

Executive summary

In our first report in 2008 we recommended that the UK should set a 2050 target to reduce emissions of all Kyoto greenhouse gases by 80% relative to 1990 levels. This would be appropriate as a minimum contribution to a global deal required to limit risks of dangerous climate change, and would be technically feasible at a cost of 1-2% of GDP.

We also recommended the first three carbon budgets, setting a ceiling on emissions of greenhouse gases in the UK for the three periods 2008-2012, 2013-2017 and 2018-2022.

We considered feasible emissions reductions, the path to the 2050 target, and the EU framework. We recommended that Interim budgets based on a 2020 emissions reduction of 34% relative to 1990 levels should be legislated in the first instance. We also recommended that Intended budgets based on a 42% emissions reduction in 2020 should subsequently be enacted if and when there was progress towards a deal to reduce global emissions.

The 2050 target was included in the Climate Change Act, and our recommended carbon budgets were enacted in secondary legislation in May 2009.

In this report we set out our advice on the fourth carbon budget, covering the period 2023-2027. This advice is required under the Climate Change Act prior to the Government proposing and Parliament legislating the fourth budget before June 2011. In line with the required timetable, this report comes only two years after our first report. However, from now on budget advice reports will be delivered every five years (i.e. advice on the fifth carbon budget, covering the period 2028-2032, will be provided in 2015).

In developing advice we have started by considering an appropriate and feasible target for UK emissions in 2030 – half way between now and the 2050 target in the Climate Change Act. This 2030 indicative target needs to reflect likely emissions in the early 2020s, feasible and cost-effective emissions reductions in the 2020s, and feasible pathways to further reductions between 2030 and 2050.

This report therefore joins up the detailed analysis that we have previously published on the path to 2020, with longer-term analysis of the path to 2050.

Our advice is based on consideration of the latest climate science, the evolving international framework, feasible and cost-effective emissions reductions in the UK through the 2020s, and plausible paths to the 2050 target. It comprises recommended budgets with associated costs and investment requirements. It also includes implications for Government policies required to ensure emissions reductions in the 2020s can be achieved (e.g. the need for electricity market reform and support for technology development).

Box 1: Key recommendations and findings

- An **Indicative 2030 target** to reduce emissions by 60% relative to 1990 levels (46% relative to 2009 levels).
- A **Domestic Action** fourth carbon budget of 1950 MtCO₂e to be legislated in the first instance and to be achieved on a gross basis (i.e. without credit purchase).
- A **Global Offer** budget of 1800 MtCO₂e indicating a minimum UK contribution to a future global deal to be legislated when a global deal for the 2020s is agreed.
- The **second and third budgets** should be adjusted to reflect the level of ambition in the Intended budget for the non-traded sector, giving an economy-wide reduction of 37% in 2020 relative to 1990.
- **International aviation and shipping** should in future be included in carbon budgets.
- The **cost** of meeting the Domestic Action and Global Offer budgets is under 1% of GDP.
- Annual **investment** requirements through the 2020s are around £16bn.
- New **policies** will be required, including fundamental reform of the electricity market.

The key messages in the report are (Box 1):

- **Global emissions pathways.** We have assessed the latest climate science and the international context. Our conclusion is that the climate objective and the global emissions pathway underpinning our first report recommendations remain appropriate. Our advice on the fourth carbon budget is therefore based on the need for the UK to be on a pathway to 80% cuts in greenhouse gases below 1990 levels by 2050, with maximum 2050 emissions of 160 MtCO₂e. It also reflects the need for deep emissions cuts at global and therefore UK levels through the 2020s, and the rising carbon price (e.g. to £70/tCO₂, real terms £2009, by 2030) that this implies.
- **2030 emissions reductions.** By 2030, the UK should aim to have reduced total greenhouse gas emissions from today's level of 574 MtCO₂e to around 310 MtCO₂e (a 60% reduction relative to 1990); this 46% reduction over the next twenty years will require a subsequent 62% reduction between 2030 and 2050 to meet the 2050 target. We believe that this 'back-ending' is justifiable given the feasibility of accelerated emissions reductions in the 2030s and 40s if key enabling technologies and conditions (e.g. a largely decarbonised power sector) are in place by 2030. But any less ambitious target for 2030 would endanger the feasibility of the path to 2050.
- **The fourth carbon budget for the period 2023-2027.** We recommend that Parliament legislates a 'Domestic Action' budget for 2023-2027 which will place the UK on a feasible and cost-effective path towards the indicative 2030 and legislated 2050 targets, but that the Government should be prepared to commit to a more ambitious 'Global Offer' budget, if and when a global deal covering action in the 2020s is agreed:
 - **Domestic Action budget.** This budget reflects our assessment of feasible and cost-effective emissions reductions in the UK through the 2020s, consistent with the path to the 2050 target. It limits emissions over the period 2023-2027 to 1950 MtCO₂e (average

390 MtCO₂e a year). It embodies an emissions cut of 50% in 2025 below 1990 levels (32% below 2009 levels). This budget should be legislated in the first instance, with the aim to achieve it through domestic emissions reductions only (i.e. without recourse to purchase of credits in international carbon markets, including through the EU ETS). The level of ambition in this budget should be regarded as an absolute minimum, and more may be both feasible and required as current uncertainties over emissions projections and abatement opportunities are resolved.

- **Global Offer budget.** This budget represents our assessment of a minimum UK contribution likely to be appropriate to a future global deal covering the 2020s. It limits emissions over the period 2023-2027 to 1800 MtCO₂e. The Global Offer budget should be legislated in the context of a global deal covering the 2020s. The aim should be that this budget would be met largely through domestic emissions reductions (e.g. consistent with reductions in the Domestic Action budget or more), together with possible purchase of credits at the margin.
- **The first three carbon budgets: Interim and Intended.** The Domestic Action budget recommended for 2023-2027, and the indicative 2030 target, will be difficult to achieve unless the UK enters the 2020s at a level of emissions consistent with the Intended budgets for the non-traded sector, rather than with the less ambitious Interim budgets. Our latest emissions projections which include the impacts of the recession suggest that in the non-traded sector the UK will meet the Intended first, second and third budgets as long as it implements public policy measures to which the Government is already broadly committed at a high level, and which are required to make the path to the 2050 target feasible. We therefore recommend that Parliament should now legislate to adjust the first three budgets to reflect non-traded sector emissions under the Intended budgets. The UK should also argue for a tightening of the EU ETS cap which constrains traded sector emissions: if and when such tightening is agreed, the UK should then adjust its traded sector budgets onto the Intended path.
- **International aviation and shipping.** The UK's legislative framework does not currently include international aviation and shipping (IA&S) emissions in carbon budgets. But it is clear that the UK's contribution to IA&S emissions should be reflected in carbon targets, and the Committee has been asked to consider how and when they can be incorporated within the budgeting approach. We recommend that the Government accepts the principle that IA&S emissions in future be included in carbon budgets, and we intend to make specific recommendations on how to adjust the second, third and fourth budgets to allow inclusion following our review of international shipping emissions, to be published in autumn 2011. In the meantime, the recommended Domestic Action and Global Offer budgets for the fourth period do not include IA&S, but have been set so as to be compatible with meeting a 2050 total emissions target of 160 MtCO₂e with IA&S included.
- **Costs and investment requirements.** We estimate the cost of meeting the Domestic Action budget is under 1% of GDP in 2025. Meeting the Global Offer budget would require an additional cost of 0.1% of GDP based on credit purchase at projected carbon prices.

Annual investment requirements include £10 billion for power sector decarbonisation, £1 billion for reducing emissions in industry and £3 billion (over and above business as usual expenditure) for reducing emissions from heating buildings.

- **Implications for Government policies.** New policies are required to ensure that the emissions path through the 2020s can be achieved, and to lay the foundations for further progress in the 2030s and 2040s. These include:
 - **Electricity market reform.** Our analysis suggests the need to decarbonise the power sector through the 2020s by adding 30-40 GW of low-carbon plant. This would reduce average emissions from current levels around 500 gCO₂/kWh to around 50 gCO₂/kWh by 2030. Existing electricity market arrangements are not well designed to ensure this progress occurs in a cost-effective fashion. Therefore we recommend that new arrangements are introduced entailing competitive tendering of long-term contracts for investment in low-carbon capacity.
 - **Carbon price underpin.** Given carbon price volatility and the current low carbon price, a carbon price underpin would complement electricity market reforms. It could also strengthen incentives for investment in low-carbon technologies in other sectors, subject to competitiveness and affordability concerns being addressed. A carbon price underpin which reached at least £27/tCO₂ (i.e. 30 euros per tonne) in 2020 and rising through the 2020s would provide appropriate signals.
 - **Funding and policies to support development of technologies and new markets.** Key technologies which should be demonstrated now for deployment in the 2020s include CCS in power generation and industry, electric cars and vans, and electric heat pumps. Comprehensive programmes in each of these areas should be developed as a matter of urgency to ensure timely disbursement of funds committed in the 2010 Spending Review, with further funding committed as appropriate (e.g. electric cars) and as fiscal constraints ease.
 - **New policies to deliver the first three budgets.** As explained above, our recommended fourth budget will be difficult to achieve unless the UK enters the 2020s with non-traded sector emissions in line with the Intended budget. This Intended budget looks attainable in light of latest projections which include the impacts of the recession, but only if new policy measures recommended in our reports to Parliament are effectively implemented. As we highlighted in our June 2010 progress report to Parliament, progress in reducing emissions during the first budget period has so far primarily reflected the recessionary effect, and it remains essential to achieve the step change in the pace of underlying emissions reductions that we called for in both the October 2009 and June 2010 progress reports. New policies to drive the step change include approaches to energy efficiency improvement in residential and non-residential buildings, roll-out of smart meters, consumer behaviour change in transport, and more widespread use of carbon-efficient practices on farms.

- **Further evidence to resolve uncertainties.** There are a number of promising but uncertain options for cutting emissions in the 2020s. These include district heating, and abatement options in agriculture and industry. The evidence base should be developed in these areas, with new policies introduced as appropriate.
- **Implications for EU policies and measures.** There is a set of policies that the UK Government should push for to set the EU on a cost-effective and credible path to its 2050 target, and which would reinforce UK action to meet the fourth carbon budget, including:
 - Supporting the move to an EU 30% emissions reduction target in 2020 relative to 1990 levels.
 - Agreeing an appropriate emissions reduction target for 2030 (e.g. around a 55% reduction relative to 1990).
 - Tightening of the EU ETS emissions cap, both in 2020 and through the 2020s.
 - Setting 2030 targets for new car and van emissions (e.g. around 50gCO₂/km for cars and 80gCO₂/km for vans).
 - Reforming the EU Common Agricultural Policy, which is due for revision in 2013, so that it links subsidies and incentives to climate change mitigation objectives.
 - Supporting technology development, particularly for CCS in industry.

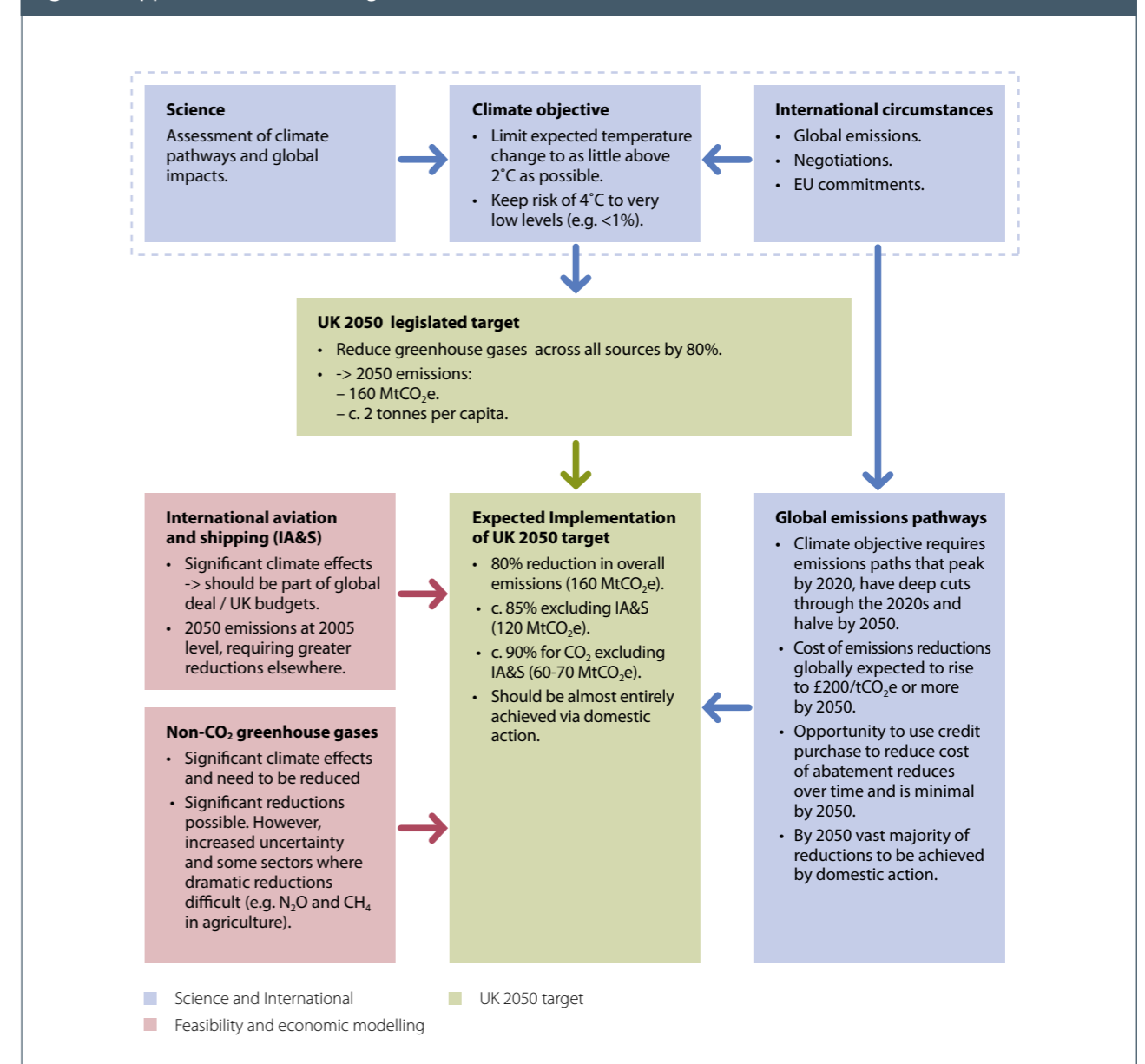
We set out our summary in 6 sections:

1. Global emissions pathways and the 2050 target: climate science and the international context.
2. The fourth carbon budget (2023-2027)
3. The path from 2030 to 2050
4. The first three carbon budgets (2008-2022): Interim versus Intended, and the treatment of international aviation and shipping (IA&S)
5. Developing options for meeting the fourth budget: policy implications
6. Wider economic and social considerations and differences in national circumstances.

1. Global emissions pathways and the 2050 target: climate science and the international context

In advising on carbon budgets, we are required under the Climate Change Act to consider climate science and the international context. In our 2008 report we set out why these considerations led us to recommend that the UK should set a 2050 target to reduce total greenhouse gas emissions by 80% relative to 1990 levels: this implies maximum 2050 emissions of 160 MtCO₂e. This section sets out why we believe that target remains appropriate; it highlights the fact that achieving 80% overall reductions will entail still higher reductions in some sectors of the economy. It considers required global emissions pathways, which also carry implications for the UK's appropriate contribution to global emissions reductions between now and 2050, and for the likely evolution of carbon prices. These aspects – the 2050 target, global pathways and implications for UK pathways – inform our specific fourth carbon budget recommendations (see Section 2 below). Figure 1 illustrates the key steps in our analysis.

Figure 1: Approach to the 2050 target



Assessment of the latest climate science

Recent controversies concerning the University of East Anglia and the IPCC have raised some concerns about transparency and IPCC process which are now being addressed.

However, our assessment of the latest climate science, including a review that we commissioned covering over five hundred recently published peer-reviewed papers, confirms that the fundamental science remains robust:

- Global climate change is already happening.
- It is very likely that this is largely a result of human activity.
- Without action, there is a high risk of global warming well beyond 2°C, with potentially very significant changes in regional climate.
- This would have damaging consequences for human welfare and ecological systems over the course of this century and beyond. If anything, our assessment is that risks have worsened since we advised on the 2050 target in 2008, but not sufficiently to change our climate objective.

Therefore the climate objective and the global emissions pathway underpinning the Climate Change Act remain appropriate.

- The climate objective is to limit central estimates of global mean temperature change by 2100 to as little above 2 degrees as possible, and to limit the likelihood of temperature change above 4 degrees to very low levels (e.g. to below 1% probability).
- Global emissions pathways that deliver this objective are characterised by peaking of global emissions around 2020, followed by deep cuts in the 2020s and a halving of emissions by 2050, with further cuts thereafter.

The international context

Whether this global emissions pathway remains feasible depends on the international context. Of particular importance is agreement on and delivery of pledges under the Copenhagen Accord:

- Our assessment of the Copenhagen Accord is that peaking of global emissions by 2020 is still feasible if the most ambitious pledges can be delivered, but with important issues to be resolved relating to land-use change, and to the sale of excess rights to emit under the Kyoto Protocol (the so called “hot air” issue).
- Delivering these pledges will be difficult, however, particularly given the current political situation in the US.
- But slow progress in agreeing a global deal should not and will not preclude action to reduce emissions. In parallel to negotiations on a global deal, there is significant action at the country level (e.g. in China, India, EU member states, and states within the US). These and other countries acting early will be well-placed in a carbon-constrained world.

The UK's 2050 target and contributions to global emissions reduction

Overall therefore, while developments in science since our 2008 report have marginally increased the strength of the case for forceful global action to reduce emissions, the likelihood of getting early global agreement has decreased. This cannot be taken, however, as a reason for reducing the UK's 2050 target since:

- Radical cuts in global emissions by 2050 – to around 20-24 GtCO₂e annually – remain essential if the world is to reduce significantly the risks of seriously harmful climate change.
- The logic which led to the UK's specific 160 MtCO₂e target remains robust: it is difficult to imagine a global deal emerging that does not require developed countries to reduce per capita emissions to a level broadly in line with that which can be sustained globally.
- A key objective of the Climate Change Act was to set a target which would not vary with the ups and downs of global negotiations, but would provide certainty within which policies and technologies could be developed.

In addition, our assessment remains that deep cuts in global emissions are both required and possible through the 2020s. This implies the need for deep cuts in UK emissions, and via its implications for the global carbon price, informs the appropriate level of domestic emissions reduction effort in the UK.

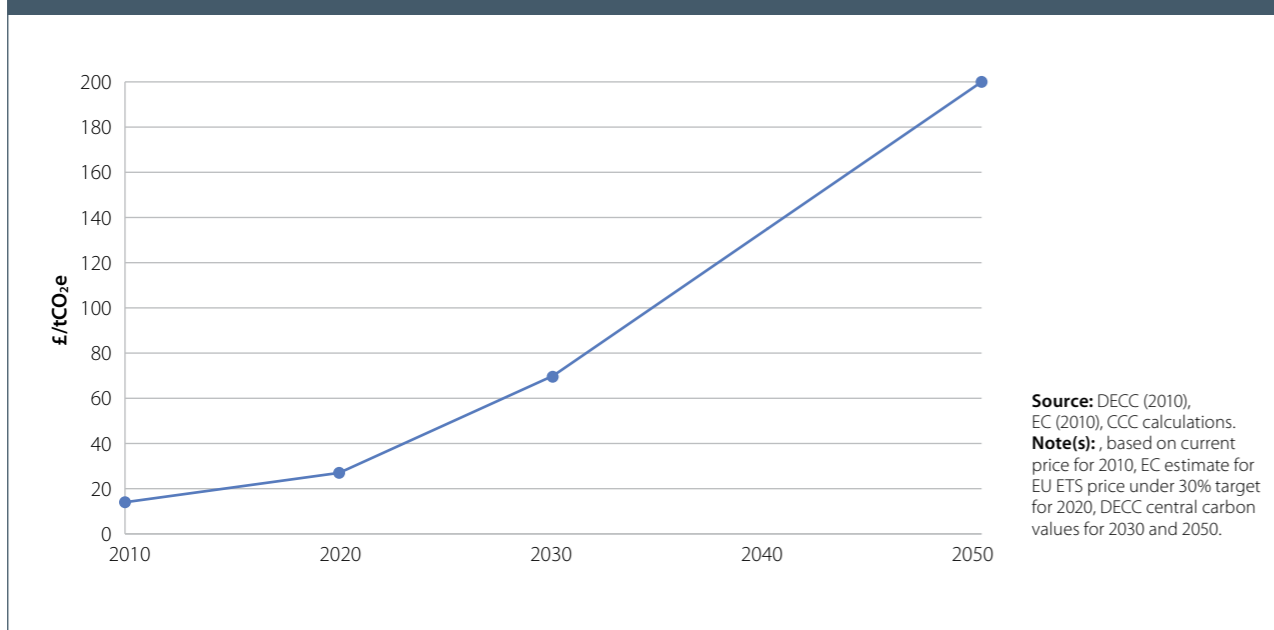
Our recommendations for the fourth carbon budget are therefore designed to be compatible with progress towards achieving an 80% cut in the UK's total greenhouse gas emissions by 2050, implying maximum emissions in 2050 of 160 MtCO₂e (including IA&S), and the need for deep cuts in emissions through the 2020s at global and UK levels.

Implications of the 80% target: specific sectors and the domestic action/credit purchase split

It is important to note, however, that an overall target of 80% reduction by 2050 will require still higher percentage reductions in some sectors of the economy. This is because there are some sectors where feasible reductions are likely to be considerably less. In particular:

- It is vital that the UK's target includes the UK's contribution to international aviation and shipping (IA&S) emissions (and as described in Section 4 below these should in future be included in the legally binding carbon budgets). The UK is now committed to ensure that 2050 aviation emissions do not exceed 2005 levels, and it is essential that this target is met. But it is unlikely to be optimal to reduce aviation emissions by 80%, since, unlike in other sectors (e.g. power generation), alternative technologies which could make radical reductions feasible without major economic cost are less likely to be available. If we assume that IA&S emissions in 2050 are at 2005 levels, other sectors of the economy will need to cut by 85% in 2050.

Figure 2: Carbon price projections (2010-2050)



- Similarly, the attainment of radical reductions in agricultural non-CO₂ emissions poses significant challenges. Large reductions from today's level of around 45 MtCO₂e will be essential if the overall 80% reduction target is to be attained, and a more robust policy framework to drive emissions reductions is likely to be required. But even with such a framework, cuts as high as 80% in agriculture itself may not be feasible. If agricultural and other non-CO₂ emissions are reduced by 70% by 2050 (relative to 1990), while IA&S emissions are held flat at 2005 levels, emissions of CO₂ in other sectors of the economy will have to fall by around 90%.

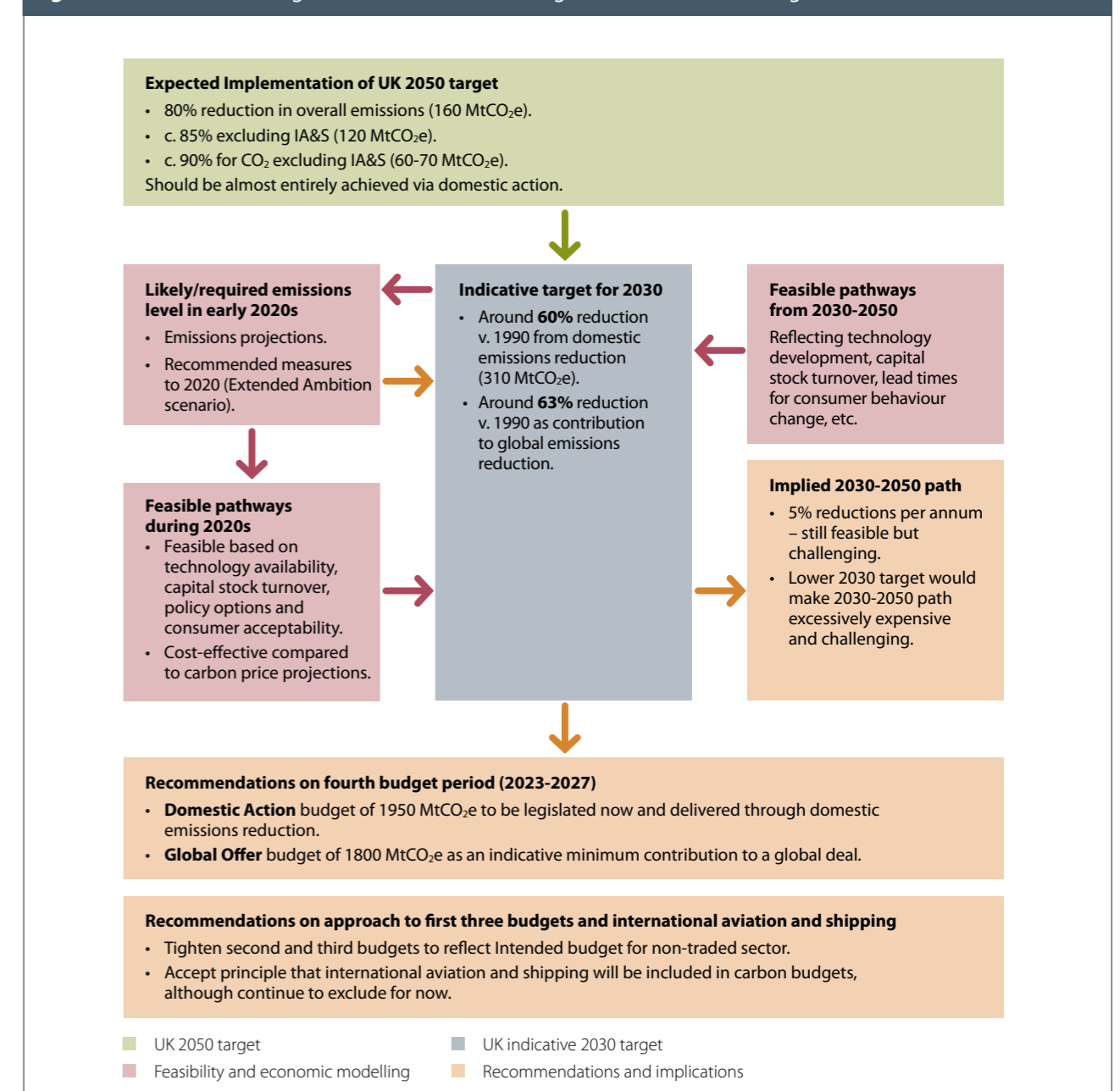
In addition, we need to face the reality that in the long term, reductions in emissions will need to be achieved almost entirely through domestic action. Whereas at present and for the foreseeable future, there may exist opportunities to buy carbon credits internationally at a price below the marginal cost of emissions reduction in the UK, by mid-century global prices will need to have reached several hundred £s per tonne if climate objectives are to be achieved (see Figure 2), and some current sellers of emissions credits (e.g. China) are as likely to be buying credits from the UK as vice versa. By mid-century, a UK target of 160 MtCO₂e is likely to require that our domestic emissions are close to this level.

Our budget recommendations therefore assume that the UK needs to reduce total greenhouse gas emissions to 80% below 1990 levels, non-IA&S emissions by 85%, and non-IA&S CO₂ emissions by around 90%, and that these emissions reductions will need to be achieved entirely domestically. This has implications for the progress needed in decarbonising the economy to 2030, and for the Domestic Action budget for 2023-2027.

2. The fourth carbon budget: 2023-2027

Figure 3 sets out the considerations which have informed our recommendations for the fourth carbon budget. A key objective has been to create a clear link between near- and medium-term budgets out to 2027, and the overall required pathway to 2050. To create this link we have considered what an appropriate indicative target would be for 2030 – halfway between now and 2050.

Figure 3: From the 2050 target to an indicative 2030 target and a 2023-2027 budget



The key building blocks in the analysis are:

- We accept as a given the overall 2050 80% target, and the need to achieve still larger reductions in non-IA&S sectors and in CO₂ (as against other greenhouse gases).
- We therefore define a range of possible indicative targets for 2030, based on:
 - The level of emissions with which we are likely to enter the 2020s, and/or could enter the 2020s with appropriate intensity of policy effort over the first three budget periods.
 - The feasible and cost-effective pace of emissions reductions through the 2020s.
 - The feasible pace of emissions reductions from 2030 to 2050.
- The indicative targets for 2030, together with the pace of emissions reductions in the 2020s, then inform our recommendations for the fourth budget period. They also inform our recommendations for the adjustment of the first three budgets; these, together with our recommendations on the budget treatment of IA&S, are set out in Section 4 below.

In setting out our recommendations for the fourth budget, we have distinguished between the path which makes sense for UK domestic action, and the path that the UK should be willing to offer as part of a global deal:

- **Domestic Action indicative 2030 target and fourth budget.** These reflect a bottom-up assessment of abatement opportunities during the 2020s, and include abatement measures which will either be cost-effective at projected carbon prices or which will be necessary to ensure a feasible path from 2030 to 2050. We recommend that the Domestic Action budget for 2023-2027 is legislated now, with the aim to meet it through domestic emissions reduction (i.e. without recourse to credits purchased in international carbon markets including the EU ETS).
- **Global Offer indicative 2030 target and fourth budget.** These are intended to illustrate a possible UK contribution to the overall global emissions reductions required to achieve the climate objective discussed in Section 1 above. They are slightly more ambitious than the Domestic Action target and budget: the additional ambition could be achieved either via the purchase of emission reduction credits in international carbon markets, or via accelerated domestic abatement. The Global Offer budget is intended to be indicative of a minimum contribution to a global deal. It would only be legislated in the context of a global deal covering the 2020s, with a precise level of ambition to reflect the deal achieved.

We now consider in turn:

- Possible emissions levels in the early 2020s.
- Feasible emissions reductions in the 2020s and an appropriate Domestic Action 2030 target and fourth carbon budget.
- The indicative Global Offer budget.

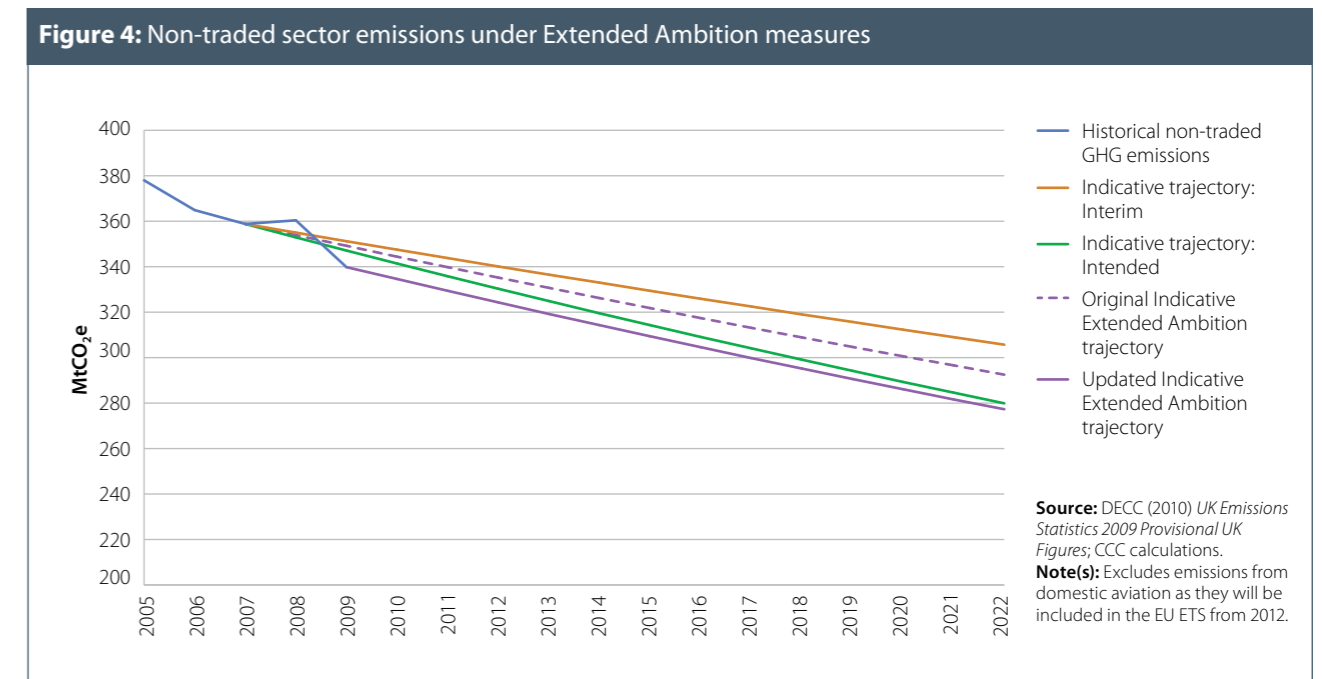
The feasible pathway between 2030 and 2050 is considered in Section 3. Recommendations for the approach to carbon budgets in the first three periods, and to international aviation and shipping, are covered in Section 4.

(i) Possible emissions levels in the early 2020s

Following the Committee's advice in our 2008 report, and Parliament's decision in June 2009, the UK is currently legally committed to the Interim budgets, which entail emissions falling from 3018 MtCO₂e in the first five-year budget to 2544 MtCO₂e in the third. It was hoped that progress to the Intended budgets, in which emissions reduce to 2245 MtCO₂e in the third budget period, would become possible after a global deal at Copenhagen, and an EU commitment to a 30% (rather than 20%) emissions reduction target for 2020.

Since the decision to proceed with the Interim budget, however, UK emissions have fallen significantly due to the recession. 2009 emissions were 8.6% below 2008 levels: at 574 MtCO₂e they are significantly below the average 604 MtCO₂e per annum allowed in the first budget period. Our latest projections moreover suggest that if the UK successfully implements measures which we had previously thought necessary to meet the Interim budget (the "Extended Ambition" scenario described in our 2008 report) we will enter the early 2020s with emissions levels in line with the Intended rather than the Interim budget in the non-traded sector (Figure 4).

We therefore design the fourth budget around the assumption that the Intended third budget is achieved in the non-traded sector. Indeed, this will be essential for progress through the 2020s, and we discuss the implications for appropriate policy adjustments to the second and third budgets in Section 4 below.



(ii) The Domestic Action budget

Scenarios for UK emissions through the 2020s

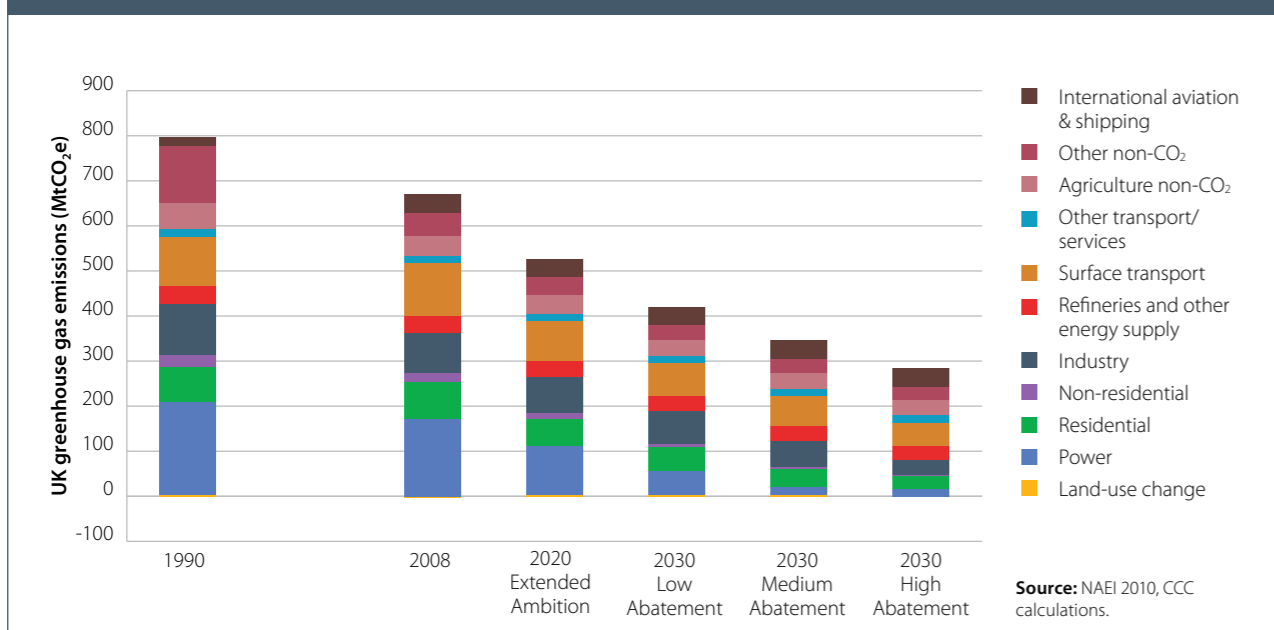
Future technological developments and costs are uncertain. It is not the role of the Committee to predict what precise mix of different technologies will be used to deliver future carbon budgets.

But our budget recommendations need to be based on confidence that there exists a range of technological options which are likely to make the budgets attainable; and we need to identify if there are policies required to increase the likelihood that potentially important options will be available for deployment. As in our 2008 report, we therefore set out a range of emissions scenarios based on a bottom-up analysis of abatement opportunities in each sector of the economy.

We have developed scenarios for UK emissions through the 2020s based on assessment against four criteria:

- **Feasibility** given current technology readiness and possible innovation, capital stock turnover, build rates, consumer acceptability and new policies to support uptake.
- **Sustainability** of bioenergy in particular given tensions between use of land for growth of bioenergy feedstocks versus food, and possible air quality impacts from burning biomass.
- **Cost-effectiveness** relative to our projected carbon prices through asset lives; we follow DECC in assuming a carbon price rising to £70/tCO₂ in 2030 and £135/tCO₂ in 2040.
- **Consistency with the 2050 target** given the long lives of assets, limits on the pace of emissions reduction beyond 2020, and the need to achieve the 2050 target largely through domestic abatement.

Figure 5: Economy-wide abatement scenarios



We construct three scenarios (Low, Medium, High abatement) which meet the four criteria above to differing extents, and which deliver emissions reductions of 51%, 60% and 69% in 2030 relative to 1990 levels (Figure 5).

The Medium abatement scenario (Box 2) forms the basis of what we should plan for in the 2020s as it prepares sufficiently for 2050 whilst being feasible, sustainable and cost-effective:

- It reflects significant uptake of abatement potential that currently appears to be cost-effective for different assumptions on key cost drivers and carbon prices.
- It balances the risks of under-achievement versus risks of excessive costs during the 2020s.
 - It keeps other scenarios in play and therefore maximises flexibility (e.g. if deeper cuts are required, depending on the outcome of a future global deal covering the 2020s, it could be possible to move to the High abatement scenario; or the Medium abatement scenario could be delivered through a different technology mix).
 - Planning for higher ambition currently appears to entail significant further costs, but could become desirable in the future (e.g. depending on low-carbon technology innovation, and/or in the context of a global deal).
 - Planning for a lower level of ambition would carry three risks. It could result in investment in carbon-intensive assets in the period to 2020 which, while compatible with meeting the first three budgets, would impede further progress in the 2020s. It could fail to develop adequately technologies that will be required in the 2020s. It could also fail to put appropriate policies in place far enough in advance of the fourth budget, resulting in limited investments with long lead times and limited supply chain expansion. It could therefore necessitate scrapping of high-carbon assets and/or the purchase of high-cost carbon credits in the 2020s.
- It implies a feasible path to 2050 in terms of required annual emissions reductions and abatement options beyond 2030. Lower cuts through the 2020s would not sufficiently develop abatement options required in subsequent periods, and would leave a need for very challenging and expensive emissions reductions beyond 2030, whilst higher cuts are not necessary and would involve additional costs on the path to 2050 (see Section 3 below on the path from 2030 to 2050).

Given these properties, we use the Medium abatement scenario as the basis for our Domestic Action budget.

Box 2: The Medium abatement scenario

The Medium abatement scenario includes the following measures:

- Power:** Addition of 30–40 GW¹ low-carbon capacity to the system through the 2020s. This results in a reduction in carbon intensity from around 300 gCO₂/kWh in 2020 to around 50 gCO₂/kWh in 2030. The scenario includes a 30% demand increase from 2020 to 2030, reflecting increased uptake of electric vehicles and heat. The scenario could be delivered through a mix of technologies including renewable (e.g. wind, marine), coal and gas CCS, and nuclear. This scenario also includes investments in smart meters and increased interconnection with Europe to provide greater system flexibility, therefore addressing potential problems associated with intermittency.
- Buildings:** Ongoing energy efficiency improvement through the 2020s, including insulation of 3.5m solid walls in the residential sector. The key option for supply-side decarbonisation in this scenario is heat pumps. These reach a penetration rate of 25% in the residential sector, and around 60% in the non-residential sector by 2030. There is a limited assumed role for district heating, reflecting uncertainties around technical and economic aspects of this option, with the possibility of deeper penetration as uncertainties are resolved. There is some use of biomass and biogas, although the majority of these energy sources is used in the industrial sector, given the lack of low-carbon alternatives for industry decarbonisation.
- Industry:** Use of biomass and biogas, which together account for around 25% of total heat demand by industry in 2030. There is a growing role for CCS in industry through the 2020s, which by 2030 reduces emissions by around 5 MtCO₂.
- Transport:** Ongoing improvement of conventional vehicle efficiency, to 80 gCO₂/km for conventional cars and 120 gCO₂/km for conventional vans in 2030. There is 60% penetration of electric vehicles in new sales by 2030, the majority of which are assumed to be plug-in hybrids rather than pure electric, reflecting ongoing concerns around range constraints. There is a role for hydrogen vehicles in niche sectors (e.g. 50% of new buses in 2030 are hydrogen), with the possibility of broader penetration. We take a cautious approach to sustainable biofuels, with these remaining at levels recommended for 2020 in the Gallagher Review through the 2020s.
- Agriculture non-CO₂:** Continuation of progress over the next decade implementing soils and livestock measures. The scenario recognises the possibility of, but does not require, consumer behaviour change, both as regards reducing waste and rebalancing diet to less carbon-intensive foods. It includes emissions reduction potential from increasing afforestation in the 2020s. The overall emissions reduction to 35 MtCO₂e in 2030 is low relative to abatement potential from all these measures, and could therefore be delivered in different ways.

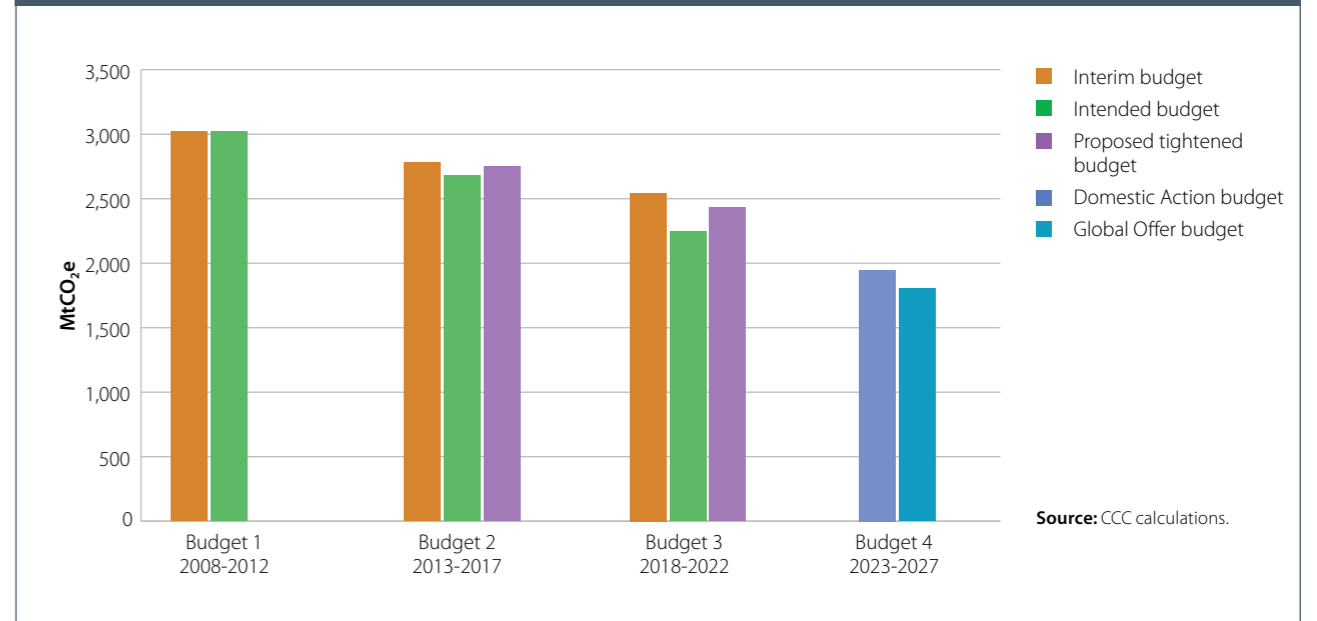
The Domestic Action indicative 2030 target and fourth budget

The Domestic Action budget follows the trajectory for the Medium abatement scenario through the relevant part of the 2020s, and limits greenhouse gas emissions (excluding IA&S) to 1950 MtCO₂e over 2023–2027, an annual average of 390 MtCO₂e (Figure 6). It embodies an emissions cut of 50% in 2025 below 1990 levels (32% below 2009 levels), on the path to an indicative 2030 target of a 60% cut in emissions relative to 1990 levels (46% relative to 2009 levels).

We recommend that the Domestic Action budget is now enacted. Under the Climate Change Act this budget will legally commit the UK to keeping net emissions (i.e. emissions adjusted for any net credit purchase in EU ETS or in global carbon markets) below the defined level. But the Domestic Action budget will only be a feasible stepping stone to the 2030 and 2050 targets if it is met on a gross basis (i.e. if the UK's domestic emissions are at or below this level). We therefore recommend that, alongside legislating this budget, the Government commits to bring forward policy measures which will make it attainable without the purchase of credits (additional reductions under the Global Offer budget could be delivered via credit purchase, see below).

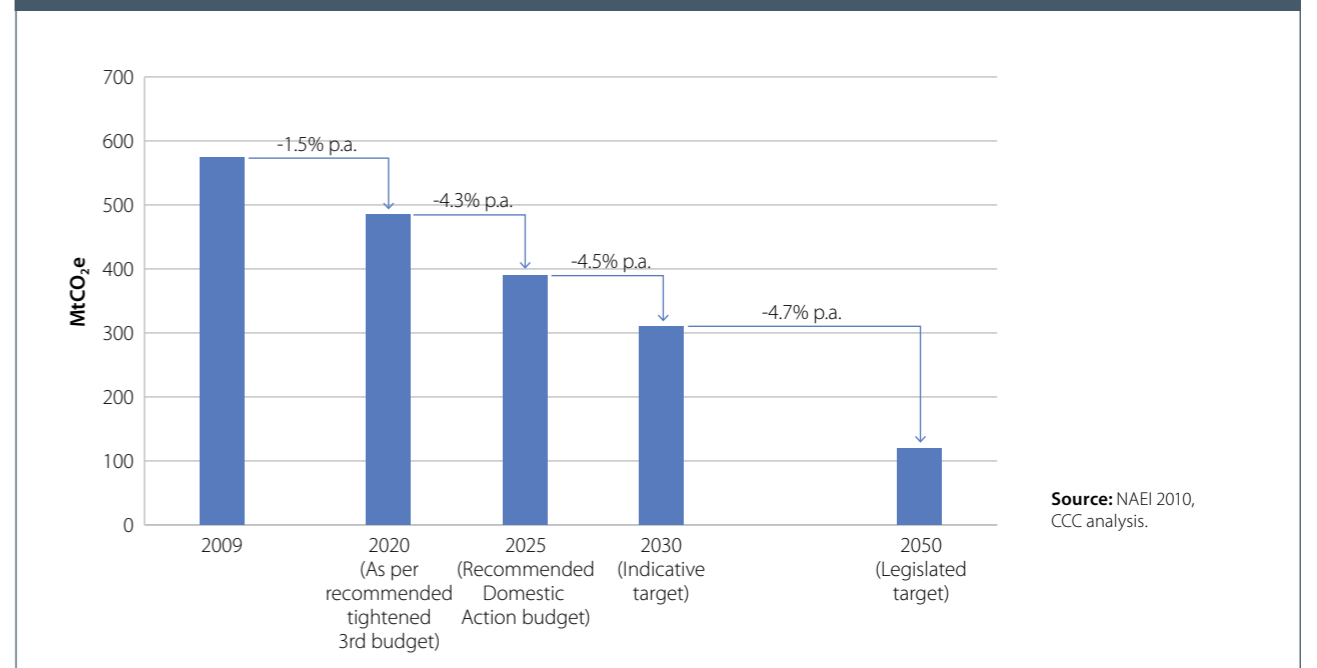
¹ Capacity is adjusted to reflect annual availability – these figures are for baseload-equivalent GW.

Figure 6: First four UK five-year carbon budgets (2008–2027)



It is important to recognise that the recommended budget requires steady acceleration of progress over time. Our proposed pace of progress through the 2020s is significantly faster than that required to meet carbon budgets in the 2010s, and faster still in the late 2020s and between 2030 and 2050 (Figure 7), as reflected in total required emissions reductions of 46% between 2009 and 2030 and 62% between 2030–2050. This is acceptable given the range of available technologies likely to be available through the 2020s and from 2030 to 2050. But the Committee judges any further 'back-ending' of the reduction path (i.e. a less ambitious budget, requiring further acceleration towards the end of the 2020s) would risk making the indicative 2030 target unattainable, which would in turn put the 2050 target at risk (see Section 3 below).

Figure 7: Rate of reduction of greenhouse gas emissions, excluding international aviation and shipping (2009–2050)



In addition, our recommended budget is based on uncertain reference emissions projections from the DECC Energy Model. The Committee has concerns that this model may underestimate the future extent of decoupling of energy demand from GDP growth, for example concerning industrial energy and materials demand. Therefore our reference emissions projections may be too high, in which case a tighter budget would be appropriate. We will work with DECC in 2011 to try to resolve this issue.

Therefore for these two reasons – back-ending and uncertainty over emissions projections – the recommended budget should be regarded as an absolute minimum level of ambition. This could be adjusted over time, and the precise mix of abatement options determined if and as uncertainties over emissions projections and abatement opportunities are resolved. One specific opportunity to implement such an adjustment would be in the context of moving from the Domestic Action budget to the Global Offer budget, to which we now turn.

(iii) Fourth budget based on a UK Global Offer

Our top-down approach derives a fourth carbon budget from the global pathway described in Section 1 above (i.e. peaking of emissions by 2020, deep cuts through the 2020s and a halving of emissions by 2050).

- At a minimum the UK contribution to global effort should track the global pathway (e.g. broadly characterised by equal annual percentage reductions from the early 2020s towards 2 tonnes per capita by 2050).
- It is hard to envisage a situation where the UK is less ambitious than the global average, which would require that other countries are more ambitious.
- Beyond this minimum, more is likely to be required, depending on financing agreed under a future global deal (e.g. depending on the burden share methodology)².

A UK path tracking the global pathway (i.e. equal annual percentage cuts from the Intended budget in 2020 to the 2050 target) gives an indicative Global Offer budget of 1800 MtCO₂e, an annual average of 360 MtCO₂e (i.e. 8% lower than the Domestic Action budget), on the path to an indicative 2030 target of a 63% reduction relative to 1990.

We recommend that this budget is legislated in the context of a global deal for the 2020s, once specific global emissions pathways and financing arrangements are more certain. The aim should be to meet this budget largely through domestic abatement given cost-effective abatement opportunities in the UK and on the path to the 2050 target, with possible purchase of credits at the margin (e.g. depending on technology costs and carbon prices, and on the role of financial flows as part of a future global deal).

² At the country level equal annual percentage reductions to emissions of 2 tCO₂e per capita in 2050 would vary by country according to their 2020 entry point and would imply greater reductions on a per capita basis given rising population.

3. The path from 2030 to 2050

The challenge from 2030

In the previous section, we considered the feasible path of emissions reduction in the 2020s, and defined a Domestic Action indicative 2030 target and a Domestic Action recommended fourth budget for 2023-2027 which are likely to be attainable at acceptable macroeconomic cost (see Section 6 below on costs). We need to check, however, if this target and budget are sufficiently ambitious to make achieving the 2050 target feasible, given the further reductions that would be required between 2030 and 2050.

Given delivery of the Medium abatement scenario to meet the Domestic Action budget without purchase of credits, remaining UK emissions in 2030 would still be 310 MtCO₂e (excluding IA&S). Further reductions of around 200 MtCO₂e would then be required to meet the 2050 emissions target through domestic action (Figure 8).

To understand the scale and sectoral mix of further reductions required beyond 2030, it is useful to be clear about how emissions scenarios for progress vary by sector (Figure 9). Reductions achieved by 2030 in our Medium abatement scenario vary from over 90% below 2008 levels in power generation, to 56% in buildings and 43% in surface transport, to only 28% in industry (including refineries and other energy supply) and just 19% in agriculture.

Figure 8: Scenarios for UK greenhouse gas emissions (1990-2050)

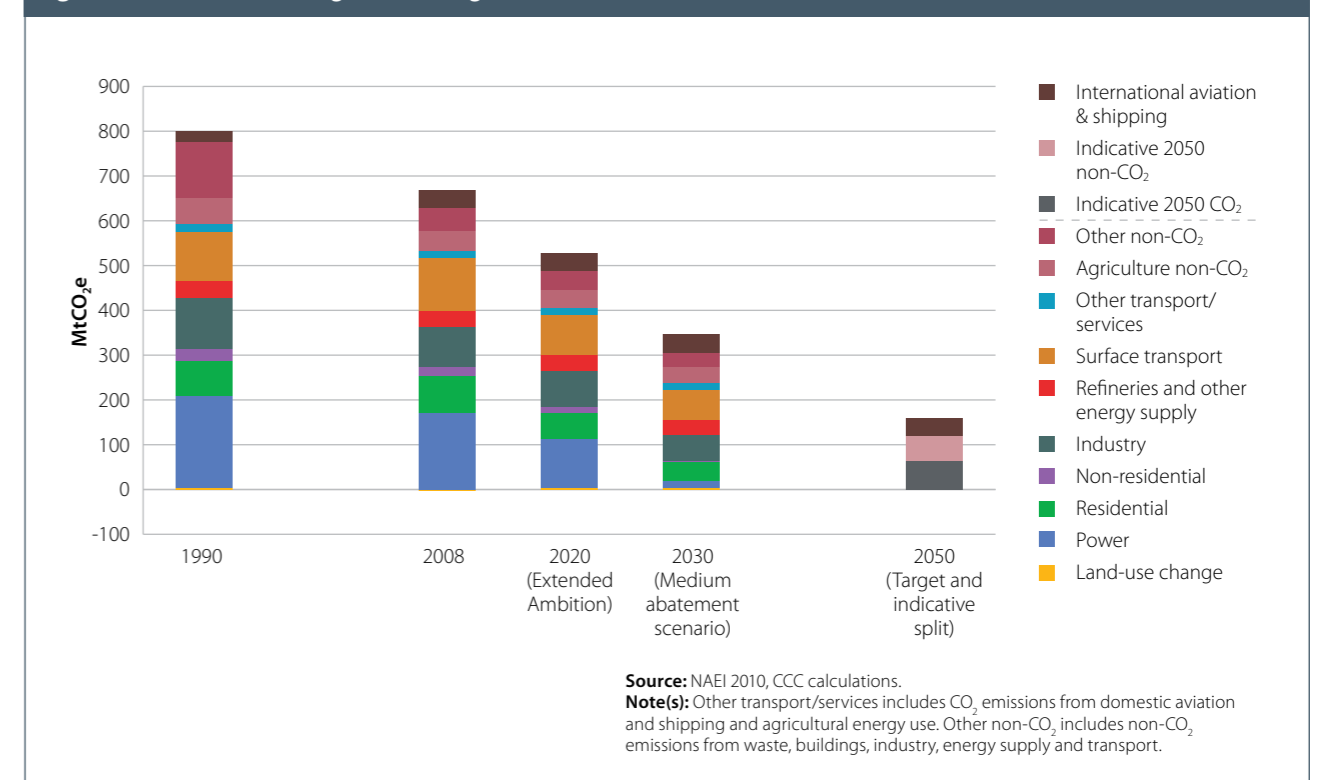
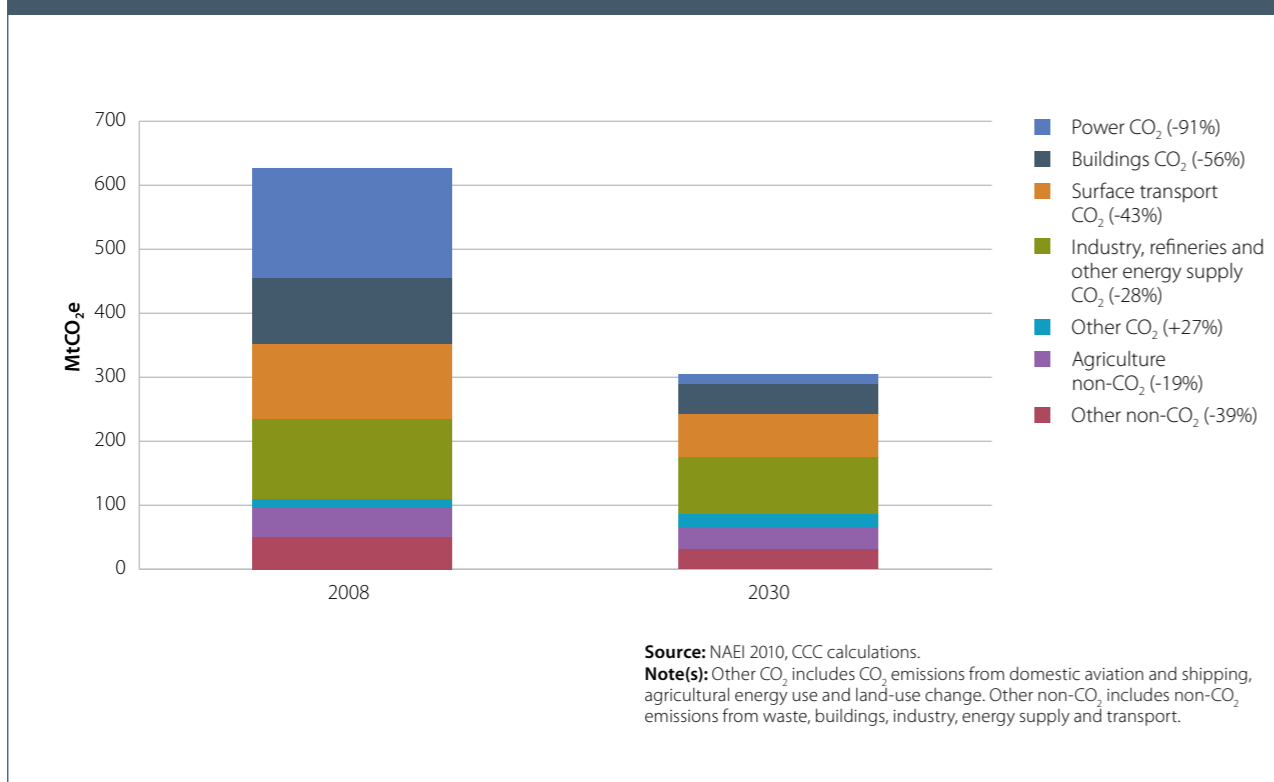


Figure 9: Possible sectoral emissions reductions achieved by 2030



Options from 2030 to 2050

Reductions beyond 2030 will require both a move to near full decarbonisation of those sectors where this is technologically possible, and significant emissions reductions in industry and agriculture, two sectors where radical reductions pre-2030 may prove more difficult to achieve. While it is not possible or necessary to specify what mix of technologies and/or consumer behaviour change will provide the optimal path to reductions over the 2030-50 period, the following review of potential options suggests that the 2050 target of 160 MtCO₂e (around 120 MtCO₂e excluding IA&S) could be attained from the 2030 starting point defined by our indicative target:

- **Power sector.** Power sector emissions are reduced to low levels in 2030 under the Medium abatement scenario. Further reductions will be required to 2050, such that the sector is close to zero emissions (or even negative emissions if biomass generation with CCS features significantly). At the same time, demand is likely to increase considerably in line with increased penetration of electric vehicles and heat (e.g. from around 425 TWh in 2030 to well over 500 TWh total annual consumption in 2050)³. Continued investment in new power generation between 2030 and 2050 (e.g. at the rate assumed for the 2020s, 3-4 GW per annum) would be necessary to complete the decarbonisation of the power system and to meet likely increasing demand.

- **Buildings.** Direct emissions from heat in buildings are reduced significantly by 2030, as a result of major improvements in energy efficiency and roll-out of low-carbon heat, especially heat pumps. Beyond 2030, further reductions are required, through energy efficiency improvement, further deployment of heat pumps where suitable, possibly combined with conventional electric heat and a potentially important role for district heating in those built-up urban areas for which heat pumps are not suitable. A feasible pace of deployment could almost fully decarbonise heat in buildings by 2050.
- **Surface transport.** Emissions from this sector remain a large share (22%) of total emissions in 2030 under the Medium abatement scenario. However, this would fall through the 2030s and 2040s with increasing penetration of electric cars and vans (e.g. with 100% penetration of pure electric vehicles in new sales by 2035, there would be no emissions from these vehicles in 2050). Alternatively, if the experience to 2030 suggests limits to penetration of electric vehicles, there could be scope for increased penetration of hydrogen cars and vans. HGVs could be decarbonised through hydrogen produced from low-carbon sources (e.g. electrolysis using low-carbon electricity, pre-combustion CCS or bioenergy). Biofuels could meet any residual demand for liquid fuels, for example, from plug-in hybrid vehicles or those HGVs not using hydrogen, but should not be relied upon as the main decarbonisation strategy given sustainability concerns.
- **Industry.** By 2050 we would expect available biomass and biogas to be used in industry rather than residential and commercial buildings, where electrification would dominate. In addition, there should be scope for reducing industry emissions through deployment of CCS in the 2030s. Together these options could reduce industry emissions to close to 40 MtCO₂ in 2050. Further abatement potential may be available through electrification, product substitution, and restructuring of the refinery sector as downstream demand is reduced.
- **Agriculture.** With no further emissions reductions beyond 2030, non-CO₂ emissions from agriculture would be around 35 MtCO₂e. Emissions at this level, combined with those from other difficult to reduce sectors (e.g. IA&S, industry), would make the overall target of 160 MtCO₂e extremely difficult to attain. A long-term plan to achieve more radical agricultural emissions reductions will therefore be needed. Further work is required to identify the options for additional reductions, and the policy levers needed to ensure implementation, but these options may need to include radical and controversial measures on both the supply side (e.g. the use of GM organisms) and in consumer behaviour (e.g. waste reduction or rebalancing of diet).
- **Other non-CO₂ emissions.** Residual emissions of other non-CO₂ gases in 2030 (i.e. from waste, buildings, industry, energy supply and transport) would be around 30 MtCO₂e. Options to reduce emissions further to 2050 include further diversion of waste from landfill, reduction of energy supply and transport non-CO₂ emissions as fossil fuel use is reduced, and phasing out use of F-gases.

³ MARKAL modelling by University College London for the CCC suggests that power generation may need to increase to around 515 TWh per year by 2050, compared with today's 372 TWh per year, an increase of around 40%. DECC's 2050 Pathways work includes six indicative scenarios that meet the 2050 target, with power generation ranging from 744 (Scenario C) to 972 (Scenario F) TWh per year in 2050, i.e. an increase of 100-160% on today's system.

In addition it is important to remember that while the UK is now committed to keep aviation emissions in 2050 no higher than 2005 levels, and while we have assumed that the same is true for the UK's international shipping emissions, strong policy action and significant technological development is required to meet these targets. The policies and technologies required in aviation are set out in our December 2009 report *Meeting the UK aviation target*; those required in shipping will be set out in our review of international shipping emissions in 2011.

Domestic Action indicative 2030 target as a minimum ambition on the path to 2050

As noted above, the recommended budget and the indicative 2030 target imply accelerated progress from 2020, with further acceleration in the late 2020s, and from 2030 to 2050. This can be justified given abatement opportunities from 2030, provided key enabling technologies and conditions (in particular a largely decarbonised power sector) are by then in place.

But setting a lower level of ambition to 2030 and for 2023-2027 would require a very challenging pace of annual emissions reduction from 2030, given rates of capital stock turnover, feasible investment levels, and new technology deployment:

- At the economy-wide level, the Stern report suggested that annual emissions reductions beyond even 3% would be very challenging⁴.
- Lower ambition on key abatement options would be incompatible with meeting the 2050 target, based on current understanding of sectoral opportunities:
 - As noted above, decarbonisation of surface transport requires that all new vehicles beyond 2035 should be ultra low-carbon; this implies the need for very significant penetration of ultra low-carbon vehicles by 2030.
 - A similar point applies to low-carbon heat, given a fifteen-year period for turnover of the boiler stock.
 - Deep decarbonisation of the power sector is required through investment in low-carbon technologies through the 2020s, given asset lives of forty years or longer.
 - Some progress in less well understood areas (e.g. agriculture and industry) will be required to lay the foundations for potentially more radical options beyond 2030.
- The DECC 2050 pathways scenarios reflect the need for deep cuts in emissions by 2030 on the path to 2050, and actually include more aggressive emissions reductions to 2030 than in our Medium abatement scenario (e.g. the range for emissions excluding international aviation and shipping in 2030 in the DECC scenarios is 248-297 MtCO₂e, compared to our indicative Domestic Action target for 2030 of 310 MtCO₂e).

Overall therefore, our conclusion is that there is a feasible pathway from our 2030 indicative target of 310 MtCO₂e (excluding IA&S) to the required 2050 target (160 MtCO₂e in total, but around 120 MtCO₂e excluding IA&S). But any less stretching target for 2030 risks making the 2050 goal unachievable over the subsequent 20 years.

⁴ The Stern Review, *The Economics of Climate Change*, chapter 8 'The Challenge of Stabilisation'

4. The first three carbon budgets (2008-2022): Interim versus Intended and the treatment of international aviation and shipping

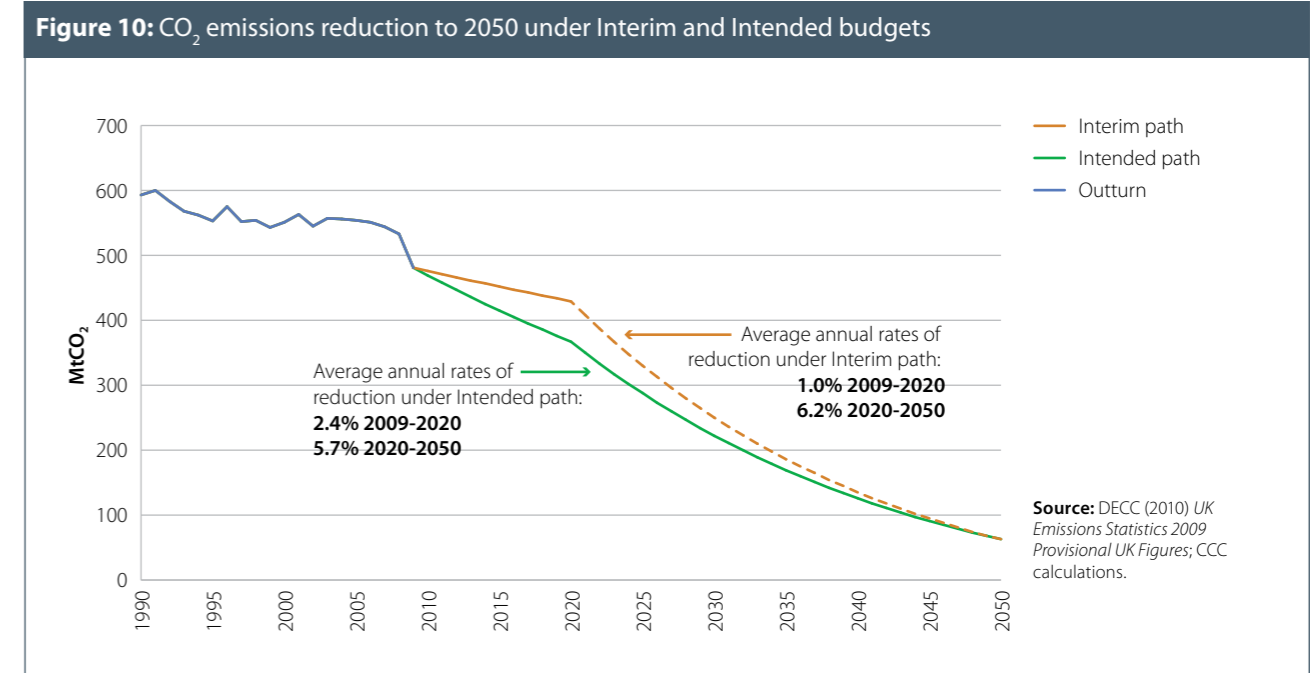
(i) Interim versus Intended budgets

In Section 2 above we described how emissions trends have been influenced by the recession, and the fact that on our current projections the UK is well placed to enter the early 2020s with emissions in line with the Intended third budget for the non-traded sector, rather than the Interim budget legislated by Parliament in June 2009. We have therefore assumed that the Intended budget emissions levels in the non-traded sector are the starting point for our consideration of feasible emissions paths in the 2020s.

It is important to note, however, that this is not just an assumption but necessary to mitigate risks of meeting the fourth budget, as is clear from Figure 10. From the third Intended budget to the fourth Domestic Action budget would entail a feasible reduction of 13% over a five-year period: from the third Interim budget to the fourth Domestic Action budget would require a much more challenging 23% reduction.

We therefore recommend that government policy should be designed to ensure that emissions in the third budget period are in line with the Intended rather than Interim budget.

Ideally we would reflect this policy commitment in an immediate move to legislate the Intended budget. However, in practice, this could not be delivered without a tightening of the EU ETS cap (because this defines the net carbon account for the traded sector under the Climate Change Act). And it would in any case be highly desirable that any UK commitment to tighten the traded sector budget should be made in combination with similar tightening across Europe.



Therefore we recommend the following approach (Table 1):

- The Government should commit not to bank outperformance of the first carbon budget through to the second budget period.
- The Government and Parliament should adjust the second and third carbon budgets to reflect allowed non-traded sector emissions under the Intended budgets. With this adjustment the third carbon budget would require a 37% emissions reduction in 2020 relative to 1990 (versus 42% under the Intended budget for both the traded and non-traded sectors and 34% under the legislated Interim budget).
- A full move from the Interim to the Intended budget should be legislated in line with a tightening of the EU ETS cap, as and when this occurs.
- The Government should aim to deliver the Intended budget through domestic abatement in the non-traded sector, and through domestic abatement together with limited purchase of credits in the traded sector.

We reflect this approach in our fourth budget advice, which takes as its starting point a 37% emissions cut in 2020 consistent with delivery of our proposed tightened budget with no net credit purchase.

Table 1: Proposed tightening of second and third budgets to include Intended budget for non-traded sector

	Budget 1 (2008-2012)	Budget 2 (2013-2017)	Budget 3 (2018-2022)
Interim budget	3018	2782	2544
Interim traded	1233	1078	985
Interim non-traded	1785	1704	1559
Intended budget	3018	2679	2245
Intended traded	1233	1009	800
Intended non-traded	1785	1671	1445
Proposed tightened budget	3018	2749	2430
Interim traded	1233	1078	985
Intended non-traded	1785	1671	1445

Source: CCC analysis.

(ii) International aviation and shipping (IA&S)

We are required under the Climate Change Act to advise on inclusion of IA&S in the context of our advice on the fourth carbon budget.

As already discussed in Section 1, it is clear that these sectors need to be included within the overall UK target framework, and our recommendations for the fourth budget have been designed to be compatible with the UK achieving by 2050 a maximum emissions level of 160 MtCO₂e including the UK's contribution to IA&S emissions.

Our previous advice was however that these sectors should not be explicitly included in the first three carbon budgets. This was because of complexities around methodologies for inclusion and lack of progress towards an international deal in the case of shipping.

Since 2008 there has been progress in resolving methodological complexities (e.g. as regards accounting for international aviation in the EU ETS). However, further analysis is required to determine specific UK emissions projections for these sectors.

We therefore recommend that Government should accept the principle that IA&S emissions of CO₂ will be included in carbon budgets; further assessment is required in order to determine the appropriate approach to potentially significant non-CO₂ emissions and effects.

The Committee intends to make specific recommendations for limits on emissions from these sectors following completion of our shipping review in Autumn 2011. The second, third and fourth budgets recommended would then be adjusted to include IA&S by adding in emissions limits for these sectors to economy-wide budgets.

This is within the schedule set out in the Climate Change Act, which requires the Government to take a decision on inclusion before the end of 2012.

In this report we allow for IA&S by including these in the 2050 target; given limited scope for abatement in these sectors, this implies the need for deeper cuts in other sectors than would otherwise be the case.

5. Developing options for meeting the fourth budget: policy implications

A number of new policy approaches are required to develop options for meeting the fourth budget. These include power market reform, a carbon price underpin, support for technology development, and policies to drive emissions reductions through the first three carbon budgets (e.g. to encourage energy efficiency improvement). In some key areas, improvements to the evidence base are needed to inform design of new policies. We also draw out implications for EU policies and measures.

Reform of power market arrangements

To meet the indicative 2030 target, putting the UK on the path to 2050, it is essential radically to decarbonise power generation, cutting emissions intensity from today's level of around 500 gCO₂/kWh to around 50 gCO₂/kWh in 2030. This will require the addition of up to 40 GW of (baseload-equivalent) low-carbon plant during the 2020s, on top of the 30 GW (on a nameplate basis) needed over the decade 2010-2020.

Current market arrangements are unlikely to deliver required investments in low-carbon capacity on this scale and/or are likely to result in unnecessarily high electricity prices.

Tendering of long-term contracts (e.g. through low-carbon Contracts for Differences or Power Purchase Agreements) would provide confidence that required investments will be

forthcoming at least cost to the consumer, since they mitigate risks which energy companies are not well placed to manage.

Other mechanisms (e.g. reliance on a carbon price alone or extension of the current Renewables Obligation) would not provide confidence around delivery of required investments, and would involve unnecessarily high costs and electricity prices.

Given the need to decarbonise the power sector and the long lead times for low-carbon investments, reform of the current market arrangements to introduce a system of tendered long-term contracts is an urgent priority.

Our recommendations on power market reform are set out in more detail in Box 3.

Underpinning the carbon price

We have previously highlighted the importance of a robust carbon price in encouraging low-carbon investments. However, we have argued that the low and volatile carbon price generated in the EU ETS does not provide such a signal.

Our analysis in this report suggests that unless the EU ETS cap is tightened significantly, the carbon price in 2020 is likely to remain low relative to expectations before the recession. Latest estimates suggest a possible price of 30 euros per tonne in 2020 versus the 55 euros per tonne which we assumed for a 30% reduction target in the 2008 report.

To provide a stronger signal, there should ideally be a carbon price underpin (i.e. a guaranteed minimum price) at the EU level consistent with the required pathway to 2050 (e.g. reaching at least the EC's projected price of 30 euros, or around £27/tCO₂, in 2020 and rising through the 2020s to £70/tCO₂ in 2030).

In the absence of an EU underpin, a UK underpin (e.g. in the form of a carbon tax or a contract for difference) would strengthen incentives for low-carbon investments in power generation and more generally. It should be introduced subject to addressing competitiveness concerns in the energy-intensive sectors and affordability/fuel poverty concerns in the residential sector.

Box 3: Recommendations on power market reform

We recommend that tendering of long-term contracts for low-carbon capacity would provide most confidence about delivery of required investments, at least cost to the consumer. Other mechanisms (such as reliance on a higher carbon price alone or extension of the current Renewables Obligation) would not provide confidence about delivery of investments, and would involve unnecessarily high costs and electricity prices, delivering economic rents to some generators. These other mechanisms seek to compensate for high risk by providing subsidy; the optimal policy would instead reduce the risks which private operators currently face but are not well placed to manage relative to government or consumers.

There are five arguments underpinning this conclusion:

- **Rapid power sector decarbonisation will be needed to meet the fourth carbon budget.** A feasible path to 2050 requires early power sector decarbonisation and the large-scale deployment of low-carbon electricity in transport and heat sectors during the 2020s.
- **Risks under current arrangements are likely to limit investment in and increase the cost of low-carbon generating capacity.**
- **Faced with these adverse impacts, government policy can either seek to reduce risks, or subsidise to offset risks; the former strategy is the optimal one.**
 - Reducing risks is the optimal public strategy given that the private risks faced by investors do not correspond to the social risks of the investments, and can therefore be removed from the private sector by the Government at limited cost to itself or consumers. Lower electricity prices than in the subsidy strategy will result.
 - Analysis conducted for the Committee by Redpoint suggests that a strategy of reducing risks could lower the weighted average cost of capital up to 3 percentage points and could reduce the cost of decarbonising the power sector by around £5 billion annually by 2030.
- **Tendering of long-term contracts for low-carbon generation would allocate risks appropriately while providing the discipline of price competition, including allowing new players to enter the market. It would provide most confidence that required investments will be delivered at least cost to the consumer.**
 - The long-term contracts tendered could take a number of forms, including: (i) low-carbon Contracts for Differences around the fluctuating electricity wholesale price, which could preserve positive aspects of the existing market arrangements (e.g. providing incentives for appropriate location of wind farms and investment in system flexibility, and ensuring efficient dispatch), or (ii) Power Purchase Agreements/low-carbon tariffs in a separate low-carbon market.
- **Other mechanisms that rely on subsidy rather than risk reduction would not ensure a required scale of investment and would be unnecessarily expensive:**
 - Carbon price strengthening without long-term contracts would result in escalating electricity prices in line with the increasing cost of unabated gas-fired generation. Relying on carbon price strengthening alone could result in continued investment in unabated gas generation, and would deliver economic rents to low-carbon generators.
 - Extension of the current Renewables Obligation to cover all low-carbon generation may work, but at an unnecessary cost to electricity consumers, since the premium price paid to low-carbon generators would need to be high enough to compensate for the risks they would still face.
 - Capacity mechanisms applicable to all types of generation (whether high- or low-carbon) may have a useful complementary role to play in securing balancing and peaking capacity, but will not ensure a shift to low-carbon generation alone, and could result in inappropriately high levels of unabated gas generation in the system.

We therefore strongly recommend that a system of tendering for some form of long-term contract for low-carbon capacity is introduced. Relying on other mechanisms would reduce the likelihood of meeting carbon budgets and/or increase the net cost to society of meeting them.

Support for development of new technologies and markets

Feasibility and cost risks in meeting the fourth budget would be mitigated through Government support for development of key technology options including, but not restricted to:

- **CCS in power generation.** The current proposal to support four CCS power generation projects (in the Coalition Agreement, reconfirmed in the 2010 Spending Review), would result in a critical mass for potential roll-out from the early 2020s. It is important that a funding mechanism for the four projects is finalised and that these are tendered in 2011 to facilitate early deployment. Given the extent of decarbonisation required by 2030, and the possibility that future gas prices may be lower than seemed likely at the time of our 2008 report, CCS for gas as well as coal generation will be a crucial set of technologies. The Government's recent announcement that gas CCS will be included in the demonstration projects is therefore welcome.
- **Offshore wind.** Given the vast UK resource, this is a valuable option for power sector decarbonisation. Deployment in the 2020s could play a significant role in power decarbonisation; the appropriate scale will depend on cost reductions achieved in the period to 2020 and the pace of development and deployment of other technologies. We will consider offshore wind in detail in our renewable energy review, to be published in Spring 2011.
- **Electric vehicles.** We have previously estimated that government financial support of around £800 million will be required to fund purchase of electric cars in the period to 2020, with possible additional costs for funding investment in a battery charging network. Analysis in this report suggests that government funding of these initial costs is clearly justified since early development of the electric car option will reduce the costs of meeting later budgets (e.g. the present value cost saving through supporting early-stage market development for electric vehicles is over £5 billion in the period to 2050). Announced Government support of £400 million for ultra low-carbon vehicles over the Spending Review period could provide useful support for development of electric vehicles. Further funding is also likely to be required in the period to 2020 to ensure that this key technology option is developed and deployed. In addition further funding for hydrogen technology and infrastructure development is likely to be required.
- **Low-carbon heat.** Electric heat pumps and heat from bioenergy are potentially major contributors to required emissions cuts through the 2020s. In both cases, technologies are mature but not demonstrated in all relevant sectors in the UK context. Financial support and other policies to encourage take-up will therefore be required. The Renewable Heat Incentive (RHI) announced in the 2010 Spending Review could provide the required financial support. However, it is not clear whether this policy will provide appropriate incentives for energy efficiency improvement, or will address non-financial barriers to deployment; we will consider the RHI in detail in our renewable energy review, to be published in Spring 2011.

- **CCS in industry.** This is a major option for cutting emissions in heavy industry, especially in those applications where significant emissions result from chemical reactions as well as from fossil fuel combustion (e.g. iron and steel, cement). Without CCS, required cuts in industry emissions to 2050 will be very challenging. To ensure that this technology is available for deployment from the 2020s, a policy approach is required which either funds demonstration, or ensures that demonstration elsewhere (e.g. under the EU's CCS demonstration programme) will provide scope for timely deployment in the UK.
- **Aviation.** There is a need to develop new aviation technologies in order to help limit emissions in 2050 at 2005 levels. These include evolutionary innovations such as narrow body aircraft and open rotor engines, and more radical options such as blended wing aircraft. As set out in our July 2010 report *Building a low-carbon economy – the UK's innovation challenge*, the UK has strong capabilities in these areas, and public support for more radical options in cooperation with EU partners should be seriously considered.

New policies to deliver the first three carbon budgets

Achieving the fourth budget will only be feasible if the UK enters the 2020s with non-traded sector emissions in line with the Intended rather than Interim third budget. This will require the implementation of the emissions reduction measures which our 2008 report included within our 'Extended Ambition' scenario, achieving a step change in the underlying pace of reduction. New policies are required to drive this step change:

- **Energy efficiency improvement.** New approaches are required to address financial and non-financial barriers to energy efficiency improvement. The focus should be strengthening incentives in residential and SME sectors, and ensuring a coherent approach across all sectors given the current multiplicity of policy instruments (EU ETS, Climate Change Levy, Climate Change Agreements, Carbon Reduction Commitment, etc.).
- **Roll-out of smart meters.** This is planned for the period to 2020 and will be crucial in providing flexibility to respond to volatile power demand and intermittent supply. For example, smart meters together with time of day pricing would allow charging of electric vehicle batteries when there is spare power capacity on the system, and possibly allow these also to act as extra capacity at times of low system reserve margin.
- **Transport consumer behaviour change.** There is a low-cost opportunity for significant emissions reductions through roll-out of Smarter Choices policies which encourage rationalisation of car trips (e.g. through switching to public transport, car pooling). The £560 million announced in the 2010 Spending Review for a Sustainable Travel Fund should be designed in a way that would allow national roll-out of Smarter Choices, given its carbon and wider economic benefits.

- **Changing agricultural practices.** New approaches are required to support wider uptake of low-cost measures to reduce soils and livestock based emissions. The current industry-led approach, supported by action from retailers, and EU policies (e.g. the Nitrates Directive) should strengthen incentives for action. However, stronger levers may be required, particularly to deliver more expensive measures. The Government has committed to a review of the policy framework in 2012. This should include a full range of options to buttress the current voluntary approach.
- **Afforestation.** There is potential for significant emissions reduction over the next decades through afforestation. This is likely to require a planned rather than reactive approach. There are a range of options to implement a planned approach which should be considered now given the long lead time for afforestation.

Areas where further evidence is required

There are a number of abatement options in our scenarios where further evidence is required to inform policy development. Major areas include:

- **District heating.** Our analysis suggests that district heating using waste heat from low-carbon power generation could be very cost-effective and suitable for houses not well-suited to fitting heat pumps. The option to roll out district heating would be useful, but significant uncertainties over technical and economic aspects of this technology still need to be resolved.
- **Implications of vehicle battery charging for power networks.** Slow charging of electric vehicle batteries off-peak is attractive given that this uses spare low-carbon capacity, and minimises implications for investment in power networks. Analysis of trip data suggests that slow off-peak charging should be feasible for most drivers, given smart meters and time of day tariffs. However, precise implications of battery charging for power networks are uncertain, particularly as regards implications of a fast charging network to complement slow off-peak charging. As implications are better understood, these can be reflected in the regulatory regime for power networks (e.g. through license requirements to install fast charging points, and allowing investments to upgrade networks in the regulatory asset base).
- **Radical abatement options in industry.** Our high-level assessment has identified key options for decarbonising industry emissions including use of biomass, biogas and CCS. However, there are other promising options which we have not yet considered in detail including electrification, resource efficiency and product substitution (e.g. use of low-carbon construction materials such as wood rather than carbon-intensive cement and steel); such additional options are likely to be required in the context of the 2050 target, and may have a role to 2030.

- **Abatement options in agriculture.** There is considerable uncertainty around emissions and abatement potential in agriculture: this derives partly from incomplete scientific understanding, and partly from a lack of good information over current farming practice. This means that it is difficult to evaluate abatement opportunities as they relate to soils and livestock measures to be pursued over the next two decades, and to more radical options such as the use of genetically modified organisms (GM). Uncertainties should be resolved given that currently identified potential for reducing agriculture emissions is unlikely to be compatible with meeting the 2050 target.
- **Biofuels.** We have adopted a cautious approach to use of biofuels through the 2020s to reflect sustainability concerns, mainly relating to tensions between use of land for growth of biofuels feedstocks versus growth of food for a significantly increasing global population. There is a high degree of uncertainty over future levels of sustainable biofuels, which we will consider further in our bioenergy review in 2011.

These areas are priorities for development of the evidence base. We will work with Government to address them, drawing out any implications for design of new policies.

Implications for EU policies and measures

There is a set of policies that the UK Government should push for in Europe to set the EU on a cost-effective and credible path to its 2050 target, and which would reinforce UK action to meet the fourth carbon budget, including:

- Supporting the move to an EU 30% emissions reduction target in 2020 relative to 1990 levels.
- Agreeing an appropriate emissions reduction target for 2030 (e.g. around a 55% reduction relative to 1990).
- Tightening of the EU ETS emissions cap, both in 2020 and through the 2020s.
- Setting 2030 targets for new car and van emissions (e.g. around 50gCO₂/km for cars and 80gCO₂/km for vans).
- Reforming the EU Common Agricultural Policy, which is due for revision in 2013, so that it links subsidies and incentives to climate change mitigation objectives.
- Supporting technology development, particularly for CCS in industry.

6. Wider economic and social considerations and differences in national circumstances

The Climate Change Act requires that our budget advice includes consideration of six sets of wider economic and social issues:

- Macroeconomic impacts (e.g. costs and investment requirements),
- Fiscal impacts,
- Competitiveness impacts,
- Affordability/fuel poverty,
- Security of supply,
- National circumstances.

We considered these impacts in detail in our 2008 report, where we concluded that the various risks (e.g. for competitiveness, fuel poverty, security of supply) could be mitigated through available policy levers.

In this report, we update our earlier analysis, and consider high-level incremental impacts through the 2020s. We reach a similar set of conclusions to those in our first report: the budget can be achieved at a manageable economic cost; to the extent there are risks of adverse impacts, these can and should be mitigated through appropriate policy.

Macroeconomic impacts: costs and investment requirements

Based on detailed assessment of specific abatement options, we estimate that meeting the Domestic Action budget will cost under 1% of GDP in 2025 (i.e. the mid-year of the budget period), with additional costs of the order 0.1% of GDP for meeting the Global Offer budget.

The additional cost of meeting the Global Offer budget is the projected carbon price (£45/tCO₂) multiplied by possible credit purchase (around 30 MtCO₂); costs would be lower if credit purchase were to be substituted by lower-cost domestic abatement, but could be greater if the carbon price were higher than £45 per tonne, or if the Government chose to make a more ambitious commitment within global negotiations.

The main investment costs associated with delivering the Domestic Action budget relate to the power and heat sectors. These are larger than recent investment costs in the energy sector, but small relative to the investment ratio for the economy as a whole:

- The largest investment costs in the Medium abatement scenario relate to low-carbon power generation with, for example, average annual capital spend of around £10 billion over the period 2021 to 2030.
- Average annual investments in abatement technology in the industry sector would be around £1 billion.

- There will also be significant up-front costs in the buildings sector, which if financed via energy companies may also be considered as investment costs. These costs are around £6 billion annually in our Medium abatement scenario.
- There may be additional investment costs related to this scenario for rolling out a charging network for electric cars, and associated power distribution and transmission network strengthening.
- Total investment requirements are under 1% relative to GDP through the 2020s, relative to an investment ratio for the economy as a whole which was at around 19% of GDP before the recession.

New policies will be required to improve the investment climate for development and deployment of low-carbon technologies in power, heat and other sectors. In addition, a Green Investment Bank would provide focus and could address market failures in the financial sector, potentially mobilising new sources of funds for required investments.

Fiscal impacts

In our 2008 report we identified key fiscal impacts of meeting carbon budgets to 2020 as being increased auction revenues from the EU ETS, offset by decreasing revenues from fuel duty and Vehicle Excise Duty (VED). We concluded that to the extent there could be net negative impacts, these would be small enough to be manageable.

In this report we have extended the analysis to cover emission scenarios for the 2020s:

- The UK's EU ETS auction revenues should increase through the 2020s, potentially reaching £3 billion to £8.5 billion in 2030 depending on the level of allowance auctioning.
- Under the current structure of taxes, receipts from road fuel duty would fall, by around £3 billion in 2030 relative to our reference emissions projection, reflecting reduced fuel use from more efficient conventional vehicles and as more electric vehicles penetrate the fleet.
- With no change in duty categories, VED revenues (of up to £7 billion) would be virtually eliminated by 2030, reflecting the lower rates of duty currently attached to more efficient vehicles. This indicates the need to tighten VED banding in line with improving average efficiency to maintain incentives to purchase more efficient vehicles.

The order of magnitude of any fiscal impacts through the 2020s is likely to be small, and with adjusted VED banding and full auctioning of EU ETS allowances could be broadly neutral or even positive. To the extent that further rebalancing is necessary or desirable, there is a long lead time for this, with key options for raising revenue including introduction of new green taxes (e.g. a carbon price underpin, aviation taxes) and other taxes (e.g. congestion charging would have both environmental and economic benefits).

Competitiveness impacts

The assessment of competitiveness impacts in our 2008 report showed that there were risks of leakage for a limited number of sectors subject to a combination of high energy costs and significant exposure to international competition, accounting for less than 1% of GDP nationally, but significantly more at the local level. We argued that it would be important to address these impacts, as recognised by the EU in granting free allowances to firms in the EU ETS in sectors potentially subject to competitiveness risks.

If a global deal for the 2020s were to result in carbon constraints for some but not all countries, there would be the risk of leakage, particularly as regards energy-intensive industries. This could be addressed either through sectoral agreements or through the imposition of border carbon price levies, with the specific policy instrument to be determined as any competitiveness risks are better understood.

In the particular case of agriculture, whilst measures required over the next ten years are generally cost saving, some more expensive measures required through the 2020s and beyond could potentially have competitiveness impacts. Options to mitigate any impacts include EU-level policies, or unilateral UK downstream carbon taxes; these should be considered further as part of broader policy development for the agriculture sector.

Affordability/fuel poverty

In our 2008 report we suggested that meeting carbon budgets need not increase the number of households in fuel poverty, because the impact of higher energy prices in 2020 could be broadly offset by energy efficiency improvements.

Recent increases in energy prices have substantially added to the number of fuel poor and the Government's latest estimate is that there were 4.5 million fuel poor households in 2008, with a projection that this could rise further to 5.4 million in 2010. Therefore in 2020, it is likely that there would be significantly more households in fuel poverty than previously envisaged, although not as a consequence of meeting carbon budgets.

The range of policy levers for addressing fuel poverty to 2020 and beyond includes targeted installation of energy efficiency measures and some low-carbon heat options, and social tariffs/income transfers (e.g. winter heating allowance). In addition, introduction of new electricity market arrangements will have an important role, since electricity costs and prices will be higher without this.

With appropriate policies in place, meeting carbon budgets is compatible with significantly reducing the number of households in fuel poverty.

Security of supply

In our 2008 report we noted that carbon budgets will have an impact on two aspects of security of supply:

- **Technical security of supply (or reliability).** Potential issues related to increasing levels of intermittent power generation can be addressed through a range of flexibility options (e.g. demand response, interconnection, flexible generation) and the package of electricity market reforms (e.g. to incentivise back-up capacity).
- **Geopolitical and economic security of supply.** Increased low-carbon power generation and extension to other sectors will increase the diversity of energy supply and reduce vulnerability to supply interruption and price volatility.

On balance, therefore, negative security of supply impacts can be addressed, with net positive impacts ensuing through reduced exposure to the risk of supply interruption and price volatility associated with imported fuels.

National circumstances

There are significant opportunities for emissions reductions in each of the UK nations, with an important role for the devolved administrations in planning for and delivering deep emissions cuts through the 2020s:

- Much of the UK renewable electricity resource lies in the devolved administrations, with significant targets in place in Scotland, Wales and Northern Ireland to develop this potential.
- Agriculture forms a larger share of emissions in Scotland, Wales and Northern Ireland than the UK as a whole. Our analysis finds abatement potential in line with these shares for a range of soils and livestock measures.
- We also find significant abatement potential from low-carbon heat, insulation and energy efficiency measures, other options in carbon-intensive industries and transport (from both more efficient and ultra low-carbon vehicles and demand-side measures).

Combining these opportunities with our reference emissions projections for the devolved administrations suggests potential to reduce direct emissions by 48%, 36% and 49% respectively in Scotland, Wales and Northern Ireland by 2030 (relative to 2008). Achieving these reductions will require active policy support from the UK and devolved governments, given the balance of reserved and devolved powers.

The emissions path through the 2020s is of crucial importance in building a low-carbon economy. During this period there is scope for widespread deployment of low-carbon technologies including clean power generation, electric vehicles and low-carbon heat generation. Therefore there is an opportunity to build on the progress required under the first three carbon budgets, and accelerate the pace of emissions reduction from 2020 to 2030. The need for such an acceleration is reflected in our recommended budget. This is stretching but feasible, and can be delivered at a cost of under 1% of GDP. It will bring economic benefits to the UK and, with similar action in other developed countries, will mitigate risks of dangerous climate change. Given these benefits, we urge the Government and Parliament to legislate the proposed Domestic Action budget, and to put in place the policies required to ensure that that budget can be delivered.

7. Key findings

Reduction in UK greenhouse gas emissions by 2050 (relative to 1990 levels) required to limit the risks of dangerous climate change.

80%
by 2050



Emissions reduction in 2020 (relative to 1990) under our proposed tightening of second and third carbon budgets.

37%

Our proposed fourth budget for 2023-2027 – to be delivered through Domestic Action.

1950
MtCO₂e

Required reduction in emissions from today to 2030.

46%

Further required reduction in emissions from 2030-2050.

62%

The cost of meeting the fourth carbon budget and the 2030 target.

Under
1%
GDP