3. POSSIBLE UK PATH TO AN 80% REDUCTION: TECHNOLOGIES AND COSTS

In Chapter 1 we recommended that the UK's reasonable share of a global deal to cut emissions by 50% by 2050 would entail a cut in UK emissions (all sectors and all Kyoto GHGs) of 80% below 1990 levels by that date. Analysis suggests that cuts of this magnitude are technically feasible at an economic cost in 2050 in the range of 1 to 2% of GDP.

We have used the MARKAL model to conduct this analysis. The model (described in Box 2.1) incorporates assumptions on costs for a wide range of technologies and enables us to search for a least-cost optimisation path, and to investigate the implications for cost if a particular technology option (e.g. CCS) were not available as the base case assumes. The model covers CO_2 emissions for almost all sectors of the economy, but it does not cover international aviation nor non-CO_2 GHGs. Nor, as discussed in Chapter 8: *International Aviation and Shipping* and Chapter 9: *Non-CO_2 gases in agriculture, waste and industry*, do we have alternative sources which enable us to model emissions reduction in aviation or non-CO_2 with as much detail and certainty that is possible in the MARKAL model.

We therefore need to make assumptions about the scale of abatement which might be possible in those other sectors and gases. Figure 2.28 shows a reasonably cautious scenario, in which emissions from international aviation remain at the proposed allocation under Phase 3 of EU-ETS (5% below the average of 2004-06 emissions), shipping follows the same pattern, while non-CO_2 emissions fall by 70% relative to 1990 levels. It may be that these assumptions are pessimistic given the technology options discussed in Chapters 8 and 9, but if they were the limit of emissions reduction in these sectors, CO_2 emissions in non aviation would have to be cut by 89% against 1990 levels in order to achieve an overall GHG cut of 80%.

We have therefore used MARKAL to model the feasibility and the costs of scenarios for both 80% and 90% cuts in UK energy and industrial process CO_2 emissions. The 80% scenario represents a situation in which non-CO_2 and International Aviation and Shipping are able to contribute their full share to achieving the 80% overall target, while the 90% scenario represents a situation in which less can be achieved in these other sectors. We set out below:

(i) Possible technology paths

(ii) Possible costs of domestic action.

The potential reduction in costs which could be achieved via international trading are discussed in Section 4.

Acknowledgement
This report is Chapter 3 in Part I, Section 2 of the First Report of the Committee on Climate Change December 2008, " Buildinga low-carbon economy - the UK's contribution to tackling climate change "

Box 2.1 The MARKAL model

The analysis of pathways to, and costs of, meeting ambitious targets for CO_2 abatement over the period to 2050 has been undertaken using the UK MARKAL (MARKet ALlocation) model. MARKAL is a least-cost optimisation model of energy use, representing the entire energy system, from primary energy resources through to demands for energy services (e.g. passenger-kms driven). The model is rich in technological detail, both on costs and other characteristics such as lifetime and efficiency, with assumptions drawn from multiple sources and extensively peer-reviewed.

The model imposes a cap on overall CO_2 emissions, allowing trade-offs between abatement measures in different parts of the energy system (e.g. electricity generation, transport, heat) to be examined. The representation of entire energy chains allows the model to choose combinations of primary energy resources and technologies to minimise the cost of meeting energy service demands (e.g. using wind energy to generate electricity to power battery electric vehicles). Where constraints on primary energy (e.g. biomass) supply exist, insights can also be gained on the best use of this finite resource.

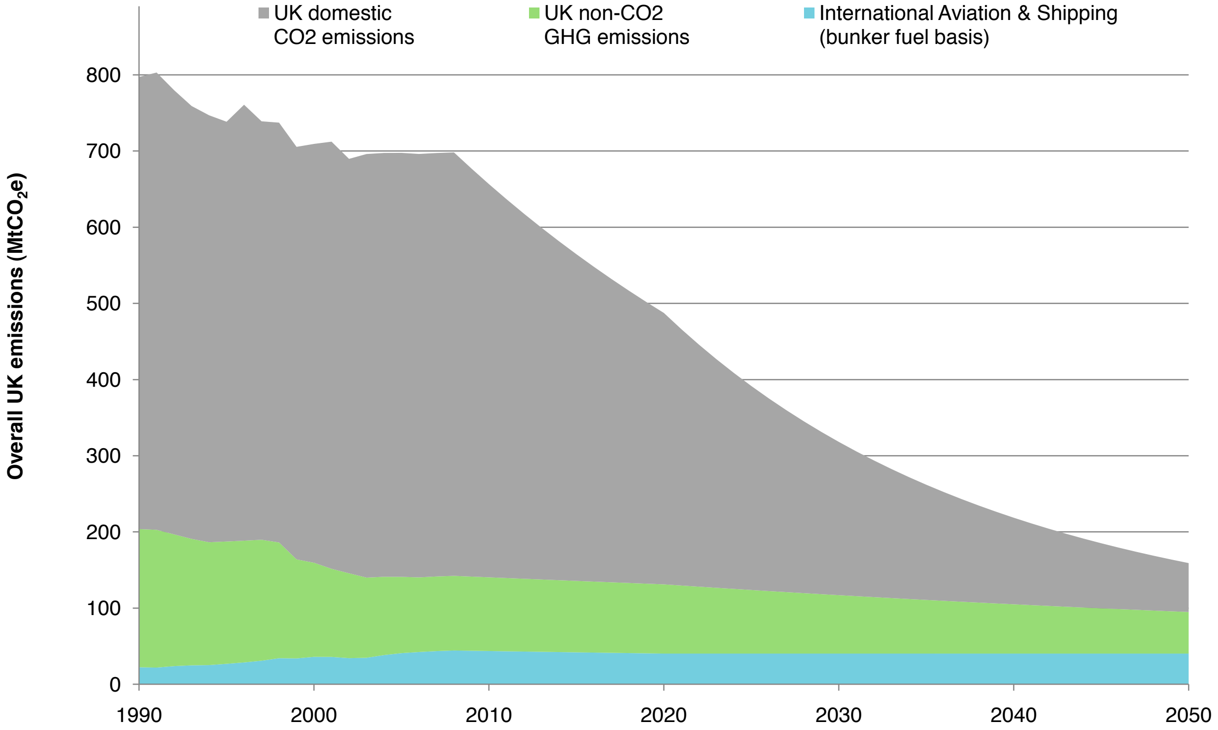
As an optimisation model, MARKAL's results represent the least-cost solution to meeting energy service demands under the emissions constraints imposed. Hence, it provides an indication of what could be achieved under optimal policy and decision-making; by definition, deviation from this optimal solution will tend to increase overall costs. As well as providing results regarding the total and marginal costs of meeting different emissions path, the model provides outputs that describe how the energy and transport systems might evolve, with regard to the technologies and fuels that would be used over the period to 2050.

MARKAL's optimisation implicitly assumes perfect foresight out to 2050. Clearly, such foresight is impossible, so we have not used the model to specify a precise path, but to establish that such a path can exist and how much it could cost. There are also limitations in MARKAL's representation of temporal and spatial variations in energy supply and use, implying that some scenarios will be more reliant on the increased flexibility in demand management discussed earlier in this chapter.

Multiple versions of MARKAL exist and it is used in many regions internationally. We have used the latest update to the UK MARKAL model: MARKAL Elastic Demand (MED). In MED demands for energy services are allowed to change in response to changes in costs of meeting them. In addition to the introduction of the Elastic Demand element, two further innovations were used in this modelling: the use of offset credits and emissions allowances in meeting abatement targets, to examine the importance of carbon trading in meeting targets; and the use of a two-stage optimisation, in order to limit the foresight of the model and gain insights into the implications of decisions in the period to 2020.

The modelling for CCC has been undertaken by AEA Energy & Environment, and reviewed by King's College London, who developed the UK MED version.

Figure 2.28 Implications for domestic UK CO_2 emissions to 2050 of achieving less than 80% reduction in other emissions categories



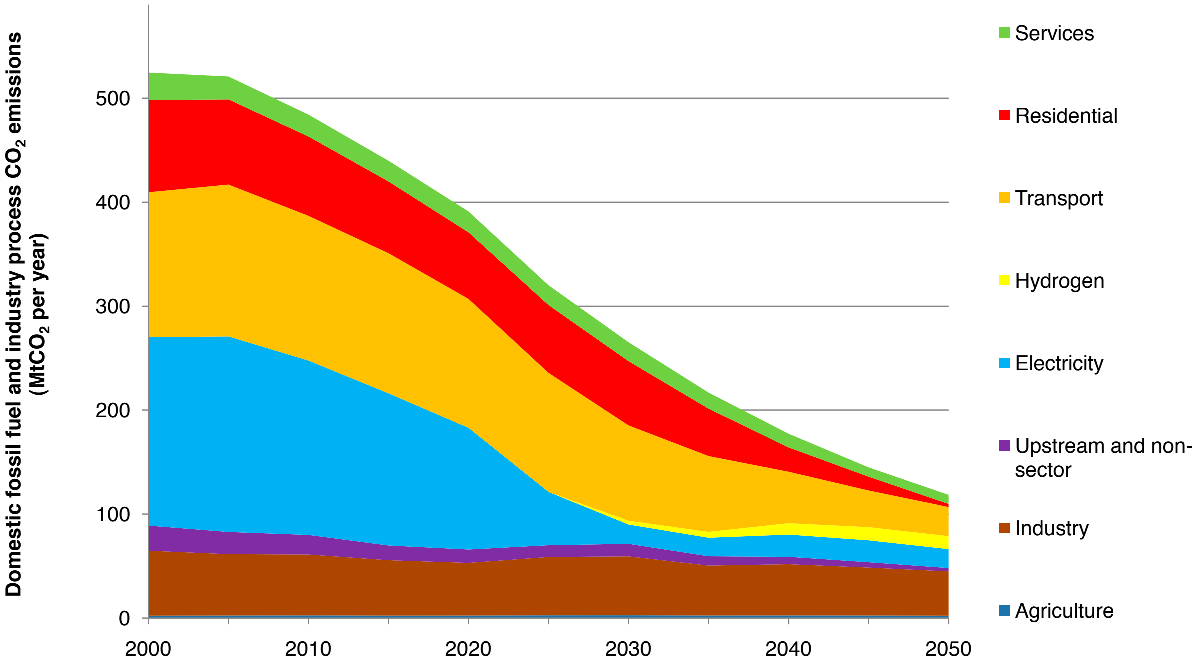
Source: NAEI and CCC calculations.

(i) Possible technology paths

Both the 80% reduction case and the 90% alternative illustrate the pattern which Section 1 (v) above suggested might be implied by the technology options available (Figures 2.29 and 2.30).

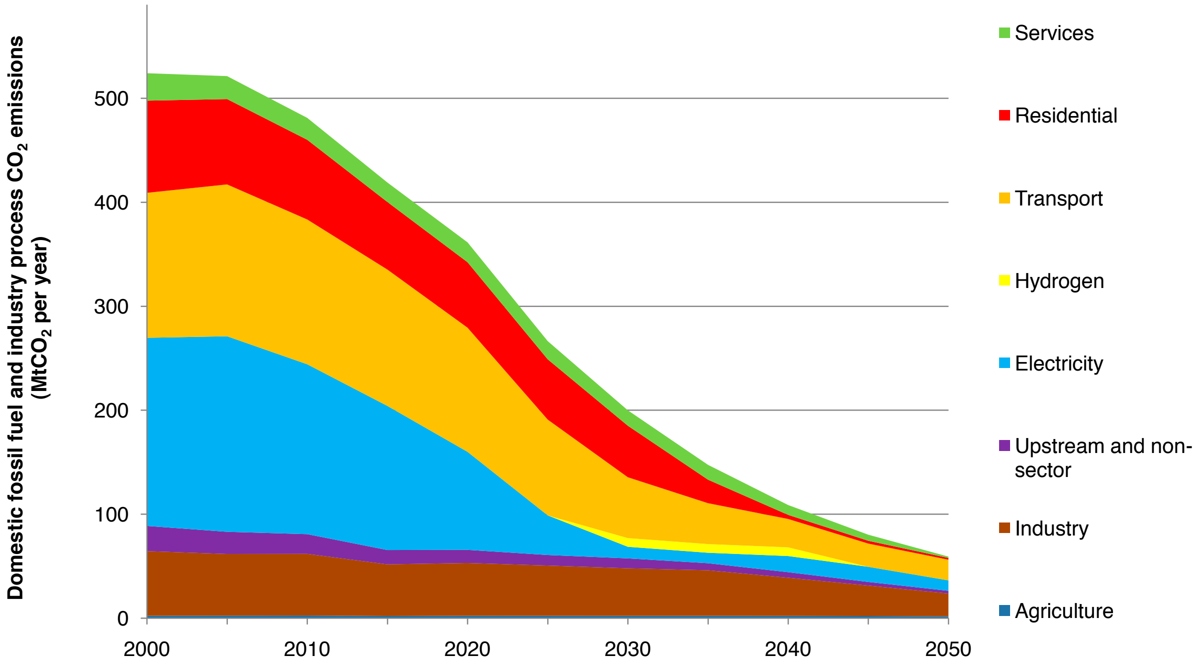
- In both scenarios the most dramatic early reduction occurs via the decarbonisation of electricity generation, which needs to be close to complete by 2030, with g/kWh below 70 by 2030 in the 80% scenario and below 40 in the 90% scenario (Figure 2.31), falling further to 35 and 20 respectively by 2050.
- Important early progress is also made in the residential sector via improvements in home insulation and improved efficiency of electrical appliances, lighting and ICT, and in the transport sector via the rapid improvements in the fuel efficiency of petrol and diesel vehicles.
- From the 2020s onwards, decarbonised electricity is increasingly used to drive further significant abatement in the car and light van subsectors of transport (via plug-in hybrid and battery electric vehicles) and in residential heat-related emissions.
- As a result electricity demand, having first been reduced through energy efficiency measures, is likely to increase significantly (Figure 2.32). If all technologies are available this additional electricity is supplied from a combination of nuclear, renewables (predominantly wind), and fossil fuel plants with CCS. This path implies very significant investment in new low-carbon generating capacity, and given that there are limits to the pace at which capacity can be added, provides a rationale for early action.

Figure 2.29 UK sectoral CO_2 emissions to 2050 on an 80% emissions reduction path (MARKAL)



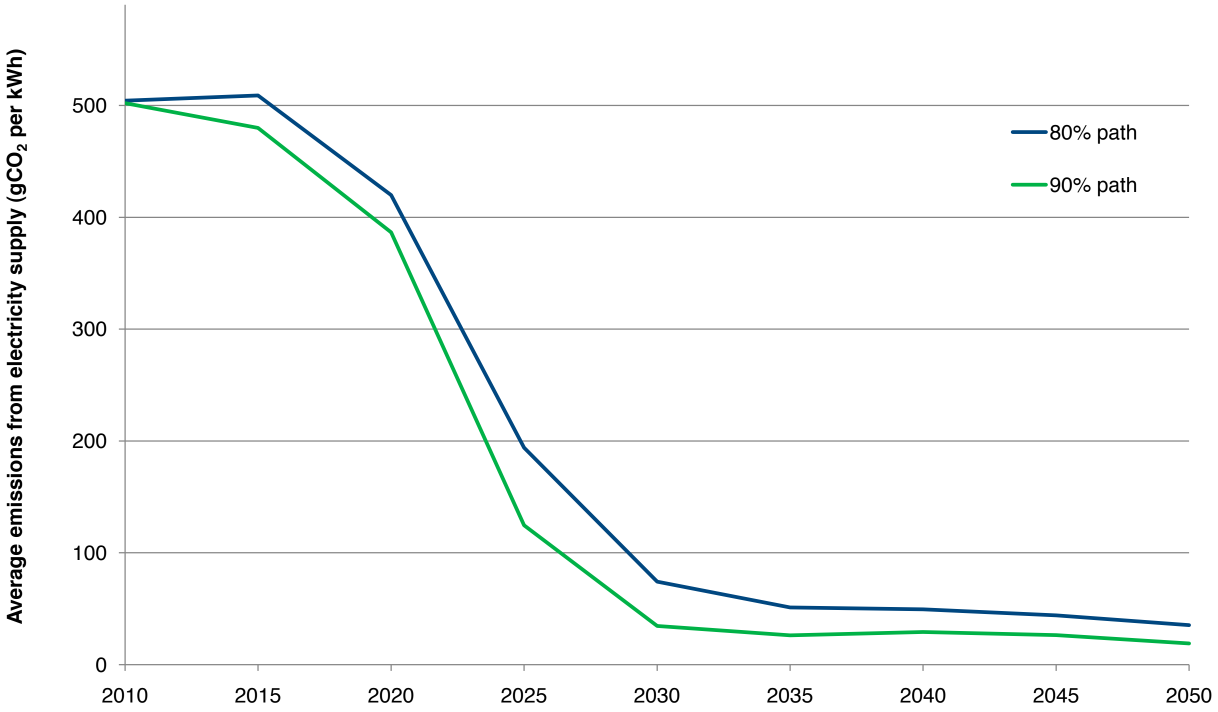
Source: MARKAL modelling based on CCC assumptions (2008).

Figure 2.30 UK sectoral CO_2 emissions to 2050 on a 90% emissions reduction path (MARKAL)



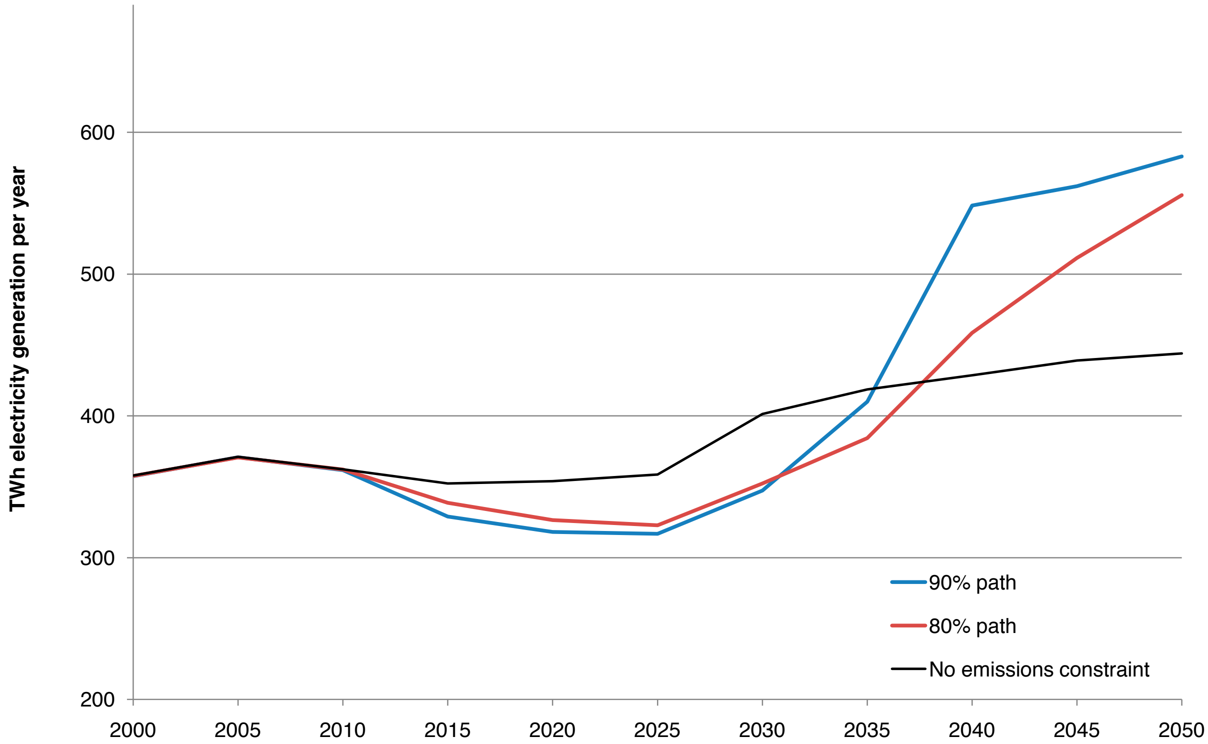
Source: MARKAL modelling based on CCC assumptions (2008).

Figure 2.31 Carbon-intensity of UK electricity generation under 80% and 90% emissions targets for 2050 (MARKAL)



Source: MARKAL modelling based on CCC assumptions (2008).

Figure 2.32 Aggregate generation under various emissions trajectories, 2000-2050 (MARKAL)

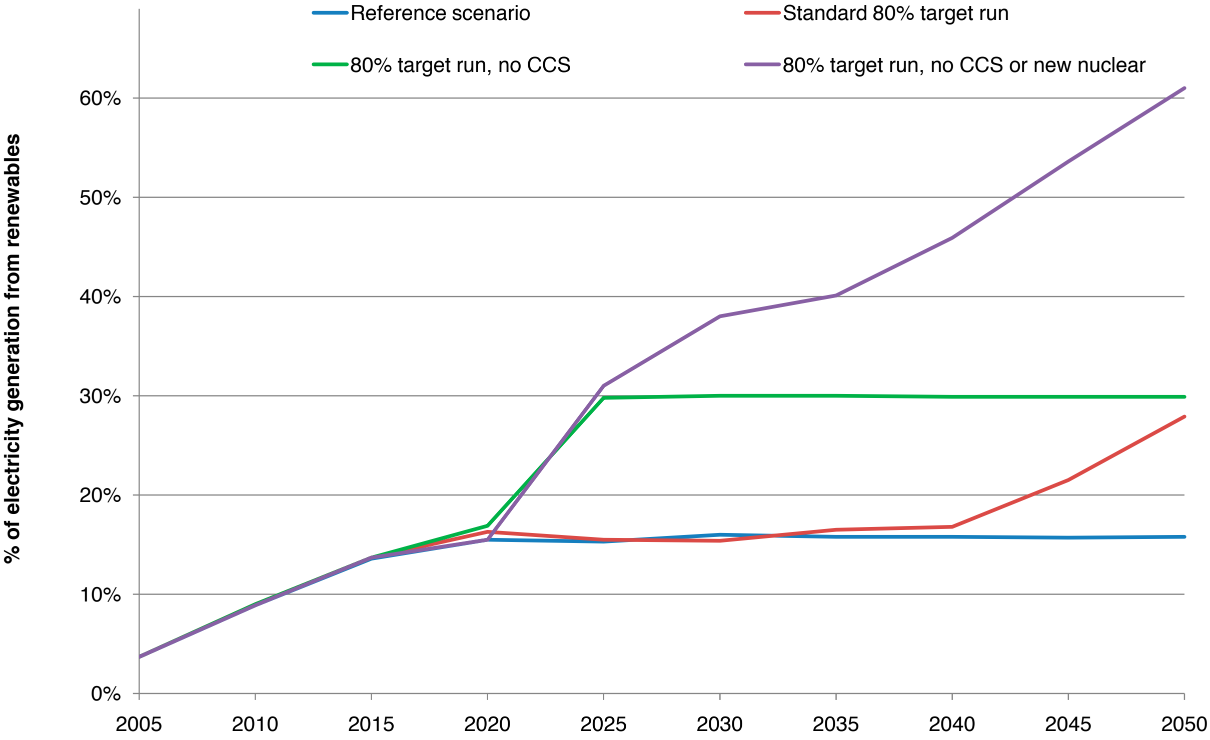


Source: MARKAL modelling based on CCC assumptions (2008).

The model also enables us to consider what might happen if key technologies were not available or if society chose not to deploy them.

- CCS is currently not a proven technology at full commercial scale. If it were unavailable at reasonable cost, the MARKAL model suggests that a huge expansion of nuclear power would be the least-cost option, but that renewables would also need to expand to 30% of supply by 2025 (Figure 2.33).
- If nuclear as well as CCS were not available, the model suggests that 80% or even 90% reductions would still be attainable, but at substantial additional cost, and with greater energy demand reduction (either price-induced or via life-style change).

Figure 2.33 Proportion of electricity generation coming from renewable sources under different scenarios, 2005-2050 (MARKAL)



Source: MARKAL modelling based on CCC assumptions (2008).

And it allows us to understand the consequences of choosing to invest in particular technologies:

- The Government has committed to an EU target that the UK will produce 15% of all its energy from renewable energy sources. Meeting this target is likely to require that 30% or more of total electricity generation comes from renewable sources in 2020, because the heat and transport sectors are less well placed to contribute to achieving this target. We have modelled a situation where there is 32% renewable electricity from 2020. In this scenario, MARKAL suggests that although there is a modest cost premium in the 2010s to achieve the CO_2 targets with this higher level of renewables, this does not add significantly to the costs of meeting longer-term emissions targets.

- We have also modelled a situation where there is significant investment in conventional coal-fired technology in the period to 2020, and where this cannot subsequently be retrofitted with CCS technology. MARKAL suggests that beyond 2020, this new-build coal plant is marginalised in the electricity system and is not dispatched at all beyond 2030. It is cheaper to strand this plant and to invest in new low-carbon capacity. The implication is that there is a very limited role for conventional coal-fired generation, and that the only rationale for adding conventional coal-fired capacity in the period to 2020 can be with a view to this being retrofitted with CCS.

Finally, the model enables us to consider the difference between 80% and 90% reductions in domestic CO_2 emissions. While the patterns of abatement are broadly similar, the key differences are:

- The model suggests that a 90% emissions reduction is achievable, but requires earlier and deeper progress in the reduction of power sector emissions and the earlier application of electricity to reduce emissions in the transport and heat sectors.

- Apart from its use in CCS power plants, natural gas features less in the 90% scenario, being displaced by lower-carbon options in power generation (nuclear and renewables), heat supply (biomass and low-carbon electricity) and hydrogen production (low-carbon electricity).

- Moving from an 80% to 90% abatement scenario, there is a reduction in the demand for energy services in response to a higher marginal cost of abatement and implied carbon price.

These technology paths should only be considered as indicative, with precise paths to be chosen in the light of evolving technological possibilities and costs, and of the availability of policy levers which can drive different categories of energy efficiency and new energy source deployment. Practical issues relating to the availability of policy levers are considered in Chapter 3 when we look at appropriate 2020 targets and in Chapters 5 to 7 which look at specific sectors.

But the two key conclusions can be drawn: first that 80% to 90% cuts in domestic CO_2 emissions are feasible: second that the radical decarbonisation of the electricity generation by 2030 is vital. There are no feasible scenarios which assume a more than trivial level of conventional (non CCS) fossil fuel plant on the system after the mid 2020s.

(ii) Possible costs

MARKAL modelling suggests that a reduction of 80% or more in domestic CO_2 emissions is feasible at manageable economic cost, even if no international emissions trading is possible.

- Our central scenario is based on oil, gas and coal prices from the Department of Energy and Climate Change (DECC) central fossil fuel price scenario[64], representing a world in which the global oil price is in the range $65-75 per barrel in real terms out to 2030.

- In our analysis of costs we have constrained the model not only to achieve various levels of reduction by 2050, but also to achieve various intermediate levels of reduction. This informs our Chapter 3 discussion of the appropriate budgets for the first three budget periods. The analysis suggests that a reduction of 80% to 90% in domestic CO_2 emissions by 2050 might reduce 2050 GDP by between 1% and 1.5% versus the MARKAL reference case.

- These estimated costs do not increase significantly if CCS is not available, with the model assuming that cost-competitive nuclear power can expand instead. But the costs do increase significantly if neither CCS or nuclear are available, reaching 2% of GDP in the 80% target case, but 3% in the 90% case.

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[64] Update to present the latest fossil fuel price assumptions following the January 2008 Call for Evidence. DECC, May 2008.

- In the high-high fossil fuel price scenario, which sees the oil price rise to $150 per barrel in real terms by 2015 and stay at that level thereafter, estimated costs of meeting emissions reduction targets fall as cost penalties of low-carbon technologies are eroded.

- These costs do not, however, cover emissions from international aviation and shipping or of non-CO_2 GHGs. Analysis of these sectors is at a less detailed stage but initial results suggest that the overall 80% target could be met at a cost of around 1.7% of GDP in 2050[65]. This is within the range of global estimates produced by the IEA, when we make allowance for non-CO_2 abatement.

Our conclusion is therefore that our recommendation for an 80% cut in the UK's GHG emissions below 1990 levels by 2050 is achievable at a relatively small cost to GDP, and that costs can be appreciably reduced by keeping all technology options for electricity generation open: renewables, nuclear and CCS.

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[65] Based on MARKAL results of runs including international aviation and assuming that abatement in sectors not covered can be undertaken at a similar average cost.