Scope of carbon budgets
Statutory advice on inclusion of international aviation and shipping

Committee on Climate Change | April 2012

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Preface

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

Setting carbon budgets

In December 2008 we published our first report, *'Building a low-carbon economy – the UK's contribution to tackling climate change'*, containing our advice on the level of the first three carbon budgets and the 2050 target. This advice was accepted by the Government and legislated by Parliament in May 2009.

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

Progress meeting carbon budgets

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

Advice requested by Government

We provide ad hoc advice in response to requests by the Government and the Devolved Administrations. Under a process set out in the Climate Change Act, we have advised on reducing UK aviation emissions, Scottish emissions reduction targets, UK support for low-carbon technology innovation, design of the Carbon Reduction Commitment, renewable energy ambition and a review of bioenergy. In September 2010 and July 2011, we published advice on adaptation, assessing how well prepared the UK is to deal with the impacts of climate change.

Inclusion of international aviation and shipping in carbon budgets

We are required by the Climate Change Act to provide advice to Government on whether the net carbon account should be defined to include emissions from international aviation and shipping. Government is required to make a proposal to Parliament by the end of 2012 on whether or not to include these emissions.

In preparation for this advice we published a *Review of UK Shipping Emissions* in November 2011 and a *Bioenergy Review* in December 2011. We previously published analysis of UK emissions from aviation in December 2009 in response to a request from Government, *Meeting the UK aviation target – options for reducing emissions to 2050*.

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

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Foreword

This report addresses a specific sectoral issue: the appropriate treatment of the UK's attributable emissions from international aviation and shipping. It recommends that emissions from both should be included in UK carbon budgets. But this inclusion will have an importance which goes beyond the specific issue of international aviation and shipping. It will ensure that the UK has a fully comprehensive budgeting framework to deliver its 2050 target – to reduce total UK attributable emissions down to around 160 $MtCO_2e$ by 2050, a cut of 80% below 1990 levels.

That target was accepted by government and Parliament following the Committee on Climate Change's recommendation in our first report in December 2008. Achieving it will, as the Committee then argued, represent a fair UK contribution to a global programme to limit harmful climate change. It can be attained at an acceptable economic cost. In this report, further analysis confirms our previous estimates that the target can be met at a cost of only 1%-2% of GDP in 2050.

Government and Parliament's agreement to the 80% reduction target has provided the context for all the Committee's subsequent work. Our recommendations for the first four carbon budgets – which cover the years 2008 to 2027 – have been designed to ensure a path of emissions reductions which is consistent with achieving 160 $MtCO_2e$ by 2050, which is technologically feasible at modest cost, and which does not rely on over-optimistic assumptions about the pace of further emissions reductions possible in later budget periods.

This will be the last report published by the Committee during my time as Chairman. I am therefore particularly glad that this report makes a recommendation which, if now accepted by government and Parliament, will complete the UK statutory framework.

The overall design of that framework – established by the Climate Change Act of 2008 – has proved very successful and is a model which now attracts considerable interest from other countries. It provides certainty to business investors that the UK is on a path to a low-carbon economy; and it provides a discipline which will ensure that governments stick to that path, designing and implementing appropriate supporting policies.

The Committee's annual reports on progress against budgets play a crucial role in ensuring that discipline. Our first three progress reports have recorded an acceleration in the pace of emissions reduction, but have also cautioned that this has been primarily due to the impact of the recession. But there has also been some important underlying progress: rapid improvements in car fuel efficiency, a steady build up of the pace of renewables investment, and commitment to a new policy framework for the electricity market which will be more favourable to low-carbon generation investment – whether nuclear or renewable. Looking forward, the Committee's annual monitoring reports will likely play an increasingly important role, as economic recovery leads to emissions increases in some sectors, and as the budget constraints become steadily more binding.

The Committee is intended by the Climate Change Act to be a permanent part of the UK policy framework, ensuring progress to the staging post of 2050, and beyond that towards the further reductions which will be necessary and possible in the second half of this century. It has been a great honour to have been Chairman for the past four years of the Committee's life. The Committee has, I believe, established a very strong reputation, both for its fact-based analytical rigour and for its robust independence. I would like to thank all of the Committee members for their hard work and commitment to those values. And I would like to thank all of the members of the Secretariat, and in particular the Chief Executive David Kennedy, for the excellent support they have given, and for the quality of analysis which is evident yet again in this report.

Adair Turner
Chairman
April 2012

The Committee

Lord Adair Turner, Chair

Lord Turner of Ecchinswell is the Chair of the Committee on Climate Change and Chair of the Financial Services Authority. He has previously been Chair at the Low Pay Commission, Chair at the Pension Commission, and Director-general of the Confederation of British Industry (CBI).

David Kennedy, Chief Executive

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

Professor Samuel Fankhauser

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

Sir Brian Hoskins

Professor Sir Brian Hoskins, CBE, FRS is the Director of the Grantham Institute for Climate Change at Imperial College and Professor of Meteorology at the University of Reading. He is a Royal Society Research Professor and is also a member of the National Science Academies of the USA and China.

Professor Julia King

Professor Julia King CBE FREng is Vice-Chancellor of Aston University. She led the 'King Review' for HM Treasury in 2007/8 on decarbonising road transport. She was formerly Director of Advanced Engineering for the Rolls-Royce industrial businesses. Julia is one of the UK's Business Ambassadors, supporting UK companies and inward investment in low-carbon technologies.

Lord John Krebs

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

Lord Robert May

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

Professor Jim Skea

Professor Jim Skea is Research Director at UK Energy Research Centre (UKERC) having previously been Director of the Policy Studies Institute (PSI). He led the launch of the Low Carbon Vehicle Partnership and was Director of the Economic and Social Research Council's Global Environmental Change Programme.

Executive Summary

The Climate Change Act (2008) set up the framework for the UK's carbon budgets and the 2050 target to reduce emissions by at least 80% below 1990 levels. The budgets and the 2050 target currently cover all UK emissions of greenhouse gases *except* those from international aviation and shipping[1].

Under the Climate Change Act, the Government must make a proposal to Parliament on inclusion of international aviation and shipping emissions by the end of 2012, taking into account the statutory advice of the Committee on Climate Change, which is set out in this report.

Both we (in our advice on carbon budgets) and the Government (in its December 2011 Carbon Plan) have assumed emissions pathways that would achieve an overall 80% reduction across *all* sectors in 2050 (i.e. including international aviation and shipping). Currently legislated budgets that *exclude* international aviation and shipping are therefore designed to put the UK on track to an 80% reduction target that *includes* international aviation and shipping emissions.

In this report we conclude that there is no longer any reason to account for these emissions differently to those from other sectors (e.g. power, buildings, surface transport), and that to do so creates uncertainty.

We therefore recommend that the current approach should now be formalised through including emissions from international aviation and shipping in carbon budgets and the 2050 target.

- Emissions from international aviation and shipping cause warming and therefore must be managed.
- The current approach (i.e. an assumption that the 80% reduction includes international aviation and shipping) lacks legal underpinning and should be formalised in order to remove current uncertainties around the future interpretation of the 2050 target.
- Including these sectors in carbon budgets and the 2050 target would be the most transparent, comprehensive and flexible approach.
- Potential complexities that we previously identified (relating to design of the EU ETS cap for aviation and the accounting methodology for shipping) no longer exist.

1 International aviation and shipping refers to journeys by air or by sea where one of the departure/destination points is within the UK and the other is outside.

Our recommendation should be implemented by increasing currently legislated carbon budgets two to four (covering 2013 to 2027) to allow for international aviation and shipping as shown in Table 1:

- International aviation emissions should be added to budgets based on the UK share of the EU ETS cap (i.e. 31 $MtCO_2e$ per year).
- International shipping emissions should be added at around 9 $MtCO_2e$ per year, based on a projection of UK emissions which reflects current international policy (i.e. the Energy Efficiency Design Index (EEDI) adopted by the International Maritime Organisation (IMO)).
- Non-Kyoto climate effects of aviation (e.g. contrails and induced cirrus) and shipping should be further researched, closely monitored and reduced where possible, but not included in carbon budgets.

There are no additional costs associated with the budget adjustments, given that these reflect commitments that have already been made (i.e. to currently legislated budgets, to inclusion of aviation in the EU ETS, and to the IMO's policy for reducing shipping emissions). The overall costs associated with meeting a 2050 target that includes international aviation and shipping emissions, of the order of 1-2% of 2050 GDP, were accepted at the time the Climate Change Act was legislated.

Our proposals for inclusion do not imply UK unilateral approaches to reducing international aviation or shipping emissions, which could have perverse consequences including competitiveness impacts and would therefore not be desirable. Competitiveness risks associated with inclusion of aviation in the EU ETS are very limited, and the IMO's approach to reducing shipping emissions provides a level playing field across all countries.

A failure to include international aviation and shipping emissions in the accounting framework of the Climate Change Act would represent a departure from the approach taken by the Government in its Carbon Plan, and from international approaches. It could result either in increased costs and risks of meeting carbon budgets, or in accepting higher risks of dangerous climate change.

Table 1: Historic emissions and recommended adjustments to carbon budgets 2-4 to include international aviation and shipping

	Outturn annual emissions		**Five-year budgets**		
$MtCO_2e$	**1990**	**2010**	**Budget 2 (2013-2017)**	**Budget 3 (2018-2022)**	**Budget 4 (2023-2027)**
Sectors covered by currently legislated budgets	766	590	2782	2544	1950
International aviation	16	32	155	155	155
International shipping	9	9	47	47	45
TOTAL	**791**	**631**	**2984**	**2746**	**2150**

Source: NAEI (2012), CCC calculations.
Note: Section 2 sets out these adjustments in detail.

We provide a detailed summary of conclusions and recommendations in Box 1, and set out underpinning analysis in six sections and in a full technical report published on our website:

1. Why emissions from international aviation and shipping should be included in UK carbon accounting
2. How to include international aviation and shipping emissions in legislated carbon budgets
3. Meeting a 2050 target that includes international aviation and shipping emissions
4. Costs of meeting carbon budgets and the 2050 target including international aviation and shipping emissions
5. Implications of inclusion for approaches to reducing international aviation and shipping emissions
6. Summary

Box 1: Summary of conclusions and recommendations

- **Inclusion of emissions from international aviation and shipping.** These should be included in the accounting framework of the Climate Change Act. This would ensure that carbon budgets and targets are compatible with, and provide the most flexible means for meeting, the internationally agreed climate objective.
  - The international climate objective is to limit warming to 2°C above pre-industrial levels. If the UK were to ignore emissions from international aviation and shipping and this approach were to be replicated by other countries, the result would be higher risks of dangerous climate change
  - To exclude international aviation and shipping emissions from the accounting framework but to reflect them in emissions targets (e.g. through requiring a larger 2050 reduction for sectors currently covered under the Act) would be unnecessarily rigid (e.g. it would fix the balance of emissions reduction effort between international aviation and shipping and other sectors).
  - To include them in carbon budgets and the 2050 target would provide the most flexible means for meeting the climate objective. For example, if progress in reducing aviation emissions were to be better than expected, this would allow lower effort and reduced costs in other sectors. Similarly, greater progress in other sectors could allow for increased emissions from aviation.
- **Timing of inclusion.** Emissions from international aviation and shipping should be included *now* to provide a clear basis for design of the fifth carbon budget and supporting policies.
  - The 2050 target is a key criterion for setting carbon budgets. If the 2050 target were to be interpreted as an 80% reduction versus 1990 levels for other sectors (excluding international aviation and shipping), this could result in insufficiently ambitious carbon budgets which would not prepare adequately to meet longer-term challenges.
  - This is potentially important in the context of the fifth carbon budget, on which we will start work in 2014 for legislation in 2016, and for design of supporting policies.
  - Therefore international aviation and shipping emissions should be included now – rather than further delaying the decision on inclusion – to provide a clear basis for setting the fifth carbon budget and supporting policies.
  - There are no longer any practical barriers to inclusion, given that complexities we have previously identified have now been resolved. The UK share of the EU ETS cap for international aviation can now be calculated on a basis that is consistent with the UK's fair share of emissions. For international shipping, our November 2011 Shipping Review showed that there is a sensible basis for estimating and projecting UK emissions.

Box 1: Summary of conclusions and recommendations

- **Adjustment of legislated budgets.** Emissions from international aviation should be added to currently legislated budgets based on the UK share of all departing flights under the EU ETS cap for aviation. Emissions from international shipping should be added on the basis of projections reflecting existing international policies. These adjustments reflect commitments already made, and therefore entail no additional cost.
  - Currently legislated budgets were designed to cover all sectors *excluding* international aviation and shipping, whilst putting the UK on a trajectory to reach an 80% reduction target for 2050 that *includes* international aviation and shipping emissions. Inclusion of international aviation and shipping emissions does not therefore imply the need for additional emissions reduction effort from other sectors.
  - International aviation emissions should be added at 31 $MtCO_2e$ annually (i.e. 155 $MtCO_2e$ per five-year budget period), on the basis of the UK's share of emissions from all departing flights under the EU ETS cap for aviation.
  - International shipping emissions should be added at around 9 $MtCO_2e$ annually (i.e. around 45 $MtCO_2e$ per budget). This reflects a bunker fuels methodology and a broadly flat projection based on the Energy Efficiency Design Index (EEDI) adopted by the International Maritime Organisation (IMO).
  - There would be no additional cost to inclusion, given that no additional effort is required for aviation beyond the EU ETS, for shipping beyond the EEDI, or for other sectors beyond that implied by current carbon budgets.
  - Budgets should not be adjusted to reflect non-Kyoto emissions/effects (contrails etc). These are important however, and should be kept under review, with options to reduce them developed over the next decade.
- **Meeting the 2050 target.** A 2050 target that includes international aviation and shipping emissions can be met based on currently identified measures and at a cost previously accepted by Parliament.
  - We have previously shown how such a target could be achieved, in our 2008 advice on the 2050 target, and in our 2011 Bioenergy Review. In 2008, we estimated that the 2050 target could be met at a cost of around 1-2% of GDP in 2050. This was accepted at the time that the Climate Change Act was legislated.
  - The Government set out scenarios for meeting a 2050 target including international aviation and shipping emissions in its December 2011 Carbon Plan.
  - In this report, we address questions raised in the Bioenergy Review and the Carbon Plan, and provide more confidence as to how a 2050 target including international aviation and shipping emissions could be achieved (e.g. through deep cuts in power, buildings and surface transport emissions).
  - The cost estimates from this new analysis for meeting the 2050 target are towards the low end of the previous estimate of 1-2% of 2050 GDP (i.e. at the level previously accepted).
  - Attempting to reduce these costs by not including international aviation and shipping emissions could result in setting of insufficiently ambitious carbon budgets, implying a more expensive path to achieving the climate objective.
- **Planning assumptions for aviation and shipping.** As for other key sectors, there should be planning assumptions for longer-term emissions from aviation and shipping. These should be to keep aviation emissions in 2050 broadly at 2005 levels and for shipping emissions around a third below current levels in 2050. The key driver of emissions reductions will be EU or global policies, and should not be UK unilateral approaches; therefore these assumptions should be kept under review with respect to the evolving international framework, and changed as appropriate.

1. Why emissions from international aviation and shipping should be included in UK carbon accounting

Where sectors produce emissions that contribute to climate change they should be included in the accounting framework of the Climate Change Act unless there is a good reason to exclude them.

In this section we consider specific consequences of excluding international aviation and shipping emissions for achieving climate objectives and setting of carbon budgets.

We highlight inconsistencies and ambiguities under the current approach, which could result in failure to achieve climate objectives and setting of carbon budgets which are insufficiently ambitious given longer-term challenges.

We consider alternative means to address these shortcomings, and conclude that inclusion of international aviation and shipping emissions in the accounting framework under the Act would provide the most flexible and therefore the lowest cost approach to meeting climate objectives.

In section 2, we consider the possible practical barriers that we have previously highlighted to inclusion in carbon budgets and conclude that these are no longer significant for either international aviation or international shipping.

Box 1.1 summarises why emissions from international aviation and shipping should be included.

Box 1.1: Summary of why international aviation and shipping should be included in the UK accounting framework

1. Emissions from international aviation and shipping cause warming.
2. These emissions must therefore be managed, which could be done either inside or outside of the formal accounting framework.
3. Accounting for these emissions inside the formal framework is clearer and more flexible than accounting for them outside the framework.
4. There are no longer any practical barriers to inclusion (see section 2).

UK and international climate objectives

Our advice in relation to the Climate Change Act is underpinned by a climate objective. This is to limit central estimates of global temperature increase by 2100 to as little above 2°C over pre-industrial levels as possible, and limit the likelihood of a 4°C increase to very low levels (e.g. less than 1%).

We developed the objective based on consideration of damages resulting from different degrees of climate change, noting that high concentrations of greenhouse gases already in the atmosphere and continuing global emissions growth constrain what may now be feasible.

This was accepted by the Government and Parliament as part of our broader advice on the Climate Change Bill before this became law in 2008 (e.g. as set out in the Government's Impact Assessment[2]).

The EU and the UNFCCC have adopted similar climate objectives:

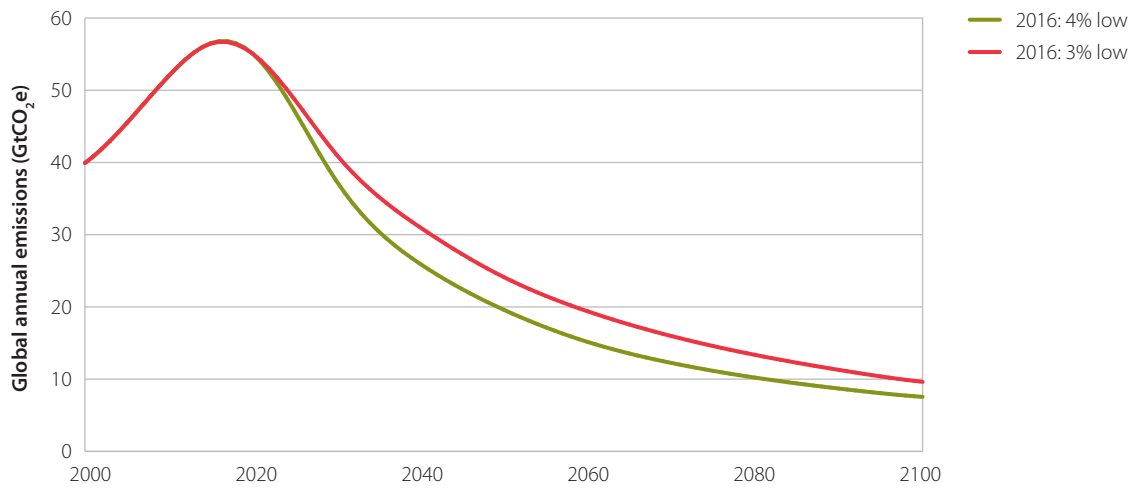
- The EU has a stated goal of limiting the average increase in global temperature to no more than 2°C above pre-industrial levels.
- In 2010 the UNFCCC adopted the Cancun Agreements, in which all participating nations recognised the need to hold temperatures to less than 2°C above pre-industrial levels.

If anything, the objective used by the Committee may be less ambitious than these international objectives, given that the probability of exceeding 2°C under the Committee's objective is slightly over 50%.

Global emissions pathways to achieve climate objectives

In developing our advice on the 2050 target, we assessed multiple global emissions pathways and identified those that would achieve our climate objective. The suitable pathways we identified were characterised by early peaking of global emissions (i.e. by 2020) and deep cuts thereafter (e.g. 50% by 2050), see Figure 1.1.

Figure 1.1: Global emissions trajectories consistent with the climate objective, as proposed in CCC 2008 report (2000-2100)



Source: CCC (2008).
Notes: Both trajectories involve CO_2 emissions peaking in 2016 and then declining at 3% or 4% annually. Non-CO_2 emissions are reduced at consistent rates. See the technical appendix to Chapter 1 of the Committee's 2008 report for a full description.

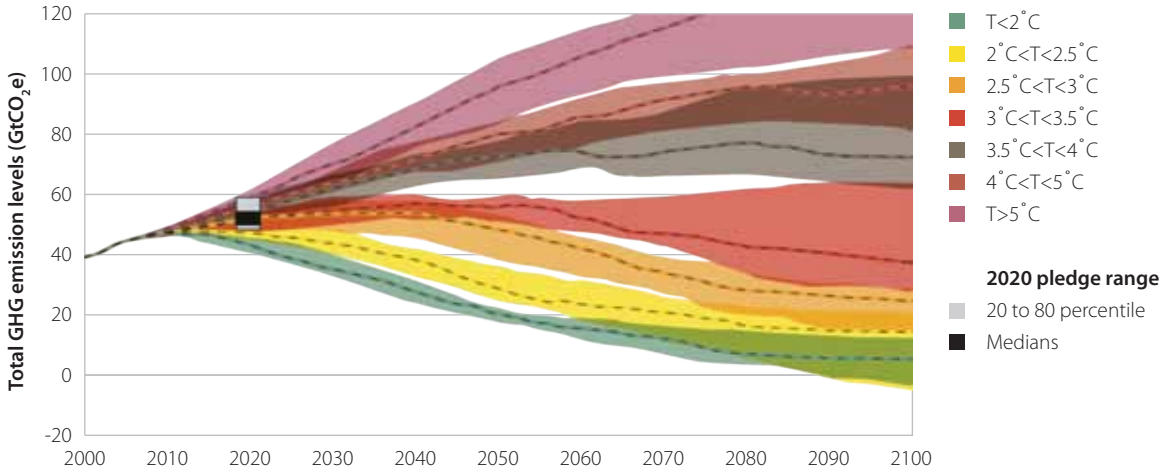
2 DECC (2009), *Climate Change Act 2008, Impact Assessment.*

For the purposes of this report, it is important to note that these global pathways cover all emissions, including those from international aviation and shipping. By 2050, emissions from these sectors could account for 10-20% of the total[3].

The EC has also recognised the importance of these emissions, for example, through including international aviation emissions in its 2050 pathways analysis, through endorsing global pathways that reduce total emissions to at least 50% below 1990 levels by 2050, and through targeting an EU emissions reduction of 80-95% by 2050[4].

At the global level, UNEP (United Nations Environment Programme) emissions pathways include international aviation and shipping emissions and also imply around a halving of overall emissions by 2050 to have a likely chance of staying below 2°C (Figure 1.2). The UNFCCC (United Nations Framework Convention on Climate Change) accounts for aviation and shipping emissions by asking countries to submit estimates based on bunker fuel use, and the Kyoto Protocol requires Annex 1 countries (including the UK) to develop mitigation approaches through the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO).

Figure 1.2: UNEP trajectories for global emissions including international aviation and shipping (2000-2100)



Source: UNEP (2011) Bridging the Emissions Gap.
Notes: Coloured ranges show the 20-80 percentile ranges of the sets of analysed emission pathways that have approximately the same "likely" (i.e. 66% probable) avoided temperature increase in the 21st century. Dashed lines show the median transient emission pathways for each temperature level. Figure includes estimated emissions in 2020 resulting from current pledges.

3 Owen and Lee (2005) Allocation of international aviation emissions from scheduled air traffic - future cases, 2005 to 2050; Lloyd's Register & DNV (2011) Assessment of IMO mandated energy efficiency measures for international shipping; compared to CCC (2008) '2016:4%' low trajectory.

4 European Commission (2011) *Impact Assessment accompanying the Roadmap for Moving to a Competitive Low Carbon Economy in 2050.*

Previous recommendations on the approach to international aviation and shipping emissions under the Climate Change Act

The global pathways consistent with achieving the climate objective imply average emissions in 2050 cannot be much higher than 2 tCO_2e per capita, including international aviation and shipping emissions.

In advising on the 2050 target, we argued that it is hard to imagine a future global agreement under which the UK and other developed countries are allowed higher emissions per capita than the global average, since this would require developing countries to have lower emissions.

We therefore recommended a 2050 target for the UK reflecting emissions of slightly over 2 tCO_2e per capita, which (under median UN population projections) translated to an 80% emissions cut on 1990 levels, including international aviation and shipping emissions.

However, we did not include international aviation and shipping emissions in our recommended carbon budgets, given complexities at the time in estimating and projecting these emissions at the UK level. For aviation, these related to proposed methodologies for allocating the EU ETS aviation cap to Member States, which would not have been a fair representation of the emissions impact of UK aviation. For shipping, we identified potentially large uncertainties over the UK share of international emissions and over future emissions in the absence of policies to limit them.

Current approach to international aviation and shipping emissions under the Climate Change Act

The Climate Change Act defines carbon budgets and the 2050 target in terms of the same *net carbon account*. As a result, international aviation and shipping are either included in the 2050 target and carbon budgets or excluded from both[5].

The net carbon account currently includes emissions from domestic aviation and shipping but excludes international emissions from these sectors. As such, it excludes the vast majority of total UK aviation and shipping emissions, which are international (Figure 1.3).

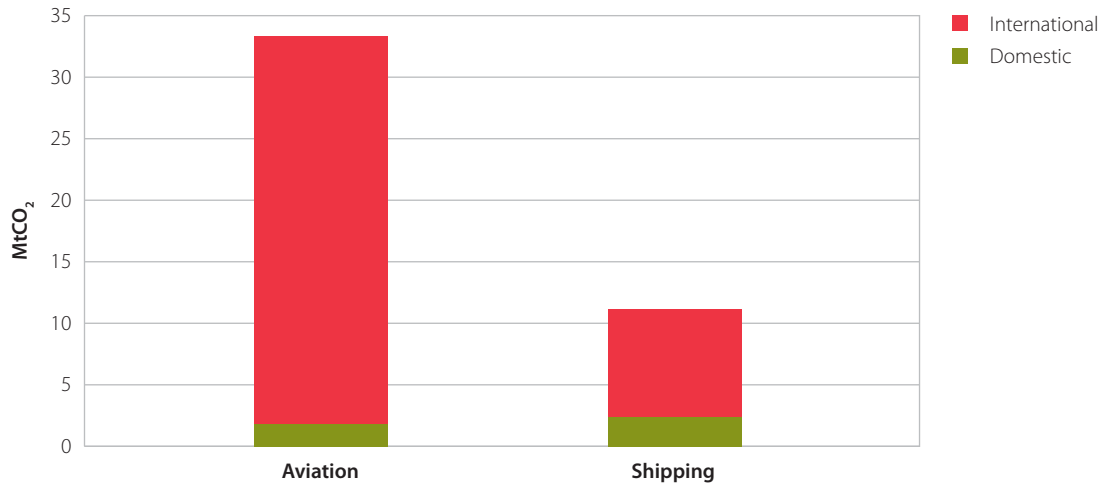
However, under the Act a decision on inclusion of international aviation and shipping emissions is required by the end of 2012. This will be informed by the Committee's advice set out in this report, followed by legislation tabled by Government for approval by Parliament.

Whatever this decision, the Act requires that carbon budgets reflect international aviation and shipping emissions both *implicitly* and *explicitly*, stipulating that carbon budgets should be set with regard to "scientific knowledge about climate change" and "circumstances at the European and international level", and should take account of "the estimated amount of reportable emissions from international aviation and shipping"[6] (Box 1.2).

The Government interpreted these various provisions to imply an 80% target including international aviation and shipping emissions for the modelling in its December 2011 Carbon Plan (see Box 3.3 below).

5 Climate Change Act 27, 30.
6 Climate Change Act 10(2)(a), (h), (i).

Figure 1.3: UK CO_2 emissions from aviation and shipping – international and domestic (2010)



Source: NAEI (2012).

Box 1.2: Budget-setting criteria related to international aviation and shipping

The Climate Change Act includes a number of criteria that should be taken into account in setting carbon budgets. These include three criteria which relate *implicitly* or *explicitly* to international aviation and shipping emissions:

- **Scientific knowledge about climate change.** The climate objective follows directly from judgements based on climate science. Achievement of the climate objective depends on global emissions pathways that reflect all greenhouse gas emissions, including those from international aviation and shipping, since all emissions contribute to climate change. Ignoring emissions from these sectors would result in total emissions being too high to deliver the climate objective (e.g. by up to 25% in 2050, if international aviation and shipping emissions are in line with the scenarios set out in section 3).
- **International circumstances.** The climate objectives agreed by the EU and UNFCCC are broadly consistent with (if not more stringent than) the climate objective underpinning our recommendations and the Climate Change Act. Again, the global and EU emissions pathways to achieve this objective must include international aviation and shipping emissions, since these also contribute to climate change. The UK also has obligations under the EU climate package, which already includes emissions from international aviation and is likely to also cover international shipping in the future (e.g. the EC have stated they will bring shipping into the EU framework next year if sufficient progress is not made through the IMO or UNFCCC).
- **Emissions from international aviation and shipping.** The requirement to take account of the amount of these emissions when setting carbon budgets implies that where they are excluded from budgets (as under the current definition in the Climate Change Act) a lower budget is required to maintain consistency with the science and international circumstances.

These criteria suggest that the *total* emissions from sectors currently covered by carbon budgets *plus* emissions from international aviation and shipping should be compatible with required global emissions pathways that would achieve the climate objective.

There was a similar interpretation in the High Court judgement on Heathrow expansion in 2010 (Box 1.3). The basis for this judgement was that climate change policy has implications for international aviation emissions, even though these are not currently included in the net carbon account of the Climate Change Act.

Box 1.3: 2010 High Court judgement on Heathrow expansion

In April 2009, a number of local councils, green groups and residents brought a case against the Government's January 2009 policy decision to support a third runway at London's Heathrow Airport.

A key claim was that the Government had not shown that the decision on Heathrow was compatible with climate change policy. The sequence of events was:

- Government support for a third runway was first indicated in its Air Transport White Paper (ATWP), published in December 2003, and subject to the need to consider environmental effects.
- In November 2008, the Climate Change Bill passed into law.
- In January 2009, the Government announced support for a third runway, stating its satisfaction that the environmental conditions set out in the 2003 ATWP had been met.
- The Government also announced a new target for aviation emissions in 2050 to be capped at or below 2005 levels, and requested that the Committee on Climate Change advise on how best to meet this target.
- In December 2009, the Committee published its advice, concluding that given likely developments in technology and biofuels, demand growth should not exceed 60% between 2005 and 2050 in order to meet the target.[7]

In March 2010, the High Court ruled that, in light of significant developments in climate change policy since 2003, the Government's decision to proceed with its plans for Heathrow expansion was "untenable".[8] The ruling concluded that developments in climate change policy had implications for aviation policy not reflected in the 2003 ATWP and should be taken into account, even though aviation is not specifically included in the net carbon account of the Climate Change Act.

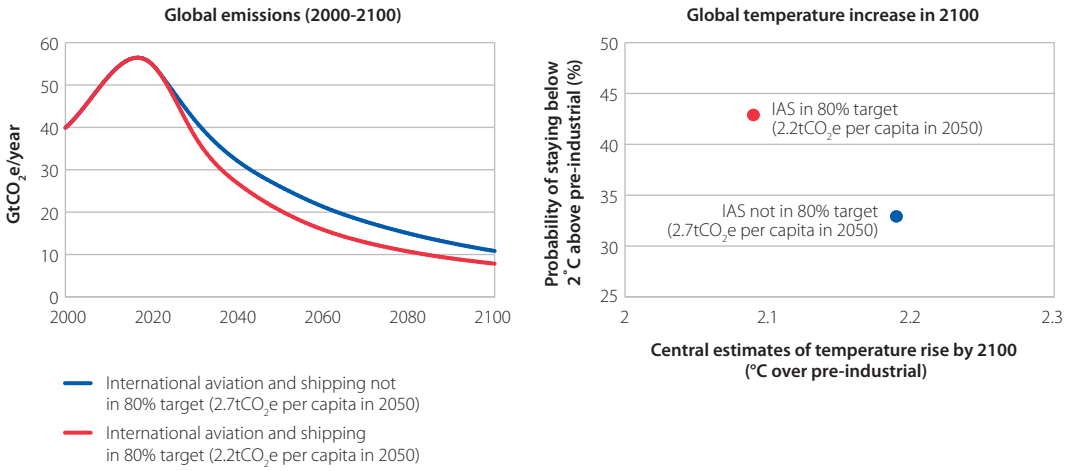
Inconsistencies and ambiguities caused by the current definition of the 2050 target in the Climate Change Act

An 80% emissions reduction excluding international aviation and shipping emissions (which is the minimum ambition for 2050 as currently defined under the Climate Change Act) would not be deep enough to achieve UK and international climate objectives:

- An 80% emissions reduction excluding international aviation and shipping emissions implies emissions from other sectors of 2.2 tCO_2e per capita in 2050 in the UK. This increases to 2.7 tCO_2e per capita when emissions from international aviation and shipping are added, assuming these are around 2005 levels for aviation and around a third below current levels for shipping.
- This level of per capita emissions, if replicated globally, would increase the risk of dangerous climate change (e.g. increasing the probability of exceeding 2°C by around 10%, see Figure 1.4).

7 Committee on Climate Change (December 2009), *Meeting the UK aviation target – options for reducing emissions to 2050.*
8 See *http://www.bailii.org/ew/cases/EWHC/Admin/2010/626.html*.

Figure 1.4: Excluding international aviation and shipping emissions from the 2050 target implies increased global emissions and greater warming



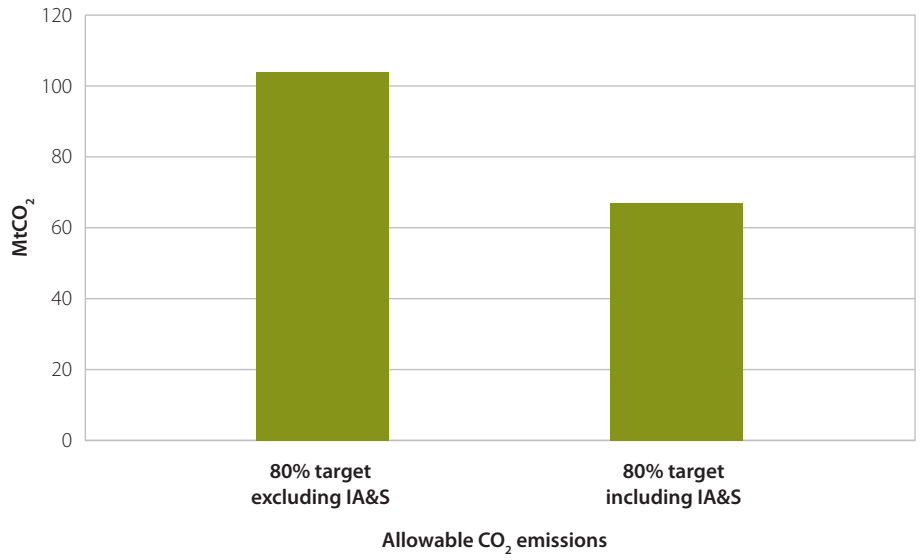
Sources: CCC and Met Office Hadley Centre calculations.
Notes: Global emissions and temperature increase are calculated following the CCC method outlined in *Model emissions and climate data*, a technical appendix available for download at www.theccc.org.uk. CO_2 emissions reduction rates are fixed during 2020-2100 such that per capita GHG emissions in 2050 are 2.2 tCO_2e or 2.7tCO_2e, assuming the population projections used in CCC (2008) *Building a low-carbon economy*.

Although the Act allows emissions reductions deeper than 80% (the target is defined as a reduction of 'at least 80%' on 1990 levels), we cannot be confident that such interpretations (e.g. as in the Government's December 2011 Carbon Plan) will continue.

This inconsistency between the 80% target and the climate objective is particularly problematic given the crucial role of the 2050 target for designing medium-term emissions pathways, and could result in these being insufficiently ambitious:

- The 2050 target is one of a number of criteria to be considered when legislating carbon budgets (Climate Change Act, Section 10).
- These criteria are potentially ambiguous with respect to carbon budgets (e.g. there is a tension between the 2050 target and the science and international criteria).
- If international aviation and shipping emissions were to be excluded from the 2050 target, this would suggest scope for higher levels of CO_2 emissions in other sectors (Figure 1.5), and could result in carbon budgets being insufficiently ambitious.

Figure 1.5: Implied scope for CO_2 emissions from domestic sources in 2050 under an 80% target with and without international aviation and shipping (IA&S) included



Source: CCC calculations.
Note: Non-CO_2 emissions assumed to be inflexible at 50 $MtCO_2e$ in both cases, with IA&S emissions in line with the central scenarios set out in section 3.

If unresolved, this could have implications for near-term decisions on the fifth carbon budget and policies to build a low-carbon economy:

- The fifth carbon budget, on which we will start work in 2014/15 for legislation in 2016, would be more difficult to design and agree if current ambiguities between budget-setting criteria are not resolved (e.g. this could be insufficiently ambitious if it is aligned to the current definition of the 2050 target interpreted as a reduction of 80% – and no more – across all sectors excluding international aviation and shipping).
- This could have knock-on consequences for supporting policies, which should be tailored to achieving carbon budgets (e.g. support for deployment of electric vehicles and electric heat, the pace of power sector decarbonisation).
- The combination of these factors could raise costs and risks of meeting budgets (e.g. if insufficiently ambitious budgets and policies require later scrappage of high-carbon infrastructure).

Therefore there is now a need to formalise the current approach – which *assumes* an 80% reduction across all sectors including international aviation and shipping – in order to provide certainty that this will continue in future, and to avoid costs and risks associated with less ambitious interpretations of the 2050 target.

Resolving inconsistencies and ambiguities: recommendation on including international aviation and shipping emissions in carbon budgets and the 2050 target

Whereas in our 2008 advice we identified complexities related to international aviation and shipping emissions which prevented initial inclusion in carbon budgets, we show in section 2 below that these have now been resolved for both aviation and shipping.

Given that this is the case, there is no longer any reason why international aviation or international shipping should be treated differently to other sectors (e.g. power, buildings, surface transport).

Although it would be possible to reflect but not include emissions from these sectors through increasing the minimum ambition in the 2050 target, this would leave an incomplete and inflexible framework (Box 1.4).

Therefore, international aviation and shipping emissions should be included in the net carbon account under the Climate Change Act. This would provide the most transparent, comprehensive and flexible approach to ensuring that the 2050 target is compatible with achieving the climate objective and with international agreements, and that carbon budgets set to achieve this target are compatible with required longer-term emissions pathways.

Box 1.4: Extra flexibility in a target that includes emissions from international aviation and shipping

In principle there are two options for correcting the inconsistencies between carbon budgets, the 2050 target and the climate objective:

- **Option 1: change the definition of the net carbon account.** To change the definition of the net carbon account to include emissions from international aviation and shipping.
- **Option 2: increase the minimum ambition of the 2050 target.** To keep the definition of the net carbon account the same, but to increase the minimum ambition of the 2050 target (e.g. to 85%) such that the combination of the target together with projected emissions from international aviation and shipping gives an 80% emissions reduction overall.

The first of these two options would provide a greater degree of flexibility to respond to changes in international frameworks for reducing aviation and shipping emissions in the longer term:

- If projected international aviation emissions were to fall following a global agreement, for example, then the climate objective could be achieved with less effort from other sectors. Under Option 1, this would require an adjustment to the level of ambition in policies for these other sectors. Under Option 2, a legal and Parliamentary process would be required to change the 2050 target.
- Additional targets for aviation and shipping emissions could be required under Option 2, in order to provide confidence around consistency of the 2050 target, emissions from aviation and shipping, and the climate objective. However, given uncertainty over future aviation and shipping emissions, and the fact that these will be highly influenced by international agreements, such targets may be inappropriate at the UK level.

Therefore, a 2050 target that includes international aviation and shipping is preferred and offers greater flexibility than a target that excludes these sectors and makes assumptions over success in reducing their emissions.

Moreover, inclusion in carbon budgets and the 2050 target would make the accounting framework of the Climate Change Act fully transparent and comprehensive.

2. How to include international aviation and shipping emissions in legislated carbon budgets

Currently legislated budgets are already designed to reflect international aviation and shipping emissions. This implies there is no need for additional effort from other sectors when international aviation and shipping emissions are included in carbon budgets. It leads us to recommend that inclusion should be through the addition of international aviation and international shipping emissions to currently legislated budgets.

In this section we first explain how currently legislated budgets were designed and then consider how much these should be increased to accommodate international aviation and international shipping.

Although our focus is on CO_2 emissions, we also consider aviation and shipping non-CO_2 emissions and effects, both those covered by the Kyoto basket (i.e. methane and nitrous oxide) and those not covered (e.g. contrails and induced cirrus).

We set out our analysis in five parts:

(i) How currently legislated budgets are designed to reflect emissions of international aviation and shipping

(ii) Recommended approach to inclusion of international aviation emissions

(iii) Recommended approach to inclusion of international shipping emissions

(iv) Approach to non-CO_2 emissions and effects

(v) Recommended carbon budgets

(i) How currently legislated budgets are designed to reflect emissions of international aviation and shipping

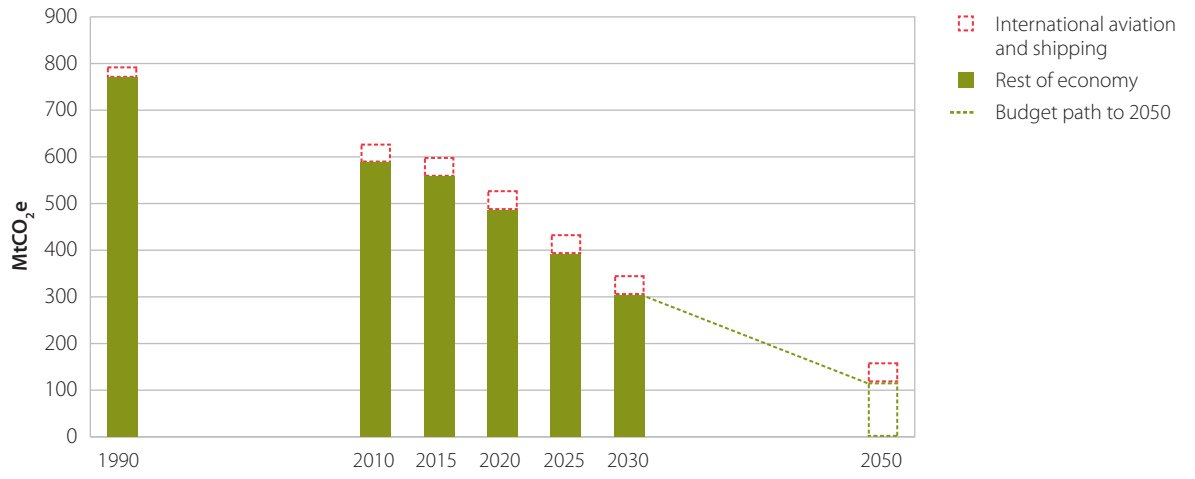
The first four carbon budgets already build in sufficient effort from other sectors to allow for international aviation and shipping emissions (Figure 2.1):

- The first three carbon budgets (i.e. covering the period to 2022) reflect UK shares of EU targets, which in turn reflect international aviation emissions.
  - The EU's economy-wide targets include international aviation emissions.
  - EU sub-targets for other sectors (i.e. not international aviation) are set lower to allow for international aviation emissions.
  - It follows that the UK's share of these sub-targets reflects projected international aviation emissions.
  - The first three carbon budgets were set based on the UK's share of these sub-targets, and therefore reflect international aviation emissions.
- Although international shipping is not included in the EU targets, inclusion would make very little difference to targets for other sectors.
  - EU economy-wide targets are defined as a percentage reduction relative to 1990.
  - Inclusion of international shipping emissions would increase both 1990 emissions and the absolute level of emissions allowed under targets.
  - If shipping emissions were to be included in EU targets, the level of effort in other sectors would have to be only slightly increased (e.g. the required emissions reduction could increase from 20% to 21%).
- Measures that we have identified as feasible and cost-effective to meet the third carbon budget (2018-22) together define an appropriate path towards meeting the fourth carbon budget (2023-27).
- The fourth carbon budget was calculated on a bottom-up basis for sectors other than international aviation and shipping. It includes measures on the feasible and cost-effective path to a 2050 target which includes international aviation and shipping emissions.

Therefore inclusion of international aviation and shipping in carbon budgets should be through adding emissions from these sectors on top of existing budgets, rather than keeping budgets constant and requiring extra abatement effort from other sectors.

This raises questions over the methodology on which international aviation and shipping emissions are estimated and projected, and the approach to carbon budget management once these have been added.

Figure 2.1: Existing budgets are on track to a 2050 target that includes emissions from international aviation and shipping



Source: CCC calculations.
Notes: Emissions for 2015-2020 are based on CCC's Extended Ambition scenario as set out in December 2008 advice on the first three carbon budgets. Emissions for 2025-2030 are based on the Medium Abatement scenario from our December 2010 advice on the fourth carbon budget.

(ii) Recommended approach to inclusion of international aviation emissions

Aviation CO_2 emissions (we consider non-CO_2 emissions in section 2(iv)) have been included in the EU Emissions Trading Scheme (ETS) since 1st January 2012, with the overall cap likely to be tighter as a result (Figure 2.2):

- Prior to inclusion, the EU ETS cap was set at 1,777 $MtCO_2$ for the other capped sectors in 2020.[9]
- Aviation emissions were added to this cap at 209 $MtCO_2$ per year from 2013 to 2020.
- The resulting total EU ETS cap is 1,986 $MtCO_2$ in 2020.
- Gross aviation emissions in 2020 are likely to be significantly higher than the cap (e.g. with growth in line with the pre-recession trend these would be 280 $MtCO_2$ in 2020, around 70 $MtCO_2$ higher than the adjustment to the cap).
- Therefore the aviation industry is likely to be a net purchaser of allowances, paying for emissions reductions in other sectors (e.g. more switching from coal to gas in power generation). This will result in an EU ETS carbon price that is higher because of the inclusion of international aviation emissions.

Given that it is now included, aviation should be treated in the same way as other sectors in the EU ETS, and included in carbon budgets at the level of the cap (see Section 27 of the Climate Change Act).

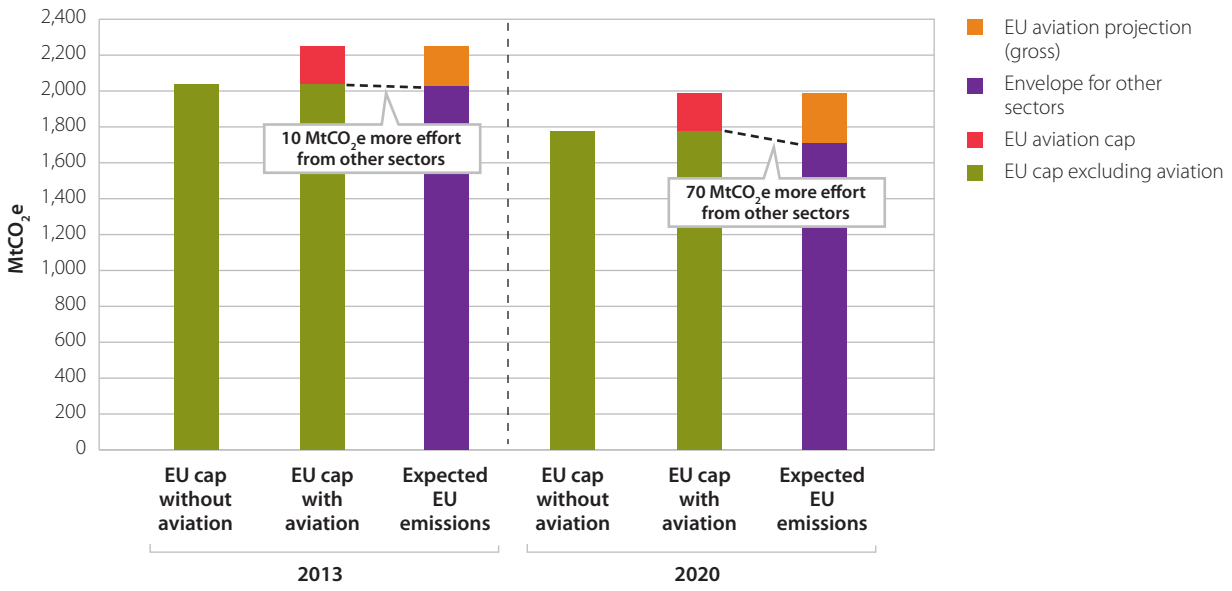
9 Note that the scope of the EU ETS has changed since our 2008 budget advice (i.e. new sectors have been included). As such the cap is higher than our previous expectation of 1720 $MtCO_2e$.

We suggested in 2008 that proposals at that time for allocating the EU ETS cap to the country level would not be a sensible basis for inclusion in carbon budgets. This reflected that proposals for country-level allocation were based on where airlines were headquartered (so for example, a flight from Rome to New York could be counted as a UK flight if most of the airline's operations were based in the UK).

However, under the final design of the scheme, country-level caps can be calculated using a methodology based on departing flights, which accurately reflects the emissions for which a country is responsible. Therefore inclusion of international aviation emissions in carbon budgets should be on the basis of an all-departing methodology reflecting the UK's share of the EU all-departing cap (Box 2.1).

We note that there are currently various challenges to the inclusion of aviation in the EU ETS (e.g. the Civil Aviation Administration of China has banned its airlines from complying with the ETS), but do not consider these as a reason to exclude international aviation from the net carbon account (Box 2.2).

Figure 2.2: Illustrative impact of including aviation emissions in the EU ETS



Source: CCC calculations.
Notes: EU aviation emissions in 2013 assumed to be at 2009 levels; emissions in 2020 extrapolated based on pre-recession trend. EU aviation cap covers emissions from EU all-departing flights and non-EU arriving flights.

Box 2.1: Accounting methodology for including international aviation emissions in carbon budgets

Inclusion of international aviation emissions in carbon budgets on the basis of all departing flights is sensible and feasible given the approach to aviation in the EU ETS:

- An all-departing-flights methodology is an accurate measure of country-level emissions.
  - Measuring emissions from both departing and arriving flights would double-count emissions at a global level (since each departing flight would also be counted elsewhere as an arriving flight). Therefore, to avoid double-counting it is important to record emissions from either all departing or all arriving flights only.
  - Emissions measured on an all-departing basis correlate very closely to the bunker fuel methodology used to report country-level emissions to the UNFCCC (e.g. DfT's all-departing estimate of emissions is within around 1% of the bunker fuels estimate).
- Initially the EU ETS also includes emissions from flights arriving from outside the EU to avoid perverse incentives.
  - This is to ensure that flights within the EU are not disadvantaged compared to flights leaving the EU. If only departing flights were included in the scheme, then for return flights within the EU both legs would need to purchase allowances (since both would depart from within the EU), but for destinations outside the EU only the outbound leg would be covered.
  - The cap has been set higher to allow for non-EU arriving emissions. The cap for 2012 is set at 97% of average 2004-06 emissions from all departing flights and all non-EU arriving flights, declining to 95% for 2013-2020.
  - In order to avoid double-counting emissions in future, the EU ETS approach has been designed to allow non-EU arriving flights to be removed from the scheme (and the cap reduced accordingly) should other regions implement comparable policies or if a global policy is agreed. These non-EU arriving flights will also not count against the EU economy-wide target to reduce emissions by 20% in 2020 compared to 1990 levels.
- The EU ETS share of the all-departing cap is likely to be separately identifiable, in which case it can be allocated to the country level based on that country's share of 2010 emissions (this will be the methodology for sharing out auction rights).
- Until the all-departing cap is available (it is expected during 2012), carbon budget adjustments can be calculated using bunker fuels estimates:
  - At 95% of average 2004-06 EU international aviation emissions (on a bunker fuel basis) the EU all-departing cap would be 124 $MtCO_2$ per year.
  - Scaling this to the UK's share of EU emissions in 2010 (using 2009 data, given that data for 2010 – the year on which auction rights will be allocated – is also not yet available) gives a UK share of the cap of 30.5 $MtCO_2$ per year.
  - This implies 153 $MtCO_2$ per five-year budget period (for CO_2 only) .

Our recommended adjustments to carbon budgets set out in Table 2.1 below are based on this UK share of the EU ETS cap calculated using bunker fuels, as a proxy for a measure based on all departing flights.

In monitoring performance against carbon budgets it will be important to measure aviation emissions on this same basis (i.e. all departing flights, or bunker fuels as a proxy) and to calculate credit purchase by the UK aviation industry as the difference between that and the all-departing share of the cap.

Box 2.2: Legal challenges to inclusion of aviation in EU ETS

In 2008 the EU decided to include aviation in its Emissions Trading Scheme (ETS), with effect from 1 January 2012.

Although this decision has been subject to legal challenge, the European Court of Justice has ruled that inclusion of aviation does not contravene international laws:

- In 2010 several airlines and airline associations took legal action, challenging the measures taken to implement the EU Directive on the inclusion of aviation in the EU ETS. They claimed that inclusion of aviation was illegal in that it breaches a range of international laws and agreements, and applies beyond the EU's territorial jurisdiction.
- In December 2011, the European Court of Justice published their decision, stating that the inclusion of aviation in the EU ETS was legal and did not contravene international law.[11]

Therefore, we do not expect aviation to leave the EU ETS. Even if it were to leave, this would not be a barrier to inclusion within UK carbon budgets and the 2050 target:

- The Climate Change Act incorporates provision to alter carbon budgets in the event of significant changes in international circumstances.
- A failure of the EU ETS in respect of aviation would classify as such a change. Aviation would then move to the non-traded sector and could be included on the basis of projected emissions on a bunker fuels basis (which is a good proxy for emissions from all departing flights).
- Further revisions would then be possible following introduction of alternative EU or global policies to reduce aviation emissions.

Therefore, possible uncertainties over the future of aviation in the EU ETS are not a reason to exclude emissions from carbon budgets or the 2050 target.

(iii) Recommended approach to inclusion of international shipping emissions

Methodologies for estimating international shipping emissions

We considered various methodologies for estimating international shipping emissions in our 2011 Shipping Review, and identified bunker fuels, trade-based (top-down) and activity-based (bottom-up) methodologies as the main candidates for inclusion in carbon budgets:

- **Bunker fuels.** This is the convention used for reporting shipping emissions to the UNFCCC under the Kyoto Protocol, and is used in the UK's greenhouse gas inventory. It is based on the amount of shipping fuel sold in the UK. Bunker fuels estimates *may* not accurately reflect country-level shipping activity and related emissions, given that ships stop and potentially refuel at multiple ports on routes.
- **Trade share (top-down).** This methodology allocates an estimate of global shipping emissions on the basis of national shares in global trade. It should provide an accurate representation where carbon intensity of ships and journey lengths are uniform across countries, but has several drawbacks:
  - It could over or under estimate emissions at the national level where carbon intensity of ships or journey lengths differ from the global average (e.g. where ship journeys are short relative to the global average, this approach would over allocate international emissions).

10 See www.curia.europa.eu, case number C-366/10.

- It leads to different estimates of national emissions depending on whether trade shares are estimated on the basis of imports or exports, even though the number of ships arriving is the same as the number of ships departing.
- Since national allocation is on the basis of trade it may lead to distortions where countries have large non-cargo based traffic (e.g. from passenger, fishing, or service vessels).

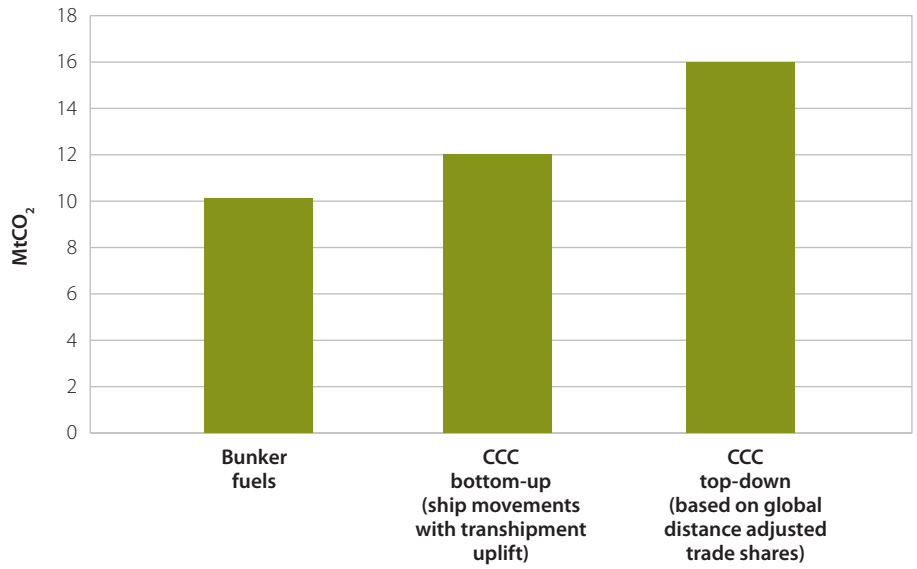
- **Activity-based (bottom-up).** This methodology estimates shipping emissions from the bottom up using data on trade, ship movements and carbon intensity of shipping. Although potentially the most accurate, this methodology is not yet fully developed or agreed internationally for annual reporting (e.g. by UNFCCC or IMO). Therefore, further work is required before it could form an agreed basis for inclusion in carbon budgets.

The analysis in our Shipping Review suggested a likely range for current UK international shipping emissions of 10-16 $MtCO_2$ in 2006, with bunker fuels at the low end of the range, activity-based in the middle, and trade-based at the high end (Figure 2.3).

We conclude based on this analysis that whilst bunker fuels is an imperfect basis for including international shipping emissions in carbon budgets, the difference as against other methodologies is unlikely to be material (e.g. the difference between bunker fuels and our activity-based estimate is around 2 $MtCO_2$, less than 0.5% of annual emissions allowed under the first four budgets).

Moreover, whereas inclusion of international shipping emissions in carbon budgets would ideally be via an activity-based methodology, estimates at the national level on this basis have not yet been developed and accepted by relevant international bodies for annual reporting (e.g. by the UNFCCC). In contrast, bunker fuels meet both criteria.

Figure 2.3: Estimates of UK international shipping emissions under different methodologies (2006)



Sources: NAEI (2012), CCC (2011), *Review of UK Shipping Emissions.*

Therefore inclusion of international shipping emissions in carbon budgets would initially have to be on a bunker fuels basis, moving to inclusion on an activity-based methodology once this is sufficiently developed and agreed internationally.

Shipping emissions projections

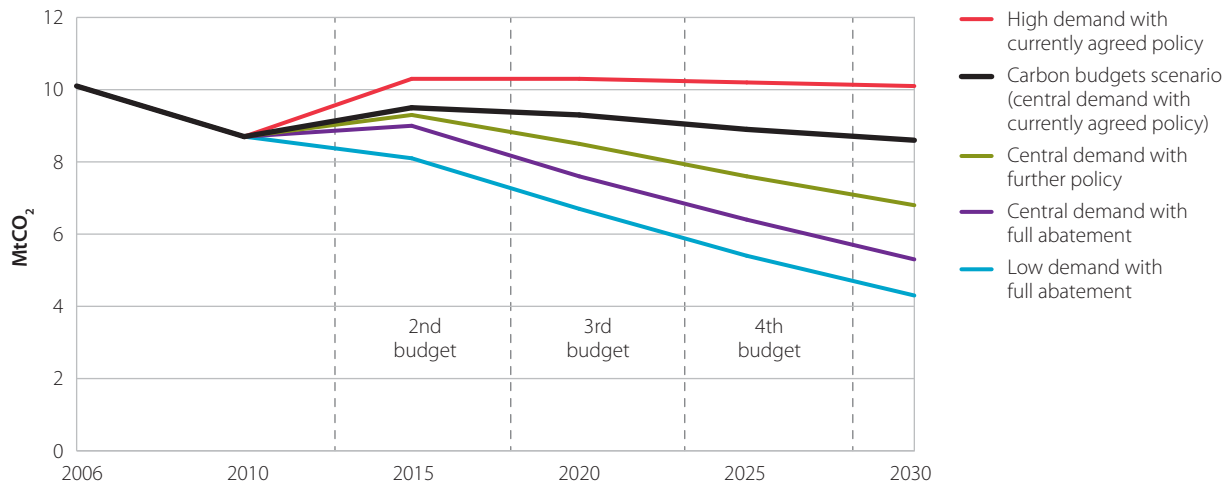
Since our 2008 report we have provided detailed analysis of possible future UK shipping emissions, and a new IMO approach to encourage emissions reductions has been introduced (the Energy Efficiency Design Index for new ships).

Our scenarios for international shipping emissions are based on an estimate of current emissions, which we project forward using assumptions on future shipping demand and carbon intensity of ships (see Figure 2.4 and section 3(ii) for more details):

- **Shipping demand.** The key drivers of shipping demand include GDP growth, fossil fuel and carbon prices, and UK consumption of fossil fuels and bioenergy.
- **Carbon intensity of ships.** Scope for reducing carbon intensity of ships exists through innovative design and operational approaches to improve fuel efficiency, and through possible use of biofuels or liquefied natural gas (LNG). The extent to which these are taken up will depend on the strength of international policies in place and under development (e.g. through the IMO).

The appropriate scenario for initial inclusion in carbon budgets is one based on a central assumption for demand coupled with carbon intensity projected under currently agreed policies (i.e. the EEDI adopted by the IMO). This implies an adjustment to budgets of around 9 $MtCO_2$ each year.

Figure 2.4: UK international shipping emissions to 2030 (bunker fuel basis)



Sources: NAEI (2012) and CCC Analysis.
Notes: Currently agreed policy reflects the IMO's EEDI. In the carbon budgets scenario, fall in emissions after 2015 reflects impact of the EEDI.

Options for including international shipping emissions and potential to review budgets

In our 2011 Shipping Review, we set out three options for inclusion of international shipping emissions in the accounting framework of the Climate Change Act:

- **Option 1.** International shipping emissions are included now in carbon budgets and the 2050 target.
- **Option 2.** International shipping emissions are included in carbon budgets and the 2050 target when progress has been made on developing internationally agreed methodologies for estimating emissions.
- **Option 3.** International shipping emissions are included in the 2050 target now, but in carbon budgets at a later date.

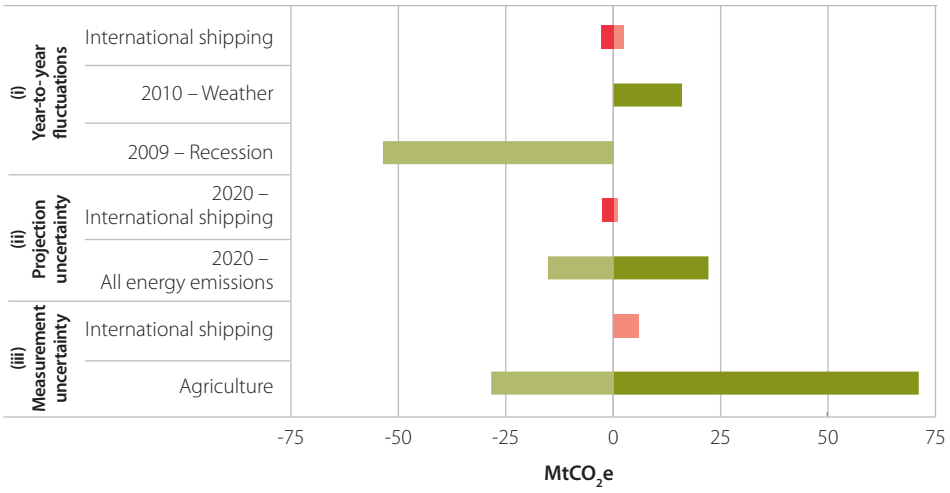
Of these options, the first would provide a complete accounting framework and appropriate flexibility, while the second and third would be problematic:

- **Option 2** would result in an incomplete framework, with political but not legal commitments to introduce international shipping emissions at a future stage. This would involve a risk that international shipping emissions remain outside the accounting framework in the longer term, when their relative importance could increase.
- **Option 3** would require a change in primary legislation, such that the net carbon account relates to carbon budgets but not the 2050 target. Although possible, this would be an unnecessarily burdensome route to achieving a framework which would remain incomplete with respect to international shipping emissions, while yielding little advantage in terms of managing budgets.

A potential concern under Option 1 is that changes in the agreed accounting methodology or a new international agreement to tackle shipping emissions (e.g. market-based measures currently being considered by the IMO) could imply unintended changes to the required effort from other sectors covered by carbon budgets. However, this is unlikely to be material, and if necessary could be managed under provisions set out in the Climate Change Act.

- Our analysis above suggests that the likely impact of a new methodology and the uncertainty in emissions projections are both relatively small. This is consistent with the fact that year-to-year fluctuations in bunker fuels estimates have historically been small. As a result, any consequences for carbon budget management would also be small relative to factors already included in budgets (Figure 2.5).

Figure 2.5: Uncertainties in international shipping emissions compared to uncertainties for carbon budgets as a whole



Sources: NAEI (2012); DECC (2011), *Updated energy and emissions projections 2011*; AEA Technology (2011) *National Inventory Report*; CCC calculations.
Notes: Chart compares: (i) The largest year-on-year change in estimates of international shipping since 1990, against fluctuations in total emissions in 2009 and 2010, reflecting the impact of the recession and cold weather respectively; (ii) Projection uncertainty for shipping emissions reflecting our Low and High scenarios, against DECC's estimate of uncertainty in projecting all energy CO_2 emissions resulting from uncertainty in input assumptions (95% confidence interval); (iii) The uncertainty range from different approaches to estimating shipping emissions (see Figure 2.3), against the uncertainty for agriculture non-CO_2 emissions reported in the National Inventory Report. Positive numbers indicate that emissions could be higher than expected, and negative numbers show where emissions could be lower.

- If there were to be a large change (e.g. due to the IMO agreeing a much more ambitious carbon policy), this could be managed through adjustment of carbon budgets as allowed under Section 21 of the Climate Change Act.[11] An adjustment could be appropriate depending on the extent of any change in shipping emissions, and implications that this would have for emissions reduction in other sectors.
- For example, an adjustment could be justified if a significant increase in estimated shipping emissions would otherwise result in the need for unilateral policies to reduce these emissions, increased effort in other sectors beyond that required to prepare for the 2050 target, or the purchase of offset credits by the UK Government before other countries are committed to similar approaches.
- Given that an adjustment may be desirable, shipping emissions should be closely monitored and the basis for their inclusion in budgets periodically reviewed.

Even with such potential for adjustment, inclusion is strongly preferred given that this ensures both a holistic approach to accounting for emissions, and that the 2050 target is aligned to the climate objective, with implications for other sectors properly understood (see section 1).

11 Section 21 allows for revisions to carbon budgets if "since the budget was originally set (or previously altered), there have been significant changes affecting the basis on which the previous decision was made."

We therefore recommend that international shipping emissions are included in the net carbon account, and that carbon budgets two to four should be adjusted by adding an appropriate amount for UK emissions from international shipping. The appropriate level for this adjustment should be the current inventory method of measuring emissions (i.e. bunker fuels), and our projection reflecting current policies (i.e. the IMO's Energy Efficiency Design Index). This implies an adjustment of around 9 $MtCO_2$ per year. Carbon budgets could then be reviewed periodically, with adjustments made as appropriate depending on progress developing activity-based methodologies or agreeing new policies, and for differences in projected and realised demand.

(iv) Approach to non-CO_2 emissions and effects

Aviation non-CO_2 emissions and effects

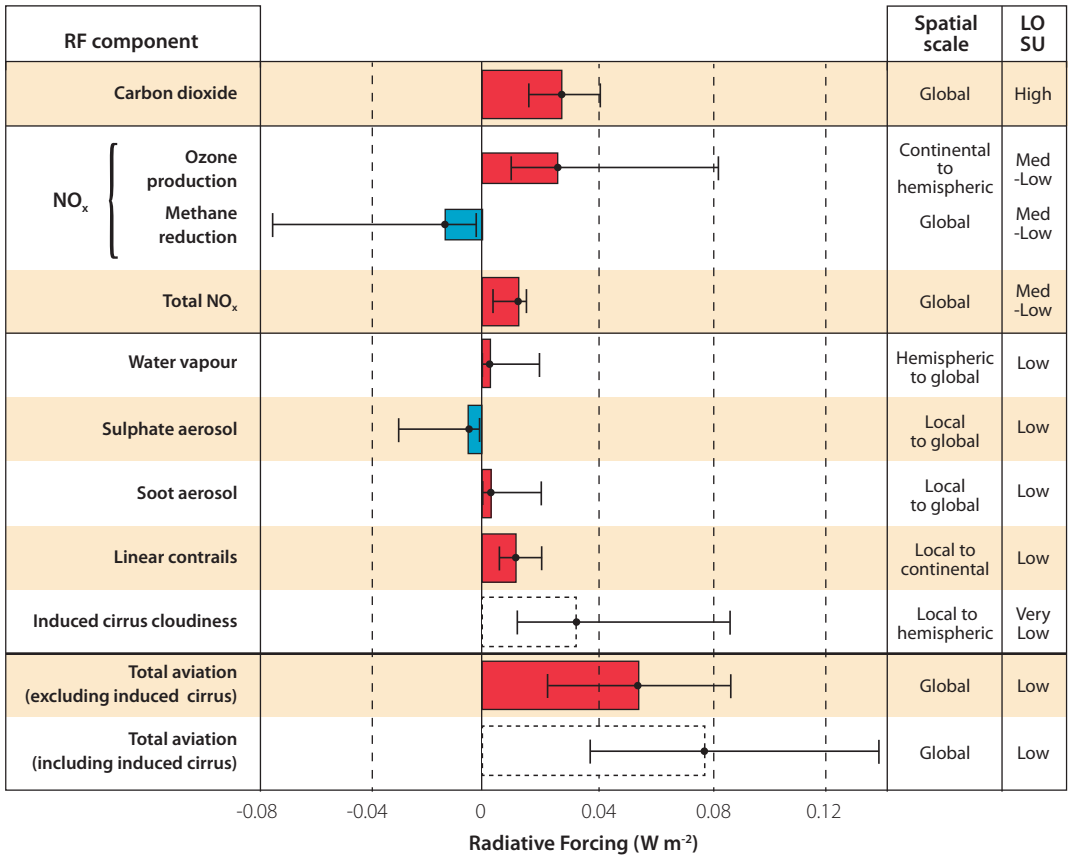
As well as CO_2, fuel combustion in aircraft results directly in emissions of methane and nitrous oxide, which are also included in the Kyoto basket of greenhouse gases[12]. These non-CO_2 effects are relatively small in magnitude (e.g. around 0.3 $MtCO_2e$ in 2010). They should be included in carbon budgets, as they are in other sectors (e.g. power and industry).

Potentially of more significance is that aviation also has a number of other non-CO_2 effects that are not included in the Kyoto basket, of which NO_x, contrails and induced cirrus are the most important contributors in terms of potential warming (Figure 2.6):

- **NO_x emissions.** These are created from air in the engine during fuel combustion. Through chemical reactions in the atmosphere they result in a short-lived warming effect by enhancing ozone, and a longer-lived cooling effect by reducing methane. The size of these two effects depends on the timing and location of NO_x emission. Some measures to reduce NO_x can increase CO_2 emissions (e.g. raising engine temperature and pressure) while others will decrease CO_2 as well (e.g. more efficient combustor designs, improved air traffic management).
- **Contrails and induced cirrus.** Contrails are lines of cloud caused by aircraft flying through supersaturated air. Induced cirrus cloud comes from spreading contrails, or from aircraft aerosol emissions. At the level aircraft fly, both have a significant warming effect but this only lasts up to a few hours. The actual extent of aircraft induced cirrus cloud and the magnitude of the current warming associated with the increased cloud is very uncertain. The best estimate is that it is comparable to the CO_2 impact of aviation, but it could be a small fraction of it or up to three times as large. There is scope to reduce these along with CO_2 emissions through flight path optimisation (e.g. routing of aircraft to avoid or make use of certain weather systems) although in some cases there may be a trade-off between CO_2 and cloud reduction.

12 Kyoto greenhouse gases are the major long-lived greenhouse gases covered by the Kyoto Protocol: carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, hydrofluorocarbons and perfluorocarbons.

Figure 2.6: Non-CO_2 effects from aviation



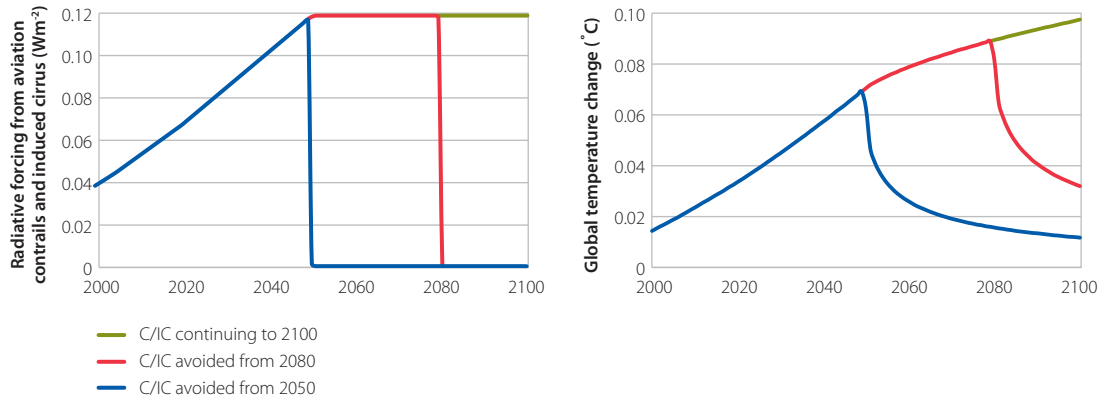
Source: Lee et al. (2010) Transport impacts on atmosphere and climate: aviation, *Atmospheric Environment*.
Notes: Each component of aviation's effect on climate is shown in terms of radiative forcing, which measures the current atmospheric imbalance (in Watts per square metre, Wm^{-2}) due to aviation activity up until now. Note that it does not give a measure of future effects from current activity - for instance, emitted CO_2 will reside in the atmosphere for many decades, whereas today's contrails will only last up to a few hours. Whiskers denote 90% confidence intervals and LOSU indicates the Level of Scientific Understanding regarding each effect. Induced cirrus is shown as a dotted bar due to high uncertainty.

These effects are important for near-term climate change.[13] However, they do not need to be reflected or included in carbon budgets now, given potential to reduce them before they materially affect the temperature in 2100, and possible perverse incentives associated with proposed methods of inclusion:

- Policies are already in place to limit NO_x emissions during take-off and landing because of their impacts on air quality. The European aviation industry has an ambition for 2020 to reduce NO_x emissions by 80%[14].
- Contrails and induced cirrus formed from today's aviation activity have a negligible impact on long-term temperature (Figure 2.7). This provides time to develop policies to reduce or avoid these impacts before they significantly affect the climate objective.
- Applying a multiplier to aviation CO_2 emissions has been suggested in order to reflect total aviation effects on the climate. However this would not provide a direct incentive to reduce the non-CO_2 effects, and may instead lead to CO_2 measures being taken which actually increase NO_x or contrails and induced cirrus.

13 For an illustration of the near-term importance of short-lived effects, see UNEP (2011), *Integrated assessment of black carbon and tropospheric ozone*.
14 www.acare4europe.com. The ACARE 'Vision for 2020' incorporates a reduction in CO_2 of 50% per passenger-km by 2020 measured against 2000 levels, and a reduction in NO_x emissions of 80%.

Figure 2.7: Effect of aviation contrails and induced cirrus on temperature to 2100



Sources: CCC and Met Office Hadley Centre calculations; Lee et al. (2009) Aviation and global climate change in the 21st Century, *Atmospheric Environment*.
Notes: Graph on left shows three scenarios for growth in contrails and induced cirrus (C/IC) based on projections to 2050 in Lee et al. First, all C/IC formation is avoided from 2050; second, it is held fixed at 2050 levels until cessation in 2080; and third, it is held fixed at 2050 levels to 2100. Graph on right shows resulting temperature change measured against a background global emissions pathway similar to those shown in Figure 1.1. If C/IC ceases in 2050, almost no temperature effects remain by 2100.

Therefore the appropriate approach is to develop scientific understanding, and to ensure that options to markedly reduce contrails and induced cirrus are developed over the next decade.

Depending on progress made, there may be a need for a future adjustment to carbon budgets. For example, if there were still to be significant NO_x emissions or production of contrails and induced cirrus in several decades, this would be a cause for concern, and could require that carbon budgets are tightened in order that the climate objective is achieved.

This is something that we will monitor in the context of our annual reports to Parliament and advice on setting carbon budgets.

Shipping non-CO_2 emissions and effects

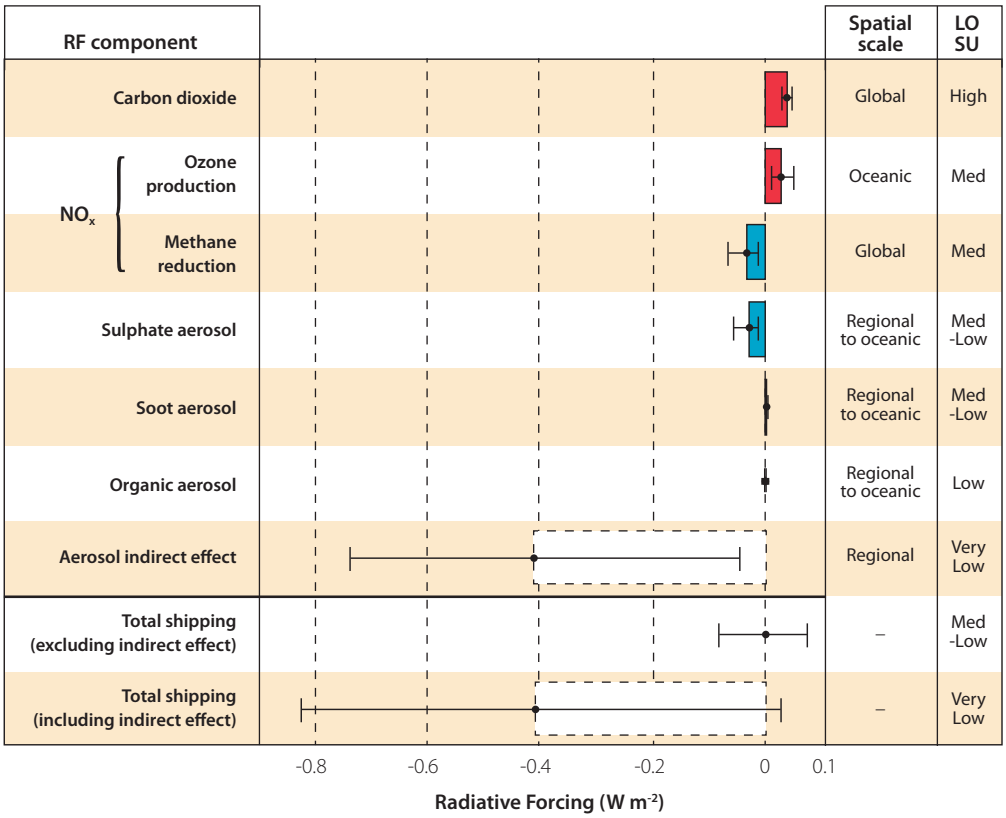
Fuel combustion in shipping also results in methane and nitrous oxide emissions. As for aviation, these are small (around 0.1 $MtCO_2e$ in 2010) but should be included in carbon budgets.

There are also non-CO_2 effects not covered by the Kyoto basket. These relate primarily to sulphate aerosols, which are emitted during fuel combustion and have a large but short-term cooling effect (Figure 2.8):

- The warming effect of CO_2 lasts for centuries and will build over time as emissions continue to accumulate in the atmosphere. In contrast, sulphate aerosols only last for several days, and their cooling effect will only last for as long as they continue to be emitted.
- Sulphate aerosols are likely to be significantly reduced in future as forthcoming air quality regulations reduce the sulphur content of shipping fuels.

Given the short-term nature of impacts from sulphate emissions, and the expectation that these will be significantly reduced in future, these do not need to be reflected or included in carbon budgets. This is the approach adopted in other sectors (e.g. surface transport and power) where sulphate aerosol emissions are not offset against CO_2 emissions in carbon budgets.

Figure 2.8: Non-CO_2 effects from shipping



Source: Eyring et al. (2010) Transport impacts on atmosphere and climate: shipping, *Atmospheric Environment*.
Notes: Each component of shipping's effect on climate is shown in terms of radiative forcing, which measures the current atmospheric imbalance (in Watts per square metre, Wm^{-2}) due to shipping activity up until now. Note that it does not give a measure of future effects from current activity - for instance, emitted CO_2 will reside in the atmosphere for many decades, whereas today's aerosols will only last up to a few days. Whiskers denote the range of estimates in the literature and LOSU indicates the Level of Scientific Understanding regarding each effect. Aerosol indirect effect is shown as a dotted bar due to high uncertainty.

(v) Recommended carbon budgets

In summary, we recommend that international aviation and shipping emissions should be included in currently legislated carbon budgets through the following adjustments:

- **International aviation** CO_2 emissions should be added at 30.5 $MtCO_2$ per year, which is the UK's share of the EU ETS cap for aviation, calculated based on all departing flights.
- **International shipping** CO_2 emissions should be added at around 9 $MtCO_2$ per year, reflecting bunker fuels estimates projected under assumptions of central demand and currently agreed policies (i.e. the EEDI). This element of the carbon budget should be kept under review and adjusted as appropriate (e.g. contingent upon development of an activity-based methodology for estimating shipping emissions, or introduction of new policies).
- We also add an allowance for both international aviation (0.3 $MtCO_2e$ per year) and international shipping (0.1 $MtCO_2e$ per year) to cover the small amount of other greenhouse gases from the Kyoto basket, notably methane and nitrous oxide emissions resulting directly from fuel combustion.

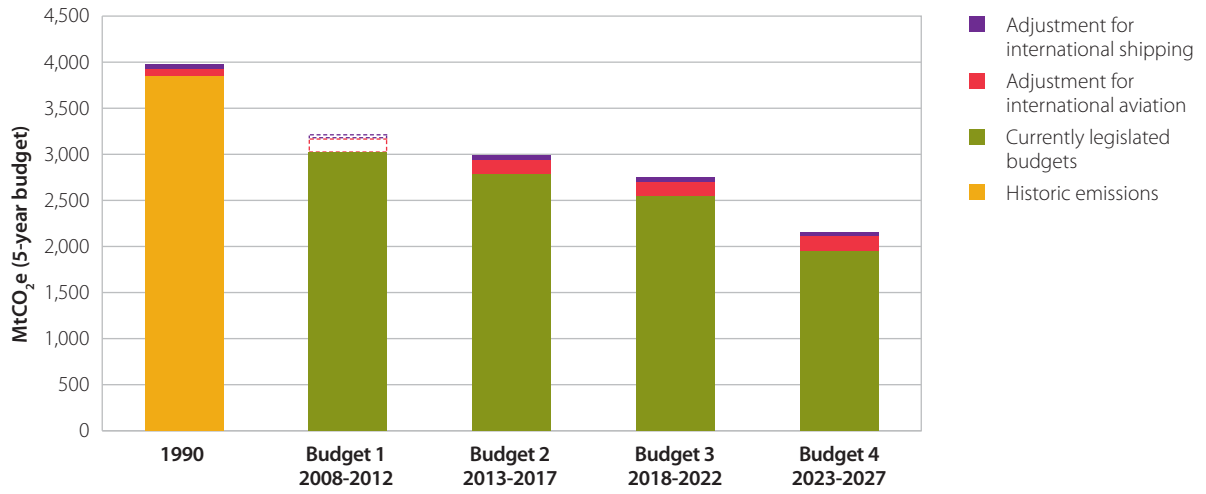
The resulting budget recommendations are set out in Table 2.1 and Figure 2.9.

Table 2.1: Recommended adjustments to carbon budgets 2-4 to include international aviation and shipping

$MtCO_2e$	1990 outturn emissions	2010 outturn emissions	Budget 2 (2013-2017)	Budget 3 (2018-2022)	Budget 4 (2023-2027)
Sectors covered by currently legislated budgets	766	590	2782	2544	1950
International aviation CO_2	16	31	153	153	153
International shipping CO_2	9	9	47.0	46.2	44.7
International aviation non-CO_2	0.2	0.3	1.8	2.0	2.1
International shipping non-CO_2	0.1	0.1	0.4	0.4	0.4
TOTAL	**791**	**631**	**2984**	**2746**	**2150**
Reduction against 1990 base year		21%	25%	31%	46%

Sources: NAEI (2012), CCC calculations.
Notes: Reduction against base year is measured for average annual emissions in budget period. Base year defined as 1995 for F-gas emissions, and 1990 for all other emissions. Non-CO_2 refers to Kyoto emissions only (i.e. methane and nitrous oxide). Table 1 includes CO_2 and non-CO_2 combined. Numbers may not sum due to rounding.

Figure 2.9: Recommended carbon budgets including emissions from international aviation and shipping (2013-2027)



Source: CCC calculations.
Note: International aviation and shipping are shown for Budget 1 for illustrative purposes only. 1990 emissions are multiplied by five to be on a comparable basis.

3. Meeting a 2050 target that includes international aviation and shipping emissions

It is not necessary, possible or desirable *now* to specify the precise mix of technologies and/or consumer behaviour change to achieve a 2050 target including international aviation and shipping emissions.

However, it is important to establish that plausible scenarios do exist for reaching such a target and to consider their potential costs.

We have previously shown how an 80% 2050 target including international aviation and shipping emissions could be achieved (e.g. see the MARKAL modelling in our 2008 report on the 2050 target and our 2010 report on the fourth carbon budget, and analysis in our 2011 Bioenergy Review).

The Government has presented similar analysis in its December 2011 Carbon Plan[15]. The modelling in the Carbon Plan assumed a 2050 target, such that emissions from international aviation, shipping and other sectors in 2050 would together imply an 80% reduction on 1990 levels.

We use this report as an opportunity to develop and reinforce previous analysis of 2050 emissions pathways, answering questions raised in the Bioenergy Review and the Carbon Plan, thus providing a greater degree of confidence around how a 2050 target including international aviation and shipping emissions could be achieved.[16]

In considering how a 2050 target including international aviation and shipping emissions might best be met, it is important to note that this does not imply that all sectors should reduce emissions by 80%.

Rather, the appropriate approach is to consider the set of abatement opportunities across the economy, and target emissions reductions in sectors where these are feasible and cost-effective. Remaining emissions allowed under the 2050 target would then occur in hard-to-treat sectors where opportunities for reducing emissions are more limited.

In what follows we first consider opportunities for reducing emissions from aviation and shipping, and then develop economy-wide scenarios for meeting a 2050 target including international aviation and shipping.

We now consider:

(i) Aviation emissions to 2050

(ii) Shipping emissions to 2050

(iii) Meeting a 2050 target that includes international aviation and shipping emissions

15 HM Government (December 2011), *The Carbon Plan: Delivering our low carbon future.*

16 We set out the full analysis of 2050 emissions pathways in a technical report, *The 2050 target – achieving an 80% reduction including emissions from international aviation and shipping.* The report is available on our website: www.theccc.org.uk.

(i) Aviation emissions to 2050

Aviation demand and emissions are likely to continue to grow. Therefore the EU ETS cap on aviation emissions will be met partly through the purchase of offset credits, which are currently abundant and cheap.

However, scope for low-cost purchase of offset credits by UK or EU firms is likely to become limited over time:

- The current abundance of offset credits reflects widely available abatement potential under loose European and international carbon constraints.
- This potential will become exhausted as all countries must meet demanding carbon targets, and availability of low-cost offset credits will as a result become increasingly limited.
- Therefore, while there may be some continued purchase of credits and carbon trading in the longer term (e.g. reflecting rich-poor country trading, or aviation hubbing), it is not clear that low-cost abatement (and therefore low-cost credits) will remain in any sectors or any countries. To the extent that carbon credits are available for purchase they are likely to be expensive, and may be as likely to be generated by rich countries or hard-to-treat sectors as to be available to offset emissions from these sources.

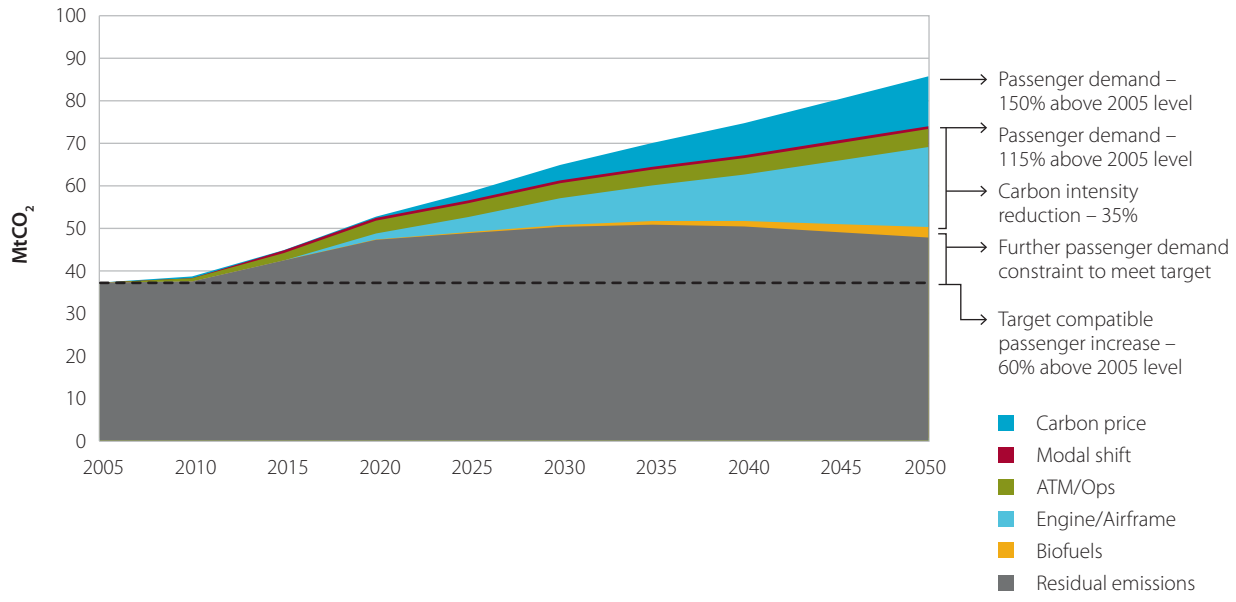
Therefore, over-reliance on credits should be avoided in the long term, as these are likely only to be available at very high cost. For example, the Government's carbon values reach £200/tCO_2e in 2050 in a central case, global modelling we commissioned from UCL suggests carbon prices upwards of £500/tCO_2e, and estimates in the literature are often £100s/tCO_2e in 2050 for global emissions trajectories consistent with limiting warming to 2°C.[17]

Recognising this, the previous Government set a target that gross aviation emissions (i.e. emissions before any adjustment is made for trade in carbon credits) should return to 2005 levels by 2050. Subsequent analysis has shown this to be feasible and broadly cost-effective, with different scenarios for demand growth and technology deployment reaching a similar emissions outcome:

- Our review of aviation emissions in 2009 showed that there are various options for meeting this target, including fuel efficiency improvement, operational efficiency improvement, use of biofuels, modal shift and constraints on demand growth (Figure 3.1). We presented scenarios with baseline demand growth of 150% from 2005 to 2050, falling to 115% when exposed to a carbon price that reaches £200/tCO_2 in 2050; in our 'Likely' scenario, emissions reductions were delivered through a 0.8% annual improvement in fuel efficiency, by meeting 10% of fuel demand with biofuels and by constraining demand growth to 60% from 2005 (a 75% increase from 2010 given that demand fell during the recession).

17 UCL Energy Institute (2012), *Modelling carbon price impacts of global energy scenarios*, available for download at www.theccc.org.uk. For a review of results from various global models, see, for example, O. Edenhofer, B. Knopf, et al (2010), The Economics of Low Stabilization: Model Comparison of Mitigation Strategies and Costs, *Energy Journal* 31: 11-48.

Figure 3.1: UK aviation emissions to 2050 – CCC Likely scenario



Source: Committee on Climate Change (2009), *Meeting the UK Aviation Target – options for reducing emissions to 2050.*
Note: Shows total UK aviation emissions (international and domestic).

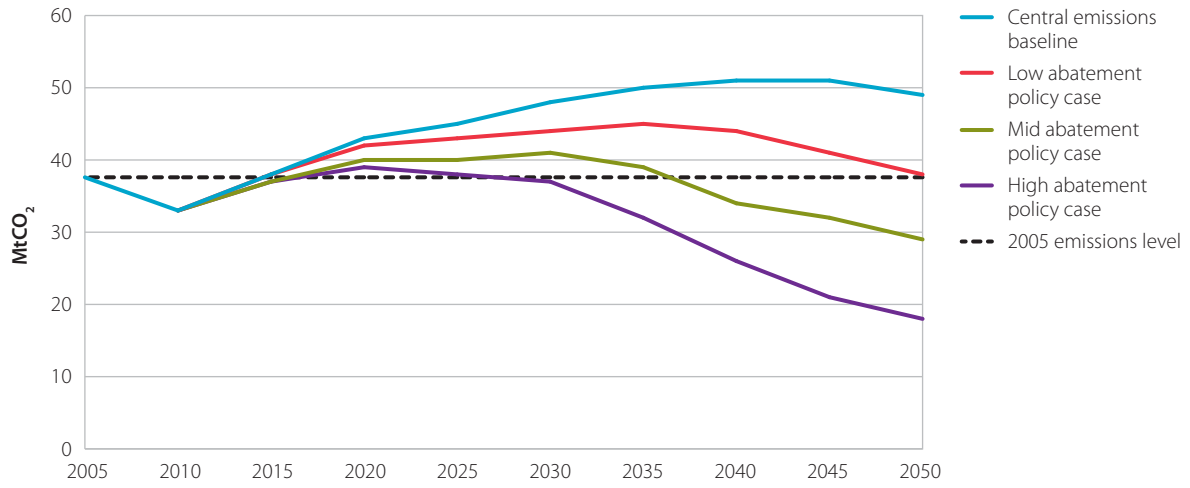
- More recently, our Bioenergy Review suggested potentially limited biofuels use in aviation where CCS is available as an option to generate negative emissions elsewhere in the economy, and up to around 20% biofuels use if CCS is not available.
- In summer 2011 DfT published an aviation abatement cost curve alongside revised aviation emission forecasts to 2050[18]. These suggest that there is scope, at reasonable cost, to reduce emissions in 2050 to around 2005 levels, through a combination of improvements in aircraft fuel efficiency, operational measures, biofuels penetration and some demand growth constraint (Figure 3.2). DfT's scenario projects demand growth of 125% from 2010 when a carbon price is included (a 105% increase from 2005). Achieving 2050 emissions at 2005 levels can then be achieved through a 1.2% annual improvement in fuel efficiency of planes, 10% biofuels use and a moderation of demand growth to 90% on 2010 levels.

Our analysis and that of DfT is consistent with long-term objectives of the aviation industry, although the industry envisages that these will be achieved through greater deployment of supply-side measures and therefore less need for constraining of demand growth:

- **At the UK level,** Sustainable Aviation, an industry group, has proposed a trajectory under which emissions return to 2005 levels in 2050.[19] Their scenario assumes demand increases in line with DfT's 2011 analysis (i.e. a 125% increase from 2010), with offsetting savings based on a combination of improvements in engine and aircraft efficiency, improvements in aircraft operations and air traffic management (combining to give a 1.2% annual carbon intensity improvement), and an 18% emissions saving from use of biofuels (Figure 3.3).

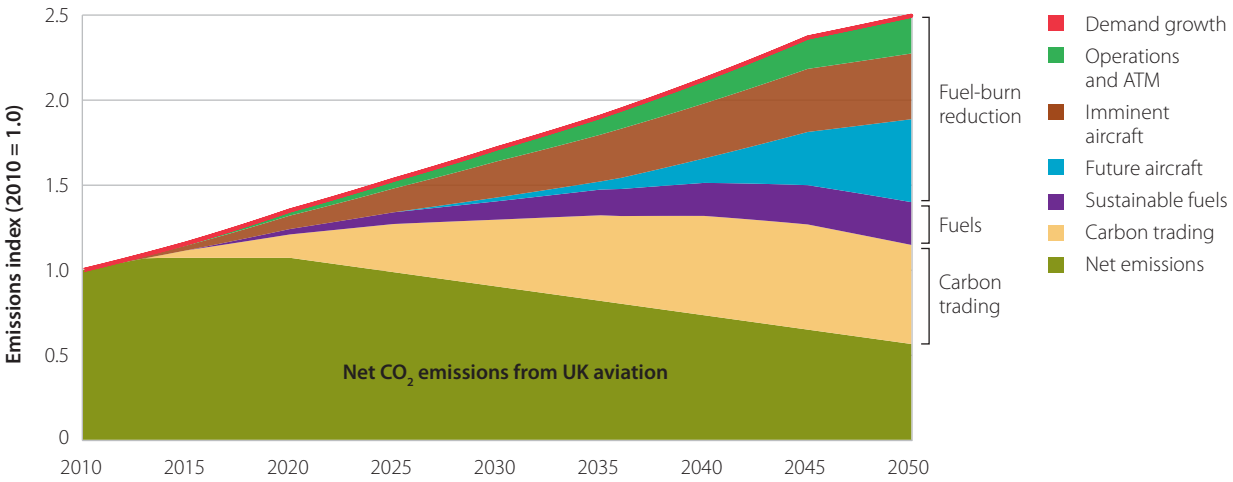
18 Department for Transport (August 2011), *Government response to the Committee on Climate Change Report on Reducing CO_2 Emissions from UK Aviation to 2050.*
19 Sustainable Aviation (March 2012), *Sustainable Aviation CO_2 Road-map.*

Figure 3.2: DfT UK aviation emissions forecast with abatement potential to 2050



Sources: DfT (August 2011) *UK Aviation Forecasts*; EMRC/AEA (2011), *A MACC model for the UK aviation sector.*
Notes: Shows total UK aviation emissions (international and domestic). 2005 and 2010 are outturn emissions. Policy cases show total abatement potential and have the same set of measures but with increasing levels of ambition. The main abatement options include: improvements in fuel efficiency from ATM, operations and achievement of ICAO-CAEP technology goals; penetration of biofuels (10%, 20% and 40%); airport capacity constraints; early fleet retirement; behaviour change.

Figure 3.3: Sustainable Aviation CO_2 Roadmap



Source: Sustainable Aviation (2012), *Sustainable Aviation CO_2 Roadmap.*
Note: Demand growth includes both passenger and freight traffic.

- **At the global level,** IATA has set targets for carbon-neutral growth from 2020, and a reduction in CO_2 emissions of 50% on 2005 levels by 2050[20]. IATA envisages that this target will be achieved through significant reductions in gross emissions, together with some purchase of offset credits in 2050.

Given these industry objectives and evidence that these can be achieved through measures that are feasible and broadly cost-effective, our 2050 scenarios for economy-wide emissions (see below) assume gross international aviation emissions in 2050 at 2005 levels (i.e. 35 $MtCO_2e$).

20 IATA (2009), *A global approach to reducing aviation emissions.*

(ii) Shipping emissions to 2050

As noted in Section 2, the key drivers of future shipping emissions are shipping demand and carbon intensity of ships.

In our 2011 Shipping Review we developed three scenarios for future shipping demand, varying according to different assumptions on demand drivers (e.g. GDP growth, fossil fuel and carbon prices, and UK consumption of fossil fuels and bioenergy). Since our Shipping Review we have published detailed analysis of potential for UK bioenergy consumption. We therefore update our demand scenarios to reflect this analysis.

Our demand scenarios result in demand growth to 2050 ranging from a 1.0% annual decline to a 0.5% annual increase:

- In our **Low demand** scenario tonne-miles fall by 1.0% p.a. between 2006 and 2050. This scenario includes a carbon price rising to £200/tCO_2 in 2050, and reflects a combination of lower GDP growth, deep decarbonisation of fossil fuel sectors and bioenergy consumption at the low end of the scenarios in our Bioenergy Review.
- In our **Central demand** scenario tonne-miles are broadly flat, with reduced consumption of fossil fuels largely offset by increases in container goods driven by GDP growth. Tonne-miles fall by 0.1% p.a. between 2006 and 2050 if a carbon price is introduced, and increase by 0.1% p.a. if not.
- In our **High demand** scenario tonne-miles increase by 0.5% p.a. between 2006 and 2050. This scenario does not include a carbon price, and reflects a combination of higher GDP growth, decarbonisation of fossil fuel sectors and consumption of bioenergy at the higher end of scenarios from our Bioenergy Review.

The key options identified in our Shipping Review for reducing carbon intensity of ships are use of larger ships, technology and operational innovation to improve fuel efficiency, and the use of biofuels or liquefied natural gas (LNG) as a substitute for fossil fuels:

- **Larger ships.** Carbon efficiency of ships improves significantly with ship size (e.g. the largest crude tankers are around ten times more carbon efficient than the smallest).
- **Technological improvements** include upgrades to propulsion systems (including towing kites) and optimising hull designs and coatings.
- **Operational measures** include reducing speed, and use of software to optimise route planning given weather conditions and port congestion.
- **Biofuels and LNG** are technically feasible in ships but deployment may be limited. In the case of biofuels, this would be due to limits on availability of sustainable bioenergy, which may be more highly valued in other sectors. As regards LNG, there are practical constraints on use related to low energy density and lack of refuelling infrastructure, and limited emissions reduction potential relative to conventional fuel.

Taking these options together our analysis suggested scope for reducing average carbon intensity of ships by up to 65% by 2050, which is within the range suggested by other analysis[21].

21 For example the IMO estimate scope for a 25-75% reduction: IMO (2009), *Second GHG Study*; Lloyds/DNV estimate 13-72%: Lloyds/DNV (2010).

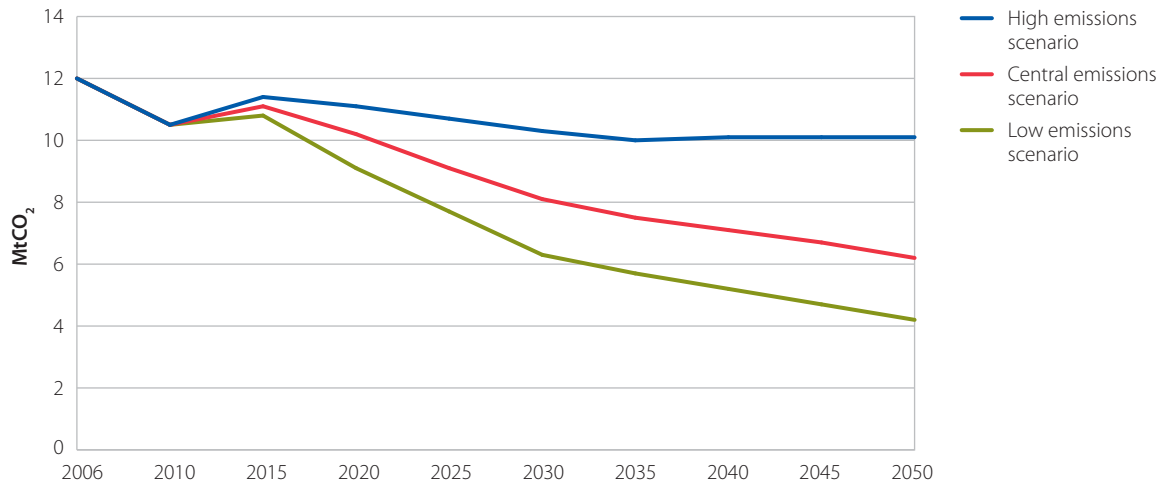
Our three emissions scenarios modelled the impact of different policies on uptake of abatement measures overlaid on our central demand scenario:

- **High emissions scenario.** This reflects the IMO's Energy Efficiency Design Index (i.e. 30% improvement in new ship fuel efficiency by 2025), but limited further abatement.
- **Central emissions scenario.** This assumes that take-up of abatement measures goes beyond that required to meet the EEDI. It includes speed reductions and increases in the average size of unitised container ships, as well as some limited penetration of biofuels and LNG.
- **Low emissions scenario.** This assumes strong policy action to incentivise full take-up of abatement potential from technological and operational measures. It assumes more increases in ship size and further, but still limited, penetration of biofuels and LNG.

The range for international shipping emissions in 2050 across these scenarios under an activity-based methodology for estimating current emissions (see Section 2(iii) above) and assuming a central demand scenario is 4-10 $MtCO_2$ (Figure 3.4). This range widens to 3-12 $MtCO_2$ under low to high demand scenarios, and emissions could be as high as 17 $MtCO_2$ under a trade-based top-down methodology, with high demand growth and limited abatement.

Given the uncertainties implied by this range, in our economy-wide scenarios we assume a 2050 level of international shipping emissions based on an activity-based methodology for current emissions, which are then projected assuming central demand and abatement scenarios (i.e. around 6 $MtCO_2$ in 2050, roughly a third below reported 2010 levels). We also consider the alternative scenarios as sensitivities which could either increase or reduce emissions reductions required in other sectors.

Figure 3.4: Future emission scenarios for UK international shipping (2006-2050)



Source: CCC analysis.
Note: These projections take into account 2 $MtCO_2$ from transhipment, and are based on our central demand scenario.

(iii) Meeting a 2050 target that includes international aviation and shipping emissions

Options for meeting a 2050 target with international aviation and shipping emissions included

We have built on our analysis for the fourth carbon budget and Bioenergy Review, and assessed the extent to which the 2050 target would be achieved with full deployment of technologies which are or are likely to become technically feasible and cost-effective, along with some consumer behaviour change.

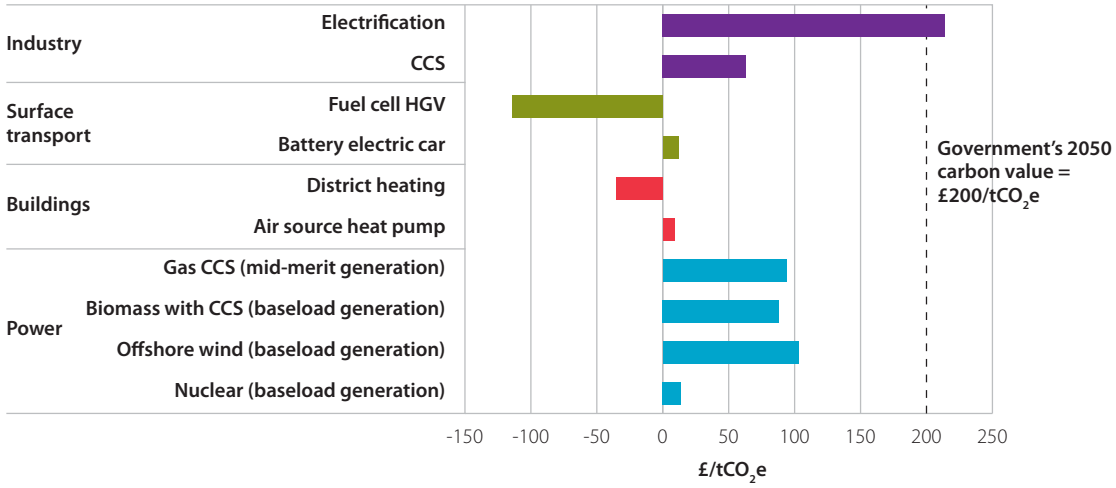
These technologies and behaviours include low-carbon power technologies, electric technologies for heat in buildings and surface transport, use of bioenergy together with CCS in energy-intensive industries and in other applications:

- **Power.** Nuclear, renewables and CCS all offer the potential to produce electricity without significant emissions. Some of these technologies (e.g. nuclear and onshore wind) will be cost-competitive against unabated gas in 2020 under the Government's planned carbon price underpin, while others have scope to become cost-competitive as a result of learning and innovation (e.g. offshore wind, marine, solar, CCS). Responsive demand, interconnection to other power systems and various modes of storage offer the opportunity for low-carbon approaches to meeting demand peaks without emissions.
- **Buildings.** Energy demand can be reduced through improved buildings fabrics, more efficient lights and appliances, and small emissions reductions are achievable through behavioural change (e.g. turning down thermostats). Heat pumps, use of waste heat from low-carbon power stations or local bioenergy resources in district heating systems, solar thermal and resistive electric heating can all be used to meet remaining demand without direct emissions.
- **Surface transport.** Some emissions reductions are available through demand-side measures (e.g. Smarter Choices and eco-driving), improved vehicle efficiency and sustainable biofuels in the near-to-medium term. Electric and hydrogen vehicles offer the chance to eliminate emissions completely for all vehicle types (when the electricity and hydrogen are produced from low-carbon sources), and could be widely deployed and cost-effective from the 2020s.
- **Industry.** Options in industry differ by sector, and include: improved efficiency, application of CCS, electrification and use of bioenergy or hydrogen to replace fossil fuels. Over a long time period (e.g. to 2050) introduction of these measures can be aligned to capital replacement cycles. There may also be opportunities to reduce emissions through material efficiency and product substitution and as industry restructures to meet the demands of a low-carbon economy (e.g. with less requirement for fuel refining).

- **Non-CO_2 emitting sectors.** Waste emissions are expected to fall as EU Landfill Directives divert biodegradable waste away from landfill. Agriculture emissions can be reduced by changed farming practices (e.g. on-farm efficiencies, improved animal fertility), reduced food waste and adjustment of diet towards less carbon-intensive foods. Fugitive emissions in the energy sector will be reduced as fossil fuel use declines, and F-gases could be replaced by alternative coolants.
- **Negative emissions from bioenergy.** Our Bioenergy Review identified two potential routes to negative emissions through use of bioenergy in combination with CCS (e.g. in the power sector or energy-intensive industry) and through using wood in construction.

Our analysis suggests that there is scope for the full range of these technologies to become cost-effective relative to carbon price projections over the next decades (Figure 3.5).

Figure 3.5: Costs of key abatement technologies versus carbon price in 2050



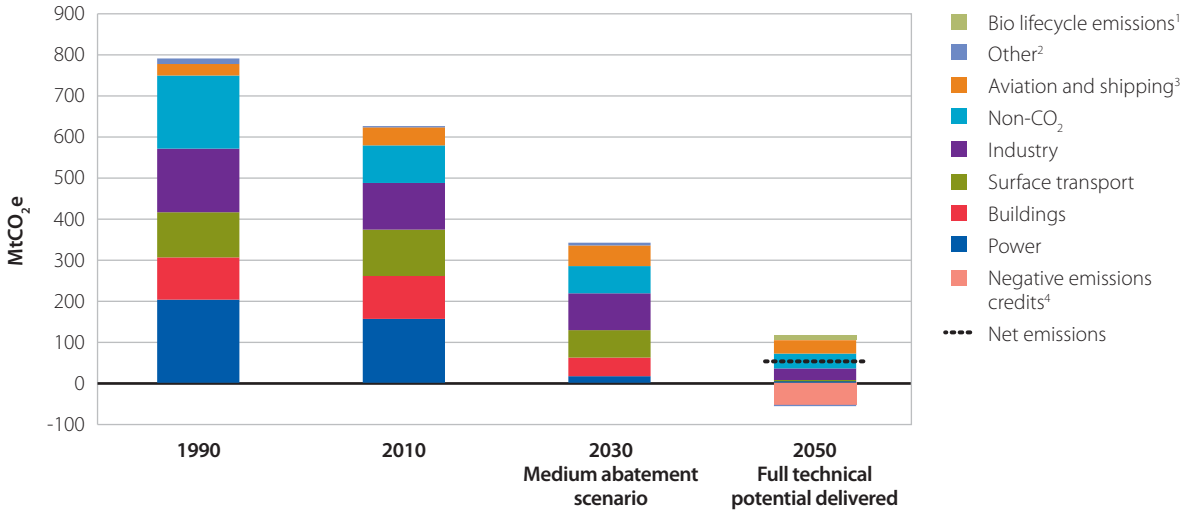
Source: CCC Calculations.
Note: Costs are measured relative to a reference technology (e.g. unabated gas generation in the power sector). Non-CO_2 measures (not shown) are diverse, but generally low cost or cost-saving. See the technical report for a full set of measures, their costs and underlying assumptions.

Plausible scenarios for meeting a 2050 target with international aviation and shipping emissions included

Given the set of available technologies and behaviours, there is scope in principle to reduce emissions to well below the level required to meet the 2050 target with international aviation and shipping included (i.e. well below 160 $MtCO_2e$, see Figure 3.6).

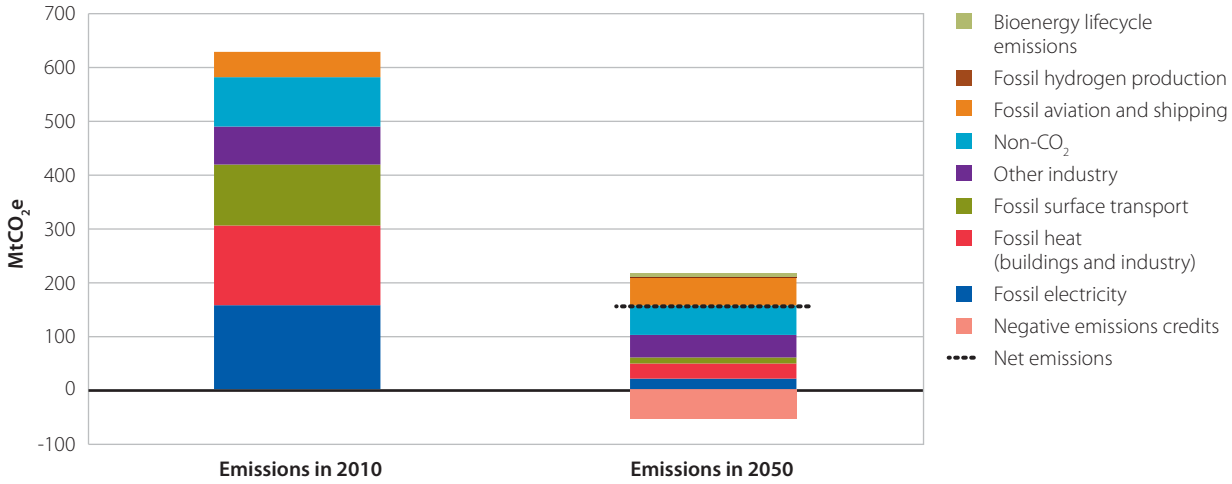
In our Bioenergy Review we used a cost-optimising model to develop scenarios consistent with achieving – but not exceeding – the 160 $MtCO_2e$ target under various scenarios for bioenergy and technology availability. In a scenario with a bioenergy share equal to 10% of total primary energy demand (our 'Extended Land Use' scenario) and with CCS available, the target is achieved through decarbonisation of power and electrification of surface transport and buildings, with any remaining emissions concentrated in industry, aviation and shipping, and non-CO_2 emitting sectors (Figure 3.7).

Figure 3.6: Technical abatement potential to 2050



Source: CCC calculations.
Note: [1]Bioenergy lifecycle emissions include overseas lifecycle emissions for imported bioenergy, as well as those occurring in the UK. [2]Other emissions include military aviation and shipping, emissions from hydrogen production via CCS, emissions removals from LULUCF, and abatement from injection of biogas from anaerobic digestion into the gas grid. [3]International and domestic. [4]Negative emissions credits are from use of bioenergy in combination with CCS or from use of wood in construction.

Figure 3.7: Scenario for meeting the 2050 target developed for our Bioenergy Review using cost-optimising model



Source: CCC (2011), *Bioenergy Review.*
Notes: Non-CO_2 and Other industry emissions are outside the scope of the model. Other industry emissions include industrial process CO_2 emissions, emissions from refineries, other energy supply industries and other sources; these are assumed to be 42 $MtCO_2$ in 2050 incorporating 27 $MtCO_2$ of abatement potential from CCS on process emissions. Emissions from CHP are included in Fossil heat in 2010 and in Fossil electricity in 2050. Bioenergy availability is assumed to be 213 TWh in 2050. Bioenergy lifecycle emissions include overseas lifecycle emissions for imported bioenergy, as well as those occurring in the UK. Negative emissions credits are from use of bioenergy in combination with CCS or from use of wood in construction.

However, there is a high degree of uncertainty around the extent to which full potential could be delivered in practice, which would imply a divergence from the cost-optimised modelling. This relates to the fact that technologies are often at an early stage of development (e.g. CCS), to deployment barriers (e.g. potential consumer resistance to new technologies such as heat pumps and electric vehicles), and to uncertainties over the level of sustainable bioenergy that will be available.

Therefore, we have built on our previous analysis by developing plausible scenarios for meeting an 80% 2050 target that includes international aviation and shipping emissions under different assumptions about technology availability, and the extent to which available technologies are deployed. For example, we show how the 160 $MtCO_2e$ target could be achieved with higher emissions from industry; or from aviation, shipping and non-CO_2; in buildings due to gas heating where heat pumps are not suitable; or in surface transport due to niche use of liquid fuels, along with some emissions in power from gas-fired power generation to meet spikes in power demand (Box 3.1).

Two particular uncertainties we identified in our Bioenergy Review related to the availability of CCS and bioenergy resources. We have now explored those risks further and identified possible scenarios under which the 2050 target could still be met without CCS and/or with very limited bioenergy (Box 3.2). While technically feasible, these scenarios involve significantly increased delivery risks and costs. We therefore reiterate our previous conclusions that successful demonstration of CCS remains an urgent priority and that the 2050 target will be very hard to meet without access to some bioenergy resources (e.g. to account for around 10% of UK primary energy demand).

The Government in its December 2011 Carbon Plan also set out ways in which an 80% 2050 target including emissions from international aviation and shipping could be met (Box 3.3).

Therefore our analysis and that of the Government suggest a 2050 target including international aviation and shipping could be achieved based on currently identified measures.

As recommended in our advice on the fourth carbon budget, the approach now should be to deploy extensively the range of low-carbon measures in order to prepare for the very deep reductions required by 2050, and to make choices around the balance between options as better information becomes available about feasibility and relative cost.

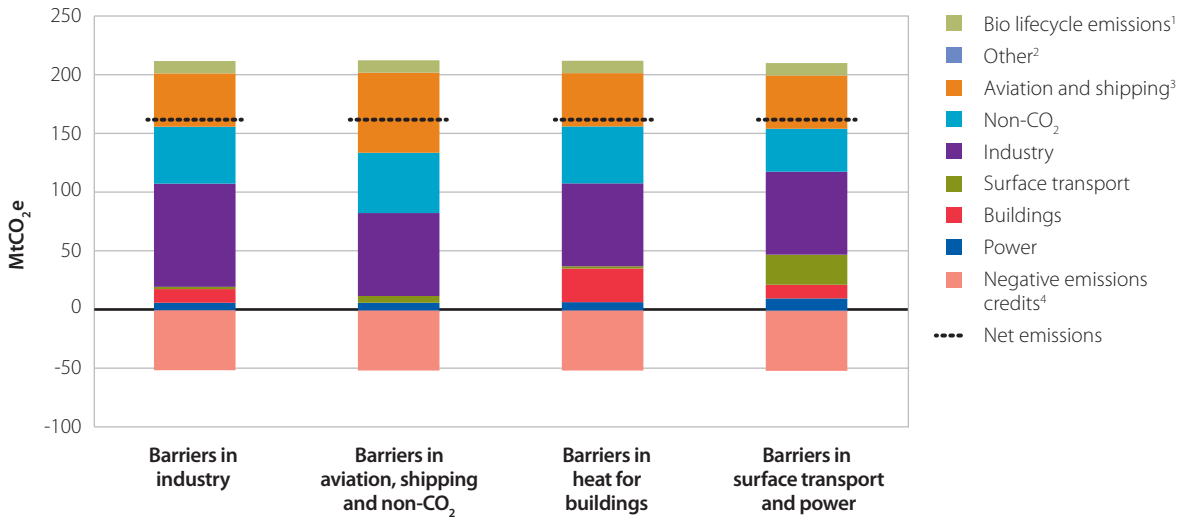
Box 3.1: Scenarios for meeting a 2050 target that includes emissions from international aviation and shipping

There are risks to delivery of abatement measures across the emitting sectors. In our four scenarios these delivery risks occur primarily in different sectors leading to higher emissions in those sectors: mainly industry; mainly aviation, shipping and non-CO_2; mainly in buildings; or mainly transport (Figure B3.1):

- **Barriers in industry.** In this scenario emissions remain relatively high in industry as there is limited application of CCS and no electrification. Greater success is achieved in other sectors, with transport, heat and power largely decarbonised (notwithstanding some residual gas use in power and heat), and all but the most challenging abatement options deployed to reduce non-CO_2 emissions. Aviation and shipping emissions are in line with our proposed planning assumptions.
- **Barriers in aviation, shipping and non-CO_2.** In this scenario emissions are higher for aviation and shipping (in line with DfT's baseline emissions for aviation and our High emissions scenario for shipping) and there is limited success in reducing non-CO_2 emissions. However power and surface transport are largely decarbonised, (expensive) resistive heating is deployed in buildings and significant reductions are achieved in industry.
- **Barriers in heat for buildings.** This scenario reflects a world where barriers remain to full decarbonisation of heat. As a result fewer energy efficiency measures are deployed, there is lower applicability of heat pumps and a failure to deploy low-carbon district heating, with efficient gas boilers meeting remaining demand. Conversely, transport and power are decarbonised, and significant reductions are made in industry and non-CO_2 emitting sectors. Aviation and shipping emissions are in line with our proposed planning assumptions.
- **Barriers in surface transport and power.** This scenario reflects a world where, for example, consumer acceptance and/or cost reductions for ultra-low carbon vehicles are more limited. As a result fossil fuels are used for around a third of car and van miles, together with half of HGVs. We also assume in this scenario that there is less success in deploying flexibility mechanisms to decarbonise peak demand in power. To compensate, heat is largely decarbonised and challenging measures (e.g. diet change or industrial electrification) are required from non-CO_2 or industry. Aviation and shipping emissions are in line with our proposed planning assumptions.

Notwithstanding the uncertainties, there are a number of common themes which run through the scenarios including efficiency improvements, decarbonisation of power generation, extensive electrification of heat and transport, and prioritised use of scarce bioenergy to reduce (or offset) emissions from applications with few alternative abatement options. All scenarios imply very challenging levels of emissions reduction and deployment of abatement measures across the economy.

Figure B3.1: Scenarios for meeting the 2050 target



Source: CCC Calculations
Note: [1]Bioenergy lifecycle emissions include overseas lifecycle emissions for imported bioenergy, as well as those occurring in the UK. [2]Other emissions include military aviation and shipping, emissions from hydrogen production via CCS, emissions removals from LULUCF, and abatement from injection of biogas from anaerobic digestion into the gas grid. [3]International and domestic. [4]Negative emissions credits are from use of bioenergy in combination with CCS or from use of wood in construction.

Box 3.2: Meeting the 2050 target without Carbon Capture and Storage and/or with limited bioenergy

We have considered three key sensitivities over how the 80% 2050 target could still be met without CCS and/or with very limited bioenergy. In these cases other sectors have to deliver close to the theoretical maximum abatement, implying very major delivery risks and potential cost escalation.

- **No CCS.** This scenario requires that the majority of abatement potential identified from all other measures is delivered, including (expensive) electrification in industry. It could also require some resistive electric heating and challenging non-CO_2 measures such as diet change away from livestock products. In power, additional renewables and nuclear capacity could replace power stations operating with CCS, albeit with increasing costs as these (high capital cost) plants are required to run at lower load factors. This may also raise additional challenges associated with site availability and acceptability. In this scenario, bioenergy that would have been used with CCS (to generate negative emissions) is diverted to energy-intensive industry and aviation and shipping.
- **Limited bioenergy.** In this scenario, availability of bioenergy is reduced from around 210 TWh (in line with the Extended Land Use scenario from our Bioenergy Review) to around 110 TWh (in line with the Constrained Land Use scenario). The limited bioenergy that is available is concentrated in CCS applications that generate negative emissions. In order to compensate for lost abatement from use of bioenergy in non-CCS applications, other measures must deliver fully and some very high-cost/challenging measures are required (e.g. resistive electric heating).
- **Limited bioenergy and no CCS.** Without these two key options, meeting the 2050 target becomes very difficult. Full technical abatement potential is required from most other options identified including some that are currently uncertain such as phasing out of F-gases. Nuclear and renewables must replace CCS in power generation. In theory, further abatement potential could be delivered by applying capture equipment to relevant industrial plants that are no longer suitable for CCS, but instead diverting this CO_2 to mineralisation processes, or the production of algae or synthetic fuels. However these options are uncertain and potentially very expensive due to high energy input requirements.

We therefore reiterate our previous conclusion that successful demonstration of CCS technology and access to some (albeit limited) bioenergy resources will be important to the successful building of a low-carbon economy.

Box 3.3: Scenarios for meeting an 80% 2050 target including international aviation and shipping in the Government's November 2011 Carbon Plan

The Government's Carbon Plan set out four alternative 2050 'futures'. Three 'futures' are constructed using DECC's 2050 Calculator, benchmarked to a run of the MARKAL model, which is set up to align to the 80% 2050 target for all sectors including international aviation and shipping:

> *"The UK MARKAL model covers CO_2 emissions from energy use and does not model non-CO_2 greenhouse gases (GHGs), land use, land use change and forestry (LULUCF) and international aviation and shipping sectors. As a consequence, the 80% 2050 target covering all GHGs on the net UK carbon account was translated to a 'MARKAL equivalent' of a 90% reduction for the core MARKAL run."* (page 122)

The four 'futures' involve:

- In the '**Core Markal**' run, demand for energy is roughly halved via energy efficiency measures, electrification of heat and transport, and service demand reduction in response to cost increases. District heating and biofuels for transport also play a role. CCS is applied widely in industry. In electricity generation, there is a balanced generation mix across nuclear, CCS and renewables with unabated gas for system balancing.
- The '**Higher renewables, more energy efficiency**' future sees an even greater reduction in per capita energy demand through behaviour changes and uptake of efficiency measures, facilitated by smart new technologies such as heating controls. Heat, transport and industry are all mostly electrified. Major cost reductions for renewable generation alongside advances in storage capacity mean that renewable technologies including wind, solar, marine and others meet a large share of overall electricity demand. This future could be consistent with a world in which high fossil fuel prices or a global commitment to tackling climate change drive investment and innovation in renewables.
- The '**Higher CCS, more bioenergy**' future reflects a world in which CCS is successfully deployed at commercial scale in power generation and industry, and is relatively cheap due to availability of low-cost gas (e.g. shale gas). Plentiful, cheap resources of sustainable bioenergy are also available and can be used with CCS to generate negative emissions. These create headroom for some fossil fuel use in other sectors. As a result, district heating and CHP replace heat pumps for half of demand, which is higher due to less take-up of insulation measures. In transport around a third of vehicles still use liquid fuel, including more biofuels.
- The '**Higher nuclear, less energy efficiency**' future is one where innovation in newer technologies is less successful and the extent to which people change their behaviours and energy consumption patterns is lower. CCS is not commercially viable and major cost reductions in renewables are not achieved. This future thus relies heavily on nuclear generation to supply power, with unabated gas for meeting peak demand. On the demand side, there is less take-up of insulation measures and smart technologies to reduce energy demand, and people continue to travel by car for most journeys, although heat and transport are still largely electrified. Without CCS to generate negative emissions, bioenergy is key to reducing emissions in 'hard to reach' sectors in this scenario.

Therefore, as in our analysis, the Government has identified multiple scenarios consistent with meeting the 2050 80% target including international aviation and shipping. These scenarios also cover various possibilities for the sectors in which remaining emissions are concentrated, and the technologies that are deployed to reduce emissions.

Source: HM Government (2011) *The Carbon Plan: Delivering our low carbon future.*

4. Costs of meeting carbon budgets and the 2050 target including international aviation and shipping emissions

Costs of meeting carbon budgets to 2030 with international aviation and shipping included

In our advice on the fourth carbon budget, we estimated that required emissions reductions to 2030 across sectors excluding international aviation and shipping could be delivered at a cost of less than 1% of GDP (Table 4.1).

Table 4.1: Costs of delivering required emissions reductions in 2030 excluding international aviation and shipping

	% of GDP
Medium Abatement scenario abatement costs (additional to 2020 costs)	0.4%
Of which:	
Power*	0.3%
Buildings	0-0.1%
Industry (including refineries)	– (0-0.1)%
Transport (domestic)	0-0.1%
Non-CO_2**	0%
Abatement costs to 2020 ***	0.2%
TOTAL abatement costs	**0.6%**

Source: CCC (2010) *The Fourth Carbon Budget*
Notes: These costs are based on assumptions from December 2010, some of which have now changed (e.g. DECC's latest assumptions are for higher fossil fuel prices).
***** Costs of low carbon electricity are allocated to power for increased demand in the transport sector (which will largely use off-peak electricity) and to buildings and industry for increased demand there (which will generally be peak or seasonal demand for heat).
****** We expect net abatement costs in agriculture and other non-CO_2 emitting sectors to be negative; in these calculations we assume zero costs due to uncertainties around exact magnitudes.
******* Based on our Extended Ambition scenario, see our 2008 report *Building a low-carbon economy*, and our annual progress reports to Parliament.

This cost to 2030 would not increase if the 2050 target were to include international aviation and shipping emissions, given our recommendation that emissions from these sectors should be added to currently legislated budgets and given that those budgets already build in sufficient effort to be on track to an 80% 2050 target that includes international aviation and shipping.

Costs directly related to international aviation and shipping emissions – including implications for other sectors in the EU ETS facing a higher carbon price – would be at levels already committed, given our recommendation that these should be added at levels that reflect current policies (i.e. the EU ETS for aviation and the EEDI for shipping).

Cost of meeting a 2050 target with international aviation and shipping emissions included

We previously considered the cost of meeting the 80% 2050 target (including emissions from international aviation and shipping) in our 2008 report *Building a low-carbon economy*. There we found, based on analysis using the UK MARKAL model, that the 2050 target could be met at a cost in the order of 1-2% of GDP in 2050. We noted that this was consistent with estimates from other sources, including the Stern Review and the Intergovernmental Panel on Climate Change (IPCC).

We have now complemented that analysis by building on our detailed bottom-up modelling for our advice on the fourth carbon budget, to produce bottom-up estimates of the cost of meeting the 2050 target.

The cost of meeting a 2050 target that includes international aviation and shipping compared to the cost of meeting carbon budgets in 2030 would depend on the level of additional abatement required from 2030 to 2050, the changing mix and relative cost of abatement technologies, and fossil fuel prices:

- **Additional abatement.** The required reduction in emissions from 2010 to 2030 is around 280 $MtCO_2e$, rising to 470 $MtCO_2e$ by 2050 (i.e. costs would increase by around two-thirds under an assumption of constant abatement costs per tonne).
- **Low-carbon technology costs.** The average cost of low-carbon options beyond 2030 could rise as potential cost reductions through learning are more than offset by the need to deploy more stretching abatement measures:
  - **Technology cost reductions.** Key technologies to meet the fourth carbon budget and the 2050 target are low-carbon power generation, electric vehicles and heat pumps. We envisage some but limited reduction in costs of these technologies beyond 2030 given that there will have already been twenty years of learning and innovation by this time.
  - **Changing technology mix.** Beyond 2030 we envisage increased investment in higher-cost technologies to reduce emissions, including low-carbon sources for peak power demand, industrial CCS and low-carbon heat sources.
- **Fossil fuel prices.** The future price of fossil fuels is highly uncertain. Given this, we use DECC's range of scenarios for 2050 prices. These include coal prices from around 20% above to 40% below 2011 levels, future gas prices of around 60% above to 30% below 2011 levels, and future oil prices from 55% above to around 30% below 2011 levels (Table 4.2). The wide range for these projections implies a wide range for the counterfactual cost of high-carbon technologies. If prices were higher still, then costs of decarbonisation would be lower.

Table 4.2: DECC assumptions for 2050 fossil fuel prices.			
	Low	**Central**	**High**
Coal ($/tonne)	80	110	155
Gas (p/therm)	45	70	100
Oil ($/bbl)	75	130	170

Source: DECC (October 2011) Fossil fuel price projections, DECC (October 2011) IAG guidance for policy appraisal.
Notes: 2011 real prices.

Allowing for all of the above factors, we estimate a cost for meeting the 2050 target including international aviation and shipping emissions at the low end of those previously suggested (Table 4.3).

- Our cost estimates relate to the total cost in 2050 of meeting the 80% target including international aviation and shipping emissions.
- We do not estimate the incremental cost of including international aviation and shipping emissions. This is because we take the climate objective as a given. Therefore the relevant cost relates to the 2050 target including international aviation and shipping emissions, which is compatible with achieving the climate objective.
- As in our fourth carbon budget advice, we present resource cost estimates, which sum all the additional costs associated with low-carbon technologies across the economy, but do not attempt to predict how resources may be reallocated in response to these higher costs.
- Our cost estimates are not reduced to allow for potential benefits such as improved air quality, increased security of energy supply, or economic opportunities for the UK in the global market for low-carbon goods and services; to the extent that these benefits transpire, net costs will be lower.

This provides more confidence that a 2050 target including aviation and shipping emissions can be achieved at a cost of 1-2% of GDP, which was accepted at the time the Climate Change Act became legislation.

Table 4.3: Costs for meeting the 2050 target including international aviation and shipping

Costs of meeting target (% of GDP)	Central case	Low fossil fuel prices	High fossil fuel prices	High abatement technology costs	Low abatement technology costs
Power	0.3%	0.4%	0.1%	0.5%	0.2%
Buildings	0.1%	0.1%	0.1%	0.2%	<0.1%
Industry (including refineries)	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Surface transport	0.0%	0.4%	-0.3%	0.2%	-0.1%
Non CO_2	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Aviation and shipping	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
TOTAL abatement costs	**0.5%**	**1.0%**	**0.1%**	**0.9%**	**0.2%**

Source: CCC calculations.
Notes: Costs for increased demand for low-carbon electricity from abatement options in end-use sectors (buildings, industry and transport) are allocated to those sectors (rather than the power sector). Costs are based on our 2050 scenario with high industry emissions. Costs are similar in other scenarios under our central assumptions.

As set out in section 1 above, failure to accept this cost now could result in setting of insufficiently ambitious carbon budgets. These would imply higher costs further out in time, for example due to required scrapping of capital, rapid supply chain expansion, and purchase of increasingly expensive offset credits.

Therefore the economically sensible approach to meeting the climate objective is now to accept and to prepare for these future costs by including international aviation and shipping emissions in the 2050 target, and designing carbon budgets that are compatible with achieving this.

5. Implications of inclusion for approaches to reducing international aviation and shipping emissions

Policy approaches and competitiveness impacts

We were very clear in our 2008 report on carbon budgets and the 2050 target that the appropriate approaches to reducing international aviation and shipping emissions are at the global, or possibly EU, level rather than unilateral at the UK level.

A UK unilateral approach would have limited impact reducing emissions and could result in perverse outcomes or leakage, given the specific characteristics of these sectors:

- Unilateral UK action would not result in technology innovation as regards aircraft or ships, given that these industries are international, and require a critical mass of countries to support innovation.
- A UK-only policy in shipping, such as a bunker fuels tax or a cap and trade scheme, would displace bunkering to elsewhere in Europe, and result in transhipment via other European ports, with no overall reduction in emissions or increased incentive for efficiency improvement.
- A UK unilateral approach to aviation could result in displacement of hubbing to other airports in Europe (e.g. UK passengers might fly short-haul to other EU airports and connect to long-haul flights) without an overall reduction in emissions.

In contrast, EU and global approaches offer scope for limiting emissions whilst avoiding perverse outcomes:

- **Aviation.** Although there would ideally be a global agreement given the need to limit aviation emissions globally, inclusion in the EU ETS entails very limited competitiveness impacts.
  - The risk of leakage associated with EU ETS is very limited given that there is a level playing field between EU member states, that the vast majority of flights to and from the EU cannot be displaced elsewhere, and that aircraft will tend to only carry enough fuel for their current journey to avoid efficiency penalties from carrying excess weight.
  - Although there is the possibility that EU hubbing between America and Asia could be displaced, this relates only to about 1% of total EU traffic, and the risk is currently limited given that the majority of EU ETS allowances are given to airlines for free.
  - To the extent that this risk may increase over time in line with demand growth and a move to greater auctioning of allowances, this could be addressed through introduction of global policies which provide a level playing field between regions. In this respect, ICAO (i.e. the body nominated by the UNFCCC to lead in this area) is due to propose a global approach in 2013.

- **Shipping.** Limiting international shipping emissions may be more complex at the EU level, given that refuelling can be displaced outside the EU, and given the possibility of transhipment (i.e. shipping goods via a nearby hub outside the EU). However, a global approach, whether in the form of a carbon tax or a cap and trade scheme, could set clear limits on shipping emissions without risk of leakage between countries or regions.

Our proposals for inclusion of international aviation and shipping emissions in carbon budgets in section 2 above are consistent with the principle that approaches should be at the global or possibly EU level rather than unilateral by the UK (i.e. we proposed that emissions be added to existing budgets in line with current EU commitments for aviation and global commitments for shipping). They therefore imply neither a unilateral UK approach to reducing emissions from these sectors, nor the perverse outcomes (i.e. leakage) that could result from such an approach.

There are also no additional competitiveness risks for other sectors of the economy, since our proposals imply no increase in required effort from those sectors beyond currently legislated budgets. Although risks for a small number of electricity intensive industries were identified in discussions about the fourth carbon budget, these have since been mitigated through measures set out in the 2011 Autumn Statement.

Longer-term planning assumptions on international aviation and shipping emissions

Inclusion of international aviation and shipping emissions in the 2050 target does not require that the UK should set unilateral emissions targets for these sectors, and indeed the Climate Change Act does not provide for this.

However, sectoral planning assumptions are required under the Act:

- Specifically, the Act requires that the Government is able to show how its policies and proposals are compatible with meeting the 2050 target (Climate Change Act 13, 14).
- It is under this requirement that we and the Government have set out sectoral contributions to meeting carbon budgets and the 2050 target.
- For example, we have highlighted the need for early decarbonisation of the power sector, and suggested that the planning assumption should be to reduce carbon intensity of power generation from current levels of around 500 gCO_2/kWh to 50 gCO_2/kWh in 2030.

In the case of aviation and shipping, planning assumptions are required and useful in informing approaches to meeting the economy-wide target, and specific approaches to reducing aviation and shipping emissions:

- **Economy-wide targets.** A planning assumption on aviation and shipping emissions together with an overall target that includes emissions from these sectors implies a limit on emissions in the rest of the economy, around which approaches to wider decarbonisation can be developed (e.g. as in section 3 above).

- **Aviation and shipping.** Planning assumptions on aviation and shipping emissions can inform negotiating positions in international agreements, underpin technology policy (e.g. to support development and uptake of more efficient planes or ships), and are additional factors which should be considered in the context of infrastructure investment (e.g. airport capacity development and possible expansion).

Until longer-term global or EU agreements limiting emissions from international aviation and shipping are agreed, the emissions pathways in section 3 above should be regarded as proxies for outcomes under international agreements, and should be used as the basis for planning assumptions. These imply international aviation emissions in 2050 at around 2005 levels, and 2050 international shipping emissions roughly a third below 2010 reported levels.

Given the high degree of uncertainty (e.g. relating to policy and technology innovation, in aviation and shipping and other sectors), both the level of ambition for reducing aviation and shipping emissions, and the balance of measures to achieve this ambition, should be kept under review.

For example, upon agreement, current planning assumptions should be replaced by emissions pathways implied under new EU or global policies.

Outstanding challenges in developing effective international frameworks

In its EU and international policy dialogue around aviation and shipping emissions, and in its supporting technology policies, we recommend that the UK Government should:

- **Aviation.** Continue to support implementation of the EU ETS, which will provide increasing incentives to reduce emissions as the carbon price rises and involves minimal competitiveness risks. Building on this, the Government should work with other countries in ICAO to agree a global mechanism for reduction of aviation emissions. In its technology policy, the Government should support development of more efficient airframe and engine designs and advanced biofuels.
- **Shipping.** Continue to support development of market-based proposals by the IMO. To the extent that these are not forthcoming with a sufficient degree of ambition, inclusion in the EU framework (e.g. in EU ETS) should be seriously considered as part of the transition to a broader international approach. As for aviation, the Government should support technology development towards more efficient and lower-carbon shipping.
- **Non-CO_2 effects.** Support research into non-CO_2 (non-Kyoto) effects of aviation and support development of policies aimed at reducing their warming impact.

We will continue to closely monitor progress in developing the EU and global frameworks for reduction of aviation and shipping emissions in our annual reports to Parliament, and will advise on any changes to carbon budgets and longer-term planning assumptions as appropriate.

6. Summary

The current approach to carbon budgets and the 2050 target under the Climate Change Act is ambiguous, and can be interpreted in a way that would be incompatible with internationally agreed climate objectives.

This carries the risk that insufficient effort could be built into future carbon budgets and supporting policies.

This could either raise the costs and risks of meeting carbon budgets (e.g. if budgets and policies fail to prepare sufficiently for the deep emissions reductions required in the long term), or imply acceptance of higher risks of dangerous climate change (e.g. if looser emissions reductions are accepted in the long term).

Whereas we have always been clear that the 2050 target to reduce emissions by 80% against 1990 levels should include international aviation and shipping emissions, we previously identified complexities which prevented inclusion in carbon budgets.

Given that the Climate Change Act was subsequently drafted such that international aviation and shipping emissions must be in both or neither of carbon budgets and the 2050 target, this resulted in these emissions initially being excluded from the 80% target.

However, there has since been further policy development and we have completed new analysis, indicating that both international aviation and international shipping emissions can and should now be included in carbon budgets and the 2050 target.

This would remove current uncertainties and ambiguities in the various provisions under the Act, providing the most comprehensive, transparent and flexible framework for the UK's contribution to tackling harmful climate change.

It would do so at no additional cost to that previously accepted, and without competitiveness risks or potential leakage of aviation or shipping emissions to other countries.

The next steps in the legislative process are for Government to consider our advice over the coming months, to table legislation in Parliament, and for Parliament to take a decision on this issue by the end of 2012.

Given a positive decision to include, this would then provide a clear basis for the future setting of carbon budgets and for implementation of the Government's Carbon Plan.

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Committee on Climate Change
7 Holbein Place
London
SW1W 8NR

www.theccc.org.uk