Appendix D: Delivery and economics in 2020: the contribution of wind, wave and tidal power to UK power supplies

Key points

- Wind energy and the marine renewables are capable of delivering 6% of UK electricity supplies by 2010, (4.6% from onshore wind, 1.3% from offshore wind) and 21% by 2020 (about 9% each from onshore and offshore wind, the rest from marine renewables and small wind systems), based on BWEA central estimates
- The growth of wind energy will be influenced partly by international developments and partly by UK Government actions
- Despite a current shortage of wind turbines, the international outlook is currently bright, and growth for the next few years is likely to be strong. This will lead to significant cost reductions, both onshore and offshore
- UK onshore wind is progressing well, with substantial amounts of capacity in the planning pipeline. The most likely constraint may be the implementation of transmission reinforcements and timely action is needed to initiate these
- Offshore, there is currently an international hiatus, although there are nearly 10,000 MW of European plant at various stages of planning. The UK has the second highest capacity in the world, but action is needed to maintain (or improve) this position, in particular:
    - Place responsibility for construction of offshore transmission onto the Transmission System Operator. This will assist projects to become more viable and at the same time improve network security
    - Ensure stable income streams accrue to developers, either from the Renewables Obligation or any alternative scheme
- The extra costs to the consumer are currently determined by the Renewables Obligation but on a level playing field with gas, onshore wind can be competitive in many locations, though potential UK sites have a considerable spread of wind speeds, and some of the most attractive ones for wind generation may not be accessible due to planning restrictions. Offshore wind may become cheaper within 10-12 years, depending on the trajectory followed by gas prices
- Fuel price risks do not exist with wind energy and making allowances for these – as suggested by several analysts – improves the competitive position of wind significantly, beyond the position suggested by simple generation cost comparisons.

D1 Introduction

As the performance of the UK renewable energy market will depend, to a certain extent, on international developments, there is a brief discussion of these first. This also shows that the UK is not attempting something which has not been achieved elsewhere: the projections we present for 2010 and 2020 can be considered conservative given the build rates and total development in other European countries. The next section deals with the resources available and the one after with likely capacity and energy contributions by 2010 and 2020, followed by longer-term assessments.

The issues associated with resource delivery are different for each of the technologies; these may be summarised below and more detailed discussions follow later:

- **Onshore wind**: the technology is well established and there is now a well-established planning framework. Steady growth is likely over the next few years and the principal constraints are likely to be the resource that is environmentally acceptable, and possible transmission constraints given the high proportion of the resource that is located in Scotland
- **Offshore wind**: there is a worldwide hiatus in offshore wind energy development, due partly to a shortage of wind turbines, partly to higher machine costs, and partly to problems with some of the early windfarms. In the UK, the principal difficulty is cost (of the installations) and price (of the electricity)

uncertainty. The UK resource is huge, and this is not an issue; transmission constraints exist, but are not critical

- **Small wind**: there is increasing interest in the potential of microgeneration (around 1kW size) and small wind turbines (10-100 kW), and there are various mechanisms that provide support for electricity consumers who wish to install such wind systems. The resource is not well characterised and uncertainty surrounds the consumer response
- **Marine renewables**: here, the principal uncertainties are associated with the technologies and how rapidly they proceed towards commercialisation. That, in turn, depends on the extent of Government support in the short and medium-term. The resources are reasonably well understood and transmission constraints are unlikely to be an issue until significant capacity is installed.

D1.1 International perspectives

There is now over 60,000 MW of wind capacity installed worldwide, of which two-thirds is in Europe. Capacity increased by nearly 12,000 MW in 2005 – the highest increase ever. Most commentators expect strong growth to continue, so that by 2020 capacity in Europe may be between 100 and 180 GW[1]. As wind energy capacity doubled every three years from 1990 to 2005, these estimates may be conservative. Germany, with over 18,000 MW, has the highest capacity, but Denmark, with over 3,000 MW, has the highest level per capita, and the highest penetration into the electricity network – around 18%. Spain comes next, with just over 8% penetration, and Portugal (5%) comes third.

Denmark

Wind production in Denmark accounts for about 18% of electricity consumed. Although western Denmark – where 80% of the capacity is installed – has connections with Germany, Norway and Sweden, the significance of these tends to be overstated. Western Danish wind capacity is effectively feeding into a larger electricity network, but the total capacity of the links is less than the capacity of the thermal plant in this part of Denmark. Taking this into account, the effective penetration level is around 12%, which is still significant.

In 2003, more than 25% of the electricity and district heating consumed was produced on the basis of renewable energy. On the basis of various scenarios, the Danish Energy Authority has prepared projections to 2025. With moderate rises in oil prices and in CO_2 allowance prices, the contribution of renewables to electricity supply will amount to more than 36%. Wind energy will account for a major part of this increase, and, allowing for the existence of the external links, the effective penetration level will be about 22%.

Denmark has 3,100 MW of wind plant, of which about 420 MW is offshore. After many years of sustained growth, onshore progress has now plateaued, but there are plans for further offshore wind farms. Most of the growth in wind is now expected to come from offshore developments.

Denmark is actively involved in the promotion of a wide range of other renewable energy sources, including biomass and wave energy.

Spain

With over 10,000 MW, Spain has the second highest wind capacity (after Germany) in the world. That capacity is expected to double by 2010, following approval of a new Renewable Energy Plan. The aim of this plan is to meet 12% of primary energy needs by renewables by 2010. The method is to create a framework of incentives to encourage private sector investment in renewable energy technologies, and the contribution of public funds to these investments is estimated to be 3% (about £470 million)[2].

Wind plant operators have a choice of trading on the power pool and being paid a production incentive, set at 50% of the average electricity tariff, or opting for a feed-in tariff, offering earnings around £41/MWh in 2005. (The production incentive delivered average earnings about 6% higher in 2005)[3].

Portugal

The development of wind energy in Portugal has accelerated rapidly since the turn of the century, and in 2005 450 MW was installed, bringing the total to around 1,000 MW. In common with many European states, there is a 'feed in' tariff. The payments step down after 2,000 hours of generation in a year, to inhibit over-development of the windiest sites, and the average remuneration is estimated to be just over £48/MWh[4].

The Portuguese Government has also established a tariff mechanism to support the first generation of wave energy projects. The tariff has been set for the first 20 MW, possibly more, of wave energy projects built and operating. The wave tariff pays about £110/MWh. Ocean Power Delivery has secured an order for a wave farm from a Portuguese consortium led by Enersis SA. The 2.25 MW scheme is being installed off northern Portugal as the first stage of a 24 MW plant.

United States

Wind energy capacity in 2005 increased by over 3,000 MW in the United States. It was (and is) encouraged by a £10/MWh 'Production Tax Credit'. This currently expires at the end of 2007 but if gas prices stay at their present high levels this could 'provide some of the certainty needed to stabilise the industry's outlook.'[5] The use of renewable technologies for electricity generation is projected to grow, stimulated by improved technology, higher fossil fuel prices, extended tax credits and State renewable energy programs. Although the Federal tax credits are currently scheduled to end after 2007, the US Department of Energy's projections suggest wind energy production will increase rapidly to 51 TWh by 2010 (the output of about 20,000 MW of wind capacity). These projections are based on a modest (about 10%) drop in installed costs. Levelised costs for 2015 are put at just under $50/MWh (around £29/MWh)[6].

Germany

Germany, with over 18,000 MW of wind, has the highest capacity in the world. Developments have been encouraged by 'feed-in tariffs', which, in the past, may have been generous, but which are now much less so, given that the average productivity of German wind plant is about half that of UK wind plant. The length of time for which the 'headline' tariffs are paid depends on the wind speed at the site. The starting rate for onshore wind is now £58/MWh, falling to £36/MWh. The starting rate falls by 2% every year. No allowances are made for inflation. The rate for offshore plant online by 2010 is £60/MWh for at least 12 years. As with onshore plant, the period for which the rate is paid depends on the wind plant's performance. It then drops to £41/MWh.

After several years of very rapid growth, capacity in 2005 increased by only 11%, although that amounted to 1,800 MW, an increase second only to the United States last year. Although there are ambitious plans for several offshore wind farms, only two near-shore machines have so far been installed.

Technical issues

The unprecedented worldwide growth rate in 2005, which is expected to continue this year, has led to supply bottlenecks and concerns that manufacturers may not be able to keep pace with the demand. A 'seller's market' has also been partly responsible for an upturn in wind turbine prices – the first for many years. This was also due to increases in the price of steel, copper and other raw materials. The strong demand has been driven partly by vigorous development in the United States, as noted above.

The rapid growth in world wind capacity has been stimulated by financial support mechanisms of various kinds, but also by a very rapid maturing of the technology. Wind's success has also been due to the growing awareness that the resources are substantial – especially offshore – and that energy costs are converging with those of the 'conventional' thermal sources of electricity generation. In some instances the price of wind-generated electricity is now lower than prices from the thermal sources.

Offshore wind energy capacity amounts to about 750 MW, of which 214 MW is in the United Kingdom. Denmark leads with over 420 MW and other countries with offshore capacity, or plans, include Germany, the Netherlands, Sweden, China, Japan and the United States. There are about 10,000 MW of offshore projects at various stages of the consenting process in Europe[7].

Offshore winds are less turbulent then onshore winds and the wind shear is lower as well, so that the dynamic loads on the machines are expected to be less severe. Although gearbox and transformer problems on Danish offshore wind farms have received much publicity, there is little evidence that any of these problems are the result of any unforeseen difficulties associated with the offshore environment. The transformer problems at Horns Rev, for example, appear to be due to insufficient insulation thicknesses – due either to an incorrect specification, or deficiencies in manufacture.

It may be noted that energy productivity from the Danish offshore wind farms – once problems have been resolved – is in line in with or in excess of expectations. The average power output of the installation at Nysted, for example, has been 40% of the rated power for two years running.

D1.1.1 Wind plant costs and electricity generation prices

Until 2005, installed costs of wind energy plant, worldwide, showed a strong downward trend and numerous analyses had suggested that the 'learning curve ratio' was between 8 and 15%. (This is the reduction in cost that is achieved with a doubling of installed capacity.) The recent upturn in prices is the first in about 15 or more years that has upset this trend. The upturn, as noted above, was due partly to increases in the costs of raw materials, partly to the need for manufacturers to increase the narrow margins on which many had been operating and partly to 'supply and demand' pressures, as demand in 2005 exceeded supply.

Nevertheless the trends that were responsible for the earlier cost reductions are still at work. Manufacturers are developing more cost-effective production techniques, so the price of machines is likely to fall from the 2005 level. Machine sizes are increasing, which means that fewer are needed for a given capacity, and so the installed costs of wind farms are decreasing. In addition, larger windfarms are being built, which spreads the costs of overheads, roads, electrical connections and financing over greater capacities. The use of larger wind turbines also means that they intercept higher wind speeds; this increases energy generation, reducing generation costs.

Electricity generation prices from wind energy depend on the institutional framework, but a good indication of current onshore levels comes from Canada, where wind contracts are being let at around £30/MWh (with a mechanism similar to the Non-Fossil Fuel Obligation). The most recent and reliable offshore data comes from the Danish Horns Rev 2 project, which will be paid €69/MWh (around £47/MWh) for about 12 years[8]. Danish developers do not have to pay for grid connection costs, and in both these cases contracts are long-term and fixed price, eliminating price risk from developments and thus reducing cost of capital and returns required.

A number of estimates of future wind costs appeared in the Sustainable Development Commission's report[9] , since when more have appeared. The most recent[10, 11], both suggest a continuing downward trend, as 'learning curve' influences are still at work – manufacturers are establishing improved production methods and reducing the (significant) labour content of wind turbines. Offshore, additional savings will be realised with larger wind farms.

A conservative estimate of future UK onshore cost trends comes from consultants Garrad Hassan[12] who suggested that onshore costs would fall to 89% of their 2003 level by 2010 and 81% by 2020. The corresponding figures for offshore costs are a drop to 73% of the 2003 figure by 2010 and to 57% by 2020. So far, however, there has been little sign of the learning curve effect operating for offshore wind; costs have been at around the same level for the last four years, despite about three doublings of capacity in that time. However, the number of projects has been small, and learning effects should kick in as that number increases.

D2 UK Wind energy resources

To establish the potential contribution that wind energy might make to UK energy supplies, knowledge of the resource is an essential starting point. What matters is the 'accessible' resource – the wind power capacity that could be installed after various constraints, such as built-up areas, Areas of Outstanding Natural Beauty, and forests are taken into account. Offshore, the constraints are different, and include areas with dredging concessions, submarine practice areas and those with unsuitable water depths or seabed conditions. The offshore resource can probably be established with greater precision, as uncertainties associated with visual effects and planning decisions are less of an issue.

D2.1 Onshore wind energy

Resource

Numerous estimates have been made of the onshore wind energy resource. Table 1 includes a limited selection and the estimates are compared with data on current developments. It must be emphasised that these estimates do not take account of transmission constraints. The early studies are, broadly speaking, still likely to be valid. Although machine sizes have increased, the necessary spacings have also increased, and so planting densities are still in the range 7-10 MW per square kilometre, although much depends on the exact configuration of a wind farm.

The table highlights the importance of the contribution from Scotland. This currently accounts for 50% of the installed capacity, and this will rise to over 70% if all the plant in planning came to fruition. The ETSU estimate suggests that the Scottish resource accounts for 60% of the total accessible resource (11,500 MW), although the more detailed study carried out by the utilities and others suggested the feasible capacity was lower (7,300 MW).

Points to note in the table overleaf are:

- The English figure of 1,600 MW (consented and planned) is about half the ETSU estimate of the accessible resource. However, it may be noted that sensitivity analyses in the ETSU study suggest that an additional 30% may easily be realised, taking the figure to around 4,000 MW
- The Scottish figure for all consented and planned plant (7,200 MW) is close to the 'accessible resource' figure from the Scottish utilities (ref 15), although ETSU and Garrad Hassan suggest a figure that is about 50% higher.

Table D1. Current activity and resource estimates for the UK. All figures in MW

	England	N.I.	Scotland	Wales	Total
Current developments					
Operating	211	90	569	255	1,125
Constructing	112	41	523	47	723
Consented, but with 10% attrition rate included	452	28	635	24	1,139
Sub-total	*775*	*159*	*1,727*	*326*	*2,987*
In planning	823	600	5,402	184	7,009
…of which – expected to build by 2010	*351*	*364*	*1,173*	*104*	*1,992*
Anticipated projects	*630*	*20*	*513*	*75*	*1,238*
Total expected by 2010	***1,756***	***543***	***3,413***	***505***	***6,217***
Resource estimates					
ETSU[13]	3,240	3,044	11,594	1,591	19,469
DTI/ETSU contracts		9,900[14]	7,300[15]		
Garrad Hassan estimate[16]			11,500		

Installation rates and energy delivery

BWEA has carried out a very detailed analysis of the way and that wind farm planning applications have progressed through the various consent mechanisms so as to provide authoritative estimates of likely future progress[17]. Key conclusions from this analysis, which are reflected in Table 1, are:

- 2,987 MW of onshore wind development is operational, under construction or approved
- 1,297 MW of capacity, currently within the local authority planning system, is expected to be approved and operational by 2010. To this, 700 MW of capacity should be added from Section 36 approvals (50% success rate assumed with a 36 month determination time) – total 2,000 MW

- 1,238 MW of capacity is expected to be submitted to the planning system, approved (taking into account current approval rates and times), and be operational by 2010.

The 'central estimate' of onshore capacity for 2010 is therefore around 6,200 MW, which would generate about 16 TWh of electricity (a little under 5% of UK supply). This represents an average increase in capacity of about 1,000 MW per year. This is about half the capacity installed in Spain and Germany in 2005, and less than the capacity installed in Germany every year from 1999 onwards.

The lower and upper bound estimates for 2010 are 4,700 and 7,500 MW, respectively. The former figure results from pessimistic assumptions on planning decisions, and takes into account the likely impact of grid constraints in Scotland.

Beyond 2010, the rate of growth will depend on the ability of the Renewables Obligation to deliver robust contracts – an ability that will become more difficult towards 2020. However, the competitive position of wind relative to gas will also be important. If gas prices have not declined from their current levels, onshore wind may be able to deliver significantly lower generation costs.

Assuming a modest growth rate of 1,000 MW per annum from 2010 onwards (still much lower than levels achieved in Germany, Spain in the United States) would result in an onshore capacity of 15,000 MW by 2020. However, this is considered to be an 'upper bound' estimate, with the lower bound around 12,000 MW. Our baseline estimate of 12,500 MW would deliver nearly 33 TWh (9% of supply). Once again, grid constraints may lower these figures, but if, as seems likely, the competitive position of wind improves, the case for building the necessary extra connections becomes much stronger, and there is time to plan and build the new infrastructure in the 2020 timescale.

D2.2 Offshore wind energy

Resource

The offshore wind energy resource is undoubtedly large. A very detailed evaluation of the UK resource[18], which took into account a very wide range of constraints, suggested that it is at least 230 TWh. Although completed over 20 years ago most of the key assumptions remain valid (shipping lanes, water depths, seabed conditions, a minimum distance from shore, nature conservation areas). In practice, some of the constraints are now regarded as unduly restrictive (e.g. minimum water depth) and developments are now taking place in some areas that were ruled out.

The resource study acknowledged the need to identify possible constraints due to military radar, and that uncertainty remains. However, the fact that developers bid 26,000 MW of plant as expressions of interest under the Round Two bidding process indicates that resource constraints are unlikely.

Offshore economics

The future of offshore wind energy in the UK is heavily dependent on movements in generation costs. These, in turn, will depend on worldwide developments. The Danish Energy Authority suggests they might fall by about 25% by 2020[a], and the Garrad Hassan study, cited earlier, suggested a 40% fall in installed costs. If, however, international development remains sluggish, these cost reductions are less likely to be realised.

Delivery

Offshore delivery may be more susceptible to international influences than onshore, given the current market conditions for wind turbines. BWEA has commissioned research on the future delivery of current UK offshore projects, which is reported in Appendix B. In this work, an 'optimistic' scenario was developed, where international development is buoyant and brings about significant reductions in installed costs, alongside additional support for offshore in the UK, making developments feasible under the Renewables Obligation. In a 'pessimistic' scenario, international development remains sluggish, and no additional UK support is forthcoming. The capacity developed in these scenarios lies between 1,300 and 2,500 MW in 2010. Constraints on turbine delivery may restrict the maximum capacity to around 2,100 MW in 2010; a figure of 1,500 MW has been taken as the baseline estimate here. This would deliver around 4.6 TWh (1.3% of supply). With offshore wind being at an early stage of its development, forecasting a figure for delivery in 2020 is not easy. If it is assumed that delivery averages 1,000 MW per year over the

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[a] The future projections in the Danish report start from a lower baseline, so it is assumed that a 25% reduction is achieved from the current (higher) baseline.

decade following 2010, this would result in a total capacity of 11,500 MW. This capacity would deliver around 35 TWh – 9.4% of projected supply.

The 'optimistic' assumptions, however, assume that other possible difficulties are overcome, including wind turbine and supply chain bottlenecks (including cables and monopiles), and access to installation vessels.

Particular difficulties in the UK include:

- Uncertain income streams under the Renewables Obligation
- The cost of finance is raised to account for the perceived risks, both financial and technical. (The WACC is typically 11-12%, compared to around 8% in mature onshore markets)
- A tendency for developers to prefer turnkey contracts, which mean high risks for the contractors. There is now a move towards multi-partner contracts, with each specialist shouldering the appropriate risks[19]
- The costs of a grid connection have, up to now, pushed up the overall UK costs[b], and the removal of this requirement under the recently settled regulatory regime for offshore transmission will benefit developers. Although they will pay additional transmission charges, the change will be beneficial. (The TSO recovers these costs over 40 years at a test discount rate of 6.25%; offshore developers typically recover costs over 10-12 years at 10-12%). This arrangement might also enable the TSO to increase network security[c].

D2.3 Small wind

In recent years, there has been increasing popular interest in the potential of microgeneration, and that is now reflected in various support schemes operated by Government and local authorities. There are a few British manufacturers, hoping to harness this segment of the market. The wind turbines are typically rated at 1-2 kW, with rotor diameters around 1.5-3 metres. The market is partly domestic and partly commercial, as small wind turbines – often in conjunction with photovoltaics – provide power at various sites on the rail and road networks, for example.

Although the size of the market – in energy terms – is modest, it has popular appeal, as it enables domestic consumers to make a tangible contribution towards energy and emission savings. It is also viewed as a vehicle for promoting greater awareness of the importance of energy issues.

Assessments of the energy-saving potential are difficult to make with high accuracy, as wind speeds are uncertain and performance data from the small machines are not always well documented. However, a 3 metre diameter, 1.5 kW machine[d], operating at sites with mean wind speeds of 4-4.5 metres per second[e], may be expected to deliver about 1-1.4 MWh annually[20]. These machines cost around £2,000/kW and electricity generation costs in the 'Micro-Generation Study' were estimated to be currently in the range £150-250/MWh[21].

The manufacturers expect machine prices to come down with volume production and the Micro-Generation Study suggested breakeven prices (with domestic electricity) would be achieved between 2008 and 2013. Sales, however, will be dependent on continuing subsidies for some time to come. The Micro-Generation Study suggests a maximum contribution to UK electricity consumption of 1.3% by 2030. This would probably be a mixture of the domestic machines cited in that study, and larger (5-10 kW) machines. The study suggests that the contribution to electricity supply from micro-wind by 2020 will be very small, but may increase after that, depending on the costs of the machines, and the arrangements for purchasing surplus electricity.

In addition, there is scope for about 1,200 MW of 'small wind' (20-100 kW machines) by 2020, sited in or near commercial premises and industrial sites[22]. This study (by CCLRC and others) suggested that the total electricity generation from all small and micro-wind would lie in the range 1.7-5.0 TWh.

The two studies cited provide somewhat different estimates of the electricity generating potential and so BWEA has consulted with the manufacturers to derive a better appreciation of possible trends. It has also made its own assessments, based on the characteristics of the available machines and considering each sector of the housing market, following the approach in the CCLRC study. A cautious estimate of 0.5 TWh

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[b] Danish offshore wind developers do not pay grid connection costs

[c] A new link from Ken□

[d] These parameters have been chosen to line up with the example in the Microgeneration Study

[e] The mean wind speed at Heathrow is 4 m/s. Although higher wind speeds may be found near coasts, lower speeds will prevail in many urban areas. Heathrow is a good site, relatively free of obstructions.

from the microgeneration market by 2020 has been adopted, plus 1,200 MW of small wind (2 TWh), as per the CCLRC study. The eventual resource from both these sources is difficult to judge, but may reach 5 TWh by 2030.

D2.4 Marine energy systems

The prospects for marine energy systems have been examined in some detail in a recent report from the Carbon Trust[23]. The best resources are on exposed western coasts – especially off Cornwall, south Wales, the Western Isles and the extreme north of Scotland. The tidal stream resource is estimated to be around 18 TWh/year; the near-shore wave energy resource around 8 TWh/year, and the total UK practical resource around 50 TWh/year, or more. The UK has some of the best wave energy resources in Europe.

Grid constraints may inhibit development in the north, although the picture may have changed by the time large-scale commercial developments are proposed. A 'wave hub' is planned as a connection point for experimental facilities to be tested off Cornwall. The Carbon Trust suggests generation costs for wave energy are in the region £220-240/MWh, and those for tidal stream in the range £110-140/MWh. The tidal stream resource is, however, smaller.

The contribution from both sources by 2010 is expected to be quite small. Beyond 2010, the key factor is clearly whether commercial viability is believed to be a feasible proposition. If so, and assuming appropriate support, analysis carried out for the BWEA suggests that arrays of tens of megawatts might be installed from around 2009, and larger arrays from around 2012. The 'high end' scenario suggests marine renewables might contribute about 3% (12 TWh) of UK electricity needs by 2020[24].

The Carbon Trust suggests that between 1.0 GW and 2.5 GW of each of wave and tidal stream energy could be installed across Europe by 2020 and that a large share of this deployment could occur in the UK. As a baseline figure BWEA estimates that 3 GW (7.88 TWh) of wave and tidal stream could be installed in the UK by 2020, this represents 2.1% of UK electricity supply in 2020 based on a total supply estimate of 374 TWh.

D2.5 Total wind and marine energy capability

Table 1, overleaf, and the supporting analysis shows that wind and the marine energies in 2010 are capable of delivering 23 TWh (plus or minus 5 TWh) – around 6.5% of expected electricity supply needs. For 2020, the uncertainty margins are higher, due to the difficulties of forecasting delivery in all the technologies. The central estimate is 75 TWh – 20% of supply. The 'low' estimate is about 47 TWh (around 12% of supply), and the 'high' estimate corresponds to about 104 TWh (91 TWh of wind, plus 13 TWh of marine renewables), or around 28% of supply.

Table D2. Capacity and energy estimates for wind and marine renewables

		2010		2020		Notes
		MW	**TWh**	**MW**	**TWh**	
Onshore	Lower	4,700		12,000		
	Upper	7,500		15,000		
	Baseline	**6,220**	**16.35**	**12,500**	**32.85**	1
	Percentage of supply		**4.7%**		**8.8%**	
Offshore	Baseline	**1,500**	**4.60**	**11,500**	**35.26**	1
	Percentage of supply		**1.3%**		**9.4%**	
Marine	Lower	70		2,000		
	Upper	70		5,000		
	Baseline	**70**	**0.21**	**3,000**	**7.88**	1
	Percentage of supply		**0.06%**		**2.1%**	
Micro & Mini	Micro				**0.5**	2
	Mini			1,200	**2.10**	3
	Percentage of supply				**0.7%**	
Total TWh			**21.16**		**78.60**	
Total supply (TWh)			350		374	4
Percent of supply			**6.06%**		**21.01%**	

Notes:

1. 30% capacity factor for onshore wind and marine renewables; 35% for offshore
2. BWEA estimate, based on EST and CCLRC reports (refs 21 and 22), and further analysis
3. CCLRC estimate of capacity; 20% capacity factor
4. Source: DTI[25]

D3 Costs to the electricity consumer

In the short to medium term, the additional costs of renewable energy to the electricity consumer fixed by the structure of the Renewables Obligation, and are not sensitive to the actual electricity generating costs of the individual technologies. Towards 2020, however, the periods over which remuneration from the Obligation will be available will gradually get shorter. It is possible that some "follow-on" mechanism may be established but that will depend on the competitive position of renewable energy technologies in the power market. It is possible that onshore wind, in particular, may be viable without further support.

When assessing the additional costs of renewable technologies at some point in the future, in the absence of the Renewables Obligation, the "reference" generation technology for assessing additional costs to the electricity consumer is usually gas-fired (CCGT). Gas prices have moved steadily upwards over the last two years and future gas prices are extremely uncertain. The indications from the futures markets are that the price will remain above 50p/therm (roughly the average 2005 beach price) until 2009, at least. However, prices in those futures markets have moved steadily upwards for most of the last 18 months or so. The availability of liquid natural gas at one time was thought to bring about a downward pressure on prices, but very strong demand from the United States may temper this effect. The United States Department of Energy's price projections have also moved steadily upwards for several years now, although they suggest falling prices from 2007 onwards. The latest prices in their futures markets do not seem to show any strong downward trend in the short term and the average for 2006 is around 45p/therm.

With gas at 45p/therm and carbon at €25/tonne of carbon dioxide (the level early in 2006), CCGT generation costs are around £49/MWh. Several onshore wind energy projects in Canada and United States have realised cheaper prices than this and several UK NFFO projects are recouping similar or lower prices. As the future price of gas is so uncertain, Table 3 illustrates the installed cost targets for a range of gas prices from 28p/therm to 48p/therm.

Table D3. Indicative breakeven prices for onshore and offshore wind

UK gas price p/therm	Onshore breakeven £/kW	Offshore breakeven £/kW
28	690	744
38	820	919
48	950	1097

Carbon dioxide at €25/tonne, 8% (real) weighted average cost of capital, 15-year depreciation, onshore capacity factors 30% and offshore 35%.

Although straightforward comparisons of generation costs enable reasonably accurate assessments of the competitive position of generation technologies, somewhat more sophisticated techniques are needed when high levels of penetration from the variable renewable sources are examined. This is because the variable sources incur additional balancing costs to cope with the variability and, in addition, the capacity credit declines with increasing penetration. To overcome this difficulty, the best way of making fair comparisons is to look at the total costs of two electricity systems: one with 10% wind (say), and an all-gas system. This reasoning led to the publication of a paper in 2003, which has been widely quoted (and misquoted)[26].

"Total cost estimates" include four elements:

- The additional generation cost of wind, compared with gas
- Extra balancing costs
- Extra costs incurred due to the fact that the capacity credit of wind (in percentage terms) declines with increasing wind energy penetration
- Extra transmission and distribution costs.

The modelling made allowances for additional transmission expenditure on the basis of capital costs per kilowatt of installed wind energy. With 20% wind energy, the additional transmission and distribution costs incurred were around £3,500 million. In practice, the additional investment does not increase smoothly with increase of capacity, but is stepped. The precise sums will also depend on exactly which additional transmission connections are authorised. The Transmission Issues Working Group suggested that expenditure of £1,500 million might be necessary to connect up to 6,000 MW of wind in Scotland, to which additional sums need to be added to allow for other reinforcement in England and Wales. However, the latest report from the Group[27] notes that proposals for new fossil generation may also introduce pressure for reinforcement and so it becomes difficult to separate the extra costs due to wind from those due to conventional generation. The allowances made for extra transmission and distribution costs in the modelling therefore seem to be realistic, and may be conservative.

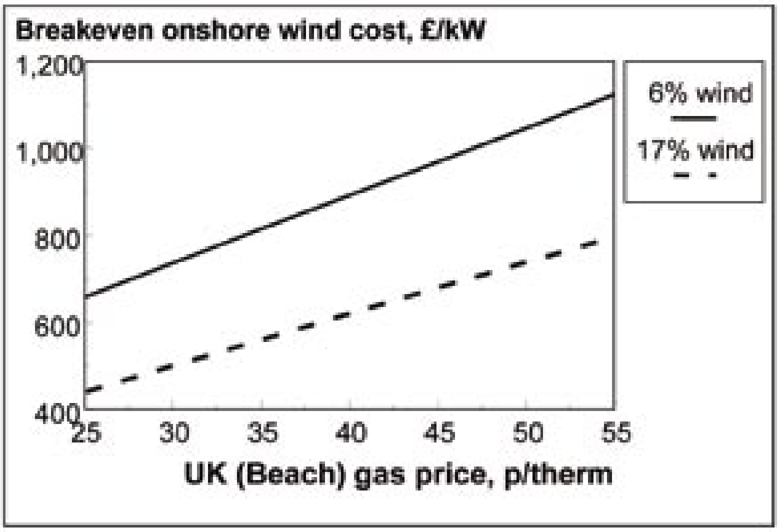
The original analysis of "Total extra costs" suggested that that extra cost of 20% wind energy would represent an additional 0.3p/kWh on consumer electricity bills. It was necessary to make projections about future trends in wind energy costs.

As the assumptions about gas prices for 2020 (19p/therm) made in the 2003 study were too low by 2005, a later analysis[28] included updated estimates for wind plant costs and showed the extra costs as a function of the "beach" price of UK gas. The Sustainable Development Commission's "Wind Energy Report"[29] took the analysis a stage further by making allowances for the "cost of carbon". With gas at 40p/therm (the highest value used), and carbon at £19/tonnes of CO_2, 20% wind would lower electricity prices to all consumers by about 0.1p/kWh.

During 2005, there was a marked upturn in the installed costs of wind plant, primarily due to increases in the price of wind turbines. This, in turn, was due to increases in the prices of steel, copper and blade materials. As a result, the estimates for installed costs used in the SDC report for 2020 may now be optimistic for 2020. To deal with this uncertainty, and avoid making any particular assumptions about gas or wind plant installed costs, breakeven costs for wind plant, as a function of UK gas prices, have now been calculated for the amounts of wind likely to be installed by 2010 and 2020, discussed earlier. This avoids the necessity of pinning the results to any particular value of installed cost.

In 2010, the central estimate is for about 6% wind (4.6% onshore, plus 1.3% offshore). In 2020, the central estimate is for 21% from wind and marine renewables; wind contributes about 18%, with roughly an equal onshore/offshore wind split. Figure 1 shows the breakeven costs for these amounts of wind.

Figure D1. Breakeven costs for wind energy



Assumptions: Transmission and distribution costs, financing costs, capacity factors and operating costs are unchanged from reference 26. The price of carbon is taken as €25/tonne. It is assumed that installed costs offshore are 50% higher than onshore costs.

With 6% wind, and gas at 45p/therm, the graph indicates that the breakeven onshore cost is £970/kW (so offshore would be £1455/kW). If wind costs were less than this – wind energy would reduce electricity prices to consumers; if they are more, electricity prices increase. The breakeven prices are lower with 17% wind, as there is a higher proportion of offshore wind.

D3.1 Quantifying fuel price risks

Recent studies have attempted to quantify the value of the "price certainty" of wind energy – once the plant is built, the generation costs are virtually fixed, and there is no danger of costs escalating due to the highly volatile nature of fossil fuel prices. By contrast, future fossil fuel prices have recently become even more uncertain. The US Department of Energy, for example, notes that its latest projection (February 2006) of the 2025 oil price is $21/barrel higher than its estimate 12 months ago[30].

Shimon Awerbuch at the University of Sussex suggests that the most logical way to deal with "fuel price risk" is to add a premium to the observed gas prices[31]. Awerbuch argues that standard, finance valuation models show that the generation cost for many renewables is less than gas-fired electricity. Adding renewables to a fossil-generating portfolio reduces overall generating cost as well as risk. This result derives from basic portfolio theory, as renewables have zero-beta "systematically riskless" costs. Properly adjusted for market risk, the cost of gas-based generation is 60-100% higher than widely believed. Adding renewables, he argues, enhances energy diversity and security.

An analysis from the Lawrence Berkeley National Laboratory at the University of California have used similar reasoning[32], linked to the differences between market prices and long-term contracts, although their latest "price premium" for gas-fired generation costs is quite modest – about £4/MWh. In other words, generation cost estimates for gas, based on current price forecasts, are likely to be optimistic by about £4/MWh.

An additional factor that may be difficult to quantify is the impact that wind may have on gas prices, by reducing the demand. Taking this into account, the Union of Concerned Scientists has estimated that increasing the generation from wind and other renewables in America from 2% to 20% by 2020 would reduce gas used by 6% and save consumers nearly $27 billion[33]. If wind energy were to supply 15% of UK electricity demand by 2020 that would reduce gas demand by about 10%, based on the current level of consumption, and assuming wind plant inhibited the construction of new gas plant.

Another angle on the "additional value" of renewables comes from consultants Oxera, who estimated the value attached to security of supply as the dependency on imported gas increases. Drawing on data from the insurance market, they estimated the possible number of supply interruptions and the implications as far as electricity generation shortfalls[34]. In order to translate these to monetary estimates, it was necessary to assume a "Value of Lost Load". This is a fairly standard concept in electricity studies, although the exact levels vary. The study used a value of £3,000/MWh. The security of supply benefit, in a system with 14,200 MW of wind (just over 10% of UK supply) was £5.1/MWh.

D4 References

1 European Wind Energy Association, 2006, *Europe's Energy Crisis – the No Fuel Solution*

2 Source: IDAE (Institute for the Diversification and Saving of Energy), quoted on Renewable Energy and Energy Efficiency Partnership web site, www.reeeep.org

3 Subsidy cut sees trading surge – Power sales switch, *Windpower Monthly News Magazin*e, February, 2005:24

4 Doing big business in Portugal at last – Red tape barriers demolished, *Windpower Monthly News Magazine*, March, 2004:66

5 American Wind Energy Association, *Wind Energy Weekly* #1161 (30 September 2005), Turbine supply constraints won't ease soon, experts say

6 Energy Information Administration, US Department of Energy, 2006, *Annual Energy Outlook 2006*, With Projections to 2030. DOE/EIA-0383(2006)

7 Lonker, O and May, H, 2005, All aboard! *New Energy*, October

8 Danish Energy Authority, 2005, *Offshore Wind Power – Danish Experiences and Solutions*

9 Sustainable Development Commission, 2005, *Wind power in the UK*

10 Coulomb, L and Neuhoff, K, 2005, *Learning curves and changing product attributes: the case of wind turbines*, Faculty of Economics, University of Cambridge, paper eprg0601

11 Ragwitz et al, 2005, *FORRES 2020: analysis of the renewable energy sources evolution up to 2020,* European Commission, Directorate General for Energy and Transport

12 Garrad Hassan and Partners, 2003, *Offshore wind: economies of scale, engineering resource and load factors*, Department of Trade and Industry/Carbon Trust

13 Brocklehurst, F, 1997, *A review of the UK onshore wind energy resource*, ETSU-R-99

14 Department of Economic Development, 1993, *Prospects for Renewable Energy in Northern Ireland*

15 Scottish Hydro-Electric Plc, Scottish Power Plc, Department Of Trade And Industry, Scottish Office, Scottish Enterprise and Highlands and Islands Enterprise, 1993, *An Assessment of the Potential Renewable Energy Resource in Scotland*

16 Garrad Hassan and Partners, 2001, *Scotland's renewable resource*, Report for Scottish Executive

17 British Wind Energy Association, 2005, *Onshore Wind Energy in the UK: Meeting the 2010 Target*. Supporting documentation

18 Milborrow, D.J., Moore, D J, Richardson and Roberts, S C, 1982, *The UK offshore windpower resource. Proc 4th International Symposium on Wind Energy Systems, Stockholm*. BHRA

19 Westwood, A, 2006. Rising costs, *ReFOCUS*, January/February 2006

20 Gipe, P, 2004, *Wind power*, James and James (Science Publishers) Ltd, London, Correlated with data from seven manufacturers of micro wind turbines

21 Energy Saving Trust, Econnect and Element Energy, 2005, *Potential for micro generation: study and analysis*

22 Dutton, A, Halliday, J and Blanch, M, 2005, *The feasibility of building-mounted/integrated wind turbines*, Part-funded Carbon Trust project

23 Carbon Trust, 2006, *Future Marine Energy*

24 Ibid

25 DTI, 2006, *UK Energy and* CO_2 *Emissions Projections: Updated Projections to 2020*

26 Dale, L, Milborrow, D, Slark, R and Strbac, G, 2003, A shift to wind is not unfeasible, *Power UK*, Issue 109, 17-25

27 DTI, 2005, *RETS Revisited. Connecting Renewables to the Grid – A Report by the Transmission Working Group of the Department of Trade & Industry*

28 Milborrow, D, 2005, Wind and gas – the gap narrows, *Power UK*, Issue 134, 11-14

29 Sustainable Development Commission, 2005, *Wind Power in the UK*

30 Energy Information Administration, US Department of Energy, 2006, *Annual Energy Outlook 2006, With Projections to 2030*, DOE/EIA-0383(2006)

31 Awerbuch, S and Berger, M, 2003, Applying portfolio theory to EU electricity planning and policy-making, *IEA Report EET/2003/03*

32 Bolinger, M, and Wiser, R, 2005, *Comparison of natural gas price forecast to futures prices*, Ernest Orlando Lawrence Berkeley National laboratory, (Includes references to other papers on the topic)

33 Deyette, J and Clemmer, S, 2004, Renewable energy can help ease natural gas crunch, *Global Windpower 2004 Conference, Chicago*, American Wind Energy Association

34 Oxford Economic Research Associates, 2001, *The non-market value of generation technologies*

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