Accelerating Deployment of Offshore Renewable Energy Technologies

Final Report Appendix E

February 2011
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</table>
Appendix E. Country Profiles

E.1. Introduction

This Appendix outlines the country profiles of the 18 countries in terms of the current industry context. The list of countries is shown in Table E.1 below.

Table E.1: Countries covered by study

<table>
<thead>
<tr>
<th>RETD Countries</th>
<th>Other Countries of Interests</th>
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</thead>
<tbody>
<tr>
<td>Canada</td>
<td>Belgium</td>
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<tr>
<td>Denmark</td>
<td>Finland</td>
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<td>Taiwan</td>
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<td>Netherlands</td>
<td>Portugal</td>
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<tr>
<td>Norway</td>
<td></td>
</tr>
<tr>
<td>UK</td>
<td></td>
</tr>
</tbody>
</table>

For each country, an overview of the following areas is provided, including:

- Offshore Wind Resource;
- Wave Resource;
- Tidal Resource;
- Processes for Permitting, Licensing and Allocating Seabed Rights;
- Support Mechanisms for Project Deployment;
- Support Mechanisms for Development of Technologies;
- Other Support Initiatives (where applicable); and
- Deployment.

The references given correspond with the full reference list provided in the main report.
E.2. Canada

E.2.1. Offshore Wind Resource

Canada has a good coastal and offshore wind resource as shown in Figure E.1. The near shore wind resource is characterised by a mean wind speed of 6 m/s and above. Offshore wind speed is approximately 8 m/s and above. Wind speeds at the southern regions of the Atlantic and Pacific coasts tend to be lower than in the north.

Figure E.1: Canadian Wind Energy Atlas, Mean Wind Speed 50 m above Ground


E.2.2. Wave Resource

Assessments of the yearly wave energy flux suggest that Canada has a relatively intense wave climate at both the West and East coast. Depending on the locations and the distance from shore, 40 to 60 kW/m can be achieved\(^1\). Monthly variation of the wave regime have been analysed by the Canadian Hydraulics Centre drawing on a range of measurement positions in water depth greater than 200 m. These assessments suggest that wave energy is highest during winter times (November to March) and lowest during the summer months. The distribution of wave energy in water depth shallower than 200 m is noted to be poorly assessed to date\(^2\).

\(^1\) Fugro Oceanor (2008)
\(^2\) Cornett (2006)
Figure E.2: Mean Annual Wave Power for Canada’s Coasts

Mean annual wave power in the NE Pacific derived from WW3-ENP hindcast data. Mean annual wave power derived from AES40 hindcast data.

Source: Canadian Hydraulics Centre, Cornett, 2006

Figure E.2 shows the distribution of wave energy at the East and West coast of Canada. The mean annual wave energy flux at exposed sites in deep water off the eastern coast is in the range of 45 to 55 kW/m. Near shore the mean power available is in the order of 30 to 45 kW/m. At the east coast, the energy flux is in the range of 42 to 45 kW/m with a near shore intensity of around 25 to 30 kW/m. The annual mean wave power off Canada’s Pacific coast along the 1,000 m isobath is estimated to be around 37 GW. Equally, for Canada’s Atlantic coast around 146 GW is estimated\(^3\).

E.2.3. Tidal Resource

While wave energy is available throughout the ocean in varying intensity, tidal energy is varying largely and its force is amplified by bathymetry and coastal features. The maps of the east and west coast of Canada shown in Figure E.3 indicate some sites with good to high energy potential for a tidal energy scheme. According to assessments undertaken, Canada has a potential tidal current energy resource of 42,240MW\(^3\).

\(^3\) Cornett (2006)
A number of potential sites with a size of above 1 MW are shown in Figure E.4. Overall, the realisation of all 191 proposed schemes with an average size of 221 MW would lead to a total capacity of 42,240 MW⁴.  

⁴ Cornett (2006)
E.2.4. Government Bodies for Permitting, Licensing and Allocating Seabed Rights

The Government department for Fisheries and Oceans in Canada collaborates with other federal departments and coastal provinces regarding ocean energy developments.\(^5\)

For offshore renewable energy projects located within provincial boundaries, the provinces have primary responsibility for permitting and managing projects (e.g. land tenure, electricity regulation). The federal government is responsible for regulating activities under its jurisdiction (e.g. fisheries, navigable waters).

Offshore renewable energy projects located outside the boundaries of the province are subject to a federal land tenure authorization, which is administered by Natural Resources Canada.

\(^5\) Fisheries and Oceans Canada (2010)
E.2.5. Support Mechanisms for Project Deployment

Canada has an incentive payment scheme at federal level. The ecoENERGY for Renewable Power program was established in 2007 and provides an incentive of CDN 1 cent/kWh (0.64 €cent/kWh) for up to 10 years for electricity generated from eligible renewable energy projects commissioned between 1 April 2007 and 31 March 2011. Some individual provinces have also legislated renewable portfolio standards, use procurement mechanisms, such as calls for power and requests for proposals, while others established or intend to establish renewable feed-in-tariffs (FITs) programs. Ontario's FIT program was introduced in October 2009. The tariffs provided are intended to cover total project costs and provide a reasonable rate of return over a 20-year contract for most technologies, and 40 years for waterpower.  

E.2.6. Support Mechanisms for Development of Technologies

The national ecoENERGY Technology Initiative is a CAD 230 million investment in clean energy RD&D programme to support the development of next-generation energy technologies. It is a five-year programme which runs until 2012. It includes funding for offshore wind and ocean energy technology RD&D.  

Introduced in 2009, the Clean Energy Fund aims to reduce greenhouse gas emissions through green technology demonstration. The Fund will invest $795 million for large scale carbon capture and storage demonstrations, including renewable and alternative energy technologies. Three carbon Capture projects have been announced totalling $466 million. In January 2010, 19 successful projects were announced in response to a call for proposals under the Renewable and Clean Energy portion of the Fund and up to $146 million will be invested in these projects over five years.  

E.2.7. Other Support Initiatives

Another initiative that supports the offshore energy sector in Canada is the Ocean Energy (OE) Atlas project, which was established in 2005 after recognition that development of a comprehensive assessment of Canada's marine resources was a fundamental step towards the development of ocean energy in Canada. Funding for the first year was provided by the Technology and Innovation Research and Development Program, administered by Natural Resources Canada. The project maps, at a regional scale on an interactive digital website, Canada's renewable ocean energy resources.

E.2.8. Deployment

North America’s largest offshore wind project is proposed near British Columbia, totalling 1,750 GW and built over five phases. The first phase will comprise 110 3.6 MW Siemens turbines.

The Fundy Ocean Research Centre for Energy (FORCE), a public/private partnership in Nova Scotia, is developing a multi million dollar tidal pilot demonstration project in the Minas Passage of the Bay of Fundy.  

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6 IEA (2010)  
7 Invest in Canada (2010)  
8 Personal communication with Natural Resources Canada (2010)  
9 Canadian Hydraulics Centre (2006)  
10 EWEA (2010a)
This will be the first Canadian deployment of commercial-scale tidal turbines. It has been given US$ 70 million of funding and will comprise three large scale (1MW) machines. The project is expected for completion in 2010.\textsuperscript{11}

\textsuperscript{11} EPRI (2009)
E.3. Denmark

E.3.1. Offshore Wind Resource

Figure E.5 shows the Danish wind resource map. It is apparent that Denmark has a considerable wind resource with an average shoreline and offshore wind speed of above 7 m/s. The Danish offshore wind resource is estimated to amount to 8,000 MW or around 26 TWh/year with an additional 4,000 MW at water depth greater than 20 m\textsuperscript{12}.

\textsuperscript{12} Duwind (2001)
Figure E.5: Danish Wind Resource Map, 1999

Source: Risø DTU’s Wind Power Meteorology Programme and Energy & Environmental Data (EMD), Aalborg, http://www.emd.dk/Documentation/DK%20Wind%20Resource%20Map/
E.3.2. Wave Resource

While Denmark is located in a relative sheltered area of the North Sea, some locations in the North-western regions experience a relatively favourable wave regime with estimates of about 30 TWh/year\textsuperscript{13}. An assessment of specific sites in the Danish North Sea undertaken by Rambøll\textsuperscript{14} shows that wave energy flux is strongly dependent on water depth and therefore distance from shore. The wave energy flux at the selected sites varies between 7 kW/m for sites at water depth of 20 m and 24 kW/m at depth of 71 m. Measurements points are shown in Figure E.6.

Figure E.6: Overview of Assessed Locations in the Danish North Sea

| Punkt 1 | 7 | 94 | 20 | 0.7 |
| Punkt 2 | 11 | 100 | 31 | 8.4 |
| Punkt 3 | 16 | 150 | 36 | 9.6 |
| Punkt 4 | 17 | 150 | 40 | 9.3 |
| Punkt 5 | 14 | 100 | 50 | 11.4 |
| Punkt 6 | 11 | 60 | 166 | 10.6 |
| Flensborg | 7 | 4 | 20 | 8.4 |
| Esbjerg | 24 | 300 | 71 | 12.6 |

Source: Rambøll, Kortlægning af bølgeenergiforhold i den danske del af Nordsøen, 1999

E.3.3. Tidal Resource

No studies related to the Danish tidal resource have been available.

\textsuperscript{13} Marine Institute, Sustainable Energy Ireland (2002)
\textsuperscript{14} Rambøll (1999)
E.3.4. Processes for Permitting, Licensing and Allocating Seabed Rights

The Danish Energy Agency is the competent authority for offshore wind power projects in Denmark. It is responsible for approving new projects, as well as carrying out research on environmental impacts and future locations. It cites itself as a “one-stop-shop” for offshore wind permits, since it coordinates with other relevant authorities on the different permitting aspects. The permitting conditions for offshore farms are set by the Danish Electricity Supply Act of November 2008. There are two main ways to apply for an offshore wind permit: responding to a government call for tenders for development at specific sites, or through the ‘open-door procedure’ for other non-tendered locations.15

E.3.5. Support Mechanisms for Project Deployment

Denmark’s 2009 Promotion of Renewable Energy Act establishes FITs for renewable energy. Wind generation projects connected under the ‘open-door procedure’ receive a subsidy that amounts to around DKK 0.273/kWh (3.7 €cents/kWh) on top of the electricity market price, for power exported during the first 22,000 full load hours, which is equivalent to the order of 8 years operation at typical capacity factors and availabilities.15

Where offshore wind farms are developed following a call for tender, the State specifies the fixed electricity price in the call.15 The wind farm at Horns Rev 2, for example, will be provided a FIT that, when added to the market price of electricity, will amount to DKK 0.518/kWh (~7 €cents/kWh). For the wind farm at Rødsand 2, the total tariff (premium plus market price) will equal DKK 0.629/kWh (~8.4 €cents/kWh). A price supplement is also granted to cover payment of any feeding fee related to supplying electricity to the grid. The premiums apply to up to 10 TWh of electricity generation (depending on the specific contract terms) and for a maximum of 20 years after the wind farm has been connected to the grid.16 In February 2008, the Danish parliament set a target for a further 400 MW of offshore wind turbines to come online in 2012.17

For wave energy and other renewable technologies considered of strategic importance by the Danish government, the price received is DKK 0.60/kWh (8 €cents/kWh) for ten years from the date of grid connection, and DKK 0.40/kWh (5 €cents/kWh) for the next ten years.17

E.3.6. Support Mechanisms for Development of Technologies

In February 2008, the Danish government signed a broad-ranging energy agreement that ensures the development of renewable energy, increased energy efficiency and more research into energy technologies. However, limited publicly available information was found.

E.3.7. Deployment

In 2009, Denmark installed 98 offshore turbines, totalling 230 MW across 2 separate wind farms. This brought the installed total by the end of 2009 to 305 turbines, totalling 639.15 MW across 9 wind farms.18 Danish offshore wind farms are shown in Table E.2 and marine energy installations in Table E.3.

15 Danish Energy Agency (2010)
16 IEA (2010)
17 EREC (2009)
18 EWEA (2010a)
Table E.2: Danish Offshore Wind Farms

<table>
<thead>
<tr>
<th>Project</th>
<th>No of Turbines/Capacity</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Tunes Knob (1995)</td>
<td>10 turbines</td>
<td>5 MW</td>
</tr>
<tr>
<td>5. Renland (2003)</td>
<td>8 turbines</td>
<td>17 MW</td>
</tr>
<tr>
<td>8. Frederikshavn (2003)</td>
<td>3 turbines</td>
<td>7 MW</td>
</tr>
<tr>
<td>10. Avedøre Holme (2009/10)</td>
<td>3 turbines</td>
<td>10-13 MW</td>
</tr>
<tr>
<td>12. Redsand II (2010)</td>
<td>90 turbines</td>
<td>207 MW</td>
</tr>
<tr>
<td>13. Anholt (2012)</td>
<td>400 turbines</td>
<td>400 MW</td>
</tr>
</tbody>
</table>

Source: Danish Energy Agency (2010)

Table E.3: Danish Marine Energy Installations

<table>
<thead>
<tr>
<th>Stage</th>
<th>Capacity (kW)</th>
<th>Date commissioned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave Star</td>
<td>5.5</td>
<td>2006</td>
</tr>
<tr>
<td>Wave Dragon</td>
<td>20</td>
<td>n.c.</td>
</tr>
<tr>
<td>Poseidon</td>
<td>140</td>
<td>2008</td>
</tr>
</tbody>
</table>

Source: EurObserv'ER (2010)

Waveplane has also been tested at two separate sites in Denmark until August 2009. A DEXA Wave Energy model was also tested until October 2009 and an application for further testing until August 2011 is in process.19

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19 Danish Energy Agency (2009)
E.4.  France

E.4.1. Offshore Wind Resource

Figure E.7 shows that the Atlantic shores of France are exposed to a good wind climate with wind speeds of around 8 m/s at 50 m heights. At the Mediterranean coasts, the local phenomenon of the Mistral winds is evident which leads to a high wind resource particularly in comparison to other areas of the Mediterranean. Wind speeds at 50 m heights can exceed 8 m/s. France’s offshore wind resource at a water depth below 40 m and a distance from shore below 30 km has been estimated to amount to 13,000 MW and 44 TWh/year respectively\(^{20}\).

Figure E.7: European Wind Resource over Open Sea

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E.4.2. Wave Resource

Annual power levels at the Atlantic coast are suggested to range between 30 – 40 kW/m and up to 5 kW/m in the Mediterranean Sea\(^{21}\). The total resource is estimated to be approximately 28 GW\(^{22}\).

\(^{20}\) Duwind (2001)

\(^{21}\) Fugro Oceanor (2008)

\(^{22}\) Clement et al (2002)
E.4.3. Tidal Resource

While favourable locations might be present at the Atlantic Coast of France, no specific research has been identified.

E.4.4. Processes for Permitting, Licensing and Allocating Seabed Rights

The framework for undertaking offshore economic activity is not adapted to wind energy, and there is no specific legislative or administrative framework for offshore wind energy development in France. This has led to long delays to the first proposed offshore wind farm announced in 2005 (see below). Work has begun on simplifying offshore planning procedures in this regard, however.23

E.4.5. Support Mechanisms for Project Deployment

Since 2001, France has promoted renewable energy projects through a feed-in tariff (FIT) mechanism and a tender system for large projects. For offshore installations, there is a fixed tariff of 13 €cents/kWh for the first ten year period. The following ten years the tariff is set at 3 €cents/kWh for 3,900 hours (and more) and at 13 €cents/kWh for 2,800 hours (or less), with a sliding scale for amounts in between.24 For ocean energy, the tariff is fixed at 15 €cents/kWh for 20 years. Under the tender system, one offshore wind project (105 MW) was announced in 2005.25

In 2007, the French Syndicat des Energies Renouvelables (SER) suggested an offshore wind power capacity target of 6 GW by 2020.26

E.4.6. Support Mechanisms for Development of Technologies

In July 2008, a demonstration fund was created by three government ministries to provide €400 million over four years to help finance the development of energy technologies for which there currently is no viable market. The fund is a joint effort between the Ministry of Ecology, Energy, Sustainable Development and Territorial Planning; the Ministry of Higher Education and Research and the Ministry of Economy, Industry and Employment, and is managed by the French Environment and Energy Management Agency, ADEME. The fund targets manufacturers or public-private partnerships in need of financing for high-cost demonstration projects with experimental goals, for which market prospects are long-term.27

In July 2009, the fund issued a call for proposals in offshore energy demonstration projects. The call was open to tidal and wave, offshore wind, and ocean thermal projects. It closed on 15 October 2009.28 As of February 2010, the results have not been released.

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23 GWEC (2010)
24 DGEC (2010)
25 EREC (2009)
26 GWEC (2010)
27 IEA (2010)
28 ADEME (2009)
E.4.7. Deployment

Due to permitting problems delaying its first planned offshore wind farm, France currently has no offshore wind installations. The only non-barrage project includes a 10 kW Hydro-Gen marine device being tested since 2008.29

EDF, the leading electricity producer in France, plans a pilot tidal turbine system off the coast of Brittany. The project, consisting of 4 to 10 turbines, with a total capacity of between 2 and 4 MW will be sited at Paimpol-Bréhat (Côtes d'Armor). In October 2008, EDF stated that the company had appointed OpenHydro of Ireland to equip the demonstration tidal farm, which is scheduled to be connected to the grid from 2011 onwards.30

29 EurObserv'ER (2010)
30 WEC (2009)
E.5. Germany

E.5.1. Offshore Wind Resource

Germany’s coasts both in the North and Baltic Sea are exposed to considerable wind speeds above 8 m/s at 50 m heights (see Figure E.7). Estimates of the theoretical German offshore wind resource depend on the assumption of feasible water depth and distance from shore. The following estimates of have been made:

- Up to 10 m water depth and 10 km distance from shore = 20 TWh/year;
- Up to 20 m water depth and 20 km distance from shore = 130 TWh/year; and
- Up to 30 m water depth and 30 km distance from shore = 200 TWh/year.

Other estimates considering locations up to 40 m water depth and below 30 km distance from shore amount to an offshore resource of 13,000 MW and 45 TWh/year.

E.5.2. Wave Resource

Due to the sheltered location in the North Sea the German coast has a poor wave resource with below 10 kW/m wave energy flux.

E.5.3. Tidal Resource

The North Sea coast of Germany experiences tidal variations that have lead to the formation of the Wadden Sea, which is a strongly protected ecosystem. No tidal resource assessments regarding the potential energy output can be referenced.

E.5.4. Processes for Permitting, Licensing and Allocating Seabed Rights

The Federal Immission Control Act governs the licensing and construction of wind farms in coastal waters (up to 12 nautical miles from the coastline). The licensing procedure must be carried out by the competent immission control authorities in the relevant coastal states, including an environmental impact assessment and public participation. The construction and operation of offshore wind farms in the Exclusive Economic Zone, which comprises the marine territory beyond the coastal waters, is based on the Federal Maritime Responsibilities Act in conjunction with the Offshore Installations Ordinance. These state that the construction, operation and significant alteration of fixed or floating structural or technical equipment for the generation of energy from wind must be licensed by the Federal Maritime and Hydrographic Agency (BSH).

E.5.5. Support Mechanisms for Project Deployment

Under the new Renewable Energy Sources Act (EEG), implemented in 2009 and superseding the 2004 Act, electricity from offshore wind farms operational from January 2009 onwards has been guaranteed a feed-in-tariff (FIT) for 20 years at the levels shown in Table E.4. The rate will be kept constant from 2009 to 2014. From 2015 onwards it will be subject to an annual degression rate of 5%. The initial tariff is paid for

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31 BWE (2010)
32 Duwind (2001)
33 German Environment Ministry (2007)
the first 12 years after commissioning, but this can be extended depending on distance from the coast and water depth. In addition an ‘early bird bonus’ tariff is available for wind farms commissioned before 1 January 2016, paid for the duration of the initial tariff payment.34

Table E.4: Offshore Wind Energy German Feed-in-tariff

<table>
<thead>
<tr>
<th>Year</th>
<th>Initial tariff in €cents/kWh</th>
<th>Early bird bonus</th>
<th>Basic tariff in €cents/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>13</td>
<td>2</td>
<td>3.5</td>
</tr>
<tr>
<td>2010</td>
<td>13</td>
<td>2</td>
<td>3.5</td>
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<td>2014</td>
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<td>10.59</td>
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</table>

Source: German Environment Ministry, 2009

The German Environment Ministry estimates that by the end of 2011, a capacity of around 1,500 MW could be installed offshore. The German Government has a long-term target of up to 25,000 MW by 2030. The potential annual electricity yield from offshore wind farms is estimated at 85 to 100 TWh by 2030 accordingly. The Infrastructure Planning Acceleration Act, established in 2006, obligates grid operators to ensure grid connection for all offshore plants for which construction has commenced prior to 31 December 2011. This will allow the grid connections of the various offshore wind farms to undergo extensive optimisation.35

The German government has offered financial support in the form of dedicated funding for the offshore wind sector, such as through non-recourse loans to wind farms, provided by KfW Bankengruppe36.

E.5.6. Support Mechanisms for Development of Technologies

The German Environment has set up a renewable energies research programme, making €50 million available for research and development in the test field.38

E.5.7. Other Support Initiatives

Expert information platforms in the field of offshore wind power have been set up in Bremen, Lower Saxony, Schleswig-Holstein and Mecklenburg-Western Pomerania. They facilitate the exchange of information and experience between plant manufacturers, assembly firms, suppliers, port management companies, shipbuilders and logistical specialists. In summer 2005, the German Environment Ministry initiated the creation of an offshore wind energy foundation. It has commissioned construction of a test field of twelve wind turbines for trials37.

34 German Environment Ministry (2009)
35 German Environment Ministry (2007)
36 EWEA (2010a)
37 German Environment Ministry (2007)
E.5.8. Deployment

In 2009, Germany installed 6 offshore turbines, totalling 30 MW at 1 wind farm. This brought the total by the end of 2009 to 9 turbines, totalling 42 MW across 4 locations\(^{38}\).

The German Environment Ministry estimates that by the end of 2011, a capacity of around 1,500 MW may be installed offshore, contributing to the German Government’s long-term target of 25,000 MW by 2030.
E.6. Ireland

E.6.1. Offshore Wind Resource

Ireland experiences one of Europe’s highest average wind speeds of approximately 9 m/s (see Figure E.7). The offshore wind resource is the highest at the western and northern shores which are exposed to the prevailing westerly winds. An assessment of the Irish offshore wind resource assuming a water depth below 20 m and a minimum distance of 5 km from shore gives an estimate of 3,300 MW or 11 TWh/year.

E.6.2. Wave Resource

Ireland experiences one of the most favourable wave regimes in Europe with a wave energy flux above 60 kW/m. The Irish wave energy resource is estimated to be between 187.5 TWh and 525 TWh. The assessment of the Marine Institute is based on the assumption of a practical wave energy resource possibly exceeding 6,000 MW and a potential for shoreline and near-shore devices of 800 MW.

Figure E.8: Indicative Wave Resource Levels in Annual MWh/m

Figure E.8 illustrates high wave energy fluxes in the north-west with 70 kW/m and 50 kW/m for shores facing north and south-west. The report quotes a theoretical wave resource of 230 TWh/year\textsuperscript{43}.

### E.6.3. Tidal Resource

The theoretical resource for tidal energy in Irish waters has been assessed to be 230,000 GWh/year\textsuperscript{43} with the practical resource estimated at 2,633 GWh/year. Figure E.9 indicates high velocity tidal currents in the northern and south-easterly waters around Ireland\textsuperscript{44}.

Figure E.9: Depth Averaged Peak Spring Tidal Currents

Source: SEAI, Tidal and Current Resources in Ireland

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\textsuperscript{43} SEAI (2005)
\textsuperscript{44} SEAI (2004)
E.6.4. Processes for Permitting, Licensing and Allocating Seabed Rights

The focus of current offshore wind development in Ireland is near shore - within 12 miles of shore. Following introduction of the Foreshore and_dumping at Sea (Amendment) Act 2009, responsibility for certain foreshore functions transferred to the Minister for the Environment, Heritage and Local Government with effect from 15 January 2010. This includes all foreshore energy-related developments, including wind, wave and tidal energy. The foreshore is the seabed and shore below the line of high water of ordinary or medium tides and extends outwards to the limit of twelve nautical miles (about 22.24 km). The Foreshore Act requires that a lease or licence is obtained for the carrying out of works or placing structures or material on State-owned foreshore. Licenses are granted by the Minister based on acceptance of an application and payment of fees and at the Minister’s absolute discretion for acceptance or rejection.

The Department of Communications, Energy and Natural Resources has charged the Ocean Energy Development Unit within national agency Sustainable Energy Ireland (SEAI), in close collaboration with the Marine Institute in Ireland, to undertake a Strategic Environmental Assessment of offshore wind and marine renewable energy in Ireland, which is underway.

E.6.5. Support Mechanisms for Project Deployment

Since 2006 Ireland has had a renewable energy feed-in-tariff (REFIT). The tariffs are theoretically guaranteed for 15 years but in fact the scheme may not extend beyond 2024. In 2008, the REFIT was amended to provide a FIT of 14 €cents/kWh for offshore wind and 22 €cents/kWh for ocean energy (wave and tidal). Details on the operating of the proposed REFIT were released in 2009, with further details expected in 2010, following clearance of the scheme with respect to state aid limitations.

The Irish Government has set a target of 75 MW by 2012 and 500 MW of installed ocean energy capacity by 2020.

E.6.6. Support mechanisms for development of technologies

A White Paper released in March 2007 sets out the Government’s Energy Policy for 2007 to 2020. It states an intention to support development of offshore wind through a review of cost benefits and R&D. It also states that the Government intends to make Ireland a world leader for Ocean Energy technologies within a decade, through the National Ocean Energy Strategy.

Following publication of an Ocean Energy Strategy in 2005, the government announced €26m of funding to support ocean energy. This led to, among other things, the establishment of the Ocean Energy Development Unit within SEAI and development of the Ocean Energy Prototype Development Fund. The fund aims to stimulate development and deployment of devices and systems. According to SEAI, it focuses on:

- Industry-led projects to develop and test wave and tidal energy capture devices and systems;
- Independent monitoring of projects/technologies;
- Industry-led R&D aimed at the integration of ocean energy into the electricity market and the national electricity grid (and network);

46 Department for Environment, Heritage and Local Government (2010)
47 SEAI (2010)
48 EREC (2009)
- Data monitoring, forecasting, communications and control of OE systems;
- Specific industry-led research projects which will be carried out by research centres, third level institutions and centres of excellence with a high level of expertise in the relevant area.

### E.6.7. Deployment

By the end of 2009, Ireland had 7 offshore turbines installed, totalling 25.2 MW at one site\(^4\). Ireland’s marine energy developments are shown in Table E.5 below.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Capacity (MW)</th>
<th>Date commissioned</th>
</tr>
</thead>
<tbody>
<tr>
<td>OE Buoy</td>
<td>Operational</td>
<td>n.c.</td>
</tr>
<tr>
<td>Wavebob</td>
<td>Operational</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Source: EurObserv‘ER (2010)

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\(^4\) EWEA (2010a)
E.7. Italy

E.7.1. Offshore Wind Resource

In Italy mean wind speed at the northern coast is below 5 m/s but can reach up to 7.5 m/s in the south. The offshore resource has been estimated to be 3,000 MW and 10 TWh/year respectively\(^49\).

E.7.2. Wave Resource

Situated in the Mediterranean Sea Italy experiences a poor wave regime with a wave power flux below 5 kW/m, increasing to 10 kW/m\(^50\) at favoured sites (e.g. Sicily or Sardinia). Studies assessing the actual power generation potential have not been identified.

E.7.3. Tidal Resource

Italy being located in the Mediterranean Sea is not exposed to a considerable tidal range. Nevertheless, specific sites such as the Strait of Messina (test location for a 500 kW prototype by Fri-El Green Power) might become of interest. No tidal resource studies were available for review.

E.7.4. Processes for Permitting, Licensing and Allocating Seabed Rights

Publicly available information on permitting, licensing and seabed rights processes in Italy was not readily identified. Further research will be carried out under Task 4.

E.7.5. Support Mechanisms for Project Deployment

Since January 2002, Italy has had a support mechanism for renewable energy generation based on Green Certificates. Generators and importers of electricity have minimum obligations for renewable energy generation which can be met through purchase of the tradable Green Certificates. Based on the Budget Law 2008, plants that have entered into operation after 31 December 2007 and are larger than 1 MW will receive the certificates for 15 years. The certificate price is equal to the difference between a reference value (18 €cents/kWh in 2008) and the annual average electricity sale price. For plants smaller than 1MW capacity, they have the option of choosing either the Green Certificates or to receive a feed-in-tariff for 15 years instead. The tariff for wave and tidal is 34 €cents/kWh\(^51\).

Investments in renewable energy in the southern regions of Italy also benefit from a rebate on VAT (10% instead of 20%) and from a 10-year corporate tax reduction\(^52\).

E.7.6. Support Mechanisms for Development of Technologies

Italian public funding for device development is available under the “Industria 2015” program, announced by the Ministry of Economic development. One recipient is Project GEOMA, a project to develop a hybrid

\(^{49}\) Duwind (2001)
\(^{50}\) Fugro Oceanor (2008)
\(^{51}\) Watson, Farley & Williams (2008)
\(^{52}\) EREC (2009)
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concrete/steel 3.5 MW floating wind turbine intended for the deep water applications such as in the Mediterranean Sea\textsuperscript{53}.

\textbf{E.7.7. Deployment}

Italy currently has no offshore wind turbines installed. It has one marine device operational, the 20 kW Kobold System\textsuperscript{54}.

\textsuperscript{53} Blue H Group (2010)
\textsuperscript{54} EurObserv'ER (2010)
E.8. Japan

E.8.1. Offshore Wind Resource

Figure E.10 presents a wind resource map of Japan as a result from a meteorological numerical model\textsuperscript{55}. The model shows that onshore winds are mostly below 5 m/s while coastal and offshore wind speeds vary depending on geographic orientation of the coast between 5.5 and 8 m/s. Offshore development faces the challenge of deep waters particularly at the east coast of the country which experiences higher wind speeds than the west coast. On the east coast water depths of 100 m and above are common at only 10 km distance from shore. In most locations water depth increases rapidly. Nonetheless Japan’s government deems 3,000 MW of wind capacity a feasible near term target in its Primary Energy Supply Plan. Meanwhile, the Japanese Wind Power Association proposes a wind capacity of 11,800 MW by 2030\textsuperscript{56}.

Figure E.10: Wind Resource Map, Japan

Source: Takagi et al, 2006

E.8.2. Wave Resource

Japan experiences a low to moderate resource with a wave energy flux between 10 and 20 kW/m\textsuperscript{57}. Studies assessing the actual power generation potential have not been identified.

\textsuperscript{55} Takagi et al (2006)
\textsuperscript{56} WEC (2007)
\textsuperscript{57} Fugro Oceanor (2008)
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E.8.3. Tidal Resource

No tidal resource assessments were available.

E.8.4. Processes for Permitting, Licensing and Allocating Seabed Rights

Publicly available information on permitting, licensing and seabed rights processes in Japan was not readily identified. Further research will be carried out under Task 4.

E.8.5. Support Mechanisms for Project Deployment

Japan has a Renewable Portfolio Standard (RPS) and a FIT, but the latter only for solar PV\(^{58}\). Further information was not readily available, but further research will be carried out under Task 4.

E.8.6. Support Mechanisms for Development of Technologies

The New Energy and Industrial Technology Development Organisation (NEDO) is responsible for R&D activities involving renewable energy in Japan. It actively undertakes the development of new energy and energy conservation technologies, verification of technical results, and introduction/dissemination of new technologies (e.g. through support for introduction). From 2008 to 2013, a 200 million yen (€ 1.5 million) per year project into offshore wind aims to identify ocean wind characteristics, and meteorological and oceanographic conditions specific to Japan, to develop suitable technologies for ocean wind observation and wind power generation, and to establish an appropriate environmental impact assessment approach. It aims to identify and utilise suitable offshore research sites\(^{59}\).

The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) supports the development of marine technologies\(^{60}\).

E.8.7. Deployment

Japan has two offshore wind turbines (600 kW each) installed off the coast of Setana in Hokkaido\(^{61}\).

In the early 1990s, an OWC prototype 60 kW converter was integrated into a breakwater at the port of Sakata, Japan\(^{62}\). From 1978 to 1986, the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) tested a large-scale floating wave generating equipment “Kaimei” (80 m long, 12 m wide), partly as joint research with the IEA. Subsequently an offshore floating wave generator prototype “Mighty Whale” (110 kW, 50 m long, 30 m wide) was constructed and tested offshore from 1998\(^{59}\).

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\(^{58}\) METI (2010)
\(^{59}\) NEDO (2009)
\(^{60}\) JAMSTEC (2010)
\(^{61}\) NEDO (2008)
\(^{62}\) IEA-OES (2008)
E.9. Netherlands

E.9.1. Offshore Wind Resource

The Netherlands are exposed to wind speeds above 8 m/s (see Figure E.7) indicating a high offshore wind resource which is estimated to be around 10,000 MW or 33 TWh/year\(^63\).

E.9.2. Wave Resource

With the coast facing in north-westerly directions and being sheltered by the British Isles, the Dutch coast experiences a moderate wave regime with an average annual wave flux below 10 kW/m\(^64\). Studies assessing the actual power generation potential have not been identified.

E.9.3. Tidal Resource

No relevant studies on the Dutch tidal resource were available for this report.

E.9.4. Processes for Permitting, Licensing and Allocating Seabed Rights

The Dutch government's 2008 draft National Water Plan looks at North Sea offshore wind power potential, alongside interests in fisheries, shipping, sand extraction, oil and gas extraction, nature conservation and coastal defences. It proposes two areas for wind energy deployment which together could theoretically accommodate over 9,000 MW of wind power, assessing grid access options and related transmission costs. The final plan (pending as of February 2010) will set the areas in which permits for offshore wind farms will be made available.\(^65\)

E.9.5. Support Mechanisms for Project Deployment

The Netherlands re-introduced a subsidy scheme in 2007 after the previous scheme was stopped in 2006. Known as the Subsidies Duurzame Energie (SDE), it pays a premium above the market rate. In February 2009, a base rate of 18.6 €cents/kWh was announced for offshore wind, paid to projects for 15 years. There is a subsidy ceiling of € 2,645 million in total after which no more capacity will be supported. It is expected to provide support for 450 MW of offshore wind capacity. A subsidy for marine energy is not specified.\(^66\)

The Netherlands also has an Energy Investment Deduction scheme which grants tax incentives for investment in renewable energy projects.\(^66\)

E.9.6. Deployment

By the end of 2009, the Netherlands had 130 offshore turbines installed, totalling 246.8 MW across 4 wind farms.\(^67\) It has one marine energy device under development, the 45 kW Tocardo.\(^68\)

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\(^{63}\) Duwind (2001)
\(^{64}\) Fugro Oceanor (2008)
\(^{65}\) IEA Wind (2009)
\(^{66}\) EREC (2009)
\(^{67}\) EWEA (2010a)
\(^{68}\)
E.10. Norway

E.10.1. Offshore Wind Resource

Norway has a long exposed shoreline facing the North Sea, the Atlantic and the Bering Sea with offshore constructions facing the challenge of deep waters relatively close to shore. In 2008, the Norwegian water and energy department (Norges vassdrags- og energidirektorat) assessed the considerable Norwegian offshore wind resource. At 50 m above ground mean wind speed for the western coast of Norway are between 7 and 9 m/s. Potential locations for offshore wind developments were considered according to water depth (10, 20 and 100 m) and a distance from shore (1 km up to 10 km). The results showed that the offshore potential was highly influenced by these factors as the potential varies between the following figures:

- around 6,000 MW - water depth of up to 20 m and minimum distance from shore of 10 km;
- around 30,000 MW - water depth of 20 m and minimum distance from shore of 1 km; and
- around 140,000 MW – for a maximum water depth of 100 m with a maximum distance of 20 km.

Figure E.11 provides an overview of wind speeds experienced 80 m above ground. NVE engaged Kjeller Vindteknikk to produce a new wind map covering the Norwegian landmass and the surrounding sea. The total theoretical potential for Norway’s offshore wind resource has been estimated to be around 14,000 TWh/year.

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68 EurObserv’ER (2010)
69 NEV (2008)
70 Kjeller Vindteknikk (2009)
71 ENOVA (2007)
E.10.2. Wave Resource

Norway experiences a very good wave regime with variations regarding geographical and seasonal conditions. The south of Norway’s coast is sheltered from predominate westerly wave direction reaching

Source: Kjeller Vindteknikk, 2009
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between 10 and 25 kW/m annual average wave power. Best wave conditions are experienced further north between the Sognefjord and the Lofoten Islands. Annual average wave power reaches figures between 40 and 60 kW/m\textsuperscript{72}. The potential resource is estimated to be around 400 TWh/year\textsuperscript{73,74}. A more recent study undertaken on behalf of Enova suggests a theoretical potential of 600 TWh/year and a technical or realistic potential of 12 to 30 TWh/year\textsuperscript{75}.

E.10.3. Tidal Resource

The Norwegian tidal resource has been quantified for specific locations north of Bodø. 24 locations were assessed and their individual potential was found to be between 3 and 758 GWh/year respectively. The overall resource has been estimated to be around 1 TWh/year\textsuperscript{76}.

E.10.4. Processes for Permitting, Licensing and Allocating Seabed Rights

A governmental proposal for a new offshore renewable energy act and national strategy is scheduled for hearing in the Norwegian Parliament before the summer 2010. According to the Norwegian Trade Portal, the new concession policy resembles the licensing rounds for offshore petroleum blocks, with public administration and control of the management of the energy resources offshore.

Offshore areas will be opened for applications following impact assessments, for early consideration and balancing of relevant interests. The proposed act includes regulations on the process of applying for concessions, establishment, operation and close-down of offshore renewable energy production and the offshore grid. Regulations on compensation to fishermen, similar to the regulations in the petroleum sector, are proposed, as well coverage of concerns related to security and working environment, area fees, system operation and export and import of electrical energy

Under the Energy Act of 1990, the NVE can grant licenses to wind farms within the sea boundary (i.e. located in the waters between the mainland and nearby islands). Projects bigger than 10 MW require an environmental impact assessment.\textsuperscript{76}

E.10.5. Support Mechanisms for Project Deployment

The Norwegian Government’s Energy Fund which provides up to NOK 25 billion (~€ 3.3 billion) over a ten-year period, administered by Enova.\textsuperscript{75} Enova is a public enterprise, owned by the Royal Norwegian Ministry of Petroleum and Energy, which has operated a program to provide investment support for ocean energy demonstration projects since 2009. Examples of projects awarded support include tidal, wave and offshore wind demonstrators, including onshore qualification testing of a 10 MW offshore wind turbine.\textsuperscript{77}

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\textsuperscript{72} Fugro Oceanor (2008)
\textsuperscript{73} Marine Institute (2002)
\textsuperscript{74} Clement et al (2002)
\textsuperscript{75} Enova (2007)
\textsuperscript{76} nortrade.com (2009)
\textsuperscript{77} SWAY (2010)
**E.10.6. Support Mechanisms for Development of Technologies**

Eight Centres for Environment-friendly Energy Research (CEER) have been established through the Research Council of Norway to pursue renewable energy and energy efficiency research. Each CEER is receiving up to NOK 20 million (€2.3 million) over the next five years, in addition to private finance from industry partners. Two of the centres are focussed on offshore wind. The Norwegian Centre for Offshore Wind Energy (NORCOWE) is an interdisciplinary resource centre which aims to take the lead in the development of new innovative and cost efficient solutions for the exploitation of offshore wind energy at large water depths and in harsh offshore environments. The Norwegian Research Centre for Offshore Wind Technology (NOWITECH) focuses on deep-sea (>30 m) technologies, including bottom-fixed and floating turbines. Its work packages cover: integrated numerical design tools; energy conversion systems; novel substructure; grid connection and system integration; operation and maintenance, and; assessment of novel turbine concepts.

In addition the Research Council of Norway operates a thematic RTD program RENERGI providing funding for energy related projects not covered by the eight centres.

**E.10.7. Deployment**

In 2009, Norway installed one offshore turbine of 2.3 MW. This is currently its only offshore wind installation.

A Norwegian government funded R&D project led to the construction in 1985 of two full-sized (350 and 500 kW rated power) shoreline prototypes near Bergen.

A wave energy converter concept, Seabased, is being tested offshore outside Runde, an island on the west coast of Norway coast. The two test units are in the order of 20 kW. The project represents a cooperative venture between Vattenfall and Tussa Energi.

According to the Norwegian Trade Portal, an increasing number of applications are being made for offshore wind projects in Norway, both fixed sea bottom projects in shallow waters and fully floating foundation projects for deeper seas. There are currently 19 notifications for offshore wind parks in Norway, seven of which are floating installations. For example, StatOilHydro’s Hywind will place a 2.3MW floating turbine 10 km off the coast north of Stavanger for a two-year test period from 2010. Another floating turbine company, SWAY, also plans to test a turbine for two years. Vestavind Kraft plans to test a floating wind turbine in three stages offshore Selje and Vågsøy. All three of these are relatively small pilot phase projects only. Licensing policy issues are causing delay to some similar projects.

Other wave and tidal demonstration projects have also been provided state funding. An example is the deployment by Hydra Tidal during 2010 of a tidal power prototype in the Gimsøyastraumen tidal current at Lofoten Islands, North Norway.

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78 NORCOWE (2010)
79 NOWITECH (2010)
80 EWEA (2010a)
81 IEA-OES (2008)
82 SWAY (2010)
83 nortrade.com (2009)
E.11. UK

E.11.1. Offshore Wind Resource

Situated in an exposed location between the Atlantic Ocean and the North Sea the UK has a high wind energy resource. The resource is estimated to be around 70 GW translating into an annual output between 230 and 334 TWh\(^8\). Figure E.12 provides an overview of the distribution of the offshore wind resource in UK waters at 100 m above water.\(^5\)

Figure E.12: UK Annual Mean Wind Speed at 100 m


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\(^{84}\) Duwind (2001)

\(^{85}\) BERR (2008)
E.11.2. Wave Resource

Wave power varies greatly along the coasts of the UK. The south and east coasts experience a low to moderate wave regime with a range below 5 up to 20 kW/m. Off the North-west coast of Scotland wave power levels are typically around 60 to 70 kW/m. Figure E.13 provides an overview of the distribution of the wave resource.

Figure E.13: UK Annual Mean Wave Power – Full Wave Field

Thorpe estimated the overall resource at 120 GW\(^{86}\). The Carbon Trust suggests a practical offshore wave energy resource to be around 50 TWh/year\(^{87}\). The UK practical near-shore and shoreline wave energy resources have been re-estimated at 7.8 TWh/year and 0.2 TWh/year\(^{88}\).

\(^{86}\) Thorpe (1992)  
\(^{87}\) Carbon Trust (2006)  
\(^{88}\) Arup Energy (2005)
E.11.3. Tidal Resource

The distribution of the tidal energy around the UK is indicated in the BERR Atlas of UK Marine Energy Resources and shown in Figure E.14.

Figure E.14: UK Average Tidal Power

In 2005, Black & Veatch assessed the total UK tidal stream resource to be around 110 TWh/year. Further analysis suggested a figure of 18 TWh/year for the technically extractable resource representing 10 to 15% of the known worldwide tidal stream resource. Only around 20% of the identified tidal stream sites are deemed to be suited to near term developments as they are located in moderate water depth between 30 and 40 m and have a tidal stream velocity between 2.5 and 4.5 m/s\textsuperscript{89}. Black & Veatch have recently assessed the technical viability of these sites through feasibility studies.

\textsuperscript{89} Black & Veatch (2005)
completed an updated UK tidal resource assessment which estimates a significantly increase from the 18 TWh/year figure. The report is to be published in early 2011.\textsuperscript{90}

Sites particularly suited for tidal stream developments in the UK are identified to include the following:
- Pentland Skerries with \( \approx 3,900 \) GWh/year;
- Storma Pentland Firth with \( \approx 2,800 \) GWh/year;
- Duncasby Head with \( \approx 2,000 \) GWh/year; and
- Casquets with \( \approx 1,700 \) GWh/year.\textsuperscript{91}

E.11.4. Processes for Permitting, Licensing and Allocating Seabed Rights

The UK sea-bed is the property of the Crown Estate. Offshore wind development in the UK has had three rounds. Each round starts by the Crown Estate setting aside zones for proposed wind development, based on the government’s Offshore Energy Strategic Environmental Assessment (SEA) that identifies areas where there are no overriding environmental concerns. Companies are then invited to bid for sites, and once awarded, lease holders can submit planning applications. Round 1 & 2 sites, awarded in 2000 and 2003, are now mostly built or under construction, with the total installed capacity expected to reach 8 GW. The round 3 development process was launched in June 2008.\textsuperscript{92} In January 2010 it was announced that Round 3 rights have been granted in 9 UK coastal zones, with potential for 6,400 additional turbines and a combined capacity of 32 GW.\textsuperscript{93}

The Crown Estate also has the power to grant leases for areas of the sea-bed to offshore energy developers. Securing a site lease requires the project developer to carry out comprehensive environmental impact assessments and monitoring, as well as demonstrating appropriate project design. Following successful issue of a sea-bed lease, developers must obtain relevant consents from the Marine and Fisheries Agency (in England and Wales), the Fisheries Research Service (Scotland) or the Northern Ireland Environment Agency, including for drilling and foundation work and for establishing an electrical connection to shore. The process necessitates consultation with a wide variety of bodies need and generally takes at least six months.\textsuperscript{94}

The Planning Act 2008 of November 2008 aims to provide a streamlined consenting process for nationally significant infrastructure projects in England and Wales, including certain types of energy. The number of applications and permits required for such projects will be reduced compared with the current legislation. The Act also allows for the Infrastructure Planning Commission (IPC) to be established. This is an independent body responsible for examining development consent applications for nationally significant infrastructure projects, including offshore energy projects over 100 MW in England and Wales. It aims to resolve any potential issues in advance of submission of the planning application and produce consent decisions in nine months.\textsuperscript{95}

Offshore energy projects of less than 100 MW capacity will be licensed by the Marine Management Organisation (MMO), a public body created through the Marine Bill. The Marine Bill also sets the
framework for a new offshore planning system, based on long-term objectives for the UK’s marine area. The new system aims to reduce the planning process to just one license for offshore energy developments96.

E.11.5. Support Mechanisms for Project Deployment

The UK government published a Renewable Energy Strategy in July 2009 which proposes 14 GW of offshore wind by 2020 – see Figure E.15 below. The UKERC Marine Renewable Technology Roadmap sets a target of 2GW of wave and tidal energy installed by 2020 in UK waters97. The Crown Estate has set a target for the Pentland Firth strategic area of 700 MW of offshore wave and tidal stream generation by 202098.

Figure E.15: Renewable Electricity Technologies – Actual Capacity in 2008 and Projected Capacity in 2020 for UK

Financial support for renewable energy generation is provided through the Renewables Obligation (RO) and Renewables Obligation (Scotland) (ROS) and Renewables Obligation (Northern Ireland) (NIRO). Banding was introduced in April 2009 so that two Renewable Obligation Certificates (ROCs) are granted for every MWh of electricity generated from a marine energy device. This is over 90 £/MWh (10 €cent/kWh) and means that marine energy generators will receive approximately 12.8p/kWh (14 €cent/kWh) when the income received from the electricity generated, levy exemption certificates and the recycle of ROCs is also included. Following approval from the European Commission, the Scottish Government plans to increase the support available through the ROS to three ROCs per MWh of electricity generated from tidal stream devices and five ROCs per MWh of electricity generated from wave energy devices98. After initially being set at 1.5 ROCs/MWh, the government reviewed the RO banding for offshore wind and announced that all

96 HM Government (2009)
97 UKERC (2008)
98 BWEA/Entec (2009)
offshore wind farms gaining full accreditation between April 2010 and March 2014 will receive 2 ROCs/MWh. Historic ROC prices are shown in Figure E.16 below, for the period October 2002 (start of CP1) to January 2010 (mid-CP8). The price has historically fluctuated around £48/MWh (~5.5 €cents/kWh).

Figure E.16: UK Historic ROC prices

Capital grant schemes include the UK Government’s Marine Renewable Deployment Fund (25% capital grant for qualifying projects and an enhanced payment of 10p/kWh (11 €cent/kWh) in addition to the normal ROC payment). It was established by the UK Government in 2004 to support the first devices operating at sea. £42 million of the £50 million MRDF (£46.2 million of €55 million) was allocated to provision of a combination of capital grant and revenue support for devices. Although a small number of applications for the MRDF have been received, to date no projects have succeeded in fulfilling the eligibility criteria of 3 months full-scale device sea trial data. The Marine Renewables Proving Fund (MRPF) is a new fund of up to £22 million (£24 million) launched by the Government in the Renewable Energy Strategy 2009. In Scotland, the Scottish Ministers’ Wave and Tidal Energy Support Scheme (40% capital grant for qualifying projects and an enhanced payment of 10p/kWh in addition to the normal ROC payment). Launched in 2006 and worth £13.5 million (£15 million) in support, it has provided support to nine schemes so far.

E.11.6. Support Mechanisms for Development of Technologies

The direct total Government spending on technology R&D (provided through the DTI new and renewable energy programme) for 1999 to 2005 was £3.9 million (£4.3 million) for wave energy and £6.5 million (£7.2

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99 DECC (2010b)  
100 NFPA (2010)  
101 BWEA/Entec (2009)
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milllion) for tidal stream energy. During the same period the Research Council spend on its wave and tidal research programme was £3.6 million (€4 million). As well as the governments’ capital grant schemes (see above), grants are provided by a number of different bodies, for example the Carbon Trust’s Marine Energy Accelerator and Energy Technologies Institute (ETI) marine energy programme102.

The Saltire Prize is a £10 million (€11 million) prize challenge for advances in wave and tidal energy launched by the Scottish Government in December 2008. It is to be awarded to the team that can demonstrate in Scottish waters a commercially viable wave or tidal energy technology that achieves a minimum electrical output of 100 GWh over a continuous 2 year period using only the power of the sea and is judged to be the best overall technology after consideration of cost, environmental sustainability and safety103.

E.11.7. Other Support Initiatives

The Crown Estate is funding a £5.15 million (€5.7 million) research and development project looking at solutions to the problem of radar interference and wind turbines. The nineteen-month R&D programme looks at how the impacts of wind turbines on the NATS En Route primary radar infrastructure can be mitigated, working with Raytheon Canada, the suppliers of the NATS systems. £1.6m of the funding comes from wind companies, £2m from The Crown Estate and £1.55m from DECC. The Crown Estate has also funded seabed surveys and aerial bird surveys in order to support offshore wind developments104.

E.11.8. Deployment

In 2008, the UK overtook Denmark as the country with the highest operating offshore wind capacity in the world (UKERC, 2009). In 2009, the UK installed 84 offshore turbines, totalling 284.4 MW across 3 separate wind farms. It now has 287 turbines, totalling 882.8 MW across 12 sites105.

By the end of April 2009, the UK had 0.5 MW installed capacity of wave energy and 1.45 MW of tidal stream energy102. The installed devices are shown in Table E.6 below.

Table E.6: UK Marine Energy Installations

<table>
<thead>
<tr>
<th>Stage</th>
<th>Capacity (MW)</th>
<th>Date commissioned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limpet</td>
<td>Operational</td>
<td>0.5</td>
</tr>
<tr>
<td>Seaflow</td>
<td>Operational</td>
<td>0.3</td>
</tr>
<tr>
<td>Open Center Turbine</td>
<td>Operational</td>
<td>0.25</td>
</tr>
<tr>
<td>SeaGen</td>
<td>Operational</td>
<td>1.2</td>
</tr>
<tr>
<td>Pulse Hydrofoil</td>
<td>Being tested</td>
<td>0.1</td>
</tr>
<tr>
<td>Sea Snail</td>
<td>Being tested</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Source: EurObservER (2010)

Further projects are also currently under development and are expected to be installed in the next few years. For example, early in 2008 Marine Current Turbine (MCT), developer of the SeaGen turbine, joined

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102 BWEA/Entec (2009)
103 Scottish Government (2010c)
104 The Crown Estate (2010b)
105 EWEA (2010a)
in partnership with npower renewables to develop a tidal stream project under the management of a newly-created company, SeaGen Wales. The plan is for a 10.5 MW farm to be located in The Skerries, off the northwest coast of Anglesey. Completion is expected in 2011/2012. Another venture for MCT, announced in November 2008, is a tidal scheme for the Pentland Firth, Scotland. The company will apply for a lease from the Crown Estate and, subject to finance and gaining consent, plans a 50 MW plant by 2015\textsuperscript{106}.

Pelamis Wave Power’s 0.75 MW was previously installed at EMEC for testing, but was removed after a successful trial period. Pelamis Wave Power is now developing the next generation Pelamis device, ‘P2’ (0.75 MW) which will be installed and tested at EMEC during 2010\textsuperscript{107}. Projections by BWEA/Entec for growth of UK marine energy capacity are shown in Figure E.17. Meeting these targets will mainly be linked to the delivery of up to 1.2 GW of wave and tidal projects which have been granted leases by The Crown Estate in the Pentland Firth and Orkney area in March 2010\textsuperscript{108}.

Figure E.17: Potential UK Cumulative Installed Capacity of Marine Energy Projects to 2020

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\textsuperscript{106} WEC (2009)

\textsuperscript{107} BWEA/Entec (2009)

\textsuperscript{108} The Crown Estate (2010a)
E.12. Belgium

E.12.1. Offshore Wind Resource

In 2004, the offshore wind energy potential on the Belgium continental shelf was assessed to be between 2 and 4 GW\(^{109}\). A review of offshore wind energy undertaken by a consortium led by University Delft gives a resource estimate of 1.2 MW and 4 TWh/year respectively\(^{110}\).

E.12.2. Wave Resource

Due to the sheltered location at the Channel and the southern North Sea, the wave energy flux is around 5 to 10 kW/m rendering wave energy an unattractive option\(^{111}\).

E.12.3. Tidal Resource

While Belgium experiences tidal fluxes no reference to tidal resource assessments have been found.

E.12.4. Processes for Permitting, Licensing and Allocating Seabed Rights

Publicly available information on permitting, licensing and seabed rights processes in Belgium was not readily identified. Further research will be carried out under Task 4.

E.12.5. Support Mechanisms for Project Deployment

National targets and policies for renewable energy in Belgium are regional rather than national, split between Walloon, Flanders and Brussels. All three regions have established quota systems. The certificates have historically been around 109 €/MWh (Flanders) and 90 €/MWh (Walloon). For offshore wind, there is currently no market price but a federal minimum price has been set. For the first 256 MW installed, this is 10.7 €/cents/kWh for the first 10 years of operation and 9.0 €/cents/kWh for the second 10 years of operation. For additional installed capacity beyond the initial 256 MW, a minimum tariff of 9.0 €/cents/kWh applies for a 20 year period\(^{112}\).

E.12.6. Support Mechanisms for Development of Technologies

Investment support schemes are available for renewable energy technologies. Further information was not readily available and further research will be carried out under Task 4.

E.12.7. Deployment

Belgium has 6 offshore wind turbines, totalling 30 MW at one site\(^{113}\).

\(^{110}\) Duwind (2001)
\(^{111}\) Fugro Oceanor (2008)
\(^{112}\) EREC (2009)
\(^{113}\) EWEA (2010a)
E.13. Finland

**E.13.1. Offshore Wind Resource**

The Finnish offshore wind energy resource is estimated to be around 6,000 MW and around 20 TWh/year respectively\(^{114}\).

**E.13.2. Wave Resource**

Finland has shores at the Baltic Sea experiencing wave fluxes below 5 kW/m and possibly up to 10 kW/m in the south-western region of Hanko\(^{115}\).

**E.13.3. Tidal Resource**

Due to the geography of the Baltic Sea the coastal regions experiences only very low tides around 10 cm height difference.

**E.13.4. Processes for Permitting, Licensing and Allocating Seabed Rights**

The Electricity Market Act (386/1995) provides guaranteed grid access for all electricity generators and users, including renewable energy generators\(^{116}\).

**E.13.5. Support Mechanisms for Project Deployment**

Energy Aid is a state grant provided for investments and research into renewable energy. The preparation and planning costs and the costs of materials are eligible for subsidies, amongst other costs\(^{117}\). The construction costs of renewable energy plant are co-financed by the government with subsidies, for example up to 40% in the case of wind. The government has imposed a tax per kWh on electricity suppliers. This is then provided to renewable generators at 0.69 €cents/kWh for wind and 0.42 €cents/kWh for other eligible technologies\(^{116}\).


Publicly available information on support for development of technologies in Finland was not readily identified. Further research will be carried out under Task 4.

**E.13.7. Deployment**

Finland has 8 offshore wind turbines, totalling 24 MW at one site\(^{118}\).

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\(^{114}\) Duwind (2001)

\(^{115}\) Fugro Oceanor (2008)

\(^{116}\) EREC (2009)


\(^{118}\) EWEA (2010a)
E.14. Spain

E.14.1. Offshore Wind Resource

The Spanish offshore wind resource is estimated to be around 2,000 MW or 7 TWh/year\textsuperscript{119}.

E.14.2. Wave Resource

The Mediterranean shores of Spain feature a very low energy flux with below 5 kW/m. North and West Spain shores are exposed to the Atlantic Ocean and experience a good wave climate with intensities between 30 and 60 kW/m\textsuperscript{120}.

E.14.3. Tidal Resource

To date, no comprehensive assessment of the tidal resource at the Spanish coast has been undertaken. The Ria de Muros, an estuary at the Galician coast has been assessed based on a numerical model\textsuperscript{121}. The estuary has a tidal range of 2.5 m and a current velocity of about 2 m/s. Further research would be beneficial.

E.14.4. Processes for Permitting, Licensing and Allocating Seabed Rights

The approval of offshore wind farms is regulated by Royal Decree 1028/2007 of 20 July 2007, which establishes a procedure in competition for offshore wind power exceeding 50 MW.

Developers may apply to establish an offshore windfarm within areas identified by the government’s “Marine Wind map”, shown in Figure E.18, as suitable (with or without constraints). At this point, rival developers may also bid for the specific area, submitting technical documentation and a tariff offer to the governmental review committee. The selected developer is eligible to apply for full administrative approval within the two years after selection, during which time they may conduct necessary studies.

An application for full administrative approval is submitted to the Directorate General for Energy Policy and Mines, Department of Sustainability and the Sea Coast and the Department of Environmental Quality and Assessment, the latter with respect to approval of the project EIA specifically. The application is then licensed following standard procedures for electric power facilities, according to Royal Decree 1955/2000 of 1 December 2000\textsuperscript{122}.

\textsuperscript{119} Duwind (2001)
\textsuperscript{120} Fugro Oceanor (2008)
\textsuperscript{121} Carballo et al (2008)
\textsuperscript{122} Spanish Ministry of Environment and Rural and Marine Areas (2009)
E.14.5. Support Mechanisms for Project Deployment

For renewable energy plants between 50MW and 100MW capacity, a bonus is paid above the market price received for electricity generation. Plants up to 50MW can choose between the bonus payment and a guaranteed feed-in-tariff. Offshore wind is eligible, up to a combined cap of 20,155 MW across onshore and offshore wind. However, it is only eligible for plants up to 100MW. Wave energy, tidal energy, ocean thermal energy and ocean current energy are also eligible and there is no cap in terms of total capacity to be supported for these technologies. The FIT is received for the entire operation of a system, but it is reduced after a certain period of operation: 25 years for marine energy and 20 years for wind energy\(^\text{123}\).

For wind farms operational since January 2008, the fixed tariff option is 7.32 €cents/kWh, reduced to 6.12 €cents/kWh after 20 years of operation. The fixed bonus option is 2.93 €cents/kWh\(^\text{124}\).

In the Basque country there is a wave energy target of 5 MW\(^\text{125}\).

\(^{124}\) GWEC (2010)  
\(^{125}\) Ente Vasco de la Energia (2009)

A €30 million initiative was announced in January 2010 to support offshore energy research in Spain. A consortium of 19 companies and 25 research centres will undertake the three-year Ocean Lider Initiative. It is backed by Spain’s Ministry of Science and Innovation and has received grants from the Spanish Centre for the Development of Industrial Technology (CDTI) and the State Fund for Local Investment. It claims to be the world’s largest marine energy R&D project. The Initiative aims to develop integrated offshore energy installations, including by combining them with proven energy sources such as offshore wind power.126

E.14.7. Deployment

Ocean Power Technologies (OPT) is developing a 1.39MW project in the north of Spain. A 40 kW PowerBuoy device was deployed there in 2008127. A demonstration project “Mutriku” of 300 kW is under construction and due for completion in 2010. An R&D facility “bimep” that can host 20 MW is at the licensing and design stage and aims to be ready in 2011.128

126 International Water Power & Dam Construction (2010)
127 BWEA/Entec (2009)
128 Ente Vasco de la Energia (2009)
E.15. Sweden

E.15.1. Offshore Wind Resource

Sweden experiences a good wind climate with the offshore wind resource being estimated to be around 7,000 MW or 22.5 TWh/year considering sites at water depth below 40 m and a maximum distance from shore of 30 km.129

E.15.2. Wave Resource

Most of Sweden’s shoreline lies in the sheltered Baltic Sea with wave fluxes below 5 kW/m. The coast with the North Sea is located in a sheltered position close to Denmark.130

E.15.3. Tidal Resource

Sweden’s coast is mainly enclosed by the Baltic Sea which experiencing only a small (~10 cm) tidal variation. Research referring to tidal stream resource has not been found.

E.15.4. Processes for Permitting, Licensing and Allocating Seabed Rights

Publicly available information on permitting, licensing and seabed rights processes in Sweden was not readily identified. Further research will be carried out under Task 4.

E.15.5. Support Mechanisms for Project Deployment

Sweden has an electricity certificate mechanism for the promotion of renewables. It is unbanded, with all technologies receiving 1 certificate per MWh generated. Wind and wave energy generation is eligible under the system. The certificates are received for 15 years or until the end of 2030, whichever is earlier. No wave energy plants are currently registered under the scheme. The average price of the certificates from 2003 to 2009 is shown in Figure E.19 below, equating to a range of approximately 1.5-4.2 €cents/kWh.131

129 Duwind (2001)
130 Fugro Oceanor (2008)
131 Swedish Energy Agency (2009b)
In 2008, a Swedish government Bill named ‘Coordinated Climate and Energy Policy – Energy’ proposed that a national planning framework for wind power should be established, and set a production target of 10 TWh per year from offshore wind by 2020. It does not set a target for marine energy development\textsuperscript{132}.

### E.15.6. Support Mechanisms for Development of Technologies

The Swedish Energy Agency is responsible for Sweden’s national energy research programme, financing energy research, technological development and demonstration activities. Under the thematic area of ‘The Power System’ it is supporting research into offshore wind, wave and marine current energy technologies\textsuperscript{133}.

### E.15.7. Deployment

In 2009, Sweden installed 10 offshore turbines, totalling 30 MW at one wind farm. This brought the installed total by the end of 2009 to 75 turbines, with a total capacity of 163.65 MW across 5 separate wind farms\textsuperscript{134}.

A wave energy converter concept, Seabased, is being tested offshore outside Lysekil, a village on the west coast. The prototype, which has been developed at Uppsala University. The test unit is in the order of 10–20 kW. A very slow speed experimental permanent-magnet generator (5 kW) to harness marine current energy has been developed but has not yet been tested in a marine environment\textsuperscript{133}.

\textsuperscript{132} Ministry of the Environment and Ministry of Enterprise, Energy and Communications (2009)

\textsuperscript{133} Swedish Energy Agency (2009a)

\textsuperscript{134} EWEA (2010a)
E.16. USA

E.16.1. Offshore Wind Resource

In 2010, the National Renewable Energy Laboratory produced a report on the opportunities and barriers for offshore wind energy in the USA. It estimates that the gross offshore wind resource over all water depths, in regions with annual average wind speeds greater than 8.0 m/s, is 2,957 GW. When average winds of 7.0 m/s are included this figure increases to 4,150 GW. Figure E.20 and Figure E.21 indicate the distribution of the US wind resource.

Figure E.20: US land-based and offshore wind resource estimates at 50-m height (wind classes 3–7)

Source: NREL (2010)
Accelerating Deployment of Offshore Renewable Energy Technologies

Figure E.21: US offshore wind speed estimates at 90-m height

Source: NREL (2010)

The wind energy resource has been assessed by most states individually. Resources maps for each state are available at the Department of Energy, produced by the National Renewable Energy Laboratory.

**E.16.2. Wave Resource**

Research by the Electric Power Research Institute suggests an available resource of 2,100 TWh/yr at the US coasts\textsuperscript{135}. Under the assumption of only 15% being utilised an offshore wave energy resource of 250 to 260 TWh/year is calculated. Figure E.22 indicates the distribution of wave energy along the shores of the US.

\textsuperscript{135} EPRI (2009)
E.16.3. Tidal Resource

In the US, various tidal sites have been assessed regarding their potential energy output. Figure E.23 gives an overview of favourable tidal sites according to EPRI\textsuperscript{136}. All these schemes combined would represent a potential tidal energy resource of about 13 TWh/year. The Georgia Tech Research Corporation (GTRC) is currently conducting a more detailed tidal resource assessment.\textsuperscript{137}

\footnotesize{\textsuperscript{136} EPRI (2007)  \\
\textsuperscript{137} DOE (2010)}
E.16.4. Processes for Permitting, Licensing and Allocating Seabed Rights

For wave energy, the relevant federal jurisdictions are:
- Plant > 3 miles offshore = MMS/FERC
- Plant < 3 miles offshore = FERC
- Plant > 3 miles offshore and in a marine sanctuary = NOAA/FERC

For tidal energy, the relevant federal jurisdictions are:
- Commercial plant > 3 miles offshore = FERC
- Pilot plant < 3 miles offshore with no grid connection = USACOE / FERC

Each state also has its own jurisdiction for offshore developments. For most states, this extends to 3 nautical miles from the shoreline, in accordance with the Submerged Lands Act (2002).

There appears to be some debate over which federal department issues permits for the Outer Continental Shelf (OCS) which could affect project development. The Department of the Interior’s Minerals Management Service (MMS) indicates that the Energy Policy Act of 2005 gave it authority as the lead agency for projects proposed on the OCS. In November 2007, MMS announced the interim policy for regulating renewable energy on the OCS. It did not allow offshore wind projects to proceed but established a leasing process for meteorological or marine data collection for 5 years. In April 2010, MMS released the

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138 EPRI (2006)
139 NREL (2010)
first RFI for Commercial Leasing for Wind Power on the OCS, for Delaware, under the new renewable energy framework. FERC also states that it has issued preliminary permits for ocean energy projects on the OCS and in the near-shore ocean environment. FERC is also developing a specific licensing process. In 2010 a National Ocean Council was created in order to strengthen ocean governance and coordination across the federal government.

E.16.5. Support Mechanisms for Project Deployment

The U.S. production tax credit (PTC) was extended for wind power through 2012, and for biomass, geothermal, hydropower and offshore power through 2013. The Emergency Economic Stabilization Act of 2008 expanded the list of eligible technologies to include wave, tidal, current and ocean thermal energy. It applies to systems over 150 kW that are in-service by the end of 2013. They receive a credit of 1.1 US$cents/kWh (0.8 €cents/kWh). Wind energy installed by the end of 2012 receives a credit of 2.1 US$cents/kWh (1.5 €cents/kWh).

President Barack Obama has urged a national U.S. standard requiring 25% renewable power by 2025. Under the Waxman-Markey cap-and-trade bill that narrowly passed the U.S. House in June and currently awaits reconciliation with its Senate equivalent bill, utilities would be required to meet a goal of 20 percent renewable energy by 2020. Currently, about 30 states have renewable portfolio standards in place.

The US DOE has a target to deploy 37 GW of marine and hydrokinetic (MHK) capacity by 2050 and 54 GW of offshore wind capacity by 2030.


The United States accounted for about 53% of reported RD&D funding provided by IEA governments from 1974 to 2003. The DOE manages a Waterpower RD&D program which began in 2008 at US$ 10 million, increased to US$ 40 million in 2009 and to US$ 50 million (€37 million) in 2010. This program is split into two components: Marine and Hydrokinetics (MHK) and Conventional Hydropower. The MHK component is allocated US$ 35 million (i.e. 70%) of the program funding in 2010. It supports various offshore energy technology projects in wave energy, current energy (including ocean, tidal and river currents) and ocean thermal energy conversion (OTEC).

Government Grants for Developing New Energy Technologies are also available for small businesses, up to the value of US$100 thousand (€73 thousand) and with the option to subsequently compete for larger awards. DOE is currently conducting a national MHK Testing Facilities Needs Assessment in order to identify key gaps in the testing infrastructure in the US. NREL will issue the report in early 2011.
E.16.7. Other Support Initiatives

US$ 50 million (€37 million) annually from 2008 to 2012 has been set aside for the creation of at least one national ocean energy research centre.

E.16.8. Deployment

13 offshore wind projects have advanced significantly along the US permitting process, together totalling around 2.5 GW of capacity. These are shown in Figure E.24 below.

Figure E.24: Proposed US offshore wind projects and capacity, showing projects with significant progress.

Ocean Power Technologies (OPT) has deployed small-scale prototypes of the PowerBuoy in the waters off Hawaii and New Jersey. Its next generation prototype (150 kW) will be deployed for testing in Oregon.

Locations where preliminary wave power plant permits have been issued are shown in Figure E.25.
Figure E.25: US Wave Power Plant Preliminary Permit Locations

Source: EPRI (2009)
E.17. China

E.17.1. Offshore Wind Resource

A publication by the China Wind Power Centre considers offshore areas with shallow waters (2 to 15 m) at the east coast. The preliminary estimate amounts to a potential of about 750 GW\textsuperscript{149}. Figure E.26 gives an overview of the wind speeds experienced in eastern China. Coastal regions are exposed to wind speeds of 7.5 m/s and above.

Figure E.26: Wind Resource Map of Eastern China at 70 m Heights and 3 km Resolution (Mean Annual Wind Speed)


\textsuperscript{149} Pengfei (2010)
The China Meteorological Association (CMA) and SgurrEnergy recently completed an assessment of offshore wind energy potential in China, assessing the resource along a 10,000 km stretch of coastline from Fujian to Shandong. The results are to be published in early 2011.\textsuperscript{150}

### E.17.2. Wave Resource

China has more than 18,000 km of coastline which is exposed to a moderate wave climate with a wave energy flux between 10 and 20 kW/m\textsuperscript{151}. Studies assessing the actual power generation potential have not been identified.

### E.17.3. Tidal Resource

While no tidal resource assessment can be referenced China has a good tidal resource\textsuperscript{152}. Especially the south-eastern coastal areas of Zhejiang, Fujian and Guangdong Provinces are considered to have substantial potential for tidal energy\textsuperscript{153}. Since 1956, China has been exploiting this resource at a number of sites with small scale schemes.

### E.17.4. Processes for Permitting, Licensing and Allocating Seabed Rights

Publicly available information on permitting, licensing and seabed rights processes in China was not readily identified. Further research will be carried out under Task 4.

### E.17.5. Support Mechanisms for Project Deployment

The National Development and Reform Commission (NDRC) issued its Medium and Long Term Development Plan for Renewable Energy in September 2007. The Plan establishes targets for the development of various sources of renewable energy up to 2020, calling for the percentage of renewable energy to rise to 10% of total energy consumption by 2010 and 15% by 2020\textsuperscript{154}. It states that China will actively promote the development and utilization of ocean energies and sets a total capacity target for tidal power generation of 100 MW by 2020. Development of one to two offshore wind farms of 100 MW are targeted for 2010, and a total installed capacity of 1 GW by 2020. It also introduced a mandatory market share (MMS) of non-hydro renewable generation\textsuperscript{155}.

China established a Renewable Energy Law in 2005. This includes provisions, for example, for energy authorities to undertake resource surveys and set out renewable development plans, develop guidance and technical support, and provide economic incentives. While to the law does not specify tariffs and technologies, it does refer to ocean energy as one of the relevant technologies\textsuperscript{156}. Some amendments to the law were passed in December 2009, introducing renewable obligations for grid companies, so putting

\textsuperscript{150} CMA and SgurrEnergy (to be published)
\textsuperscript{151} Fugro Oceanor (2008)
\textsuperscript{152} Lyard et al (2006)
\textsuperscript{153} WEC (2007)
\textsuperscript{154} IEA (2010)
\textsuperscript{155} NRDC (2007)
\textsuperscript{156} NRDC (2005)
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the MMS policy into legislation. Specific targets are still to be set by the relevant Chinese government agencies\textsuperscript{157}.

E.17.6. Support Mechanisms for Development of Technologies

The Renewable Energy Development Fund has been set up through the 2009 Renewable Energy Law amendments. It will collate the surcharge paid by end-users for the additional cost of renewable energy (set at RMB 0.004/kWh (~43 €cents/MWh) in November 2009). This will create an estimated fund of US$ 1 billion in 2010 that will compensate grid companies for the extra costs incurred and also provide investment for renewable energy projects and R&D\textsuperscript{157}.

The National Development and Reform Commission (NDRC) has put offshore wind development as one of the major R&D priority in the ‘Renewable Energy Industry Development Guideline’\textsuperscript{158}.

E.17.7. Deployment

The first offshore wind turbine in China was installed in 2007, located in Liaodong Bay in the northeast Bohai Sea and with a capacity of 1.5 MW. It was built by the China National Offshore Oil Corp (CNOOC). Construction of the first offshore wind farm in China, consisting of thirty-four 3 MW turbines, started in 2009 and is now operational. It is currently generating electricity for the 2010 Shanghai Expo. Three 3 MW turbines are also expected to be installed in Rudong Offshore Wind Farm in Jiangsu province. Other provinces that have plans for offshore wind farms are Shandong province, Zhejiang province and Fujian province\textsuperscript{159}.

China does not have non-barrage tidal plants\textsuperscript{160}.

\textsuperscript{157} Schuman (2010)
\textsuperscript{158} REN21 (2009)
\textsuperscript{159} EWEA (2010a)
\textsuperscript{160} IEA-OES (2008)
E.18. Taiwan

E.18.1. Offshore Wind Resource

With average wind speeds at the coasts between 6 and 7 m/s, Taiwan has a good wind energy resource\(^\text{161}\). Similar to Japan however, offshore development faces the challenge of deep waters surrounding the country with water depth increasing rapidly and close to shore to many 100 meters (deepest point reaching 5.5 km). Studies assessing the actual power generation potential have not been identified.

E.18.2. Wave Resource

Taiwan’s coasts are exposed to a good wave regime with a wave energy flux of 15 to 30 kW/m\(^\text{162}\).

E.18.3. Tidal Resource

Taiwan has a considerable tidal energy resource. Moreover Taiwan is investigating the potential of ocean currents with recent estimates amounting to with an estimated potential of 60 GW\(^\text{163}\). The strongest tidal currents develop between the Island of Taiwan and China’s mainland, located at the west coast of Taiwan. Currents surrounding Taiwan are presented in Figure E.27. On the west coast, the Kuroshio Current is passing the Island close to shore.

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\(^{161}\) Risø National Laboratory for Sustainable Energy, [http://www.windatlas.dk/World/Index.htm](http://www.windatlas.dk/World/Index.htm)

\(^{162}\) Fugro Oceanor (2008)

\(^{163}\) Barr (2009), citing Professor Chen Falin, Institute of Applied Mechanics, National Taiwan University
E.18.4. Processes for Permitting, Licensing and Allocating Seabed Rights

Publicly available information on permitting, licensing and seabed rights processes in Taiwan was not readily identified. Further research will be carried out under Task 4.
E.18.5. Support Mechanisms for Project Deployment

In June 2009, Taiwan’s parliament approved a renewable energy bill that calls to add about 6.5 to 10 GW of renewable energy capacity by 2030. Currently there is minimal capacity deployed\textsuperscript{164}. Technology-specific FIT levels are due to be finalised by March 2010.

E.18.6. Support Mechanisms for Development of Technologies

Starting in 2008, the Bureau of Energy, Ministry of Economy Affairs (BOE, MOEA) funded a US$ 6 million three-year project to study marine energy including ocean thermal energy, ocean wave energy and ocean current energy\textsuperscript{164}. The Industrial Technology Research Institute (ITRI), a government funded non-profit research institute and the Orkney, Scotland-based marine renewable company, Aquatera Ltd have commenced a joint study to assess a potential test site for Wave Energy Converter (WEC) technology. The forecasted wave energy development is expected to be about 75MW by 2025, should the testing be successfully accomplished\textsuperscript{165}. Joint with the Water Resource Agency of the MOEA, Taiwan Power Company, the state utility company, is studying a hybrid ocean thermal energy conversion (OTEC) system on the south east coast. The National Science Council under the Executive Yuan is currently drafting a research plan to explore the harnessing of the Kuroshio Current energy\textsuperscript{164}.

E.18.7. Deployment

Taiwan is moving closer to having its first offshore wind farm, the 600 MW Changhua Offshore Windfarm, which will be located in the Taiwan Strait. The companies involved are the Taiwan Generation Corporation (Taipower) and European company SeaEnergy Renewables\textsuperscript{166}.

There is currently no ocean energy in Taiwan, but four potential sites for deep water ocean current turbine deployment have been proposed in the Kuroshio Current area by local researchers\textsuperscript{164}.

\textsuperscript{164} Chuang et al. (2009)
\textsuperscript{165} Aquatera (2008)
\textsuperscript{166} EWEA (2010a)
E.19. Portugal

E.19.1. Offshore Wind Resource

Portugal has potential for offshore wind. The continental shelf ends 250km of the coast with the potential of 10GW or greater. Within this 250km barrier there is a limited potential of 3.5 GW\textsuperscript{167}. Assuming a 35% capacity factor, this would equate to a potential of approximately 11TWh.

E.19.2. Wave Resource

There are favourable wave power levels of 30-40 kW/m within Portuguese waters, with a total of around 21 GW of exploitable power\textsuperscript{168}. Assuming a 35% capacity factor, this would equate to a potential of approximately 64TWh.

E.19.3. Tidal Resource

Portugal has a very low tidal resource; tidal speeds range between 0 to 1 knots (0 to 0.5 m/s). Tidal devices operate at speeds above this, making the tidal resource off the Portuguese coast not suitable.

E.19.4. Government Bodies for Permitting, Licensing and Allocating Seabed Rights

The wave energy pilot zone where wave devices are tested is managed by Redes Energéticas Nacionais (REN). A team with representatives from REN, Sociedade Gestora de Participações Sociais (SGPS) and Sociedade Anónima (SA) work together to make up a company that is responsible for the pilot zone. It is expected that this arrangement will allow a one-stop-shop for licenses, permits and issuing allocations\textsuperscript{169}.

E.19.5. Support Mechanisms for Project Deployment

There are various support mechanisms for marine project deployment, including FiTs, subsidies and tax incentives. The FiT scheme was modified in 2005 and introduced a new tariff for emerging technology which includes wave energy. The FiT’s for offshore wind and wave are 7.4 €cents/kWh and 7.6-26 €cents/kWh respectively, with 15 year validity. The tariff for wave energy varies with the maturity of the technology, the stage of development and the amount of involvement of Portuguese organisations. There is no tariff for tidal energy\textsuperscript{170}.

Further investment subsidies were set up under the decree Portaria 1463/2007 with the following being available for renewable energy. The SIEST program started in 2006 and provides a 25% of total investment for all residential and commercial technologies within the Azores autonomous region. A separate scheme that started in 2007 (due to end in 2013) gives a 35% subsidy of the total invested with the maximum €250000 per project. Companies can also apply for a financial incentive under another programme that

\textsuperscript{167} Wind Power Monthly (2008)
\textsuperscript{168} Wave Energy Center (2004)
\textsuperscript{169} IEA-OES (2009a)
\textsuperscript{170} EREC (2009)
provides them with interest free loans up to €750,000 for 5 years and 2 years for capital within the same timeframe.


The main supporting institution for Portugal’s marine energy is the Instituto Superior Técnico (IST) research facility at the University of Lisbon. This facility, the National Institute of Engineering and Industrial Technologies (INETI) and the Portuguese Ministry of Economy have worked together on various research projects related to marine energy with their main focus being the OWC wave energy converters.

Portuguese research and development funding can come from several places: the Portuguese Ministry of Science and Technology, the Ministry of Economy and the European Commission.

The Portuguese government has spent an estimated 6.8 million Euros on ocean energy since 1980, averaging approximately 0.22 million Euros per year.

Another funding initiative is DEMTEC which is a programme promoting innovation and supporting research and development of new technologies, especially new pilot research projects. DEMTEC offers grants to developers piloting schemes that fit into this category. In 2006 the budget was about 5 million Euros. The DEMTEC programme was initially set up to fund the renovation of the Pico OWC device.

Portugal also has the Wave Energy Centre (WaveEC). This non profit centre provides information and supports those companies which are interested in using Portugal for wave energy testing and demonstrations. WaveEC also organises and takes part in wave energy projects and provides training.

A wave energy pilot zone has been set up to allow for pre-commercial and commercial wave devices producing electricity to be tested. This pilot zone is off the central west coast, 130 km north of Lisbon. The zone benefits from a high wave energy capacity of 30kW/m.

**E.19.7. Other Support Initiatives**

Portugal is one of the three original members of the IEA Implementing Agreement on Ocean Energy. The WaveEC in Portugal organises the common fund for the Implementing Agreement.

Portugal is also one of the members of Sustainable Economically Efficient Wave Energy Converter (SEEWEC) project. This project promotes a point absorber device to harness wave power off the European coast. The main aim of this project is to assist in developing this converter using experience from the project members.
E.19.8. Deployment

The world first wave farm was deployed in 2008 and consisted in three Pelamis 750kW devices which were installed 5 km from the Portuguese coast. The aim of the project was to increase the number of devices to 25 and produce 21MW of power. However, 2 months after deployment the project experience technical problems which required devices to be brought back to shore. The project subsequently encountered financial difficulties as the project owner went into administration. Efforts to find a new owner appeared to have failed. Lessons learnt from the Aguçadoura project have nevertheless allowed Pelamis Wave Power to improve their design for their second generation P2 device soon to be deployed in the UK.\textsuperscript{180}

Pico Island, part of the Azores group of islands, hosts a 400kW OWC device. The Pico OWC started operation in 1999 and was funded by the European commission, Electricidade dos Acores (EDA), the (original owner) and Electricidade de Portugal (EDP). Under the coordination of the IST, the device became operational but due to technical issues the project was interrupted for several years. A recovery project costing 600,000 Euros in public funding and a matched amount of private funding, including money from EDP, EDA, EFACEC, Consulmar, Irmãos Cavaco, IST and INETI, was set up to improve the device and restart operation. However, due to design limitations the OWC will not operate at 100% efficiency. This is an ongoing project for WaveEC (the new owner) and is used for demonstration purposes.\textsuperscript{181}

\textsuperscript{180} CleanTech (2010)
\textsuperscript{181} Wave Energy Centre (2010b)