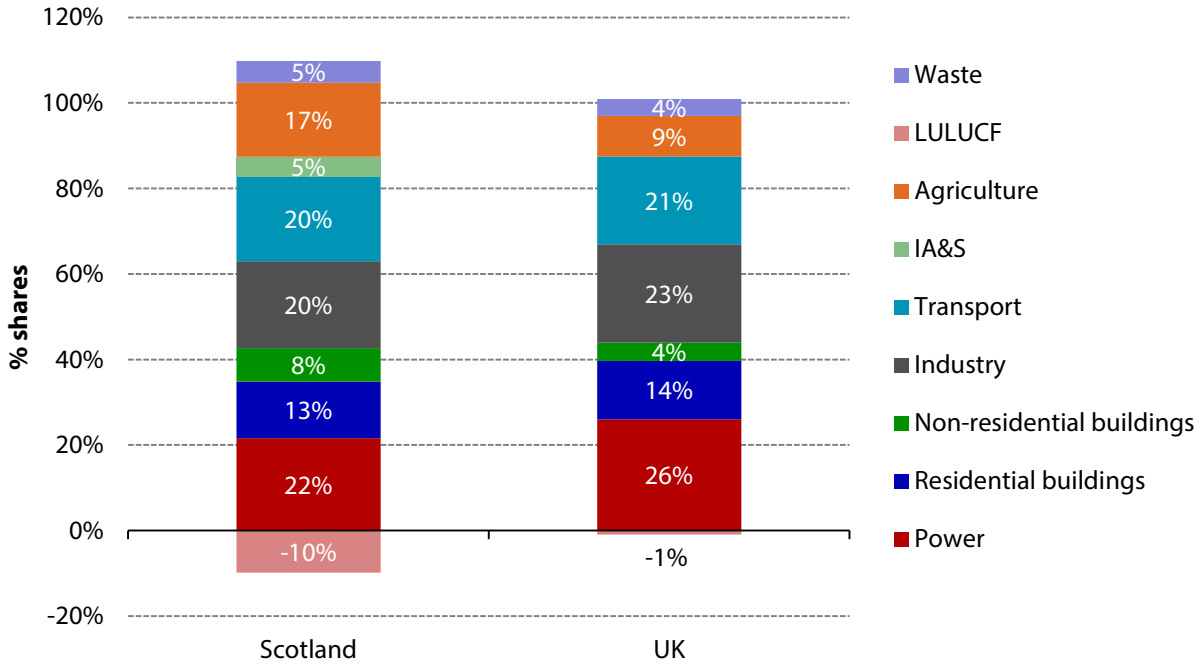
Source: CCC analysis
Note: Actual emissions are Net Scottish Emission Account, the estimate for Scottish emissions against which annual targets are judged.

Figure 3.6: Scottish sectoral reductions to 2035 compared to UK



Source: CCC analysis.
Notes: The transport sector for UK does not include international aviation.

Figure 3.7: Sectoral shares of emissions in Scotland compared to UK (2013)



Source: CCC analysis.
Notes: Shares appear greater than 100% due to LULUCF (land use, land use change and forestry) negative emissions.

Economy-wide High Ambition scenario: summary of results and comparison with legislated targets

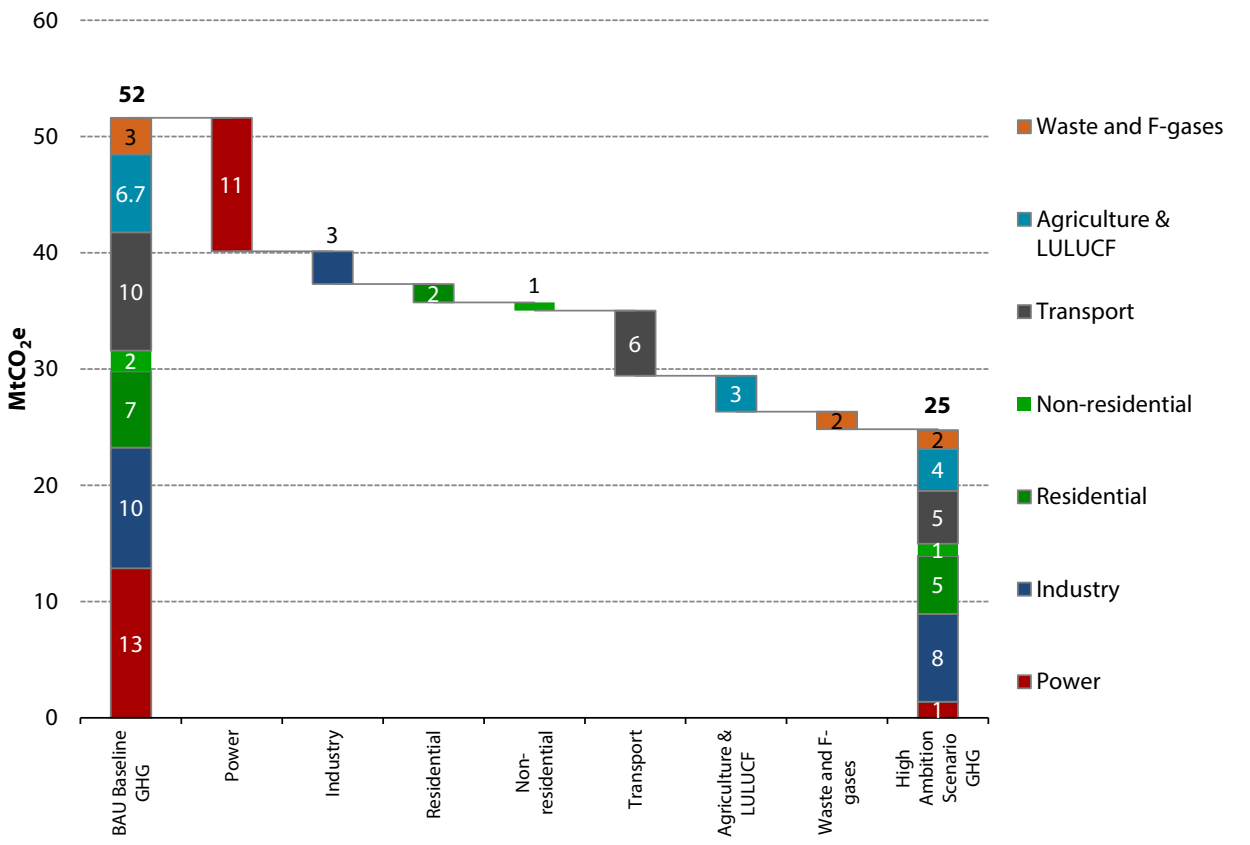
Scotland's Climate Change Act includes the same target for 2050 as the UK Act – a reduction of at least 80% on 1990 levels. However, the Scottish Act includes a higher interim ambition for 2020, and the 2050 target is likely to be more challenging to meet given the higher share of emissions in hard-to-reduce sectors like agriculture (Figure 3.7).

The Scottish High Ambition Scenario would result in a 59% reduction in net emissions from 1990 by 2030. That represents a more credible path towards the 2050 target, which would still require a slightly increased annual percentage rate of reduction from 2030 to 2050. The greater reductions to 2030 in this scenario can better prepare for the challenges to 2050. On that basis we consider it to be more representative of the "cost-effective path", in particular for the non-traded sector, to the Scottish 2050 target than the Central scenario. We reflect that in our recommendations in Chapter 5, which require delivery of the High Ambition scenario in the non-traded sector, rather than the Central scenario.

However, the High Ambition scenario also falls short of the existing targets – resulting in emissions of 35.9 $MtCO_2e$ in 2027, compared to the legislated target of 30.8 $MtCO_2e$. We reflect this in chapter 5, where we recommend that the existing targets are revised to preserve their intended level of effort (i.e. our proposed revisions still exceed the Scottish interim target for a 42% reduction by 2020 relative to 1990), whilst aligning them to latest understanding of current emissions and the EU ETS cap.

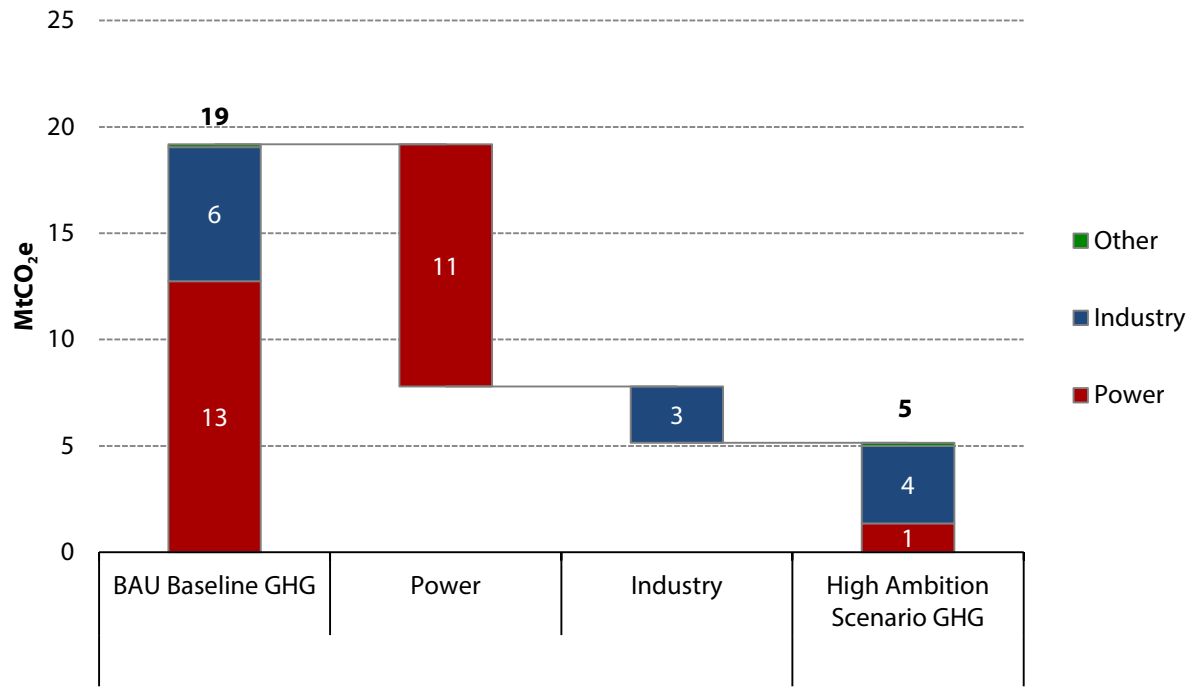
On a gross basis (i.e. ignoring implied trading in the EU ETS) actual Scottish emissions in the High Ambition scenario reduce 64-66% on 1990 levels by 2030. This would result in 2027 emissions of 30.9 $MtCO_2e$, in line with the legislated target which we originally recommended based on an assessment of actual Scottish emissions before the EU ETS cap had been set. Levels of abatement and remaining emissions in 2030 in the High Ambition scenario versus business as usual are set out on a sectoral basis in Figures 3.8-3.10.

Figure 3.8: Abatement in the High Ambition Scenario (total emissions, 2030)



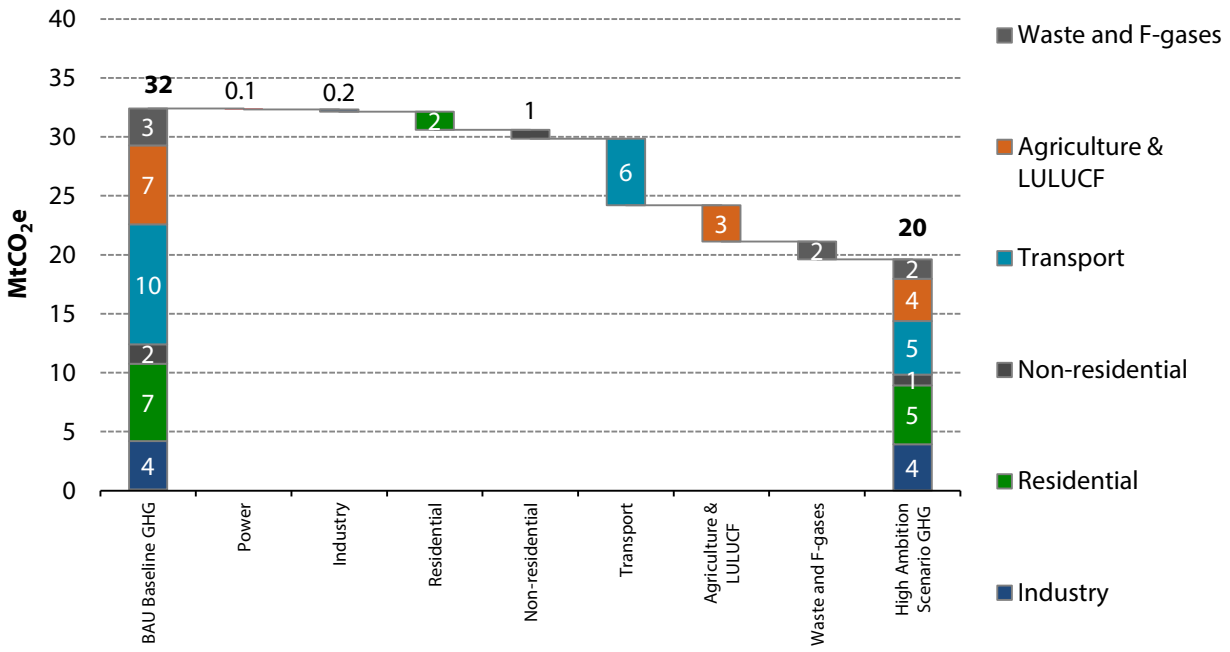
Source: CCC analysis
Notes: The Baseline is a projection of GHG emissions in the absence of further effort to reduce them. Baseline GHG emissions are drawn from Government models and our own modelling at the sector level. Biomethane in the gas grid is allocated to the industry sector. This figure does not include aviation and shipping as we have not constructed a BAU scenario for this sector.

Figure 3.9: Abatement in the High Ambition Scenario (traded sector, 2030)



Source: CCC analysis
Notes: The Baseline is a projection of GHG emissions in the absence of further effort to reduce them. Baseline GHG emissions are drawn from Government models and our own modelling at the sector level. Biomethane in the gas grid is allocated to the industry sector. This figure does not include aviation and shipping as we have not constructed a BAU scenario for this sector.

Figure 3.10: Abatement in the High Ambition Scenario (non-traded sector, 2030)



Source: CCC analysis
Notes: The Baseline is a projection of GHG emissions in the absence of further effort to reduce them. Baseline GHG emissions are drawn from Government models and our own modelling at the sector level. Biomethane in the gas grid is allocated to the industry sector. This figure does not include aviation and shipping as we have not constructed a BAU scenario for this sector.

4. Emissions by sector of the economy

Scottish annual targets are set on a net basis including a share of the EU traded sector cap and actual non-traded sector emissions. The majority of emissions from the power sector and energy-intensive industry are covered by the cap and therefore the actual emissions from these sectors are not counted towards meeting targets. However, we have analysed the potential emission reductions in these sectors for our Central and High Ambition scenarios alongside the non-traded sector to give an indication of emission reductions on a gross basis.

Our scenarios include:

- **Electricity generation.** Emissions intensity of Scottish electricity generation is reduced to 10-20 gCO_2/kWh in 2030 compared to a current level of over 200 gCO_2/kWh. Much of the reduction results from the closure of the coal power station at Longannet in 2016 which accounted for 10 of the 11.5 $MtCO_2e$ of emissions in 2013. Continued expansion of renewable generation ensures that Scotland remains a net exporter of low-carbon power during a period when existing nuclear power stations are expected to close. Storage, demand-side response and interconnection play an important role in maintaining security of supply.

- **Heat in buildings.** Heat pumps are rolled out to 18% of homes by 2030, supplemented by significant roll-out (2.6 TWh) of heat networks to homes and business premises. Almost all available cavity walls and lofts are insulated along with the majority of the solid walled houses occupied by the fuel poor.
- **Industry.** Various opportunities to improve energy efficiency are taken up, including waste heat recovery and material efficiency. There is a switch away from fossil fuels to bioenergy and some electrification for space and process heating. A Scottish carbon capture and storage cluster is developed to reduce emissions from large point sources.
- **Transport.** Vehicle efficiency improves throughout the period to 2030 and the gap between test cycles and real-world performance is reduced (this requires action at the EU level). Of all new cars and vans 65% are ultra-low emission (e.g. electric) vehicles by 2030. Further abatement is delivered from biofuels, a shift towards public and active transport (i.e. walking and cycling) and more efficient freight operations. Our scenarios reflect a detailed assessment of travel patterns in Scotland, where the average trip length is similar to the UK average.
- **Forestry and agriculture.** The rate of new tree planting increases to 16,000 hectares per year. Various measures are implemented to reduce emissions in agriculture, requiring stronger levers than the current voluntary approach: on-farm efficiency measures, improved management of crops and soils and improved animal health.

Further abatement is delivered from **waste disposal** and **F-gases.** That could largely be delivered through effective implementation of existing waste policy plans and the new EU F-gas regulation.

Although these scenarios are not prescriptive, it is clear that any scenarios to meet the annual emissions targets will involve a significant expansion of renewable energy in Scotland: in the power sector, in heat and, via electrification, in transport. Scotland would need to deliver above the UK average in these areas, for example with double the share of heat pumps in homes than we have proposed for the UK (18% compared to 9%), and as a significant exporter of renewable power to the rest of the UK. Energy efficiency also has an important role: both the carbon and energy intensity of the Scottish economy will have to significantly improve.

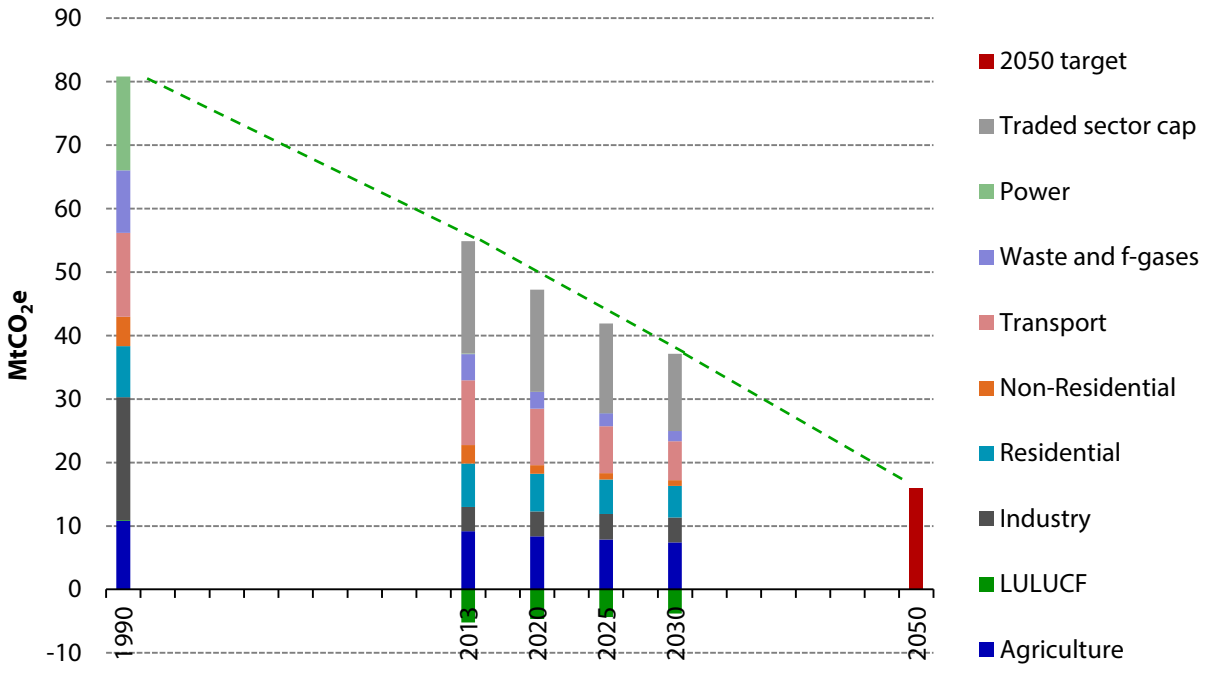
Further details of our sector scenarios can be found in the Annex at the end of this report.

5. Further progress required from 2033-2050

Beyond the 2028-2032 target period, continued emissions reduction will be required at a similar rate across the economy to the progress embodied in our High Ambition scenario (i.e. an average of 1.0 $MtCO_2e$ per year). This will likely require increased contributions from buildings and potentially industry as opportunities in the power sector and non-CO_2 are largely used up.

The shape of the emissions path under our scenarios is determined by the set of sector-specific paths, which reflect different considerations. Our current best assessment of the whole economy cost-effective path to 2050 is described in Figure 3.11).

Figure 3.11: Emission reductions in the High Ambition Scenario (2013-2030) and to 2050



Source: CCC analysis
Notes: Transport includes aviation and shipping. Between 1990 and 2013 average rate of reduction of 1.4 $MtCO_2e$, between 2013 and 2030 average rate of reduction 1.0 $MtCO_2e$, and between 2030 and 2050 average rate of reduction 0.9 $MtCO_2e$.

Chapter 4: Broader economic and social considerations

Introduction and key messages

In this chapter we consider the target-setting criteria in the Climate Change (Scotland) Act that have not been covered explicitly elsewhere in the report. These informed our recommendations in chapter 5, and are set out here in terms of how those recommendations perform against the criteria.

Our key messages are:

- **Economic circumstances:** Our proposed targets balance medium-term costs with the risk of storing up costs for the long term. They aim to follow the lowest-cost path to the 2050 target consistent with the terms of the Act. There are potential economic opportunities for Scotland and plans are in place to manage potential competitiveness risks.
- **Fiscal circumstances:** Existing targets imply a large potential fiscal liability (of over £500 million cumulatively to 2027). Our proposed revisions to targets would avoid this liability whilst increasing the credibility and therefore value of the Scottish emissions targets. There would still be a significant potential liability in 2028-2032 if abatement cannot be found consistent with the targets recommended in this advice.
- **Social circumstances:** If energy efficiency measures can be effectively targeted, then these can reduce fuel poverty in Scotland, even as energy prices are expected to rise.
- **Island and rural communities:** These communities have particular opportunities to benefit from renewable heating systems given the high proportion of fuel poor and households off the gas grid. They may also benefit from economic opportunities presented by renewable power generation.
- **Environmental considerations:** Scenarios to meet the annual targets imply significant improvements in air quality as less fossil fuels are burnt. There may also be biodiversity benefits from afforestation and reduced fertiliser use, with possible risks from onshore and offshore renewables. We will discuss the wider environmental risks from climate change in the Climate Change Risk Assessment to be published in July 2016 as well as specific advice to the Scottish Government on its adaptation programme in September 2016.

1. Economic circumstances

There is a cost to climate action since low-carbon technologies currently have higher costs than high-carbon alternatives, which do not face the full cost of their emissions. The precise costs and benefits of meeting the targets depend on a range of uncertain factors. These include the pace of innovation and the path of technology costs and performance, fossil fuel prices, wider

economic performance, the level of demand and behaviour of consumers and the mix of measures used to meet the targets.

However, the costs of action must be set against the costs of inaction. At the global level, inaction would be more costly given the very damaging impacts of unmitigated climate change. For Scotland, less action to 2032 would require more action to 2050 to reach the long-term target in the Climate Change (Scotland) Act.

Our recommendation in this report is that annual targets for 2028-2032 are set at the minimum level of ambition required by the Act (i.e. requiring a 3% annual reduction each year from 2020). Our judgement, based on the scenarios and analysis set out in chapter 3 is that these targets would suitably keep Scotland on track to the 2050 target for at least an 80% reduction on 1990 levels. They are therefore the most appropriate targets from an economic perspective: minimising costs in the medium term, without storing up higher costs for the longer term.

There is the potential for the move to a low-carbon economy to lead to higher levels of resource efficiency, and whilst the development of low-carbon goods, processes and services could generate economic growth and jobs for Scotland. This move could also make Scotland more resilient to unpredictable commodity and energy prices. Scotland's low-carbon market was worth around £8.5 billion in 2007-08 (within a GDP of around £100 billion), supports over 70,000 jobs, with £845 million worth of low-carbon technologies exported in 2009/10.[27]

Small and medium-sized enterprises can potentially benefit from these new markets. They may also be able to reduce energy bills through improvements to energy efficiency and a shift to low-carbon heating systems, as required by our scenarios in chapter 3.

Decarbonisation raises both challenges and opportunities for the competitiveness of Scottish firms. Challenges could arise if low-carbon policies disadvantage specific sectors or firms, potentially harming profits and driving location of production to other countries (often referred to as 'carbon leakage').

Earlier research [28] found that competitiveness risks of carbon budgets are limited and manageable. Since this research there have been a number of changes to global ambition, EU ETS and policies to further mitigate impact of low-carbon policies for at risk industries[29]:

- **International ambition** - Competitiveness risks posed by the transition to a low-carbon economy depend in part on how fast Scotland moves relative to others. In the 2015 Paris Agreement countries around the world pledged further and deeper action to reduce their emissions. Implementation of low-carbon technologies, laws, measures and pledges have progressed in recent years such that the competitiveness risks to Scotland are reducing.
- **Measures to reduce direct emissions** – Scottish energy-intensive industries are included in the EU Emissions Trading System (ETS), requiring them to surrender allowances to cover carbon emissions associated with their energy consumption. Paying for such allowances would raise the costs of energy-intensive industries relative to competitors outside the EU that do not face carbon costs. In order to mitigate such risks:

[27] A Low Carbon Economic Strategy for Scotland (2010).

[28] CCC (2013), *Carbon footprint and competitiveness* https://www.theccc.org.uk/publication/carbon-footprint-and-competitiveness/

[29] Industries subject to competitiveness risks due to low-carbon policies are ones that are energy-intensive and have a high degree of international trade. Key industries are paper, metals, non-metallic minerals, refineries, chemicals, rubber and plastics, wood and textiles.

  - Free allowances are granted to energy-intensive firms subject to international competition. During Phase III of the EU ETS (2013-20), sectors deemed at risk of carbon leakage are allocated 100% free allowances; subject to industry benchmarks (other sectors receive less on a sliding scale).
  - For Phase IV (2021-2030) of the EU ETS the EU proposes to continue to allocate free allowances, but the rules determining at risk sectors have been tightened and should focus more on sectors at risk compared with Phase III (2013-2020).
  - While this is our best assessment of the changes to the EU ETS rules, the rules have not yet been finalised and therefore the precise impacts of these changes are as yet unknown.
- **Measures to reduce indirect emissions** – competitiveness risks arise indirectly through measures to decarbonise the power sector which add to electricity prices. To minimise impacts on at-risk industries, the UK provides:
  - compensation for the indirect costs of the EU ETS and Carbon Price Support and,
  - exemption from additional costs of supporting low-carbon electricity investment[30] to 2019-20.

Overall, competitiveness risks to energy-intensive sectors from low-carbon policies are manageable: direct impacts are low-cost and sectors at risk are eligible for free allowances under the EU ETS; there are policies in place or planned to compensate or exempt industry from indirect impacts of higher electricity prices. Impacts of the Scottish targets are likely to be reduced given increased international pledges and action to implement low-carbon measures.

The above research also found that the transition to a low-carbon economy can create opportunities for businesses of all sizes, for example in investing in new markets and resource efficiency measures, and innovation in new technologies and processes across a range of sectors and applications.

2. Fiscal circumstances, in particular the likely impact of the targets on taxation, public spending and public borrowing

In this section we consider the impact of our scenarios through the 2020s on the fiscal position at both UK and Scottish levels. Given the balance of reserved and devolved fiscal powers, most of the potentially large UK impacts do not have a direct impact on Scotland's fiscal position, although that may change over the period based on the details of the devolution settlement. To the extent that additional public expenditure is required to meet more ambitious Scottish targets, this is likely to reflect a continuation of the level envisaged to meet currently legislated targets. Our recommended targets imply a significantly lower fiscal liability from credit purchase than currently legislated targets.

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

- **Revenues from EU ETS auctioning and carbon price floor.** These could be worth around £2.6 billion in 2030 under a central price scenario.

[30] I.e. costs of Feed-in-tariffs, Renewables Obligation and Contracts for Difference.

- **Transport revenues.** With an unchanged fiscal regime, revenues from fuel duty and vehicle excise duty are likely to fall substantially in future, as fuel efficiency of conventional vehicles improves and as electric vehicles come into the fleet. However, changes to duty bands and rates, or other measures, could be used to preserve revenues in line with the current taxation burden for drivers.
- **Low-carbon heat.** Under the current policy approach, low-carbon heat measures are funded from public spending through the Renewable Heat Incentive. The measures in our scenarios have relatively low resource costs (e.g. around £1.1 billion in 2030 across the UK), as they focus on the more cost-effective opportunities.
- **Other impacts.** There are a range of measures with smaller impacts on the fiscal balance, both positive (e.g. the Carbon Change Levy) and negative (e.g. remaining support for electric vehicles) which we did not assess in detail given their small size and/or uncertainty about policy design in the 2020s.

Overall, we concluded that fiscal impacts are likely to remain manageable, particularly given scope for fiscal rebalancing to maintain revenues in the period to 2030.

In the case of Scotland, and given the balance of reserved and devolved powers, most of the potentially large UK fiscal impacts (e.g. EU ETS auction revenues, fuel duty) do not directly impact on Scotland's fiscal position.

However, there are potential additional fiscal impacts from further devolved powers under the Smith Commission, the need to implement our High Ambition scenario in the non-traded sector, and from credit purchase:

- **Further devolved powers.** There is currently a process underway to devolve further fiscal powers to the Scottish Parliament, as recommended by the Smith Commission. The main additional potential impact is on air passenger duty (APD) from flights covered by the non-traded sector. Our scenarios, however, do not imply any loss of activity and therefore revenues.
- **Implementing the High Ambition scenario.** There will potentially be fiscal impacts from policies required to encourage uptake of the abatement measures under the 'High Ambition' scenario. For example, this includes a further reduction in emissions from car travel, more widespread use of low carbon heat in buildings and a greater rate of afforestation in agriculture. We have not quantified the fiscal impacts implied by this level of ambition because they will depend on specific policy design. We will continue, through our annual Progress Reports, to advice on specific policy options that balance fiscal and other considerations. That will help to guide policy development between now and when the targets take effect.

- **Credit purchase.** There is a gap between our High Ambition scenario and our recommended annual targets. Purchase of credits may be required to fill this gap, to the extent that it cannot be closed through measures beyond the High Ambition scenario. Our recommended targets imply a much smaller fiscal liability from credit purchase than if currently legislated targets were extended (e.g. around £0.4bn versus £1.1bn between 2017-32, assuming an average credit price of £24/tCO_2e, in line with EU ETS market price forecasts; this is likely to be towards an upper bound). Existing targets imply a potential fiscal liability totalling over £500 million over the period to 2027. However, a number of factors could reduce or eliminate this cost. Importantly, under a tighter EU ETS cap, Scotland could meet targets through the High Ambition scenario without recourse to any further purchase of emissions credits outside the EU ETS. This would also be consistent with the EU's 2050 ambition. Reform of EU ETS should be a priority for Scotland.

Overall, it will be a matter for the UK and Scottish Governments to decide the appropriate balance between taxation, regulation and public spending to drive emission reductions. To the extent that public expenditure is required through the 2020s, this is likely to reflect a continuation of the level of expenditure envisaged to meet currently legislated targets and, in the case of credit purchase, significantly less.

3. Social circumstances, in particular the likely impact of the targets on those living in poorer or deprived communities

Fuel poverty in 2014 was 34.9% (845,000 homes), down from 35.8% in 2013. Fuel poverty rates have remained high due to increased energy prices over recent years unrelated to emission reduction targets in Scotland or the UK.[31]

Over the next decade, we would expect energy prices to increase further, reflecting projected increases in carbon prices and support for investment in renewable generation, and possibly higher gas prices. However, if energy efficiency measures can be effectively targeted at the fuel poor and poorer households more generally, then overall numbers in fuel poverty would fall even as costs from supporting low-carbon investment increase.

The energy efficiency measures included in our High Ambition scenario will help to alleviate fuel poverty. The scenario includes insulation of a total of 200,000 solid walls and around 800,000 cavity walls by 2032. This could reduce energy consumption and bills. Low-carbon heat measures can also play a role in reducing fuel poverty, especially for the relatively high proportion of fuel-poor households that do not have gas heating (e.g. 60% of electrically heated homes are fuel poor).

The Scottish Government have committed funding and designated energy efficiency as a national infrastructure priority to improve the energy efficiency rating of Scotland's homes (and non-domestic buildings) over the next 15-20 years.

4. The likely impact of the targets on those living in remote rural communities and island communities

Measures required to meet the annual targets could have positive impacts for those in rural and island communities:

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

- There is a particular opportunity for cost-effective investment in renewable heat generation for off-gas grid homes, in conjunction with energy efficiency. Levels of fuel poverty in some specific rural areas are particularly high with 50%[32] of those living in rural areas in fuel poverty, including 62% of homes in the Western Isles. This is in part due to a greater proportion of households not on the gas grid and therefore facing higher energy prices (60% of those not on the gas grid are in rural areas).
- Remote and island communities are often located in areas that are particularly suitable for renewable power generation (i.e. wind and marine power). Investment in renewable generation could therefore provide local benefits in terms of employment and profit sharing, in particular with community and off-grid schemes. Projects such as the Northern Isles New Energy Solutions could help to deliver a secure, affordable and reliable energy system to islands. To realise the full potential of renewable generation in island communities, increased interconnection is likely to be needed to the larger electricity markets on the mainland.

It will be important that changes to reduce emissions from transport do not adversely affect rural or island communities. In the immediate term, plug-in hybrid vehicles are likely to be more suitable than pure battery electric vehicles in some rural areas, and opportunities for reducing private car use may be limited relative to urban areas. The overall reductions in transport emissions envisioned in the High Ambition scenario are consistent with continuing to meet the mobility requirements of those living in rural and island communities.

5. Environmental considerations and the likely impact of the targets on biodiversity

In our review of the fourth carbon budget (2013) we commissioned work from Ricardo AEA to consider the impacts of carbon budget measures on human health and the environment.[33] The report highlighted a number of impacts from carbon budgets on the environment. Key impacts which are relevant to Scottish annual targets are:

- **Air quality and noise**
  - Improved air quality from switching from coal and gas-fired generation to renewables.
  - Substantial benefits to air quality and noise from reduced congestion as a result of avoided journeys through smarter choices and improved HGV logistics.
  - Anaerobic digestion of farm waste and manure leads to a wide range of benefits including improved air and water quality.
- **Biodiversity**
  - Afforestation can lead to benefits for biodiversity, landscape, recreation and air, soil and water quality. Benefits can be maximised by choosing mixed native species, by avoiding sites with high existing biodiversity or landscape values and using sustainable cultivation.
  - Significant ecosystem benefits for air and water quality arise from measures to reduce excess application of fertilisers.

[32] Figures taken from Scottish Household Condition Survey (2014), http://www.gov.scot/Publications/2015/12/8460/downloads

[33] Ricardo AEA (2013) *Review of the impacts of carbon budget measures on human health and the environment:* https://d2kjx2p8nxa8ft.cloudfront.net/wp-content/uploads/2013/12/AEA-Review-of-the-impacts-of-carbon-budget-measures-on-human-health-and-the-environment.pdf

– Reducing vehicle-kms could, if it means fewer new roads being built have a positive impact on biodiversity and ecosystems by reducing habitat loss and fragmentation.
– There are risks of landscape and biodiversity impacts from increased deployment of onshore wind power, including visual impacts, deaths of birds and bats, removal of sensitive habitats, siting on peatlands and noise from the rotor blades. This could be partly mitigated by siting wind farms sensitively and consulting with local communities.
– There are risks of impact to marine and coastal environments from offshore renewables including bird collisions, fishing, and effects on marine life. These again can be mitigated with appropriate siting.

Overall, our assessment is that there are significant benefits from actions to meet annual targets, in addition to the long-term global benefit in mitigating climate change. Improved air quality and biodiversity accrue immediately and directly to individuals, communities and habitats. Accounting for these benefits strengthens the case for ambitious action to reduce emissions over the next two decades. At the same time, measures can be put in place to reduce local costs from action, including allowing communities to choose which approaches meet their priorities. In taking forward policies and proposals for the Scottish annual targets, the synergies, costs and benefits for both adaption and mitigation should be considered.

Chapter 5: Recommendations

Introduction and key messages

The Committee recommends that the Scottish annual targets are set to require a 61% reduction in the Scottish emission account in 2030 relative to 1990. That would keep Scotland on track to its 2050 target to reduce emissions by at least 80% on 1990 levels by 2050. It could be largely delivered by following the High Ambition scenario set out in chapter 3.

This requires that existing targets from 2017 to 2027 are aligned to the latest information on current emissions and the Scottish share of the EU ETS cap. That would preserve the value of the targets in setting a steady, achievable path to the long-term target and providing a guide to policy development and progress monitoring.

We recommend that Scotland aims to meet these targets through domestic action, without recourse to purchase of emissions credits.

This chapter sets out the recommended targets (Section 1), their implication for cumulative emissions (Section 2), the Committee's advice on the use of offset credits (Section 3) and the next steps for delivering the targets (Section 4).

1. Recommendations on annual targets

The basis for setting annual targets

As set out in chapter 1, the annual targets are only one part of the framework in the Climate Change (Scotland) Act. Their value is in setting a steady and achievable path from current emissions to the interim 2020 target and the long-term 2050 target. That path should provide a clear basis for monitoring progress from year-to-year.

Existing annual targets

Since the existing targets were set, there have been revisions to the estimates of emissions in the Scottish greenhouse gas inventory and updates to the rules for the EU Emissions Trading System. As a result of these changes, the existing targets beyond 2017 are significantly more challenging than intended when they were set (Table 5.1 and Figure 5.1).

- **Inventory changes**
  - The Committee's previous advice in 2010 and 2011 on the existing targets for 2014-2027 was based on estimated baseline (i.e. 1990) emissions of 70.2 $MtCO_2e$.
  - Latest estimates are that gross emissions in 1990 were actually around 15% higher, at 80.2

$MtCO_2e$. This reflects new scientific knowledge that led to improvements to estimates of emissions from agriculture, land use and waste, where the Committee has previously noted that significant uncertainty exists.

  - As a result, existing emissions targets, which were set to require a reduction in emissions of 51.4% from 1990 to 2025, now require a reduction of 57.8%.

- **EU ETS rules**
  - When the Committee advised on the existing targets for 2023-2027, the rules for how the EU ETS cap would be shared between countries were not known.
  - We therefore advised that targets should be set based on the lowest-cost path for actual emissions, without any allowance for trading in the EU ETS. We stated that when EU ETS rules were announced, targets may need to be revised.[34] More detail has now been published for the EU ETS through to 2030. Our estimates in chapter 3 indicate that the EU ETS rules imply a slower reduction in Scotland's net carbon account than in our High Ambition scenario for gross emissions. This would imply that Scotland was a net seller of emissions allowances to the rest of Europe.
  - Although an estimate of the cap was previously available for 2014-2022, developments in the precise rules up to 2020 have also changed our estimate of the Scottish share of the cap. That includes announced 'backloading' for 2014-2016 (see Box 2.1 in chapter 2). The Backloading provisions artificially make Scotland's emissions targets easier to meet in those years – even if emissions in the non-traded sector do not fall from 2013 to 2014 the 2014 annual target will be met.

As a result the existing targets no longer provide a steady path to the longer-term targets. Our assessment of options for reducing Scottish emissions in chapter 3 indicates that it would not be possible to meet the existing targets from 2017 even with the highest ambition we have identified (Figure 5.2). This implies that the targets cannot be a useful guide to policy or an effective signal as to future policy effort.

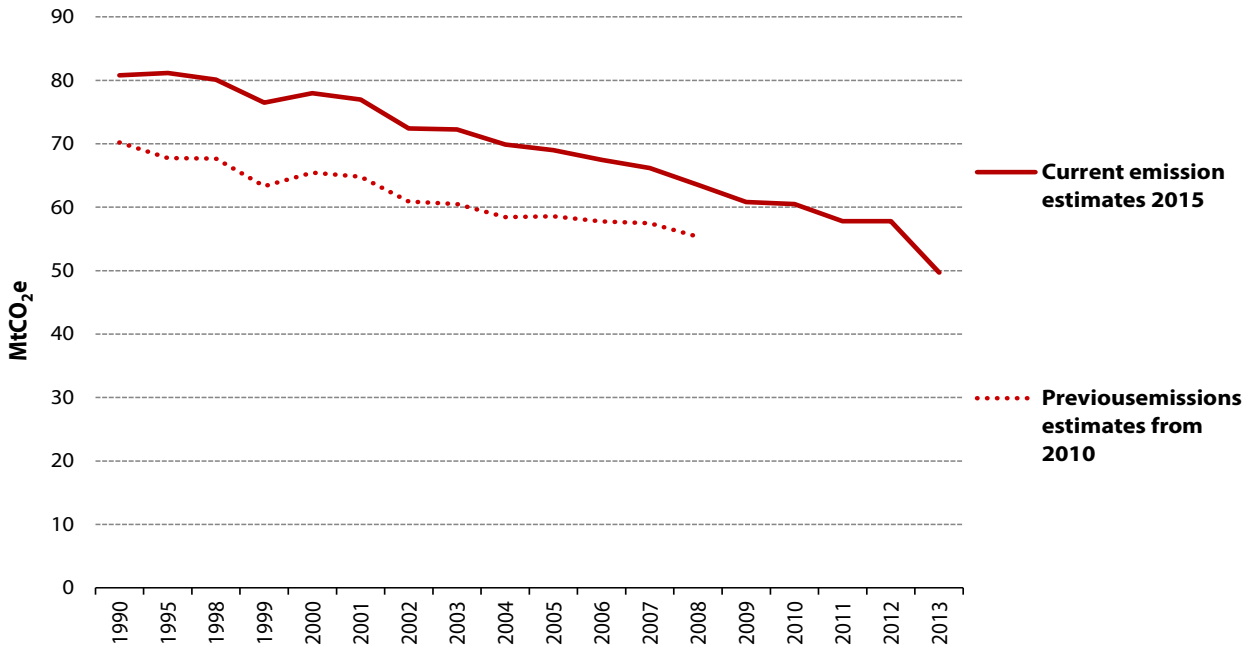
We therefore recommend that the existing targets from 2017 are revised to reflect the latest circumstances and to bring them back in line with achievable paths to the 2050 target and a steady rate of required progress.

The revisions that we propose would preserve the intention of the existing targets, whilst aligning them to the latest available information. This can be seen in Table 5.1, which shows that the actual emissions reductions implied by the revised targets are greater than envisaged when the existing targets were set. It is clearly preferable to avoid revisions to targets, but in this instance a revision is the only realistic option to preserve the value and credibility of the targets.

As described above there are risks that accounting rules for the EU ETS undermine the integrity of Scotland's targets, by artificially increasing or decreasing the effort required from sectors outside the EU ETS. It is effort in these sectors that is most relevant for Scotland, since devolved powers are strongest here. Therefore, to preserve the intention of the targets we recommend that the Scottish Government consider using the **Carbon Accounting Regulation** provision in the Climate Change (Scotland) Act to fix the net emissions account for the traded sector at the level assumed when the targets are set.

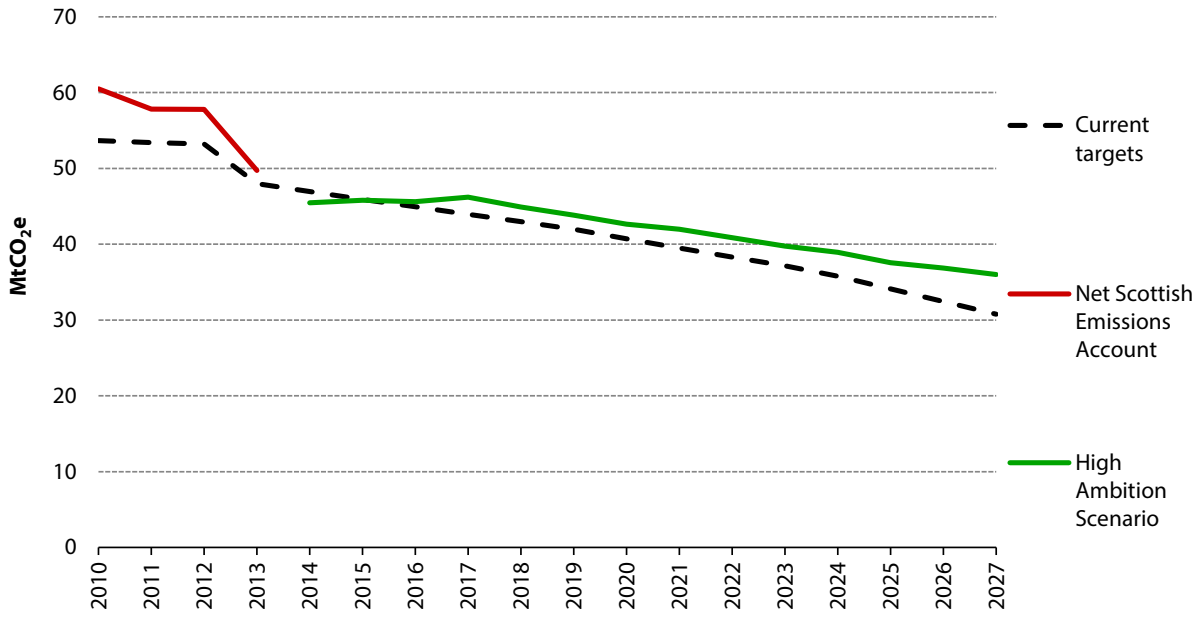
[34] CCC (2011) *Letter advising Scottish Government on emission targets for 2023-2027, Page 9:* https://www.theccc.org.uk/publication/letter-committee-on-climate-change-advice-to-the-scottish-government-on-emission-targets-for-2023-2027-and-credit-use-in-2013-2017/

Figure 5.1: Comparison of the Net Scottish Emissions Account from 2010 (1990-2008) and 2015 (1990-2013)



Source: NAEI (2015)
Notes: GHG emissions data is not available for Scotland for 1991-1994, or 1996-1997.

Figure 5.2: Net Scottish Emissions Account, current targets and High Ambition Scenario



Source: CCC analysis

Recommendations for 2028-2032 targets and revisions to existing targets

To meet the criteria of the Climate Change (Scotland) Act we recommend that the annual targets are set in line with our High Ambition scenario for 2020, followed by 3% annual reductions thereafter (Figure 5.3 and Table 5.1). These targets are therefore more ambitious than our proposals for the UK's fifth carbon budget:

- The Scottish target for 2030 requires a 61% reduction in Scottish emissions (on a net emissions account basis) relative to 1990.
- That compares to a 57% reduction recommended for the UK's fifth carbon budget. However, unlike the Scottish targets, UK carbon budgets do not include international aviation, which is expected to make less progress in reducing emissions. On a comparable basis, the UK reduction would be around 53% in 2030 relative to 1990.

This more front-loaded path may be appropriate for Scotland given the different structure of the Scottish economy – a higher share of emissions in challenging sectors like agriculture means Scotland has a greater challenge to reach its long-term target to reduce emissions at least 80% by 2050 relative to 1990. Larger reductions in the period to 2032 can help to prepare for this greater challenge.

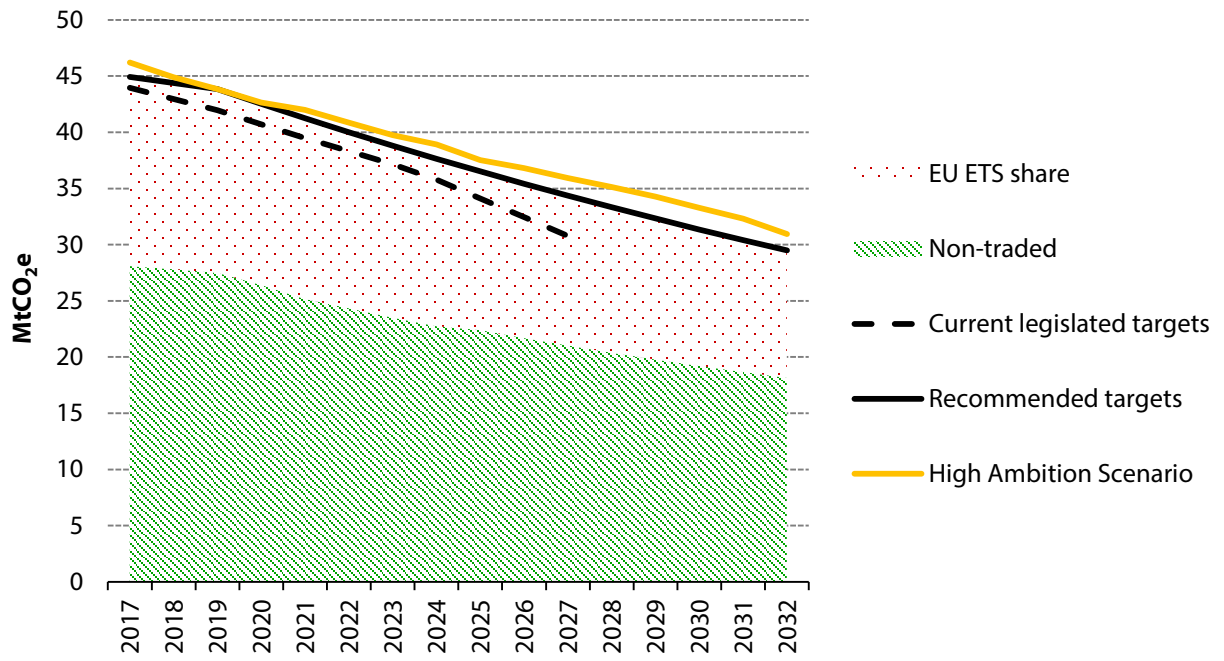
The proposed targets are in line with the requirements of the Climate Change (Scotland) Act:

- If continued to 2050, annual reductions of around 3% would meet the requirement in the Act for a reduction of at least 80% relative to 1990.
- The targets imply a 47% reduction in 2020 emissions relative to 1990, consistent with the minimum requirement of a 42% reduction in the Act.
- Targets to 2032 could be largely met by delivering our High Ambition scenario. There may be a need for some credit purchase at the margin, although this is uncertain given broader uncertainties in projecting emissions. The targets are therefore achievable based on known technologies and within reasonable fiscal and other constraints, though they require sustained policy action across all sectors with little leeway for failure in one area to be made up elsewhere.
- Pursuing the High Ambition scenario would support UK efforts to meet the fifth carbon budget and support higher ambition in the Paris agreement and an increase in ambition in the EU's 2030 climate package.
- Whilst the High Ambition scenario involves some challenging individual measures, overall it can be delivered with manageable impacts on competitiveness and energy bills, and offers potential opportunities for innovation and growth for Scottish business and industry.

Table 5.1: Recommended targets compared to previous targets and ambition (2017-2032)				
	Current legislated target level of emissions $MtCO_2e$	Reduction against 1990 baseline when targets were set using 2010 inventory	Recommended targets- consistent with Climate Change (Scotland) Act	Reduction against 1990 baseline using latest 2015 inventory
2017	43.946	37%	**44.918**	44%
2018	42.966	39%	**44.394**	45%
2019	41.976	40%	**43.837**	46%
2020	40.717	42%	**42.522**	47%
2021	39.495	44%	**41.247**	49%
2022	38.31	45%	**40.009**	50%
2023	37.161	47%	**38.809**	52%
2024	35.787	49%	**37.645**	53%
2025	34.117	51%	**36.515**	55%
2026	32.446	54%	**35.420**	56%
2027	30.777	56%	**34.357**	57%
2028			**33.327**	59%
2029			**32.327**	60%
2030			**31.357**	61%
2031			**30.416**	62%
2032			**29.504**	63%

Source: CCC analysis
Notes: The 2010 inventory covers 1990-2008, the 2015 inventory covers 1990-2013.

Figure 5.3: Recommended annual targets (2017-2032)



Source: CCC analysis

The role of the traded and non-traded sectors

The recommended targets are based on the net emissions account definition in the Climate Change (Scotland) Act. They can be met through traded sector emissions in line with the Scottish share of the EU ETS cap and non-traded sector emissions in line with the High Ambition scenario, possibly supplemented by further effort if opportunities can be found or by credit purchase at the margin.

Actual (gross) emissions in Scotland (i.e. without adjustment for emissions trading in the EU ETS) should fall by more than this. This was also our finding at the UK level, though it is likely to be even more evident for Scotland.

The difference between net and gross reflects the higher ambition for roll-out of renewable electricity generation in Scotland and the earlier phase-out of coal compared to the UK average. However, this is not reflected in the Scottish net carbon account.

Our central scenario for the traded sector of the economy alongside the High Ambition scenario for the non-traded sector implies a 64% reduction in emissions by 2030 (Table 5.2). Our High Ambition scenario for the traded sector of the economy alongside the non-traded sector implies a 66% overall reduction in emissions.

Scotland should support efforts to tighten the cap in the EU ETS. That would help the EU to stay on the cost-effective path to its long-term targets and would enable Scotland to achieve larger emissions reductions in the net account as well as in its actual emissions. Under a tighter EU package, Scotland could meet targets that involve the minimum 3% reduction in the Climate Change (Scotland) Act through the High Ambition scenario without recourse to further purchase of emissions credits outside the EU ETS.

Table 5.2: Gross emission reductions for High Ambition economy wide , and 'High Ambition non-traded sectors with Central traded sectors				
	2015	**2020**	**2025**	**2030**
Non-traded 'High Ambition'	31.3	26.5	23.4	21.2
Traded 'High Ambition' gross	19.3	9.2	9.0	6.6
Total 'High Ambition' gross	**50.6**	**35.7**	**32.4**	**27.8**
% reduction from 1990	*37%*	*56%*	*60%*	*66%*
Traded 'Central' gross	19.3	9.5	9.6	8.0
total 'High Ambition' and 'Central' gross	**50.6**	**36.1**	**33.0**	**29.1**
% reduction from 1990	*37%*	*55%*	*59%*	*64%*
Traded net (share of EU ETS cap)	17.3	16.1	14.1	12.1
Total net	**See Table 5.1**			

Source: CCC analysis
Notes: Numbers may not add up due to rounding.

2. Cumulative emissions

These recommended targets and revisions imply a higher cumulative level of emissions for Scotland. In terms of effort required, the targets are more ambitious than was originally intended for the targets to 2027 (e.g. the new targets require delivery of the High Ambition scenario, whereas the previous targets were designed to meet a Central scenario). However, the level of cumulative emissions is higher because new scientific knowledge has improved our understanding of baseline emissions.

Our assessment of a cumulative budget for Scotland using our recommended targets and equal annual percentage reduction from 2032 to 2050 would give an updated budget of 1,330 $MtCO_2e$. This level of cumulative emissions is still consistent with the global cumulative budget, as discussed in chapter 2. If global emissions can be reduced at an equal annual percentage rate

from 2020 to the per-capita level of emissions in 2050 implied by the Scottish targets, then this is consistent with broadly a 66% likely chance of limiting warming to below 2°C.

We also note that the targets for 2010-2013 were missed by a cumulative total of 17.5 $MtCO_2e$. That was a result of the changes to the EU ETS and the greenhouse gas inventory, as outlined above. These changes made the targets more difficult to achieve than intended when the targets were set. Without these changes emissions would have been below the targeted level. It is also possible that some or all of the shortfall will be made up in the years 2014 to 2016 when the rules for the EU ETS (specifically, 'backloading', see Chapter 2) are likely to have the opposite effect and make the targets easier than intended. Since we have proposed resetting targets from 2017, and since the shortfall is a result of accounting changes not a lack of action, any shortfall or excess should be monitored until the end of 2017. At that time the net shortfall or excess that is due to these accounting changes (i.e. changes to the inventory or to unanticipated allocations under the EU ETS) should be reset. Any shortfall in meeting the targets from that point should be tracked and addressed. That would ensure that the level of real action intended by the targets for 2017-2032 is preserved.

3. Use of offset credits 2018-2022

The Climate Change (Scotland) Act requires us to advise on the use of credits, specifically in meeting nearer-term targets for 2018-2022. Under our proposed revisions, the targets should be met through domestic effort (including trading in the EU ETS) from our High Ambition scenario, potentially supplemented with further measures if necessary.

Although there could be a small shortfall between the abatement in our High Ambition scenario and the required emissions reductions, this is within the margin of error and Scotland is on track to outperform its interim target to reduce emissions 42% from 1990 levels in 2020. We therefore recommend that the limit for credit use should be set at **zero for 2018-2022**. That would make it clear to investors that the Scottish Government is committed to delivering the targets through domestic action and require that effective policies are brought forward to do so.

Should the challenging nature of the targets mean that they cannot be met without recourse to credits we would revisit this advice closer to the start of the target period. The assessment at the time would consider the strength and validity of the credit market at that time.

There may also be a role for credit purchase as part of the wider financing mechanisms agreed under the Paris Agreement to support emissions reductions in developing countries. However, that should be additional to the effort required in Scotland and should not be used to meet the Scottish targets proposed in this report.

For the existing targets (i.e. if these are not revised), our assessment (chapter 3) is that these could not be met even under our High Ambition scenario. If the targets are not revised then a larger credit purchase will be required for 2018 -2022. In this case the limit should be set at 2.2 million credits per year over 2018-2022, which together with delivery of the High Ambition scenario would enable the targets to be met. This level of credit purchase would imply a cost to the Scottish Government of around £10 -20 million per year.[35] If credits are purchased this should be through a careful procurement programme that ensures genuine additionality through 'gold standard' projects. Many existing credit programmes would not meet the required standard.

[35] Based on a current EU ETS price of around £4 per tonne, projected to rise to around £8 per tonne by 2020.

4. Next steps for the Scottish Government and the Committee

The Scottish Government must legislate the targets for 2028-2032 by 31 October 2016 and a limit on credit use for the years 2018-2022 by 31 December 2016.

We will continue to monitor progress and report to the Scottish Government in September 2016 about progress against the current targets.

Annex 1: Sectoral scenarios

This annex provides further detail of the scenarios developed by the Committee to inform abatement potential at sector level.

1. Power

Emissions in the power sector in Scotland were 11.5 Mt in 2013 across 51.7 TWh of electricity generation, representing a carbon intensity of generation of 221 gCO_2/kWh.[36]

Electricity generation in Scotland is part of the wider electricity system of Great Britain. On average, generation in Scotland is greater than demand, with the surplus exported to the rest of Great Britain through the transmission network. At times, generation may be lower than demand, with the deficit met by electricity produced elsewhere in Great Britain. The appropriate distribution of generating assets between Scotland and the rest of GB will depend on many factors including the future policy regime, changing patterns of electricity demand, fossil fuel prices, available energy technologies and their relative costs, or the role of CCS and location of any CCS clusters.

These factors are subject to considerable uncertainty, and it is difficult to make a judgment now on the appropriate scale or composition of the electricity system in Scotland in the 2020s.

We therefore present our scenarios for the power sector in Scotland for illustration only. The scenarios are drawn from modelling by Imperial College, which provided the basis for our power sector scenarios to underpin our UK advice on the fifth carbon budget. These scenarios cover the wider UK electricity system, including a Scotland-specific component. The model requires security of supply to be maintained at all times and the scenarios include extensive roll-out of demand-side response, interconnection and storage to support this.

In the High Ambition scenario, total power sector emissions in Scotland decrease by 88%, from 11.5 $MtCO_2$ in 2013 to 1.4 $MtCO_2$ in 2030, as the average emissions intensity of generation decreases by 95%, from 217 gCO_2/kWh in 2013 to around 10 g in 2030, significantly outperforming the Scottish Government's carbon intensity target of 50 gCO_2/kWh in 2030. The High Ambition scenario is consistent with the UK-wide 'Max' scenario, which achieves an average emissions intensity of generation of 50 gCO_2/kWh; the emissions intensity in Scotland is significantly lower than the UK average due to relatively higher deployment of wind generation.

The reduction in emissions is largely due to the closure of coal capacity and increased low-carbon generation:

[36] This methodology is consistent with the Scottish Government's methodology for calculating carbon intensity. Scotland is a net exporter of electricity, so its emissions intensity per unit of demand would be higher.

- The High Ambition scenario incorporates the closure in 2016 of Longannet, a 2.3 GW coal-fired power station which produced 9.9 $MtCO_2$ in 2013 (i.e. around 85% of Scottish power sector emissions). This closure has already been announced, so appears in all our scenarios.
- Total wind generation increases from 11TWh in 2013 to 43 TWh in 2020 (114% of consumption) and 94 TWh in 2030 (252% of consumption). The scenario therefore exceeds the Scottish renewables target of 100% of Scottish electricity consumption from renewable energy by 2020 (Scotland is a net exporter of electricity to the UK mainland, exporting 36 TWh - 49% of generation - in 2020, and 81 TWh - or 68% of generation - in 2030).
- Beyond 2020, it is expected that Scotland's two nuclear power stations will cease operation, and will not be replaced by new build nuclear, as this is Scottish Government policy.[37]
- An additional 25TWh is generated from other low-carbon sources in 2030. These could be carbon capture and storage (CCS) plants, or additional wind or other renewable generation.
- By 2030 1 GW of dedicated energy storage is also developed in Scotland, in addition to the 0.7GW of energy storage already available.

In the Central scenarios, wind generation develops more slowly (Table A1):

As in the High Ambition scenario, total power sector emissions decrease substantially in 2030; however, wind generation is lower at 67 TWh in 2030, resulting in a slightly higher average emissions intensity of generation of around 20 gCO_2/kWh and total power sector emission decrease to 1.7 $MtCO_2$.

Table A1: Scottish power demand, generation by technology and emissions intensity, 2013 and 2030

TWh		**Demand**	**Generation**	**Wind**	**Nuclear**	**Coal**	**Gas**	**Other low-carbon (e.g. CCS)**	gCO_2/kWh
2013		38	52	11	18	11	5	6	221
2030	Central	37	92	67	0	0	1	25	18
	'High Ambition'	37	119	94	0	0	<1	25	11

Source: Imperial modelling and CCC analysis

2. Buildings

Emissions from Scottish buildings were 9.6 $MtCO_2e$ in 2013, not including F-gas emissions which are covered separately (see Section 6 on waste and F-gases). This included 6.8 $MtCO_2e$ from homes, 1.6 $MtCO_2e$ from commercial buildings and 1.2 $MtCO_2e$ from public buildings.

Our analysis suggests that these could fall by 39% by 2030 through a combination of efficiency

[37] See: http://www.gov.scot/Topics/Business-Industry/Energy/Facts/faqs

measures (including fabric efficiency, heating controls and behavioural measures), together with a roll-out of low-carbon heat (mainly heat pumps and heat networks).

Our baseline projection of emissions from homes is based on analysis using the National Household Model apportioned to Scotland on the basis of Cambridge Econometric projections of Scottish housing emissions. We take a similar approach for non-domestic buildings, except that we use the DECC Energy model projections rather than the National Household Model. The baseline emissions projections suggest that residential emissions will fall by 4% to 2030 as a result of improvements in boiler efficiency, offsetting additional emissions from new build. Commercial emissions fall 52% to 2030, and public buildings emissions 20%, due to a continuation of the trend in reduction in energy intensity of the sectors, a reduction in the public sector expenditure over the period, and a small increase in external air temperatures as the climate continues to change.

Our scenarios for emissions from Scottish buildings are stretching, but within Scotland's powers to achieve through its more ambitious energy efficiency policy, 2020 heat networks target and good progress on removing barriers to take-up of the Renewable Heat Incentive.

Our High Ambition scenario to 2030 includes:

- 2.6 TWh of low-carbon heat networks to 2030 including 1.5 TWh to 2020 in line with Scotland's district heating target. The uptake is skewed towards public and commercial buildings, which improve the overall cost-effectiveness of schemes and are more prevalent in built-up areas. In order to achieve this level of roll-out to 2030, Scotland would need to put in place an additional package of policies to drive uptake, such as requiring public buildings to connect to existing schemes.
- Further low-carbon heat roll-out includes 430,000 heat pumps in homes (18%), of which 150,000 are new builds. Heat pumps are also rolled out extensively across non-domestic properties not connecting to heat networks, firstly displacing electric and oil heating, and then gas from the late 2020s.
- We assume that almost all the potential for cavity-wall and loft top-up insulation is taken by 2030, with 800,000 of each, giving 0.3 $MtCO_2$ emissions savings. A total of 200,000 solid walled properties are also insulated to 2030 giving a saving of 0.2 $MtCO_2$. Although solid wall insulation is generally a high cost route to reducing carbon emissions (with average costs greater than the UK Government central carbon values) it is important for alleviating fuel poverty. It is estimated that around 260,000 of the country's fuel poor reside in homes with solid walls. We also include a number of other measures (e.g. floor insulation and improved glazing) that reduce demand for space heating, hot water use and electricity. Combined, the uptake of all residential energy efficiency measures in our scenario delivers 0.7 $MtCO_2$ of abatement by 2030.[38]
- A range of non-domestic energy efficiency measures include programmable thermostats, fabric measures and glazing along with Mechanical Ventilation Heat Recovery under EU Products Policy.

Overall we estimate these measures would reduce emissions from Scottish buildings in 2030 from 8.3 $MtCO_2$in our baseline scenario to 5.9 $MtCO_2$ (Table A2). The abatement is primarily due to domestic heat pumps (0.7 $MtCO_2$), low-carbon heat networks (0.4 $MtCO_2$), loft and cavity wall

[38] This is all 'direct' abatement, reducing actual emissions from burning fossil fuels directly in buildings, in contrast to 'indirect' abatement, which refers to emissions savings from reducing electricity use.

insulation (0.3 $MtCO_2$), with smaller reductions from non-domestic heat pumps (0.2 $MtCO_2$) and solid wall insulation (0.2 $MtCO_2$).

In our central scenario, there is less abatement (equivalent to1.8 $MtCO_2e$), largely due to reduced uptake of heat pumps and heat networks. By 2030 this leaves emissions of 6.5 $MtCO_2$.

Table A2: Building sector abatement in 2030 ($MtCO_2e$)

Residential	**Central**	**High ambition**
Retrofit heat pumps	0.3	0.7
Heat pumps, new-build	0.1	0.2
Heat networks	0.1	0.4
Domestic solid wall insulation	0.1	0.2
Domestic cavity wall and loft insulation top-up	0.2 & 0.1	0.2 & 0.1
Other domestic fabric measures & glazing	0.1	0.1
Domestic lighting and appliances	-0.3	-0.3
Domestic heating controls & hot water efficiency measures	0.2	0.2
Domestic behavioural measures	0.2	0.2
Non-domestic energy efficiency	0.4	0.4
Residential abatement	**1.1**	**1.6**
Non-residential abatement	**0.7**	**0.9**
Residual buildings emissions by 2030	**6.5**	**5.9**

Source: NHM and CCC analysis

3. Industry

Industry includes manufacturing, construction, water and waste management, refining of petroleum products and other energy supply (extraction and production of oil, gas and solid fuels).

Direct emissions from industry accounted for around a fifth of Scotland's greenhouse gas (GHG) emissions in 2013 (10.7$MtCO_2e$), of which over 90% are CO_2. Between 1990 and 2013 industrial

GHG emissions fell by 48%.

In our High Ambition scenario we have identified potential abatement of 3 $MtCO_2e$ by 2030, such that industrial emissions fall by 66% over 1990-2030. The majority of this abatement is covered by the EU Emissions Trading System (EU ETS), the 'traded' sector (2.8$MtCO_2e$).

Emission baseline projection

We commissioned Cambridge Econometrics to project industrial emissions in Scotland in the absence of effort to reduce them.[39] In this business-as-usual scenario:

- Traded sector emissions are projected to fall from 6.6 $MtCO_2e$ in 2013 to 6.0 $MtCO_2e$ in 2030.
- Non-traded sector emissions are projected to fall from 4.1 $MtCO_2e$ to 4.0 $MtCO_2e$.

Overall, Scotland's industrial emissions are expected to fall by 7% over 2013-2030, from 10.7 $MtCO_2e$ to 10 $MtCO_2e$.

Assumptions on current policies to 2020

The fall in emissions in the latest baseline emission projections reflects ongoing economic trends and the expected impact of current low-carbon policies implemented by the EU, the UK and Scotland. A number of policies to reduce emissions through energy efficiency and shifting to bioenergy and electricity for space and process heat are already in the baseline:

- **EU Emission Trading System (EU ETS)**. Total EU verified emissions have been consistently below the allocation of allowances, largely because of the recession. This has caused the market value of carbon to fall and remain at a low level. This reduces the incentive for energy-intensive industries to prepare for and make long-term investments in line with Scotland's targets. We have previously stated that structural reform of the EU ETS is necessary.
- **Energy efficiency**. A number of policies are in place or planned to encourage electricity and non-electricity energy efficiency. We have previously suggested rationalisation of business energy taxes and policies to promote energy efficiency, and the UK Government has recently announced a review of the business energy efficiency tax landscape.
  - **Products Policy, Climate Change Agreements (CCAs) and Carbon Reduction Commitment (CRC).**
    - Products policy acts to improve the energy efficiency of machinery and equipment through regulated standards and labelling,
    - CCAs are voluntary agreements that allow eligible energy-intensive sectors to receive up to 90% reduction in the Climate Change Levy if they sign up to stretching energy efficiency targets agreed with government,
    - The CRC is a mandatory carbon emissions reporting and pricing scheme to cover large public and private sector organisations in the UK,
    - There is considerable potential for overlap between products policy and CCAs, as investing in the latest equipment will improve energy efficiency with little additional effort required. We have in previous advice suggested that the CCA targets are not stringent enough.

[39] For the scenarios in this report the Cambridge Econometrics (CE) projection is calibrated to the latest DECC projection of UK emissions (which differs from the CE projection at the UK level).

  - **Building regulations & Private Rented Sector Regulations**. These should improve the energy efficiency of buildings to a specified minimum standard. Non-domestic buildings are already covered to some degree by other policies (i.e. the CRC and CCAs). However, these policies do not cover the entire non-domestic building stock.
  - **Resource Efficient Scotland**. Scotland has also funded expert advice and interest-free business loans of £1,000 to £100,000 to enable small and medium-sized enterprises (SMEs), private sector landlords, not-for-profit organisations and charities in Scotland to reduce their energy costs through the installation of energy efficiency measures, improving their competitiveness and profitability.
- **Bioenergy and low-carbon heat**. The Renewable Heat Incentive (RHI) encourages consumers to install renewable heating in place of fossil fuels.

Identified abatement to 2030

The industrial sector is diverse, covering the production of cement through to the manufacturing and packaging of thousands of food items. Industry is also diverse across sub-sectors: no two sites are the same even when they produce the same type of product. This creates a challenge in estimating the potential abatement of emissions and the costs involved.

In our UK advice on the fifth carbon budget[40] in 2015 we set out an assessment of the options for reducing emissions from UK industry to 2030. Overall, the evidence to inform this is the most detailed, robust and realistic to date. However, some gaps and uncertainties remain, especially for the longer term, for example the development of industrial CCS.

In our High Ambition scenario for Scotland, the majority of the identified abatement reflects analysis at the UK level in the 'Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050'. We supplement this with further assessment of the potential for low-carbon heat in industrial buildings. We have adapted both of these assessments to Scotland's industrial sector emissions. Measures in the scenario include:

- **Energy efficiency**. Upgrades and replacements to existing processes and equipment to improve their energy efficiency.
  - **Energy and process management**: a range of improvements including energy management, utilities, improved process control, and maintenance.
  - **Best available and innovative technology**: improved equipment and insulation (e.g. motors, pumps, compressors, fans), and advanced technologies (e.g. innovative furnace designs).
  - **Waste heat recovery and use**: most of the available heat to recover is lower grade. To use it effectively requires either matched heat sinks nearby, or else the heat needs to be upgraded to higher grade heat or electricity. Low-grade industrial waste heat can be used in district heating schemes, providing heat to local housing or non-domestic buildings.
  - **Material efficiency**: food waste and packaging reduction, reducing yield losses, scrap densification or shredding and reuse of steel, lighter bricks and reduced product weight (ceramics sector), and increased cullet use through recycling (glass sector).
  - **Clustering**: integration between industrial sites to optimise the use of energy and

[40] CCC (2015) *The Fifth Carbon Budget:* https://www.theccc.org.uk/publication/the-fifth-carbon-budget-the-next-step-towards-a-low-carbon-economy/

resources. For example, clustering could help co-locate industries that use lower grade heat (food and drink, semiconductor manufacturing

- **Bioenergy used in space/process heat**. Switching away from direct combustion of fossil fuels to biogas/biomass.
- **Electrification of space/process heat**. Through electric kilns, boilers and melting of glass, in conjunction with the decarbonisation of the power sector or heat pumps in space heating.
- **Carbon Capture and Storage or Use (CCS/CCU)**. Capture of waste CO_2 from large point sources, such as in cement, refining and chemicals sectors, transported to a storage site where it will not enter the atmosphere, or use in other industrial processes.

Overall, in our High Ambition scenario we have identified abatement of 3 $MtCO_2e$ in 2030 (Table A3).

- Traded sector identified abatement of 2.8$MtCO_2e$, reducing emissions in 2030 to 3.2 $MtCO_2e$.
- Non-traded sector identified abatement of 0.2 $MtCO_2e$, reducing emissions in 2030 to 3.8 $MtCO_2e$.

Our central scenario includes a similar level of energy efficiency improvement but lower abatement from bioenergy, electrification and CCS.

Table A3: Industrial GHG emission abatement in 2030 ($MtCO_2e$)

Measure	Central	High ambition
Baseline	10.0	
Energy Efficiency	0.5	0.6
Bioenergy for space/process heat	0.7	1.1
Electrification of space/process heat	0.1	0.2
Carbon capture and storage/use	0.6	1.1
Total abatement	**1.9**	**3.0**
Remaining emissions	**8.1**	**7.0**

Source: DECC GHG projections (October 2015); Cambridge Econometrics and CCC analysis
Notes: Figures may not add up due to rounding

4. Transport

Emissions from Scottish surface transport were 9.5 $MtCO_2$ in 2013. Our analysis suggests that under a High Ambition scenario this could fall by 54% by 2030 through measures such as conventional vehicle efficiency, adoption of ultra-low emission vehicles (ULEVs), reducing

demand for car travel and improving the efficiency of freight operations.

For our baseline emissions projection we use the run of the Department for Transport's National Transport Model (NTM) commissioned for our fifth carbon budget advice, which includes a separate projection for Scotland.[41] The baseline emissions projection assumes no policies to mitigate climate change after 2010 and shows a 19% increase in total Scottish vehicle-km between 2010 and 2030.

There are some differences in the geographic distribution of the population in Scotland compared to the UK as a whole which could affect travel behaviour. However, our analysis suggests that this is unlikely to have a significant impact on opportunities to reduce emissions (Box A1). Our analysis of these differences is covered in more detail in a Technical Annex published on our website alongside this report.

Box A1: Patterns of travel demand in Scotland

Patterns of travel demand can influence the potential of emissions reduction measures, such as reducing demand for car travel and uptake and usage of electric vehicles (EVs). We have analysed the National Travel Survey (NTS), a survey of weekly travel patterns in Great Britain (GB) and the Scottish Household Survey (SHS) Travel Diaries, a survey of daily travel patterns in Scotland (Transport Annex[42]). Overall travel patterns in Scotland and GB are found to be very similar.

- Comparisons of the distribution of car trip distances for Scotland and GB using the NTS data show only small differences across all distances. The NTS shows that the average car trip length in Scotland and GB were very similar at 8.4 miles and 8.5 miles.
- We also find relatively little difference in the Scottish and GB car trip distance distributions when using SHS for Scotland and NTS for GB. This data suggests that the share of very short car trips (<2km) is higher in Scotland than in GB.
- This indicates that the potential for reducing emissions through reducing demand for car travel should be broadly similar in Scotland and GB. The high share of very short trips in Scotland could mean that more car trips are amenable to shifting to walking, cycling or public transport, although this would not significantly increase the potential to reduce emissions given the very short nature of these trips.
- This also suggests that opportunities to switch to EVs are broadly similar in Scotland and in GB. For example, typical plug-in hybrid EV (PHEV) cars have a battery allowing them to travel up to 30 km in electric mode. The NTS data for Scotland shows that the percentage of distance due to trips under 30 km is around 52%, broadly in line with 50% for GB, meaning that PHEVs are expected to have a similar emissions reduction potential in Scotland.

More detail is available in the Transport Annex.

Source: NTS (2002-2012); Transport Scotland (2015) Scottish Household Survey Travel Diary results.

[41] We have opted to use the NTM rather than the Scottish Government's Transport Model for Scotland as the NTM is better suited to our analysis of emissions reduction and the overall difference in traffic growth projected by the two models is relatively small (Transport Annex).

[42] Available online at: https://www.theccc.org.uk/publications/

The Central scenario includes measures likely to reduce emissions more cheaply than the UK Government's projected carbon values (i.e. £78/tCO_2 in 2030), measures required by existing regulation and measures that at the UK level we identified as being required on the path to the legislated 2050 target. The High Ambition scenario to 2030 includes more stretching options. These are not exhaustive of all possible measures:

- **New vehicle efficiency.** There is scope for cost-effective improvements to the efficiency of conventional new vehicles through measures such as aerodynamics, weight reduction and hybridisation. New evidence indicates that the gap between test-cycle and real-world emissions could persist to 2030 but could be reduced with an improved testing regime.
  - New conventional cars and vans could reach a test-cycle CO_2 intensity of 86 gCO_2/km and 127 gCO_2/km respectively by 2030.[43] This is equivalent to a test-cycle efficiency improvement of 41% for new cars and 37% for new vans between 2010 and 2030.
  - Under testing procedures currently planned within the EU, real-world emissions for new conventional cars and vans could be 26% higher than test-cycle emissions. However, improved testing of cars and vans could help to reduce this gap to around 5% by 2030.[44]
  - In our Central scenario for Scotland (in line with the UK), real-world efficiency improves by 37% for new cars and 33% for new vans between 2010 and 2030.
  - For our High Ambition scenario, we estimate that improved testing could lead to a more significant real-world efficiency improvement of 44% for new cars and 40% for new vans over the same period. This improved testing could only be implemented at an EU level, over which the Scottish Government would have limited control.
  - The real-world efficiency of new HGVs could improve by 24% relative to 2010.
- **Electric vehicles.** Under central assumptions, electric vehicles reach around 60% of new sales for cars and vans by 2030 (around 35% PHEV and 25% BEV). Under a High Ambition scenario an additional 5% of new sales could be BEVs:
  - We have updated our modelling of how a high uptake of EVs could be achieved given capital and fuel cost projections, non-financial barriers and potential future incentives. We estimate that electric cars and vans could make up around 60% of new sales by 2030 if provided with a national network of rapid charging infrastructure[45] and a package of incentives worth around £1,000 per vehicle in 2030 (this would not have to be an upfront grant and could include favourable Vehicle Excise Duty or Company Car Tax and provision of free access to low emissions zones or parking spaces).
  - Under our High Ambition scenario, there is potential for a slightly higher sales share of 65% for electric cars and vans (35% PHEV and 30% BEV). This could be achieved if the Scottish Government is able to provide additional incentives for BEVs (again, not necessarily in the form of a grant) or if battery costs fall more rapidly than under our central assumptions.[46]

[43] We assume these vehicles are tested using the Worldwide Harmonised light-duty vehicle Testing Procedure (WLTP).

[44] Element Energy and the ICCT (2015) *Quantifying the impact of real-world driving on total CO_2 emissions from UK cars and vans.*

[45] Transport Scotland plans to have rapid chargers spaced every 35 miles on the road network.

[46] CCC (2015) *Sectoral scenarios for the fifth carbon budget* https://www.theccc.org.uk/publication/sectoral-scenarios-for-the-fifth-carbon-budget-technical-report/

  - Combined with conventional efficiency improvements, this implies a fleet-average, test-cycle CO_2 intensity of around 40 gCO_2/km for new cars and 55 gCO_2/km for new vans in 2030 under the High Ambition scenario.
  - Electric small rigid HGVs reach 40% of sales (30% PHEV and 10% BEV). Electric buses reach 25% of sales. This level of uptake is included in both the Central and High Ambition scenarios.
- **Hydrogen vehicles.** Hydrogen fuel cell buses make up 25% of new bus sales. Fuel cell vehicles may also have niche applications for other modes by 2030 but this is not explicitly included in the scenario. This level of uptake is included in both the Central and High Ambition scenarios.
- **Biofuels.** In line with existing EU regulation to 2020, increasingly sustainable biofuels displace around 0.2 billion litres of petrol and diesel, equating to around 12% of liquid fuel by energy in 2030. This level of displacement is included in both the Central and High Ambition scenarios.
- **Behaviour change.** The High Ambition scenario includes further emissions reductions from behaviour change in passenger transport and improvements to freight operations. The measures included go beyond those in our Central scenario for the UK. Whilst stretching, this level of behaviour change is potentially achievable given that Scotland has devolved powers to influence travel behaviour.
  - For cars we estimate that a 12% reduction in car-km relative to our baseline scenario could be achieved (Transport Annex), a 2% fuel saving from the use of eco-driving technology and a further 7% fuel saving from a reduction of the speed limit to 60mph on motorways and dual carriageways.
  - For HGVs we assume improved logistics provides a 16% reduction in HGV-km relative to our baseline scenario and a further 18% fuel saving from use of driver training and retrofitting fuel saving technologies.[47]
- **Rail.** Rail emissions fall by 29% compared to 2010 levels, through electrification, use of battery powered trains and improvements to the efficiency of diesel trains.[48] This level of electrification is included in both the Central and High Ambition scenarios.

Some of these measures may be challenging to implement with powers currently devolved to the Scottish Government. This scenario is not intended to be prescriptive and if it is not possible to achieve the uptake of measures set out above, this could be offset with additional measures elsewhere insofar as those can be delivered.

Overall we expect these measures to reduce Scotland's surface transport emissions from 10.0 $MtCO_2$ in our baseline scenario to 4.4 $MtCO_2$ in our High Ambition scenario by 2030. The abatement is primarily due to conventional vehicle efficiency (1.8 $MtCO_2$) and uptake of electric and other ultra-low emission vehicles (2.1 $MtCO_2$), with smaller reductions from biofuels (0.6 $MtCO_2$), behaviour change in passenger transport (0.6 $MtCO_2$), improvements to freight operations (0.4 $MtCO_2$) and rail electrification (0.1 $MtCO_2$).

In the Central scenario emissions would fall to 5.0 $MtCO_2e$ in 2030.

47 CfSRF (2015) *An assessment of the potential for demand-side fuel savings in the HGV sector.*
48 Unpublished DfT Rail Executive analysis shared with CCC.

5. Agriculture and LULUCF

Agriculture

GHG emissions from agriculture in Scotland were 9.2 $MtCO_2e$ in 2013, 18% of all emissions. This is a higher share than at the UK level (9.5%). Our analysis suggests that agriculture could deliver emissions savings of 1.5 $MtCO_2e$ by 2030 through measures such as improving management of crops and soils, improving animal health and diets, waste management and on-farm efficiency measures.

Our abatement scenarios comprise of abatement from existing uptake and future uptake of measures:

- **Existing uptake:** farmers are already implementing measures that reduce emissions, which are not accounted for in the emissions baseline projections. We estimate the level of cost-effective abatement for Scotland in this 'baseline' to be 0.4 $MtCO_2e$ in 2030.
- **Future uptake:** estimated savings are based on a bottom-up assessment of cost-effective and feasible abatement potential largely taken from work the Committee commissioned from Scotland's Rural College (SRUC) and Ricardo Energy and the Environment[49] for our UK fifth carbon budget report.

Our estimates of future abatement potential are based on future uptake of a limited set of cost-effective measures. The measures were developed from a longer list and prioritised on the basis that they:

- Have the potential to deliver a high or medium level of abatement.
- Provide certainty of practical feasibility given current evidence and/or timelines required to test and deploy options.
- Are not deemed to be high-risk or have negative effects on other objectives (e.g. on animal welfare).

Our High Ambition scenario delivers emissions savings of 1.5 $MtCO_2e$ in 2030 (Table A4). This is a stretching scenario and would entail a move away from the current voluntary approach to reducing emissions in this sector, towards stronger Government policy. Our evidence suggests that there are a large number of small measures that could reduce emissions in this sector, therefore in practice, the same level of emission savings could be achieved with a slightly lower abatement from a wider mix of measures.

Combined with the latest baseline projection (8.9 $MtCO_2e$ by 2030), this implies residual agricultural emissions of 7.4 $MtCO_2e$ by 2030 in our High Ambition scenario.

Under the less ambitious Central scenario, emissions in 2030 would be 7.6 $MtCO_2e$, with slightly lower abatement from fuel efficiency, manure management and crops/soils management.

In our scenarios for the fifth carbon budget the share of agriculture emissions in the UK total more than doubles from 9.5% in 2013 to 20% in 2030. Under the High Ambition scenario the share of agriculture emissions in Scotland will increase by much less, from 18% to 27%.

The Committee has consistently flagged the uncertainty attached to any analysis of the agriculture sector. Current activity and resulting emissions are hard to accurately identify.

[49] Scotland's Rural College (SRUC) & Ricardo Energy & Environment (2015) *Review and update of the UK agriculture MACC to assess the abatement potential for the fifth carbon budget period and to 2050.*

Ambition and potential in the sector needs to be more thoroughly assessed and we will do this in light of developments in the Smart Inventory, which will be rolled-out next year.

Table A4: Scotland direct abatement in 2030 ($MtCO_2e$)

Category	Measure	Central	High ambition
Crops and soil management	Precision farming for crops Manure planning and application Grass clover crops Controlled-release fertilisers GM crops with enhanced nitrogen use efficiency Triticale Loosening compacted soils	0.4	0.5
Livestock health measures	Improvements to cattle & sheep health	0.2	0.2
Livestock diets & breeding	Improved nutrition Probiotics & nitrate additives Use of balanced breeding goals	0.1	0.2
Waste and manure management	Anaerobic digestion Slurry acidification	0.05	0.1
Fuel efficiency	Improved housing, drying, glazing, irrigation etc.	0.1	0.2
Baseline	Measures already being taken up	0.4	0.4
	TOTAL	**1.3**	**1.5**

Source: SRUC and CCC analysis
Notes: Estimates take account of interactions, and are rounded to nearest 0.1 $MtCO_2e$.

Land use, land use change and forestry scenario

The land-use, land-use change and forestry sector in Scotland was a net carbon sink in 2013, removing 5.2 $MtCO_2e$[50] from the atmosphere. However, under the baseline emissions

[50] The latest LULUCF inventory emissions for the UK as a whole show a large increase in the net carbon sink compared to previous inventories due to a number of revisions to how emissions from grasslands are calculated. Some of these revisions may be reflected in the next inventory for Scottish emissions in June 2016.

projections, this sink is expected to reduce in the future due to the sharp decline in tree planting rates from the1980s which has reduced the ability of existing forestry to absorb carbon. Abatement options in this sector focus on increasing the sink by increasing carbon sequestration.

Our High Ambition scenario includes two abatement measures which deliver 1.6 $MtCO_2e$ by 2030:

- **Afforestation:** Increasing the rate of tree-planting (above baseline rates, assumed to be zero planting) to around 16,000 hectares a year could deliver 1.45 $MtCO_2e$ savings in 2030 in Scotland. This level of afforestation exceeds the current Scottish Government targets for an additional 10,000 hectares a year until mid-century.
- **Agro-forestry:** The integration of trees and shrubs within arable and livestock systems can deliver GHG savings, such as increased soil carbon stocks and reduced nitrogen oxide emissions from fertiliser use. In addition, it can provide a range of non-GHG benefits (e.g. improvements in water quality and soil fertility). Financial and non-financial barriers would need to be addressed for emissions savings to be realised:
  - We assume savings of 0.16 $MtCO_2e$ can be delivered by 2030. This is focused on CO_2 savings from carbon sequestration in trees and soil, and excludes other GHG savings (e.g. N_2O savings from reduced fertiliser use). This is based on increasing agro-forestry systems by an additional 0.6% of Scottish agricultural land area.
  - Our scenario assumes a high level of government support, including finance to support farmers, with Pillar II payments from the Common Agricultural Policy being one possible mechanism, as is currently the case in Scotland. However, barriers due to a lack of knowledge and awareness that currently exist among farmers about the potential benefits of agro-forestry systems are considerable and would also have to be addressed.

Our range of abatement would imply that the LULUCF sector in Scotland is a net carbon sink of 3.8 $MtCO_2e$ by 2030.

6. Waste and F-gases

Waste emissions are predominantly methane emissions which arise due to the decomposition of biodegradable waste in landfill sites in the absence of oxygen. Waste emissions were 5% of Scotland's greenhouse gas (GHG) emissions in 2013 (2.7 $MtCO_2e$), of which over 85% are methane from landfill. Between 1990 and 2013 waste emissions fell by 73%.

F-gases are used in various applications, mainly as coolants in air conditioning and refrigeration, and are typically released through leakage. F-gas emissions were 3% of Scotland's greenhouse gas (GHG) emissions in 2013 (1.5 $MtCO_2e$). F-gases have risen from 0.2 $MtCO_2e$ in 1990 due to the result of gas leakage of HFCs used in refrigeration and air conditioning as a substitute for ozone-depleting substances.

We have used DECC's published non-CO_2 projections to estimate Scotland's future waste and F-gas emissions without additional policy. Based on this we have estimated without further policy:

- Waste emissions will fall from 2.7 $MtCO_2e$ to 1.5 $MtCO_2e$ over 2013-2030.
- F-gas emissions will remain at around 1.5$MtCO_2e$ over 2013-2030.

We have identified potential abatement of 0.5 $MtCO_2e$ from waste and 1 $MtCO_2e$ from F-gases by 2030.

Waste

Government policy to reduce landfill emissions has focused on reducing waste, diverting waste from landfill and capturing the methane from landfill sites. Waste emission reduction has occurred through a combination of information and voluntary programmes to prevent waste, a landfill tax to divert waste from landfill and investment in methane capture technology. Action is being taken at EU, national, devolved administration and local authority levels:

- **EU Directive.** The 1999 EU Landfill Directive requires a 65% reduction in biodegradable municipal waste (BMW) landfilled in the UK by 2020 relative to 1995 levels of BMW production.
- **UK and Scottish waste emission policies:**
  - In order to achieve current targets under the EU Directive, the UK introduced the Landfill Tax in 1996. This imposes a charge on landfill operators for each tonne of waste landfilled, creating an incentive to reduce the waste sent to landfill either through waste prevention or diverting waste to other treatments (recycling, composting, recovery, and reuse). The tax has been increased from its initial rate of £7 per tonne in 1996 to £82.60/t in 2015/16.
  - As of April 2015, Scotland has acquired responsibility for setting its own landfill tax and in 2016/17 this will be raised to £84.40/tonne in alignment with the rest of the UK.
  - There are a number of voluntary programmes aimed at reducing packaging and food waste managed by WRAP, which has set a number of targets to reduce waste both in food production, groceries and household use.
  - Capture of methane at landfill sites has increased from an average rate of 1% in 1990 to 61% in 2013. This reflects investment driven by a combination of permit conditions and financial incentives for capturing methane from landfill and anaerobic digestion (e.g. under the Renewables Obligation, Feed-in-Tariffs, and Renewable Heat Incentive).
  - In the 'Zero Waste Plan',[51] Scotland has set a plan to reduce the environmental impact of waste and move towards a circular economy. Scotland is planning to roll out separate food waste collections from 2016 and implement a ban on biodegradable municipal waste going to landfill by 2021.

We have estimated that together these measures could save around 0.5MtCO_2e by 2030.

F-gases

Without policy it is likely that F-gas emissions would increase further. This is due increasing use of products and appliances using F-gases, such as in refrigeration and air conditioning equipment or foams used for energy efficiency measures. However, new EU regulations are expected to significantly reduce F-gas emissions across the UK. We assume that Scottish F-gases change in line with our UK scenarios.

The 2006 EU F-gas regulation and 2006 MAC Directive introduced restrictions on various uses of F-gases. However, DECC's latest projections, without further policy, show that UK emissions would stay broadly flat to 2030, with emissions from refrigeration and air conditioning accounting for 75% of the total.

The 2015 EU F-gas regulation introduced a series of measures, including a quota system, a series

[51] See: http://www.gov.scot/Topics/Environment/waste-and-pollution/Waste-1/wastestrategy

of bans and further leakage checks, which are expected to bring emissions down significantly by the early 2030s:

- It reduces the quantities of HFCs that producers and importers are allowed to place on the EU market. The allowed emissions will be reduced sequentially, starting with a 7% cut in 2016 and reaching a 79% cut by 2030.
- For new equipment, the regulation introduced a series of bans on the use of F-gases covering crosscutting areas.
- For existing equipment, there is a ban on using the most carbon-intensive HFCs (with a Global Warming Potential above 2,500) for the maintenance and servicing of existing refrigeration equipment from 2020.
- There is some strengthening of existing obligations related to leak checking and repairs, F-gases recovery and technician training.

We have estimated that together this package could save around 1 $MtCO_2e$ by 2030.

7. Aviation and shipping

The Scottish Climate Change Act includes emissions from international aviation and shipping. Our scenarios therefore include emissions from these sources.

Aviation

Our approach for aviation is based on the current policy framework, in which domestic flights and flights wholly within the EU are covered by the EU ETS. We cover the remaining non-EU international emissions and Kyoto non-CO_2 gases[52] for EU flights through projections based on our scenarios developed for the fifth carbon budget. Aviation emissions are therefore partly within the traded sector (i.e. covered by the EU ETS) and partly within the non-traded sector (outside the EU ETS):

- **Traded sector.** The EU ETS currently covers flights within Europe. The aviation cap is set at 95% of average 2004-06 CO_2 emissions. Based on the Scottish inventory, this implies a Scottish cap of 1.3 $MtCO_2$ per year for domestic and intra-EU Scottish aviation emissions.
- **Non-traded sector.** This covers emissions from flights to destinations outside Europe and non-CO_2 emissions from all flights. Our scenarios are based on UK projections of aviation emissions developed for the fifth carbon budget using the DfT's UK aviation emissions model.
  - The Central scenario reflects UK emissions in 2050 at the same level as those in 2005, which is in line with our planning assumption. The High Ambition scenario assumes further abatement such that 2050 Scottish emissions are 13% lower than the Central scenario.
  - We identify the share of Scottish emissions in these scenarios, for both Kyoto non-CO_2 emissions and non-EU international emissions. In both the Central and High Ambition scenarios these emissions are 0.6 $MtCO_2e$ in 2030.

Shipping

Both domestic and international Scottish shipping emissions are within the non-traded sector.

[52] I.e. methane and nitrous oxide, but not any warming effects from aerosols and contrails. For more discussion of these non-Kyoto sources of warming see the Committee's 2012 report on international aviation and shipping.

Our scenarios are therefore based on our projections of shipping emissions developed for the fifth carbon budget, using bunker fuel sales as reported in the Scottish emissions inventory.

The key drivers of shipping emissions are demand and carbon intensity:

- **Shipping demand.** This will be influenced in future by factors including GDP growth, fossil fuel and carbon prices, and consumption of fossil fuels and bioenergy. Our demand scenarios are consistent with our economy-wide analysis and reflect a reduction in UK demand for fossil fuels, in line with our trajectories for other sectors. They are scaled down from our fifth carbon budget scenarios, based on the historical Scottish share of demand by commodity group.
- **Carbon intensity.** The main options for reducing carbon intensity include use of larger ships, technological and operational innovation to improve fuel efficiency, and use of alternative fuels. Together these could reduce average carbon intensity by up to 65% by 2050.

Shipping is potentially at risk of carbon leakage if costly measures are adopted unilaterally. We therefore follow our approach at the UK level and develop scenarios in line with currently agreed international policy. This assumes a modest level of efficiency improvement under the International Maritime Organisation's Energy Efficiency Design Index policy.

We use this as both our Central and High Ambition scenarios for Scottish shipping emissions. Domestic and international shipping are broadly flat at current levels through the 2020s and are 1.0 $MtCO_2e$ in 2030.

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