Chapter 9

POSSIBLE UK ENERGY BALANCES IN 2050

Can the UK make very large reductions in carbon dioxide emissions over the next 50 years without unacceptable effects on the quality of life of its population? What are the options for supplying given levels of demand for energy without adding to the greenhouse effect, and what are their implications?

9.1 We have recommended that the UK should promote the principle of contraction and convergence as the basis for a future global agreement to counter the threat of climate change (4.69). We have assumed that such agreements will have the objective of limiting the concentration of carbon dioxide in the global atmosphere to not more than twice the pre-industrial level, that is, to not more than 550 ppmv, and that they will be based on convergence by 2050 on a common figure for carbon dioxide emissions per head. If so, the requirement on the UK might be to reduce its present level of carbon dioxide emissions by almost 60% by 2050 and by almost 80% by 2100 (table 4.1). In this chapter we examine the practicability of a reduction of 60% in UK carbon dioxide emissions over the next 50 years, drawing on the analysis in previous chapters. We outline and discuss four illustrative scenarios that would reduce carbon dioxide emissions by about 60% (9.9-9.26), and consider what impacts they would have on the environment in other respects, certain common difficulties they present (9.27-9.29) and what can be said about their relative cost (9.30-9.34). We conclude this chapter by identifying the nature of the questions that consideration of such scenarios raises for UK policies (9.35-9.42). We go on to discuss those questions in the final chapter of our report.

9.2 If the UK's carbon dioxide emissions had to be reduced to the extent entailed by acceptance of the contraction and convergence principle, are scenarios possible in which the supply of energy will be sufficient to meet demand?

9.3 Four scenarios were constructed for meeting energy demand in 2050, while reducing carbon dioxide emissions by about 60% from their level in 1997 (the most recent year for which final estimates are available). They differ in three main respects: the assumed demands for energy, the use made of renewable energy sources, and whether there is a baseload capacity provided either by nuclear power or by fossil fuel stations at which the carbon dioxide is recovered and disposed of. Their key features are in box 9A and a fuller description in appendix E. We emphasise that these scenarios are illustrative, and designed to highlight the nature of the choices available for the UK.

9.4 For all combustion processes, whatever the fuel used, we envisage advanced techniques would be applied to protect air quality. We likewise envisage that installations of other kinds would be designed, built and operated to high standards so as to limit the damage they cause to the environment and the risks they present. Alongside benefits in reduced carbon dioxide emissions however, exploitation of any alternative energy source would have some impact on the environment and give rise to some direct or indirect risks, as chapter 7 showed.

9.5 One aim in examining possible energy balances was to assess the types, sizes and numbers of installations required to supply energy under different scenarios. The full results are in appendix E. If nuclear power is retained, as it might be in two scenarios, large numbers of nuclear power stations would have to be constructed on new sites. All four scenarios involve a very large expansion of renewable energy sources. The contributions that can be obtained from any energy source in practice, including fossil fuels, will depend on approval being obtained for each of the necessary installations.

9.6 The contributions the UK can obtain from particular renewable sources will also depend on the development of technology that can exploit the energy sources physically available without excessive cost. To quantify the energy that might be obtained cost-effectively in the middle of the 21st century, use was made in the case of most renewable sources of the Energy Technology Support Unit's recent estimates (table 7.1) of the amount of energy that could be available in 2025 at a cost of less than 7p/kWh (calculated using an 8% discount rate), after taking into account specified constraints on the siting of installations. The main exceptions are that some scenarios include a Severn Barrage and, for reasons explained in appendix E, some include much larger contributions from photovoltaic panels than would be indicated by ETSU's assessment. We return to the cost of the scenarios later in this chapter.

9.7 In all these scenarios fossil fuels still represent a major source of energy for the UK. To simplify, it was assumed oil would be the sole primary energy source for transport. A proportion of the fossil fuels available has to be reserved to meet periodic shortfalls in the supply of electricity (9.28). Beyond that, the preferred uses for fossil fuels are the provision of high-grade heat and micro-scale combined heat and power plants supplying low-grade heat and electricity. Even with use of fossil fuels for these purposes (to varying degrees in different scenarios) carbon dioxide emissions are reduced by 60% from their 1997 level, except in the first scenario where the reduction is only 57%. We also took into account the possibility that the recovery of carbon dioxide produced at power stations and its subsequent disposal in geological strata might allow continued use of fossil fuels on a much larger scale while still reducing carbon dioxide emissions to the atmosphere to the extent indicated. As indicated previously (8.31) we would see such stations as baseload stations supplying only electricity, and they therefore appear in the scenarios as a direct alternative to nuclear power stations.

Four illustrative scenarios

9.8 We now examine each of the four scenarios in turn. We emphasise that their contents do not represent a view on our part about what mix of alternative energy sources, including what combination of renewable sources, would be the most desirable in environmental or other terms in 2050, still less a prediction about which energy sources will in the event be in use by that date and on what scales. The intention is to throw light on the broad potential of different approaches and on how they relate to each other.

9.9 The distinctive feature of ***scenario 1*** is a higher demand for energy than in the other three scenarios: final demand in 2050 remains at the 1998 level in all four categories (low-grade and high-grade heat, transport, electricity). Stabilisation, however, represents a change from previous trends. For if final energy demand were to continue to rise by just over 0.5% a year – the mean rate over the last 40 and 10 years[1] – it would be 30% higher in 2050 than it is now. The DTI's latest energy projections show final energy demand rising by 0.9% a year between 1998 and 2010 (figure 6-I).[2]

BOX 9A — FOUR SCENARIOS FOR 2050

Four scenarios were constructed to illustrate the options available for balancing demand and supply for energy in the middle of the 21st century if the UK has to reduce carbon dioxide emissions from the burning of fossil fuels by 60%:

scenario 1: no increase on 1998 demand, combination of renewables and *either* nuclear power stations *or* large fossil fuel power stations at which carbon dioxide is recovered and disposed of

scenario 2: demand reductions, renewables (no nuclear power stations or routine use of large fossil fuel power stations)

scenario 3: demand reductions, combination of renewables and *either* nuclear power stations *or* large fossil fuel power stations at which carbon dioxide is recovered and disposed of

scenario 4: very large demand reductions. renewables (no nuclear power stations or routine use of large fossil fuel power stations).

The key parameters for these four scenarios are as follows:

	scenario 1	scenario 2	scenario 3	scenario 4
percentage reduction in 1997 carbon dioxide emissions	57	60	60	60
DEMAND (%)				
reduction from 1998 final consumption				
low-grade heat	0	50	50	66
high-grade heat	0	25	25	33
electricity	0	25	25	33
transport	0	25	25	33
total	**0**	**36**	**36**	**47**
SUPPLY (GW)				
annual average rate				
fossil fuels	106	106	106	106
intermittent renewables	34	26	16	16
other renewables	19	19	9	4
baseload stations (either nuclear or fossil fuel with carbon dioxide recovery)	52	0	19	0

A more detailed description of the scenarios is given in appendix F, which also describes the methodology used to construct them.

9.10 In chapter 6 we found that if the economic potential for energy saving was fulfilled – that is, if consumers took up cost-effective energy saving measures – demand would *fall* by between 2–15% below its 1998 level by 2010. We also noted the tendency for new opportunities for cost-effective energy saving measures to arise as existing ones were taken up (6.134-6.135). We conclude that a long-term stabilisation of demand, as envisaged in scenario 1, would require changes in energy policy but these need not be massive nor disruptive. We envisage that the real prices consumers had to pay for energy would have to rise gradually over this period. The replacement of the housing stock could continue at about its current low rate, although major energy efficiency improvements would have to be made to 19th and 20th century housing. The use of private cars and the quantity of air travel might conceivably be higher than today's levels in this scenario, with substantial improvements in the efficiency of vehicles and aircraft offsetting the growth in traffic. Most cars would run on fuel cells, with the hydrogen derived from oil or gas.

9.11 Meeting demand for energy on that scale, while also reducing carbon dioxide emissions by 60%, requires either a contribution from nuclear power that is more than four times as large as at present or an equivalent contribution from fossil fuel stations at which carbon dioxide is recovered. It also requires the largest contribution in any of the scenarios from renewable sources, a more than 20-fold increase from the present output of about 2.3 GW. Because the requirements for transport, high-grade heat and back-up plants pre-empt the fossil fuels available, most of the demand for low-grade heat in this scenario has to be met by electricity, half of that through use of heat pumps.

9.12 By 2050 all the present nuclear power stations will have long since closed. The required capacity of nuclear power in scenario 1 is equivalent to 46 of the UK's most recent nuclear power station (Sizewell B). That would involve developing a number of new sites, as well as constructing one or more new stations on the sites of previous stations. Some of the new stations might be based on groups of smaller reactors rather than a single large reactor. Alternatively, a similar number of fossil fuel power stations might be constructed with equipment for recovering carbon dioxide and transferring it to underground strata.

9.13 If energy supplied as heat is taken into account as well as energy supplied as electricity, the largest contribution from renewable sources comes from hundreds, or possibly thousands of small combined heat and power (CHP) plants located in or near urban areas and connected to district heating networks that have been constructed. These are fuelled by a combination of fast-growing crops cultivated for that purpose (probably short rotation coppice) and wastes from other agricultural and forestry operations. There is a significant increase in traffic in the areas around these plants, although building small plants supplied from their immediate vicinity would minimise the impact. On the basis of present productivity, cultivation of energy crops on the scale assumed would take up some 15% of the UK's present farmland area. Municipal solid waste is also burned in CHP plants (probably larger in size), and the environmental issues raised by that are broadly similar.

9.14 Almost as large a contribution comes from generating plants offshore. Almost 200 wind farms a kilometre or more out to sea, each with 100 turbines, exploit wind energy. There are some 7,500 small wave power devices in the stormiest seas where the depth of water exceeds 40m; and in the strongest tidal currents in shallower waters within a few kilometres of the coast a score of tidal stream farms, each with at least a dozen turbines. These latter installations have only a small visual impact; but offshore wind turbines are visible on the horizon from much of the UK coastline. It may be possible to combine at least two of these technologies in a single installation. As most of the offshore energy resource is remote from centres of demand, lengthy new high-voltage transmission lines are necessary. It is assumed that a barrage has also been built across the Severn Estuary.

9.15 Another large contribution comes from electricity generated by photovoltaic panels. These cover many large flat roofs, the south-facing side of most pitched roofs on houses and the upper parts of the south-facing walls of multi-storey office buildings.

9.16 The fourth largest renewable source is onshore wind, which provides 65 times as much electricity as it does today. Wind farms cover 2,000 km^2, slightly under 1% of the UK land area. On the assumption they would not have been permitted in areas designated for natural beauty or importance to wildlife, they occupy 10% of the remaining areas with the highest wind speeds, predominantly near coasts or on higher ground, and are visible from almost everywhere in those areas. A minor source, small water power schemes, has expanded 13-fold, through installation of several thousand turbines on rivers and streams throughout the UK.

9.17 ***Scenarios 2 and 3*** are based on an alternative assumption about energy demand: that there can be an overall reduction in final demand to 36% below the 1998 level over the next half century, with the largest reduction in demand for low-grade heat. Final energy demand, in these two scenarios, is 50% of what it would have been in 2050 had the trends of previous decades continued (9.9).

9.18 We envisage this degree of demand reduction being achieved by a sustained and vigorous implementation of the full range of policies discussed in chapter 6. The real price of energy would have been raised gradually but substantially through taxation, with much of the revenues spent on supporting energy efficiency improvements. Growth in road traffic and air travel would have stabilised in the early decades of the century and then fallen slightly. As in the first scenario, fuel cells have replaced the internal combustion engine in road vehicles. A much larger share of journeys is made by public transport than is the case today and the rapid growth in personal mobility which characterised the second half of the 20th century has ceased, partly as a result of the expansion in electronic communication. A large proportion of the population work from home, or in workplaces close to their homes.

9.19 There has been major restructuring of the UK's urban fabric. The rate at which the housing stock is replaced has accelerated and energy-efficient dwellings have taken the place of many of those built in the 19th and 20th centuries. As in our first scenario, heat distribution networks supplied by CHP stations and heat pumps are found in most towns and cities. Manufacturing industry has undergone radical improvements in resource as well as energy efficiency, with very low quantities of waste materials.

9.20 In ***scenario 2*** this lower level of demand is met by a combination of renewable sources and fossil fuels, without any use of either nuclear power or recovery and disposal of carbon dioxide. That entails large-scale development of renewable sources, but not quite on the extent of scenario 1 because demand is so much lower. In ***scenario 3*** the same demand is met by obtaining equal amounts of electricity from renewable sources and from either nuclear power or fossil fuel stations at which carbon dioxide is recovered and disposed of.

9.21 Scenario 2 would require a 20-fold increase, to 45 GW, in the energy obtained from renewable sources. The installations required and their environmental impacts are for most sources the same as in scenario 1, and the same area of land is required for growing energy crops. There are only half as many onshore wind turbines as in scenario 1 and only half as much electricity is obtained from photovoltaics.

9.22 In ***scenario 3*** a similar amount of energy in total is supplied by a smaller portfolio of renewable sources and the equivalent of 19 Sizewell B power stations (or alternatively a similar number of fossil fuel power stations of similar size with equipment for recovering carbon dioxide and transferring it to underground strata). There is no Severn Barrage, and sharply reduced contributions from the onshore renewable sources that would have the most obvious visual impact. Electricity and heat obtained from energy crops total less than 2 GW, and only about 2% of UK farmland would be required for growing short rotation coppice or other suitable crops. The average annual output from photovoltaic panels is only 0.5 GW, as against 5 GW in scenario 2, and output from onshore wind turbines is only slightly higher than at present, at 0.2 GW; onshore wind farms remain a fairly rare sight, confined to a few coastal and upland areas. Municipal waste is not used as an energy source, and alternative methods would have to be found for dealing with it without causing environmental damage. Offshore energy sources (wind, wave and tidal stream) are used on the same extensive scale as in scenarios 1 and 2, as are agricultural and forestry wastes.

9.23 Because of the much smaller use of energy crops in scenario 3, and the elimination of municipal waste as an energy source, the number of CHP plants is reduced very considerably. In both scenario 2 and scenario 3 a substantial proportion of the requirement for low-grade heat has to be met by electricity (half of that through use of heat pumps), but a higher proportion in scenario 3.

9.24 ***Scenario 4*** shows the implications for energy supply if an even larger reduction in final demand for energy could be achieved over the next half century. It is assumed that the requirement for low-grade heat has been reduced to one-third the present level by 2050 and the requirements for energy in other forms to two-thirds of the present level. That represents an overall reduction of 47% in final demand from the 1997 level, or a 59% reduction from what final energy demand would have been in 2050 if current trends had continued.

9.25 There is no nuclear power in this scenario, nor recovery and disposal of carbon dioxide. Nevertheless the very large reductions in demand mean that the total energy supplied by renewable sources (20 GW) is much less than in scenario 1 (or scenario 2) and somewhat less than in scenario 3. The outputs from energy crops and photovoltaic panels, and therefore the associated environmental impacts, are at the same modest levels as in scenario 3. For onshore and offshore wind the contributions are half those incorporated in scenario 1, with a corresponding reduction in the visual impact of wind turbines. No energy is supplied by municipal waste incineration and there is a lower output from agricultural and forestry wastes and from small-scale hydro. It is assumed that a Severn Barrage has been constructed; wave power and tidal streams contribute the same amounts of energy as in the other scenarios. The requirement for new high-voltage transmission lines still remains.

9.26 This fourth scenario provides a way of making deep cuts in carbon dioxide emissions while limiting the environmental impact of alternative energy sources. It is difficult to see how energy demand reductions on this scale could be achieved; they would involve even more far-reaching changes than in scenarios 2 and 3. There might have to be some reduction, or redefinition, of living standards. That has to be weighed against the substantially smaller capacity of energy installations that would be required.

Common features of scenarios

9.27 In all four scenarios difficulties are created by the assumed nature of the electricity networks. One difficulty, identified previously, arises from the intermittent nature of the renewable energy sources that would be used to generate electricity. The other difficulty is created by the large short-term variations in demand for electricity (see figures 8-I and 8-II). In none of the scenarios would the generating plants required to supply average demand over the year be capable of meeting the winter peak demand for electricity. Nor could they readily be expanded to do so.

9.28 The solution adopted in order to make the scenarios workable is to assume that very large capacities of fossil fuel generating plants would be available both to meet periodic shortfalls in the supply of electricity from renewable sources and to meet peak demands. Plant designated for one of those roles could not be assumed to be available for the other. Although the aggregate capacity of these plants would be very large indeed they would be used rather infrequently. The addition to carbon dioxide emissions from this cause would not therefore be large. The plant capacities in each scenario and the amounts of energy that would have to be obtained for this purpose from fossil fuels are shown in appendix E (table E.6). The reduction in carbon dioxide emissions shown for each scenario takes into account the use of gas to fuel these plants; that was treated as the first call on use of fossil fuels, after transport. If some of these plants were fuelled with coal rather than gas, carbon dioxide emissions would be higher (table E.7).

9.29 The need for these back-up and peak-lopping plants arises from the lack of a method for storing the output from generating plants. It is implausible that in practice there would be such an enormous capacity of infrequently used plant. The alternatives would be to devise ways of influencing demand, so that the peaks in winter demand for electricity could be smoothed out, or to develop new technologies that would allow electricity to be stored on a massive scale at an acceptable cost. In the latter case full advantage could be taken of renewable energy sources at times when they are able to deliver their full output but the demand for electricity is relatively low. Possible candidates for a new storage technology were discussed in chapter 8.

Electricity costs in scenarios

9.30 The plausibility of any scenario depends to some extent on the scale of the costs involved in implementing it. The present costs of generating electricity from a given source can be ascertained for those technologies that are already in use on a commercial scale. A combined cycle gas turbine supplies electricity at about 2 p/kWh.[3] The cost of electricity from a new nuclear power station was estimated in 1993 as 2.9 p/kWh.[4] The cost of electricity from onshore wind farms has fallen over successive NFFO rounds to 2.9 p/kWh. These figures represent direct costs (including, in the case of nuclear power an allowance for decommissioning and waste management), but do not include external costs.

9.31 Over a time-scale as long as half a century estimates of the costs of different ways of generating electricity can at best be made in terms of orders of magnitude. There are uncertainties about the long-term trend in the prices of fossil fuels on global markets. The most recent scenarios for global emissions discussed in part I of this report (2.22 and figure 2-VII) show fossil fuel use increasing globally for at least the next half century. While reserves would not have been exhausted, oil and gas production might increasingly be confined to a few regions of the world, with possible implications for price, availability and security. As the more easily exploited resources are exhausted, the cost of production is also likely to rise. On the other hand, if carbon-free technologies are taken up extensively, the demand for, and price of, fossil fuels will fall, thus lowering the cost of their use to generate electricity.

9.32 Progress in reducing the costs of carbon-free technologies for electricity generation will depend on the efforts devoted to developing them and the scale on which they are taken up. For most technologies it is likely to be the overall scale of their development globally that will the most important factor affecting their future cost. Within the UK however another important factor will be the characteristics of the locations in which they are deployed; the larger the contribution they are expected to provide, the greater the need to use less promising locations, thus raising the cost of the energy obtained.

9.33 For most renewable sources the maximum resource incorporated in the four scenarios is what ETSU has estimated could be available for electricity generation in 2025 at a cost of less than 7 p/kWh, without moving into those parts of the resource cost curves (7.6) in which costs would increase rapidly because less favourable sites would have to be used. In fact two-thirds of that resource is estimated to be available at less than 4 p/kWh. As these estimates are for 2025, it is reasonable to expect that further reductions in costs could be achieved over the following 25 years. The overall cost of supplying electricity in those scenarios in which heavy reliance is placed on intermittent and dispersed energy sources would however be raised by the substantial changes required to electricity networks and the provision of a very large capacity of back-up plants burning fossil fuels (or alternatively provision of a new form of large-scale storage for electrical energy). The output from the back-up plants would have high unit costs because they would be used relatively infrequently.

9.34 Taking all these factors into account, it might be unwise to count on electricity from renewable sources costing much less than 3-4 p/kWh in real terms in the middle of the 21st century. That can be compared with the estimate that recovering carbon dioxide from flue gases and disposing of it might increase the cost of generating electricity from fossil fuels by half or more (3.7). There are certainly grounds for assuming that renewable sources of energy could be utilised on a very large scale within the next half century at a cost that would not exceed double the present cost of generating electricity from fossil fuels.

The way forward

9.35 The four scenarios for 2050 outlined and discussed above are illustrative. Each of them would reduce UK carbon dioxide emissions by some 60%, the scale of reduction we concluded in chapter 4 is likely to be necessary by the middle of the 21st century. Their immediate purpose is to stimulate constructive debate about how reductions of that size can be achieved over that time-scale, and thus help the UK make a major contribution to the task of finding global solutions to the threat of climate change.

9.36 The main components of UK demand for primary energy are economic growth, the efficiency with which energy is utilised by end users and the extent of losses within the energy supply system. The energy intensity of the UK economy has fallen considerably (5.9 and figure 5-III), but economic growth still exerts a strong upward pressure on energy consumption. There would have to be substantial changes in the structure of the economy to neutralise that pressure, given that such a high proportion of demand is for transport and space and water heating. A necessary condition for achieving large reductions in carbon dioxide emissions is therefore likely to be more rapid improvements in the efficiency of end use than have been achieved in the past. If efficiency can be improved rapidly enough to reduce end use of energy in the UK by about 1% a year on average, this would reduce consumption by more than a third over the next 50 years, as envisaged in scenarios 2 and 3.

9.37 All four scenarios show consumption by final users diverging sharply from the previous trend. If that were not to happen, the only ways of meeting the resulting high level of demand, without consequences which we concluded in chapter 4 would be unacceptable on both moral and prudential grounds, would be a massive programme of nuclear power stations, or possibly a massive programme of separating carbon dioxide, liquefying it and injecting it beneath the sea bed. The programme of nuclear power stations indicated would have to be much larger even than in scenario 1, which itself involves obtaining four times as much energy from nuclear power as at present. It is certainly difficult to see the expansion of renewable energy sources over the next 50 years exceeding what is envisaged in scenario 1.

9.38 While all four scenarios assume the previous trend of growing energy use will not continue, they differ considerably in other respects, and highlight the key issues which have to be faced if carbon dioxide emissions are to be reduced to the extent likely to be required. None of them stands out as the obviously preferable option. Many people will recoil from the very extensive development of both nuclear power and renewable sources in scenario 1. Many will find scenario 4 attractive because it has no nuclear power and the smallest deployment of renewables in any of the scenarios. It will not be easy however for the UK to achieve the substantial reductions in its present use of energy which would be necessary to move beyond scenario 1, still less the deep cuts in energy use that are the most distinctive feature of scenario 4.

9.39 What these scenarios have in common is that they would all involve fundamental shifts over the next half century in the ways energy is obtained and used, and the associated infrastructures. In addition to development of renewable energy sources on a very large scale, they would all require extensive modifications to both the building stock and the transport system in order to reduce the need for energy. District heating systems, supplied by combined heat and power plants, would become commonplace in urban areas, as would use of heat pumps. Electricity networks would have to be restructured to accommodate the much larger numbers of smaller generating plants embedded within them, many supplying electricity only intermittently. The differences between the scenarios lie in the relative emphasis placed on each of these changes, the particular combinations of renewable sources assumed, and whether or not there are baseload stations using either nuclear power or recovery and disposal of carbon dioxide.

9.40 While these scenarios were constructed to achieve a 60% reduction in UK emissions, as a contribution to preventing the concentration of carbon dioxide in the atmosphere from rising above 550 ppmv, it should be emphasised that very large reductions would be required in UK emissions even if a different objective were selected for global action. For example, in order to prevent the concentration in the atmosphere rising above 1,000 ppmv (a level we concluded in chapter 4 was so high as to pose an unacceptable risk), the contraction and convergence principle, with convergence at 2050, would require UK emissions to be reduced by over 40% by 2050 (table 4.1). Even on that basis many of the same measures would be needed.

9.41 Accepting 550 ppmv as an upper limit on the concentration in the atmosphere would require UK carbon dioxide emissions to be reduced even further by 2100, to not much more than 20% of the 1998 level. When we invited evidence for this study however we took the view it was not sensible to try to look further ahead than the middle of the 21st century. Over a period as long as a hundred years energy technologies may change beyond recognition, and new technologies not at present contemplated may become available. It is certainly crucial that this should happen in the case of transport, which is the dominant use of fossil fuels in all four scenarios.

9.42 Even over half a century we have not attempted to map out specific pathways that will have to be followed if one or other of the four scenarios is to be realised. It would not be feasible or sensible to attempt to do so in detail at this stage. But the way in which successive governments handle the anticipated closure of all but one of the UK's nuclear power stations over the next quarter century will decide which, if any, of the four scenarios – or something like them – are attainable. If there are no measures to stabilise or reduce demand and the nuclear stations are replaced by fossil fuel plant, without any facilities for capture and then disposal of carbon dioxide, then it seems that no further substantial cuts in UK carbon dioxide emissions will be possible. There will also have to be a very substantial deployment of renewable energy resources by 2020 – far beyond the government's current target of 10% electricity generation by 2010 – if any of the scenarios are to be achievable. It is essential that the governments and citizens of today have a keen awareness of the issues, and begin to make radical changes in direction in the next few years. We discuss in the next chapter what changes in direction are needed, and how they can be brought about.

Curbing the UK's dependence on fossil fuels is technically feasible, but far from easy. Reductions in energy use, large-scale development of non-carbon energy sources and fundamental changes in electricity networks will all be necessary. If the demand for energy can be reduced, that makes it easier to avoid large programmes of new nuclear power stations or other technologies that might prove controversial