BWEA

Delivering the UK's wind, wave and tidal energy

Entec

Marine Renewable Energy

State of the industry report – October 2009

Executive Summary

Purpose of this Report

This report has been produced for the purpose of providing BWEA with an independent review of the current status of the marine (i.e. wave and tidal stream) renewable energy industry in the United Kingdom (UK). The focus of the review was to identify the estimated cost of energy for wave and tidal stream devices and the issues that need to be addressed in order to ensure commercial deployment of devices. The purpose of the report is to help define BWEA's position on the potential for the UK marine renewable energy industry.

The review was based on public-domain information and a small survey of marine energy device developers. Entec identified and approached 20 device developers and utilities in the UK and the Republic of Ireland that we considered to be leading players in the UK marine industry; 11 of the 20 contacted agreed to be interviewed and their responses have formed the basis of this report.

The general views and opinions of the marine industry were obtained also through the attendance of Richard Boud at the BWEA Wave and Tidal 09 Conference and through the BWEA Marine Steering Group.

Quotes obtained during the survey are included in the report to reflect the current view of the industry. Please note that the quotations are individual industry points of view and do not necessarily reflect the view of BWEA or of Entec. The responses received during the survey were confidential therefore the quotes are not attributed to individuals but the type of organisation that the individuals belong to has been stated.

Summary

The review of the marine industry presented in this report highlighted the following points as the key issues / concerns faced by the industry:

- BWEA members think that most of the early UK marine energy projects will be in Scotland due to the higher level of financial support available;
- Discussions with BWEA members revealed that the industry believes that by 2020 the UK could have installed 1 GW to 2 GW of marine energy projects; however the actual level of capacity installed will be strongly dependent on enabling actions and policies that support the development of the marine industry;
- It is important for the Government to express confidence in the marine industry and the future growth of the marine energy market in order to encourage private investment, not only to make projects happen but also to ensure that companies survive;
- The industry believes that there is a funding gap between the capital grants available for small prototype development and the revenue support for long-term operation of projects;
- Based on the experience of the solar and wind industries, the level of UK support for marine energy is not yet of the magnitude required to develop a world-class industry. If this continues, this means that the UK would not obtain the social and economic benefits generated by the development of a successful marine industry;
- Based on the information provided in this report BWEA thinks that revenue support of five ROCs or equivalent would be an appropriate level to support marine energy projects after the initial 10 MW of capacity has been installed.

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1. The Opportunity

The UK is at the forefront of the marine renewable energy industry through its research and development (R&D) programmes, test facilities and marine and offshore experience gained from working in the oil and gas industries. The majority of the leading companies involved in the industry have a presence in the UK – as either UK-based companies or foreign companies utilising the world-leading test facilities available in the UK.

The successful transition of the marine industry from the developmental phase into the commercial phase would provide wealth creation for the UK and make a valuable contribution to the UK target of 20% of electricity from renewable energy sources by 2020. It is estimated that the marine industry has the potential to create value for UK plc with a home market share as high as 90% and 20% of the remaining global market by monetary value[1] .

Due to the technological support available in the UK, and the abundant wave and tidal stream resource, it is considered that a large share of the European deployment of marine energy devices by 2020 could occur in the UK. BWEA members think that most of the early UK projects will be in Scotland due to the higher level of financial support available there. Beyond 2020 it is expected that the industry would develop significantly as experience is gained of long-term offshore operation, multi-device arrays and operation and maintenance, with projects developed in the UK as well as devices being exported worldwide.

“Scotland will be the main testing market before we look at exports further afield.” – Technology developer

[1] Building Options for UK Renewable Energy, Carbon Trust, October 2003

2. Current Progress – Devices in the Water

Recent years have seen exciting progress in the marine industry with testing of full-scale prototype devices at sea and the installation of the first grid-connected deep-water wave energy device and tidal stream devices. There is significant activity in the R&D of innovate technologies as well as some devices maturing into the pre-commercial stage.

2.1 Current UK Installed Capacity

At the end of April 2009 the UK has 0.5 MW of wave energy installed and 1.45 MW of tidal stream installed. Wavegen's LIMPET shoreline wave energy device was installed on the island of Islay, Scotland in 2000 and has a capacity of 0.5 MW. OpenHydro's 250 kW Open-Centre Turbine is undergoing testing at the European Marine Energy Centre (EMEC) in Scotland and is the first tidal stream device to generate electricity onto the UK grid. Marine Current Turbines' (MCT) SeaGen (1.2 MW) is installed in Strangford Lough, Northern Ireland and is the world's first commercial-scale tidal turbine to generate electricity onto the grid. Pelamis Wave Power's 0.75 MW Pelamis was installed at EMEC for testing. It was the first commercial-scale deep-water wave energy device to be grid-connected. It has now been removed following successful completion of the testing.

In addition to the capacity in UK waters, Edinburgh-based Pelamis Wave Power has installed 2.25 MW of wave energy capacity in Portuguese waters. This is the world's first multi-unit wave farm and the first commercial order for wave energy devices. There are plans to expand this wave farm by a further 20 MW.

2.2 Current Prototype

Development and Testing
Pelamis Wave Power is currently developing the next generation of Pelamis device, 'P2' (0.75 MW), which has been commissioned by E.ON UK for installation and testing at EMEC in 2010.

Ocean Power Technologies (OPT) has deployed small-scale prototypes of the PowerBuoy in the waters off Hawaii and off New Jersey, USA. Currently a 1.39 MW project is under development in the north of Spain with the first 40 kW PowerBuoy device deployed in 2008. OPT is currently building two next generation prototype PowerBuoys (150 kW) near Warwick for deployment and testing at EMEC and Oregon, USA.

Pulse Tidal has deployed the Pulse Stream 100 tidal generator in the Humber Estuary near Immingham. Currently the 100 kW device is undergoing commissioning and testing and it is the first grid-connected shallow water tidal stream device.

Wave Dragon has submitted a planning application supported by an Environmental Statement to the Department for Business, Enterprise and Regulatory Reform under Section 36 of the Electricity Act for a 7 MW demonstration wave energy device. Following award of consent the device would be installed off Milford Haven, Pembrokeshire and tested for three to five years to gain operational experience and knowledge on the energy transfer efficiencies.

Aquamarine Power is planning to install the Oyster wave energy device (350 kW) at EMEC during the summer 2009. The device was recently tested on a full-scale test rig at the New and Renewable Energy Centre (NaREC) where it produced and exported electricity on to the grid.

Tidal Generation Limited is currently working to complete the detailed design and installation of its tidal turbine (0.5 MW) at EMEC.

2.3 Commercial-Scale Projects Under Development in the UK

There is 57.5 MW of commercial-scale marine energy projects currently being developed in UK waters; 27 MW has already obtained planning consent.

ScottishPower Renewables is developing the 3 MW Orcadian Wave Farm using Pelamis machines. The project has obtained the necessary licenses and consents and has secured a funding package from the Scottish Government through the Wave and Tidal Energy Support Scheme (WATES).

The Siadar Wave Energy Project on the Isle of Lewis was granted planning consent in January 2009. The joint project between npower renewables and Wavegen consists of an 'active breakwater' that will generate up to 4 MW of electricity. The project is expected to be fully operational in 2010/2011 and to be the first marine energy project to obtain revenue support through the banded Renewables Obligation Scotland (ROS).

The South West Regional Development Agency's (SWRDA's) Wave Hub was granted planning consent in September 2007 and is expected to be installed in spring 2010. Wave Hub aims to create the UK's first offshore facility for demonstrating the operation of arrays of wave energy devices. It has been consented for 20 MW and will have four separate berths, each capable of exporting 5 MW, and at least three developers are progressing projects.

MCT is planning to install seven 1.5 MW SeaGen turbines (10.5 MW tidal farm capacity) in The Skerries off the coast of Anglesey, Wales. The project will be taken forward as a joint venture with npower. Pre-planning studies are currently underway and subject to successful planning consent and financing the tidal farm could be commissioned as early as 2011.

ScottishPower Renewables is planning to develop a demonstration tidal site in the Sound of Islay that would have an installed capacity of up to 20 MW. It is expected that a planning application will be submitted before the end of 2009 and subject to successful planning consent the tidal devices could be operational by 2011.

2.4 Challenges

Many device developers have successfully tank tested scale-model prototype devices. The next major challenge faced by developers is deploying the first full-scale devices at sea followed by their continued operation and proving.

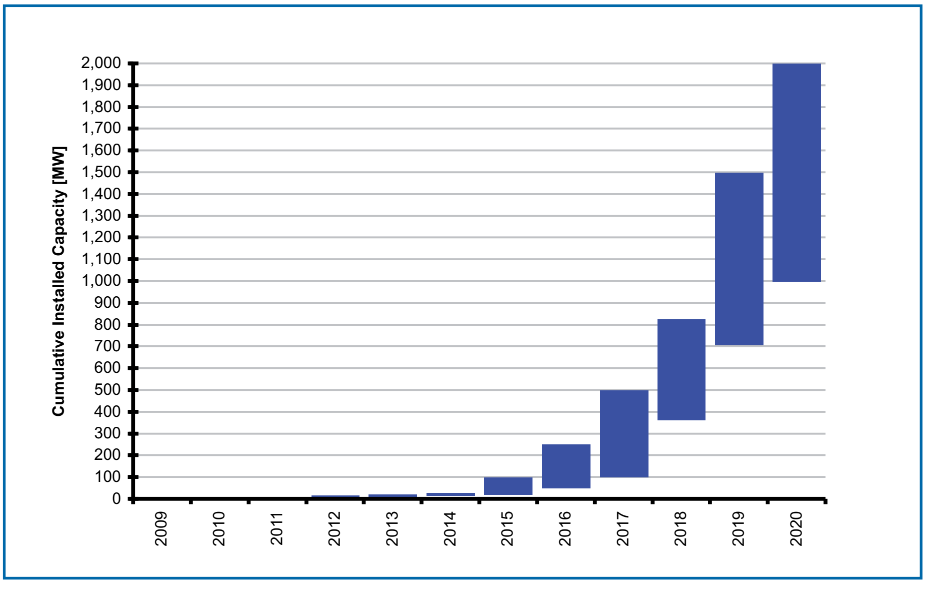
There is significant cost associated with deployment due to the requirement for specialist vessels and the risk of needing a suitable weather window for installation activities. The marine industry must compete with other industries, such as offshore wind, oil and gas, to obtain the specialist vessels.

"Project developers will only proceed at a pace commensurate with the demonstration and development of the technology." – Project developer

The marine environment can be very harsh, particularly in locations of high wave and tidal stream energy. This is often a new working environment for device developers who have limited experience of operating devices there for extended periods of time. The test centres available in the UK provide a good level of assistance with the deployment of the prototype test devices and can be used to gain experience of installation, operation, maintenance and decommissioning activities. The test centres provide the infrastructure required for monitoring the operation of the devices in the marine environment, providing valuable

"Our main focus is on engineering issues, for example collecting operating data and improving reliability, rather than trying to achieve cost targets – we need at least one year of operating data covering four seasons for cost of energy estimates to be meaningful." – Technology developer

Figure 2.1 - Potential UK Cumulative Installed Capacity of Marine Energy Projects to 2020[2]



[2] The graph is for illustrative purposes only to demonstrate the potential growth of the industry to reach the estimated targets of 1 GW installed capacity by 2020 and 2 GW installed capacity by 2020. The actual level of capacity installed by 2020 will be very dependent on enabling actions and policies that support the development of the marine industry.

information for future development of the devices. This information is required not only for the technical and engineering development of the devices, but also to model the financial viability of the devices by determining capital and operation and maintenance costs.

2.5 UK Installed Capacity in 2020

Discussions with BWEA members revealed that the industry believes that by 2020 the UK could have installed 1 GW to 2 GW of marine energy projects. Figure 2.1 provides an illustration of the growth of the marine industry and cumulative capacity that would result in the estimated installed capacities. The actual level of capacity installed by 2020 will be strongly dependent on enabling actions and policies that support the development of the marine industry. BWEA believes that if the industry receives sufficient support in the current early stages of development it can be possible to reach an installed capacity of 2 GW; however if the industry proceeds in its current manner then it may be difficult to achieve an installed capacity of 1 GW.

The Crown Estate target for the Pentland Firth strategic area is 700 MW of offshore wave and tidal stream generation by 2020, so a significant proportion of the capacity may be installed in this area.

3. Political Enthusiasm

The UK Government recognises that developing a low-carbon economy will not only achieve climate change goals but will also support the growth of the UK economy[3]. The marine industry could make a significant contribution towards a low carbon economy. The UK Government and devolved Governments are supporting the development of the industry through strategic planning and support mechanisms.

3.1 Strategic Environmental Assessment

Strategic Environmental Assessment (SEA) is a procedure required under the European Union SEA Directive to incorporate environmental considerations into policies, plans and programmes. It is necessary for an SEA to be completed prior to the strategic development of marine energy. The SEA process not only identifies areas suitable for development with minimal environmental impact, but the information gathered during the process can be used as baseline data for the Environmental Impact Assessments (EIAs) required for individual projects.

SEAs have been completed in UK waters for oil and gas and for offshore wind energy. The SEAs completed for offshore wind energy identified zones suitable for development. This allowed the Crown Estate to complete three rounds of competitive tendering to allow developers to bid for options to construct wind farms within the identified zones. The Crown Estate owns the seabed out to the 12 nautical mile (nm) territorial limit and has the rights to license the generation of renewable energy on the continental shelf within the Renewable Energy Zone out to 200 nm.

An SEA for the development of wave and tidal stream energy around the Scottish coastline has been completed. The SEA examined at length and in as much depth as possible the environmental impacts and effects associated with the deployment of a range and number of wave and tidal stream devices in some of the areas of most concentrated resources. The SEA concluded that between 1 GW and 2.6 GW of generating capacity could be developed with generally minor effects on the environment[4]. The completion of the SEA has enabled the Crown Estate to begin the competitive application process for commercial seabed lease options in the Pentland Firth strategic area for marine energy devices. This strategic area is the first location in the UK to be made available for commercial marine energy development. The Round 1 leasing programme is aimed at delivering 700 MW of new offshore wave and tidal stream generation by 2020 and is expected to bring significant economic benefits to Scotland. In the future it is expected that other areas with suitable wave and tidal stream resources will be offered for development taking into account a range of factors, including developer interest, as well as further opportunities for development in the Pentland Firth strategic area[5].

Currently an SEA is underway for offshore wind and marine energy in Northern Ireland waters. It is expected that the Crown Estate will announce a competitive application process for commercial projects in 2010[6].

Screening of the waters off the English and Welsh coastlines for marine energy potential was announced at the BWEA Wave and Tidal conference in April 2009. The purpose of the screening is to identify the potential for commercial-scale wave and tidal farms; to establish realistic timescales for when multiple devices will be installed and commissioned; and to inform whether a full SEA in England and Wales will be required. The screening is to be completed by late 2009, after which a scoping report is expected with the aim to complete the full SEA study by late 2011. The announcement of the screening is welcomed but it is important that the SEA is conducted in good time to enable the Crown Estate to lease areas of the seabed to developers and to lay the groundwork for future wave and tidal farm deployment.

3.2 The Marine Bill

The Marine and Coastal Access Bill is currently in the House of Lords and is expected to go to the House of Commons during summer 2009. The Bill

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3 Investing in a Low Carbon Britain, HM Government, April 2009

4 Scottish Marine Renewables Strategic Environmental Assessment Non-technical Summary, Faber Maunsell and Metoc Plc, March 2007

5 http://www.thecrownestate.co.uk/wave-tidal

6 http://www.detini.gov.uk/cgi-bin/morenews?utilid=1367

will create a strategic marine planning system and make changes to the marine licensing system that will result in more consistent licensing decisions. The Government plans to set up a new Marine Management Organisation (MMO) that would be a centre of marine expertise and a professional and proactive marine manager. The MMO would make decisions on the majority of marine developments for English territorial waters and offshore marine areas (for those matters that are not devolved). The MMO would license offshore energy installations of less than 100 MW generating capacity and declare safety zones around those installations.

The Bill provides for the development of a joint Marine Policy Statement (MPS). The MPS will be based on a suite of high-level marine objectives for the UK marine area agreed by the Scottish Government, Welsh Assembly Government, Northern Ireland Executive and UK Government. The MPS is due to be completed in 2011.

The Bill provides for Scotland to receive executive responsibility for planning and nature conservation out to 200 nm. The Marine (Scotland) Bill was introduced to the Scottish Parliament in April 2009. It aims to provide a more effective and sustainable approach to the management of Scotland's seas. As with the UK Bill, the Marine (Scotland) Bill plans to introduce a new statutory marine planning system so that use of the seas is well managed and a simpler licensing system that will reduce the administrative burden in areas such as renewable energy. In Scotland a new marine management body called Marine Scotland was established in April 2009 and it has direct responsibility for marine science, planning, policy development, management and compliance monitoring measures. The aim of Marine Scotland is to deliver a simplified management and regulating system for all marine activities.

Currently Northern Ireland and Wales are investigating the delivery mechanism for a marine management body for their territorial waters that will cover responsibility for Coast Protection Act (CPA) and Food and Environmental Protection Act (FEPA) consent.
A simpler licensing system is welcomed by the marine industry but it will be necessary to assess the effectiveness of the system once it is in operation.

3.3 Offshore Transmission Regime

The Department of Energy and Climate Change (DECC) and the Office of Gas and Electricity Markets (Ofgem) are developing a new regulatory regime for offshore electricity transmission[7]. Offshore transmission is defined as being any offshore transmission network that operates at 132 kV or above. The requirement for the regime is largely driven by the development of offshore wind energy but it will benefit wave and tidal stream energy in the future as it provides for the connection of offshore renewable energy generation to the onshore grid. The first offshore wind farms connected to the onshore electricity network at 33 kV; however as the installed capacity of individual wind farms has increased a grid connection at 132 kV is often now required. The regime may also allow neighbouring projects to share grid connection infrastructure.

Currently the new regime is being finalised by Ofgem and the aim is for the regime to 'Go Active' in June 2009 and 'Go Live' in June 2010. The regime will introduce a competitive tendering process for the provision of the offshore transmission infrastructure required for the grid connection of a renewable energy development. This means that the capital cost of the grid connection will be borne by an offshore transmission owner rather than the developer of the renewable energy project. The developer would be liable for an annual charge instead. This should reduce the capital cost required to develop a large-scale renewable energy project.

The Offshore Transmission regime will not be immediately relevant to the marine industry as the first devices and small arrays are likely to connect to the onshore network at 33 kV. A grid connection at 132 kV is likely to be required when marine energy projects have an installed capacity of several tens of megawatts. The threshold between connecting a project at 33 kV and 132 kV not only depends on the installed capacity of the project, but also on the distance of the development from the shore and the device installed. It may be several years before the Offshore Transmission regime is applicable to the marine industry; however it could be utilised in the Pentland Firth strategic area if a co-ordinated approach is taken to obtaining grid connections for the various projects under development.

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[7] http://www.ofgem.gov.uk/Networks/offtrans/Pages/Offshoretransmission.aspx

3.4 The Planning Act 2008

The Planning Act[8] received Royal Assent in November 2008 and it applies broadly in England, has some implications for Wales but is of limited or no application in Scotland and Northern Ireland.

The Act aims to provide a streamlined consenting process for nationally significant infrastructure projects, which covers certain types of energy, transport, water, waste water and waste projects. The number of applications and permits required for such projects will be reduced compared with the position under current legislation.

The Act allows for the Infrastructure Planning Commission (IPC) to be established. The IPC will be an independent body responsible for examining applications for development consent for nationally significant infrastructure projects. Marine energy projects with a generating capacity greater than 100 MW installed in the territorial seas of England and Wales or in a Renewable Energy Zone (except any part of a Renewable Energy Zone in relation to which the Scottish Government has functions) is classed as a nationally significant infrastructure project. The Act provides an application procedure that includes a pre-application process where consultation with relevant bodies is required and the IPC must be notified of the application prior to submission. This aims to resolve any potential issues in advance of submission of the planning application. The IPC aims to produce consent decisions in nine months as a deadline of six months is stipulated for completing the examination procedure and three months is allowed for decision making. The decision making will be guided through national policy statements, which are being developed during 2009.

Marine energy projects will be of small capacity until the industry is more developed so may not apply for planning consent from the IPC; the projects would be licensed by the relevant marine management organisation created through the Marine Bill (see Section 3.2). By 2020 individual projects may be greater than 100 MW. Projects located in Scottish Waters, for example within the Pentland Firth strategic area, will be determined by the Scottish Government; however projects located elsewhere in the UK would be determined by the IPC.

[8] Planning Act 2008 accessed at http://www.opsi.gov.uk/acts/acts2008/ukpga_20080029_en_1

4. Test Centres and Research

The UK is a world leader in R&D of wave and tidal stream energy with research carried out at a number of academic institutes and facilities available to support developers in testing their devices in tanks and at sea.

SuperGen Marine research programme funded by the Engineering and Physical Sciences Research Council commenced in 2003 and is a consortium of the Universities of Edinburgh, Heriot-Watt, Lancaster, Robert Gordon and Strathclyde. The overall aim of the programme is to complete generic research on the potential for future exploitation of the marine energy resource. The current phase of the programme aims to increase knowledge and understanding of device-sea interactions of energy converters from model scale in the laboratory to full size in the open sea. The results from the research are disseminated to stakeholders through workshops and publication of papers.

PRIMaRE is a partnership of the Universities of Exeter and Plymouth, which receives funding from the SWRDA. The purpose of the partnership is to form a team of world-class researchers to provide expertise and research capacity to address the wider considerations of all environmental and ecological aspects of marine renewable energy. PRIMaRE is directly linked to Wave Hub, the offshore facility for the testing of arrays of wave energy devices, and the associated device developers.

BWEA members describe the test facilities available in the UK as essential to the successful development of the marine industry. This has been seconded by the UK Government's supporting announcements in the Renewable Energy Strategy[9], which designates a total of £38 million to this infrastructure. Up to £10 million has been awarded to the New and Renewable Energy Centre (NaREC), up to £8 million to the European Marine Energy Centre (EMEC) and up to £20 million to Wave Hub and the South West, to create the UK's first low carbon economic area.

NaREC in Blyth, Northumberland was established in 2002 as an independent R&D centre serving the new and renewable energy industry. The consultants at NaREC provide developers with concept evaluation and technical expertise to support the progression of devices to commercial viability. NaREC has a large-scale wave flume and a tidal testing facility to allow scale models of prototype devices to be tested in a controlled and monitored environment.

The European Marine Energy Centre (EMEC) in Orkney was established in 2003 and it offers developers the opportunity to test full-scale grid-connected prototype wave and tidal streams devices. The centre operates two sites – a wave test facility and a tidal test facility – that have multiple berths that allow devices to be tested in the open sea. The berths have an existing connection to the onshore electricity network and facilities for technology and environmental monitoring.

In 2008 QinetiQ incorporated the testing of marine energy devices within its remit and their facility at Gosport, in Hampshire, provides one of the largest testing tanks in UK. The QinetiQ consultants also provide impartial services to marine energy device developers and energy suppliers, for example research, design and hydrodynamics advice and technology readiness assessment, amongst other services.

Wave Hub, 10 miles off the north Cornwall coast, aims to create the UK's first offshore facility for demonstrating the operation of arrays of wave energy devices and is expected to be installed in spring 2010. It will have four separate berths, each will be capable of exporting 5 MW; upgrading to a total capacity of 50 MW may be considered. The first wave energy devices could be installed in 2011. Three developers have secured access to the berths – Fred Olsen Limited, Ocean Power Technologies and Orecon. There are a number of developers in talks with Wave Hub to secure the fourth berth.

[9] The UK Renewable Energy Strategy, HM Government, July 2009

5. Financing and Funding

The development of the UK marine industry is supported by the UK Government and devolved Governments through the use of capital grants and revenue support, with the most attractive schemes currently available in Scotland. In addition to the public funding, UK-based developers have been successful in raising significant private finance.

Many of the marine energy device developers are small- and medium-sized companies formed with the sole purpose of developing a specific device. The developers are faced with the challenge of securing sufficient funding to support the day-to-day operation of the company and development of the device as well as the obtaining financing for the development of specific projects. Operational and development funding may be obtained from Government grants (as described in the following paragraphs) or private investors, such as venture capitalists or through the sale of shares. Generally in order to secure private finance a developer must demonstrate the potential future market for the marine energy device. Developers may obtain financing for specific projects through private investment, for example by entering into partnerships with established companies, such as utilities. This may provide useful project development skills in addition to the finance required. It is important for the Government to express confidence in the marine industry and the future growth of the marine energy market to encourage private investment not only to make projects happen but also to ensure that companies survive.
The direct total Government spending on technology R&D (provided through the DTI new and renewable energy programme) for 1999 to 2005 are £3.9 million for wave energy and £6.5 million for tidal stream energy[10]. During the same period the Research Council spend on its wave and tidal research programme was £3.6 million[10]. Grant support available for R&D is disjointed as it is provided by a number of different bodies, for example the Carbon Trust, Scottish Government, the Technology Strategy Board (TSB) (calls for new applications now discontinued) and the Environmental Technology Institute (ETI). Applying for funding can be complex as there are many avenues for funding with different criteria and timelines. It can be difficult to identify the most appropriate source of funding, resulting in developers devoting a large amount of time and energy to securing funds.

Many device developers consider the ETI model to be unsuitable as it requires a sharing of intellectual property rights in exchange for funding. There is also a potential conflict of interest with ETI members individually involved in developing competing technologies. There can be significant competition for the funding that is available due to the large number of marine energy devices currently under development in the industry and the limited sources of funding available.

The industry believes that there is a funding gap between the capital grants available for small-scale prototype development and the revenue support for long-term operation. Whilst the announcement of the Marine Renewables Proving Fund (MRPF), a fund of up to £22 million launched by the Government in the Renewable Energy Strategy[9], goes some way to filling this gap BWEA thinks that the UK Government should ensure that long term funding is available to facilitate testing at sea and to reflect the high costs of the installation of initial projects The Marine Renewables Development Fund (MRDF) was established by the UK Government in 2004 to support the first devices operating at sea. £42 million of the £50 million MRDF provides a combination of capital grant and revenue support for devices. The remaining £8 million supports

> *"UK Government has allocated funding to TSB and ETI but although the process is transparent, funds are inaccessible. There should be a rolling call to support good technologies and projects rather than a competition to support only one / few projects." – Technology developer*

> *"We need higher levels of RD&D funding." – Technology developer*

[10] http://www.parliament.the-stationery-office.co.uk/pa/cm200506/cmhansrd/vo051025/text/51025w27.htm#51025w27.html _sbhd6

environmental research, related research and infrastructure. 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. There are two main reasons for this: firstly that many developers cannot obtain the funding required to install the first full-scale device and secondly that marine energy device development is challenging, takes a significant period of time and does not allow the opportunity to prove performance onshore before going offshore. To tackle the latter, the Government needs to support the unexpected delays and costs that the industry will experience in the early years. It is expected that a number of devices will achieve the eligibility criteria in the next few years; BWEA hopes that the barriers to development will be reduced by the Government's Marine Renewables Proving Fund and the development of devices accelerated. Analysis of the MRDF has revealed that the cost of wave energy today is greater than when the MRDF was first devised therefore the MRDF will not provide the levels of support that were considered necessary for the development of wave energy projects[11]. The MRDF may require adjustment following the introduction of the banded Renewables Obligation (RO) therefore this may be a suitable opportunity for the Government to modify the financial parameters of the MRDF, for example to increase the level of capital grant provided.

"The MRDF is just £42m sitting in a pot that no one can access – if the eligibility criteria for funding are stopping companies receiving funding then Government needs to help companies to meet the criteria." – Technology developer

The Scottish Government introduced the £13.5 million Wave and Tidal Energy Support Scheme (WATES) in 2006 and has provided support to nine schemes so far. The objective of the scheme is to support the early development of marine energy devices that need to complete pre-competitive R&D. The scheme also provided funding to EMEC for infrastructure upgrades.

In April 2009 the UK Governments introduced additional revenue support for marine energy devices through the Renewables Obligation (RO), Renewables Obligation (Scotland) (ROS) and Renewables Obligation (Northern Ireland) (NIRO). The introduction of banding to the RO, ROS and NIRO allocates two Renewable Obligation Certificates (ROCs) to every megawatt hour (MWh) of electricity generated from a marine energy device. This is over £90 per MWh (9p/kWh) and means that marine energy generators will receive approximately 12.8p/kWh when the income received from the electricity generated, levy exemption certificates and the recycle of ROCs is also included[12].

"Two ROCs isn't going to make anyone do anything in England." – Technology developer

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 devices. This will be introduced through secondary legislation. When the income received from the electricity generated, levy exemption certificates and the recycle of ROCs is also included tidal stream devices will receive 17.3p/kWh and wave energy devices will receive 26.3p/kWh[12].

This level of ROC support is comparable to the level that was offered under the Scottish Government's Marine Supply Obligation (MSO); however it is believed that marine energy generation costs have increased since the MSO was designed so additional support may be required to encourage deployment[13]. A Government led study should be initiated to identify what levels of ROC banding are required for marine energy devices. The MSO was introduced in

[11] Marine Renewables: Current status and implications for R&D funding and the Marine Renewables Deployment Fund, Renewables Advisory Board, January 2008

[12] Base price of electricity is 2.5 to 5p/kWh (including levy exemption certificates), with average assumed to be 3.75p/kWh, and one ROC is assumed to be worth 4.5p/kWh (including recycle). This means that marine energy generators would receive a total of 8.25p/kWh.

[13] Modelling Changes to the Renewables Obligation, SQW Energy, Redfield Consulting, Cambridge Economic Policy Associates and Econnect, 2008

April 2007 to provide a long-term signal of support and commensurate returns for wave and tidal stream generation located in Scottish Waters. The buy-out payment levels were set at 17.5p/kWh for wave devices and 10.5p/kWh for tidal devices. The Scottish Government discontinued the MSO in April 2009 following the introduction of banding of the ROS. No marine energy projects received support through the MSO.

BWEA members welcome the higher level of revenue support in Scotland but highlight that this means that developers will concentrate on projects in Scotland as two ROCs is not sufficient support for developing projects elsewhere in the UK.

"We need five ROCs in England." – Technology developer

Wavegen's LIMPET wave energy device receives income support through the Scottish Renewables Obligation (a predecessor to the ROS). It is likely that the Siadar Wave Energy Project will be the first development to receive multiple ROCs as revenue support through the ROS.
In order to be eligible for ROCs through the ROS the marine energy projects must:

- Accord with the definition of wave or tidal stream as set out in the ROS;
- Be situated up to 200 nm off the Scottish coast;
- Be connected directly to a transmission or distribution network in Scotland.

To be eligible for the enhanced ROCs the project must not have received financial support under existing capital and revenue support schemes for wave and tidal stream energy operated by either the Scottish Government or the UK Government; where support has been received projects will be eligible for two ROCs.

"Scotland is the most attractive part of UK due to ROCs etc." – Technology developer

Other European countries provide revenue support for marine energy projects. Portugal has an attractive energy market with a support level of 23 cents/kWh. Pelamis Wave Power has developed the first multi-device project in Portugal. France provides 15 cents/kWh for wave energy and Spain provides 7.5 cents/kWh. Wavegen and OPT are planning multi-device projects in Spain where it may be possible to receive a higher wave energy tariff (in the order of 32 cents/kWh to 54 cents/kWh) on a project-specific basis.

'ROCs alone aren't enough.' – Utility
The introduction of additional ROCs for marine energy is welcomed however it is believed that further capital grant support is required to meet the exceptional capital costs of the first generation of commercial-scale projects. Currently, significant engineering and investment is required for the cost of energy of marine energy projects to be within three to five ROCs.

The funding and support currently available in the UK for the development of the marine industry is a fraction of the level of Government support that led to the successful development of the solar industry in Japan and the wind industry in Denmark. The Japanese solar industry developed through Government funding and promotion with market support and direct subsidies of around £1 billion between 1994 and 2011. This has led to the development of an industry with sales of over £2.4 billion per annum. Denmark is the world leader in the wind industry with a global market share in the turbine market of greater than 50%. This successful industry was supported by Government measures worth over £1.3 billion since 1993 resulting in annual revenues of approximately £2.7 billion. Based on the experience of the solar and wind industries, the level of UK support for marine energy is not of the magnitude required to develop a world-class industry.

"ROCs alone aren't enough." – Utility

5.1 Cost of Energy

A previous report[14] assessing the cost of energy from marine energy projects estimated that energy from initial wave energy farms costs between 12p/kWh and 44p/kWh, with central estimates for offshore wave farms in the sub-range 22p/kWh to 25p/kWh. Initial tidal stream farms are estimated to have costs of energy between 9p/kWh and 18p/kWh, with central estimates in the sub-range 12p/kWh to 15p/kWh.

[14] Future Marine Energy. Results of the Marine Energy Challenge: Cost competitiveness and growth of wave and tidal stream energy, Carbon Trust, January 2006

Another study[15] has estimated that in 2020 the cost of energy from wave energy would be 15.1p/kWh (9.6p/kWh to 21.7p/kWh) and the cost of energy from tidal stream energy would be 13.7p/kWh (9.3p/kWh to 17.9p/kWh).

Figure 5.1 shows an estimate of likely costs of energy produced by marine energy devices[16]. This was based on opinions of the BWEA membership. A learning curve has been applied to the estimated costs of energy. This shows how, as more capacity is installed globally, costs can be expected to reduce. We expect that learning rates of 85% to 90% on the total life cost of energy are likely for this industry provided that development is continuous and uninterrupted. Marine and offshore experience gained from working in the oil and gas industries can be applied and transferred to the marine industry to promote the reduction of costs improved energy capture and to increase the knowledge base.

The curves shown in Figure 5.1 relate to the development of a single device, rather than to the whole industry. There are a large number of wave and tidal energy devices currently under development and this slows down the progress of the industry as a whole as each device concept needs to follow a learning curve of this form. We can expect that the industry will consolidate to a few good concepts in time and that this would be likely to increase the rate of progress of the industry.

Figure 5.1 - Cost of Marine Energy

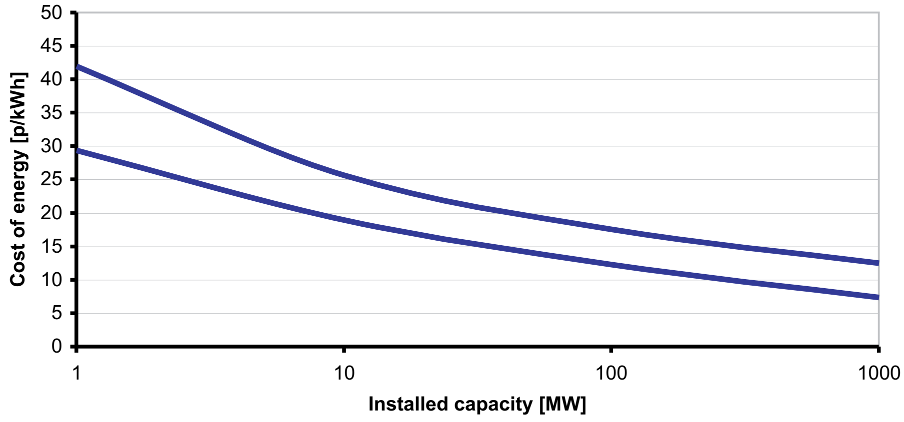


Figure 5.2 shows the same information overlaid illustratively with different ROC multiple levels[12]. This shows that if multiple ROCs were available then investment for early projects below approximately 10 MW would still be needed to cover the difference from revenue support and the normal technology development risks. This additional investment would be of the order of £0.5 million/MW to £2.6 million/MW if five ROCs were available for the first few megawatts.

At a ROC support level of two ROCs commercial-style projects are unlikely below 100 MW of installed capacity and may not appear until 1 GW of capacity. Top-up investment would be prohibitive. With two ROCs technologies in their earliest stages of development would require additional investment of £2.6 million/MW to £4.8 million/MW. In some cases this could be equivalent to the total capital costs of the projects.

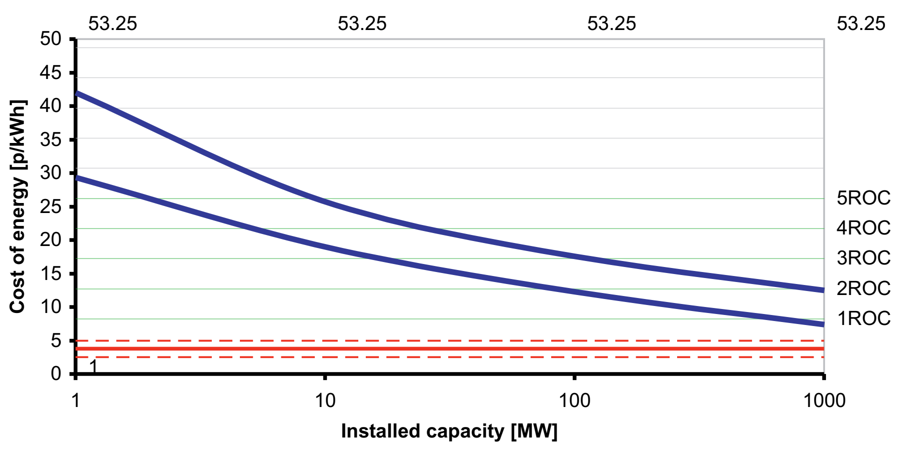
The 2.25 MW Pelamis wave farm at Agucadoura in Portugal, the first multi-device project, was developed with a specific installation cost of £3,226 per kW; which is in the range of photovoltaic solar energy and approximately four times higher than large-scale wind energy[17]. This demonstrates that significant capital investment is required to install the first projects at sea and it is acknowledged by the industry that the capital costs will remain high for some considerable time and whilst devices and schemes remain small.

The data in Figure 5.1 and Figure 5.2 are uncertain and the multiple ROC revenue support could be replaced by a mix of capital and revenue support or tax credits. Nevertheless these figures show three clear phases of technology development. The first is

[15] Impact of Banding the Renewables Obligation - Costs of electricity production, Ernst & Young, April 2007

[16] Costs are based on a simplified discounted cash flow analysis at an assumed discount rate of 15%.

Figure 5.2 - Cost of Marine Energy in Comparison to ROC Support[12]



when the technology is new and small. In this phase investment into device deployment is needed to fund the technology demonstration before it can be supported by the electricity tariff, such as the ROC market.

The second phase is when the technology receives additional support above the other forms of renewable energy. During this phase continual development is needed with improvements to whole-farm economics through higher energy performance, lowering costs, improving the supply chain and building larger projects. It is not realistic to expect that the cost reductions indicated will be realised without continuous improvement programmes and ongoing R&D. This continuous improvement is possible if there is continuous investment or there are commercial returns from previously deployed projects. It is likely that if there are interruptions to development programmes progress can halt or even reverse as skilled people move elsewhere and resources are redeployed.

In the final phase, projects are expected to scale up and project developers can make bigger investments based on more proven technology. In this phase the costs are likely to reduce so that developers can make commercial returns and eventually can operate at market prices closer to that of other renewable energy technologies.

By 100 MW to 500 MW of installed capacity well-developed technologies could compete with other renewable energy sources, such as early offshore wind projects that currently attract two ROCs.

Since it is expected that more than one marine energy technology will be successful, the installed capacity required to reach these lower cost levels will be greater than this. If, for example, four technologies reach cost levels that can be supported by two ROCs after their first deployment of 250 MW then the industry will have installed around 1 GW of capacity.

It should be noted that most developers will be progressing and building projects on a global basis and as such the industry's cumulative installed capacity and any learning effects could materialise both in the UK and in other countries, thereby helping the industry reduce costs quicker in the UK for a given UK installed capacity target.

"Lack of adequate funding is a key barrier. The Government needs to put in place funding to leverage technology." – Technology developer

The only way for the marine industry to be viable in the long-term is continual R&D, more testing and operation of devices in the marine environment and the scaling up of both the production of devices and projects. This requires significant capital investment to progress the industry from its current status to commercial viability.

Based on the information provided in this section BWEA thinks that revenue support of five ROCs or equivalent would be an appropriate level to support marine energy projects after the initial 10 MW of capacity has been installed. The development of the first small-scale projects to achieve this installed capacity would require capital grant funding in addition to revenue support.

[17] Reaping the wind and tides, Frank Rogalla, Water and Waste Treatment, November 2008

6. Grid Connection

In common with offshore wind, and to some extent onshore wind, the areas of most abundant resource for marine energy tend to be remote from onshore distribution and transmission networks or in areas of limited network capacity. This leads to high demand for grid connections in certain locations and can increase the costs associated with obtaining a connection.

EMEC and Wave Hub, once constructed, are very beneficial to the industry because they have existing grid connections that allow developers to test the operation of their devices when connected to the grid. This avoids the need to apply for and construct a new grid connection.

The marine industry, Government and electricity network operators are aware of the barriers to connecting marine energy projects to the grid and a number of scenarios for the long-term development and reinforcement of the onshore grid are being discussed. This dialogue is welcomed by the industry; however it will not facilitate the connection of the initial demonstration projects and small-scale arrays. The north and west of Scotland have abundant marine energy resources but are heavily constrained by available grid capacity. The local distribution network (operating at 11 kV and 33 kV) is sparse and has limited capacity to accommodate generator connections. Generators with a capacity of 10 MW or greater in the north of Scotland are classed as large power stations. It is necessary for the distribution network operator to consult with National Grid (operator of the transmission network) before providing an offer for grid connection to a large power station. Even once the planned grid upgrades have been completed the grid will not be able to accommodate the currently contracted queue of generation in the north of Scotland. Therefore new applicants for grid connection are generally being given connection dates of beyond 2018[18].

In order to connect the initial small-scale marine energy developments to the grid it may be necessary to implement innovative and proactive measures, for example in the form of Registered Power Zone type measures, such as the scheme that has been implemented in Orkney. The Orkney Registered Power Zone increases the capacity available for the connection of generation by managing the distribution network and connected generation; generation is constrained in line with the load on the network and the thermal capacity of circuits.

> *"The Government needs to give priority to marine energy projects in order to avoid a marine energy queue. The strategic importance of marine energy projects needs to be recognised – they should **not** be treated as "normal" commercial projects." – Technology developer*

The Pentland Firth is likely to be the first area in the UK to see the development of large-scale marine energy projects. A recent report[18] assessing the grid connection options in this area concludes that in the short term small capacities could be connected to the grid through innovative practices and minor network reinforcements. Significant reinforcement of the onshore networks would be required to connect large-scale developments. It is not clear how the reinforcements would be co-ordinated and delivered in a timely and cost-efficient manner in order to meet the targets for generation in this area.

There is a major focus by the Government on the Pentland Firth strategic area due to the Crown Estate Round 1 lease programme. The Pentland Firth is an area of high tidal stream resource but the Western Isles, which are outside the strategic area, have a more abundant wave energy resource and are likely to be a preferable location for the development of wave energy projects. Therefore it must be recognised by the Government that grid reinforcement in the west of Scotland is as important as reinforcement in the north of Scotland. Scottish Hydro Electric Transmission Limited (the transmission owner in the north of Scotland) has submitted a planning application to develop a new electricity transmission line from the Western Isles to the mainland. This application has been driven by the development of onshore wind farms on the Western Isles; it is important that any future network upgrades consider

[18] Pentland Firth Tidal Energy Project Grid Options Study, Xero Energy, January 2009

the development of marine energy projects and the likely demand for grid connections.

The new Offshore Transmission regime[7], as described previously, is welcomed by the marine industry but will not be immediately relevant to the industry. It could be utilised in the Pentland Firth if a co-ordinated approach is taken to obtaining grid connections for the various projects under development. The regime must be supported by the strategic development of the onshore distribution and transmission networks to reinforce the networks in areas that are likely to be developed for wave and tidal stream farms. At the current stage of industry development it is difficult to demonstrate the level of reinforcement that will be required. It is recognised that the marine industry must demonstrate and build large-scale projects and apply for grid connections in order to stimulate the development of the networks.

7. Social and Economic Benefits

The development of a successful marine industry will help the UK meet climate change targets and also bring social and economic benefits to the UK[14].

It is recognised that the developm ent of a commercially successful marine industry would lead to job creation within the UK; however there are differing opinions regarding the level of job creation. A study published by the Scottish Executive predicted that 7000 direct jobs could be created in a diverse marine industry in Scotland by 2020, supported by sustainable research development and skills bases[19]. A study completed for BWEA identified that the growth of the wave and tidal sector could provide up to 2100 jobs in the UK by 2020[20].

Currently the UK is one of a small number of European countries leading the development of marine energy. This means that the UK is in a strong position to develop Europe's dominant marine industry (in a similar way to how Denmark became the market leader in the provision of wind turbines) and therefore obtain the economic benefits that the industry generates. It has been estimated that by 2050 the marine energy domestic and export market could provide the UK with annual revenues between £600 million and £4.2 billion[21]. This is comparable to Denmark's current share of the wind turbine market, with annual revenues of approximately £2.7 billion[1]. In order for the UK to become the market leader it is believed that greater public support than the support offered in other countries is required over an extended period of time to develop a robust and affordable technology[20].

The economic benefits and job creation generated by the growth of the marine industry would be beneficial to the UK to counter-act the effects of the steady decline of the oil and gas industries. The production of oil and gas from the UK offshore areas is in decline as reserves are progressively exhausted. It is anticipated that the UK will be a net importer of oil and gas by 2010, if not before, and that importing energy supplies will have a large effect on the balance of payments for the UK[22].

7.1 Security of Supply

Security of electricity supply is of concern to the UK Government and devolved Governments as domestic fossil fuel reserves are depleted and the UK becomes increasingly dependent on imports. Energy diversity and the substantial indigenous renewable energy sources in the UK are useful ways of maintaining energy reliability. Renewable energy is not so acutely subject to the price volatility experienced with conventional energy generation from fossil fuels. A recent study[23] for BWEA concluded that diversifying the renewable energy mix by including a greater proportion of wave and tidal stream energy would reduce requirements for back-up and reserve capacity, lower carbon emissions and save fuel. This could lead to cost savings of as much as £900 million per annum, equal to 3.3% of the annual wholesale cost of electricity due to the increased mix diversity.

[19] Harnessing Scotland's Marine Energy Potential, Forum for Renewable Energy Development in Scotland Marine Energy Group, 2004

[20] Employment opportunities and challenges in the context of rapid industry growth, Bain and Company, October 2008

[21] Policy Frameworks for Renewables, Executive Summary, L.E.K. Consulting and Carbon Trust, July 2006

[22] Socio-economic indicators of marine-related activities in the UK economy, David Pugh on behalf of The Crown Estate, March 2008

[23] The Benefits of Marine Technologies within a Diversified Renewables Mix, Redpoint Energy Limited, 2009

8. The Future

The current short-term challenge facing the marine industry is gaining sufficient experience of operating devices and multi-device projects in the marine environment to demonstrate to all investors (public and private) that the technology works, and the future potential for the industry.

The use of the UK's R&D capabilities and internationally-recognised test facilities should be reviewed to determine how to obtain the greatest benefit from the services available.

The UK Government and devolved Governments must continue supporting the marine industry through policy and funding. The SEA announced for England and Wales and multiple ROCs for marine energy projects are welcomed. The industry does feel that additional revenue support above the recently introduced two ROCs is required. The UK Government's announcement of the Marine Renewables Proving Fund will partially provide the additional capital grant funding that is essential to allow the first marine energy projects to be installed; however it is expected that additional capital grant funding may be required. The equivalent to five ROCs for wave energy projects may be a suitable level of support once experience has been gained from initial projects. At a support level of two ROCs commercial-style projects are unlikely until each marine technology has deployed at least 100 MW of cumulative installed capacity either in the UK through additional support mechanisms or alternatively through overseas development and support. Without additional support mechanisms the UK will almost certainly lose its claim to being the market leader of the marine industry and in turn the social and economic benefits that would follow.

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