

# OFFSHORE RENEWABLES: THE POTENTIAL RESOURCE



# 2

# OFFSHORE RENEWABLES: THE POTENTIAL RESOURCE

This chapter describes the components of a wind, wave or marine current installation. It also provides estimates of the potential wind resource around the coast of England, Wales and Scotland. The prospects are shown for wind resources only, because wind generation is technically and commercially much further advanced than wave and current devices. The latter are operating or planned as demonstration plant, for example Wavegen's demonstration wave power station on Islay (operating), and Marine Current Turbine Ltd's prototype underwater turbine (planned) off the North Devon coast, but it will be a number of years before commercial plant are in production. Until then, the efficiency, size and operating conditions for the plant are especially uncertain, and any resource assessment would be highly speculative.

## 2.1 A typical wind farm and other renewables

The typical offshore wind farm has several components, as shown in Figure 2.1. The turbine is mounted on a tower, which is in turn mounted on a platform connected to the foundations. The foundations may be a monopile sunk into the seabed, an anchored tripod, or a caisson (basket) filled with aggregate. The foundations may themselves be surrounded by rocks which protect them from the scouring action of currents. A network of cables connects the individual turbines to a separate platform containing electrical switchgear and transformers which condition the power ready for transmission, along a cable to an onshore sub-station. From the sub-station the power is conveyed directly into the onshore network.

Figure 2.1: The components of a typical wind farm

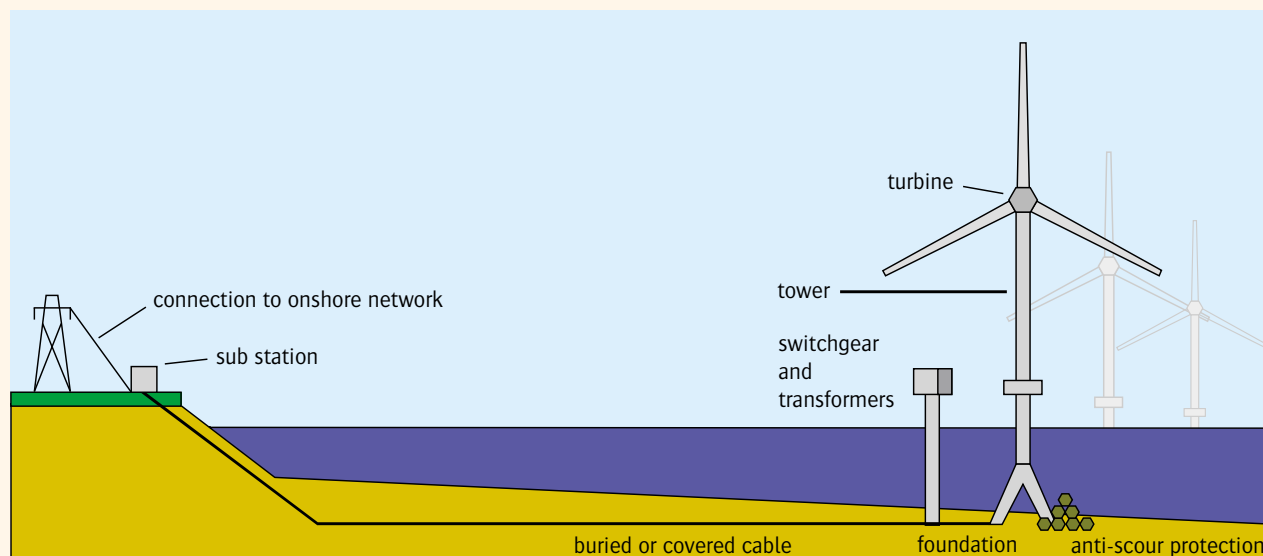
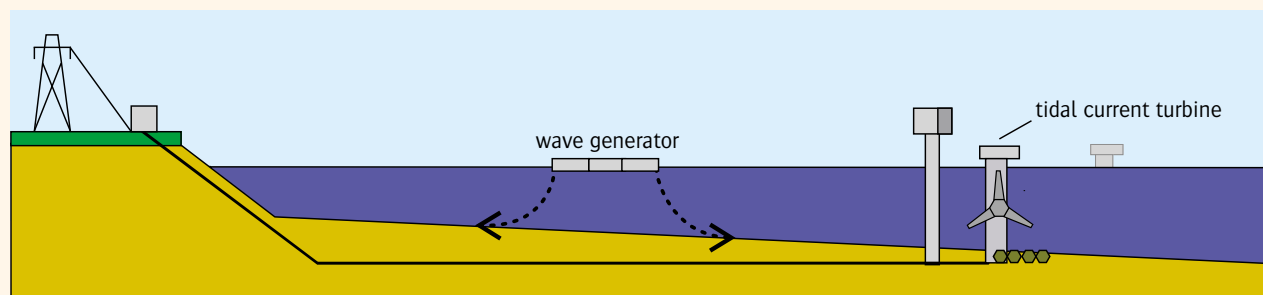


Figure 2.2: Wave and tidal current generation

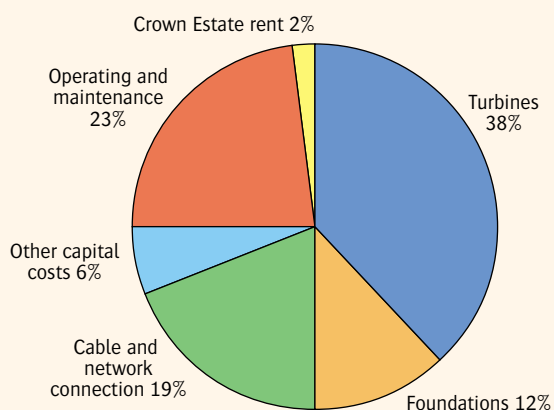


Other marine renewables may share similar electrical infrastructure. Figure 2.2 shows possible arrangements for wave and tidal current machines.

## 2.2 Cost comparisons

The approximate costs of a new wind farm are shown in Table 2.1 and Figure 2.3. About 75% of the cost of electricity generation is the capital cost of construction, and of that, about half is the cost of the turbine. The remaining main elements are the tower and the electrical infrastructure. These figures were calculated by applying the cost distribution reported by Concerted Action on Offshore Wind Energy<sup>12</sup> to a figure of £1m/MW for the capital costs of an offshore wind farm. Assuming a cost of finance of 10% and a load factor of 35% (average power output divided by maximum power output), or a cost of finance of 12% and a load factor of 40%, and depreciation charged over 20 years, the total cost of electricity is about £50/MWh.

**Figure 2.3: Breakdown of the costs of a typical (100MW) offshore wind farm within territorial waters**



**Table 2.1: Estimated costs for a hypothetical UK offshore wind farm**

Hypothetical UK wind farm	
<b>General information</b>	
Capacity (MW)	100
Load factor (%), (a)	35
Depreciation period (years)	20
Cost of capital (%)	10
Capital cost per MW (£m)	1
<b>Investment cost for 100MW installation (£m)</b>	
Turbines	51
Foundations	16
Cable and network connection	25
Other capital costs	8
Total (b)	100
Annuity, per annum, (c) = calculated from (b)	12
MWh per MW per annum, (d) = $24 \times 365 \times (a)$	3,066
Capital costs, £/MWh, (e) = (c) / (d)	38
<b>Total unit costs (£/MWh)</b>	
Capital costs, (e)	38
Operating and maintenance	12
Crown Estate rent	0.88
<b>TOTAL</b>	<b>51</b>

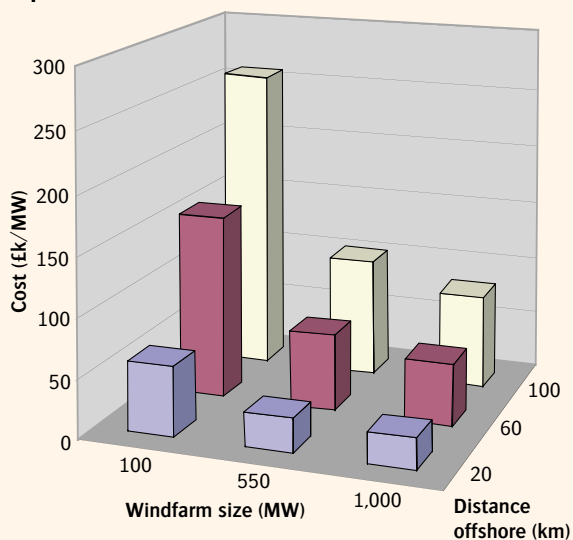
<sup>12</sup> A consortium consisting of developers, utilities, consultants, research institutes and universities, and funded by the European Commission.

## THE DISTANCE OFFSHORE

The costs will vary from site to site, depending on the seabed geology, the depth of the water and the distance from shore. The latter cost factor is particularly influential in the overall cost of smaller and medium scale installations. Figure 2.4 shows indicative costs of cabling per MW for a range of wind farm sizes and distances from shore. It shows that there are substantial economies of scale, with savings of 10% on the overall capital cost per MW if the electrical infrastructure carries 500 MW or greater over distances of more than 20km offshore.

The figure also shows that for greater distances, economies of scale in the size of the installation are more important. For a 1,000MW installation, the extra cabling cost of a location 100km offshore relative to one 20km offshore would only be in the order of 5% of the overall capital cost. It is therefore likely that the industry could consider potential sites well outside territorial waters, and perhaps as far as 100km offshore.

**Figure 2.4: Indicative costs of cabling, losses and electrical infrastructure using alternating current cable export solutions**



Note: These cost estimates are illustrative. The actual costs will depend on the site conditions. For the 1,000MW installation at 100km, a high voltage direct current cable solution may be preferred.

Source: Cost data supplied by National Grid. Paul Neilson, National Grid, presentation to BWEA Conference, 3rd October 2002.

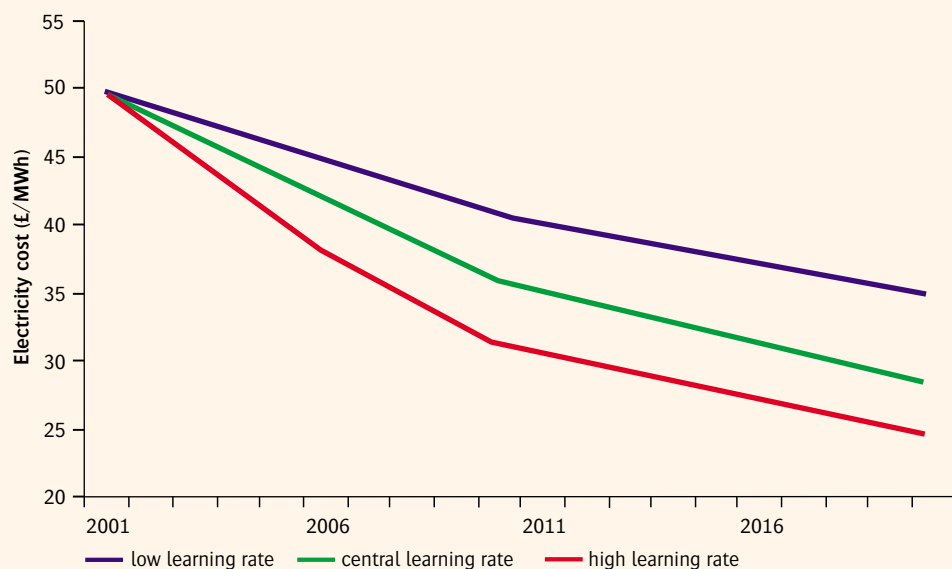
Compared with the costs of electrical infrastructure, less is known about the operating and construction costs further out to sea. An important factor is sea depth. In the first round of applications for sites, all the developers applied for sites with water depths not exceeding 17m. Most effort in mapping potential sites has focused on depths of up to 30m. However, it is expected that sites in depths of up to 50m may soon become technically feasible, although there will be higher costs associated with working in deeper waters. Already, one developer is examining a site with a water depth of 40m.

## FUTURE COSTS

Predictions can be made of the potential costs of electricity generation from offshore wind one or two decades into the future. One method is to use typical patterns of changes in unit costs observed across a range of technologies (known as learning curves) and apply them to scenarios of offshore wind farm build across Europe, as shown in Figure 2.5. Although this methodology may not be particularly accurate it does provide a useful basis for future cost predictions, suggesting that the cost of offshore wind farms could fall by up to 50% over the next 20 years, to between 20 and 30 £/MWh.<sup>13</sup> This compares to a current new build cost for combined cycle gas turbines of 18-24 £/MWh. Some of the predicted cost reduction might arise from economies of scale in manufacture, and some from improved designs, techniques and materials.

<sup>13</sup> Performance and Innovation Unit (2002), The Energy Review.

**Figure 2.5: Scenarios for future offshore wind costs**



Note: These scenarios are based on 'learning curves', which postulate that costs will fall as cumulative capacity increases.  
Source: OXERA; for research on learning curves see IEA (2000), 'Experience Curves for Energy Technology Policy', and Roberts, P. (1983), 'A Theory of the Learning Process', Journal of the Operational Research Society, 24, pp. 71-79.

## 2.3 Development of the UK industry- the first round

In December 2000, the Crown Estate invited potential offshore wind farm developers to apply to explore and then develop sites. Applications were restricted to sites of no more than 10km<sup>2</sup>, and to a maximum of 30 turbines. Some of those developers have now completed their site surveys and consent applications, and the first consents were issued in April 2002. Figure 2.6 shows the distribution of proposed sites around the coast.

## 2.4 Potential resource around England, Wales and Scotland

There is no doubt that there is a vast renewable energy resource in the marine environment available to be tapped.<sup>14</sup> The Crown Estate and the BWEA have brought together in a Geographic Information System database (Windbase)<sup>15</sup> many of the factors that will have a key role in affecting the development of the offshore wind farm industry. The data sets include the depth contours around the UK, current sea use and environmental factors. It appears clear, however, that sea depth will be a major factor affecting economic viability and for the next few years the majority of development will be concentrated in the area between 5m and 30m. The map from Windbase overleaf shows the resource between 5m and 30m water depth, and between 30m and 50m, both within and outside territorial waters.

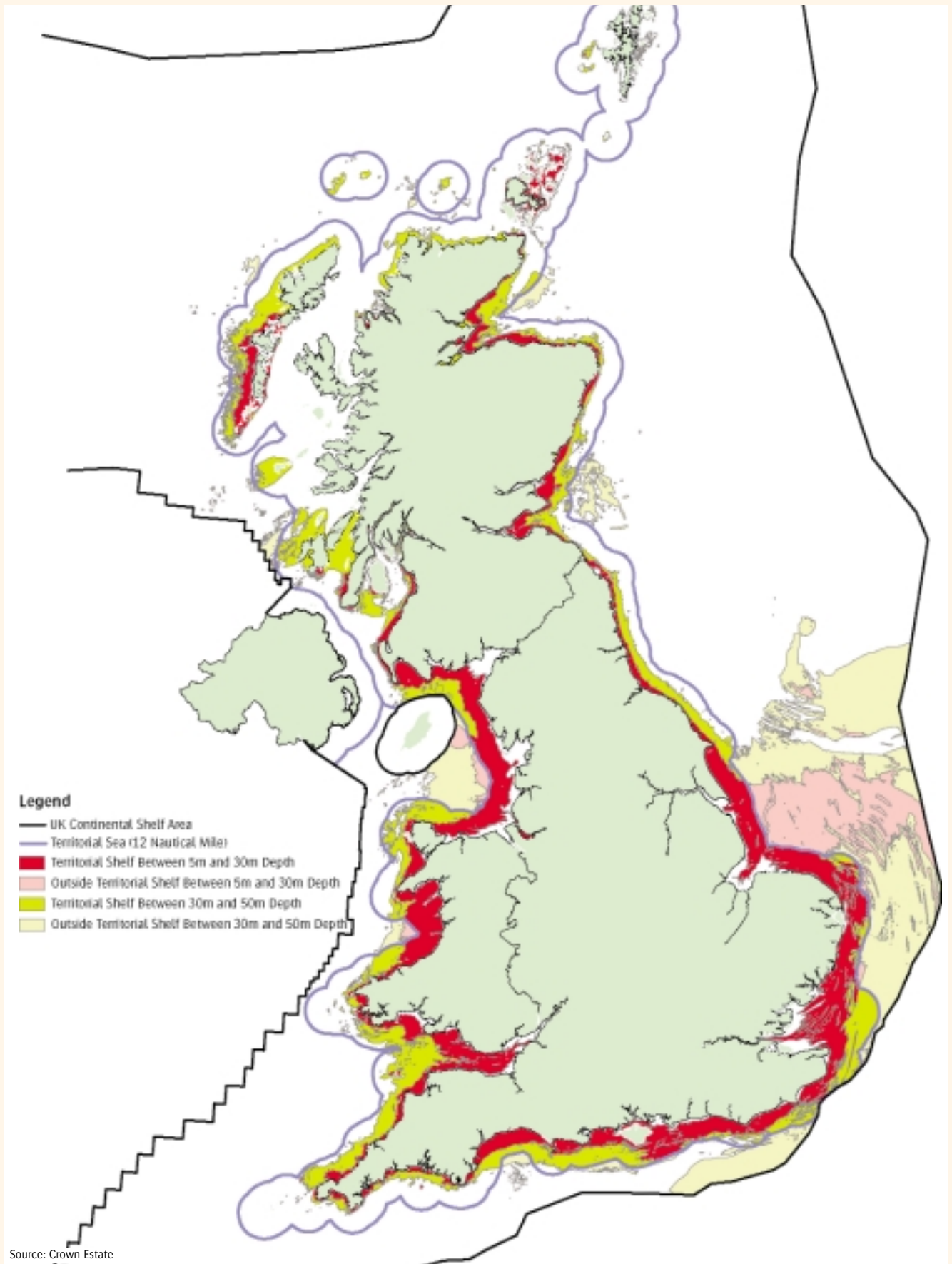
<sup>14</sup> The technically accessible wind resource alone was estimated to be 100 TWh/yr at under £45/MWh in 2010, ETSU (1999). The House of Commons Science and Technology Select Committee's Seventh Report, Wave and Tidal Energy, 2001, quoted resource estimates of 50 TWh/yr from offshore wave and 36 TWh/yr from tidal generation. The PIU's Energy Policy Review paper suggested a resource potential of 700 TWh/yr from wave and tidal power. Earlier this year, Greenpeace suggested that 30 GW of offshore wind capacity might be possible by 2020.

<sup>15</sup> Windbase can be accessed on the Crown Estate website at [www.crownestate.co.uk](http://www.crownestate.co.uk)

Figure 2.6: The first round of proposed offshore wind installations.



**Figure 2.7: Prospective areas for offshore wind installations**



Source: Crown Estate

These mapping data have been converted into potential energy resources, as shown in Table 2.2. The table identifies the potential resource available in the three strategic areas proposed for the next rounds (identified in Figure 4.1 and discussed in section 4.3.3), as well as the total resource of sea-bed which is assumed to be suitable (essentially on the basis of depth) for offshore wind farms. The area calculations exclude the region within the 5km coastal zone. This is purely an indicative assumption that large scale development very close to the coast is likely to prove more contentious than proposed development further offshore. For all regions, the potential resource is separated into the area available within territorial waters, and the potential resource beyond the territorial water limit.

Whilst these numbers indicate a vast potential overall, they should be interpreted purely as indicative of the general regions where development is likely, rather than indicating the scale of development actually possible. To date, technology has only been tested in

sea depths of 15m, so there will inevitably be an element of speculation as to the scale of development which might ultimately be feasible in sea depths of 30m or 50m. It should also be recognised that no assumptions have been made about the potential conflicts of interest or environmental impact, and how these factors might influence the amount of development which might be successful in gaining development consent.

A further factor that will influence the development of offshore renewables will be the availability of network connections onshore to export the power to centres of demand. No assumptions have been made here of the effect network constraints will have on the scale of development possible (although section 8.5 refers to a study which has estimated the potential capacity which could be accommodated in these three strategic regions without incurring major network reinforcement).

**Table 2.2: Potential offshore wind generation resource in proposed strategic regions**

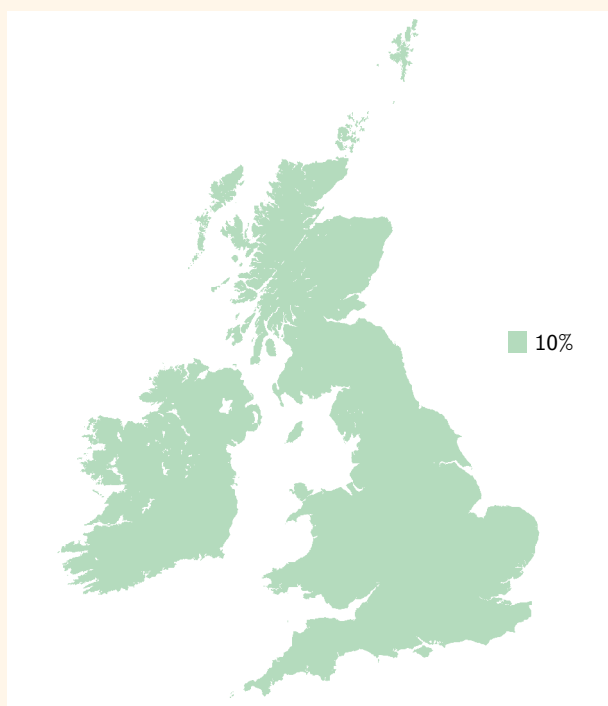
Water depths	5 to 30 metres				30 to 50 metres				
	Region	Area Sq.km	%	MW	TWh/yr	Area Sq.km	%	MW	TWh/yr
<b>Within territorial waters</b>									
North West	2,748	17	32,976	115	634	3	7,608	27	
Greater Wash	2,037	12	24,444	85	202	1	2,424	8	
Thames Estuary	2,068	12	24,816	87	812	4	9,744	34	
Other	9,769	59	117,228	410	18,371	92	220,452	771	
Sub-total	16,622	100	199,464	697	20,019	100	240,228	840	
<b>Outside territorial waters</b>									
North West	597	6	7,164	25	1,433	5	17,196	60	
Greater Wash	5,354	50	64,248	225	744	3	8,928	31	
Thames Estuary	31	0	372	1	36	0	432	2	
Other	4,662	44	55,944	196	27,070	92	324,840	1,136	
Sub-total	10,644	100	127,728	447	29,283	100	351,396	1,229	
<b>All waters</b>									
North West	3,345	12	40,140	140	2,067	4	24,804	87	
Greater Wash	7,391	27	88,692	310	946	2	11,352	40	
Thames Estuary	2,099	8	25,188	88	848	2	10,176	35	
Other	14,431	53	173,172	606	45,441	92	545,292	1,907	
<b>TOTAL</b>	<b>27,266</b>	<b>100</b>	<b>327,192</b>	<b>1,144</b>	<b>49,302</b>	<b>100</b>	<b>591,624</b>	<b>2,069</b>	

Despite these provisos, the numbers presented in Table 2.2 clearly indicate the potential importance of different regions for offshore wind farm development. In particular, the significance of the Greater Wash area, both within and beyond the limit of territorial waters, is apparent. This highlights the need for legislation to enable the full potential to be realised.

The potential generating capacities of the offshore areas have been calculated assuming that 3MW turbines are installed at a separation of 500m. The output has been estimated assuming a load factor of 40%.

The total figures of 919 GW and 3,213 TWh/yr indicate a vast potential compared with the 2010 renewables target of 10% of electricity supplied, equating to 33.6 TWh/yr.<sup>16</sup> Despite the considerable potential for expansion of the offshore wind farm sector, the total area of the seabed which might be devoted to power generation from wind energy would be small compared to the total size of the UK's marine resource, as shown in Figure 2.8.

**Figure 2.8: Area required to generate 10% of UK electricity demand**



<sup>16</sup> DTI (2001), *New and Renewable Energy: Prospects for the 21st Century: The Renewables Obligation Statutory Consultation*

## 2.5 Offshore developments in Scotland, Wales and Northern Ireland

### SCOTLAND

Under the devolution arrangements, the responsibilities of the Scottish Executive (and the Welsh Assembly Government) extend to adjacent waters as far as the 12 nautical mile limit.

In round one, two adjacent sites at Robin Rigg in the Solway Firth are within Scottish waters and applications for consent are being dealt with by the Scottish Executive.

Scotland has huge natural wind resources which are discussed in the Scottish Executive's recent consultation paper, "Scotland's Renewable Energy Potential - Beyond 2010". Developers are currently considering a number of large wind farm projects in Scotland with aggregate capacity well in excess of 2 GW. All these projects are onshore, or on offshore islands. Less attention is being devoted by developers to offshore projects in Scottish waters, although one major project is being considered on the site of the Beatrice oilfield beyond the territorial limit in the Moray Firth.

An important issue is the need for reinforcement of the grid infrastructure to accommodate a significant increase in renewable energy. This has been examined by the DTI co-ordinated Transmission Issues Working Group and follow-up discussions are taking place between the transmission system operators and Ofgem.

The Scottish Executive has devolved responsibility for the promotion of renewables in Scotland as well as consents under Section 36 of the Electricity Act - see Chapter 7 - and some of the other policy matters discussed in this document. Consequently, appropriate devolution arrangements, taking account

of existing devolved responsibilities, will need to be considered in the context of developing a comprehensive framework of law for developments beyond territorial waters in Scotland.

## WALES

There are three projects in Welsh waters under round one, at North Hoyle (off Prestatyn) and Rhyl Flats (off Abergele), both on the North Wales coast, and at Scarweather Sands (off Porthcawl) on the South Wales coast. With a total capacity approaching 300MW they will make a major contribution to the development of the renewable energy sector in Wales and will help to meet the Assembly Government's objective of establishing Wales as a showcase for clean energy developments.

Offshore wind is likely to feature strongly in the Assembly Government's future energy policy for

**Blyth offshore wind farm**



Wales which will be informed by the Economic Development Committee's current energy review. An integrated policy approach is being followed which aims to secure benefits from better relationships between developers, local authorities, community groups and economic development and environment agencies, and to ensure that in future clean energy developments are acceptable to the communities on which they impact.

Wales' extensive coastline offers potential locations for other offshore generation technologies such as tidal stream, wave, and tidal barrage (including the possibility of a major barrage across the River Severn).

The DTI currently acts as the co-ordinating body to facilitate the processing of the consents procedures for offshore wind farms in Welsh waters and is responsible for section 36 consents. The Assembly Government is formally consulted as part of this process. It has specific devolved responsibilities for Planning and Environmental issues under the Town and Country Planning Act 1990, and is also the authorising body in respect of the Food and Environment Protection Act 1985 and the Transport and Works Act 1992. Discussions on the possible wider transfer of energy functions to the Assembly are taking place.

## NORTHERN IRELAND

In June 2002 the Crown Estate granted a lease to a consortium to assess the technical and financial feasibility of developing a 28km<sup>2</sup> seabed site on Tunes Plateau, 5 kilometres off the coast of Northern Ireland. The site has the capability to hold up to 85 turbines producing up to 250MW. In tandem with the feasibility studies, the consortium will work through a detailed environmental impact assessment with a view to applying for statutory consent under Article 39 of the Electricity (Northern Ireland) Order by June 2003. If the project gains consent, it is anticipated that the first phase of turbines will be generating renewable electricity for Northern Ireland by 2005.

Wind will be a key feature of renewable energy policy in Northern Ireland and offshore wind has the potential to play a major role, subject to all the environmental concerns being adequately addressed.

Work is also underway to assess the potential of 11 sites in the waters off Northern Ireland identified as possessing significant tidal stream flows. It is possible that future development of these sites could utilise marine current turbines and wind turbines on the same foundation.

## 2.6 Progress in other countries

### REPUBLIC OF IRELAND

The Republic of Ireland is pushing ahead with the development of offshore wind installations. The Government has set out a policy framework and Airtricity, a wind energy company, is planning the construction of the world's largest offshore wind farm.

The process for developers was set out by the government in July 2000. There are two distinct phases for offshore wind projects:

- Phase 1-investigation of site suitability, including an environmental impact assessment (EIA); and
- Phase 2-construction and operation, requiring a full environmental impact statement (EIS) and full public consultation.

Airtricity's planned wind park will consist of 200 turbines with a nominal output of 520MW, which will eventually provide over 10% of the country's electricity requirements. The park will be built on a sandbank 7km off the coast of Arklow in County Wicklow. Airtricity has completed extensive site investigations and studies, and was granted a Foreshore Lease by the Department of Communications, Marine and Natural Resources in January 2002. Construction is anticipated by 2007, and the project is expected to cost €650m.

In addition to this development, a number of other consortia have been awarded licences to investigate the suitability of sites for wind energy production.

## OTHER EU COUNTRIES

The European Union plans to increase the share of renewable energy to 12% by 2010. Offshore wind could make a significant contribution to achieving this target. This is illustrated by figure 2.9 which shows estimates of the resource in some European Union countries taken from a recent study funded by the European Commission.

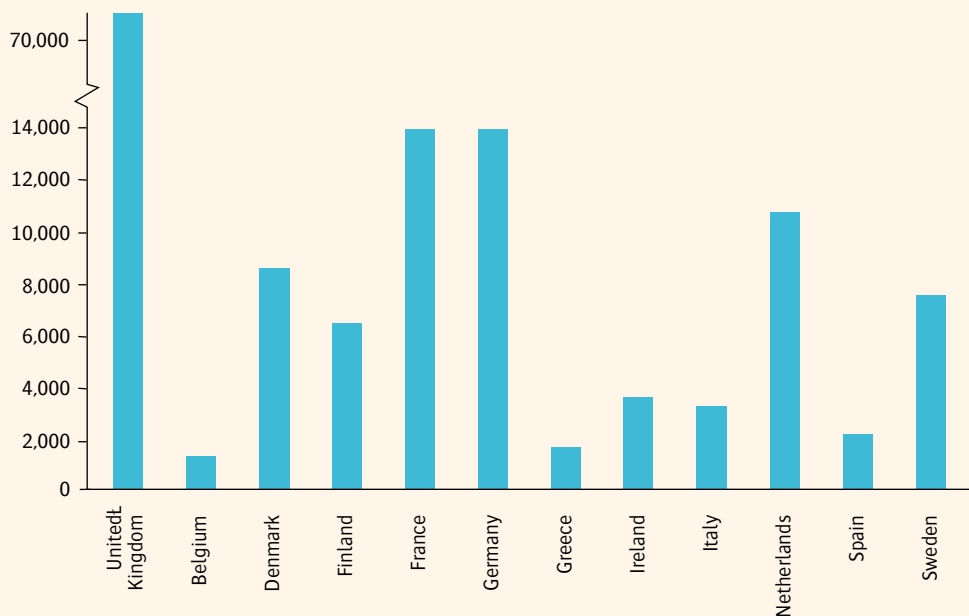
The German government has a target to double the share of renewable energy by the year 2010, implying that renewable energy will make up 12.5% of the total energy generation by 2010. The onshore wind sector has developed rapidly, although the Government anticipates that the rate of growth will slow within a few years.

In January 2002, the German government published a strategy on offshore wind. At the time, it had received applications for 29 wind farms in the German Exclusive Economic Zone (EEZ) - comprising 22 applications in the North Sea and 7 in the Baltic Sea-

in addition to several planned wind farms in German coastal waters. The strategy discussed an ambitious long-term vision which would see 20 to 25GW of installed offshore wind power in the coastal waters and EEZ, amounting to 15% of energy consumption.

Denmark has led the European field with a 40 MW offshore wind farm already in operation at Middelgrunden, a large scale development recently operational at Horns Rev, and further plans for large scale developments at Roedsand, Oeme and Laeso. Meanwhile, in Belgium, there is one offshore wind farm planned, and another project has been turned down.

**Figure 2.9: Offshore wind resource estimates for EU countries (MW)**



Source: Concerted Action on Offshore Wind Energy<sup>17</sup>.

<sup>17</sup> From Concerted Action on Offshore Wind Energy website <http://www.offshorewindenergy.org/>