Chapter 7

THE ALTERNATIVES TO FOSSIL FUELS

What are the alternatives to fossil fuels as energy sources for the UK? On what scales are they available, and how expensive will they be? What impacts would they, for their part, have on the environment? Would there be other barriers to their rapid development?

7.1 Even on an optimistic view, measures to reduce energy use, of the kinds considered in chapter 6, would not in themselves be sufficient to reduce carbon dioxide emissions on the scale we have concluded is likely to be necessary. The other major component in a long-term energy strategy for the UK must be expanding considerably the proportion of energy obtained from sources other than fossil fuels. The sources theoretically available have been enumerated already (3.45-3.48). In this chapter we look at alternative energy sources in terms of the contribution they could make to meeting the UK's energy needs.

7.2 First we describe the methodology used in assessing the potential of renewable energy sources for the UK government (7.4-7.9). We then review all the most significant alternative sources individually under four headings:

> proven ways of generating electricity on a large scale without producing carbon dioxide which are nuclear fission, large-scale inland water power and tidal barrages (7.10-7.30).
>
> other non-carbon technologies now being applied on a significant scale in some countries, such as wind power and photo-voltaics (7.31-7.53).
>
> alternative carbon-based sources, energy crops and wastes, which can be used to supply heat as well as electricity (7.54-7.85).
>
> two other technologies, the generation of electricity from wave power and tidal streams, which are at an early stage of development but could have considerable potential (7.86-7.100).

In discussing particular technologies we identify, as well as their status, the nature and extent of the likely impacts on the environment from their use, the assumptions made in official assessments of new energy resources, and the extent to which we consider those assumptions justified.

7.3 We review the current prospects for alternative energy sources (7.101-7.115), including forms of general support for renewable energy sources; and the relevance of public acceptability to the shape of the future energy system, and how energy policies and environmental policies can be integrated (7.116-7.129). In chapter 8 we go on to consider how various alternative energy sources might in practice fit together to replace a large part of fossil fuel use in the UK.

ASSESSING THE POTENTIAL OF RENEWABLE SOURCES

7.4 The potential of renewable energy sources is assessed by the Energy Technology Support Unit (ETSU), part of AEA Technology plc, for the Department of Trade and Industry (DTI). Table 7.1 summarises the findings in ETSU's most recent assessment, published in 1999,[1] about the amount of electricity that could be obtained from the 10 most significant renewable sources and its cost. For comparison, total electricity output in the UK currently averages about 41 GW.

7.5 In assessing the potential of energy sources, ETSU has used the following methodology. It first estimates how much energy is physically available from a particular source in the UK, and what proportion is in a sufficiently concentrated form to be worth exploiting. It then considers how much of that available energy is in areas which it would be undesirable for environmental reasons to use for this purpose or which are physically unsuitable for energy installations. Removing such areas from the calculation allows the *accessible resource* to be estimated.

Table 7.1

Electricity from renewable energy: ETSU's assessment of cost-effective resources in 2025

source	accessible resource (annual average rate of supply, GW)	total cost-effective resource* (annual average rate of supply, GW)	cost below which at least 90% of cost-effective resource available (p/kWh)
non-carbon-based sources			
onshore wind power	36	6.5	3.5
offshore wind power	468†	11.4	3.0
photovoltaics	30††	<0.1	7.0
small hydro	n/a	0.3	7.0
alternative carbon-based sources			
energy crops	n/a	3.7	4.0
agricultural and forestry waste	n/a	2.4	5.0
municipal solid waste	1.5§	0.8	5.0
landfill gas	n/a	0.9	3.0
technologies being developed			
wave power	95	3.7	4.0
tidal stream	4.1	0.25	6.5

* ETSU's estimate of the rate at which electricity could be generated at a cost of less than 7 p/kWh in 2025, assuming a discount rate of 8%. † assumes a load factor of 0.43. †† in the absence of an estimate for the accessible resource, the figure for maximum practicable resource is given. § referred to as total potential at current rates of waste production. n/a indicates that ETSU did not estimate the accessible resource.

7.6 The cost of energy from a particular source is then taken into account. The general assumption made is that the costs of renewable energy sources will fall over time as technology improves. *Resource cost curves* are calculated to show how much energy could be obtained from the accessible resource at a given date for a given cost. These curves are used for two purposes. One is to assess how large a resource is likely to be available at a cost that would not be excessive. In its most recent assessment ETSU has done that by estimating the resource that would be available in 2025 at a cost of less than 7 p/kWh. Another approach would be to look at the shape of the resource cost curves, and identify the level of resource at which the cost of obtaining energy would begin to increase rapidly; the great bulk of the resources shown in table 7.1 are available before the cost curves reach such a point, and the final column of the table provides an indication of where that point lies for each source.

7.7 The resource cost curves calculated are also put into a systems model of the UK energy market to indicate what use might be made in practice of renewable energy sources.[2] Various policy scenarios are considered. In some the use made of renewable energy sources is determined solely by their cost in relation to other methods of generating electricity or reducing carbon dioxide emissions. Other scenarios assume that renewable energy sources will provide a guaranteed proportion of UK electricity, and will do so in the most cost-effective way. We return to this part of the analysis later in the chapter.

7.8 Estimates of future costs are obviously subject to considerable uncertainty, especially for technologies at an early stage of development. The economic assumptions made also have a big effect. For example, when 15% was used as the discount rate, rather than 8%, the cost of electricity generation from onshore wind increased from 3.5 to 5 p/kWh.[3] The energy market model used by ETSU magnifies the effect of uncertainties by assigning energy sources solely by reference to their estimated cost, irrespective of the amounts by which costs differ. No account has been taken of factors that would alter the relative price of energy from renewable sources and from fossil fuels, such as the carbon tax we advocate in this report or trading in permits for carbon dioxide emissions. ETSU's estimates nevertheless provide information about the relative costs of different renewable energy sources; but the uncertainties involved must be kept in mind, especially for dates further into the future. Moreover, as we shall show, factors other than cost may be important in determining the take-up of particular technologies.

7.9 ETSU has estimated a *maximum practicable resource* for some energy sources which may be much smaller than the accessible resource. In doing so it takes into account, not only the estimated cost of a source, but the practicability and acceptability of exploiting it. Box 7A shows how various types of constraint have been taken into account by ETSU in the case of one source, onshore wind.

LARGE-SCALE NON-CARBON SOURCES

7.10 The two non-carbon sources of energy already used on a large scale are nuclear power and inland water power. Globally nuclear power supplied 20% of energy input to electricity generation in 1995, or 7% of total primary energy supply, but the proportions are projected to fall to 15 and 6% respectively by 2010. Inland water power supplied 7% of energy input to electricity generation in 1995, or 3% of total primary energy supply; these proportions are projected to be the same in 2010.[4] As the greater part of the energy input from nuclear power becomes waste heat however, inland water power provides a slightly higher proportion of the

BOX 7A ASSESSING THE RESOURCE: ONSHORE WIND

ETSU first estimated the *feasible resource* by modelling wind speeds; making assumptions about the characteristics of wind turbines (for example, their capacity and height); eliminating types of land cover deemed unsuitable for wind farms; and making assumptions about the placing of turbines. Areas of land designated at national level to protect the environment were then excluded in order to obtain the *accessible resource*; this was estimated to be *capable of producing* an average output of 36 GW (more than the average rate of UK electricity demand). The *maximum practicable resource* however is much less than that. Assumptions about the acceptable size and spacing of wind farms reduce considerably the resource regarded as being available; and limitations imposed by the UK electricity networks reduce it even further, to an average output of less than 1 GW. The resource regarded as being available in 2025 without excessive cost, an average output of 6.5 GW (table 7.1), is larger than the maximum practicable resource because ETSU assumed that the constraint imposed by the electricity networks could be removed by 2025. The rate at which turbines could be manufactured and installed was evaluated, but would not be a constraint in the circumstances considered.

world's electricity than nuclear power.[5] The proportions vary considerably between countries, according to their natural endowments of rivers and valleys suitable for hydro-electric schemes and the scale of their past programmes to develop nuclear power. Another source of energy available on a large scale in certain locations is the movement of tides into and out of estuaries, which can be exploited with conventional technology by placing turbines in a barrage built across the estuary. There is only one tidal barrage in the world generating electricity on a significant scale.[6]

NUCLEAR

7.11 The 28% of UK electricity generated from nuclear power[7] is well above the global average, though below the EU average;[8] the proportion in Scotland is 40%. The nuclear power station built most recently in the UK is Sizewell B in Suffolk (see photograph I), a pressurised water reactor with a capacity of 1.2 GW commissioned in 1995.

7.12 The Commission's Sixth Report in 1976 covered in detail all aspects of the environmental implications of nuclear power. We have not attempted to repeat that task or to assess the nuclear industry's current operations. The issue on which we invited views in the present study was the contribution conventional nuclear power might make to replacing use of fossil fuels in the UK, and the extent to which its contribution would be dependent on innovations in technology, establishing valid disposal strategies for wastes or public attitudes (appendix A, Q5). Nuclear technology has recently been reviewed by a joint working group of the Royal Society and the Royal Academy of Engineering.[9] We did not ourselves receive any evidence that major technological innovations are in prospect or would be crucial.

7.13 Relevant considerations in assessing the environmental impact of a proposed nuclear power station would be:

> mining uranium to provide the fuel would give rise to significant risks to human health and the environment in other countries;
>
> there would be minimal radiological impact from emissions from the reactor under normal operating conditions;
>
> if a major loss of containment released long-lived isotopes, that would have a unique environmental and social impact. Although UK reactors have been built and operated to far higher standards than those at Chernobyl, and new reactors would have even higher standards, maintaining containment in the face of all possible accidents, including aircraft crashes or sabotage would be hard to guarantee;
>
> managing the radioactive wastes created would be problematic because of the long-lived isotopes present;
>
> after the station had closed, the reactor core would have to be isolated for a period of up to 130 years (depending on the type of reactor) before decommissioning could be completed.[10]

7.14 Another relevant consideration would be whether the spent fuel would be reprocessed. That makes fuel available for subsequent use, but has proved controversial because both the reprocessing operations and the use in fuel of plutonium oxides recovered from spent fuel create additional hazards and additional wastes.

7.15 We also invited views on whether fast breeder reactors or nuclear fusion should be regarded as potentially viable energy technologies for the 21st century (appendix A, Q6). *Breeder reactors* were developed in order to use fuel from reprocessing and limit the demand for uranium. They have not been adopted in the way expected at the time of the Commission's Sixth Report. There are plentiful supplies of uranium at the moment, although market conditions would change if very large numbers of nuclear power stations were to be built across the world. Breeder technology has proved problematic, and little effort is being devoted to it at present, but it could probably be applied commercially if suitable conditions were to arise.

7.16 *Nuclear fusion* has been seen by its proponents as a clean and practically unlimited source of energy, and has been the subject of large research and development programmes. The technology is still at the research stage. Those responsible for such programmes do not expect that a commercial-scale demonstration plant could be constructed before 2050.[11] We have concluded that, even if the technical viability of nuclear fusion can be established, it would not be prudent to base energy policies on the assumption that it will become competitive in cost with other non-carbon energy sources in the foreseeable future. The environmental problems associated with fusion, such as production of secondary isotopes in the containment vessel,[12] remain to be clarified.

7.17 The problem of managing the wastes created by nuclear power already exists and requires solution in any event. But building new nuclear power stations would add to it. The approach to disposal of high-level and intermediate-level wastes favoured by the Commission in its Sixth Report[13] has in effect been rejected, leaving the UK with no generally accepted long-term policy.

7.18 The alternative approach mentioned in the Sixth Report would be to separate out the longer-lived isotopes present in the waste and break them down into isotopes with much shorter lives. At that time it was envisaged this would be achieved through fission in a nuclear reactor.[14] Recently there has been interest in the possibility that the same result might be achieved by bombarding the longer-lived isotopes with neutrons in a particle accelerator.[15] Separating out and handling those isotopes would continue to present practical difficulties.[16] Unless the advantages of this alternative approach can be demonstrated, the right course is to press ahead with more familiar approaches to waste management.

7.19 At the moment **indefinite storage of high-level and intermediate-level wastes from the existing use of nuclear power above ground has become policy by default.** We endorse the conclusions of the House of Lords Select Committee[17] on the imperative of making secure the storage of the wastes that have been produced or will be produced by existing nuclear power stations. The present arrangements are likely to be inferior in terms of both human health and environmental security to those that could be implemented using present technical knowledge. **We recommend that action is taken to design and construct an effective long-term repository as soon as practicable.** The intractable problem is to secure public agreement on the design and siting of a secure long-term repository. **Considerations of inter-generational equity embedded in the concept of sustainable development demand the solution of the waste management problem, to the satisfaction of both the scientific community and the general public, before new nuclear power stations are constructed.**

LARGE INLAND WATER POWER SCHEMES

7.20 The UK is well below the global average in the proportion of electricity generated from inland water power (1.5%, from 2% of total plant capacity);[18] although in Scotland the proportion is about 25%.[19] Only those schemes which use the natural flow of water from high ground to low ground are primary sources of energy; a 'large' scheme is typically defined as one with an installed capacity of more than 10 MW on a single site.[20] Schemes using water that has been pumped up to a high level for the purpose are in effect storage devices for electricity, and are discussed in chapter 8. The average rate of electricity generation at direct flow stations in 1998 (0.5 GW) was more than twice the average rate at pumped storage stations (0.2 GW).[21] Foyers in Scotland, with a capacity of 300 MW, is the largest plant in the UK using direct flow, albeit augmented in this case by pumped storage; the next largest plant, Sloy (see photograph XI), has a capacity of 130 MW.[22]

7.21 A large inland water power scheme usually requires the construction of dams to create reservoirs, so changing the appearance and ecology of a substantial area of the uplands. In some cases people lose their homes. It is generally considered that the likely objections to construction of large new reservoirs rule out new schemes in the UK for the foreseeable future. There may be some scope for increasing capacity by upgrading existing schemes. Reservoirs constructed for other purposes are not usually capable of making any significant contribution to electricity supplies without interfering with their primary functions. Although there is a much larger installed capacity of inland water power elsewhere in the EU, the prospects for further development present a similar picture to the UK.[23]

TIDAL BARRAGES

7.22 The potential for generating electricity from turbines in tidal barrages has been thoroughly investigated.[24] In 1986 the government, the then Central Electricity Generating Board and a private consortium commissioned a study of the economic feasibility and environmental impacts of a Severn Barrage.[25] Photograph VII shows an artist's impression of a Severn Barrage. In March 1999 the government refused funding for a new appraisal; among the reasons given were that tidal power is not likely to become economic within the next 20 years and there is no suitable developer or buyer for the amount of electricity that would be generated.[26]

7.23 Construction of a barrage across an estuary changes radically its appearance and ecology, and especially its bird life, and is therefore liable to be opposed on environmental grounds. It will also disrupt fisheries and navigation. The primary reason why such schemes have not proceeded however is their high cost. In the case of the Severn difficulties were also foreseen in accommodating within the national grid such a large source of electricity operating only at certain times.

7.24 In its 1992 report the Renewable Energy Advisory Group estimated that the technically feasible resource from tidal barrages in the UK is an average output of 5.7 GW, almost half the total for the EU; and that, if all the practicable schemes were to be developed, they might be able to supply about a fifth of electricity demand in England and Wales.[27] The lion's share of that would come from a Severn Barrage, with a capacity of 8.6 GW and an average output of 1.9 GW.[28] Almost all the other schemes investigated were assessed as less attractive in financial terms because conditions at the sites are less favourable.[29]

FUTURE POTENTIAL

7.25 The feature common to nuclear power, large inland water schemes and tidal barrages is that they all have high initial costs in relation to their generating capacity. In other respects there are crucial differences. For inland water schemes and tidal barrages subsequent costs are very low; and the structures erected can be expected to last for a century or more, although the mechanical plant would require replacement after about half that time. After the construction costs had been paid off, the cost of generating electricity would be very low: only 0.05 p/kWh in the case of a Severn Barrage according to the promoters.[30] Such structures would therefore represent an asset bequeathed to future generations. As such, they could be regarded as offsetting, to a small extent, the damage likely to be caused to future generations by this generation's profligate use of fossil fuels.

7.26 Nuclear power stations can be expected to have a life of 40 years or longer.[31] Their recurrent costs are higher than for inland water schemes or tidal barrages, but the key difference is their large back end costs. One element is expensive decommissioning: the operators expect major elements of this to be deferred up to 130 years after a station is shut down.[32] The other element is disposal of wastes, both from decommissioning of power stations and from the fuel cycle. Financial provision is now made under both headings, albeit at a low level because of the long periods over which interest will accrue. It is impossible to be sure so far ahead exactly what expenditures will be necessary at the end of the day.

7.27 To the extent that the availability or cost of capital finance is a constraint on investment decisions, any energy source with high capital costs will be unattractive. This is aggravated for very large projects such as the Severn Barrage or a nuclear power station because of the long construction periods before any energy can be obtained. Applying a 15% discount rate rather than an 8% discount rate doubles the estimated cost of electricity generated at a Severn Barrage.[33] The restructuring of the electricity market has increased the financial risk attached to investments in generating plants, and made projects with high initial costs even less attractive. Smaller nuclear power stations have been advocated, one of the reasons being to reduce the financial risks involved in their construction; but even a 200 MW nuclear power station using present technology would have high initial costs and a long construction period in relation to most other sources of energy. The decisive consideration which the government regards as ruling out both a Severn Barrage and any new nuclear power station at present is that neither project would be undertaken by a commercial company in the liberalised market for electricity that now exists.

7.28 We discuss the current prospects for *nuclear power* later in this chapter, and in chapter 9 we consider what contribution it could make to achieving very large reductions in UK carbon dioxide emissions over the next half century.

7.29 We see no reason to dissent from ETSU's assessment that construction of *large new inland water power schemes* in the UK is likely to be ruled out because of the impact that would have on the immediate environment. It is reasonable to assume that existing schemes will continue to contribute the amount of electricity they generate at present (0.59 GW annual average output),[34] unless climate change were to include significant reductions in rainfall in the regions where they are located. It would be desirable to achieve at least a modest increase in the contribution from this source. **We recommend that a full investigation be made of the scope for increasing electricity generation by upgrading existing inland water power schemes and by adapting reservoirs constructed for other reasons which are now redundant or have substantial spare capacity.**

7.30 In ETSU's most recent assessment, they report that the high capital costs of tidal barrages and their long construction periods are the barriers to the exploitation of tidal power. *Tidal barrages* were not regarded as having any potential as cost-effective energy sources in the period to 2025.[35] Nevertheless, **in view of the large amounts of energy that would be**

available, we recommend that construction of tidal barrages be kept under consideration as an option for the long term. Use of this technology to generate electricity would become more attractive if it becomes necessary to construct barrages, more probably on the east coast, in order to prevent flooding of urban areas as a result of rising sea levels. **We recommend that, if barrages have to be constructed to prevent flooding, full consideration be given to the possibility of incorporating plant to generate electricity on a significant scale.** If barrages were to be built at several different points on the coast, it is possible that, because of the variation in the timing of tides, they could in combination supply energy continuously over a much longer period than a single barrage. **We recommend that DTI commission a desk study to determine whether there are credible combinations of estuary barrages that would overcome, at least in part, the problem of intermittency of supply.** It may be the case however that tidal streams (7.91-7.93) turn out to be a more immediately attractive technology for using the energy in the tides to generate electricity.

OTHER NON-CARBON SOURCES ALREADY AVAILABLE

7.31 Other non-carbon sources of energy for which technology is already available are wind power, use of solar energy to generate electricity in *photovoltaic cells* or to provide heat, and water power on smaller rivers and streams. At lower latitudes it is practicable to concentrate solar energy by means of reflectors and produce steam, which can then be used either to generate electricity or in chemical processes, but that is not practicable in the UK. In some countries groundwater at high temperatures is abstracted from 'geothermal aquifers', but this is not a significant source of energy globally, and offers limited resources in the UK; the water temperatures here are too low to generate electricity, and the aquifers tend to be too remote for their heat to be utilised.[36]

WIND POWER

7.32 Turbines are very efficient at converting the energy present in winds into electricity. They can generate electricity at wind speeds of 5-25 m/second (11-56 mph) and the mean wind speed at which they are financially viable in the UK has fallen to 7 m/second. The declared price for wind power schemes has fallen sharply over successive bidding rounds for the non-fossil fuel obligation (NFFO).[37] This was the result of economies of scale achieved through increased size of turbines (new turbines now typically have a capacity of 1.5 MW) and their manufacture in much larger numbers. Although some components such as the blades are manufactured in the UK, the turbines are imported, and the development of wind power has been much more rapid elsewhere in Europe, especially in Germany and Denmark.[38]

7.33 The amount of energy present in winds in the UK is very large by comparison with most other European countries. As the technology has developed, assessments of the resource that could be exploited have risen sharply. About a third of the land area of the UK has sufficiently constant winds to make this viable technically as an energy source.[39] The accessible resource is equivalent to the whole of the UK's electricity supplies, although the maximum practicable resource is likely to remain much smaller (see box 7A).[40]

7.34 Although wind power would generally be regarded as a clean energy source, proposals to construct large wind farms in rural areas have encountered strong opposition, primarily because of their effect on the landscape, especially in the case of upland sites visible for many miles (see photograph X). This has brought some people to the position of opposing wind energy strongly on environmental grounds. The visual intrusion of wind farms can be reduced by not necessarily placing turbines at the heights at which wind speeds are highest, and by careful design of layout and structures and choice of colours. Another ground of objection has been noise. The mechanical components have been made much quieter, so that the main source of noise is the movement of the blades through the air. Careful modelling of noise dispersion should limit any noise problems, except possibly for houses very close to turbines. We discuss at the end of this chapter the general issue of public attitudes to new energy installations.

7.35 Some wind farms have been constructed on the edge of urban areas, for example at Blyth Harbour in Northumberland (see photograph XII) and at Workington in Cumbria. Use of urban or near-urban sites could be an effective way of limiting visual intrusion, without causing an unacceptable environmental impact in other respects. It is being advocated on those grounds in Denmark.[41] **We recommend that investigations be carried out to identify brownfield sites which have sufficiently consistent wind speeds to be suitable for wind farms and would be suitable in planning terms.**

7.36 There is an even larger resource of wind power, an order of magnitude greater, in the seas around the UK. The technology for exploiting it will be similar to that used onshore, but more stringent design will be needed to ensure reliability and durability under much harsher conditions. The sea bed must be suitable, and it is unlikely that turbines will be placed in water depths greater than 40 m. Offshore wind farms are operating in the Baltic (see photograph IX) and off Esbjerg in Denmark;[42] it is expected that two turbines will be constructed off Blyth this summer.[43]

7.37 The environmental impact of offshore wind farms will depend on the site. Construction of the towers and the cables linking them will cause some damage to the sea bed. If however precautions are taken to minimise such damage (drawing on the considerable experience gained already from the operations of the offshore oil and gas industries) and avoid the most sensitive areas, it is unlikely the effects would be serious or permanent. The selection of sites also needs to avoid, as far as possible, interference with commercial fishing, the dredging of marine aggregates, merchant shipping, military operations, or the flight paths of birds. The visual impact of a wind farm viewed from the shore also needs to be taken into account, especially in areas of beautiful or wild scenery. The most intrusive aspect of a wind farm could be the cables on shore linking it to the electricity network and any associated equipment, unless these are designed with great care and sensitivity.

7.38 After excluding offshore areas which are sensitive by reason of natural beauty or presence of wildlife, or in which there would be conflict with other activities, ETSU estimates the maximum practicable resource from offshore wind power as an average output of 11.36 GW.[44] A notable gap in the present arrangements for regulating the environmental impact of energy installations is the absence of any procedure in UK law for considering and giving approval to offshore wind farms, or indeed possible offshore generating plants of other types discussed later in this chapter. It is likely however that existing EC legislation[45] would require environmental assessments to be carried out. **We recommend that DETR, in conjunction with the Crown Estates Commissioners, bring forward proposals for giving authorisation to, and regulating the environmental impact of, generating plants using renewable energy sources offshore; and that corresponding arrangements are made in other parts of the UK.**

Generating electricity from sunlight

7.39 Electricity can be generated from sunlight by using a photovoltaic cell typically consisting of superimposed wafers of a semi-conductor (usually silicon) which differ in their electrical properties: light falling on the cell produces a difference in electrical potential between the top and bottom layers. To obtain larger currents, cells are grouped in arrays. Whereas turbines produce an alternating current, photovoltaic cells produce a direct current. In order to be fed into the public network, this has to pass through a device called an inverter. The small installed capacity of photovoltaic cells in the UK (670 kW in 1998[46]) is largely in the form of private direct current supplies used to charge batteries for remote telecommunications, navigation and signalling equipment.[47]

7.40 Photovoltaic cells convert only a small proportion of the energy in sunlight into electricity: approaching 20% in research devices, but 11-15% in multi-crystalline or single crystal devices and only 5-8% if cheaper amorphous silicon is used.[48] Moreover large amounts of energy have to be used in their manufacture.[49] Estimates of the energy pay-back period, the period over which photovoltaic cells generate the amount of energy used in their manufacture, depend on the assumptions made concerning location (levels of solar radiation) and technology. A recent study showed that for medium to high levels of solar radiation,[50] the energy pay-back period was 2½-3 years for present day rooftop installations and almost 4 years for multi-megawatt ground-based installations.[51] The major barrier to wider use of this technology is the high cost of the cells and ancillary equipment in relation to the amount of electricity produced and the 25-30 year life of cells. Manufacturers hope to reduce the cost substantially through improvements in design and a greatly increased scale of manufacture. The impetus for that will come from the growth of markets in less densely populated countries at lower latitudes.

7.41 The UK receives strong direct sunlight for only a proportion of the year, and for much of the time the sun is obscured by cloud. Assessments of the potential of this technology are based on mounting arrays on buildings in order to minimise constructions costs and bring generation close to the point of use.[52] A calculation which assumes arrays would be placed on all available building surfaces throughout the UK[53] gives an estimated output of 30 GW;[54] and a calculation which assumes arrays would occupy an area equivalent to 5% of the UK land surface gives an estimated output of 62.5 GW.[55]

7.42 Arrays of photovoltaic cells are not obtrusive (see photograph XIII). They can be designed to look rather like a slate roof. They would nevertheless alter the appearance of buildings, and there could be opposition on aesthetic grounds to their installation, especially on buildings of architectural or historical importance. The large-scale manufacture and decommissioning of photovoltaic cells containing toxic substances such as cadmium and tellurium, which until now have only been used in higher efficiency prototypes, represents a potential health hazard. Use of relatively scarce minerals in some types of cell could lead to resource depletion if this technology comes to be widely used. **We recommend that, to facilitate recycling of the materials used and avoid hazards from their disposal, manufacturers and importers of photovoltaic cells should be required to take back arrays removed from buildings.**

7.43 The cost of electricity generation using photovoltaic cells would become much less of a barrier if arrays of such cells can be fully integrated into roofing or cladding panels, and the dual purpose panels can be installed when a building is being constructed or renovated, thus avoiding the costs of alternative roofing or cladding materials. This seems to be the most promising direction for future development.

USING HEAT FROM THE SUN

7.44 The sun already provides buildings with very large amounts of energy for heating and lighting. In the UK this is estimated to be supplied at an annual average rate of 16.5 GW,[56] broadly equivalent to the amount of electricity used in domestic and public administrative buildings.[57] As has been illustrated already (6.42 and box 6A), careful design of buildings and choice of materials can increase considerably the benefits obtained from this *passive solar energy* in the form of lighting, heating and ventilation.

7.45 *Active solar energy* can be used to heat water to the temperatures required for domestic hot water systems or for swimming pools. The panels on the roofs and walls of buildings required for this purpose are more obtrusive than arrays of photovoltaic cells, but there are no other significant environmental impacts. The supply of energy from this source in 1997 was estimated to have been at an annual average rate of 0.008 GW.[58] The estimated accessible resource is quite modest: 3 GW, of which 1.4 GW would be for domestic hot water systems.[59] The high cost of this technology in the UK in relation to the amounts of energy that can be obtained is the main barrier to exploitation of this resource.

7.46 The most promising future for active solar energy may well be as part of integrated designs for low-energy buildings which also take full advantage of passive solar energy, heat exchangers, and possibly heat pumps (6.100). The potential of heat pumps has received little attention in the UK up to now because they have not been regarded as economic.[60]

SMALL INLAND WATER POWER SCHEMES

7.47 Although the flow of water on smaller rivers and streams represents a large energy resource in total, many of the sites that are most suitable physically would be uneconomic to develop because of their remoteness. At many other sites there is only a small difference in water levels. The present output of electricity from such schemes is at an annual average rate of 0.037 GW.[61] Research is taking place on variable-speed turbines designed to work at hydraulic heads as small as 1m, but there is not a high probability that such devices will make possible a significant reduction in the overall cost of generating electricity under such circumstances. The environmental issues raised by small inland water power schemes may be complex in relation to the size of the scheme, and it may be difficult to acquire the small sites needed for the turbines.[62]

FUTURE POTENTIAL

7.48 The energy sources in this group have two key features. One is that they are ubiquitous, or at least very widely available. This is a considerable advantage if the aim is to find local methods to meet local demands for energy. Because of their dispersed nature a single installation may not have a high capital cost, but it may nevertheless be expensive in relation to the amount of energy obtained. Moreover their dispersed nature may be a disadvantage if the aim is to generate electricity on a large scale.

7.49 The other common feature of this group of energy sources is that they are neither continuously available nor predictable in the way tides are. The owner of a building with active solar heating can use the hot water tank to smooth out fluctuations in the heat coming from the sun and, when that is not sufficient, can draw energy from the public electricity network. If however a significant proportion of the sources supplying an electricity network are available only intermittently, and more especially if they are also small and scattered, the operators of the network may have difficulty in maintaining a high-quality supply to consumers. This is a fundamental issue about the large-scale use of renewable energy sources, and we discuss it in chapter 8.

7.50 *Inland water power schemes* may supply electricity continuously for long periods; but small schemes will usually not incorporate a reservoir and may cease to operate following long periods of dry weather when the water level becomes too low. The view was expressed to us, in relation to the south-west of England, that the potential of this energy source has been seriously under-estimated.[63] ETSU's overall assessment is that the average annual output obtainable cost-effectively from this source in 2025 is 0.3 GW,[64] which would represent a small but useful contribution to electricity supplies. The approach we advocate at the end of this chapter, encouraging greater local initiative in developing energy sources, should stimulate a more thorough and systematic investigation of the possibilities for small inland water power schemes.

7.51 The most promising way of taking advantage of *solar energy,* at least in the UK, is likely to be as part of an integrated approach to heat management applied to individual buildings, of the kind described and advocated in the previous chapter (6.100). This would not only make full use of passive solar energy, it would also use active solar energy to heat water. It might well make use of photovoltaic cells, and might also make use of heat exchangers box 6A, 6.90) and heat pumps (3.43). The marginal cost of utilising these technologies would be reduced by incorporating them into the design of buildings right from the beginning and by achieving economies of scale that would reduce considerably the production costs of equipment.

7.52 There are widely differing views about the potential of *photovoltaic cells* to contribute to future electricity supplies. These stem not primarily from the difficulties of feeding the energy from such a diffuse and intermittent source into public electricity networks, but from different assumptions about how quickly production costs will fall, the circumstances in which arrays of cells are likely to be fitted to buildings, and the net cost of installations to building owners. We received several submissions which expressed the view that photovoltaic cells represent one of the most promising renewable energy technologies,[65] particularly low-impact modules integrated into new buildings. However, support was needed in the form of subsidies to deliver market penetration. ETSU estimates that there will be no photovoltaic resource available at a cost of less than 7 p/kWh by 2010, and only a very limited amount (average output of 0.2 GW) by 2025. It has been suggested that if the government was to invest in a programme to develop photovoltaics and a manufacturing base could be established, the costs of generation would fall more quickly.[66] ETSU's assumption that only a limited solar resource is available at low cost has also been called into question. In some of our scenarios for developing alternative sources (considered in chapter 9) we have assumed that the widespread deployment of photovoltaics throughout the UK in 2050 could generate electricity an annual average rate of 10 GW at reasonable cost.[67] This is based on the assumption that costs for manufacturing photovoltaics will continue to decline between 2025 and 2050.

7.53 *Wind power* certainly represents a very large energy resource for the UK, and appears to be capable of supplying electricity at a cost broadly comparable to conventional sources. Although the resource is widely dispersed, some areas are much more favourably endowed than others. Unfortunately the areas with the largest resources of wind power, the west and north coasts and the uplands, are mostly remote from the demands for energy and the existing bulk transmission network. There have been serious difficulties in these areas in gaining

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approval for building wind farms. Industry's plans for further development are now based to a large extent on sites offshore, where an even larger proportion of the available resource is to be found. We have recommended new arrangements for the environmental regulation of offshore schemes and consideration of brownfield sites for onshore wind farms. We discuss later in this chapter the future prospects for gaining planning permission for wind farms on land.

7.54 The third group of alternative energy sources identified at the beginning of this chapter can be used to provide either heat or electricity or both. For thermodynamic reasons explained in box 3A, a large part of their energy content can be obtained only in the form of low-grade heat. This important fact has been obscured because policy measures to promote use of renewable energy sources have been directed towards electricity supply. The nature of the support available under NFFO has led the developers of projects using these sources to design them solely to generate electricity. And ETSU's assessments of their potential have related solely to the amount of electricity that can be generated.

7.55 Because all the sources in this group contain carbon, carbon dioxide is emitted when their energy content is released. Their use is nevertheless beneficial in limiting the greenhouse effect. In the case of plant material, or animal wastes in which the energy content derives ultimately from plant material, the carbon dioxide emitted can be balanced by carbon dioxide removed from the atmosphere by growing vegetation (3.47). Whether that occurs in practice depends on whether the plant material being utilised directly or indirectly as an energy source is replaced by new growth, without any long-term depletion in the organic content of the soil. The best assurance of this happening is in a managed rotation in which fast-growing crops, such as short rotation coppice, are cultivated for this specific purpose.

7.56 Technologies for burning plant materials and wastes are well established, although fuels that do not have consistent characteristics can cause problems. There has been much more experience of generating electricity from wastes than from energy crops.[68] The alternative to combustion is to use a thermochemical process, *pyrolysis*, to produce a gas for use in a combined cycle gas turbine. This can raise the conversion efficiency for electricity generation from the 20-25% typical of a steam turbine[69] to 44% using the most mature technology.[70] Gasification technology is still at the demonstration stage: box 7B describes a plant which is using forestry waste initially, and will later use short rotation coppice. As with any other plant of comparable size a plant using these alternative fuels must be designed to avoid unacceptable effects from noise, vibration and stack emissions.

7.57 Municipal solid waste is usually regarded as a renewable energy source and a form of biomass, even though part of its content derives from fossil hydrocarbons. If landfilled, municipal solid waste decays to produce methane, a very powerful greenhouse gas (box 2C). It therefore helps significantly in limiting the greenhouse effect if, instead of reaching the atmosphere, methane can be collected from landfill sites and used as a fuel; this produces carbon dioxide, but the emissions have a much lower global warming potential than the methane would have had. The same objective can be achieved even more effectively if, instead of being landfilled, the waste is incinerated and its energy content recovered by that means.[71]

BOX 7B **DEMONSTRATION PLANT USING BIOMASS**

The ARBRE project (ARable Biomass Renewable Energy) is a demonstration 10 MW electricity generating plant sited at Eggborough, North Yorkshire, fuelled by wood chips from short-rotation coppice (SRC) and forestry residues. The Eggborough plant will use gasification technology whereby the wood is converted to a gas which fuels an efficient combined cycle generating process with a conversion efficiency of 31%.[72] The plant will begin to generate electricity in June 2000 and will be fully operational by November. Kelda Group plc (formerly Yorkshire Water) leads the ARBRE project in which there is a total capital investment of approximately £30 million. The project is supported by £10 m from the European Commission THERMIE programme, and is contracted under the third round of the NFFO.

The primary fuel supply will be new short-rotation coppice (SRC) of high-yield willow clones, grown within a 45-kilometre radius of the Eggborough plant. A total of 488 hectares have been planted to date; each hectare provides 10-15 oven dry tonnes of wood chips per year and the plant has an annual requirement of 43,500 oven dry tonnes. Whilst new SRC plantations are being established the plant will be fuelled primarily by forestry residues, but once coppices mature, SRC will account for 65-75% of total fuel input.

Approximately 100 farmers in the UK for whom SRC is a new crop are now involved in the ARBRE project. Incentives to growers include 15-year contracts (matching the period of NFFO support), and planting grants of £400 per hectare for set-aside land and £600 per hectare for non set-aside land under the Woodland Grants Scheme (WGS). Additionally, MAFF secured supplementary payments to the WGS for ARBRE.

One of the products following gasification of the fuel is a solid carbon char.[73] In the ARBRE project the possibility of burning this carbon with fossil fuels at a large power station nearby is being explored.[74]

7.58 Sewage sludge or agricultural wastes with a high water content can be treated by anaerobic digestion to produce ‘biogas’, in which methane is the main constituent.

URBAN WASTES

7.59 Of the 27 million tonnes of municipal waste produced in the UK each year, four-fifths is landfilled and one-fifth incinerated. Under anaerobic conditions the organic content of landfilled waste decays to produce landfill gas (40-60% methane, the rest mainly carbon dioxide). As well as being a greenhouse gas, methane also represents an explosion hazard. Systems to collect landfill gas are therefore compulsory for all new landfill sites in the UK and will be compulsory under the EC Landfill Directive at all sites receiving biodegradable waste.[75] The collection system at a large site may produce useable amounts of gas for 15-30 years. It is clearly beneficial to the environment to exploit this energy source.

7.60 The stack gases from incineration of municipal waste contain numerous pollutants, including hydrogen chloride, hydrogen fluoride and heavy metals. Inadequate control of emissions in the past gave incineration plants a bad reputation. Strict limits are applied to the quantities of these substances that can be emitted to the atmosphere, and technologies are available to comply with those limits. To prevent dioxins forming, the gases given off during combustion are rapidly cooled. That, and the low energy content of municipal waste limit the conversion efficiency that can be achieved.

7.61 The use of other types of waste as fuel, for example solvents or motor tyres, has no apparent advantage over use of fossil fuels in terms of countering climate change, although it may resolve awkward waste disposal problems and can be regarded as recovering some of the energy used in their original manufacture.

7.62 Sewage sludge can be either burnt or digested anaerobically to produce biogas. It was not included in NFFO after the first two rounds. Traditionally its energy content has been used mainly within sewage works for sludge-drying.

AGRICULTURAL AND FORESTRY WASTES

7.63 Aided by NFFO, several plants, with a total capacity of 64 MW, are generating electricity by burning agricultural and forestry wastes.[76] These plants have been designed to use a particular type of agricultural waste (straw or poultry litter) as their primary fuel, although this may be supplemented by forestry wastes.[77]

7.64 The ash from burning poultry litter can be sold as fertiliser (though it may be necessary to add nitrogen). The environmental advantages of using as fuel the one-third of straw for which there is no other agricultural use and which is otherwise ploughed back into the soil and the 20-50% of above-ground biomass discarded during harvesting and thinning of timber are less clear-cut. Although removal of these wastes may facilitate replanting and reduce fire and disease risks, it removes nutrients and may lead to erosion and compaction of soil. However ETSU concluded that it was unlikely to cause significant damage except in very sensitive areas.

7.65 Although exploitation of this resource is proceeding quite rapidly, its ultimate potential is limited, perhaps 4 million tonnes a year of straw, 1 million air-dry tonnes of poultry litter and 1.7 million dry tonnes of forestry waste, generating an average rate of 2 GW of electricity. For comparison it is estimated that 1 million tones of firewood is used in the UK each year.

7.66 Anaerobic digestion of farm slurries has clear advantages in terms of preventing odour problems and avoiding the spread of animal diseases. The residue from anaerobic digestion can be sold as fertiliser. Some small plants have been built to generate electricity from the biogas produced, but the accessible resource in the form of farm slurries appears to be small, about 0.33 GW average output of electricity.

ENERGY CROPS

7.67 Crops grown for fuel should be fast-growing, that is, they should use sunlight efficiently. This is important primarily to increase the efficiency with which land can be used for this purpose, and hence profitability. Perennial crops, such as grasses or deciduous trees, are preferable to annual crops because they require lower energy inputs in the form of fertiliser and other agrochemicals. The currently favoured crop under northern European conditions is willow grown as *short rotation coppice* (see photograph XIV). The coppiced stems are cut above soil level, thus avoiding the losses of carbon to the atmosphere that would occur if the soil was disturbed. The interval between harvesting is reduced from over 10 years in traditional coppicing to 2-4 years. Thus the stems are always at the stage of rapid growth, when most carbon dioxide is removed from the atmosphere. Smaller stems are also easier to harvest mechanically. Willow varieties are chosen for disease and pest resistance, in particular resistance to rust and willow beetles.

7.68 The main alternative which has been considered is a tropical plant, elephant grass *(Miscanthus)*, which would be harvested every year. This has the advantage of a lower moisture content and a higher yield (15-30 dry tonnes/ha a year against 10-20 dry tonnes/ha a year currently for short rotation coppice). However there is only limited experience of growing it on a commercial scale in the UK; there is some doubt whether it can be grown outside the south of England, though with warmer temperatures that might change.[78] Other plants which might be suitable as energy crops are poplar and hemp. Techniques for cultivating energy crops have received little attention up to now, and it is reasonable to assume that yields could be increased considerably over the next few decades.

7.69 For energy crops to be available as fuel, farmers and landowners have to be willing to devote land to their production in preference to other possible uses. They cannot readily be grown in the uplands because the ground conditions are unsuitable for mechanical harvesting, which normally takes place in winter. Short rotation coppice can be grown on arable land or grassland, or on reclaimed colliery spoil or sand and gravel workings.[79] The general assumption has been that it would not be grown on land that could be used for food production. Under present conditions the areas most likely to be used are those withdrawn from food production under schemes to cut agricultural surpluses *(set-aside land)* and less productive stretches of land within farm estates.

7.70 Some imaginative small-scale schemes have been undertaken, and may have an important role in familiarising farmers with this relatively novel concept. On the Brook Hall Estate in County Derry, Northern Ireland around 16 hectares of set-aside land are being grown with willow coppice for use, along with forestry wastes, in a small-scale gasification plant on the farm designed to generate around 100 kW – enough for a small rural factory or around 150 homes.[80] Half of the capital cost of the plant itself had been funded by the European Commission, and a 15-year contract had been awarded under the Northern Ireland NFFO scheme which unlike its counterpart in England and Wales had encouraged small-scale biomass.[81]

7.71 A scheme of this size makes productive use of agricultural land not being used for food production; can employ technology which is readily used by the farming community; and, if sensitively handled, minimises the types of transport or environmental issues which need to be considered with larger schemes. Such schemes may not be suitable for all areas of the UK, but replicated on a much wider scale could help bring down existing costs (we were informed, for example, that current costs of willow cuttings in the UK were five times that in Sweden), involve farmers in local energy production, and overall make a useful contribution to energy needs. We commend the Department of Agriculture and the Electricity Regulator in Northern Ireland for their efforts in encouraging this type of scheme.

7.72 In 1992 the Renewable Energy Advisory Group gave two estimates of the potential for generating electricity from energy crops by 2010 at less than 10 p/kWh (1991 prices, 8% discount rate):

> 21.5 GW average output (equivalent to about two-thirds of UK electricity consumption) on the assumptions that 5.5 million hectares of agricultural land would have been converted to growing coppice and the average yield would have risen to 21 dry tonnes/ha a year;
>
> 7.5 GW average output (equivalent to about a fifth of UK electricity consumption) on the assumptions that 2.8 million hectares of agricultural land would have been converted to coppice, average yield would be 15 dry tonnes/ha a year, and conversion efficiency had not risen above 25%.[82]

Those assumptions about the areas of land that would go out of agricultural use by 2010 have proved to be far too high. Agricultural land becoming surplus by 2010 is not now expected to exceed 1 million ha; ETSU's estimate of the accessible resource assumes that 88% of that land would be used for energy crops by 2020.[83]

7.73 Planting energy crops on a large scale would change both the appearance and the ecology of the countryside. While there has been concern on that score, we believe it has been largely misplaced. Except in areas where the existing landscape is of high value, cultivation of short rotation coppice would not be visually intrusive, provided plantations are sensitively sited and designed.[84] The impact on wildlife will depend on the type of land use being displaced and the vegetation in adjoining areas. Research by the Game Conservancy Trust indicates that coppicing can benefit biodiversity through the creation of wildlife habitats in carefully designed plantations and headlands, where song birds and warblers are found in large numbers. Although there would be less diversity overall than in permanent woodlands or other species-rich habitats, short rotation coppice supports the highest number of invertebrates of all types of woodland.[85] Concern has been expressed that the planting of monoculture energy crops may lead to a reduction in biodiversity, particularly on land formerly under set-aside. However, biodiversity may be enhanced if energy crops are grown in place of monoculture arable crops or pasture, with the additional benefit of providing wildlife corridors between woodland habitats. The impact of energy crops on biodiversity has not been a topic of significant research effort in the UK, partly due to the absence of large-scale plantations.

7.74 On previously arable land the result of planting energy crops is likely to be less soil erosion, smaller inputs of pesticides and herbicides, and less leaching of nitrate than on arable land. On what was previously grassland, these advantages would be less clear cut.

7.75 Although we were satisfied that this type of scheme could be developed without undue environmental impacts (and indeed could increase biodiversity compared to the growing of arable crops), we recognise that commercial pressures could lead to environmental short-cuts. **We therefore recommend that, in co-operation with farming organisations and the nature conservation agencies, Agriculture Departments produce a Code of Good Environmental Practice for the growing of energy crops.**

7.76 Because they are fast-growing, energy crops need more water than arable crops, and that could cause difficulties in the drier parts of the UK. This form of fuel has a large volume in relation to its energy content, and a relatively large area would therefore be needed to store it. Transporting it would also require large numbers of vehicle movements, and these would be the most obviously negative impact from its use.

7.77 Uniquely among alternative sources of energy, plant material can be processed to provide liquid fuels to power vehicles. The most important route is fermentation of plant material to produce alcohol, usually ethanol, which is then distilled. In Brazil three-fifths of the requirements for transport fuel (12 billion litres a year) are met by ethanol produced in the Proalcool programme; and some other countries have run smaller programmes on similar lines.[86] However this is an inefficient process in energy terms. Another disadvantage is that the stillage from the distillation process is difficult to treat and dispose of, although in Brazil it is now being digested anaerobically to produce biogas. Another liquid fuel produced from crops is biodiesel obtained from rape seed, on which the European Commission has funded research. This was attractive because it was claimed to give rise to lower particulate emissions than traditional diesel, but has proved difficult to produce to a consistent specification; trials in the UK have been disappointing. The advantage in reducing pollution carries less force now that the permitted sulphur content of diesel is being considerably reduced. The processes for producing biodiesel create significant pollution.

FUTURE POTENTIAL

7.78 In addition to their ability to provide heat as well as electricity, alternative carbon-based energy sources have three distinctive features that are important in assessing their future potential. The first is that, unlike most of the non-carbon energy sources, they can be continuously available because fuel can be stored. There are limitations on the scale on which they can be stored however because of their liability to decay and their second distinctive feature, their bulk.

7.79 Another consequence of their bulk is that the size of generating plant is likely to be limited by the availability of fuel within the distance (perhaps 40 km) over which it is economic to transport it. Plants using short rotation coppice or forestry wastes are unlikely to have a capacity of more than 30MW; some plants burning municipal solid waste are much larger, but plants burning biogas from farm slurries will be much smaller. There are other advantages in building plants of modest sizes. The vehicle mileage required to deliver fuel will be less; and avoiding the import of wastes from outside the area removes an obvious ground for public opposition.

7.80 The third distinctive feature of alternative carbon-based sources is their dependence on other areas of public policy: in the case of energy crops on policies about agricultural support and the future of the countryside; for many wastes, especially municipal wastes, on the regulatory framework for waste disposal. The EC Landfill Directive will limit the organic content of landfilled wastes, and thus the amount of methane produced. Landfill gas cannot therefore be relied upon as an energy source in the long term. Proportionately more municipal waste is likely to be incinerated. However policies to reduce waste arisings or increase recycling could reduce the total amount of waste requiring disposal. Similar considerations apply to commercial or industrial wastes that might provide an energy source.

7.81 The quantities of agricultural and forestry wastes available may be more stable, provided there are no radical changes in agricultural practices. There is only a limited potential available however, and under the stimulus of NFFO it is being exploited quite rapidly.

7.82 Energy crops have a much greater long-term potential as an energy source. However the attractiveness of these crops to farmers depends on the profitability of the land in alternative uses. That in turn depends on the terms of agricultural support schemes, and currently the European Union's Common Agricultural Policy, and on policies more generally for the future of the countryside. They cannot at present obtain as high a return from energy crops as from subsidised arable or livestock production; but they are allowed to grow energy crops on land for which they receive set-aside payments to keep it out of food production. If reform of the EU Common Agricultural Policy leads to a generally lower level of subsidies, the balance will tilt towards energy crops, still more so if production-related subsidies are replaced by area payments which are independent of the crop grown. The present reduction in demand for livestock may also turn out to be long term. Proposals have been put forward within the EU for specific subsidies for energy crops, particularly those grown to produce liquid fuels, but have not been supported by UK governments. We welcome the decision by the Ministry of Agriculture, Fisheries and Food to allocate about £30 million to support the growing of energy crops.[87] Locational supplements will be around £1,000 per hectare per year (over five years), suggesting the fund would initially support around 6,000 hectares, a small area by comparison with the potential. **We recommend that production of crops for energy purposes should be regarded as a primary use for agricultural land, and policies and support measures should reflect that.**

7.83 The ultimate potential of specially grown crops as energy sources is very large. However radical changes in the use of agricultural land cannot be achieved without a complete transformation of agricultural support mechanisms, which are almost wholly determined at EU level. An area of 5.5 million hectares devoted to energy crops (7.71) would represent 30% of the present total of agricultural land in the UK, or almost two-fifths more than the total area used for cereals at present.[88] Looking further ahead however these estimates provide some indication of the ultimate potential for generating electricity from energy crops in the UK.

7.84 The constraints imposed by availability of land lend additional emphasis to the point that the managed use of energy crops provides a more effective and reliable way of countering climate change than planting trees to offset continuing use of fossil fuels. A sustained programme of afforestation of 30,000 ha per year (combined with replanting of harvested areas) would sequester less than 2% of UK fossil fuel carbon emissions.[89]

7.85 Realising the full potential of energy crops will be a massive undertaking. With energy crops, as with wastes, policies in other fields will have a considerable influence, not merely on the availability of the resource but on the cost at which it will be available for energy use and on the willingness of those controlling it to enter into long-term contracts for its supply. Companies promoting generating plants, at least in the early stages, will want a guaranteed long-term supply of fuel. On the other hand farmers may be reluctant to enter into long-term contracts which might prevent them from taking up other and more profitable opportunities at a future date. There is some flexibility in the fuels that can be used in plants, but that cannot be regarded as representing a satisfactory solution on a large scale or for the longer term. All the essential connections will have to be made between siting of plants, availability of fuel within an acceptable distance, and the identification and servicing of demands for heat.

Technologies requiring further development

7.86 The final category of alternatives to fossil fuels are renewable energy sources which seem to have considerable potential in the UK, but have received little support so far, and require much further work in order to assess their practicability and demonstrate the technology. In this category we place wave power and turbines placed in tidal streams (as distinct from tidal barrages, which were discussed at 7.22-7.24 and 7.30). Another technology regarded at one time as possibly having a large potential, exploitation of geothermal heat by injecting water into otherwise dry rock formations (‘geothermal hot dry rock’), was not shown to be feasible in a programme carried out between 1976 and 1991,[90] or in a contemporary US programme, and is not therefore discussed here.

Wave power

7.87 Energy is present both in the lateral movement of waves and in their height. Different technologies have been developed for shoreline, near shore and offshore conditions. Most of the devices built have been based on an oscillating water column (OWC) which, as it rises and falls inside a hollow structure with the movement of the waves, alternately compresses and depressurises the column of air above it, so driving a turbine. The government provided support for research on wave power from 1974, but the level of support was reduced sharply in 1983 following a recommendation from a review of energy research and development that no new development work should be supported on large-scale offshore devices.[91] Until recently government support for development of wave power was confined to desk studies to assess new designs which offer the prospects of improved economic performance.[92] We regret that more support has not been provided.

BOX 7C **CURRENT WAVE POWER DEVICES**

A prototype 75 kW OWC (oscillating water column) device operated for some years on the island of Islay, but has now been decommissioned.

Although there are numerous designs for wave power devices none has established itself as yet.[93] There are firm plans to install and operate two devices under the third round of the Scottish Renewables Obligation:

> the LIMPET (Land Installed Marine Powered Energy Transformer), an *onshore* system consisting of an OWC and a 0.5 MW turbine, is due to be commissioned in August 2000 on Islay;[94]
>
> the Pelamis, or sea-snake (see photograph XV), is an *offshore* system consisting of an articulated structure in which the motion induced in the joints during the passage of a wave is resisted by hydraulic rams which drive hydraulic motors.[95] Two 375 kW devices are due to be installed off the coast of Islay in 2001, with a grid connection planned in 2002.[96]

The combined capacity of these two installations will exceed the total capacity of wave power devices operating elsewhere in the world at the beginning of 1999.

7.88 Recently support for wave power has been provided under the Scottish counterpart to the NFFO (5.38). There are currently three wave power schemes undergoing development in Scotland, described in box 7C.

7.89 The environmental impacts of wave power installations will raise similar issues to those discussed previously in relation to offshore wind farms (7.38). Because the equipment would be largely, or almost entirely, submerged it would represent less of a hazard to birds, but more of a hazard to fish and marine mammals. In order to protect them, it may well be necessary to erect screens. Shoreline or near shore wave power generators would be more visible to people on land. It is claimed such devices would bring incidental benefits in reducing coastal erosion, and possibly also in facilitating growth of plant and animal communities.[97] Some promising sites which are also of ecological importance, and at which the depth of water does not exceed 6 m at low tide, may have legal protection under the Ramsar Convention.[98]

7.90 One question mark over the technology is that wave power devices and their connecting cables are intended to operate with high reliability over long periods under the most arduous conditions. It has yet to be demonstrated that they can do so, particularly in the offshore waters where most of the available energy is to be found.[99] However advantage can be taken of the extensive experience of engineering for adverse conditions gained in the offshore oil and gas industry.

Tidal streams

7.91 The technology used in tidal streams is akin to that used in wind turbines. Although speeds of the water are lower than wind, the greater density of sea water results in much higher energy densities and requires smaller turbine diameters of the order of 20 m. The technology is still at the early stages.[100] So far projects have been small, in the order of tens of kilowatts. But if proved successful, the schemes could have long operating lives and relatively low operating costs. One full-size prototype scheme (300 kW capacity) is under construction in the UK for use off the coast of Devon or Cornwall. The only other company developing this technology is Blue Energy Canada which is investigating a 30 MW scheme in the Philippines.

7.92 The UK has a number of excellent tidal stream sites around its coastline, notably the Pentland Firth, Mull of Galloway, Barry Island and Portland Bill where tidal stream velocities range from 2.5 to 6 m/s. The factors which determine the size of the tidal stream resource are the tidal velocity and the volume through which the current flows. Tidal stream data is provided in Admiralty Tidal Stream Atlases. Taking into account factors such as normal shipping routes, the rating and the efficiency of the turbines (which result in a density of 37 turbines per square kilometre of sea-bed) and availability, the accessible tidal stream resource is estimated by ETSU to be about 4 GW. The true resource may be somewhat higher because there are numerous small sites with high tidal current velocities with insufficient information available to assess them.[101]

7.93 The environmental impact of tidal stream turbines would be broadly similar to that of offshore wave power devices (7.89). The rotors of the turbines might represent rather more of a hazard for fish and marine mammals, but it may be possible to erect protective screens.

FUTURE POTENTIAL

7.94 The sources these newer technologies seek to exploit resemble the second group of non-carbon sources discussed above in being widely dispersed. At the same time the amounts of energy present vary considerably from place to place; for shoreline and near shore wave energy, and still more so for tidal streams, the highest concentrations are in quite small areas. The studies so far carried out have focused on assessing the resources in such areas, and the costs and outputs of devices located there; the energy present elsewhere is likely to be too diffuse to be worthwhile exploiting. Some favourable areas, notably the Bristol Channel, are close to major demand centres; others (the Outer Hebrides, Orkneys and Shetlands for wave energy, and Alderney in the Channel Islands for tidal stream) are very remote.

7.95 The energy in tidal streams is available at predictable times, and for a much higher proportion of the time than would be the case for a tidal barrage, as the turbines can be reversible. Load factors for tidal stream turbines are very consistent, but site-specific, with typical values of between 0.28 and 0.4. Electricity generation from wave energy is likely to be possible at favourable locations, although output will be intermittent with a typical load factor of 0.25,[102] hence the amounts of energy available will vary considerably.

7.96 The amounts of energy it is practicable to obtain from tidal streams and shoreline wave energy seems likely to be quite modest. On present assessments that is also true for near shore wave energy. Larger resources are available offshore, but much less progress has been made in developing suitable technology for that zone.

7.97 Because of its long and exposed coastline the UK is one of the best endowed countries in terms of the energy available in waves. A study of the four most exposed lengths of the west and north coasts of Britain and of the Orkneys and Shetlands concluded that there is an accessible resource of about 0.22 GW of electrical output in the most favourable shoreline sites, 11.4-15.9 GW near the shore (in water depths of 10-25m) and 68.2-79.5 GW offshore (in water depths typically exceeding 40m). After eliminating areas that are likely to be uneconomic because of low energy levels, and taking into account environmental and other constraints on use of sites, the UK's practicable resource of wave energy was estimated to be 6 GW of electrical output, of which 5.7 GW is offshore, 0.24 GW near shore and 0.05 GW shoreline.[103] DTI's 1994 review of renewable sources nevertheless listed wave power as having no accessible resource, on the basis that the technology was too expensive to be competitive;[104] but it is now included among longer-term technologies expected to have potential after 2010 (see box 7E). ETSU's assessment for 2025 now points to an annual average output of 3.75 GW from wave power and 0.25 GW from tidal stream. The ultimate contribution from wave power could be much greater than that.

7.98 In many cases it may be desirable to deploy more than one technology on a single site. As well as minimising, for any given power output, both visual intrusion and disruption to other maritime activities, this approach should also produce significant reductions in the cost of support structures and electrical connections. Against that would have to be set any loss in potential yield if the same sites are not optimal for both sources. The OSPREY device for near shore wave power has been designed to incorporate a wind turbine. If wave power devices for deeper waters are designed to float, incorporation of a wind turbine may not be practicable. **We recommend that DTI commission studies of the feasibility of combining different offshore power generation technologies in a single structure so that, if the findings are promising, further development of the technologies can take place on that basis.**

7.99 Wave power appears to be a field in which the UK has a world lead. Estimated generating costs of electricity from both shoreline and offshore wave power are now much more competitive having fallen over recent years from around 15 p/kWh in 1980 to 5 p/kWh in 1999[105] (assuming an 8% discount rate and that research and development is completed successfully and that current designs will function as predicted without incurring additional costs). There has also been a significant amount of research elsewhere over the last 20 years, mainly in Scandinavia and Japan. Current interest is more widespread, and includes a 1 MW scheme planned in India[106] and a 1 MW pilot plant sponsored by the European Commission in the Azores.[107] If the technology is developed successfully, there could be a large export market.[108] The pace of development is now rapid, and concern has been expressed that the advantage the UK has at the moment could quickly be eroded.[109] Given its natural advantages, and the inventiveness its engineers have shown, it would be regrettable if the UK became dependent on imported technology, as has happened in the case of wind power.

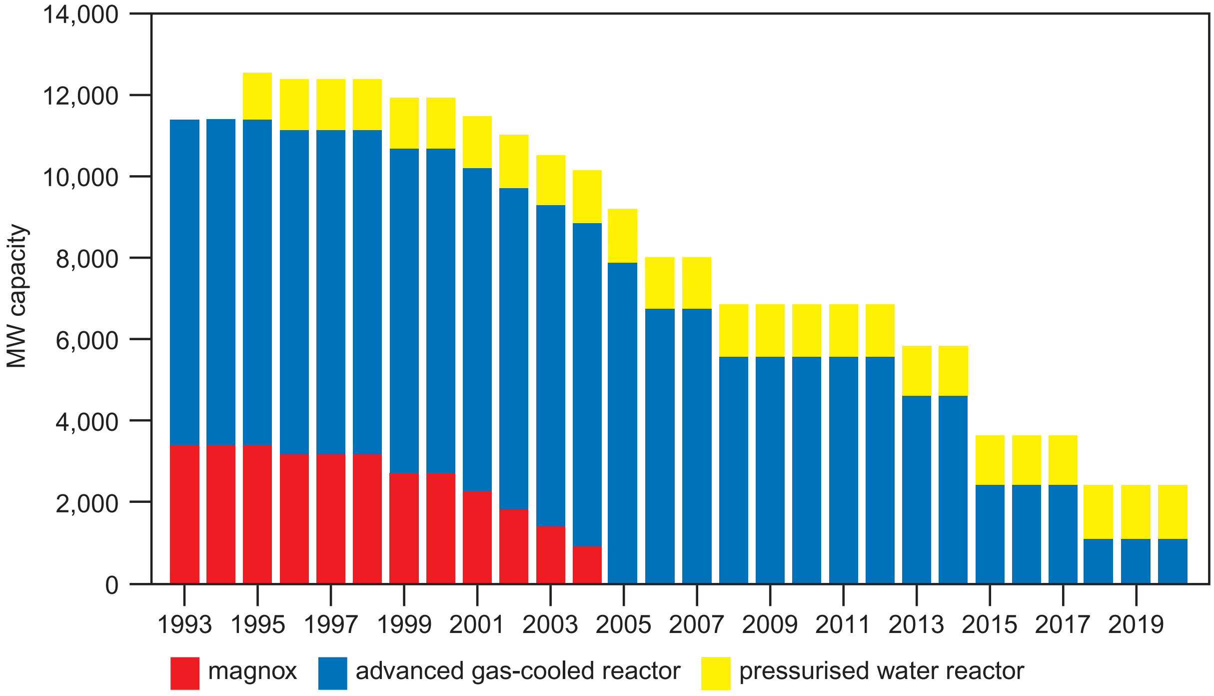
7.100 The global market for tidal stream technology is assessed to be far smaller because of the high initial costs of devices.[110] Nevertheless this is also a field in which the UK has a world lead. The government has not provided any support for tidal stream technology; a grant towards the cost of the prototype device being constructed has been provided by the European Commission.[112] **We recommend that stronger support be given to wave power and tidal stream technology, which have considerable promise. Support can take the form either of funding research and development or of awarding contracts for electricity generated by these methods.**

CURRENT PROSPECTS FOR ALTERNATIVE ENERGY SOURCES

7.101 In the previous sections of this chapter we have reviewed the use made in the UK at present of the energy sources which provide alternatives to fossil fuels and their long-term potential. We now discuss their current prospects over the next two decades in the light of present government policies, including the proposals recently put forward for future support to renewable energy sources. We then consider public perceptions of alternative energy sources and the relevance these have for any strategy for their future development. In the next chapter we go on to consider the roles alternative sources could play in the longer term within the overall energy system for the UK.

7.102 Nuclear power is used on a substantial scale at present, but the capacity of nuclear power stations is starting to decline as the first generation stations are closed. A further large reduction is scheduled over the next two decades as the second generation stations are progressively closed. Figure 7-I shows the projection submitted to us in evidence by the company which owns and operates the newer stations.[113] In the absence of new construction, the third generation station, Sizewell B, is likely to be the only one still operating in 2025. The government's draft Climate Change Programme gives a broadly similar picture.[114]

Figure 7-I
Nuclear power: retirement pattern of existing power stations*



*source: British Energy

7.103 The prospects for nuclear power in the UK were reviewed by the previous government in 1995.[115] A second pressurised water reactor (Sizewell C) was identified as the best option for a new nuclear station in the short term. Estimated to produce electricity at a price of 2.9 p/kWh (with an 8% discount rate), it was not regarded as competitive with gas-fired stations. This cost is however below those of many of the other alternatives to fossil fuels.

7.104 In 1998 the House of Commons Trade and Industry Committee recommended that: 'A formal presumption be made now, for purposes of long-term planning, that new nuclear plant may be required in the course of the next two decades.'[116] This recommendation has been supported by a joint working group of the Royal Society and the Royal Academy of Engineering, which has further urged that:

> The timetable for such consideration should allow a decision to be taken early enough to enable nuclear to play a full, long-term role in national energy policy. This is likely to mean early in the next administration if a damaging decline in the role of nuclear is to be avoided.[117]

7.105 The government has recently said that: 'Questions of cost, waste disposal and public acceptability would need to be resolved before industry put forward any proposals for approval.'[118] We concur in that view. We emphasise however that, unless closure of nuclear power stations is offset by construction of new generating plants which do not emit carbon dioxide, there will be a direct conflict with any strategy to counter climate change, in that electricity generation will become more carbon-intensive.

7.106 In principle renewable energy sources could be developed on a scale that would compensate for the reduced contribution from nuclear power. But government policy does not provide for that. Its proposed target, still subject to consultation, is that the proportion of UK electricity requirements met from renewables should be increased from 2.5% now to 5% by the end of 2003 and 10% by 2010.[119] Nothing has so far been said about any further increase beyond 2010.[120,121] **We recommend that longer-term targets be set for expanding the contribution from renewable sources well beyond 10% of electricity supplies to cover a much larger share of primary energy demand.**

7.107 Whether the target for 2003 is achieved will largely depend on the successful implementation of renewable energy schemes which have been accepted by the government under the non-fossil fuel obligation (NFFO) (5.38), the system of support which has operated up to now. In principle this is a subsidy to renewable energy sources at the expense of consumers (albeit a much smaller one than the subsidy originally provided by consumers to nuclear power under the same procedures, but now removed). The size of this subsidy has been reduced because the system of competitive bidding under NFFO has halved the average declared price, so that in the fifth and final round it had fallen to 2.71 p/kWh, only marginally above the average pool selling price of 2.60 p/kWh in 1998.[122] As can be seen, this is below the most recently quoted cost for electricity from a new nuclear power station (7.103). There would nevertheless be a continuing subsidy under NFFO contracts already entered into: but in practice that may be overtaken by transitional arrangements being devised to ensure that contracts continue to be viable under the new system of support described below.[123]

7.108 In the liberalised electricity market consumers can now make a personal choice to support renewable energy sources by opting for a *green tariff*, either from a major supplier or from an independent supplier using only renewable sources. Some green tariffs involve payment of a premium which will be invested in a fund to support development of renewable sources. The Energy Saving Trust has established an accreditation scheme to ensure that green claims by suppliers are supported by independent auditing and that customers know the mix of generation used to fulfil the tariffs they are choosing.[124]

7.109 Support for projects which obtained contracts in the first two rounds of NFFO terminated at the end of 1998. They will be eligible for the new system of support described below, but for the moment are largely dependent on contracts negotiated with companies offering green tariffs. Such tariffs have not in most cases been marketed intensively, and they have not apparently met with an enthusiastic response from consumers. We regard support and incentives provided by government as a more appropriate and effective way of stimulating development of renewable energy sources. It is not clear how green tariffs will be affected by the new system of government support described below.

7.110 The government will provide a fiscal incentive for firms and public bodies to use electricity from renewable sources (other than large-scale hydro) by exempting such supplies from the climate change levy which will apply from April 2001. The expected rate for the levy in the case of electricity is 0.43 p/kWh. Heat from renewable sources will also be exempt from the levy. The upstream carbon tax we advocate (6.156-6.158) would provide a more general, and a more appropriate, incentive for using energy sources which do not add to the concentrations of greenhouse gases in the atmosphere.

7.111 The government has decided to replace NFFO with a Renewables Obligation which will require licensed suppliers to provide a specified proportion of their electricity supplies to their customers from renewable sources. It has included powers for this in the current Utilities Bill. This system will apply throughout Britain, although there is likely to be a separate order for Scotland. It is described in box 7D. **We recommend that new arrangements for supporting renewable energy sources should also be introduced in Northern Ireland.**

BOX 7D **PROPOSED RENEWABLES OBLIGATION**

The government's intention is that all electricity suppliers (with only small exceptions, for example for new entrants), should be required to obtain the same proportion of their supplies from renewable sources in any given year. Each supplier will be able to pass on any additional cost incurred to its customers. There will be a cap on the additional cost, expected to be about 2 p/kWh, in that a supplier will be able to buy out all or part of its obligation to supply from renewable sources in a particular year by making a payment to the Office of Gas and Electricity Markets (OFGEM). The proceeds will be recycled to suppliers under a formula designed to act as an incentive for compliance with the obligation. The buy out provision has been explained as a safeguard against a sharp rise in the cost of electricity from renewable sources if there were to be serious delays in developing new sources.

To enable companies to plan ahead the period of the obligation is expected to apply until at least 2025. Suppliers may enter into individual agreements with generators using renewable sources, or may do so collectively, or in some cases may themselves own the generating plant. It is likely that large inland water power schemes will not be eligible, on the ground that this technology is already well-established and competitive.

Suppliers will have the option to fulfil their obligation by purchasing, either from other suppliers or from intermediaries, green certificates representing metered units of electricity from renewable sources, certified by OFGEM. In that event however their customers would not be able to claim exemption from the climate change levy. The government sees green certificates as facilitating transition from a subsidised regime to a position where renewables compete on a commercial basis.

An annual report by OFGEM will cover the additional cost to consumers, and may distinguish between different types of consumer.

7.112 We welcome the introduction of a scheme to replace NFFO and the Scottish Renewables Obligation (SRO), and support the general approach the government has adopted. We are concerned however that, because all generating plants using renewable energy will be competing against each other on price, there will not necessarily be sufficient support for those technologies which have the greatest long-term potential but may be more expensive at present. The experience under NFFO illustrates what we see as the danger.

7.113 A large proportion of the projects accepted under NFFO have involved three sources: municipal and industrial waste, large wind farms and landfill gas. The low average contracted price in NFFO-5 reflects not only the reduction in the price of wind power schemes but also the low prices bid for landfill gas and waste-to-energy plants, which can be regarding as reflecting the fact that disposal of wastes and collection of methane are activities that have to be undertaken whether or not electricity is generated. The average price in NFFO-5 was 2.63 p/kWh for plants burning municipal solid waste and the highest price for plants burning landfill gas was 2.9 p/kWh.[125] Municipal solid waste, and more especially landfill gas, have only limited long-term potential.

7.114 The government has recognised the need to take other measures in order to encourage renewable energy technologies which may have a big long-term potential, but might not attract immediate support from electricity suppliers under the new scheme. Its categorisation of the prospects of different technologies is given in box 7E. It is considering supplementary support for offshore wind and energy crops, as technologies that could contribute by 2010, but has not yet decided what form that support would take. It has canvassed the idea of demonstration projects. DTI's research and development programme has been expanding, but remains modest at a planned £18 million in 2001/02. **We recommend that the government provide part-funding for demonstration projects for those renewable technologies which have major long-term potential but are unlikely to attract support from electricity suppliers under the new Renewables Obligation; and should use for that purpose some of the £50 million a year for carbon-saving measures that is being made available from the revenue raised by the climate change levy.**

BOX 7E DTI'S CLASSIFICATION OF NEW AND RENEWABLE ENERGY TECHNOLOGIES

NEAR TERM

Technologies closest to being competitive in UK or with immediate export potential:

UK and Export Market

wastes and some biomass residues, landfill gas, onshore wind, hydro, passive solar

Primarily Export Market

photovoltaics (stand alone), biomass residues, active solar

MEDIUM TERM (BY 2010)

Additional technologies which could contribute by 2010 and would be needed to meet a 10% UK target, or with export potential:

UK and Export Market

some biomass residues, offshore wind, energy crops

Primarily Export Market

photovoltaics, fuel cells

LONGER TERM (AFTER 2010)

Technologies with longer term potential if pursued via R,D&D programme:

UK and Export Market

fuel cells, photovoltaics (building integrated), wave, photoconversion

Primarily Export Market

solar thermal electricity

VERY LONG TERM (AFTER 2025)

Technologies unlikely to be worth pursuing extensively at this time except at the fundamental research level where this would be perceived as necessary:

UK and Export Market

tidal barrage, hydrogen, geothermal hot dry rock, ocean thermal currents

7.115 One source of concern about the prospects for achieving the 10% target for 2010 is the very mixed success of NFFO and SRO schemes in terms of actual implementation. This applies in a striking way to the three technologies which provided 97% of the projects accepted in NFFO-5. By the end of 1998, 95% of landfill gas schemes under NFFO 1-3 had been commissioned but only a quarter of the waste-to-energy projects; the proportion for wind farms was 39%, but had declined with time.[126] Achieving any target for alternative energy sources will depend crucially on gaining public acceptance for the necessary installations.

PUBLIC ACCEPTANCE OF NEW ENERGY SOURCES

7.116 Although there is great potential for the UK to obtain energy from sources other than fossil fuels, exploiting those sources will depend on public acceptance for the installations that would be required. Proposals to construct energy installations have often proved contentious, and history provides salutary lessons on how public perceptions of an energy source can change. The opening in 1956 of Calder Hall, the first nuclear station to contribute to the National Grid, was hailed as the dawn of an era of limitless cheap electricity from what was seen as an environmentally benign source. Forty years later, in part because of events outside the UK but also because of failure to solve the problems of nuclear waste, many people had come to regard nuclear power as unacceptable on environmental and social grounds. The most contentious energy developments have been in the nuclear field, as evidenced by the lengthy public inquiry before consent was given for the most recent nuclear power station, Sizewell B.

7.117 Renewable energy sources have been hailed as environmentally benign. Most of them do not emit carbon dioxide or other substances, or give rise to solid or liquid wastes. All energy installations however take up areas of land or sea. They are sometimes of considerable size and/or located in areas which are highly prized for their beauty or isolation or wildlife. Plants generating electricity are often linked to overhead transmission lines, which cause further visual intrusion. There may be other impacts, for example new access roads or increased road traffic. Many of the recent examples of contentious energy developments have been proposals for wind farms. Planning applications have met with so much resistance in numerous localities that the development of wind energy on land in the UK is, in effect, stalled.

7.118 It was put to us in evidence that the problems in finding sites for wind turbines amount to a failure of the planning system. The body representing the promoters of wind energy schemes contended that their 'visual impact ... is not an environmental impact per se, but an aesthetic judgement'; and argued that opposition comes from 'minority groups', that there is often significant local support, and that criticism of wind energy is 'misinformed'.[127] It wanted the government to make clear that, as with new housing or extraction of sand and gravel, every local planning authority must play its part in providing sites for renewable sources of energy; in effect, that the balance in planning decisions must be tilted towards energy installations. Friends of the Earth suggested clearer guidance should be given to planning authorities about renewable energy projects.[128]

7.119 Bodies concerned to protect the countryside placed a different interpretation on what has happened.[129] They pointed out that the proposals which have run into difficulties tend to involve large wind farms in areas with high wind speeds, where the most electricity can be generated at the lowest cost, and that such areas are often environmentally sensitive. There is a national interest in protecting wild and beautiful landscapes and not creating hazards to birds in flight. The Countryside Commission suggested that the reductions in carbon dioxide emissions as a result of constructing wind farms would be small in comparison with the total reductions required or the annual growth in UK electricity consumption, implying that degradation of the landscape for this purpose could not be justified.[130]

7.120 The conflict between protecting landscapes from large installations and obtaining energy without emitting carbon dioxide may amount to a conflict of values, of the kind discussed in our report *Setting Environmental Standards*.[131] We concluded there that difficulties have arisen largely because the planning system was not used in a proactive and strategic way to frame appropriate questions and explore possible solutions.

7.121 The Countryside Commission expressed the view that many problems could be averted if a strategic approach is adopted to the planning of wind energy at regional level, bringing together the main stakeholders at an early stage so that sensitive landscapes can be avoided from the outset.[132] The Commission's successor, the Countryside Agency, recently published, in conjunction with Scottish Natural Heritage, interim guidance on assessing landscape character.[133]

7.122 The government intends to promote a positive strategic approach to planning for renewable energy in England based on regional renewable energy assessments, which will provide a framework for regional planning guidance, and so in turn for local authority development plans. The Government Offices for the Regions are setting in motion the preparation of such assessments with the intention that they will include planning targets for renewable energy provision. Different arrangements will need to apply in Scotland, Wales and Northern Ireland.[134] **Renewable energy assessments, and in particular any targets they contain, should give full weight to landscape character and should be subject to a strategic environmental assessment.** It is likely that this kind of overall environmental assessment of programmes for developing energy sources will in any case be required under an EC Directive now being considered.[135]

7.123 Development in coastal areas may raise particularly difficult problems. Offshore energy installations (offshore wind power, wave power and tidal stream) are not subject to the land use planning system. However a recent court decision appears to require the EC Habitats and Species Directive to be applied to a distance of 200 miles from shore. Moreover, as well as competing with established maritime activities such as fishing and navigation, these technologies may also be in competition with each other for suitable sites. **Regional renewable energy assessments should give particular attention to identifying areas that are likely to be acceptable on environmental grounds for offshore renewable energy technologies.** One of the aims of the exercise should be to exploit suitable opportunities for incorporating more than one of these technologies in a single structure (7.98).

7.124 Another reason for local opposition to wind farms identified in the evidence we received from countryside protection bodies was that people do not perceive large schemes feeding into the National Grid as meeting the energy needs of their own communities. Every community, rural or urban, should be encouraged to review its impact on the environment in terms of demands for energy and the ways in which they are met. That will involve considering the scope for reducing demand by increasing efficiency, and the extent to which the expected level of demand could be met through sources of energy available locally. At the regional level this approach has been pioneered by the Northern Energy Initiative in an energy strategy for the North East of England, covering the next decade, published in November 1999.[136] This could serve as a model for other regions, with the time-scale extended in future cases to the 15-20 year time-scale of regional planning guidance and county structure plans.

7.125 A similar approach can be adopted at a more local level. In some other European countries there is a long tradition of ownership of energy utilities by local communities, which can benefit either through lower energy prices or through use of the profits for other local purposes. This gives them a direct interest in developing new energy sources. In contrast, the UK has liberalised markets for electricity and gas, with tariffs that apply nationally. Tangible advantages to the local community from construction of an energy installation are therefore confined to any employment provided and any incidental benefit by way of planning gain.

7.126 The principle that the price paid by customers for energy should not reflect their distance from the source of supply may be questioned now that clear distinctions have been drawn between responsibility for supply, transmission and (in the case of electricity) distribution, and these activities are being separately costed. If local communities found they could avoid increased prices for electricity by choosing suppliers which do not have to incur large charges for transmission and distribution, they would have a direct incentive to achieve greater self-sufficiency in energy.

7.127 The situation has changed in one respect since we took evidence. Whereas under NFFO the contract to purchase electricity from a specified renewable energy scheme preceded the grant of planning permission, electricity suppliers will now have to seek out generators who will enable them to comply with their obligation to obtain a given proportion of electricity from renewable sources. It will be prudent for companies wishing to undertake renewable energy schemes to open discussions at an early stage with the local planning authority and local people and develop proposals in consultation with them.

7.128 There is one type of renewable energy scheme in which the full involvement of the local community will be crucial, and which will also bring them direct advantage. That is the development of combined heat and power schemes using renewable energy sources and supplying residential neighbourhoods both with electricity and with heat through district heating networks.

7.129 Achieving very large reductions in carbon dioxide emissions is likely to involve the development of new energy sources on a scale that will raise issues of public acceptance at national level, as well as local level. For such policies to be acceptable to the public, they must have clearly understood objectives, be based on a full examination of the options, and represent an integrated approach which seeks to reconcile conflicting considerations. In the next chapter we discuss how an integrated approach can be based on an understanding of the dynamics of the UK energy system. Then in chapter 9 we consider some possible options for supplying given levels of energy demand while at the same time making deep cuts in carbon dioxide emissions, and what impacts those options would have on the environment in other respects.

There is great potential for the UK to obtain energy from renewable energy sources. Realising that potential will be dependent on adequate government support, careful attention to their particular characteristics and public acceptance for the necessary installations. Before new nuclear power stations are built, the waste management problem would have to be solved, not only to the satisfaction of the scientific community, but as a necessary part of gaining public acceptance