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The Economics of Renewable Energy

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NOTE:

(Q) refers to a question in oral evidence

(p) refers to a page of written evidence

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ABSTRACT

The British economy will increasingly feel the impact of the Government's commitment to reducing carbon emissions, including targets for greater use of energy from renewable sources. The Government describes its targets for renewables as challenging; others have suggested they are unachievable. In any event, the effort to meet them will come at a cost and, if not properly managed, risks distracting attention from other means of reducing emissions.

It seems timely, therefore, to examine the economics of renewable energy. We take as a given the Government's wish to reduce carbon emissions; we do not address how far such reductions are justified as a contribution to a world-wide effort. We note the following main points:

—EU targets have focussed the spotlight on renewables rather than other means of reducing emissions such as energy efficiency or greater use of nuclear power.

—The EU is committed to a binding target that 20% of its energy consumption should be from renewable sources by 2020. Individual states' contributions to the overall target are still only proposals and some remain a matter of dispute. The Government seems ready to accept the Commission's proposal that the UK target should be 15% of energy from renewables by 2020.

—The expected UK target implies a dash from 1.8% renewable energy now to a near-tenfold increase in 12 years.

—Most of the increase in renewable energy in Britain is expected to come from electricity generation—although electricity represents only a fifth of the country's energy consumption—with an anticipated rise from 5–6% renewables now to 30–40% in 2020.

—Most of the extra renewable generation is expected from wind turbines, which offer the most readily available short-term enhancement of renewable electricity at a relatively cheap base cost; but they produce electricity only intermittently and the scope in the UK for increases in more dependable supply from other renewable sources—particularly hydro-electric, domestic biomass and solar—is limited, while tidal barrage and wave are still at an early stage of development in Britain.

—To make up for its intermittency, a significantly greater capacity of wind than of conventional or nuclear plant is needed for any given output of electricity; furthermore, in the absence of technological advances in electricity storage and of greater interconnection of the British and Continental transmission networks, back-up conventional plant will be essential to guarantee supply when required, to compensate for wind's very low capacity credit (probable output of power at the time of need).

—Wind generation should be viewed largely as additional capacity to that which will need to be provided, in any event, by more reliable means; and the evidence suggests that its **full** costs, although declining over time, remain significantly higher than those of conventional or nuclear generation.

—The dash for intermittent renewable generation will coincide with, and be in addition to, the programme to replace substantial amounts of old coal and nuclear plant and to meet increases in demand—amounting to about a quarter of current capacity.

—In short, the pursuit of a 15% renewables target will roughly double the requirement for new capacity for power generation that would otherwise be due in the UK between now and 2020; the scale and urgency of such investment is formidable. It is also subject to planning consents.

—The extra cost of electricity generation and transmission in Britain in 2020 with 34% renewables is likely to be £6.8 billion a year, an extra 38%. Most of this would be met by the consumer; about £80 a year (at current prices) for the average household.

—There would be little investment in renewable electricity generation without Government support.

—Heating and transport each represent some two-fifths of the country's energy consumption but have received relatively little Government support or attention by comparison with electricity generation.

The UK has a poor record in meeting targets in this area and it must be doubtful whether a 15% EU target can be met under current policies. If it were met, it would mark a step change in the use of renewable energy but take Britain into a degree of dependence on intermittent renewables unprecedented elsewhere in Europe, with the attendant risks. Determination to meet the target may lead to over-emphasis on short term options, simply because they are available, rather than because they offer the most effective and economical means of reducing carbon dioxide emissions over the longer term.

The Government rightly aims to ensure reliable and affordable energy supplies and is right to say that a portfolio of policies is needed if we are also to reduce carbon emissions. But, in pursuing its renewable energy target, to guard against the risk of power shortages it should look beyond the generation of electricity by intermittent means and encourage other economic and effective ways of reducing carbon emissions across all sectors, so that investment in them is not diverted by incentives for intermittent sources of supply. Specifically, the Government should:

—Give a firm lead and maintain a stable investment framework for large-scale, low carbon alternatives to renewable power generation. Nuclear is not intermittent; neither is fossil fuel generation with carbon capture and storage, if and when that becomes available.

—Emphasise and promote the opportunities for renewable heat as strongly as for renewable electricity generation.

—Look afresh at the UK's research effort into renewables and consider how to promote more, and more focussed, research leading to new, effective and economical ways to reduce carbon emissions; it should also consider offering a substantial annual prize for the best technological contribution.

—In particular, encourage research into energy storage technologies with a view to mitigating the disadvantage of intermittency in the types of renewable generation likely to prevail in the UK.

The Economics of Renewable Energy

CHAPTER 1: INTRODUCTION

1. The Government is committed to a substantial increase in renewable energy over the next decade as a major part of its programme to reduce carbon emissions. Currently 1.8% of energy used in Britain comes from renewable sources—the Government aims to increase this to 15% by 2020 in line with European Commission proposals.¹ Greater use of renewables is expected to increase energy costs. But the cost of non-renewable sources of energy can also rise as recent volatility of oil and gas prices shows.
2. We decided it would be timely to examine the economics of renewable energy. The Committee's starting point is the Government's wish to reduce carbon emissions—this report does not discuss whether or how far it is necessary to do so. An earlier report by the Committee on climate change examined the issue in 2005.²
3. Chapter 2 gives a brief overview of Britain's energy system and outlines the Government's energy policy objectives.
4. Chapter 3 examines the different renewable technologies used to generate electricity. Electricity generation is often cited as the sector with the most potential for increasing the use of renewable sources, although it represents only around 20% of UK final energy consumption. The chapter compares the generation costs from different renewable sources with each other and contrasts them with fossil fuel-fired plants and nuclear power.
5. In Chapter 4, we move from power generation to the electricity system as a whole. We explore the issues involved in balancing the irregular supply from renewable generators which depend on weather conditions against the continuous demand for electricity. We examine the costs of connecting renewable generators to the electricity grid which carries power to homes and businesses across the country.
6. In Chapter 5, we examine the potential for renewable sources of heat and of transport fuels—areas often overlooked, although they represent roughly 80% of UK energy consumption. We look at the options in these sectors and compare the costs to those of renewable electricity generation.
7. Chapter 6 looks at the key policy issues surrounding renewable energy, such as how much support, and of what kind, the sector should get. We consider the impact of renewable policy on fuel poverty, the planning system for renewable energy, and whether the 15% target proposed by the European Commission is achievable.

¹ The European Commission has set a binding target that 20% of the EU's energy consumption must come from renewable sources by 2020. However, the individual member states' contributions to this target are still only proposals and are a matter of dispute. For the United Kingdom, the European Commission has proposed that 15% of its energy come from renewable sources.

² House of Lords Select Committee on Economic Affairs, 2nd Report (2005–06), *The Economics of Climate Change*, (HL 12)

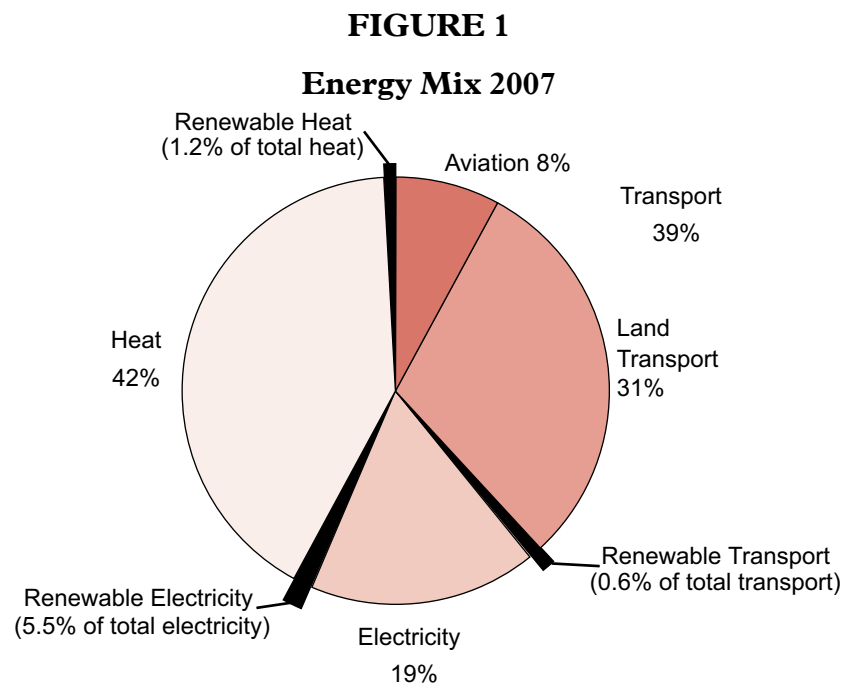
8. To keep the scope of this report manageable, we decided not to cover energy efficiency. It remains the case, however, that improvements to the way in which we use energy may be among the most cost-effective ways to reduce carbon emissions. We emphasise that nothing in this Report should be taken to imply that we do not recognise the critical importance of energy efficiency measures.
9. The geographical focus of the Report is the UK and the EU. The electricity system in Northern Ireland is run separately from that in Great Britain; almost all the evidence we received related to the system in Great Britain. As witnesses noted, the impact on carbon emissions of measures taken in the UK on its own (or, indeed, even in Europe as a whole) is likely to be minimal unless similar policies are adopted elsewhere.

CHAPTER 2: RENEWABLES AND THE UK ENERGY SYSTEM

10. Renewable energy differs from conventional fossil fuel or nuclear energy in that the latter are dependent on finite resources, while the former is not. Currently renewable energy supply is only a small part of Britain's energy system. In this chapter we give an overview of the energy system and the Government's energy objectives.

Britain's energy system

11. There are three main uses for energy—heating, transport and as electricity. In 2007 heat accounted for 42% of final energy consumption in the UK, transport for 39% and electricity for 19%.³ The share of heat has been falling in recent years, and those of transport and electricity have risen. Overall, renewables accounted for only 1.8% of energy used in Britain, calculated on the basis used by the European Commission.⁴ Most of this has been to generate electricity. About 5.5% of electricity came from renewables in 2007 but only around 1% of the energy used in heat and transport was renewable.

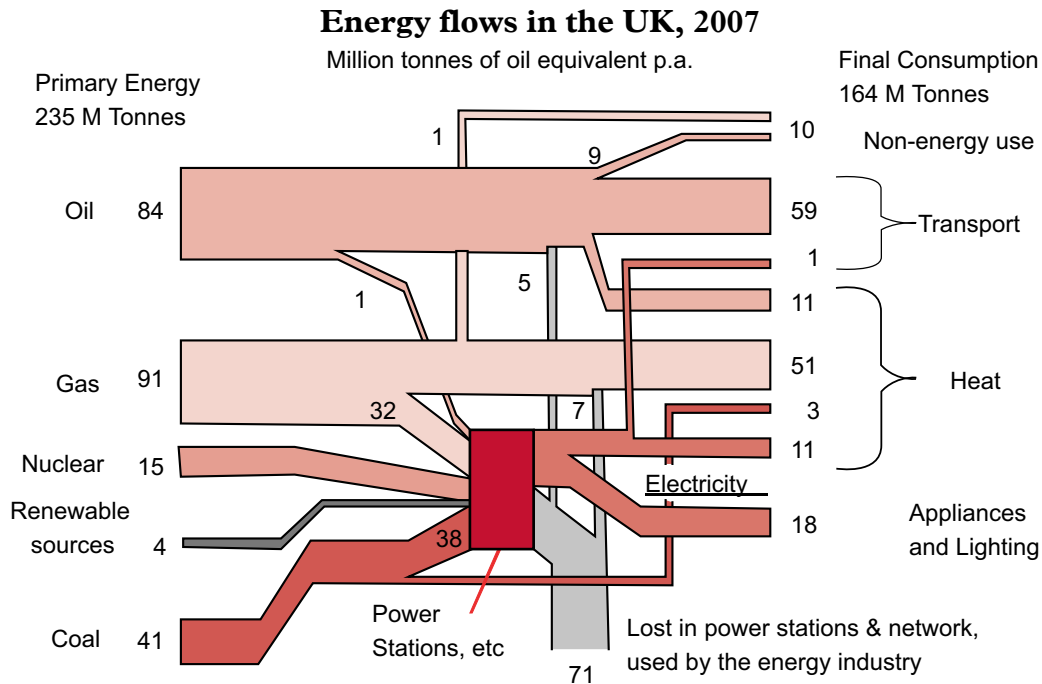


Source: *Digest of UK Energy Statistics*

³ Digest of UK Energy Statistics, 2007 edition. Electricity used to provide heat is counted as “electricity” rather than as “heat”. Final energy consumption, as defined in UK statistics, also includes non-energy use—mainly when oil and gas are used as chemical feedstocks—which makes up 6% of it.

⁴ The European Commission excludes the non-energy use of oil and gas, and includes electricity used at power stations and lost in transmission and distribution networks—both changes have the effect of raising the share of electricity in final energy consumption, compared to the standard UK definition.

FIGURE 2



Numbers have been rounded, and do not balance exactly in the source

Source: BERR

12. Figure 2 shows the main sources of energy, giving domestic production plus net imports of coal, oil, gas, nuclear electricity and renewable power, measured in millions of tonnes of oil equivalent.⁵ Oil is by far the most important transport fuel, but around 11 million tons is used for heating. A small amount is burned in power plants to generate electricity, and a significant quantity is used outside the energy industry, as a chemical feedstock. Gas and coal are burned in power plants to generate electricity (in roughly equal amounts) and are also burned to provide heat. The other sources of electricity are from using uranium in nuclear power stations, and from renewable power sources. Only part of the energy that goes in to power stations is converted into electricity, while the rest is lost as waste heat. Electricity is also lost in the transmission and distribution wires, while some gas is used to power the compressors that move it around the pipeline network. These losses are shown in the flow that leaves the bottom of the diagram. Nearly two-thirds of our electricity is used for lighting and appliances, where it has no effective substitute, but much of the rest is used for heat. This is illustrated approximately in Figure 2, which shows a higher overall share of heat than Figure 1. A small proportion of our electricity is used in transport, mainly on the railways.

The electricity system

13. Much of this report is concerned with the use of renewable sources to make electricity. Unlike coal, gas and oil, electricity cannot be stored easily on a large scale. This means that we must consider the industry's capacity—the amount that can be produced at any moment—alongside the energy that it

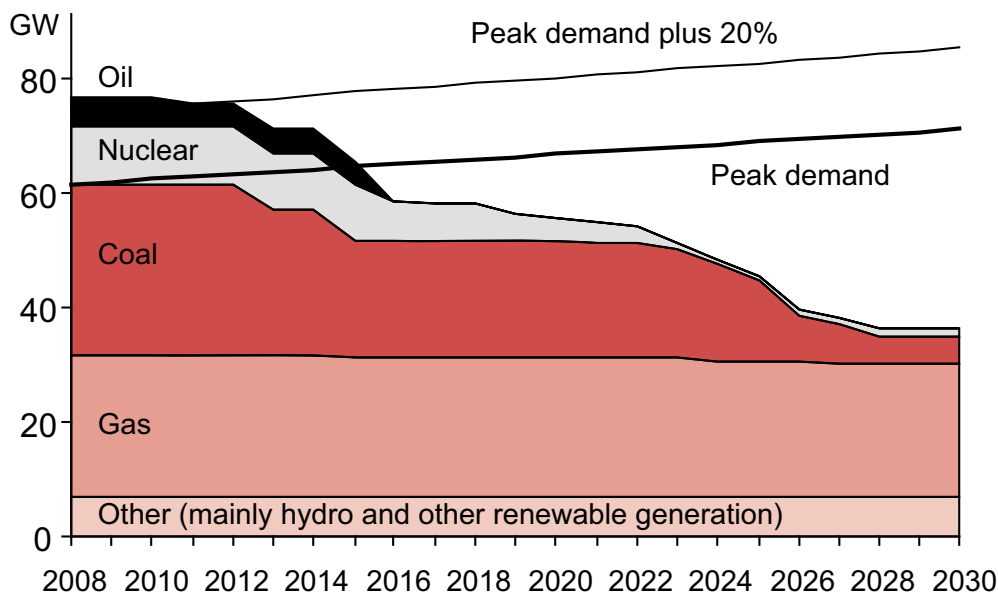
⁵ A million tonnes of oil equivalent—the unit used in Figure 2—is the amount of energy released by burning 1m tonnes of crude oil, and is equal to 11.63 billion kilowatt hours (the standard unit of electrical energy). A one bar electric fire consumes approximately one kilowatt of power.

produces. Britain has 76 GW (1 GW = million kilowatts) of electricity generating capacity, a margin of roughly 25% over the highest electricity demand in 2007 of 61.4 GW. Average demand was just under 40 GW. The largest power station in Britain, Drax in Yorkshire, has a capacity of 4 GW, but most of the gas-fired power stations built in the last two decades have a capacity of between half and one GW.

14. Even without renewables, Britain's electricity system will go through a period of heavy investment. 18 GW—almost a quarter—of electricity generating capacity is due to close by 2020. Of this, 8.5 GW of coal-fired plants will close to meet EU requirements on pollution⁶ as will another 2.5 GW of oil-fired stations. A further 7 GW of nuclear power is scheduled to close by 2020, based on the published lifetimes of the plants (which have, in the past, been extended, subject to meeting safety requirements). The impact of these closures on Britain's electricity generating capacity is shown in figure 3 below. In the meantime, demand for electricity is also expected to increase which will also have to be met by greater capacity. The dotted line shows a 20% margin over peak demand which is the current amount of spare capacity available to ensure there are no power cuts when power plants need to be turned off for maintenance and repairs. If this margin is to be maintained at around 20% then new power stations need to be built in good time to replace these closures and to meet increases in demand. On this basis, the Government has calculated that around 20–25 GW of new power stations will be needed by 2020.⁷ These figures do not take the new renewables targets into account.

FIGURE 3

Predicted electricity demand and generation capacity after forecast closures



Source: E.ON UK

⁶ The Large Combustion Plant Directive requires coal- and oil-fired power stations either to fit Flue Gas Desulphurisation equipment or to close by the end of 2015.

⁷ Department of Trade and Industry, *Meeting the Energy Challenge*, A White Paper on Energy, May 2007, p 128–129.

Energy policy objectives

15. In last year's energy white paper the Government said, "Our four energy policy goals are:
- to put ourselves on a path to cutting the UK's carbon dioxide emissions—the main contributor to global warming—by some 60%⁸ by about 2050, with real progress by 2020;
 - to maintain the reliability of energy supplies;
 - to promote competitive markets in the UK and beyond, helping to raise the rate of sustainable economic growth and to improve our productivity; and
 - to ensure that every home is adequately and affordably heated".⁹
16. The Government's second objective—maintaining the reliability of electricity of energy supplies—has several aspects. The country must have access to sufficient supplies of primary energy; it must have an adequate infrastructure for delivering those supplies to consumers; and that infrastructure must be available when required.¹⁰ Long-term security of supply—availability of primary energy—is normally improved by having access to a portfolio of energy sources, diversified both in terms of fuel and (if imported) source country. Increasing the use of renewable energy in the UK will add diversity to our portfolio, but will not necessarily add to reliability of supply, as some forms of renewable electricity generation will not always be available when required, depending on the wind, the waves, the tides or the sun.

Renewables and energy policy

17. The Government's main reason for increasing the share of renewable energy is to contribute to the reduction of carbon emissions. Some renewable generators emit practically no carbon dioxide when they are running (such as wind power). In others such as those using biomass (fuel from organic matter) most of the carbon released was taken from the atmosphere by the plants used.
18. The EU has agreed on a legally binding target for renewable energy equal to 20% of the total of all member states' overall energy consumption in 2020.¹¹ At present, the European Commission has proposed different targets for different countries in order to meet the overall 20% target. Some of these are still the subject of dispute within the EU. In the UK's case the proposed EU target is 15% of energy from renewables, which the Government describes as "very challenging".¹²

⁸ The Secretary of State for Energy and Climate Change announced on 16 October that "The Government accept all the recommendations of the Committee on Climate Change. We will amend the Climate Change Bill to cut greenhouse gas emissions by 80 per cent by 2050, a target that will be binding in law." Hansard, 16 October 2008, cols 935–937.

⁹ Department for Trade and Industry, *Meeting the Energy Challenge—A White Paper on Energy*, May 2007, p 6.

¹⁰ Department for Business, Enterprise and Regulatory Reform and Ofgem, *Energy Markets Outlook*, October 2008, Chapter 3.

¹¹ The House of Lords EU Committee, 27th Report (2007–08) *Renewable Energy: The EU's 20% by 2020*, (HL 175).

¹² Department for Business, Enterprise and Regulatory Reform, *UK Renewable Energy Strategy* consultation, June 2008, p 3.

19. Renewable energy is not the only way to reduce carbon emissions. Nuclear power is a well established low carbon source of electricity. Coal-fired power plants with carbon capture and storage (CCS) might at some point be another option but it is still unclear if and when they will become practicable (EDF p 272, British Energy pp 238, 243).¹³ Although the main technologies involved are all, separately, in operation, no commercial-scale power plant has yet been fitted with CCS (E.ON QQ 237–9). E.ON expects CCS to be competitive with costs of conventional fossil generation if the price per tonne of CO₂ under the EU Emissions Trading Scheme rises to Euro 40–50—roughly double the current level (Q 213).
20. Some have argued that renewables can also help with another aim, increasing security of supply. (BERR p 210, EDF pp 272–273, Scottish & Southern p 92). As noted in paragraph 16 above, renewables might do so by increasing the diversity of Britain’s energy sources. This could be important as Britain’s domestic sources of oil and gas dwindle—three-quarters of the UK’s gas is expected to be imported by 2015 compared to around 20% today (Centrica p 96). Many of these imports are expected to come from regions where political as well as market factors could affect supply.
21. These developments are occurring amid high and volatile wholesale energy prices. The risk is less that Britain’s oil and gas supplies would be cut off and more that it would be exposed to volatile price swings by having to rely more on imported oil and gas. In addition to the political and price risks, while new oil and gas reserves continue to be found they are in less accessible locations from which they are expensive to extract. James Smith, chairman of Shell UK, said: “The ‘easy’ oil and gas has probably been found and produced.” (Q 336)
22. Exposure to price volatility could be lessened by using renewables. But greater use of nuclear power and/or coal—of which Britain and close geopolitical allies such as Australia still have large supplies—could provide similar benefits.
23. Furthermore, renewables have a potential **negative** effect on security of supply in that they can be markedly less reliable than fossil fuels in generating energy to meet peak demand. For example, wind turbines produce no power if the wind does not blow or blows too hard. To provide an acceptable level of security, it is necessary either to have strong interconnections to other countries (which the UK lacks) (British Energy p 238) or to build a significantly higher level of overall capacity than in an equivalent system without wind power. Both of course significantly add to the cost of electricity.
24. We have received different estimates of where the 15% share of renewable energy might come from. All expected a higher share of renewable electricity than of transport fuel or heat. The range of estimates of the share of electricity generation from renewables needed in 2020 to meet the target is from 30 to 40%. Those based on a 10% share of renewable energy in transport (the level set by EU policy) and on 10% in heat imply 40% renewable electricity. The Government expects to achieve a heat share of 14%, reducing the share expected of renewable electricity to 32%. Given the much larger share expected in electricity, we turn to this sector in Chapters 3 and 4. We return to heat and transport in Chapter 5.

¹³ In May 2007, Alistair Darling, the then Secretary of State for Trade and Industry, warned that carbon capture and storage at coal-fired power plants “might never become available”. Hansard, 23 May 2007, column 1289

CHAPTER 3: TECHNOLOGIES FOR RENEWABLE ELECTRICITY GENERATION

25. This chapter focuses on renewable technologies for electricity generation, considering each of those technologies in isolation. The following chapter deals with the costs of connecting renewable generators to the electrical system as a whole, and operating them in a coordinated way to meet demand.
26. Electricity can be generated from five groups of renewable sources which are used to varying degrees in Britain. These are briefly outlined below¹⁴ with more details about their potential in Appendix 4.

Wind

27. Wind is likely soon to become Britain's largest source of renewable electricity generation. There were 179 onshore wind farms in October 2008 which can generate up to 2.3 GW—the equivalent of nearly 3% of Britain's electricity capacity. Another 424 farms are under construction or going through the planning approval process, which would give a total capacity of 13.8 GW.
28. So far there are only eight offshore wind farms in operation, with 0.6 GW of capacity.¹⁵ But offshore wind is seen as a major source of growth of renewable energy. The Government has awarded leases to developers with proposed projects that could generate up to 8.2 GW of power—just over 10% of current generating capacity.¹⁶ It has announced plans to allow the development of a further 25 GW of capacity.
29. Both onshore and offshore wind generation, by their very nature, are intermittent—when the wind does not blow or is too strong, electricity is not generated. It is therefore particularly important to consider the load factor achieved by a wind generator when calculating its costs and its value to the system. The load factor is the actual electricity generated expressed as a percentage of the potential amount had the turbines been operating at full capacity all the time. An indicative figure of 30% is often used but in practice the average load factor for onshore wind farms in 2007 was 27.5%.¹⁷ Professor Michael Jefferson used Ofgem data to show that only 13.6% of 81 onshore wind farms examined in England achieved load factors of 30% or over in 2007. In other words, the vast majority—86.4%—were generating less than 30% of their capacity. In Scotland one third of wind farms achieved a load factor of 30%, in Northern Ireland 26% but in Wales the figure was less than 20% (Jefferson p 376).
30. Offshore wind generators are expected to have a higher load factor than those onshore, but those in operation achieved only 28.3% in 2007. Other

¹⁴ Much of the material for the definitions of different forms of renewable generation came from Department for Business, Enterprise and Regulatory Reform (2008), *UK Renewable Energy Strategy*; Consultation Document, p 53–60.

¹⁵ British Wind Energy Association at <http://www.bwea.com/offshore/index.html>.

¹⁶ The 8.2 GW includes the eight offshore wind farms that are already up and running. Figures calculated from BERR consultation document, p 55.

¹⁷ Digest of UK Energy Statistics, 2008, table 7.4.

types of generator have suffered teething problems which have reduced their load factors in their early years of operation. Dr Simon Watson told us that the output from offshore turbines was likely to be less variable (Q 22).

31. Dr Watson told us that micro-generation from wind suffered because small turbines were less efficient. Large turbines were able to extract energy from the wind close to the theoretical maximum of 59%, whereas small turbines could only extract half as much. Furthermore, in urban areas, low and variable wind speeds meant that a typical wind turbine would have a load factor of only 1 or 2%. (QQ 26, 30)
32. Wind accounted for 43% of renewable generation electricity **capacity** in Britain at the end of 2007—37% onshore and 7% offshore. But the low load factor of wind farms means the proportion of electricity actually generated from renewables was much lower. Wind contributed about one quarter of the UK's renewable electricity generation—23% onshore and 4% offshore.

Wave and tidal generation

33. Wave and tidal generation come in three broad forms: **tidal ranges or barrages** trap water during high tide using barrages and lagoons before releasing it to turn turbines to generate electricity; **tidal stream** devices harness the energy from fast-flowing tidal currents; and **wave** power converts the energy contained in the movement of the waves into electricity. Professor Abubakr Bahaj told us that most tidal stream devices were based on the kind of turbines (with a horizontal axis) used in wind farms. Three technologies were competing in wave power. An oscillating water column allowed a wave to come into a chamber where it compressed air to drive a generator—the Limpet shore-based generator has been operating on Islay since 2000 (p 493). Pelamis Wave Power Limited, based in Edinburgh, is testing a series of articulated cylinders which will move up and down with the waves, compressing air to power a generator. The third technology is a power point absorber which moves with the waves, capturing energy for generation (Q 39). Currently, there is next to no generation in Britain from these sources. Professor Bahaj told us that the majority of the devices were on hold waiting for investment in order to deploy prototypes. The Government's view is that these technologies are relatively undeveloped and unlikely to generate much electricity by 2020. Ignoring cost, in the longer term the UK has the potential for wave energy to generate about 15% of its current electricity consumption, and tidal stream energy to provide about 5%, according to the UK Energy Research Centre.¹⁸
34. Like wind, tidal power is intermittent. The key difference is that tidal power is as predictable as the tides while windspeeds cannot easily be foreseen.
35. With tidal range systems, however, water can be released to turn the turbine when electricity is needed, not just in response to tidal movements. This in effect means electricity can be stored for use when demand is high, whereas storage is very limited with wind and most other forms of renewable generation. Despite these advantages wave and tidal technologies are still

¹⁸ UKERC (2008) UKERC Energy Research Landscape: *Marine Renewable Energy*.

mostly at an early stage of development and are much more expensive than wind generation.

Hydroelectric

36. Hydroelectric power is the most developed source of renewable energy and makes up 27% of renewable generation capacity in Britain. Most (24% of the renewable capacity) consists of large-scale schemes with dams and reservoirs in mountainous areas. Because the water is stored, the generator has some flexibility over when to produce power, although there may be limits on the minimum and maximum quantities of water that can be released at any one time. Small-scale hydro generation schemes (those with a generation capacity below 5 MW, which make up 3% of the UK's renewable capacity) are often sited on rivers, with little water storage and hence less flexibility over when to generate.
37. In the Government's view the scope for further large-scale hydro-electric schemes is very limited for lack of suitable sites.¹⁹ The British Hydropower Association say that another 3.2 GW of hydroelectric capacity could be built—the equivalent of 4% of the UK's current generating capacity (British Hydropower Association p 246). But the Institution of Engineering and Technology sees scope for only 1 GW of extra capacity (IET p 365 and in the table in Appendix 4).

Biomass

38. Biomass covers a range of renewable fuel sources derived from organic matter. In 2006, about 2.3% of electricity generated in Britain came from biomass sources such as landfill gas from the decomposition of organic material in landfills, sewage gas from biodegradable waste, wood from virgin timber, forestry management wastes and recovered waste wood, and specially grown energy crops. Sometimes these materials are burned with fossil fuels in power plants. Professor Tony Bridgwater told us that this was a very effective way of using renewable energy, since almost all the capital investment was already there (Q 33). With co-firing, a small amount of biomass could be used in a large, efficient, power station, whereas dedicated biomass plants were often small because they drew on limited nearby supplies of biomass fuel (Q 33). The most popular energy crops were willow and miscanthus grass. Willow could produce ten tonnes of biomass per hectare per year, miscanthus up to twenty (Q 31). Land available in the UK for growing biomass was limited, and farmers might be reluctant to commit themselves to a crop (like willow) that can only be harvested after several years: on one occasion, the power station that was to have bought the crop went bankrupt in the interval (Q 35).
39. Biomass is a versatile source of renewable energy, since it can be used, in solid form or as a gas (sometimes after conversion) for generating power and for heat. Professor Bridgwater also pointed out that biomass has unique advantages compared to other renewable energy sources as a source of

¹⁹ Department for Business, Enterprise and Regulatory Reform (2008), *UK Renewable Energy Strategy: Consultation Document*, June 2008, p 58.

carbon which can be converted into transport fuels²⁰ (Q 31). Other renewable sources mostly provide electricity, not yet widely used for transport. Professor Bridgwater also told us, however, that the crops grown in the UK for transport biofuels produce only about one tonne of biomass per hectare per year.

40. Landfill gas is currently the largest source of biomass generation in Britain. But there is little scope for growth in the short term as most large landfill sites are already being exploited. The use of landfill gas may even decline as existing sites are depleted. Any growth in biomass generation will likely come from burning more waste and/or energy crops. Energy produced from non-biodegradable materials such as plastics is not counted as renewable, although burning them may relieve the pressure on landfill sites.
41. Dedicated biomass power stations made up 29% of Britain's renewable generation capacity in 2007. Biomass, unlike wind, wave or tide, does not suffer the handicap of being intermittent. For this reason, biomass generators are used more intensively than most other renewable generators, so the share of electricity generation from biomass is greater than its share of capacity. Biomass provided almost half the UK's renewable electricity in 2007, with 24% from landfill gas, 10% from co-firing biomass in power stations, and 6% from municipal solid waste combustion. Sewage sludge and animal biomass each provided 3% of renewable electricity generation, and dedicated plant biomass stations produced 2%.

Solar

42. Solar energy can be used in a number of ways. For electricity generation the most common process is through solar photovoltaics. Solar PV cells have long been used to power small electronic devices such as calculators. But large groups of solar PV cells can be added together, powering small solar panels in individual households or larger arrays feeding power directly into the electricity grid. In 2007, solar PV provided 0.3% of the UK's renewable generation capacity and 0.1% of its renewable electricity. Professor Bahaj told us that the UK had a very limited resource for solar power, and the likely capacity factor was of the order of 11% (Q 45). Solar generation is more costly than most other forms of renewable generation.

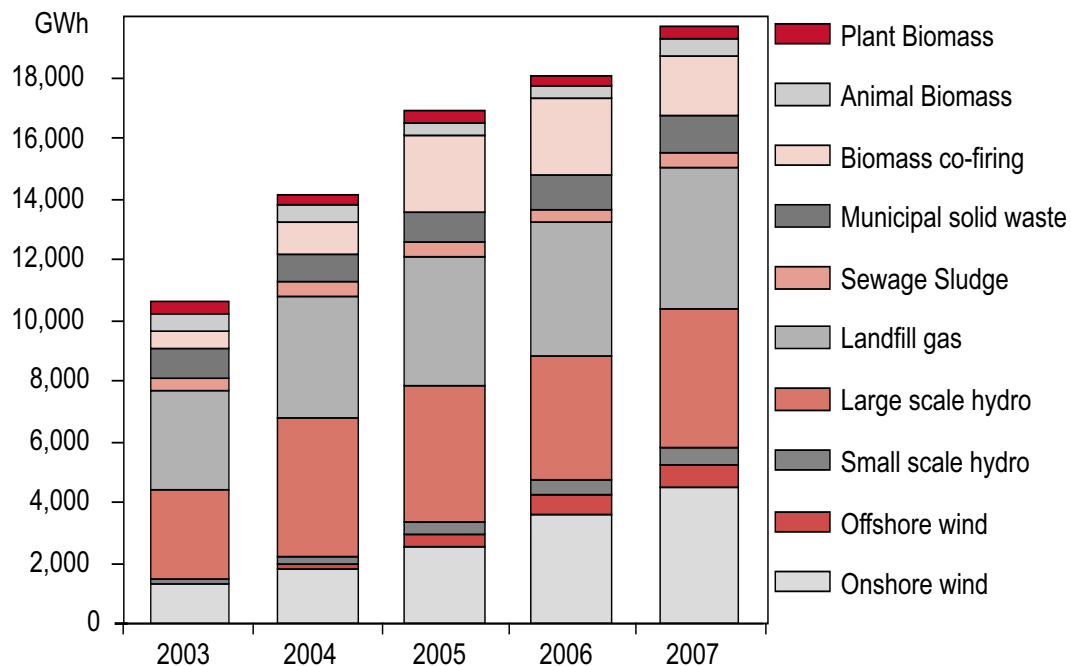
Renewable generation mix

43. Figure 4 shows how much electricity each of the main types of renewable generator produced over the last few years—the key feature is the rapid growth of many kinds of output, particularly that of wind power. Appendix 4, provided by the Institution of Engineering and Technology, summarises its view of the main renewable generation technologies, with the current position, scope for further development, and the main barriers to further deployment.

²⁰ Transport fuels based on oil are hydrocarbons, containing mostly carbon and hydrogen, as are their biofuel replacements.

FIGURE 4

Generation from renewables in the UK



Source: *Digest of UK Energy Statistics, 2008, table 7.4*

Britain compared to other European countries

44. About 4.6% of electricity in Britain in 2006 was generated from renewable sources—far below the European average of just over 14%.
45. As shown in Table 1, many countries which generate large shares of their electricity from renewables, such as Austria, Sweden, Portugal, Latvia, Romania and Slovenia, have an advantage in topography suitable for hydroelectric power. Around half of Austria and Sweden's electricity is generated from renewables—the highest in the EU—with the vast majority from hydroelectricity. Less than 10% of Austria's renewable generation comes from wind, biomass and solar power.
46. But some EU countries have reached higher levels of generation from renewables than Britain with little use of hydroelectric power: just over a quarter of Denmark's electricity comes from renewables with more than three-fifths of that coming from wind and most of the rest from biomass. In Denmark and Finland over 10% of electricity comes from biomass compared to 2.8% across the EU. The transmission networks connecting Denmark with its neighbours are strong. This eases the task of accommodating a large amount of intermittent generation. Spain, in contrast, has rapidly increased its use of wind power, despite having limited connections to its neighbours. Some countries with relatively high levels of (non-hydro) renewable generation have above-average carbon emissions, typically because they also generate a high proportion of their power from coal (Keay Q 82).

TABLE 1
Gross Electricity Consumption from renewable sources in the EU 2006 (in percentages)

	Total Share	Hydro*	Wind	Biomass	Solar	Geothermal	2010 TARGET
EU27	14.5	9.2	2.4	2.7	0.074	0.2	21.0
EU25 #	14.3	8.8	2.5	2.8	0.076	0.2	21.0
Belgium	3.9	0.4	0.4	3.1	0.002		6.0
Bulgaria	11.2	11.1	0.1				11.0
Czech Republic	4.9	3.6	0.1	1.3	0.001		8.0
Denmark	25.9	0.1	15.7	10.1	0.005		29.0
Germany	12.0	3.2	5.0	3.4	0.358		12.5
Estonia	1.4	0.1	0.8	0.4			5.1
Ireland	8.5	2.5	5.5	0.4			13.2
Greece	12.1	9.3	2.6	0.2	0.002		29.4
Spain	17.3	8.5	7.7	1.0	0.042		21.0
France	12.4	11.0	0.4	1.0	0.004		21.0
Italy	14.5	10.3	0.8	1.8	0.010	1.5	25.0
Cyprus	0.0				0.021		6.0
Latvia	37.7	36.5	0.6	0.6			49.3
Lithuania	3.6	3.3	0.1	0.2			7.0
Luxembourg	3.4	1.3	0.7	1.1	0.266		5.7
Hungary	3.7	0.4	0.1	3.2			3.6
Malta							5.0
Netherlands	7.9	0.1	2.3	5.5	0.029		9.0
Austria	56.6	49.6	2.4	4.5	0.021		78.1
Poland	2.9	1.4	0.2	1.3			7.5
Portugal	29.4	20.2	5.4	3.7	0.009	0.2	39.0
Romania	31.4	31.4	0.0	0.0			33.0
Slovenia	24.4	23.7		0.7			33.6
Slovakia	16.6	15.1	0.0	1.5			31.0
Finland	24.0	12.3	0.2	11.6	0.003		31.5
Sweden	48.2	41.3	0.7	6.2			60.0
United Kingdom	4.6	1.1	1.0	2.5	0.002		10.0
Croatia	33.4	33.2	0.1	0.1			
Turkey	25.5	25.3	0.1	0.0		0.1	
Iceland	100.0	73.4		0.0		26.5	
Norway	98.3	97.4	0.5	0.4			
Switzerland	49.5	46.4	0.0	3.1	0.034		

Source: Eurostat, May 2008 and Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market.

Total Share = $a / (b+c)$

a = Gross Electricity Generation from Renewable Sources

b = Total Gross Electricity Generation

c = Net Imports of Electricity

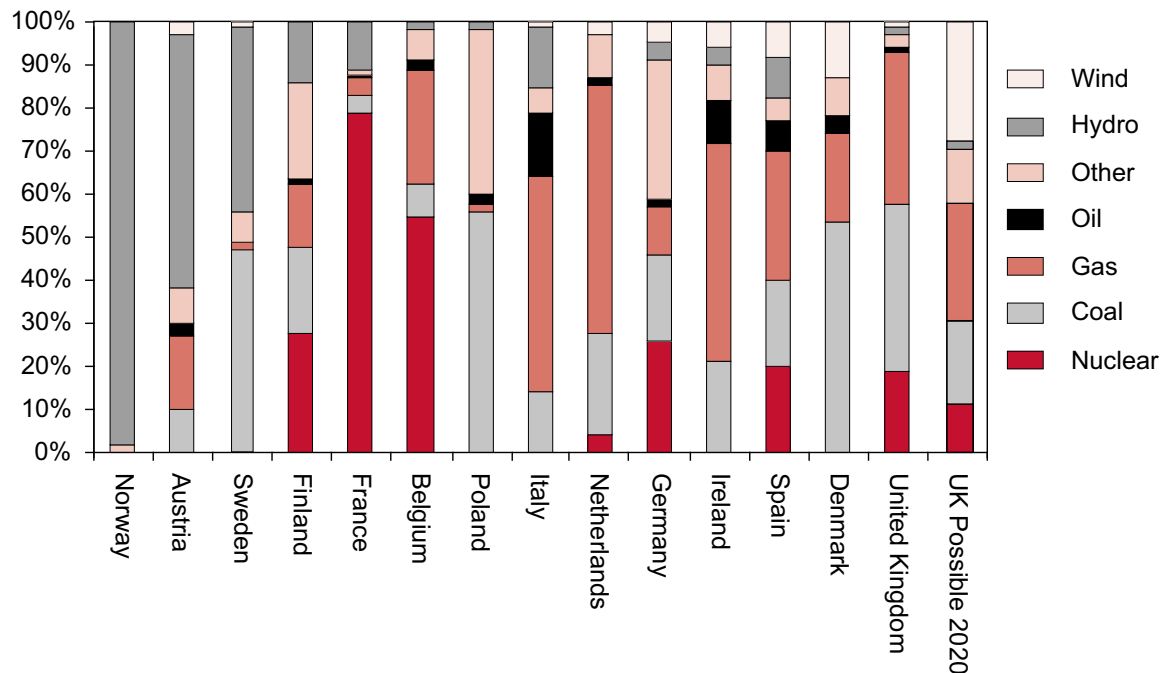
*Note: Does not include pumped storage

EU 25 is the EU 27 less Bulgaria and Romania which joined in 2007.

47. France and Italy generate respectively 12% and 15% of their electricity from renewables—much higher than in Britain—with the lion’s share in both cases coming from hydroelectric plants. Germany generates 12% of its electricity from renewables, of which around two-fifths comes from wind power. Denmark and Germany are encouraging investors to re-power wind farms with larger turbines, which can increase output significantly without taking up more land.
48. A number of EU countries, including Belgium and Luxembourg and newer members such as Estonia, Lithuania, Hungary and Poland, generate less electricity from renewables than Britain.
49. Figure 5 shows the main sources of generation in a number of European countries. At the left are several countries with a very high share of hydro generation—the extreme case of this is the practically all-hydro system in Norway (not an EU Member State, but tightly integrated with the electricity industries in Denmark, Finland and Sweden). Most European countries generate the vast majority of their electricity from fossil fuels or nuclear power. The countries with the highest levels of wind generation are towards the right-hand end of the graph. The penultimate column shows the UK’s generation mix in 2006, while the right-hand column indicates a possible mix that would allow the UK to meet a 15% target for renewable energy in 2020. This would require us to have a share of wind power more than twice as great as any European country achieved in 2006.

FIGURE 5

Generation sources in Europe, 2006



Source: Eurostat

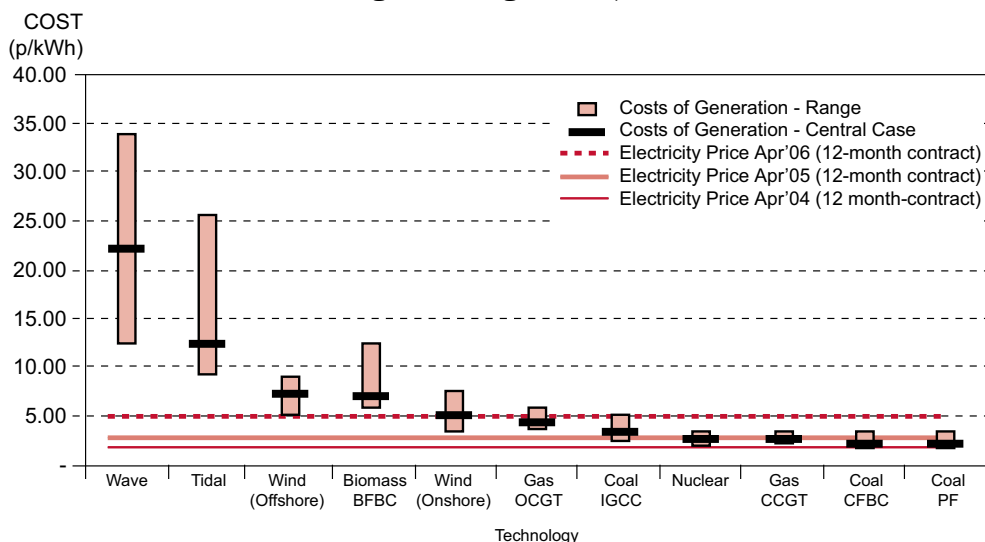
“Other” includes lignite (particularly in Germany and Poland) and biomass (particularly in Denmark, Finland and Sweden)

The base cost of electricity generation from renewable sources (excluding additional system costs, addressed in Chapter 4, and support costs, addressed in Chapter 6).

50. The first step in calculating the base costs of renewables is to calculate costs of generation at each type of plant. (As usually presented, these do **not** include significant additional system costs to provide back up for wind turbines when the wind is not blowing—or is too strong—or to reinforce the transmission grid. We deal with these additional costs in Chapter 4 below). The estimates varied considerably and most submissions gave little information on the assumptions underlying them. Most present a range of costs (Centrica p 102, E.ON p 109, British Energy p 242, Renewable Energy Foundation pp 46–47, Laughton p 387). Among the renewable technologies listed, onshore wind costs least—and in some cases its basic costs are almost as low as gas or coal-fired plants—partly because it is the most mature and developed technology. Off-shore wind is next followed by tidal, with wave power much the most expensive. We also received evidence (not shown in Table 2) that solar photovoltaics were expensive, with high capital costs (Ofgem Q 413, Energy Technologies Institute p 147). We did not receive estimates of the cost of generation from waste or landfill gas. The scope for expanding the latter is however very limited, as noted above. Most estimates show nuclear to have the lowest base cost of all forms of generation, although no station has been built in the UK for many years.
51. The cost of generation depends critically on the assumed capital cost of a power plant, the rate of return required by the generator, the cost of fuel (except for some renewable generators) and the amount of output that the plant is expected to generate (its load factor). Figure 6 below illustrates how different assumptions can lead to very different cost estimates, particularly for some technologies (Royal Academy of Engineering p 450, Institute of Mechanical Engineering p 373).

FIGURE 6

Costs of different types of electricity generation (excluding back-up and grid integration)



Taken from 'Powering the Nation', March 2006© PB Power

Key

Biomass BFBC—Biomass Bubbling Fluidised Bed Combustion

Gas OCGT—Open Cycle Gas Turbine

Coal IGCC—Coal Integrated Gasification Combined Cycle

Gas CCGT—Combined Cycle Gas Turbine

Coal CFBC—Coal Circulating Fluidised Bed Combustion

Coal PF—Pulverised Coal

52. Construction costs can vary for many reasons. For wind farms they vary from site to site. For example, different ground conditions can affect costs of cable lengths and the foundations of turbines (IET p 370). Copper and steel prices affect the cost of building wind turbines yet are extremely difficult to predict so a range is often used. The cost of land to build renewable projects also varies (IET p 370).
53. Financing costs vary depending on the perceived risk of the investment. Risks include engineering performance and changes in the regulatory environment. For the mature technologies, such as onshore wind generation, the performance risks are relatively low but are significant for newer technologies (IET p 371). The higher the assumed rate of return required by the generator, the greater the cost per year per MW of capacity. This effect will be particularly important for generators with high capital costs, such as nuclear stations and many renewable generators. Different companies will have different costs of capital—Shell told us that they had withdrawn from the London Array (a 1 GW offshore wind farm in the Thames Estuary) because the projected returns did not meet their investment hurdle rate (Q 348). But the company's partners, E.ON and DONG (a Danish generator), are continuing the project with Masdar, an investment fund for renewable technologies owned by the Government of Abu Dhabi.
54. The expected load factor and plant life will affect the capital cost per unit of output. This is particularly important for wind and marine generators, with few costs apart from capital costs. The higher the load factor, the lower the cost per unit of output. Possible sites for wind farms, for example, can be more or less windy and so have different costs per unit of power. The windier sites will have lower costs per unit of electricity generated as they produce more power with little or no increase in cost at the station. But many are remote from the main centres of demand and have higher costs of connection to the electricity system.
55. Between different biomass and waste plants, transport can be a substantial variable cost. Some plants are close to a ready supply of fuel such as woodchips from a wood processing plant. But those which take fuel from sources of waste or energy crops further afield will incur transport costs. They may also have to compete for alternative uses for the feedstock such as food production, or alternative biomass power plants (IET p 371).
56. For biomass, the UK's relatively small land area means that a heavy dependence would imply substantial imports, where costs could vary substantially depending on demand from other countries and international crop yields (IET p 371).
57. Finally, there is no commercial-scale generation of electricity from wave or tidal generators in the UK. Cost estimates for commercial-scale generation are extrapolated from small, often experimental, projects and accordingly have wide margins of error.

Inferring costs from feed-in tariffs

58. The cost estimates presented to us can be compared with the prices actually paid to renewable generators in Germany and Spain, where the authorities set feed-in tariffs—a form of subsidy used to remunerate renewable generators.²¹ These tariffs can be expected to exceed the actual cost of renewable generation; and clearly there would be little or no investment if the tariffs were **less** than cost.
59. The system of tariffs used in Germany is complex. A wind farm at a site with good wind conditions receives a starting price for five years, and a lower basic price for fifteen. Both decline gradually in nominal terms during the life of the contract. This front-loads the support received by the generator, reflecting the dominance of capital costs. A wind farm at a site with less favourable wind conditions receives the starting price for longer, and may receive it for the entire twenty-year length of its contract. Sites with poor wind conditions are not eligible for support.
60. Between 2003 and 2006, the average amounts received by German wind generators varied between 7 and 7.25 pence per kWh.²² Around 2,000 MW of capacity was added in each of the years 2004–2006. A revised tariff has been introduced for 2009 onwards, reflecting the higher price of steel, which has increased the cost of wind turbines (EWI pp 316–317).
61. In Spain, most wind generators have chosen to receive the wholesale market price plus a support premium, rather than a feed-in tariff. The premium is now adjusted so that the combination of the market price plus the premium has a floor of 5.7 pence per kWh and a cap of 6.8 pence per kWh.²³ Around 1,800 MW of capacity were added each year between 2004 and 2006, which doubled to 3,500 MW in 2007.

Comparing the cost of renewables with fossil fuel and nuclear power

62. One of the key questions is how the cost of electricity produced from renewable sources compares with that of power from fossil fuel or nuclear stations. When making comparisons, the different cost structures of each type of generation need to be borne in mind. Renewable and nuclear plants have high initial capital costs but most of their costs are then fixed (Royal Academy of Engineering p 445). The cost of electricity from fossil fuel power stations by contrast depends crucially on the volatile price of the fuel. For EU generators, the cost of carbon emissions permits (effectively a tax)²⁴ under the EU Emissions Trading Scheme will also be a factor. Long-run calculations of power generation costs

²¹ We discuss the use of feed-in-tariffs as a policy measure in Chapter 6.

²² The original tariff range in Euros was 8.76 to 9.06 cents per kWh which was converted to sterling at an exchange rate of €1.25 to the pound.

²³ The original figures were a floor of 7.1 euro cents per kWh, and a cap of 8.5 euro cents per kWh, again converted to sterling at an exchange rate of €1.25 to the pound.

²⁴ The scheme requires companies to hold permits to emit carbon dioxide, which are traded and have a price, and the “tax revenue” is the value of these permits. If the Government auctions the permits, it gets to keep this tax revenue, but if it allocates them without charge to energy-using companies, those companies effectively keep the tax revenue.

therefore vary with estimates of the prices of fuel and the cost of carbon permits (IET pp 371–372).

63. Gas and oil prices, which have risen in recent years, are linked through indexation clauses in long term gas supply agreements in Europe. As the UK is now a net importer of gas and linked to the Continental gas network, gas prices in the UK tend to move with those in Europe. Coal prices depend more on the global market, and are also high, driven by demand in emerging economies and high oil and gas prices. The range of predictions of fossil fuel prices leads to a range of estimates of costs for electricity generated from gas and coal fired plants.
64. A modern gas-fired power station emits roughly 0.4 kg of carbon dioxide per kWh of electricity, while a new coal-fired power station should emit 0.8 kg per kWh. When deciding whether to build wind farms or conventional plants, the generator will include the cost of buying emissions permits for coal and gas-fired power stations—assuming that few permits, if any, will be allocated free of charge to the power sector after 2012. As emission permits are a policy measure to increase the cost of high-carbon generation, their price depends on government decisions on how many permits to issue.
65. The price premium of renewable over conventionally-generated electricity is reduced when the cost of fossil fuels rises. Witnesses who submitted evidence on the cost of renewable generation also gave estimates of the cost of electricity from fossil fuels and nuclear power. In these estimates, reproduced in Appendix 5, nuclear power is typically the cheapest form of generation. In most estimates, generation from coal or gas is cheaper than renewable power, although some evidence suggested that onshore wind generation could be as cheap as fossil fuels. We received some predictions of the costs of coal-fired stations with carbon capture and storage (CCS)—inevitably speculative since no commercial plant has been built—which were higher than the accompanying estimates of the cost of onshore wind.
66. We do not know the assumptions on fuel, carbon or construction costs, or interest rates, which underlie the estimates in Appendix 5. We have therefore made our own estimates (Table 2 below) of the cost of wind power and of the three main options, coal, gas and nuclear power, based on work done for the Government for its renewable energy consultation,²⁵ with the exception of our estimates of fossil fuel prices, where we took the actual prices paid in the twelve months to June 2008. During this period, the price of oil averaged \$96 per barrel. The coal price was 0.74 pence per kWh (£54 per tonne) and the price of gas was 1.4 pence per kWh (40.6 pence per therm). We assumed that the thermal efficiency of a new coal-fired station (the fraction of its fuel converted into electricity) would be 45%, and that of a new gas-fired station 55%. For a biomass station, we used a fuel cost of 1.3 pence per kWh (£3.60 per GigaJoule) and a thermal efficiency of 28%. In the case

²⁵ Redpoint (2008) *Implementation of EU 2020 Renewable Target in the UK Electricity Sector: Renewable Support Schemes*. A report for the Department of Business, Enterprise and Regulatory Reform, June 2008.

of nuclear power, we take the cost of fuel per kWh of nuclear output from the Government's nuclear consultation.²⁶

67. Table 2 shows that coal, gas and nuclear power have similar base generation costs, and that these are much lower than the cost of wind power (either onshore or offshore) and biomass. The cost of the three non-renewable forms of energy is around 4 pence per kWh, while the cost of onshore wind is 7 pence per kWh, and that of offshore wind 8 pence per kWh. Biomass generation is predicted to cost 9 pence per kWh.
68. The table divides the costs into capital costs—the cost of paying for the plant itself—and running costs, chiefly fuel and operations and maintenance costs. Four of our technologies—all except biomass and gas—have similar running costs in the region of one and a half to two pence per kWh. The high costs of wind generation are due to its much higher capital costs per kWh actually generated. Although capital costs per kW of **capacity** for onshore wind and coal are similar, costs for power actually generated by wind are much higher because of the relatively low operational availability of wind turbines. The running costs of biomass generators are high because they use a lot of fuel for each unit of electricity produced.
69. The second part of the table gives the key assumptions made in preparing these cost estimates. The power station's construction cost includes a local connection to the grid, but not the cost of any more distant reinforcement work required—as with intermittency, this is not a cost which the individual generator is asked to bear. We have used the same cost of capital for each technology, although generators might require a higher expected rate of return to invest in those perceived as more risky. The base case excludes the cost of carbon permits for coal and gas-fired plants.
70. The third part of the table shows what happens when we vary these key assumptions. The relative cost of coal, gas and nuclear plant might change, particularly if the cost of one technology was altered, but not that of the others. This might be most relevant for fuel costs, since fossil fuel prices have been more volatile than the cost of nuclear fuel. The penultimate line of the table includes the amount coal and gas generators would need to spend on carbon permits at a price of £20 per tonne of CO₂ (2 pence per kg),²⁷ given that the coal-fired plant would emit 0.76 kg of carbon dioxide per kWh it generated, and the gas-fired station would emit 0.37 kg,²⁸ while the other types of power station have practically no emissions. At this carbon price, nuclear power would be expected to cost less than coal or gas-fired generation. The final line includes the cost of carbon permits at £50 per tonne of CO₂—roughly the level (\$85 per tonne of CO₂) recommended by the Stern Review of Climate Change.

²⁶ Department for Trade and Industry (2007) *The Future of Nuclear Power: The role of nuclear power in a low carbon UK economy*. Consultation Document, May 2007.

²⁷ This is roughly the current price.

²⁸ Gas-fired stations convert more of their fuel to electricity than coal-fired stations do, and gas contains more energy per tonne of carbon than coal does.

TABLE 2

Estimates of the cost of electricity *generation* in pence per kWh produced. These figures exclude the costs of backup conventional plant and grid integration, which are explored in Chapter 4

	Coal	Gas	Nuclear	Biomass*	Onshore Wind	Offshore Wind
Base cost (pence per kWh) ²⁹	4.1	3.9	4.5	9.0	7.3	8.1
Capital cost (pence per kWh)	1.9	0.9	3.0	3.4	5.5	6.0
Running cost (pence per kWh)	2.1	3.0	1.5	5.6	1.7	2.1
Key assumptions						
Construction cost (£ per kW of capacity)	£1,070	£523	£1,500	£1,837	£1,111	£1,574
Average output relative to capacity (load factor)	81%	81%	77%	80%	27%	37%
Plant life (years)	25	20	30	20	20	20
Interest rate	10%	10%	10%	10%	10%	10%
Fuel cost (pence per kWh of output)	0.74	1.38	0.44	4.6	0	0
Emissions of carbon dioxide (kg per kWh)	0.76	0.37	Nil at the station	Nil at the station	Nil at the station	Nil at the station
Base cost of electricity given:						
Assumptions above	4.1	3.9	4.5	9.0	7.3	8.1
Construction cost up 20%	4.5	4.1	5.1	9.7	8.4	9.3
Interest rate of 13%	4.6	4.1	5.6	9.9	8.4	9.5
Lifetime up by 25%	4.0	3.9	4.4	8.8	6.9	7.7
Load factor down by one-fifth	4.6	4.2	5.5	10.1	9.1	10.1
Fuel price up by 50%	4.9	5.2	4.7	11.3	7.3	8.1
Buying carbon permits at a price of £20/tonne CO ₂	5.6	4.6	4.5	9.0	7.3	8.1
Buying carbon permits at a price of £50/tonne CO ₂	7.9	5.7	4.5	9.0	7.3	8.1

* specialised power plants burning biomass material (not energy crops)

²⁹ Base cost equals capital cost and running cost. The numbers do not add exactly due to rounding.

71. On the basis of these figures, we estimate the average base cost of generation across the whole system with the current share of each type of output to be 4.3 pence per kWh. In the next chapter (Table 3) we use these figures to show how the total base cost of generation in Great Britain would change with different levels of renewable generation.
72. Of the variables in the third part of Table 2, only one, carbon permits priced at £50 a tonne of CO₂, would by itself make onshore wind competitive with coal, while offshore wind would remain slightly costlier; gas (and nuclear) would both remain cheaper than either form of wind power. An alternative hypothesis of, say, an increase of 50% in fossil fuel prices together with carbon permits priced at £20 a tonne, would bring the cost of coal- and gas-fired power close to that of an onshore wind station with a high (over 30%) load factor. Nuclear power would still be significantly cheaper (in the absence of changes to its own costs), and offshore wind and biomass generation would remain more expensive than electricity from fossil fuels.
73. We have not made our own estimates for other forms of renewable energy, or for plants with carbon capture and storage. There are only a few prototypes for wave and tidal power, and no commercial scale carbon capture and storage project exists. This means that cost estimates for these technologies can only be very tentative. We did not receive estimates for the cost of landfill gas or waste burning, which we believe to be cheaper than other renewables, but there is little scope to expand these.
74. All the cost estimates showed that nuclear power was cheaper than renewable energy. The cost of nuclear power is little affected by the oil price, although the uncertainty over the cost of decommissioning and waste disposal is a unique risk for nuclear stations. Nuclear plants have very low emissions and are not affected by changes in the cost of carbon. **We cannot consider renewable energy in isolation from the rest of the UK energy system and we support measures to include nuclear plants as an essential element of the UK's energy mix.**
75. **In summary, the cost of electricity from onshore wind farms at good locations would only be comparable with that from fossil fuel generators when prices of oil, gas and coal are very high or allowance is made for the price imposed for carbon emissions permits (effectively a tax). It is more expensive than nuclear generated power. In our base case, onshore wind cost 7 pence per kWh, as opposed to around 4 pence per kWh for the other technologies—coal, gas and nuclear. Offshore wind, biomass, wave and tidal power are even more expensive. And these estimates exclude the additional costs of integrating more renewable generation into Britain's electricity grid.** (These are outlined in Chapter 4.)

Future changes in the costs of renewable generation

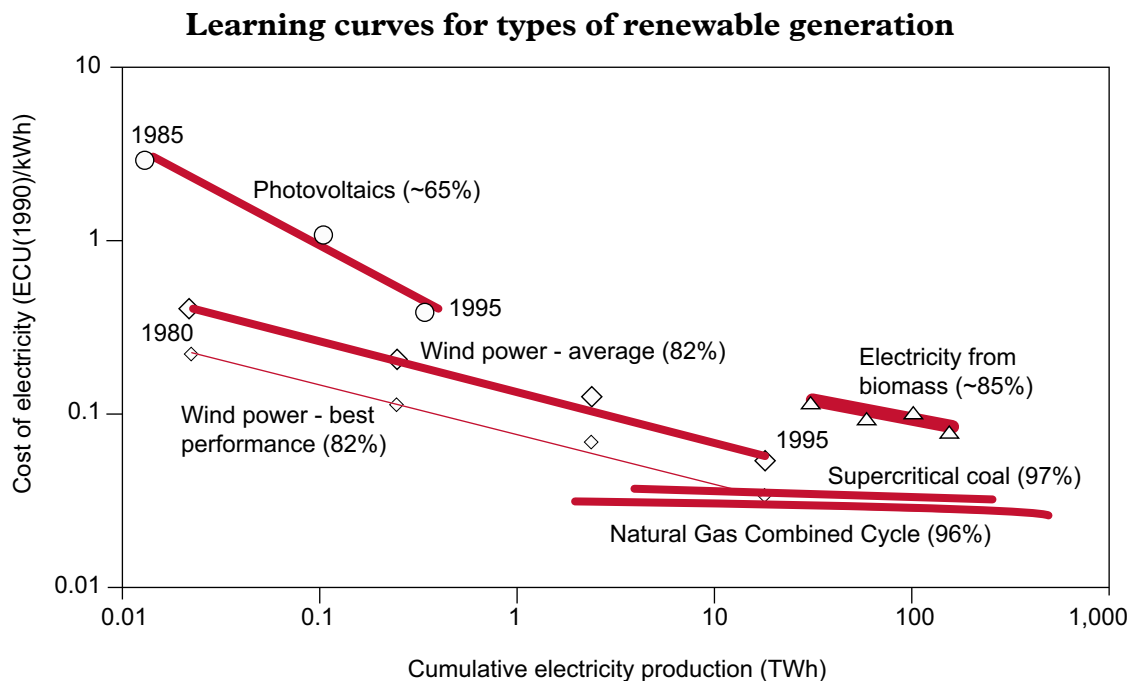
Technology developments

76. Future developments in technology—such as advances in equipment design, manufacturing and installation—can be expected to reduce the costs of renewable energy significantly, as well as of some alternatives such as nuclear power. This is borne out by the long term trend of falling costs for onshore wind. But forecasting costs on the basis of these expected developments is far

from a precise science. As a result it is only sensible to present a range of cost estimates.

77. Such estimates are nevertheless crucial in assessing the likely costs of renewable energy. The International Energy Agency has shown how the costs for various forms of renewable generation have fallen as more generators are built. The “learning curves”—which are the straight lines in figure 7 below—show how the cost per kWh of electricity produced by various technologies has fallen as the total amount generated by them has risen. For example, the top line in figure 7 below shows that over a period in which the cumulative output of photovoltaic power doubled, the cost of electricity from new installations fell to 65% of its level at the start of the period. In other words, unit costs fell by 35%. Total generation (or in other studies installed capacity), rather than the mere passage of time, appears to be the critical factor in reducing costs.
78. The steeper the learning curve, the more the costs have fallen as the amount of installed capacity increases. The percentages show what has happened to the cost of generation each time cumulative output doubles. So while the cost of solar photovoltaic power falls to 65% of its previous (very high) level, giving a reduction of 35%, the reduction in the more mature technologies of coal and natural gas combined cycle generation are much lower, at 3% and 4% respectively. These curves represent technical progress at the power station and take no account of possible improvements in technology to extract fossil fuels, which could also reduce costs.

FIGURE 7



Learning Curves for generation technologies

Source: International Energy Agency

79. Figure 7 shows straight lines but both axes use logarithms. Moving along each line from left to right means successively greater increases in cumulative output are required to give successively smaller absolute reductions in costs.

80. Studies cited by Dr Karsten Neuhoff found costs for various renewable technologies fall 10–20% as installed capacity doubles (p 196). This does not however mean that the fall in costs is smooth or constant. Cost reductions of wind farms have been interrupted in the last few years because of supply bottlenecks and/or fossil fuel and commodity price increases. These bottlenecks have led to higher prices for turbines coupled with long lead times. Similarly, all marine energy technologies, including off-shore wind, are competing with the offshore oil and gas industry for installation vessels and other equipment (Neuhoff p 197).
81. As a technology such as onshore wind power is more widely used, cost increases can still occur when investment rises. Similar increases caused by supply bottlenecks may also occur in other forms of renewable generation as they are rolled out (Neuhoff pp 195–196). There is also a shortage of engineers, scientists and skilled craftsmen (Royal Academy of Engineering p 445). Dr David Clarke of the Energy Technologies Institute said: “There is evidence that the capacity in the supply base is inadequate for what we currently need.” He added: “If I talk to the marine power developers then they will most definitely cite shortage of skills in the marine industry from the point of view of dockside skills in terms of fabrication, assembly of very large structures” (Q 324). Neil Hirst, director for energy technology and R&D at the International Energy Agency also referred to industrial infrastructure as a factor in the different costs of renewable electricity generation in various countries: “In many cases you will find the costs are actually lower where the deployment is highest, simply because there is an industrial infrastructure for manufacturing and there is a learning by deploying elements which tends to bring costs down” (Q 394).
82. The cost of solar photovoltaics has followed a similar pattern. After three decades during which the cost was reduced by a factor of 100 (i.e. to 1% of its initial level), the price stabilised in the last four years, during which Government support for solar power in various countries led to a surge in demand and supply bottlenecks (Neuhoff p 196).
83. Once extra supply resolves these bottlenecks the cost of wind-generated electricity and solar power are expected to resume their downward trends. Dr David Clarke of the Energy Technologies Institute said of offshore and onshore wind: “There is real potential to drive down the cost from those systems to a level that is competitive with current centralised generation” (Q 309, Neuhoff p 196).
84. Wave and tidal generation costs are even more difficult to predict as the technology is at an early stage of development. So far many of the companies pursuing demonstration projects are small start-ups, focussed on getting the next round of funding for their first large-scale demonstration plant and showing that their concept has merit. Mass production that would reduce costs but seems far off and difficult to predict (Neuhoff p 196).
85. **Future developments in the base generation costs of electricity from renewable sources depend upon many variable factors such as technological development, the rate of return required by generators and construction costs. But from the evidence we have seen it seems clear that as things stand the base costs of generation of electricity from onshore wind are likely to remain considerably higher than those of fossil or nuclear generation and that costs of generation of marine or solar renewable electricity are higher still.**

Research to improve renewable energy technologies and reduce their costs

86. The Energy Technologies Institute (ETI) was set up to help sustainable low-carbon energy technologies become commercially viable. It is a 50:50 public/private partnership with BP, Caterpillar, EDF Energy, E.ON, Rolls-Royce and Shell. Each private sector partner will contribute £5 million a year for ten years, and the Government is prepared to match the contributions from up to 11 partners, giving a potential budget of £1.1 billion.
87. The ETI aims to:
- (i) reduce greenhouse gas emissions
 - (ii) accelerate development and deployment of affordable low carbon technology solutions
 - (iii) increase security of energy supply in conjunction with greenhouse gas mitigation
 - (iv) increase the level and capacity of the low carbon skills pool—both in the UK and internationally
88. Investment in the UK has mostly been in research on novel technologies or in setting up full-scale systems ahead of commercial deployment. The important intermediate stages of development—technology integration and system demonstration—have been less well supported despite their importance in developing investor confidence. The ETI aims to help bridge this gap (p 146).
89. Offshore wind was cited as an area where research on improving the reliability of the wind turbines could reduce costs. Some wind turbines offshore had not been designed to cope well there (Clarke Q 310). Dr David Clarke, the Chief Executive of the ETI, said “The way to reduce the cost of those systems and to bring down the cost of the electricity generated in many cases is to improve the reliability and the operating costs of the machines themselves and then the systems, including the grid and the network infrastructure that is necessary to support those, whether it is gas or electricity. Those are the kinds of issues that we are seeking to address through the Energy Technologies Institute” (Q 308).
90. Research council spending on renewable energy projects has risen from £8.3m in 2000/01 to £30m in 2007/08. Solar power and fuel cell projects received over £6m each in 2007/08. Wind—which is a mature renewable energy technology—receives less than £1m (Research Councils UK p 441). This is only 1% of the Research Councils’ total budget of £2.8 billion.
91. Dr Strachan of King’s College London and the UK Energy Research Centre pointed out that some new technologies would not succeed. He advocated supporting a range of technologies with broad-based near-term support until it was clear which technologies were improving and which were offering cost and other advantages (Q 14).
92. This report is mainly about technologies in use or development. There are many other fields where basic or applied research might also yield practicable and cost-effective ways to help safeguard the environment and ensure reliable and secure supply of energy. Researchers, industry and Government can all play a part by remaining alert to the possibilities and flexible in their response. We list at Appendix 6 some potentially promising areas.

93. **We hope that the ETI's work will yield technological advance and lower costs. The Government should consider, perhaps in collaboration with others, offering a substantial annual prize for the best technological contribution to renewable energy development.** An initiative on these lines might help set the scene for a wider effort by the Government to encourage and promote research across on a range of technologies aimed at finding new and cost-efficient ways to reduce carbon emissions. We return to this theme in Chapter 6.

Noise, visual and other negative impacts of renewable deployment

94. There are widespread local objections to renewable generators—especially wind farms. These include:
- (a) the visual impact of wind turbines (Campaign to Protect Rural England (Devon) p 252, Penk p 419, Jack p 374, Bishopton Village Hall Management Committee p 233);
 - (b) noise from the turbines and their potential impact on family life and health (Hadden p 325);
 - (c) effect on value of homes (Hadden p 325);
 - (d) economic impact on the community (Hadden p 325); and,
 - (e) perceived disregard for the opinion of rural communities (Hadden p 325).

Wind farms can also disturb wildlife (Two Moors p 492 and The Royal Society for the Protection of Birds)³⁰.

95. Most offshore projects would have less impact on local communities. But there are particular concerns about the proposed Severn Barrage. The Environment Agency in Wales said: “The estuary supports important habitats and a unique ecology which have strong protection under international law. The construction of a barrage would have significant impacts on the estuary, for example on wildlife, flood protection, navigation and the landscape.”³¹
96. **Although their declared purpose is to improve the environment, it is clear that renewable energy installations can also have adverse environmental impacts which the Government should bear in mind as it weighs the benefits and costs of expansion of renewable generation.**

³⁰ See Royal Society for the Protection of Birds at <http://www.rspb.org.uk/ourwork/policy/windfarms/index.asp>

³¹ *Severn estuary barrage—a good idea*, Environment Agency Wales, 2006, available at: http://www.environment-agency.gov.uk/regions/wales/426317/1508205/?lang=_e

CHAPTER 4: RENEWABLES IN THE ELECTRICITY SYSTEM

97. This chapter considers issues affecting the electricity system as a whole if, as estimated in Paragraph 24, 30–40% of electricity is to come from renewable sources. The first is the problem of intermittency. Second, we consider the impact of different levels of renewable electricity on the overall cost of generation across the industry. Third, connecting renewable generators will require significant investment in the transmission and distribution systems. Finally, we consider the way in which these systems are operated, and the implications of power flows which may be more variable in future than at present.

Intermittency—a constant problem?

98. Matching electricity supply to demand is challenging as it is not presently economic, or technically feasible, to store electricity on a large scale. Electricity can be stored in batteries for portable applications but their costs are too high for use in the national electricity grid. Electricity generation must be matched to demand on a minute-by-minute basis, or power cuts result. Some power plants are therefore kept running at less than full load, to respond rapidly to a sudden increase in demand or to make up for a power plant failure elsewhere in the system.³²
99. But not all power stations can be “dispatched” to change their output level quickly. Coal, gas- and oil-fired stations are generally straightforward though their response speeds vary. Nuclear stations are relatively inflexible, and are best operated at a constant (full) load. Renewable generators burning biomass, and hydro generators, can generally be dispatched.³³
100. Wind, wave and tidal stations are inherently not dispatchable. They can only generate when conditions are right—if there is no wind, or too much wind, no electricity can be produced. Tidal generators can produce much more at the spring tides (with a high variation in the water level) than at neap tides (low variation). The tides are predictable far in advance, but the wind is almost impossible to forecast more than a few days in advance, and even day-ahead forecasts can be inaccurate.

Short term fluctuations

101. The first cost imposed by intermittency is that more plant has to be held in reserve to cope with short-term fluctuations in output. At present, National Grid, which operates the electricity system,³⁴ keeps a number of power stations running at less than their full capacity, providing about 1 GW of spinning reserve—that is capacity which can automatically respond to any

³² The limited number of pumped storage stations in Scotland and Wales also increase output when necessary. They use electricity to pump water uphill, and release it when necessary to turn a turbine to generate power. But pumped storage carries an efficiency penalty, in that less electricity is generated at the end of the cycle than is required at the start. Nonetheless, it can be economic if the electricity used in pumping is cheap (which is typically the case overnight), and the water is released at peak times when power can be sold for a high price.

³³ However, a hydro station may have to “spill” water if its storage is full and its generation is not required.

³⁴ In Great Britain, the system operator is National Grid, controlling its own transmission system and those owned by Scottish Power and Scottish and Southern Energy. In Northern Ireland, SONI (System Operator for Northern Ireland Ltd) is a subsidiary of Northern Ireland Electricity.

shortfall in generation within seconds (Q 293).³⁵ The company also contracts with other stations to start generation quickly and has arrangements with industrial consumers to reduce their demand at short notice, in order to restore the level of spinning reserves as soon as possible after they are used. The company holds about 2.5 GW of this standing reserve (Q 293); 70% of this comes from generation, and 30% from industrial consumers (p 144).

102. As the amount of wind generation rises, the potential short-term change in wind output will also increase, and National Grid will have to hold more reserve to cope with this increase. The company told us that if renewables provided 40% of electricity generation—the share the company believes would be needed to meet the EU's 2020 energy target—its total short-term reserve requirements would jump to between 7 and 10 GW. Most of this would be standing rather than spinning reserves. This would add £500 million to £1 billion to the annual cost of these reserves—known as balancing costs—which are now around £300 million a year (Q 293). This is equivalent to around 0.3 to 0.7 pence per kWh of renewable output.
103. Estimates of balancing costs vary widely. The government has commissioned research from the consultancy SKM,³⁶ which estimated that if renewables provided 34% of electricity by 2020, with 27.1% from wind power, the extra cost of short-term balancing would be about 1.4 p/kWh of wind output³⁷ (Q 481). This equates to a total cost of £1.4 billion, well above that assumed by National Grid. Several pieces of evidence cited a 2006 report by the UK Energy Research Centre (UKERC),³⁸ which had estimated the balancing costs with up to 20% of intermittent renewable output in Great Britain at 0.2–0.3 pence per kWh. Although the share of renewables in the SKM study was less than double that of UKERC, the balancing costs per unit were more than five times higher. In part, this may reflect higher fuel costs since the studies surveyed by UKERC were performed; but it will also reflect the greater challenges of dealing with larger shares of intermittent renewable generation.
104. **Fluctuations in wind speed lead to short term changes in electricity output from wind farms. Greater use of wind power and other intermittent renewable sources therefore requires more backup generation capacity to respond very quickly to, for example, reductions in the output of wind turbines when the wind drops. But the technical challenges and costs of backup generation on a scale large enough to balance an electricity system with a high proportion of intermittent renewable generation are still uncertain.** There is currently no experience elsewhere in Europe of the scale of dependency on

³⁵ For the purpose of comparison current total generation capacity is 76 GW. The amount of spinning reserve that National Grid holds is currently based on the size of the largest single generator on the system. This allows the company to cope with any single failure, on the basis that the near-simultaneous failure of two large generators is sufficiently unlikely.

³⁶ Sinclair Knight Merz (2008) *Growth Scenarios for UK Renewables Generation and Implications for Future Developments and Operation of Electricity Networks* BERR Publication URN 08/1021

³⁷ SKM presented these costs as 0.07 pence per kWh of **total** generation in a scenario with low levels of wind power (3.1%), and as 0.45 pence per kWh of **total** generation in a scenario with wind power making up 27.1% of total generation (table 7.12). We divided the difference of 0.38 pence per kWh by 27.1% to give the figure for the increased cost per kWh of wind generation.

³⁸ Gross, R., P. Heptonstall, D. Anderson, T.C. Green, M. Leach and J. Skea (2006) *The Costs and Impacts of Intermittency: An assessment of the evidence on the costs and impacts of intermittent generation on the British electricity network*, London, UK Energy Research Centre.

intermittent renewables expected in the UK. **Whereas the highest share of intermittent renewable electricity now being generated is 15% in Denmark, the UK is expected to reach a share of some 30%–40%. We recommend that the Government should ensure that further work is carried out to clarify the costs and encourage development of technical solutions to deal with intermittency.**

105. Running a conventional plant at part load to provide spinning reserve reduces efficiency which leads to higher emissions per unit of electricity actually generated at that plant. Some commentators, such as Campbell Dunford of the Renewable Energy Foundation, argue that this might have offset the CO₂ savings from renewable generation in Denmark. Denmark's carbon emissions per kWh generated have fluctuated from year to year, although the trend is steeply downwards, as set out in Appendix 7. Calculations based on the loss of efficiency from running a power station at part load, and the amount of extra reserve required, also suggest that the extra carbon emissions in the UK from additional spinning reserve would be very small in comparison to the savings from renewable generation. The Government has estimated the net saving from raising the share of renewable electricity to 32% to be about 45–50 million tonnes of carbon dioxide—about 8–9% of total CO₂ emissions—after taking account of the cost of part-loading plant.³⁹ **The need to part-load conventional plant to balance the fluctuations in wind output does not have a significant impact on the net carbon savings from wind generation.**

Peak demand and capacity credit

106. The second cost due to intermittency comes from the need to have enough capacity available to meet peak demand. No power station is guaranteed to be available at peak demand. So the industry holds extra capacity over and above the expected peak demand to cope with stations that turn out not be available when most needed, or higher than expected demand. As a rule of thumb, a 20% margin of extra capacity has been sufficient to keep the risk of a power cut due to insufficient generation at a very low level, given the characteristics of the current system.
107. A fossil-fuelled station has around a 5% chance of not being available to generate at the time of the system peak because of breakdowns or essential maintenance (p 119). One plant's breakdown is rarely correlated with another. Nuclear plants have a similar risk, although they sometimes suffer from generic issues that require maintenance at all of the stations of a similar design.
108. But for renewables it is very different. At peak demand not only are the chances of a wind farm not being fully available much higher but it is very likely that, if so, nearby wind farms will also be at least partially unavailable because it is not windy in the area. This correlation will fall for distant wind farms—for example, the wind could well blow in Scotland when conditions in Cornwall are calm. But within the UK, the correlation does not fall to zero.
109. As a result, the proportion of renewable generation which can be relied on at peak demand is much lower than for fossil fuel plants and more complicated

³⁹ Department for Business, Enterprise and Regulatory Reform (2008), *UK Renewable Energy Strategy: Consultation Document*, June 2008. The UK emitted 557 million tonnes of CO₂ in 2006.

to calculate. We received several estimates of how far wind capacity could be counted on to contribute to meet peak demand—its “capacity credit”. BERR uses a range of between 10% and 20% of wind stations’ capacity, so that 25 GW of wind plant could displace between 2.5 and 5 GW of conventional plant (Q 483). E.ON suggest that the capacity credit of wind power in the UK should be only 8% (p 119).

110. As wind generation increases, its capacity credit will tend to fall because low winds over part of the country can affect many wind turbines simultaneously. Extra, offsetting conventional plant is needed. The Renewable Energy Foundation’s rule of thumb is to treat the square root of the wind capacity in GW as if it were conventional capacity (Q 112). On that basis, for example, 25 GW of installed wind generation capacity could be counted on for the same contribution to peak demand as 5 GW of conventional capacity; and it would take 36 GW of wind plant to match 6 GW of conventional plant.
111. Under any of these assumptions it is clear that much conventional capacity will be required to support renewable generators coming on stream in the period up to 2020, during which many of Britain’s coal and nuclear power plants are scheduled to close. To replace them, the Government has calculated that 20–25 GW of new power stations will be needed by 2020—the equivalent of more than a quarter of today’s 76 GW of electricity capacity. But that calculation assumes replacement on a like-for-like basis and does not take account of the target for renewables. **If some 30 GW of additional (Q 487) renewable capacity were required to meet the EU’s 2020 target for the UK (and its capacity credit did not exceed 6 GW), a further 14–19 GW of new fossil fuel and nuclear capacity will still be needed to replace plants due to close and meet new demand. The total new installed electricity generating capacity required by 2020 would thus be roughly double the level needed if renewable generation were not expanded.**
112. The intermittent nature of wind turbines and some other renewable generators means they can replace only a little of the capacity of fossil fuel and nuclear power plants, if security of supply is to be maintained. **Investment in renewable generation capacity will therefore largely be in addition to, rather than a replacement for, the massive investment in fossil-fuel and nuclear plant required to replace the many power stations scheduled for closure by 2020. The scale and urgency of the investment required is formidable, as is the cost.**
113. The UKERC study calculated the cost of building additional conventional capacity to maintain reliability in Great Britain, with up to 20% of intermittent generation would be between 0.3–0.5 pence per kWh of that intermittent generation. These costs are dominated by the fixed costs of building plant and payments to generators to keep the capacity available even though they may rarely need to generate the power.
114. The SKM report for BERR estimated the cost of additional generating capacity to maintain security of supply with a renewable share of 34% would be £316 million a year, or 0.31 pence per kWh of wind output.⁴⁰ This

⁴⁰ SKM assumed that in a scenario with 27% of wind generation (and 34% renewable generation in total) 19.5 GW of conventional capacity would be needed but would not generate throughout the year, compared with 10.4 GW in a scenario with 3% of wind generation. The cost of the extra 9.1 GW of conventional

estimate is at the bottom of the UKERC range, because SKM assumed that the reserve capacity would have lower costs per kW than did UKERC.⁴¹ If the studies had used the same cost of capacity, the SKM cost per kWh of wind generation would have been slightly higher than the UKERC figure, at 0.6 pence per kWh. This is because, as we have noted at paragraph 110, the capacity credit of each additional wind power station—i.e. the amount it can reliably contribute to peak electricity demand given the problems of intermittency—declines as more of them are added.

Storage—a permanent solution to intermittency

115. A sufficiently great advance in electricity storage technology would help solve many of the problems of intermittency (Q 98). If the storage could be charged and emptied quickly, this would be an attractive way of balancing the system. If the cost of storage capacity is sufficiently low, it would be an effective alternative to building additional generation capacity to deal with the peak levels of demand. The Royal Society of Edinburgh reported that a range of alternative storage technologies are being considered alongside the existing use of pumped storage hydroelectricity (p 453). Ofgem told us that fuel cells could become economically viable if their costs continued to fall, or electricity prices rose (p 171).
116. Dr Clarke of the Energy Technologies Institute told us more resources had recently been applied to developing energy storage, with major industrial corporations becoming involved. He pointed out that large-scale schemes might be located close to generators, and would then smooth out the load on the transmission system, reducing its costs. Small-scale storage could help to manage local demand. High-temperature batteries, mainly used by the military at present, are more efficient than conventional batteries, and could provide a significant opportunity where waste heat from combined heat and power schemes could keep them hot enough to work properly (QQ 318–20).
117. **A breakthrough in cost-effective electricity storage technology would help solve the problem of intermittency and remove a major stumbling block to wider use of renewable energy in the longer term. However, no evidence we received persuaded us that advances in storage technology would become available in time materially to affect the UK's generating requirements up to 2020. We recommend that the Government should as a matter of urgency encourage more research, development and demonstration in energy storage technologies.**

The impact on the system average cost of electricity generation of an increased share from renewables

118. Chapter 3 discussed the evidence we received on the cost of individual technologies for renewable generation. We now consider the total cost of generation across the system. This requires us to take account of the mix of capacity, the load factors that different plants achieve, and the costs of intermittency discussed in the previous section.

capacity would be £316 million a year, which gives 0.31 pence for each of the 102 billion kWh of wind generation. (table 7.13)

⁴¹ UKERC based their estimates on a new Combined Cycle Gas Turbine plant costing £67 per kW per year, whereas SKM assumed that already existing plant could be kept open at a cost of just £35 per kW per year.

119. In Table 3, we use the figures in Table 2 to estimate the impact of increased renewable generation on base generation costs.⁴² We assume that the amount of onshore wind generation rises from 2% to 8% of the total, and that offshore wind output rises to 19%. We assume that 75% of this extra renewable output would replace gas-fired generation, and 25% would replace coal. We find that if the share of renewable output rose to 34%, the base cost of generation would rise by £4.3 billion, or 1.1 pence per kWh of total output. We also consider a case with higher coal and gas prices—50% above 2007–8 prices. The increase in generation costs is somewhat smaller, at 0.8 pence per kWh or £3.0 billion.

TABLE 3

Prediction of the impact of increasing amounts of renewable power on the system average base cost of generation

All figures use 2008 prices	Current fuel prices		Fuel prices rise by 50%	
	Base cost in pence per kWh	Base cost in £ billion	Base cost in pence per kWh	Base cost in £ billion
Base cost of generation with current share of renewable output (6%)	4.3 p/kWh	£16.2 billion	5.2 p/kWh	£19.6 billion
Base cost of generation with an additional 5% onshore and 13% offshore wind (25% renewable in all)	5.0 p/kWh	£18.6 billion	5.6 p/kWh	£21.2 billion
Base cost of generation with an additional 6% onshore and 19% offshore wind (34% renewable in all)	5.4 p/kWh	£20.5 billion	6.0 p/kWh	£22.6 billion

120. The SKM study⁴³ cited by government witnesses also predicted a sizeable, but lower, increase in generation costs.

Investment in the Electrical Grid

121. National Grid told us that capital investment to reinforce the onshore transmission networks—the wires and pylons that carry electricity over long

⁴² We have followed the Government's consultants in assuming that the capital costs of generators will fall slightly over the years to 2020—if we were to assume constant costs over the period, the additional cost of renewable generation would be higher by about £500 million a year.

⁴³ Sinclair Knight Merz (2008) *Growth Scenarios for UK Renewables Generation and Implications for Future Developments and Operation of Electricity Networks* BERR Publication URN 08/1021 SKM estimated the average base cost of generation in 2020 with 6% of renewable output would be 4.68 pence per kWh. If the share of renewable output rose to 34% the average base cost of generation would be 5.19 pence per kWh. This gives an increase of 0.51 pence per kWh of total output, or £1.9 billion, which in turn implies that the base cost for each kWh of renewable output is about 2 pence higher than the base cost of the kWh of conventional output it replaced. Our figures are based on Table 2, which predicts offshore wind to cost roughly 4 pence per kWh more than coal- or gas-fired electricity.

distances—to accommodate 40% of renewable generation would cost around £3.5 billion. This included reinforcements to the transmission network to accommodate an additional 10 GW of renewable generation in Scotland, developments in Eastern England to accommodate up to 19 GW of offshore wind generation in the North Sea and an overhead line in mid-Wales to accommodate an extra 1 GW of onshore wind generation (p 127 and appendix 2; Q 267).

122. These figures cover only the cost of upgrading the onshore transmission system. Laying cables along the sea bed to connect offshore wind farms will be expensive. National Grid expected the cost for the 19 GW of offshore wind—which it views as necessary if the EU 2020 targets are to be reached—to be in the region of £6–10 billion (Q 271). To connect 33 GW of offshore capacity to the Grid, Ofgem expected a cost of around £10 billion which is at the more optimistic end of National Grid’s range of costs. Any of these figures would be well above the amounts for local connection costs included in the estimates of power station costs presented in Chapter 3.
123. National Grid’s figures did not include the costs of improving local distribution networks that may be necessary in some areas to connect up the new generators. In areas where renewable resources are plentiful, the distribution system is often sparse, and new generation will trigger significant infrastructure investment, in many cases including the construction of new overhead lines. The Energy Networks Association described the provision of infrastructure to accommodate 2020 targets as challenging (p 285).
124. The SKM study cited by the Government estimated £10.2 billion would need to be spent in total on the transmission and distribution networks. That is at the low end of National Grid’s range of estimates, despite the fact that SKM have included distribution costs. But SKM’s figures apply to 34% of electricity coming from renewables while National Grid’s are estimated for a 40% share.
125. SKM calculated these transmission and distribution costs would add a further 0.34 pence per kWh to the cost of the renewable scenario, or 1.25 pence per kWh of wind generation. Added to the other costs outlined earlier for balancing and security of supply the renewable scenario would be 27% more expensive than the conventional scenario, at 6.17 pence per kWh as opposed to 4.86 pence per kWh.
126. Table 4 gives our own estimates of the total cost of moving to a high level of renewable electricity generation in 2020. The top line of the table gives the predicted base cost of generation in 2020, on the assumption that there is no further increase in the share of renewable generation, taken from Table 3. The second line includes the cost of system balancing and consumers’ payments for the existing transmission network. The third line gives our prediction for the total costs of generation and transmission in 2020, with 6% of renewable power.
127. The rest of the table considers the additional costs imposed by increasing the share of renewable generation. First, there is the higher base cost of renewable generation, from Table 3, which would add £4.3 billion. Second, there are the costs of system integration—additional balancing and reserve costs, and extra investment in the onshore and offshore transmission networks. We use the middle of the ranges given to us by National Grid for balancing and transmission costs, and the upper end of the UKERC range

for reserve costs. These add £2.5 billion to the predicted cost. In total, increasing the share of renewable generation to 34% would raise the annual cost of generation and transmission by £7.5 billion. In other words, the cost of generation and transmission would rise from 4.7 pence per kWh of total output to 6.7 pence per kWh.

TABLE 4

Predicted total costs in 2020 of electricity generation and transmission with 34% of generation from renewables, including allowance for back-up and grid integration

	Pence per kWh of total output	£ billion per year
Predicted base generation cost with 6% renewables	4.31 p/kWh	£ 16.2 bn
Cost of balancing and existing transmission system	0.41 p/kWh	£ 1.5 bn
Predicted total cost with 6% renewables	4.82 p/kWh	£ 17.7 bn
Extra costs of moving from 6% to 34% renewables		
Generation base cost	1.14 p/kWh	£ 4.3 bn
Predicted additional costs of system integration		
Intermittency (See para 102 and 113)	0.33 p/kWh	£ 1.3 bn
Transmission (See para 121–3)	0.32 p/kWh	£ 1.2 bn
Predicted total integration costs	0.65 p/kWh	£ 2.5 bn
All extra predicted costs for moving from 6% to 34% renewables	1.79 p/kWh	£ 6.8 bn
Predicted overall cost of generation and transmission with 34% renewables	6.61 p/kWh	£ 24.5 bn

128. **Our calculations suggest that the total extra annual cost of increasing the share of renewables in electricity generation from 6% to 34% in 2020 would be £6.8 billion or an extra 38%—the equivalent of an extra £80 a year for the average household. Emissions of carbon dioxide would be reduced by 52 million tonnes a year—in 2007, the UK’s emissions were 544 million tonnes. This implies that the additional cost is about £130 per tonne of carbon dioxide emissions avoided.**

Grid connection policy

129. The current policy is for each project developer to arrange a separate connection between an offshore generating plant and the electricity network

on land. Ofgem is required to seek the best route forward through competition and markets wherever appropriate, and to secure value for money for consumers. They and BERR have decided to base future arrangements around competitive tenders for the major offshore transmission projects. (QQ 442–443, p 171).

130. National Grid and EDF agreed that this “radial connection” approach was fit for purpose when the decision was made. But the need to develop renewables offshore had changed significantly since then. They questioned whether this approach could be sustained for an offshore wind programme of three times the size originally envisaged. The proposed regime appeared overly complex to National Grid, with many areas still uncertain and undecided. The company believed simple, co-ordinated, regulated transmission build would be more effective to help ensure the infrastructure was in place when new renewables were ready to connect. Ofgem said if it transpired that they needed to develop an offshore grid, rather than taking a radial approach, they would not rule it out.
131. **We note that the regulator’s statutory duties require the use of competition wherever appropriate, and therefore give it some discretion about the use of markets. Although competition is usually preferable, we are concerned that the use of competitive tenders implies a piecemeal approach to building the networks of wires and cables required to connect offshore wind farms to the electricity grid, and that as a result the programme could become overly complex and costly. We recommend that the regulator implements the new system in a way that allows a coordinated approach for organising grid connections to offshore wind farms.**

Grid charges and access

132. A second set of transmission-related issues concerns the terms on which renewable generators are able to access the grid. First, renewable generators in some parts of the country (and particularly in Scotland) face significant delays before they can be connected. In the face of insufficient transmission capacity, National Grid’s response has been to delay connecting generators to the system, rather than to connect them and ration capacity (e.g. through market prices) when required. Second, there will be times when the grid cannot accept all the power generated within an area, and generators will be unable to sell their power. Third, we received some evidence querying whether the charges levied for using the transmission grid are appropriate.

Delays in Grid connections

133. National Grid has signed agreements with 49 GW of new generation since 2005, equivalent to nearly two-thirds of the 77 GW of capacity currently connected to the system. This has created a backlog for getting projects connected to the Grid. National Grid has established the “GB queue”, which promises to give generators access to the grid in the order in which they signed connection agreements with the company. But new entrants may receive a connection date in ten years’ time, according to Scottish and Southern Energy (p 85).
134. Ofgem and BERR have recently concluded a Transmission Access Review, which asked National Grid to take a more proactive approach to managing this queue, giving priority to projects that had received planning permission

for their plant. Ofgem told us that National Grid is now taking a more robust approach to removing unviable or purely speculative projects (p 171). **We welcome these measures to organise better the queue of renewable generation projects awaiting connection to the electricity grid. They should reduce delays in connecting viable generation projects and push back schemes unlikely to get off the ground.**

Surplus power

135. When National Grid is unable to accept power from a generator, through a lack of transmission capacity, it has to compensate the generator accordingly. But as wind output grows, flows on the transmission system will become more variable. British Energy pointed out that at very high levels of wind-generated electricity, there may be periods when it will be necessary for National Grid to instruct wind generators to spill power because renewable generation exceeds demand, net of other plants that are required to run. National Grid's policy at present is to invest in a way that keeps the cost of transmission constraints at about £100 million a year. They noted that without additional investment on the lines between Scotland and England, the cost of constraints might rise to between £500 million and £1 billion a year. This would cost a household consuming the average amount of electricity between £7 and £14 a year.
136. It is important that the transmission companies strike the right balance between investing in transmission and paying stations to be constrained off (p 311). It would not be economic to build a network in which transmission constraints were very rare, as the capacity needed to achieve this would cost too much. For an analogy, a motorway with six lanes in each direction might never see a traffic jam, but it would be a better use of resources to build a three-lane motorway and accept a few hours of congestion each month. A two-lane road that was congested for several hours a day would be inadequate, however. If the electricity transmission companies do not invest enough in the grid, congestion costs will be excessive; the cost of inadequate capacity is not a traffic jam, but that the system operators may have to use expensive stations near the loads rather than cheaper stations further away. Transmission access arrangements should address this issue. A series of proposals are outlined in Appendix 8. The key feature is that if new generators in areas likely to have a surplus of power must pay more to use the grid, they will tend to avoid these areas, reducing the amount that needs to be spent on transmission investments.

Transmission charges and losses

137. The Transmission Use of System charges are set by National Grid to recover the costs of all three transmission system owners in Great Britain. Generally, the more remote a generator, the higher the charges it has to pay because of the greater investment required in the transmission network to carry the electricity to centres of high demand. So a wind farm in the Highlands faces higher charges than an identical one near London. However, Professor Bain argued that the transmission charging system did not take account of the electricity lost in transmission (p 227). While these losses are only equal to 2% of electricity generated on average (p 144), they rise with the distance that power has to travel (Q 291). Furthermore, when power flows increase, the marginal losses are twice the average level. National Grid's Seven Year

Statement⁴⁴ shows that an extra 100 MW of generation in the Highlands would only replace 90 MW in the Midlands, as a result of the additional transmission losses incurred. In 2002, Ofgem proposed that transmission losses should be taken into account in the industry's trading mechanisms, but was over-ruled by the Government.

138. The Government was concerned about the impact on the costs of renewable generators located in Scotland. The higher the cost, the greater the financial support required (cf. chapter 6). If the system of support gives similar payments to every generator (of a given type), then the costs of the most expensive generator deemed to deserve support (the marginal generator) determine the payments to each of them. If the marginal generator is located in Scotland, then charging for transmission losses would increase the amount of support it required, and raise the amount of profit made by those generators in areas with lower transmission losses.
139. In the broader context, E.ON told us that charging for use of the transmission system should continue to reflect the costs to the system associated with generating from renewables and other generation at that location on the system. This would help ensure that these costs are taken into account in the decision where to site the project in the first place (p 108). But Scottish and Southern Energy, which has wind farms in remote parts of Scotland, argued against “the current perverse mechanism of regional charges”. Ofgem has successfully defended a judicial review on the basis that “it was absolutely right that people who were at the extremities of the system should pay very high charges that reflected the economic costs of transmitting electricity a long way from where it is produced to where it is used” (Q 422). We agree with this position. **We consider that the current system of Transmission Use of System charges sends broadly appropriate signals of the costs of locating generators at different points on the system.**

Mitigating intermittency by more connections to the Continental grids

140. Over the long term the costs of intermittency could be mitigated by greater interconnection between the electricity grids of Britain and the rest of Europe (p 56, Q 20). Unlike Denmark, for example, Britain has very little capacity to import or export electricity to other countries. There is a link to France with 2 GW of capacity. National Grid and the Dutch transmission operator are building a cable to the Netherlands with 1 GW of capacity, expected to cost £480 million. Three other lines—to Belgium, Norway and the Republic of Ireland—have been studied, but no contracts have been signed. Even if all three were built, the total import capacity would be roughly 6 GW, compared to our peak demand of over 60 GW. Britain is, in effect, an ‘island generator’. This complicates the task of managing intermittent generation.⁴⁵
141. Greater inter-connectedness would allow Britain to tap renewable sources over a wider area which would reduce the problems with intermittency. For example, when the wind is blowing in Denmark but not Britain, electricity from Danish wind farms could then be imported. The wider the area of

⁴⁴ National Grid, *Seven Year Statement*, May 2008, table 7.5

⁴⁵ Spain, however, is in a similar (or worse) situation to the UK, in that its link with France allows it to import only about 1 GW of power, but has successfully integrated 15 GW of wind capacity, meeting 10% of demand. (p 464, para 13, plus European Transmission System Operators [ftp://www.etsa-net.org](http://www.etsa-net.org))

interconnectedness, the more likely it is that variations in wind patterns will cancel out, although the weather may sometimes be similar over even a wider area. For example, we received some evidence that low wind speeds in the UK could coincide with similar conditions in Germany, Ireland and even as far away as Spain.⁴⁶ Furthermore, it would not be economic to build enough interconnector capacity to solve our problems with intermittency, for wholesale electricity prices in the UK and on the Continent would then converge, whereas the interconnectors need different prices in the two markets to profit from trading between them. **Greater interconnector capacity with the Continent would reduce, but not solve, the problems of intermittent renewable generation.**

⁴⁶ The Renewable Energy Foundation sent us a copy of a paper on this issue: Oswald, J., M. Raine and H Ashraf-Ball (2008) "Will British weather provide reliable electricity?" *Energy Policy*, vol. 36, no. 8, pp 3212–3225

CHAPTER 5: RENEWABLES FOR HEAT AND TRANSPORT

142. Most of the debate on renewable energy has focussed on electricity generation. This chapter considers renewable sources for the two other main uses of energy—heat and transport, which together account for roughly 80% of the UK’s final energy consumption.

Heat

143. Renewable heat sources could make a significant contribution to reducing carbon emissions, according to a number of submissions. Scottish Power believe renewable sources of heat have “significant undeclared potential” while Philip Wolfe of the Renewable Energy Association said this area had been “neglected” (Scottish Power p 646, Philip Wolfe Q 175).
144. There are four main renewable sources for heat:

(a) Biomass

Biomass heat comes from the burning of organic matter with wood the most common source. Biomass heat is often generated on the site where it is to be used from households to intermediate industrial use but it can also be distributed through district networks or grids.

(b) Biomethane

Some types of biomass can also be used to produce ‘biogas’—a mixture of methane and carbon dioxide—through anaerobic digestion, which turns the material into compost in the absence of oxygen. Removing the carbon dioxide leaves bio-methane. Akin to natural gas, bio-methane can be pumped through the gas networks or grid to customers. Such systems are already used in Sweden and Switzerland. Injecting bio-methane into the gas network effectively reduces the carbon intensity of gas.

(c) Heat pumps

Heat pumps work by first compressing a liquid or gas which naturally heats it, allowing the heat to be used to warm a building. The liquid or gas is then allowed to expand, releasing heat as it cools down (which could be used in air-conditioning or refrigeration). The resulting cooler liquid or gas is circulated via a pipe next to a natural source of warmth, either in the ground or the air. The cooler liquid or gas will absorb heat from the warmer surroundings until it reaches the same temperature. The process is repeated by compressing the liquid or gas again. The heat already absorbed by the liquid or gas reduces the amount of compression needed to reach a given temperature. This allows heat pumps to generate considerably more energy in heat than they consume in electricity, so they are regarded as renewable sources.

Ground source heat pumps extract the energy absorbed from the sun. A few metres below the ground, the earth keeps a constant temperature of around 11–12 degrees centigrade through the year. A length of pipe is placed in the ground through which a combination of water and anti-freeze is pumped to absorb the heat from the ground. Ground source heat pumps can transfer this heat from the ground into a building to provide space heating and, in some cases, pre-heating domestic hot water. For every unit of electricity used to pump the heat, 3–4 units of heat are produced, according to the Energy Saving Trust.⁴⁷ Some systems can be run in reverse to provide cooling in hot weather.

⁴⁷ Energy Saving Trust factsheet on Ground Source Heat Pumps available at: <http://www.energysavingtrust.org.uk/uploads/documents/myhome/Groundsource%20Factsheet%205%20final.pdf>

(d) Solar thermal

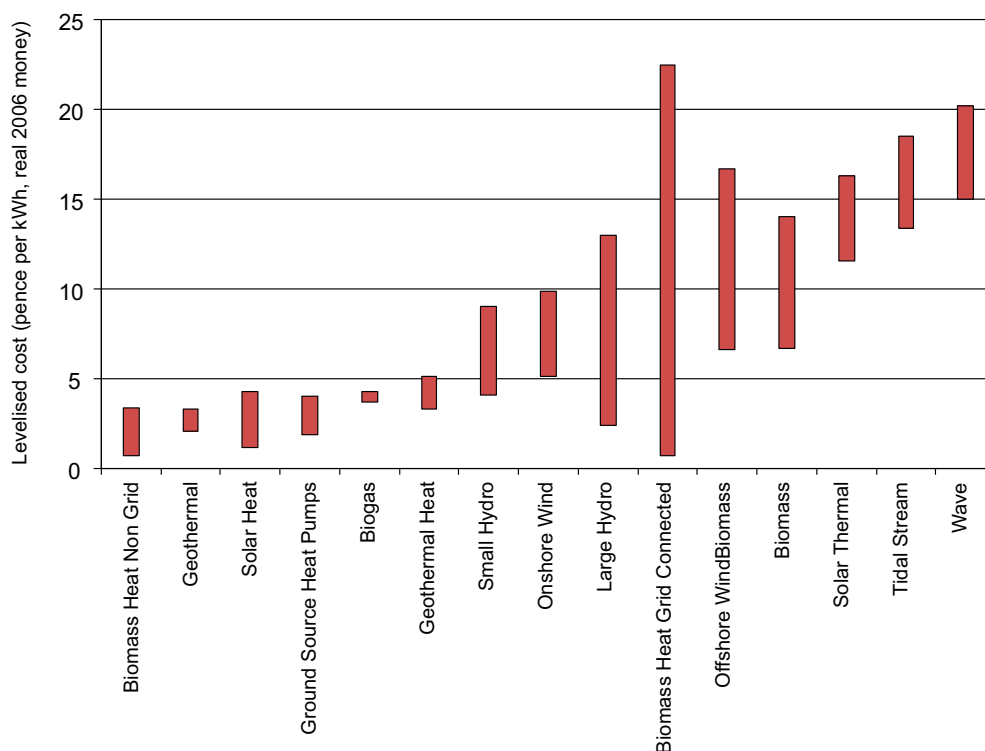
Solar thermal panels use the energy from the sun for heating. These have been found to be most cost-effective when they produce 50–70% of a household's average hot water requirements, according to the Government's recent renewable energy consultation paper.

Combined Heat and Power

145. Combined Heat and Power (CHP) captures and uses the waste heat produced during generation of electricity and so can lower carbon emissions. It tends to work best at community level on residential developments rather than in individual houses. Some industrial firms also use CHP. But since in Britain CHP is mostly derived from fossil fuels, it is not a renewable source of energy. The Government's consultation paper on renewable energy nevertheless sees potential for renewable forms of CHP using biomass and biogas.

Costs surrounding greater deployment of renewable heat technologies

146. The Government stated in its consultation paper that biomass heat was “one of the most cost-effective potential sources of renewable heat”, while Scientists for Global Responsibility argued: “Biomass can be used directly for heating—e.g. wood pellet boilers or domestic wood burning stoves—at low cost” (Scientists for Global Responsibility p 459).
147. Figure 8 shows small scale biomass heat—i.e. not connected to a grid for wider distribution—to be comparatively cheap. But the chart also shows that for larger scale biomass heat projects, which might well need to be connected to distribution grids, the costs range from relatively low to expensive. The wide range is due to the different costs of various biomass fuels and their high transport costs depending where they are sited. Biogas projects have a very small cost range and are only slightly more expensive than small-scale biomass heat.

FIGURE 8**Levelised project cost ranges at 2006 prices by the Pöyry energy consultancy group**

148. Biomass and bio-methane are normally generated from locally sourced feedstock. But widespread deployment of biomass would require imports, with relatively high carbon emissions from transport. Both biomass and bio-methane may also use energy crops which compete with food crops for arable land.
149. Centrica cautioned: “More work needs to be done on the economics and supply chain risks of biomass, especially where it is produced from specifically grown crops (albeit it is less critical when using existing waste). This is a new commodity, global demand is likely to increase dramatically, and as such its future price and availability are extremely difficult to predict” (Centrica p 95).
150. Some bio-methane production could come from waste and sewage, with the added benefits of capturing the greenhouse gas methane and avoiding the need for incineration (National Grid p 145).
151. A report commissioned by the German government in 2007 on possible European biogas strategies found that EU-produced bio-methane has the potential to replace roughly 50% of EU natural gas imports from Russia by 2020. This highlights the potential for bio-methane injection into the gas network on a large scale (National Grid p 145).
152. But there are technical issues—in particular whether the bio-methane meets UK gas quality requirements; and the expensive equipment needed to inject bio-methane into the grid, so that large-scale deployment is required for economic viability (National Grid p 145).
153. Heat pumps, which are already widely used in parts of continental Europe, were favoured in a number of submissions as a good source of renewable energy (Renewable Energy Foundation p 327, EDF p 271, Mayer and Bentley p 399). The Pöyry chart shows they are only slightly more expensive than small-scale biomass heat. But heat pumps also consume some electricity, as already indicated at paragraph 144(c).
154. Other barriers to greater use of smaller scale renewable heat technologies include lack of familiarity among households, unsuitability for flats, and high up-front capital costs, although operating costs for heat pumps are lower and could lead to lower household energy bills (Renewable Energy Foundation p 327).
155. EDF favours heat pumps over biomass for “delivering low carbon heat as biomass supplies are limited and the transport of large volumes of biomass into urban environments is problematic” (EDF p 271).
156. Solar thermal heating is a high cost option compared to other forms of renewable heat as shown on the Pöyry chart. A good solar thermal system can provide around 50–70% of a dwelling’s hot water demand and with more panels around 30% of its space heat demand (Genersys p 311).
157. The Government has estimated that 14% of heat would need to come from renewable sources if Britain is to hit the EU’s proposed target of 15% of all energy in Britain coming from renewables by 2020. At present only 1.2% of heat comes from renewable sources. Biomass and heat pumps are the most cost-effective ways of increasing the share of heat from renewables, as shown in Figure 8. The Government expects they would make up the lion’s share of any renewable heat deployment in the near term. But supplying enough biomass and heat pumps to ensure 14% of heat came from renewables by

2020 would be extremely difficult. So more expensive sources such as solar thermal and biogas might be used to reach the 14% target. The Government is considering ways to encourage renewable heat generation such as mandating energy companies to supply a proportion of heat from renewable sources, or requiring suppliers to pay generators of renewable heat an above market price. We note that the Secretary of State for Energy and Climate change stated on 16 October that he would soon make further announcements on the role of renewable heat.⁴⁸

The costs of renewable heat compared to electricity

158. Some witnesses argued renewable heat should be making a greater contribution towards meeting Britain's carbon emission targets. Campbell Dunford of the Renewable Energy Foundation said the "low hanging fruit" of renewable heat was being missed because "everybody is fixated with the holy grail of generating electricity [from renewable sources] at a micro and a macro level" (Q 115). Philip Wolfe of the Renewable Energy Association said: "The heat sector is still largely ignored and its contribution can be as large as electricity. The cost of producing renewable heat, the incremental cost, is substantially lower than the incremental cost of producing renewable electricity and it has been estimated that one could achieve the same carbon savings in renewable heat for about a third of the cost of the same carbon savings in renewable electricity." He suggested that it had appeared to be easy to design policy for the small number of large electricity generators, whereas renewable heat would come from a large number of small plants (Q 175).
159. The Pöyry chart (figure 8) shows that various heat technologies such as biomass and heat pumps have lower costs than those for electricity such as wind generation. But solar thermal heat and the top end of the range for biomass heat connected to the grid are relatively expensive.
160. A number of witnesses argued that it was more cost-effective to use biomass for heat than for generation of electricity (Renewable Energy Association p 424, Centrica p 95). The Government's recent consultation paper on renewables also assessed the use of biomass for heat as more cost-effective in terms of pound per tonne of carbon abated than for electricity.
161. EDF argued that the key question when comparing the costs of renewable heat and electricity technologies was whether the marginal technology in the electricity sector—which they argued was likely to be offshore wind—requires more or less subsidy than the marginal technology in the heat sector. EDF expects heat pumps to be the key form of low carbon heat. EDF's analysis indicates that a heat pump, which can be retrofitted to a conventional hot water and radiator heating system in an existing property, would require less subsidy per kWh of renewable energy produced than an offshore wind farm. But the heat pump's cost per tonne of CO₂ abated is considerably higher because it runs on electricity, which itself involves carbon emissions. In the long term an increase in electricity generation from renewables might increase the carbon saved by heat pumps (EDF p 280).
162. Renewable heat can also help avoid costs associated with intermittency of many forms of renewable electricity generation such as wind farms. Heat can

⁴⁸ Hansard, 16 October 2008, col 936.

also be safely and easily stored, unlike electricity (EDF p 280, Genersys p 311).

163. **Harnessing renewable sources of heat is often cheaper than for electricity generation and it offers a larger target area, as heat accounts for two-fifths of final energy demand in the UK, as opposed to around 20% for electricity. Unlike wind power—the dominant source of renewable electricity generation and the renewable source to which the Government has paid most attention—there is no intermittency problem with renewable heat. We recommend that the Government should lay at least as much emphasis on encouraging the development and use of renewable heat as on renewable electricity generation.**

Transport

164. For transport the main alternative source of energy to fossil fuels is biofuels.

(a) Biofuels

Biofuels can be made from a range of organic materials including oilseeds, wheat and sugar, and are typically blended with conventional petrol and diesel. At present the two main types of biofuel are biodiesel and bioethanol. Biodiesel, a diesel substitute, is generally produced from oily feedstocks such as rapeseed, sunflower or palm oil, or from recovered cooking oil. Bioethanol, a petrol substitute, is generally produced from starchy feedstocks, such as wheat, sugar beet or sugar cane—although it can be produced from any organic substance such as wood, grass or municipal solid waste. Bioethanol and biodiesel can simply be added to existing liquid fossil fuels and at low percentages require little or no changes to either the vehicles or the fuel infrastructure. Other forms of biofuels include biomethane, which is a gas produced by the biological breakdown of organic matter and can be used as a renewable alternative to natural gas, either as a transport fuel or for electricity generation and heating.

(b) Electric and plug-in vehicles

Small cars powered by electricity through a battery rechargeable from the electricity mains are now available. Due to their limited power the current range is seen as suitable only for short daily journeys. For more general use, the plug-in hybrid, which has sufficient battery capacity charged from the mains supply for most daily use, with a small internal combustion engine able to provide power on extended journeys, may be more promising. Plug-in hybrids are to be marketed by US and Japanese manufactures in the near future (Scientists for Global Responsibility p 459).

(c) Hydrogen vehicles

Hydrogen fuelled vehicles are still being researched and may be a renewable technology of the future. Two types of hydrogen powered vehicles are possible. One uses hydrogen as the fuel for an internal combustion engine. The second uses hydrogen in fuel cells which when combined with oxygen is turned into electricity to power the vehicle. Most hydrogen today comes from non-renewable sources such as natural gas. But it could in theory be produced in a renewable way through electrolysis which splits water into hydrogen and oxygen. Transport for London has signed a contract to have 10 hydrogen fuelled buses operating in the capital by 2010 after trials.

165. The Government in April introduced a requirement that 2.5% of fuel sold in British forecourts must come from renewable sources.⁴⁹ The European Commission has proposed that 10% of energy for transport in each EU member state come from renewable sources by 2020.⁵⁰ The appeal of biofuels was outlined by the Royal Academy of Engineering: “Biofuels ... can simply be added to existing liquid fossil fuels and at low percentages require little or no changes to either the vehicles or the fuel infrastructure. It is likely that the ease of adding biofuels to road transport fuel is one of the main reasons that governments ... have introduced targets for their introduction” (Royal Academy of Engineering p 445).

Costs and carbon emissions

166. Biofuels have been controversial as some of them appear to have little impact on reducing carbon emissions—the key aim of all renewable energy. The Royal Academy of Engineering explained that in theory biofuels should be zero carbon. As with other plants, energy crops—which are used to make biofuels—absorb CO₂ as they grow. When the energy crop is burned or processed the CO₂ that has been absorbed during the plant’s growth is then released. In theory, the amount of CO₂ released should be the same as the amount absorbed during the plant’s growth making the process carbon neutral. But in practice there will often be more CO₂ emissions from fertiliser production and as biofuels are processed, so that they do not provide zero carbon energy. In some cases these emissions can “render the biofuel almost pointless in terms of carbon savings” (Royal Academy of Engineering p 445). Furthermore, soil degradation can occur where single energy crops, such as oil palms, replace rain forest. This is “ultimately unsustainable”, according to the Royal Academy of Engineering, and results in the loss of crucial carbon sinks—areas of soil which can store large amounts of carbon that have previously been absorbed by the rain forest (Royal Academy of Engineering p 445).
167. Today’s commercially produced biofuels are made from the parts of plants that could otherwise have a food use, such as wheat grain, beet or cane sugar, or vegetable oil. In the production of bioethanol or biodiesel, very little of the plant is actually converted into the fuel with most of the plant discarded (Royal Academy of Engineering p 445).
168. The Gallagher Review commissioned by the Government expressed concerns about the impact on people in developing countries from agricultural land and food crops being used for biofuels.⁵¹ It concluded that: “The introduction of biofuels should be significantly slowed until adequate controls to address displacement effects are implemented and are demonstrated to be effective. A slowdown will also reduce the impact of

⁴⁹ The Government initially planned to increase the share of fuel sold in forecourts coming from renewables to 5% in 2010–11. But in July the Government decided to consult on whether this should be slowed down to reach 5% in 2013–2014 in line with the recommendations of The Gallagher Review of the *Indirect Effects of Biofuels*, July 2008.

⁵⁰ The target does not cover transport energy from oil products other than diesel and gasoline, and therefore means that aviation (which uses kerosene) is excluded, although it is included in the denominator of the 20% EU target for the overall use of renewable energy.

⁵¹ The Gallagher Review of the *Indirect Effects of Biofuels*, July 2008, which can be viewed at: <http://www.dft.gov.uk/rfa/reportsandpublications/reviewoftheindirecteffectsofbiofuels.cfm>

biofuels on food commodity prices, notably oil seeds, which have a detrimental effect upon the poorest people.”

169. Second generation biofuels are manufactured from waste, residues such as straw and whole plants not suitable for food. So they should offer greater benefits, using about one third of the land and lower other inputs. But they are still emerging and not yet available on a commercial scale (Scientists for Global Responsibility p 459).
170. Others argued that many of the first generation of biofuels lead to sharp reductions in greenhouse gas emissions compared to fossil fuels. The Renewable Energy Association argued: “Many current generation biofuels produced in the UK can deliver significant greenhouse gas savings entirely sustainably. For example, British Sugar has announced that its sugar beet-to-ethanol plant in Norfolk delivers a 71% saving against fossil petrol, and Argent Energy delivers an 83% saving against fossil diesel at its tallow-to-biodiesel plant in Motherwell” (Renewable Energy Association p 424).
171. Yet the cost of obtaining reductions in carbon emissions from biofuels was far higher than for renewable sources of electricity and heat. A study by Pöyry for the Government modelled the most likely mix of renewables in electricity, heat and transport sectors to meet the EU’s proposed targets that 15% of all of Britain’s energy and 10% of transport fuels come from renewables in 2020. The study also estimated the costs and the reduction in carbon emissions in the electricity, heat and transport sectors over the lifetime of the renewable projects.⁵² From these figures, Pöyry calculated the cost of reducing each tonne of carbon dioxide emissions over the lifetimes of the renewable projects in each sector—known as the lifetime abatement costs—as shown in Table 5. This differs from earlier cost tables in the report which show the cost per unit of energy. The estimated cost of reducing carbon dioxide emissions by one tonne using biofuels for transport was £189—more than 5 times the average cost of using renewable sources of electricity and heat.

TABLE 5

Cost estimates of carbon reduction using renewable energy sources

	£/tonne of CO ₂ abated ⁵³
Electricity and Heat	36
Transport	189
Weighted average	46

Source: Pöyry Energy Consulting, *Compliance costs for meeting the 20% renewable energy target in 2020*

172. In transport there are few renewable options other than biofuels. Electric and hydrogen powered vehicles, described in paragraph 164, both use electricity. They can only count as renewables if they use renewable sources, and, as we

⁵² Lifetime costs and emissions figures cover periods beyond 2020. For example, a wind farm built today to help meet the EU’s proposed targets will most likely continue to operate after 2020 incurring costs and reducing carbon emissions.

⁵³ The figures were originally in euros:—Total Renewable Energy Sources €57, Electricity and Heat RES €45 and Transport RES €236. These figures were converted at an exchange rate of €1.25 to the pound.

have seen, renewables still only account for around 5% of total electricity. But if, for example, wind farms generate a larger share of electricity in future, electricity generated during periods of low demand, such as the early hours of the morning, could be stored in the batteries of electric cars (Q 223).

173. **We share the concerns raised in the Gallagher Review about existing biofuels. We consider that steps should be taken towards developing second generation bio-fuels as soon as possible. Until the costs of carbon emissions reduction through biofuels come down we recommend that the Government should not seek to increase further the use of biofuels.**

CHAPTER 6: POLICY ON RENEWABLE ENERGY

174. This chapter considers a range of policy issues relevant to renewable energy. We cover the role of renewable energy in UK energy policy, the justification for supporting it, and the best means of doing so. We also comment on micro generation, the impact on consumers' bills, support for technology development and the planning system. Finally, we ask whether the proposed 15% target for UK renewable energy by 2020 is achievable, and if so, at what cost.

The role of renewable energy in UK energy policy

175. In July the Government published its consultation on a UK Renewable Energy Strategy. The Secretary of State for Business, Energy and the Regions (BERR) wrote that "Renewable energy is key to our low-carbon energy future" The UK already has a legal commitment to the EU's target that 20% of Europe's energy should come from renewable sources by 2020, within which the proposed UK target is a renewable energy share of 15%. The (then) Minister of State for Energy told us that "decisions on renewable energy cannot be made merely on the basis of cost in the short term; it is about tackling climate change and securing energy supplies for the future. The Stern Review into the economics of climate change was absolutely clear that we need to invest now or pay a higher price later" (Q 472).
176. The then Minister said we needed a suite of policies. Diversity in our energy sources was important. The more energy the UK produced for itself, the better for security of energy supply. Civil nuclear power should play a role, although public spending would not subsidise it. The earliest a nuclear power station could be built was 2017–2020 (QQ 476, 477, 479, 480). Fossil fuel generation was also important, for diversity and for operation of the network, and because it could come on stream faster than nuclear power; development of carbon capture and storage (CCS) would be important to reduce emissions. It was hoped that a Government-funded CCS demonstration project would be operating by 2014.
177. **It is clear that, although the cost of the technology for carbon capture and storage (if and when it becomes a practical possibility) is inevitably highly speculative, it will always be more expensive than large-scale carbon-based energy without CCS.** Retrofitting the technology to stations not designed for it might be particularly expensive, but would be necessary to have a significant impact on the very large volume of emissions from existing plant.
178. We note that the Government has announced arrangements to charge a fixed unit price for disposal of some nuclear waste and spent fuel, and some respondents to a recent consultation on this issue expressed the view that this might provide a potential subsidy to nuclear power.⁵⁴ While the Government rejects this view, and we would not argue for a nuclear subsidy, we are conscious of the anomaly that the Government publicly supports a subsidy for renewable energy but not for the other main source of low-carbon energy.

⁵⁴ BERR (2008) *The Government Response to the Consultation on Funded Decommissioning Programme Guidance for New Nuclear Power Stations*, September 2008, para 4.3.

179. Other witnesses had a range of views on the place of renewables in the Government's energy policy. Professor Paul Ekins told us that renewables could contribute to the objectives of carbon reduction and energy security. He believed that the government was currently "giving most attention to the reduction of carbon emissions, but energy security is coming up fast on the inside track and may indeed overtake it at some point" (Q 3). Malcolm Keay of the Oxford Institute for Energy Studies argued that renewables had had very little impact on the UK's carbon emissions so far and were unlikely to make a significant impact by 2020. Much of the reduction in emissions in Britain had come from replacing coal with gas-fired plants in the 1990s. Countries with very low carbon electricity systems had a combination of nuclear and hydroelectric generation (Q 82). Mr Keay saw a danger that uncertainty over Government policy on renewable energy might deter needed investment in new conventional generating capacity, with some risk of power shortages, or, more likely, increased carbon emissions from running on old plant. If the capacity was then replaced in haste with new gas-fired plant, the renewables policy might increase the risks to the UK's energy security (Q 88).
180. Professor Gordon MacKerron saw a potential trade-off between objectives: policies designed to counteract climate change were nearly always good for security,⁵⁵ while policies designed to be good for security, such as more use of coal, were not always good for climate change. Renewables added diversity to the UK's energy portfolio, and reduced pressure on world fossil fuel markets. The real difficulty for the Government would be to retain public support for difficult choices in meeting emissions targets (Q 248).
181. The Renewable Energy Foundation told us that renewable generation had to fit in with the rest of the system, where new conventional plant would contribute to emissions reduction through better thermal efficiency. If renewable investment did not support conventional generation, the money would be "wasted". Renewable energy policy should also devote more attention to the heat sector, where solar thermal and ground source heat pumps could make a big contribution (Q 114).

Government intervention in the energy market

182. Cost comparisons between renewable and conventional electricity generation are complex and depend on many variables. But witnesses generally agreed that renewables are more expensive.
183. **It seems clear there would be little investment in renewable energy without substantial Government support and that a 15% target would not be met without it.**
184. Professor David Newbery told us that the context for renewable policy was a world in which some countries were tackling carbon emissions through the most obvious and direct way of pricing them, but some countries were not going to be part of the carbon pricing system. Support for renewable energy therefore helped to develop low-carbon technologies to the point where they might be commercially viable and adopted abroad (Q 184)

⁵⁵ We infer that he was talking of energy security in the medium-term sense of being able to rely on adequate supplies of fuel, since large amounts of intermittent renewable generation can make it harder to maintain the minute-by-minute availability of electricity.

185. The then Minister of State for Energy told us that in Phase III of the EU Emissions Trading Scheme, people were projecting a carbon price of about €35 per tonne of CO₂ (£28 per tonne at current exchange rates), whereas a price of somewhere between €100 and €200 per tonne would be required to develop renewables through that mechanism alone. The Minister did not think that this gap reflected a weakness in the trading mechanism, and agreed that it indicated that renewables were a high cost means of achieving reductions in CO₂ emissions. Over time, he expected costs of renewables to come down (QQ 473–475).
186. Many companies told us that even if the present level of carbon and fossil fuel prices were enough to cover the cost of onshore wind power, there was no guarantee these prices would continue, so that there was no sound basis for investment without additional support.

Support mechanisms and their costs

187. The most direct mechanism used by the British Government is Renewables Obligation Certificates (ROCs), which replaced a Non-Fossil Fuel Obligation. ROCs require electricity suppliers to deliver a set proportion of power from renewable sources. Generators receive one ROC for every 1,000 kWh of renewable electricity generated, and can sell these to suppliers. A supplier unable to surrender ROCs equal to the set percentage must pay for each missing certificate into a buy-out fund which is then redistributed amongst the suppliers who surrendered ROCs. The market price of ROCs rises above the buy-out price if a shortfall is expected, for each ROC allows the holder not only to avoid paying the buy-out price, but also to share in the money paid in by those with a shortfall. The design of the Renewables Obligation effectively means that the total payment to renewable generators, over and above the market price they receive for their power, should be fixed. A fuller description of the Renewables Obligation is at Appendix 9. The equivalent mechanism in use in Germany is the feed in tariff, which guarantees a price to the producer. In both cases, the extra cost is passed on to the consumer.
188. Witnesses expressed a range of views on the relative merits of the schemes. Some saw the RO rewarding the least capital intensive technology (Renewable Energy Foundation Q 123). The overall cost in Britain was seen as less but the feed-in tariff in Germany has produced more renewable energy at lower unit cost (Ekins Q 11). There is some convergence between the two systems as the UK introduces banding of the RO, which will give some technologies more than one ROC per 1,000 kWh, while some countries are changing feed in tariffs from a fixed total payment to a fixed supplement to the market price (IEA Q 399). Power companies valued a stable investment framework and generally preferred to retain the RO in the British market (Scottish and Southern Energy, Centrica Q 241; E.ON p 108). A number of witnesses however supported the adoption of a feed-in tariff for small scale generation (Friends of the Earth Q 60; Keay Q 96).
189. **We note the evidence that the cost per kWh of renewable electricity supported by the Renewables Obligation has been significantly higher than the amounts paid via feed-in tariffs abroad, and that much of the excess has been due to other differences in the environment for renewable generation, particularly in the planning system.** The renewables support mechanisms have already gone through a number of

changes including the banding of the Renewables Obligation to give different levels of support to different forms of electricity generation. Introducing feed-in tariffs at this stage for large-scale generation⁵⁶ would create more uncertainty and risk deterring investment in the sector. **Given investors' need for a predictable framework, it seems right to retain the Renewables Obligation, if it is desired to continue increasing generation of electricity from renewable sources.**

190. The EU Emissions Trading Scheme (ETS) also supports renewables by putting an additional cost on emitting carbon. Every EU Member State has allocated allowances to electricity generators and companies in some industrial sectors, and each allowance gives the holder the right to emit one tonne of carbon dioxide. Should individual generators or companies need to emit more than this, they can buy extra permits from groups who did not use up all their carbon allowances. So far, most permits have been allocated without payment, but because every tonne of carbon dioxide either requires the generator to buy a permit or to forgo the opportunity of selling a spare permit, the scheme raises the marginal cost of generating power from fossil fuels. This raises the price of power, creating an incentive to invest in low carbon or renewable forms of energy by tagging a cost on to carbon emissions.
191. The Government has also operated a separate UK-only emissions trading scheme for large companies and public sector organisations that are not heavy emitters of carbon. The UK Emissions Trading Scheme was launched in 2002 and operated in a similar way to its EU counterpart. The scheme ended in 2006 and a replacement, the Carbon Reduction Commitment is being developed. The new scheme will place an emissions cap on up to 5,000 large business and public sector organisations.⁵⁷
192. The Climate Change Levy is a tax on the use of energy in industry, commerce and the public sector, with offsetting cuts in employers' national insurance contributions and additional support for energy efficiency schemes and renewable sources of energy. The aim is to encourage users to improve energy efficiency and reduce emissions of greenhouse gases through greater use of renewables. Fuels used by the domestic and transport sectors and to generate electricity are exempt from the levy, as is energy used by charities or very small firms. Climate Change Agreements allow energy intensive businesses to receive an 80% discount from the levy, in return for meeting energy efficiency or carbon saving targets.
193. The Carbon Emissions Reduction Target (CERT)⁵⁸ requires gas and electricity suppliers, each with over 50,000 household customers, to achieve targets for a reduction in carbon emissions generated by the domestic sector. Ofgem, which administers the CERT, checks whether suppliers' schemes will result in an improvement in energy efficiency and therefore a reduction in carbon emissions.
194. Finally, the Renewable Transport Fuels Obligation introduced in April requires 2.5% of the petrol and diesel sold in forecourts comes from

⁵⁶ On 16 October the Secretary of State for Energy and Climate Change announced his intention to introduce feed-in tariffs for small-scale generation, complementing the Renewables Obligation.

⁵⁷ House of Commons, Written Ministerial Statement by Hilary Benn, Secretary of State for Environment, Food and Rural Affairs: Update on the Carbon Reduction Commitment—16 July 2008

⁵⁸ This follows on from the Energy Efficiency Commitment which was run in a similar way to the CERT.

renewable sources or biofuels. The obligation will rise to 5% by 2010. If petrol companies do not meet the renewable obligation they have to buy out the balance of their obligation at a price set by the Government. This has been set at 15p per litre until 2010. Biofuels also pay 20 pence a litre less tax than petrol or diesel.

195. Table 6 gives estimates of the current annual cost of these various support schemes. These costs are likely to rise significantly as the level of renewable energy increases in future. Most are borne by energy consumers, rather than by taxpayers. Renewable generators receive around £1¼ billion a year from increased electricity prices caused by the Renewables Obligation, Emissions Trading Scheme and Climate Change Levy, mostly from consumers. Taxpayers fund the Research Councils, £30 million a year on renewable energy research, and the Environmental Transformation Fund, about £130 million a year on grants to renewable generators and farmers growing energy crops. The amount that the Energy Technologies Institute (part-funded by taxpayers) will spend on renewable energy has not yet been announced; nor the proportion of the Carbon Emissions Reduction Target that will be spent on microgeneration. The total support for renewable generation, from taxpayers and from energy consumers, is now of the order of £1.4 billion a year.
196. We can only estimate the cost of support for renewable transport fuels. In 2007, the duty rebate on biofuels cost the taxpayer £100 million, but these comprised only about 1% of road transport fuel. In the first three months of the obligation, biofuels provided 2.6% of road transport fuels, and the annualised cost would have been correspondingly higher. Since fuel suppliers have chosen to meet the target for biofuels, this must imply that the cost of doing so (net of the rebate) is less than the buy-out price of 15 pence per litre. The change in the cost (and hence price) of fuel will be between zero and £200 million in 2008/9.

TABLE 6

Support for renewable energy

Scheme	Description	Cost	Paid by
Renewables Obligation	Electricity suppliers must buy a proportion of their sales from renewable generators, or pay a buy-out charge	£874 million in 2007/8 ^a	Electricity consumers
EU Emissions Trading Scheme	Renewable generators indirectly benefit from the increase in electricity prices as other companies pass the cost of emissions permits into the price of power	Perhaps £300 million in 2008, given current permit prices ^b	Electricity consumers
Carbon Emissions Reduction Target	Energy companies must install low-carbon items in homes, which could include microgeneration from 2008	Total cost will be £1.5 billion over 3 years—most spent on energy efficiency	Gas and electricity consumers

Scheme	Description	Cost	Paid by
Renewable Transport Fuel Obligation	Fuel suppliers must supply a proportion of biofuels or pay a buy-out charge	No more than £200 million in 2008/9 ^c	Consumers
Climate Change Levy	Electricity suppliers need not pay this tax (passed on to non-domestic consumers) on electricity from renewable generators	£68 million to UK generators; £30 million to generators abroad in 2007/8	Taxpayers, via reduced revenues
Lower fuel duty for biofuels	The rate of fuel duty is 20 pence per litre below that for petrol and diesel	£100 million in 2007	Taxpayers, via reduced revenues
Environmental Transformation Fund	Grants for technology development and deployment, including subsidies for installing renewable generation, planting energy crops and developing biomass infrastructure.	£400 million over three years from 2008/9	Taxpayers
Research Councils	Grants for basic science research	£30 million in 2007/8	Taxpayers
Energy Technologies Institute	Grants to accelerate development (after the basic science is known) of renewables and other energy technologies	Allocation (and eventual size) of budget not yet announced.	Taxpayers and sponsoring companies

a This is the buy-out price multiplied by the size of the obligation. Source: Ofgem

b Permit prices are currently about £19/tonne CO₂, and coal-fired generators are normally setting the electricity price, passing 0.9 kg per kWh through to consumers

c This upper limit is set by the buy-out price of 15p per litre—if the extra cost of biofuels (net of the fuel duty rebate) is more than this, companies will opt for the buy-out instead.

Micro generation

197. Witnesses' views on micro generation of energy by households and businesses varied. For micro-generated electricity, the Renewable Energy Foundation said: "We see the costs as astonishingly high and the gains as very modest." As a result the organisation felt that any policies requiring a certain amount of micro-generated electricity would "only drive in sub-optimal technologies at enormous expense" (Renewable Energy Foundation p 45).
198. The Government supports micro-generation for reasons other than economics. Former energy minister Malcolm Wicks said: "If we were just focusing on the economics, we probably would not want to look seriously at micro-generation [but] many concerned citizens are asking how they can personally make a difference" (Q 503). **We are not persuaded that the wish of concerned citizens to make their own contribution to emissions reduction is an adequate justification for a public subsidy to micro-generation.**

199. Energywatch accepted that micro-generation had “a high cost for a modest contribution to fuel saving and emissions reduction” (p 294), but supports the introduction of a feed-in tariff for small scale renewables as it could attract new investment, change the balance between consumers and energy companies, stimulate energy-reducing behavioural changes and alleviate fuel poverty. This last benefit was contingent on mechanisms such as installation subsidies to ensure that low-income consumers could benefit from the technologies, particularly in hard-to-treat properties (pp 294–297).
200. While Professor MacKerron described micro-wind generation for individual urban households as a “dead duck” he argued there was potential for the micro-generation of electricity for blocks of flats. He called for improvements to the grid and distribution system to enable the sale of micro-generated electricity. The grid was originally designed to carry electricity from large power plants to homes and businesses. But the system needs to be adjusted to be able to take more easily micro-generated power **from** households and businesses as well, said Professor MacKerron (QQ 254–255).
201. When people approach the power suppliers they find themselves “bogged down in a set of tariffs [that]require a PhD and an awful lot of time to work out which of the suppliers is offering you the best deal”, according to Stephen Smith, managing director of networks at Ofgem. The regulator is working with the industry to simplify the arrangements for micro generation. It argued micro generators needed a one-stop shop to provide advice and suggested that the Government should fund an existing price comparison web site to do this (Ofgem QQ 448–449).
202. While the economics of micro-generated electricity appear dubious, especially at the individual household level, the potential for the micro-generation of heat is much greater. Much of the technology for generating renewable heat is at the household level. As was shown in Chapter 5, the cost of renewably generated heat is relatively cheap compared to electricity, and it avoids the problems of intermittency.
203. The Renewable Energy Foundation—which was very sceptical about micro-generated electricity—argued in favour of measures to boost micro-generated heat. While they argued that the sector would not need much help Campbell Dunford, chief executive, said: “We believe that measures to encourage the take-up of heat saving and heat generation measures within the household are fundamentally good” (p 52, Q 133).
204. **The returns from micro-generated electricity look too small and uneconomic for the Government to support. But the gains from households using micro-generated heat look much more promising. Government policy should focus instead on households generating renewable heat and on schemes that use renewable heat on a larger scale, such as those covering a housing development, or group of public buildings.**

Fuel bills

205. The Committee are very conscious of the high cost of energy—driven mainly by the record oil prices reached this year—and its impact on the heat and electricity bills of households and businesses. Support for renewable energy increases costs further. Alistair Buchanan, chief executive of Ofgem, said: “One of the features of the renewables strategy is that of a £1,000 bill

currently for the average household, £80 is environmental connected” (Q 413).

206. Energywatch estimate that the current Renewables Obligation—which is only one of the support mechanisms for renewables—will cost households an extra £33 a year by 2020. But this is based on the scheme only delivering 20% of electricity from renewables. If the EU targets are to be met, with relatively small contributions from heat and transport, many expect 30–40% of electricity to have to come from renewables with greater costs to consumers.⁵⁹ With this in mind, Energywatch called for measures to help low-income households deal with the likely extra costs (Energywatch p 290).
207. The Church of England’s House of Bishops Europe Panel were concerned that higher energy prices arising from renewable energy would lead to more people facing fuel poverty⁶⁰ (p 349). Alistair Buchanan, chief executive of Ofgem, told us that for every 1% increase in power prices 40,000 people were added to the fuel poor lists (Q 413). Given that he had calculated that environmental measures were raising prices by 8%, this would place an extra 320,000 people in fuel poverty.
208. **On the evidence submitted to us, renewable electricity is clearly more expensive than fossil fuel-fired and nuclear generation and leads to higher energy bills for consumers and businesses. We estimate that a household which consumes the average amount of electricity will have to pay in 2020 about £80 extra a year. The Government will need to take this on board in framing its policies towards fuel poverty, noting the high correlation between fuel poverty and poorly-insulated homes.**

Support for the development of renewable energy technology

209. The then Minister told us that the Government believed renewable energy could create thousands of business and employment opportunities, and that the Government was committed to ensuring that many of these jobs were created in the UK (Q 472).
210. The IEA told us that the costs of Danish wind power were amongst the lowest they had looked at, because learning by doing had brought the cost down. Denmark’s strategic decision 20 years ago to develop wind energy meant that their wind turbine manufacturing industry was now a world leader (QQ 394–398). China was by far the leading country in thermal solar

⁵⁹ We set out the additional costs of renewable electricity in Chapter 4. The Renewables Obligation exists so that renewable generators can recover the difference between their base costs and prices in the electricity wholesale market. In Appendix 9, we estimate that the Renewables Obligation, or equivalent schemes, will cost an average household £50–£60 a year in 2020. Higher charges from National Grid for transmission and system operation, to cover the cost of integrating renewable generators, will cost an average household £30 a year. This does not include the benefits renewable generators get from not having to buy carbon permits. Renewable generation will have little impact on the amount by which emissions trading raises the price of power, since this works by changing the prices charged by coal- and gas-fired generators. As long as the number of permits available is adjusted to reflect the amount of renewable output, renewable generation will not affect these prices. Electricity bills also cover the existing distribution and retailers’ costs—these would be hardly affected by the growth of renewable generation. For an average household electricity bill of £400 an extra £80 represents a 20% increase—smaller than the 38% increase in the cost of producing the electricity.

⁶⁰ Fuel poverty is defined at the household level as needing to spend more than ten per cent of income (after tax and benefits) on heating and lighting to achieve an acceptable standard of comfort.

heating for domestic water, developing a huge industry and a low-cost technology with millions of installed systems (Q 408).

211. The ETI saw an opportunity to use the UK to demonstrate technological and engineering developments and sell capability worldwide (Q 326). The UK also had the potential to develop a renewable power industry: Vestas Wind Turbines, on the Isle of Wight, sells every turbine blade it produces to the United States (Q 330).
212. It would help the UK meet the EU renewable target if the supply chain for renewable energy were to be developed. But this is unlikely to lead to an overall increase in employment, as the number of jobs in the UK depends on conditions in the economy as a whole. People who might gain jobs in renewable energy would normally have been able to work in a different sector, possibly more productively,⁶¹ had renewable energy not been expanded.
213. The Committee heard that a much greater research and development effort is needed on renewables and other measures to cut carbon emissions. Professor Paul Ekins of King's College London argued for the equivalent of twin Manhattan projects—the scientific research programme which developed the atomic bomb. One would enhance energy efficiency, the other promote energy supply technologies including renewables. In his view, countries need to work together on this research. He said: “It is terribly important that we get globally the biggest bang for our buck and have properly coordinated basic scientific research.” (Q 16). We draw attention (Paragraph 117) to the need for a greater research effort on electricity storage. We heard of research in areas ranging from floating marine turbines to solar thermal arrays in deserts. A substantial annual prize for research for the best technological contribution to renewable energy development, as recommended in paragraph 93, would symbolise the importance of applied research in the field. **We call on the Government to look afresh at the UK's research effort into renewables and to consider what more might be done, in a global context, to promote more, and more focussed, research across a range of technologies leading to new, effective and economical ways to reduce carbon emissions.**

Renewable energy in the Planning system

214. Many generators complain about delays in obtaining planning approval, leading to delays in the deployment of renewable generators. A lower level of capacity than expected means that the payments via the Renewables Obligation are spread across a lower level of generation, increasing the support cost per kWh.
215. Scottish and Southern described the planning system as “not fit for purpose” (p 88). A new onshore wind farm could require around 2–3 years of preparatory work, and the planning process could take up to 5 years, followed by a further 1–2 years of construction. Building new transmission infrastructure could in parallel take 3–4 years preparation, plus 2–4 years to construct, and again up to 5 years in planning. Centrica added that around 8 GW of renewable developments are held up in the planning system—the equivalent of 10% of total existing generation capacity (p 97).

⁶¹ Prima facie, subsidised employment will be less productive than unsubsidised.

216. National Grid saw planning delays as the most significant obstacle to the timely connection of projects and the development of network capacity. Of contracted wind projects in Scotland, only 17% have planning consents. Across Great Britain, only 23% have consents. National Grid supports reform of the planning regime and in particular the Government's proposals to provide for greater certainty in reaching decisions. Scottish and Southern Energy told us that they did not expect every planning decision to be a yes, but they wanted "quick 'yeses' and quick 'nos'". The Renewable Energy Systems said of the planning system: "It is time-consuming and unpredictable, making it a lottery for developers large and small" (Scottish and Southern Energy p 88, Q 229, National Grid p 129, Renewable Energy Systems p 433).
217. But many individuals and community groups felt their views were being ignored, as outlined in Chapter 3. They argued that the planning process did not take account of the effect of wind farm developments on surrounding properties, the landscape and the effects on quality of life through constant low level noise (Two Moors Campaign p 491, John Muir Trust p 382, Barker p 230, Hadden p 325).
218. The Government meanwhile aims to streamline planning processes for major infrastructure projects including energy, establishing a new Infrastructure Planning Commission (IPC). Its remit would cover only onshore wind farms generating more than 50 MW, in England and Wales, so that, in the view of Renewable Energy Systems (p 434) "only 300MW out of the 8000MW of capacity currently in the planning system is affected and not until after 2010".
219. Law firm Lawrence Graham argued that too many obstacles were being put in the way of smaller offshore renewable energy projects, which will be not be handled by the IPC but, amongst others, the proposed Marine Management Organisation "The MMO will have wide-ranging responsibilities, not just in relation to licensing but also nature conservation, spatial planning and enforcement, and concerns have already been expressed as to whether it will also have the resources necessary to handle applications for the more complex developments in any sector. Any perception that as a result the operators of smaller offshore projects may be subject to a less favourable consenting process is likely to make it harder for them to raise capital and may well discourage innovation and more experimental developments offshore" (Lawrence Graham p 397).
220. **We recognise that power companies need a streamlined planning system to approve or reject projects more quickly.** Otherwise the Government's targets for renewable (or, indeed, conventional) energy will be more difficult to meet. **But local and national concerns about environmental degradation must also be addressed and we have received much evidence that this may not be the case at present. It is important to ensure that the planning system adequately assesses the costs to local communities and the balance between national priorities and local decision-making. The Government should also examine how far local communities share in the economic benefits created by wind farm deployment and other renewable projects.**

The 15% target

221. The former Minister of State told us the Government was committed to achieving the 15% target and the resultant ten-fold increase in renewable energy use. It would however be hugely challenging, a view shared by most other witnesses. The Government favoured some trading within the EU if it would bring down the cost to consumers. In particular, the former Minister told us that the last percentage point of renewable energy, needed to raise its share in the UK from 14% to 15% “would probably be the most expensive point to achieve.” But in the former Minister’s view the target could still be achieved without trading (Q 492). Much may depend on the outcome of negotiations in the EU; there was substantial disagreement over individual national targets at the October European Council.
222. Professor MacKerron thought it was possible but unlikely the target would be achieved, If it were met, it would be at high cost as we would have to build renewable generators at less and less favourable locations (Q 265). Dr David Clarke of the ETI cited the Renewables Advisory Board which believes it is nearly achievable (Q 333).
223. BP saw a risk that because the time scale for the targets was short, investment would be skewed to technologies that worked today as opposed to those which might be right for the longer term (Q 360) Malcolm Keay suggested the pressure to meet the EU target led to too much emphasis now on increasing the quantity of renewable projects at the expense of all other factors and interests involved. He said: “the problem with renewables now is that it is based very much on just getting a certain quantity of renewables built rather than thinking about the ultimate objectives which include reducing carbon emissions but also include preserving local landscapes, amenities and many other things” (Q 101). He thought that “an approach more focused on actual technology development rather than just building arbitrary quantities of renewables might be more effective” (Q 104).
224. A number of witnesses thought the target was impossible to achieve. Mr Keay pointed out that “every single renewables target ever in the UK has been missed and by quite a long way” (Q 82). Professor Helm’s view is that “we should have a credible [renewables target] that there is a reasonable prospect that we can achieve” (Q 184). He believed that the government had a policy of providing leadership, and had set a policy of reducing carbon dioxide emissions by 20% between 1990 and 2010. The intention was to demonstrate that, through renewable energy and energy efficiency, this could be done at an extremely low cost, so that other countries would be willing to sign up to Kyoto. In practice, he believed that we had demonstrated that we were unable to achieve the objective, that what we have achieved has been at extremely high cost, and this has not been persuasive. Professor Helm agreed that “we should show leadership and ... adopt a tight set of carbon targets, but what I think is most important is that we do not go around wishfully promising that we are going to achieve this renewables target or that particular CO₂ target in a way that is just not credible” (Q 183).
225. **We endorse the Government’s objective of ensuring a secure, reliable and affordable supply of energy.**
226. **The Government is right in stating that a portfolio of policies is needed to achieve this objective, if we are also to bring about reduced carbon emissions.** Renewable energy has a part to play, as does nuclear

power, the only other currently existing source of low-carbon energy. Investment in conventional power (preferably equipped with CCS, if and when it becomes available) will also be needed, together with improvements in energy efficiency. **Against a background of developing technologies and uncertain costs, the Government will need to give a firm lead, with clear priorities and realistic objectives, while maintaining the stable framework needed by investors in the context of the long lead times needed by many energy projects.**

227. The main plank of Government policy on renewables is the proposed target of a 15% share of total energy by 2020, most of which is expected to be met by increasing to 30–40% the share of renewables in electricity generation, with most of that coming from wind power, onshore and later offshore. Witnesses' views of the target ranged from challenging to unattainable. The Government is however committed to achieving it and estimates that £100bn of private investment will be needed by 2020. Most, if not all of the cost is to be passed on to the consumer.
228. **We recognise that the Government has committed the UK to contribute to the EU target of 20% renewable energy by 2020 and that a target of 15% for this country is envisaged. But the bulk of the evidence presented to us casts doubt whether, under current policies and with current resources, it will be feasible to increase the share of renewable energy so much in the UK over the time available. This is especially so, as most of the growth is expected to occur in power generation, which represents only a fifth of the UK's energy use, and that this growth will be largely in addition to the substantial replacement programme of old conventional and nuclear plant that has to take place over the same time period.** The UK has a track record of missing its targets in this area and, although meeting this one would mark a step change in the use of renewable energy, failure to meet it would negate the effect of setting and achieving realistic targets and reduce the UK's credibility still further.
229. **We are also concerned that determination to meet the target may lead to an over-emphasis on promoting short-term options, simply because they are available, rather than because they offer the most effective and economical means of reducing carbon dioxide emissions over the longer term.** For example, as we have mentioned earlier in this Report (Chapter 5) the Government should lay at least as much emphasis on the opportunities for renewable heat as on power generation.
230. **We have a particular concern over the prospective role of wind generated and other intermittent sources of electricity in the UK, in the absence of a break-through in electricity storage technology or the integration of the UK grid with that of continental Europe. Wind generation offers the most readily available short-term enhancement in renewable electricity and its base cost is relatively cheap. Yet the evidence presented to us implies that the *full* costs of wind generation (allowing for intermittency, back-up conventional plant and grid connection), although declining over time, remain significantly higher than those of conventional or nuclear generation (even before allowing for support costs and the environmental impacts of wind farms). Furthermore, the evidence suggests that the capacity credit of wind power (its probable power output at the time of need) is very**

low; so it cannot be relied upon to meet peak demand. Thus wind generation needs to be viewed largely as additional capacity to that which will need to be provided, in any event, by more reliable means.

231. We consider that the Government, if it pursues a renewable energy target in addition to its targets for reducing carbon dioxide emissions across the board, should prioritise the development and promotion of the other effective and economic options, both to bring down carbon dioxide emissions and to achieve security of electricity supply. In that regard it will be important to ensure that incentives to promote those renewables which offer only intermittent supply do not divert attention from, and deter investment in, other low-carbon generation options and thereby risk power shortages. So far as reliability is concerned, the best options among renewable sources of generation are tidal barrage and biomass, which are problematic for other reasons, and hydro-power, which is not, but is already near the limit of its potential in the UK. The most reliable low-carbon alternative to renewables is nuclear power (together with conventional fossil fuel generation with carbon capture and storage, if and when that becomes available).

CHAPTER 7: RECOMMENDATIONS AND CONCLUSIONS

232. We cannot consider renewable energy in isolation from the rest of the UK energy system and we support measures to include nuclear plants as an essential element of the UK's energy mix (paragraph 74).
233. The cost of electricity from onshore wind farms at good locations would only be comparable with that from fossil fuel generators when the prices of oil, gas and coal are very high or allowance is made for the price imposed for carbon emissions permits (effectively a tax). It is more expensive than nuclear generated power—base cost 7 pence per kWh, as opposed to around 4 pence per kWh for the other technologies. Offshore wind, biomass, wave and tidal power are even more expensive. And these estimates exclude the additional costs of integrating more renewable generation into Britain's electricity grid (paragraph 74).
234. Future developments depend upon many variable factors But it seems clear that the base costs of generation of electricity from onshore wind are likely to remain considerably higher than those of fossil or nuclear generation and that costs of generation of marine or solar renewable electricity are higher still (paragraph 85). We hope that the Energy Technologies Institute's work will yield technological advance and lower costs. The Government should consider, perhaps in collaboration with others, offering a substantial annual prize for the best technological contribution to renewable energy development (paragraph 93).
235. Although their declared purpose is to improve the environment, it is clear that renewable energy installations can also have adverse environmental impacts which the Government should bear in mind as it weighs the benefits and costs of expansion of renewable generation (paragraph 96).
236. Fluctuations in wind speed lead to short term changes in electricity output from wind farms. Greater use of wind power and other intermittent renewable sources therefore requires more backup generation capacity to respond very quickly to, for example, reductions in the output of wind turbines when the wind drops. But the technical challenges and costs of backup generation on a scale large enough to balance an electricity system with a high proportion of intermittent renewable generation are still uncertain. Whereas the highest share of intermittent renewable electricity now being generated in Europe is 15% in Denmark, the UK is expected to reach a share of some 30%–40%. We recommend that the Government should ensure that further work is carried out to clarify the costs and encourage development of technical solutions to deal with intermittency (paragraph 104).
237. The need to part-load conventional plant to balance the fluctuations in wind output does not have a significant impact on the net carbon savings from wind generation (paragraph 105).
238. If some 30 GW of additional (Ev Q 487) renewable capacity were required to meet the EU's 2020 target for the UK a further 14–19 GW of new fossil fuel and nuclear capacity will still be needed to replace plants due to close and meet new demand. The total new installed electricity generating capacity required by 2020 would thus be roughly double the level needed if renewable generation were not expanded (paragraph 111). Investment in renewable generation capacity will therefore largely be in addition to, rather than a

replacement for, the massive investment in fossil-fuel and nuclear plant required to replace the many power stations scheduled for closure by 2020. The scale and urgency of the investment required is formidable, as is the cost (paragraph 112).

239. A breakthrough in cost-effective electricity storage technology would help solve the problem of intermittency and remove a major stumbling block to wider use of renewable energy in the longer term. However, no evidence we received persuaded us that advances in storage technology would become available in time materially to affect the UK's generating requirements up to 2020. We recommend that the Government should as a matter of urgency encourage more research, development and demonstration in energy storage technologies (paragraph 117).
240. Our calculations suggest that the total extra annual cost of increasing the share of renewables in electricity generation from 6% to 34% in 2020 would be £6.8 billion or an extra 38%—the equivalent of an extra £80 a year for the average household. Emissions of carbon dioxide would be reduced by 52 million tonnes a year—in 2007, the UK's emissions were 544 million tonnes. This implies that the additional cost is about £130 per tonne of carbon dioxide emissions avoided (paragraph 128).
241. Ofgem is required to use competition wherever appropriate. We are concerned that the use of competitive tenders implies a piecemeal approach to building the networks of wires and cables required to connect offshore wind farms to the electricity grid, and that as a result the programme could become overly complex and costly. We recommend that Ofgem implements the new system in a way that allows a coordinated approach for organising grid connections to offshore wind farms (paragraph 131).
242. We welcome measures to organise better the queue of renewable generation projects awaiting connection to the electricity grid. They should reduce delays in connecting viable generation projects and push back schemes unlikely to get off the ground (paragraph 134).
243. We consider that the current system of Transmission Use of System charges sends broadly appropriate signals of the costs of locating generators at different points on the system (paragraph 139).
244. Greater interconnector capacity with the Continent would reduce, but not solve, the problems of intermittent renewable generation (paragraph 141).
245. Harnessing renewable sources of heat is often cheaper than for electricity generation and offers a larger target area, as heat accounts for double the final energy demand of electricity. There is no intermittency problem with renewable heat. We recommend that the Government should lay at least as much emphasis on encouraging the development and use of renewable heat as on renewable electricity generation (paragraph 163).
246. We share the concerns raised in the Gallagher Review about existing biofuels. Steps should be taken towards developing second generation bio-fuels as soon as possible. Until the costs of carbon emissions reduction through biofuels come down we recommend that the Government should not seek to increase further the use of biofuels (paragraph 173).
247. It is clear that, although the cost of the technology for carbon capture and storage (if and when it becomes a practical possibility) is inevitably highly

speculative, it will always be more expensive than large-scale carbon-based energy without CCS (paragraph 177).

248. It seems clear there would be little investment in renewable energy without substantial Government support and that a 15% target would not be met without it (paragraph 183).
249. We note the evidence that the cost per kWh of renewable electricity supported by the Renewables Obligation has been significantly higher than the amounts paid via feed-in tariffs abroad, and that much of the excess has been due to other differences in the environment for renewable generation, particularly in the planning system. However, given investors' need for a predictable framework, it seems right to retain the Renewables Obligation, if it is desired to continue increasing generation of electricity from renewable sources (paragraph 189).
250. We are not persuaded that the wish of concerned citizens to make their own contribution to emissions reduction is an adequate justification for a public subsidy for micro-generation (paragraph 198).
251. The returns from micro-generated electricity look too small and uneconomic for the Government to support. But the gains from households using micro-generated heat look much more promising. Government policy should focus instead on households generating renewable heat and on schemes that use renewable heat on a larger scale, such as those covering a housing development, or group of public buildings (paragraph 204).
252. On the evidence submitted to us, renewable electricity is clearly more expensive than fossil fuel-fired and nuclear generation and leads to higher energy bills for consumers and businesses. We estimate that a household which consumes the average amount of electricity will have to pay in 2020 about £80 extra a year. The Government will need to take higher costs on board in framing its policies towards fuel poverty, noting the high correlation between fuel poverty and poorly-insulated homes (paragraph 208).
253. We call on the Government to look afresh at the UK's research effort into renewables and to consider what more might be done, in a global context, to promote more, and more focussed, research across a range of technologies leading to new, effective and economical ways to reduce carbon emissions (paragraph 213).
254. We recognise that power companies need a streamlined planning system to approve or reject projects more quickly. But local and national concerns about environmental degradation must also be addressed. It is important to ensure that the planning system adequately assesses the costs to local communities and the balance between national priorities and local decision-making. The Government should also examine how far local communities share in the economic benefits created by wind farm deployment and other renewable projects (paragraph 220).
255. We endorse the Government's objective of ensuring a secure, reliable and affordable supply of energy (paragraph 225).
256. The Government is right in stating that a portfolio of policies is needed to achieve this objective, if we are also to bring about reduced carbon emissions. Against a background of developing technologies and uncertain costs, the Government will need to give a firm lead, with clear priorities and realistic objectives, while maintaining the stable framework needed by investors in the

context of the long lead times needed by many energy projects (paragraph 226).

257. We recognise that the Government has committed the UK to contribute to the EU target of 20% renewable energy by 2020 and that a target of 15% for this country is envisaged. But the bulk of the evidence presented to us casts doubt whether, under current policies and with current resources, it will be feasible to increase the share of renewable energy so much in the UK over the time available. This is especially so, as most of the growth is expected to occur in power generation, which represents only a fifth of the UK's energy use, and that this growth will be largely in addition to the substantial replacement programme of old conventional and nuclear plant that has to take place over the same time period (paragraph 228).
258. We are also concerned that determination to meet the target may lead to an over-emphasis on promoting short-term options, simply because they are available, rather than because they offer the most effective and economical means of reducing carbon dioxide emissions over the longer term (paragraph 229).
259. We have a particular concern over the prospective role of wind generated and other intermittent sources of electricity in the UK, in the absence of a breakthrough in electricity storage technology or the integration of the UK grid with that of continental Europe. Wind generation offers the most readily available short-term enhancement in renewable electricity and its base cost is relatively cheap. Yet the evidence presented to us implies that the **full** costs of wind generation (allowing for intermittency, back-up conventional plant and grid connection), although declining over time, remain significantly higher than those of conventional or nuclear generation (even before allowing for support costs and the environmental impacts of wind farms). Furthermore, the evidence suggests that the capacity credit of wind power (its probable power output at the time of need) is very low; so it cannot be relied upon to meet peak demand. Thus wind generation needs to be viewed largely as additional capacity to that which will need to be provided, in any event, by more reliable means (paragraph 230).
260. We consider that the Government, if it pursues a renewable energy target in addition to its targets for reducing carbon dioxide emissions across the board, should prioritise the development and promotion of the other effective and economic options, both to bring down carbon dioxide emissions and to achieve security of electricity supply. It will be important to ensure that incentives to promote those renewables which offer only intermittent supply do not divert attention from, and deter investment in, other low-carbon generation options and thereby risk power shortages. So far as reliability is concerned, the best options amongst renewable sources of generation are tidal barrage and biomass, which are problematic for other reasons, and hydro power, which is not, but is already near the limit of its potential in the UK. The most reliable low-carbon alternative to renewables is nuclear power (together with conventional fossil fuel generation with carbon capture and storage, if and when that becomes available) (paragraph 231).

APPENDIX 1: ECONOMIC AFFAIRS COMMITTEE

The members of the Select Committee which conducted this inquiry were:

Lord Best
Lord Griffiths of Fforestfach
Baroness Hamwee
Lord Kingsdown
Lord Lamont of Lerwick
Lord Lawson of Blaby
Lord Layard
Lord Macdonald of Tradeston
Lord MacGregor of Pulham Market
Lord Moonie
Lord Paul
Lord Turner of Ecchinswell*
Lord Vallance of Tummel

* Lord Turner has not taken part in the work of the Committee since July 2008.

Professor Richard Green, Director, Institute for Energy Research and Policy, University of Birmingham, was the Committee's Specialist Adviser.

Declaration of Interests

Full lists of Members' interests are recorded in the Lords Register of Interests. Details can be found at the following web address:

<http://www.publications.parliament.uk/pa/ld/ldreg.htm>

APPENDIX 2: LIST OF WITNESSES

The following witnesses gave evidence. Those marked * gave oral evidence.

- * BP
- * Professor AbuBakr Bahaj, Southampton University
 - Mr Andrew Bain
 - Ms Carolyn Barker
 - Mr Derek Birkett
 - Bishopton Village Hall Management Committee
 - Mr Philip Bratby
- * Professor Tony Bridgwater, Aston University
 - British Energy
 - British Hydropower Association
- * British Wind Energy Association
 - Campaign for Responsible Energy and Development in Tynedale
 - Campaign to Protect Rural England, Devon
 - Campaign to Protect Rural England, Durham
 - Carbon Capture and Storage Association (CCSA)
 - Maureen and Peter Caswell
- * Centrica
 - Christofferson Robb and Company
- * Climate Change Capital
 - Jane and Julian Davis
- * Department for Business Enterprise and Regulatory Reform: Malcolm Wicks, a Member of the House of Commons, Minister of State for Energy, Mr Simon Virley, Head of the Renewable Energy and Innovation Unit, and Ms Tera Allas, Chief Economist Energy Group
- * E.ON UK
 - EDF Energy
 - EEF
- * Professor Paul Ekins, King's College London
 - Energy Networks Association
- * Energy Technologies Institute
 - Energy Technology for Sustainable Development Group
 - Energywatch
 - Environmental Defense Fund
 - Environmental Industries Commission
 - Environmental Research Institute

- Dr John Etherington
- * Falck Renewables Limited
- Mrs Barbara J Frey
- * Friends of the Earth
- Genersys plc
- Mr Colin Gibson
- Christiane Golling and Marco Nicolosi, Institute of Energy Economics,
Cologne
- * Greenpeace
- Grünhaus Project, Liverpool
- Mr Peter Hadden
- J.H.R. Hampson
- * Professor Dieter Helm, Oxford University
- Highlands Against Wind Farms
- Highlands Before Pylons
- Rear Admiral Robin Hogg and Professor Leslie Bradbury
- Mr Robert Horler
- House of Bishops' Europe Panel, Church of England
- W.J. Hyde
- Institute of Physics
- Institution of Engineering and Technology (IET)
- Institution of Mechanical Engineers
- International Energy Agency
- Mrs Delia Jack
- Professor Michael Jefferson
- Professor Nick Jelley
- John Muir Trust
- * Mr Malcolm Keay, Senior Research Fellow, Oxford Institute for Energy
Studies
- Mr Neil Kermode
- Professor Michael Laughton
- Lawrence Graham LLP
- Dr and Mrs J Lyne
- Dr Rayner Mayer and Dr Roger Bentley
- Sir Donald Miller
- Mynydd Llansadrwn Action Group
- * National Grid
- Natural England

- Mr Michael Negus
- * Dr Karsten Neuhoff, University of Cambridge
 - * Professor David Newbery, Cambridge University
 - * Ofgem
- Mrs N Penk, Mr C Penk and Mr DPC Penk, Pitfield Farm
- Richard Phillips
- Renewable Energy Association
- * Renewable Energy Foundation
- Renewable Energy Finance-Policy Project, Chatham House
- RES UK & Ireland Ltd
- Research Councils UK (RCUK)
- Royal Academy of Engineering
- Royal Society of Edinburgh
- Scientists for Global Responsibility
- * Scottish and Southern Energy plc
- Scottish Power Ltd
- Scottish Sustainable Energy Foundation
- Mr Alan L. Shaw
- * Shell UK
- Professor Peter Smith
- Mr Paul Spare
- * Dr Neil Strachan, King's College London
- Town and Country Planning Association
- Two Moors Campaign
- * Dr Simon Watson, Loughborough University
- Wavegen
- Revd John Wylum

APPENDIX 3: CALL FOR EVIDENCE

The Economic Affairs Committee has decided to conduct an inquiry into ‘The Economics of Renewable Energy’.

Evidence is invited by 16 June 2008. The Committee will welcome written submissions on any or all of the issues set out below.

Amid concerns over climate change the Government aims to increase the use of renewable energy sources, such as wind, tidal, biomass, biofuels and solar power, alongside other measures to reduce greenhouse gas emissions such as promoting greater energy efficiency.

Under EU targets, 15% of energy consumed in the UK should come from renewable sources by 2020. Yet Government figures show only 1.8% of Britain’s energy came from renewables in 2006. Electricity generation, as opposed to heating and transport, is widely thought to have the most potential for greater use of renewable sources. But while the share of renewables in electricity generation has been growing, it was still only 4.5% in 2006.

This inquiry aims to set out the costs and benefits of renewable energy and establish how they compare with other sources of energy. It will also examine the Government’s policy towards renewable energy.

Among the issues being examined in the inquiry are:

- (1) How do and should renewables fit into Britain’s overall energy policy? How does the UK’s policy compare with the United States, Australia, Canada, and other EU countries?
- (2) What are the barriers to greater deployment of renewable energy? Are there technical limits to the amount of renewable energy that the UK can absorb?
- (3) Are there likely to be technological advances that would make renewable energy cheaper and viable without Government support in the future? Should, and how could, policy be designed to promote such technological advances?
- (4) Has Government support been effective in leading to more renewable energy? What have been the most cost-effective forms of support in the UK and other countries and what should the balance be between subsidies, guaranteed prices, quotas, carbon taxes and other forms of support? Should such support favour any particular form of renewable energy over the others? For instance, what are the relative merits of feed-in tariffs versus the UK’s present Renewables Obligation Certificate (ROC) regime?
- (5) On top of the costs of building and running the different types of electricity generators, how much investment in Britain’s transmission and distribution networks will different renewable energy sources require compared to other forms of generation? Are the current transmission and distribution systems capable of managing a large share of intermittent renewable electricity generation and, if not, how should they be changed? Are the rules about how we connect capacity to the grid supportive of renewables?
- (6) How do the external costs of renewable generation of electricity—such as concerns in many affected rural areas that wind farms and extra pylons

spoil areas of natural beauty—compare with those of fossil fuels and nuclear power? How should these be measured and compared? Is the planning system striking the right balance between all the different considerations?

- (7) How do the costs of generating electricity from renewables compare to fossil fuel and nuclear generation? What are the current estimates for the costs of “greener” fossil fuel generation with carbon capture and storage and how do these costs compare to renewable generation? What impact do these various forms of electricity generation have on carbon emissions?
- (8) How do the costs and benefits of renewable electricity generation compare to renewables in the other key forms of energy consumption—transport and heating?
- (9) If the UK is to meet the EU target that by 2020 15% of energy consumed will come from renewables, will most of this come from greater use of renewable sources in electricity generation? If so, why? Should British support for renewables in other countries be allowed to contribute towards meeting the target for the UK?
- (10) How would changes in the cost of carbon—under the European emissions trading scheme—affect the relative costs of renewables and other sources of energy? Would a more effective carbon emissions trading scheme remove the need for special support of renewable energy?
- (11) What are the costs and benefits of the present generation of biofuels? Will there be a second generation of biofuels and, if so, what are the estimated costs? What are, or are likely to be, the carbon emission impacts of first and second generation biofuels, and what are the other relevant environmental effects?

APPENDIX 4: CURRENT STATUS, FUTURE PROSPECTS AND ACTIONS ON RENEWABLE TECHNOLOGIES IN THE UK

Where are we?	What can be achieved?	What is holding it back?	What needs to be done?
<p>ON-SHORE WIND POWER</p> <p>Technology is mature and economical with current policies in utility scale application.</p> <p>Not really effective in small scale application.</p> <p>Very large projects will have significant visual impact in UK landscape</p>	<p>Gradual expansion of capacity (over 15GW of potential wind capacity has been applied for in Scotland alone).</p>	<p>Objections under planning regime.</p> <p>Transmission grid capacity.</p> <p>Increasing costs due to global competition for raw materials and equipment.</p> <p>Concerns about managing variability for increased wind capacity.</p>	<p>R, D&D into active grid management.</p>
<p>OFF-SHORE WIND POWER</p> <p>Fundamental technology is mature but uneconomic under current policies.</p> <p>Deployment offshore will continue to bring technological and operational challenges.</p>	<p>Potential for large scale development.</p>	<p>High capital cost—increasing due to global competition for raw materials and equipment.</p> <p>Transmission grid capacity.</p> <p>Transmission/distribution grid expansion.</p> <p>Concerns about managing variability for increased wind capacity.</p>	<p>May be favoured under reformed (banded) Renewables Obligation.</p> <p>R, D&D into active grid management.</p>
<p>HYDROELECTRIC POWER</p> <p>Mature technology.</p>	<p>Around 1000 MW of future potential in UK, vast remaining potential worldwide</p>		
<p>TIDAL POWER</p> <p>Several technologies exist in prototype, in need of full-scale demonstration and commercialisation.</p> <p>About 10–15 years from full commercialisation, and uncertainties over cost competitiveness.</p>	<p>Sizeable natural resource to be exploited in UK.</p> <p>Potential for technology export.</p>	<p>Risk/cost of demonstration.</p> <p>High initial costs and extended operating lifetimes.</p>	<p>Demonstration support.</p> <p>Development of standards.</p>

Where are we?	What can be achieved?	What is holding it back?	What needs to be done?
<p>WAVE POWER</p> <p>Several technologies exist in prototype—all inevitably large with high embedded energy and uncertain maintenance and operating costs.</p> <p>At least 15 years from large scale commercialisation.</p>	<p>Sizeable natural resource to be exploited in UK.</p> <p>Potential for technology export.</p>	<p>Risk/Cost of demonstration. No large companies pushing the technology.</p> <p>Size of devices (typically 100m per MW) and impact on shipping. Requires hundreds of machines, each the size of a tube train, packed with hydraulics, generators, etc</p> <p>Energy transmission from large numbers of floating structures.</p> <p>Limited supply chain.</p>	<p>Demonstration support.</p> <p>Development of standards.</p> <p>Deployment requires the commitment of large shipbuilders and power engineering companies—commitment that will take time to build.</p>
<p>TIDAL BARRAGE</p> <p>Technology is proven, but capital costs tend to be very high.</p>	<p>Multi GW scale possibilities in UK (e.g. Severn Barrage), but power limited to certain (changing) times of day.</p>	<p>Cost, environmental issues, investment risk, grid connections.</p>	<p>Studies in progress. Substantial structural change to electricity market and/or government subsidies probably needed for large schemes.</p>
<p>SOLAR PHOTOVOLTAICS</p> <p>Mature but costly technology, currently used mainly in niche and ‘showcase’ applications.</p>	<p>Limited potential for improvement of current (first and second generation) technology but some scope to improve production costs through improved manufacturing processes.</p> <p>Higher efficiency and more flexible materials currently in development could result in lower-cost, higher-efficiency applications.</p> <p>Mass deployment has been achieved where government support has been substantial (e.g. Germany, Japan).</p>	<p>High capital cost.</p> <p>Competition for raw materials (silicon) resulting in high cost.</p> <p>Lack of skilled installers.</p> <p>Lack of information and accreditation schemes.</p>	<p>R&D into manufacturing.</p> <p>R&D into “second generation” thin film silicon PV, organic PV and high-efficiency “third generation” PV (e.g. quantum dots).</p> <p>Skills development.</p> <p>Technology and installation accreditation.</p>

Where are we?	What can be achieved?	What is holding it back?	What needs to be done?
<p>SOLAR THERMAL ENERGY</p> <p>Technology is mature and relatively cost-effective.</p>	<p>Large potential for domestic use, both retrofit and new build.</p>	<p>Lack of skilled installers.</p> <p>Lack of information and accreditation schemes.</p> <p>Integration with building stock.</p>	<p>Skills development.</p> <p>Technology and installation accreditation.</p> <p>Introduction of ‘microgeneration-ready’ standards for new homes.</p>
<p>CONCENTRATED SOLAR ELECTRICITY</p> <p>Mature but quite expensive.</p>	<p>Very suitable for desert regions—requires plenty of sunshine and large land areas.</p>	<p>Not suitable for UK; long term potential for mass application in North Africa and export to Europe.</p>	<p>Support studies.</p>
<p>ENERGY FROM WASTE</p> <p>A variety of mature or near-market technologies exist for recovering energy from waste.</p> <p>Electricity generation from landfill gas is the most widely used.</p>	<p>Significant potential, depending on local circumstances.</p>	<p>Potential for landfill gas limited by restrictions on landfill.</p> <p>Planning consent for thermal waste to energy plants.</p>	<p>Interaction with waste management policies.</p>
<p>BIOMASS</p> <p>Technologies using ‘first generation’ biomass resources for heat, power generation and transport are fairly mature but relatively costly.</p> <p>Higher-yield ‘second generation’ biofuels are being researched but are at least 10–15 years from commercialisation.</p>	<p>Biomass for heat and power generation could be more widely used in parts of the country.</p> <p>Potential limited by other demands for land use, especially food crops.</p> <p>Currently biomass is imported from Europe, this is likely to reduce as EU states all turn to biomass to achieve their renewable energy targets.</p>	<p>Lack of supply chain coordination.</p> <p>Lack of skilled installers.</p> <p>Lack of information and accreditation schemes.</p>	<p>Establishment of sustainable supply chains.</p> <p>Skills development.</p> <p>Resource, technology and installation accreditation.</p> <p>R&D into ‘second generation’ biofuels.</p>

Where are we?	What can be achieved?	What is holding it back?	What needs to be done?
<p>GEO THERMAL</p> <p>Mature but costly technology for UK. Applied on a large scale at lower costs in countries with good resource (e.g. Iceland, Philippines).</p>		<p>High cost of installation.</p> <p>Lack of skilled installers.</p> <p>Lack of information and accreditation schemes.</p> <p>Integration with building stock.</p>	<p>Skills development.</p> <p>Technology and installation accreditation.</p> <p>Introduction of 'microgeneration-ready' standards for new homes.</p>
<p>GROUND SOURCE HEAT PUMPS</p> <p>Mature technology that can be cost effective.</p>	<p>Significant opportunities in space heating, easiest to apply in new buildings or major refurbishments.</p>	<p>Getting people to apply the technology.</p>	<p>Changes to building regulations</p>
<p>GREEN BUILDING DESIGN (USING NATURAL HEAT, LIGHT AND COOLING)</p> <p>Exemplar projects abound but not deployed universally.</p>	<p>Huge opportunities for new construction and retrofit, more examples of best practice needed for retrofit.</p>	<p>Lack of interest/knowledge amongst people commissioning buildings or retrofits; weak building regulations and enforcement.</p>	<p>Aggressive approach to building regulations and their enforcement; better marketing of the benefits, higher energy prices.</p>
<p>HYDROGEN AND FUEL CELLS</p> <p>Hydrogen is not inherently renewable; in the near term, the most likely sources are fossil fuels, resulting in CO₂ emissions unless accompanied by abatement technology. This is an immature technology.</p>	<p>Trials in USA using fuel cells power by off peak electricity to provide hydrogen for motorcycles.</p> <p>Portable power sources (e.g. phones, laptops) in advanced development.</p>	<p>Finding cost effective applications and developing hydrogen production infrastructure.</p> <p>Also ensuring that power to make the hydrogen does not come from high carbon sources.</p>	<p>Basic R&D on hydrogen generation.</p> <p>R&D on hydrogen transport infrastructure requirements.</p>

Where are we?	What can be achieved?	What is holding it back?	What needs to be done?
STORAGE TECHNOLOGIES			
<p>PUMPED STORAGE HYDRO</p> <p>Mature technology, often quite expensive</p>	<p>Allows storage of energy to balance intermittent renewables and/or demand peaks and troughs. Large scale possibilities exist in UK and have been studied in the past.</p>	<p>Not an attractive investment, also potential environmental issues.</p>	<p>Flagging of opportunities, and impact on market price of intermittency. Will not be commercially attractive until value of intermittency or gap between peak and base prices becomes high.</p>
<p>DEMAND CONTROL</p> <p>Technically possible but massive deployment challenge</p>	<p>Potentially allows non essential demand to be removed at times of peak demand or low outputs from intermittent generation.</p>	<p>Market not yet ready to deploy it; attention needed to regulatory and legislative frameworks.</p>	<p>Deployment of smart meters is a first step and government is active through Energy Bill enabling provisions, changes to domestic appliance standards and wiring regulations may be needed. Deployment of ESCOs would help (as in Energy White Paper)</p>
<p>SMART WHITE GOODS</p> <p>Manufacturers are engaged with innovators; selective trials taking place.</p>	<p>Potentially allows interruptible demand to be 'intelligently disconnected' at times of power system stress. The value of this is could be significant because it may be a cost effective way of replacing expensive fast-response standby generation on the grid.</p>	<p>Constructing the 'value chain' so that those who bear the costs can receive the rewards. Also needs mass roll out. Needs consumer acceptance.</p>	<p>Proving the technology (in hand with some big white goods manufacturers); demonstrating it effectiveness and commercial value; constructing a route to market and the value chain for rewards.</p>
<p>ELECTROCHEMICAL STORAGE</p> <p>Significant R,D and D done in UK a few years ago but subsequently abandoned.</p>	<p>Short term energy storage to manage demand peaks or low intermittent generation</p>	<p>Market not yet interested.</p>	<p>More development work. Will not be commercially attractive until value of intermittency or gap between peak and base prices becomes high.</p>

Source—*The Institution of Engineering and Technology*

APPENDIX 5: COMPARATIVE COST ESTIMATES SUBMITTED TO THE INQUIRY IN MID-2008 OF RENEWABLE (EXCLUDING HYDRO), FOSSIL AND NUCLEAR ENERGY GENERATION. IN THE CASE OF RENEWABLES, THEY DO NOT ALLOW FOR EXTRA COSTS OF BACKUP CONVENTIONAL GENERATING CAPACITY OR GRID INTEGRATION, WHICH ARE EXPLORED IN CHAPTER 4.

	Laughton and REF ^a using figures from PB Power	REF ^a using IPA figures	British Energy using IPA for REF ^a (with varying carbon price)	British Energy using BERR Energy Review 2006	Centrica	E.On	British Wind Energy Association
Offshore wind	10	6.4–6.9	6.6	5.6–8.9	7.4–11	10.7	
Onshore wind	5.6	4.1–4.8	4.4	5.1–6.4		7.5	6.2
Biomass	7						
Tidal	12.6						
Wave	21.8						
Combined Cycle Gas Turbine (CCGT) ^c	4.2	4.8–5.1	4.7–5.7	4.5–5.2	5.6–9.2	4.4–5.9	5.5–6.3
Open Cycle Gas Turbines ^c	7						
Coal Plant with no carbon abatement technologies	4.2	4.4–4.9	4.2–6.4	2.6–4	5.5–8.0	4.2–7.1	5.0–6.8
Coal with carbon capture and storage ^b		4.9–5.4	5.1–5.3			6.8–7.1	
Cleaner coal—Integrated Gasification Combined Cycle (IGCC)	6.4	4.9–5.1	4.5–6.6	2.9–4.3	6.0–8.9		
IGCC with carbon capture ^b				4.5–5.2	5.7–8.5		
Nuclear	3.8	3.6–3.9	3.7	3–4.4	5.0–7.0	3.9	6.0

a REF stands for Renewable Energy Foundation.

b No power plant currently operates with carbon capture and storage.

c Both Closed Cycle and Open Cycle Gas Turbines use gas mixed with air to fuel a turbine. But the CCGT also uses the heat from the turbine exhaust to also create steam which turns a second turbine. The CCGT is therefore more efficient and hence cheaper.

APPENDIX 6: FUTURE RENEWABLE ENERGY TECHNOLOGIES

New forms of renewable energy and improvements to existing technologies such as wind would help cut carbon emissions. A long term prospect sometimes discussed is the possibility of importing electricity generated from panels of solar photovoltaic cells placed in the Sahara desert. Another possible development in the Sahara is solar thermal power. Steel and glass mirrors would capture energy from the sun to boil water with the resulting steam used turning turbines to generate electricity. Algeria is reported to be building an experimental solar thermal power plant 400 miles south of Algiers which could open next year.⁶² One of the key difficulties with both ideas would be transmitting the electricity over the huge distance from the Sahara to consumers in Britain. The Institution of Engineering and Technology argued such projects had long term potential for North Africa with energy being exported to continental Europe but were not suitable for the UK. Another possibility might be to use solar generated electricity to obtain hydrogen which could then be shipped to the UK (and other countries) as a transport fuel.

Researchers are also examining ways to improve wind power, a relatively well-established form of renewable generation. Norwegian oil company StatoilHydro is testing technology that would enable offshore turbines to float instead of having to plant them on the seabed. If the tests are successful turbines could then be used in much deeper water where the stronger wind is more consistent. More power could then be generated which could help bring down the cost per unit of electricity of offshore generation which is currently higher than that of the more widely used onshore turbines.

As outlined in Chapter 5 a heat technology that could be developed in the future is the injection of biomethane that can be injected into the gas grid. Biogas—a mixture of methane and carbon dioxide—is first produced by bacteria breaking down organic material such as food waste in the absence of oxygen through a process called anaerobic digestion. The carbon dioxide is then removed from the biogas to leave biomethane. Some European countries have already begun injecting biomethane into their gas grids but the Government's renewable energy consultation document says such technologies require more innovation before they can be deployed in the UK. The Government has contributed £10m towards the construction of new anaerobic digestion plants.

In transport, scientists are developing 'second generation' biofuels. First generation biofuels—which are in commercial production today—are made from the parts of plants that could otherwise be used as food such as wheat grain and sugar cane. But second generation bio-fuels—which are not yet available on a commercial scale—would be made using parts of plants not used for food or whole plants that are not suitable for food. Other possible avenues include electric cars, which are not yet widely available, and hydrogen powered vehicles, which are still in development. While both use electricity they could count as renewable technologies if they use renewable sources of power. Furthermore, as outlined in Chapter 5, such vehicles could store electricity which would help ease the problems of intermittency associated with most forms of renewable power generation.

⁶² The Economist, The Future of Energy, June 19, 2008

APPENDIX 7: RENEWABLE ELECTRICITY IN DENMARK

Denmark has the highest share of wind-generated electricity in the EU—15.7% of its total consumption in 2006. The country is accordingly held up as an example by some commentators, while others draw attention to features of the country's experience that may not be transferable abroad. Denmark is a relatively small country, with strong transmission links to Germany, Norway and Sweden. The (separate) electricity systems in Eastern and Western Denmark joined the Nordic electricity wholesale market, Nord Pool, in 1999 and 2000 respectively. When the transmission lines are not congested, this market sets a single price for power in Denmark, Finland, Norway and Sweden, ensuring efficient levels of cross-border trade.

The columns in figure below show how the level of generation in Denmark has varied over time. The output of wind generators has increased by a significant amount, whereas the output of coal-fired plants has fluctuated dramatically from year to year. The top line in the figure shows that Danish electricity consumption has grown steadily, and cannot be the cause of the fluctuating output.

The bottom line in the figure shows Denmark's net exports of electricity.⁶³ There is clearly a strong relationship between net exports and the output of coal-fired generation. The graph does not show this, but those net exports are, in turn, strongly linked to the output of hydro-electric power in Finland, Norway and Sweden. In dry years, with relatively little hydro output, exports from Denmark (and Germany) make up some of the slack.⁶⁴ There is little sign of a long-term trend for exports to either increase or decrease over time.

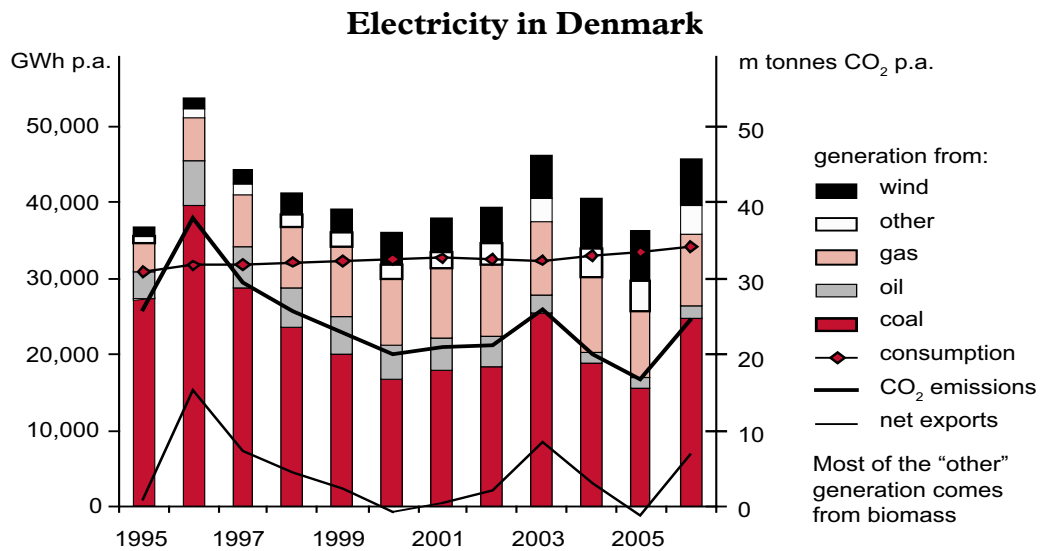
The middle line in the figure shows Denmark's emissions of carbon dioxide from electricity generation. These emissions are clearly linked to the amount of coal- (and oil) fired generation. In other words, Denmark emits more carbon dioxide in years when dry conditions in Scandinavia mean that Danish generators are able to send more power northwards. They do so by increasing the output of coal-fired power stations.

Since Denmark's total output of electricity does not depend solely on conditions within the country, the country's movement towards a lower-carbon energy system is better measured by emissions of carbon dioxide per kWh generated than by total emissions. Carbon dioxide emissions per kWh of electricity generated were 24% lower in 2006 than in 1995.⁶⁵

⁶³ The vertical axis starts at zero, although net exports can be negative, because in the two years in which Denmark was a net importer of electricity, the amounts involved were small (665 GWh in 2000 and 1,369 GWh in 2005).

⁶⁴ The correlation coefficient between Denmark's net exports and hydro generation in the other three countries is -0.75, showing a strong inverse relationship, while the correlation between Danish net exports and coal-fired generation is even stronger, at 0.89.

⁶⁵ The 2006 figure did represent a slight increase on 2005, but this was because the increase in net exports led to an increase in the level of coal-fired generation, and the average emissions rose accordingly.



The Danish wind industry does gain significantly from the country's strong interconnections to its neighbours. On an hour-to-hour basis, there is a clear tendency for Denmark to export power when the wind is high, and to import power when it has little wind generation. Without the ability to exchange power with its neighbours, Denmark would find it more difficult to integrate its wind generators—we have not attempted to assess how difficult. However, the exchanges within a year tend to balance themselves out—over a year as a whole, we found no evidence of a correlation between Denmark's net exports and its output from wind generation.

APPENDIX 8: TRANSMISSION ACCESS PROPOSALS

The industry is currently assessing longer-term changes to the organisation of transmission access. National Grid told us that it is developing three proposals (p 129). The first is to move away from a philosophy of “invest then connect” to one of “connect and manage”. Rather than waiting for distant reinforcements to the grid to be completed, the transmission companies would connect a new generator as soon as the local system was capable of accepting its output. If constraints elsewhere on the system meant that from time to time the generator’s output could not be accepted, the station would have to be “constrained off”, and would be compensated for the fact that it could not sell its power.

The second proposal involves the short-term trading of access rights between generators. This would allow a wind farm to connect to the system with access rights to sell only a proportion of its potential output, if that was all that the grid could accept. If the wind is strong and the wind farm could generate more than this proportion, it would find another generator (which would probably have to be in the same area) that was not using all of its access rights, and buy the surplus. Since the conventional stations would not all be needed when the wind was strong, there should in principle be rights available, and this would allow stations to share transmission capacity.

The third proposal is to bring in a series of auctions for long-term capacity rights. Ofgem told us that if generators have to make a clearer financial commitment of their future demand for capacity, this would give National Grid a lot more information about generators’ demand for access to the network (p 176).

A number of companies commented on this review. A key concern of EDF Energy is that the Transmission Access Review primarily introduces measures to improve short term allocation efficiency which could in turn increase long term uncertainty for market participants, and undermine long term investment in both generation and transmission. In the company’s view, the core issue is the scarcity of transmission capacity, and so securing this capacity and utilising it well must remain the prime objective of the review (p 174).

Renewable Energy Systems UK and Ireland Ltd argued that “giving priority access for connection and production to renewable energy capacity means not doing so for centralised fossil plant. It is essential to overcome resistance from the affected incumbents. Renewables must have priority grid access and dispatch. Shared access rights and flexible security of supply rules need to be introduced” (p 436).

E.ON argued that the reform of transmission access arrangements will need to balance the need to connect new renewable generation and the need to avoid imposing additional costs on the system by constraining off thermal and fossil plant which National Grid then has to compensate (p 108). The Renewable Energy Association argued that renewable generators should be given priority access and dispatch rights, and that this was likely to become law under the forthcoming EU Renewable Energy Directive (Q 161).

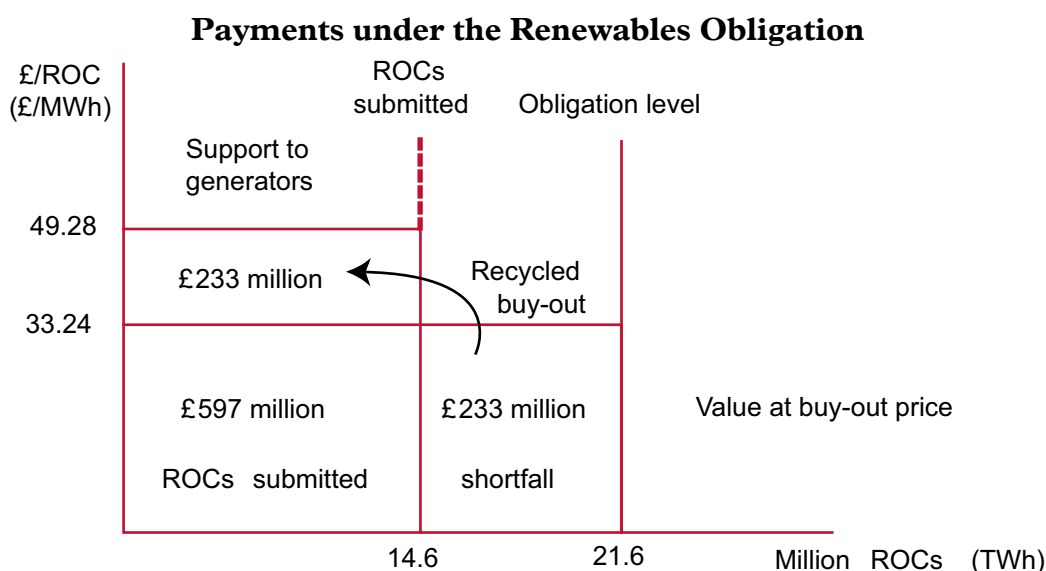
At present, if National Grid cannot accept a station’s output because of constraints on the transmission system, the generator is required to buy back its output in the Balancing and Settlement Mechanism, the short-term electricity market. A conventional generator would normally be willing to pay any price that is less than the costs it would save by not generating (which would be dominated by fuel costs) in order to buy back its power. A wind station, however, incurs very few variable costs when it generates, and gives up income from the sale of Renewables

Obligation Certificates. It might therefore ask National Grid to be compensated for giving up this income, effectively offering to buy back its power only at a negative price. In other words, National Grid would be paying the wind farm not to generate. In such circumstances, it would obviously be more economic to find a conventional plant to constrain off instead, but this might not be possible, if none was in the same (constrained) part of the grid, or all the stations there were required for balancing purposes. We are therefore uncertain that priority dispatch rights would have a significant impact in practice, given the current system of constraint payments.

APPENDIX 9: THE RENEWABLES OBLIGATION

A number of mechanisms are used to support renewable energy. Renewables Obligation Certificates (ROCs) are the most direct. The Renewables Obligation requires electricity suppliers to deliver a set proportion of power from renewable sources—9.1% was set for 2008–09.⁶⁶ Generators receive one ROC for every 1,000 kWh of electricity generated, and can sell these to suppliers. A supplier unable to surrender ROCs equal to the set percentage must pay £35.76 for each missing certificate into a buy-out fund which is then redistributed amongst the suppliers who surrendered ROCs, in proportion to the number given up. The market price of ROCs rises above the buy-out price if a shortfall is expected, for each ROC allows the holder not only to avoid paying the buy-out price, but also to share in the money paid in by those with a shortfall. The Renewables Obligation covers Great Britain, while the Northern Ireland Renewables Obligation runs on a similar basis but with a lower target (3.0% in 2008/9).

The design of the Renewables Obligation effectively means that the total payment to renewable generators, over and above the market price they receive for their power, should be fixed. In 2006–7, the amount of electricity covered by the Obligation in the UK was 21.6 TWh (6.7% of electricity supplied) and the buy-out price was 3.32 pence per kWh. If no ROCs had been submitted, suppliers would have paid £720 million to the buy-out fund. In fact, they submitted 14.6 million ROCs, and paid £233 million to the fund. This was then redistributed to the suppliers who had submitted ROCs, giving them £16.04 per ROC submitted. With hindsight, the overall value of the ROC to the supplier was thus £49.28 (£16.04 plus £33.24). If market prices had reached this level (in 2007, they were actually slightly below it), the total value to generators would have been £720 million: 21.6 TWh × 3.32 pence per kWh. The same result would hold for any level of renewable generation below the obligation level. The figure below shows this result.



Before the Renewables Obligation, renewable (and nuclear) generation was supported through a Non-Fossil Fuel Obligation (in England and Wales) and the

⁶⁶ Ofgem, Renewables Obligation—Interim total obligation levels for 2007–08, August 5, 2008, available at: <http://www.ofgem.gov.uk/Sustainability/Environment/RenewablObl/Documents1/Renewables%20Obligation%20-%20Interim%20Total%20Obligation%20Levels%20for%202007-08.pdf>

Scottish Renewables Obligation. The electricity regulator and the Non Fossil Purchasing Agency organised a series of tenders to buy power from renewable generators, mostly for 15 years, and recovered the cost from a percentage levy which suppliers had to add to consumers' bills. Many of the tenders were from generators that had not yet received planning permission, and not all of the contracted generation was delivered. The early contracts have expired, and almost all of these generators are now involved in the Renewables Obligation—the Agency resells the power and ROCs for generators with current contracts.

If renewable electricity is to supply 32 per cent of electricity demand, to take the number in the Government's Renewables Consultation, and all of this is to be supported by the Renewables Obligation, it would have to be set at a much higher level. Although the Government has announced plans for a feed-in tariff for some small scale generation technologies, we will calculate the cost of support for these "as if" it was still given through the Renewables Obligation. Ignoring the effects of banding, which will give more ROCs to technologies such as offshore wind, a Renewables Obligation for 32 per cent of electricity would add 1.14 pence per kWh to the price of electricity—that is, 32 per cent of 3.576 pence per kWh (the 2008–9 buy-out price). This would add £50 to the average domestic consumer's annual electricity bill. On top of this, the system integration costs shown in Table 4 would add a further 0.65 pence per kWh, or another £30 a year.

If we take account of the impact of banding, which gives some technologies more ROCs per MWh generated, and others less, the number of ROCs required to reach 32 per cent renewable generation will change. Since much of the additional renewable generation would come from offshore wind, which will receive more than 1 ROC per MWh (1.5 ROCs per MWh for the next few years), the number of ROCs required is likely to exceed 32 per cent. If it reaches 37 per cent of electricity supplied, the cost of the Renewables Obligation would be £60 per year for the average household.

APPENDIX 10: GLOSSARY OF TERMS AND ABBREVIATIONS

BERR	Department for Business, Enterprise & Regulatory Reform
CCS	Carbon Capture and Storage
CERT	Carbon Emissions Reduction Target
CHP	Combined Heat and Power
CO ₂	Carbon dioxide
DTI	Department of Trade and Industry
ECU	European Currency Unit
EDF	Électricité de France
ETI	Energy Technologies Institute
ETS	Emissions Trading Scheme
EU	European Union
EWI	Energiewirtschaftliches Institut (Institute of Energy Economics), University of Cologne
GW	Gigawatt
GWh	Gigawatt Hour
IEA	International Energy Agency
IET	Institution of Engineering and Technology
IPC	Infrastructure Planning Commission
kg	Kilogram
kW	Kilowatt
kWh	Kilowatt hour
MMO	Marine Management Organisation
MW	Megawatt
Ofgem	Office of Gas and Electricity Markets
p/kWh	Pence per kilowatt hour
R&D	Research and Development
R, D&D	Research, Development and Demonstration
RO	Renewables Obligation
ROCs	Renewables Obligation Certificates
SKM	Sinclair Knight Merz
SSE	Scottish and Southern Energy
UKERC	UK Energy Research Centre