renewableUK
The voice of wind & marine energy

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Wave and Tidal Energy in the UK

State of the industry report

March 2011

RenewableUK is the trade and professional body for the UK wind and marine renewables industries. Formed in 1978, and with 650 corporate members, RenewableUK is the leading renewable energy trade association in the UK. Wind has been the world's fastest-growing renewable energy source for the last seven years, and this trend is expected to continue with falling costs of wind energy and the urgent international need to tackle CO_2 emissions to prevent climate change.

In 2004, RenewableUK expanded its mission to champion wave and tidal energy and use the association's experience to guide these technologies along the same path to commercialisation.

Our primary purpose is to promote the use of wind, wave and tidal power in and around the UK. We act as a central point of information for our membership and as a lobbying group to promote wind energy and marine renewables to government, industry, the media and the public. We research and find solutions to current issues and generally act as the forum for the UK wind, wave and tidal industries, and have an annual turnover in excess of 4 million pounds.

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Executive Summary

Marine energy could provide 20% of UK electricity consumption, from a practically extractable resource of 36GW. Including a greater proportion of marine supply in the UK energy mix would reduce requirements for back-up and reserve capacity, saving the UK £900 million per annum.[1] The sector currently employs 800 full time employees in the UK[2] and by securing the current market lead by 2035 the UK marine energy industry could:

- Employ 19,500 individuals.
- Draw investment of £6.1bn.
- Generate GVA of £800m per annum.[3]

As of March 2011 the UK has 3.4MW of installed marine energy capacity (an almost 50% rise in the past year). A total of 7.4MW of prototypes are in the advanced stages of planning and fabrication for deployment in 2011, representing a potential 100% increase.

Looking further ahead, a total of 11MW of marine energy projects have been awarded consents and an additional 23MW has entered the planning system. In total, developer appetite exists to deploy 2.17GW of marine energy projects by 2020.

RenewableUK members noted that all the future development listed within this report pre-supposes that the Government will provide suitable financial support, without which, development will not occur. With EU member states aiming to deploy 1.95GW of marine energy by 2020 and the USA and Canada developing coordinated approaches to develop their markets and commercialise the sector, there is significant international competition for securing the benefits of building a domestic marine renewables industry with a significant global export potential.

With the current administration promising to be the 'greenest Government ever' and to deliver 'measures to support marine energy'; a 2011 Scottish Election, which has seen all parties pledge their support for the sector; the current Renewables Obligation review, due to conclude before the close of 2011; and the establishment of the Marine Energy Programme, there is an opportunity to coordinate industry and instigate government policy that can ensure the UK secures its global lead.

RenewableUK members believe the immediate actions which must be delivered within the next 12 months to ensure the developments up to 2014 include:

- Establishment of a support mechanism of 5 ROCs or equivalent for wave and tidal energy across the UK.
- Provision of £130 million of capital support for marine energy projects at the scale of 2-10MW to be sourced from the Department of Energy and Climate Change's Low-Carbon Innovation Fund and the Green Investment Bank.
- Definitions of a clear and concise plan to provide grid accessibility at reasonable costs in areas where there is a high marine energy resource.
- Development of a coordinated approach to understanding the environmental impacts of marine energy devices, with the aim of fast tracking consents procedures.

1. RenewableUK, Channelling the Energy, 2010
2. RenewableUK, Working for a Green Britain, 2011
3. Redpoint Energy Limited for RenewableUK, The Benefits of Marine Technologies within a Diversified Renewables Mix, 2009

Opportunity

The UK is at the forefront of the marine renewable energy industry through its research and development (R&D) programmes and test facilities. 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 and centres of academic excellence available.

The successful transition of the marine industry from the developmental phase into the commercial phase will create wealth for the UK.[4] With a practically extractable resource estimated at 36GW,[5] 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.

Although the sector is in its infancy, it could still create 19,500 jobs by 2035 and generate revenue in the region of £6.1 billion.[6] Marine energy is also an attractive form of low-carbon generation for the UK as it offers system-balancing benefits that result in an overall reduction in the cost of electricity to the consumer.[7]

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. Beyond 2020 it is expected that the industry will 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.

RenewableUK members believe they will have to seek development opportunities overseas and the UK could fail to secure the low-carbon energy production and economic development potential outlined earlier, without direct action to address the following:

- The capital and revenue support for the first pre-commercial projects (2–10MW).
- An outdated grid charging regime acts as a disincentive to the production of marine energy.
- Availability of grid connection in areas of marine energy resources.
- The unknown environmental impacts of marine energy devices to deliver consents.

4. Carbon Trust, Building Options for UK Renewable Energy, October 2003
5. Public Interest Group, The Offshore Valuation Report, 2010
6. RenewableUK, Channelling the Energy, 2010
7. Redpoint Energy Limited for RenewableUK, The Benefits of Marine Technologies within a Diversified Renewables Mix, 2009

Current Progress

As of March 2011, the UK has 3.4MW of installed marine energy capacity (an almost 50% rise in the past year[8]) with a total of 7.4MW of prototypes in advanced stages of planning and fabrication for deployment in 2011, representing a potential 100% increase.

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 wave energy and tidal stream devices. There is significant activity in the R&D of innovative technologies as well as some devices maturing to the pre-commercial stage.

To obtain a comprehensive view of the anticipated and realistic delivery profile for the marine energy industry over the next five to ten years, RenewableUK surveyed the industry to ascertain developer appetite for project development.

The contributors to this survey included: Aquamarine Power, Pelamis Wave Power, Ocean Power Technologies, Wavegen, Pulse Tidal, Tidal Energy Ltd, Marine Current Turbines, Voith, Atlantis Resource Corporation, Tidal Generation Ltd, Hammerfest Strøm, OpenHydro, ScottishPowerRenewables, EON, Scottish and Southern Electricity, MeyGen (Morgan Stanley, International Power and ARC), Vattenfall, RWE npower renewables Ltd and The Crown Estate.

RenewableUK members noted that all the future development listed within this section pre-supposes that the Government will provide suitable financial support, without which development will not occur.

Current UK Installed Capacity

At the end of March 2011 the UK has an installed capacity of 3.4MW of marine energy, consisting of 1.31 MW of wave energy capacity and 2.05 MW of tidal stream capacity. This is a 50% increase from the 2.4MW installed in 2010.

Voith Hydro Wavegen's LIMPET was the world's first commercial-scale grid-connected shoreline wave energy device, installed in 2000, with a capacity of 0.25MW and now has over 70,000 operating hours. In 2009 Aquamarine Power installed Oyster 1, a 0.315MW near-shore wave device at EMEC. EON installed the 0.75MW P2 device, fabricated by Pelamis Wave Power at EMEC in the summer of 2010.

OpenHydro's 0.25 MW 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 to the UK grid. Marine Current Turbines' (MCT) SeaGen (1.2 MW) is the world's first commercial-scale tidal turbine to generate electricity and is reported to have produced in excess of 2,500MW/h to the UK grid. Pulse Tidal deployed the Pulse Stream 100 tidal generator, a shallow-water tidal stream device, in the Humber Estuary near Immingham in 2009. 2010 also saw Tidal Generation Ltd, the wholly owned subsidiary of Rolls-Royce, install their 0.5MW DeepGen device at EMEC.

2009 was the first year in which marine energy devices entered into their decommissioning phase, when Marine Current Turbines decommissioned their 0.3MW proof-of-concept SeaFlow device, which was located off the Devon coast. This activity continued into 2011, with Aquamarine Power planning to decommission their 0.315MW Oyster 1 device, which is located at the EMEC wave site. The current lease for the Pulse Stream 100 is due for renewal in April 2011. The Technology Index provides a concise review of twenty of the leading wave and tidal energy technologies currently being developed in and around the UK.

Planned Activity in 2011

A number of devices at varying stages of development are planned for installation in 2011. Atlantis Resource Corporation has installed and grid-connected the foundation for their 1MW AK1000, which is due for reinstallation at EMEC in April 2011, having been removed in November 2010 due to blade damage.

Scottish Power Renewables has placed an order with Pelamis Wave Power and construction is already underway on a 0.75MW P2. Consent has already been granted to install the device next to the EON machine currently deployed at EMEC.

Aquamarine Power is fabricating the 0.8MW Oyster 2 device and has already obtained planning consent to deploy the device at EMEC in summer of 2011.

Ocean Power Technologies has manufactured its PB150 at Invergordon in Scotland and will conduct preliminary proving trials at a temporary site in the Moray Firth during the first half of 2011.

Scotrenewables has fabricated a 250kW device at Harland and Wolff in Northern Ireland, with plans afoot to deploy the device at EMEC in Orkney in 2011.

The wave device developer Wello Oy is currently constructing a 500kW device, with a berth secured at EMEC for its deployment planned for 2011.

8. RenewableUK, Marine Energy State of the Industry, 2010

When combined with the planned deployment of the 1MW Hammerfest Strøm HS1000 at EMEC, a total of over 4MW of prototypes are in the advanced stages of planning for deployment in 2011. This could result in a more than 100% increase in installed capacity by March 2012, representing a potential total of 7.4MW of marine energy generation that could be connected to the UK grid.

Development by 2014

Figure 1. indicates that within the next four years approximately 60MW of cumulative marine energy projects are being planned for deployment. The data, obtained from our industry survey, shows that this will be delivered through the continued deployment of prototype devices over 2011 and 2012, combined with 2-3 small arrays of less than 4MW. 2013 and 2014 are expected to bring a significant increase in activity with the deployment of 6-8 arrays at a scale of 3–10MW; totalling an installed capacity of 44MW over this two-year period.

To provide a realistic view of the expected delivery of this planned activity, RenewableUK reviewed the cumulative and annual number of megawatts that have been awarded consents within the UK. Figure 2. shows that a total of 11MW of prototype devices were awarded planning consents by March 2011.

This is from the 7MW of deployment listed above planned for 2011 and the 4MW Siadar Wave Energy project between RWE npower renewables and Wavegen, on the Isle of Lewis, which was granted planning consent in January 2009. It is also worth noting that Tidal Energy Ltd has already been awarded planning consent for the onshore work of their 1.2MW project in Wales.

Figure 1: Installed and predicted, Cumulative and Annual Marine Energy Capacity 2000-2014

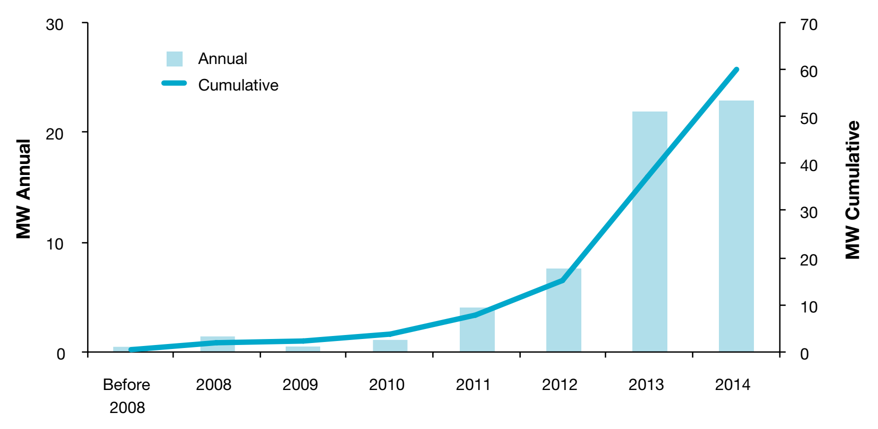
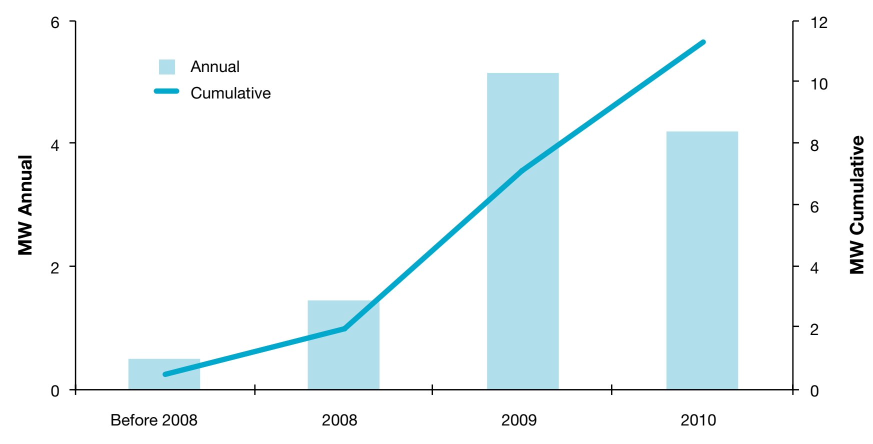


Figure 2: Cumulative and Annual Marine Energy Consents Granted 2000 – 2010



3.6MW of planning consents will need to be awarded in 2011 to achieve the 2012 predicted installed capacity of 14.6MW. However, a total of 23MW of marine energy planning applications entered the planning system in 2010 for small-scale arrays and prototypes (Figure 3.), representing two-thirds of the 36MW planned for deployment in 2013, and highlighting that plans for these deployments are already at advanced stages of development.

Installed Capacity in 2020

Numerous deployment scenarios and targets exist for installed capacity of marine energy in 2020, and Figure 4. plots three. The Renewable Energy National Action Plan,[9] in which government outlined their plan for 15% of energy from renewables by 2020, provides a target of 1.3GW for marine energy. The second scenario outlines The Crown Estate's aggregated planned delivery of the Pentland Firth and Orkney Waters Round One sites, representing a total installed capacity of 1.6GW. The final scenario, obtained via survey, represents the aggregated developer appetite for deployment, which stands at approximately 2.17GW installed capacity by 2020.

Figure 5. maps the annual installed capacity between 2010 and 2020. The Pentland Firth and Orkney Waters Round One sites annual development plan peaks in 2019, whereas aggregated developer appetite exists to develop sites outside of this leasing round, potentially with a view to bridge a future hiatus in delivery.

In the 2010 State of the Industry report RenewableUK outlined an industry target of 1-2GW.[10] Whilst it is evident that there is a well-positioned triangle of political support, industry desire and accessible sites to fulfil this ambition, as outlined in the Marine Energy Action Plan[11] the true

Figure 3: Cumulative and Annual Marine Energy Entering the Planning System 2000 – 2010

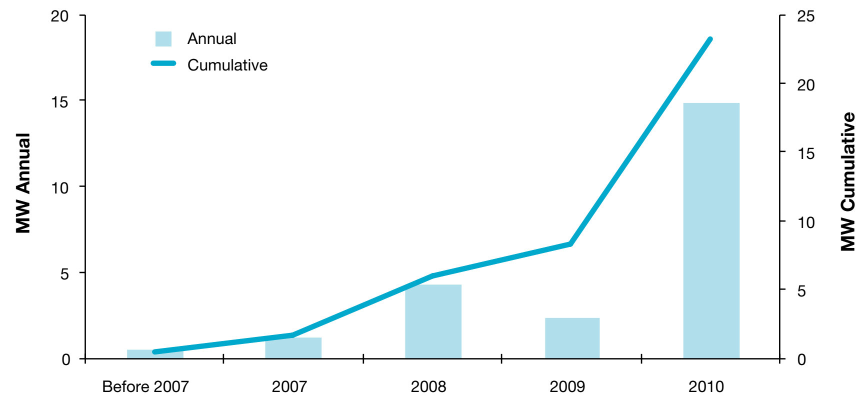
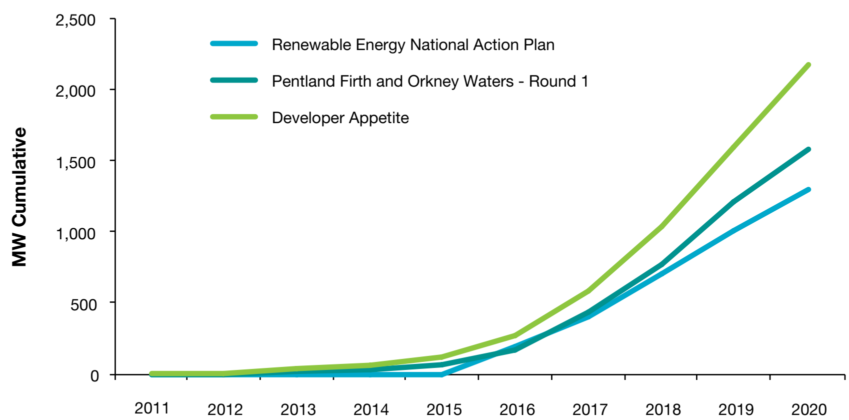


Figure 4: Scenarios for Cumulative Annual Installed Marine Capacity 2010 – 2020



9. The Renewable Energy National Action Plan is available at www.decc.gov.uk

10. RenewableUK, Marine Energy State of the Industry, 2010

11. HM Government, Marine Energy Action Plan, 2010

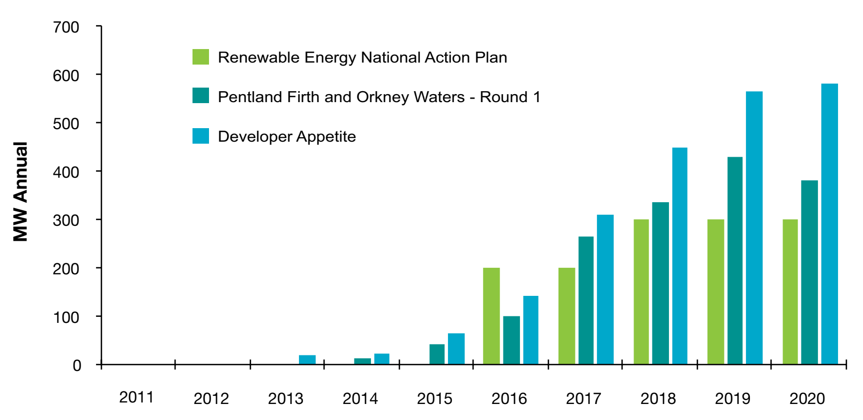
ambition and target is for the industry to be deploying arrays with a capacity of 100MW within the next 10 years. This will pave the way for rapid expansion and large-scale roll-out of marine energy across the world over the next 30 years, allowing wave and tidal energy to play a major role in the immediate UK economic recovery and acting as a cornerstone in the decarbonisation of the global energy supply

Challenges

At the start of 2011 many developers have successfully tank-tested scale-model prototype devices and several have addressed the next major challenge of deploying the first full-scale devices at sea followed by continued operation. Once developers are comfortable with the operations and maintenance regimes, reliability and predictability of power production, the following step is to deploy small-scale multi-device arrays of between 2MW and 10MW.

To get to the stage at which the UK is deploying marine energy arrays at the scale of 100MW the industry must have de-risked the technology, mastered installation and operation and maintenance techniques, obtained greater understanding of environmental impacts, developed a supply chain and secured significant sums of private investment.

Figure 5: Scenarios for Annual Installed Marine Capacity 2010 – 2020



Developer aspiration can be aided by supportive government actions addressing:

- Availability of suitable levels of capital and revenue support.
- Provision of additional leasing opportunities.
- Availability of grid in areas of high marine energy resource.
- Revision of the grid connection charging regimes.
- Development of a streamlined consenting process.

A Year in Policy

The current administration promised to be the "greenest Government ever" and to deliver "measures to support marine energy". The 2011 Scottish Election has seen all parties pledge their support for the sector. The Renewables Obligation is currently under review, which will conclude before the close of 2011. The establishment of the Marine Energy Programme offers an opportunity to coordinate industry and future government policy in order to continue to grow the industry.

General Election

The last 12 months have witnessed widespread policy activity, with May 2010 ushering a new Government for the first time in 13 years. With a high number of new MPs elected to Parliament for the first time, changes to policy positions are inevitable. The change of government has brought with it some fresh thinking on a range of policy issues, and a stated ambition that the new Conservative-Liberal Coalition Government becomes the "greenest Government ever". The forthcoming 12 months will see parliamentary bills brought forward that will have wide-ranging impacts on energy and planning policy. Some of these potential policy changes are addressed below.

Scottish Election

There will be a Scottish Parliamentary Election in May 2011, which could bring about a change to the current SNP administration. Although all parties have pledged their support for marine energy, we are awaiting the detail in the party manifestos.

Spending Review

Due to the large scale of government borrowing, the new Coalition Government quickly instigated a process of seeking out savings in government spending, with the aim of reducing the levels of debt. In response, RenewableUK submitted a document to ministers and civil servants in early September 2010, collating details of all existing government spending on renewable energy delivery and assessing how essential this spending was for the delivery of the Government's objectives for a clean, safe energy infrastructure.

The Department of Energy and Climate Change (DECC) was allocated £200 million towards "the development of low-carbon technologies" contained within Part 1.4 of the Spending Review published on October 20, 2010. With clear indications that £60 million of the fund will be allocated to offshore wind port development, it is still unclear how the remaining £140 million will be invested in renewables deployment is still unclear.

The National Renewable Energy Action Plan

Building on the Renewable Energy Strategy published in 2009, the Government officially submitted a National Action Plan (NAP) for renewable energy to the European Commission in June 2010.[15] This included a technology-by-technology breakdown of how the UK sought to meet the 2020 targets of 15% of all the UK's energy to come from renewable sources. It is clear that marine energy is a priority for the UK Government (text box below), through the statement of intent to install 1.3GW of marine energy by 2020.

Annual Energy Statement

The Government's pledge within the Coalition Agreement to publish the UK's first Annual Energy Statement was honoured in June 2010. This statement outlined 32 actions that the Government would take to deliver energy security, combat climate change and tackle fuel poverty. The statement included calls to raise the current EU target for emissions reductions from 20% to 30%

> *Marine energy is also a priority for development in the UK. The UK is a natural place from which to develop marine energy and we are lucky to have such a uniquely rich wave and tidal resource. We will be encouraging the development and commercialisation of this industry over the coming decade. The world's first full-scale wave and tidal stream devices are British innovations, which show we have the skills and know-how to develop a new world-leading UK-based energy sector. We are currently considering in detail how creating a network of marine energy parks can work to push the sector forward. Each marine energy park will be unique and different; building on the strengths of the region in which it is based.*

National Renewable Energy Action Plan for the United Kingdom, DECC, 2010 [14]

12. The Government 'green pledge' has been extensively covered in the media, see for instance, www.guardian.co.uk/environment/2010/may/14/cameron-wants-greenest-government-ever
13. HM Treasury Spending Review 2010, page 24
14. The National Renewable Energy Action Plan is available at www.decc.gov.uk
15. Ibid.

by 2020, plans to establish a Green Investment Bank following publication of the Spending Review, and proposals to re-consult on National Policy Statements for major infrastructure. Specifically Action 24 states that the Government will support the development of marine energy in the UK. This is supported by text that states it will provide the opportunity for deployment of marine energy devices alongside onshore infrastructure such as grid, industry and supply chain development, economic regeneration, skills and academic excellence.[16]

Renewables Obligation (RO) Banding Review

A review of the RO level commenced in October 2010. This review will provide a clear vision of the banding levels to be put in place on April 1, 2013. DECC initially planned to publish the results of the review in 2012.[17] However, this process has been brought forward, in a bid to provide clarity and certainty to investors on future banding levels and will now conclude by autumn 2011.[18] This re-evaluation of the level of revenue support that marine energy receives has the potential to fundamentally change the amount of marine energy built in the UK over the next decade and subsequently secure, or squander, the current global market lead. The Northern Ireland Department for Enterprise Trade and Investment is currently holding a separate consultation, in which it suggests a banding of four ROCs for tidal energy.[19]

The development of all new energy generation technologies has required support to help them through the early stages, when they will not be cost-competitive with pre-existing mature alternatives and the development of the wave and tidal industry is likely to be no different. Currently, devices do not have the same amount of track record as their conventional counterparts and therefore continue to require some level of support in order to become fully established; recent analysis from RenewableUK outlines that both wave and tidal energy should receive 5 ROCs for initial projects, to ensure continued industry development.[20]

Planning Act

The Planning Act passed into law in November 2008, enabling the creation of a new, streamlined determination process for major infrastructure projects on and offshore. The implementation of the Act continued throughout 2009 and 2010, with the creation of the Infrastructure Planning Commission (IPC) and public consultation on draft National Policy Statements (NPSs).

In January 2010 and after the public consultation process, RenewableUK gave written and oral evidence to the Energy and Climate Change Select Committee working on the NPSs. Following the General Election, these important statements of government energy and infrastructure policy will now go through further public consultation and parliamentary scrutiny with formal adoption expected in late 2011.

The Infrastructure Planning Commission (IPC) was formally inaugurated in April 2010. However, the publication of the new Coalition Government's Programme on 20 May 2010, confirmed the Government's intentions to abolish the IPC. Confirmation of this and other planning reforms have been announced in the Decentralisation and Localism Bill.

Although any institution replacing the IPC (such as the Major Infrastructure Unit [MIU]) will only deal with projects over 100MW, the long-term success of marine energy development hinges on the confidence of the parties investing in those projects. To inaugurate and abolish a planning authority in the same year does not give confidence that regulations are stable. On its part, RenewableUK is engaging closely with Government on these and other planning reforms.

Marine and Coastal Access Act

Implementation of the Marine and Coastal Access Act continued from its publication in 2009 through the whole of 2010 and is expected to influence marine planning and conservation for at least the next decade. The Marine Management Organisation (MMO) was also vested, officially launching on the 1st April 2010 and taking on a wide range of powers including marine consenting, licensing, monitoring and enforcement. The MMO will also lead on marine planning with the East of England inshore and offshore areas taken forward first. The new marine licence will also come into force in April 2011 combining the current FEPA and CPA licences.

16. The details of the Annual Energy Statement can be found on www.decc.gov.uk

17. The details of the RO Banding Review can be found on www.decc.gov.uk

18. Ibid.

19. For details of the Northern Ireland RO Banding Consultation see www.detini.gov.uk

20. RenewableUK, Channelling the Energy, 2010

Green Economy and Energy Security Bill

The Green Economy and Energy Security Bill entered Parliament in December 2010.[21] One of the potential developments of this Bill could be the creation of a Green Investment Bank. This body could support research and development as a grant-giving organisation and could support or invest directly in projects to leverage more private funds into green initiatives.

Strategic Environmental Assessments

Two Strategic Environmental Assessments (SEAs) were started or completed in the 12 months to March 2011. In March 2010 the Government launched an SEA for offshore energy, which would for the first time assess the environmental and socio-economic impacts of all marine energy technologies for English and Welsh waters and the Continental Shelf. Once complete, this work should inform the policies needed to allow wave and tidal energy projects in England and Wales. During 2009 and 2010, the Northern Ireland Assembly assessed the potential for marine renewable energy in the waters off Northern Ireland.

Electricity Market Reform

A process of Electricity Market Reform was initiated in the autumn of 2010.[22] This review seeks to examine the price of carbon and the need for capacity payments, consider the implementation of emission performance standards and review the support mechanism for low-carbon technologies including renewable energy. As “the largest shake-up of the electricity market since privatisation” these policy changes have the potential to dramatically alter the way the UK’s low-carbon economy is delivered. Maintaining the confidence of investors in current projects is crucial to ensuring the smooth delivery of any changes.

Wide-ranging Changes to the Regulation of the Electrical Grid

In the summer of 2010 numerous reviews and consultations were initiated to change the way in which new grid infrastructure is regulated. The collective scope of these different consultations ranged across almost all parts of the grid system. Proposed changes include revisions to the Ofgem remit, changing the charges levied on generators to pay for their grid connection, the introduction of a new regulatory system for offshore grid connections, changes to the way generators gain access to the national grid and a review of the financial commitments required to establish a grid connection. All these changes create the perfect opportunity to review the entire grid system and ensure it is suitable for 21st-century generation and the decarbonisation of the power sector.

Marine Energy Action Plan

DECC announced the Marine Action Plan (MAP) in the Renewable Energy Strategy,[23] as a document that would be produced by both Government and industry. The four work streams (Finance, Technology road map, Infrastructure, and Environment and consenting) were established in October 2009 DECC’s aim for the Action Plan was to set out the main challenges that need to be addressed in taking wave and tidal technologies through to mainstream deployment in the coming decades up to 2030, and the actions that would need to be taken by both government and the private sector to make this a reality.

The intention was that the Action Plan would be a realistic, practical and pragmatic document backed by both the Government and the private sector. The Marine Action Plan Executive Summary was launched on the 9th of March 2010.[24] This report supplemented “The Next Steps for Marine Energy”, published by RenewableUK.[25]

Marine Energy Road Map

In January 2009, the Forum for Renewable Energy Development in Scotland (FREDS) reconvened its industry-led Marine Energy Group (MEG) and a final report was produced in September 2009.[26] The group, which consists of both industry and government, recommended that Scottish Government provides additional capital grant funding to the sector and level ROC banding for both wave and tidal energy devices. The MEG subgroups continue to meet on an *ad hoc* basis to deliver the recommendations outlined in the report.

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21. For details of Bills see www.parliament.uk
22. For the details of the Electricity Market Reform consultation see www.decc.gov.uk
23. HM Government, Renewable Energy Strategy, 2009
24. HM Government, Marine Energy action Plan, 2010
25. RenewableUK, The Next Steps for Marine Energy, 2010
26. Forum for Renewable Energy Development Scotland, Marine Energy Road Map, 2009

Marine Energy Programme

In an effort to continue to drive the UK's marine energy sector forward the current Coalition Government has established the Marine Energy Programme; an initiative to drive public and private sector collaboration to develop the UK's nascent marine energy industry. The details of the programme and specific activities it will take forward are still to be defined in detail. However, there are already indications that the programme will recommend the development of a Marine Energy Park, which could take the form of a marine technology cluster.

NER300

The New Entrants Reserve 300 (NER300) is a common pot of 300 million credits from the EU Emission Trading Scheme (totalling approximately €4.5billion) set aside for supporting 8 Carbon Capture Storage and 34 renewable energy projects. A greater or lesser number of projects may be funded depending on the costs of the proposals.[27]

Amongst the 34 subcategories of innovative renewable demonstration projects eligible for support, DECC has stated its preference for the projects it would like to consider shortlisting for NER support. These are for the ocean energy category, covering wave energy devices with a nominal capacity of 5MW, marine/tidal currents energy devices with a nominal capacity of 5MW and ocean thermal energy conversion devices with a nominal capacity of 10MW.

The call for proposals states that part or all of the funding for a project, not exceeding 50% of the relevant costs of that project, may be awarded prior to the entry into operation, i.e. for up-front capital costs. However, where projects receive up-front capital, the government of the EU member states hosting the project must guarantee to cover these costs, if the project does not proceed or is unsuccessful in generating sufficient renewable energy.

It is of note that the UK Government does not intend to provide such guarantees for NER-funded renewable demonstration projects, so UK projects should apply only on the basis of annual performance payments. However, for carbon capture and storage, the Government is considering whether it would be appropriate to make an exception subject to the existing procurement, and will confirm their approach on this point in due course.[28]

27. For details of EU funding proposals see www.decc.gov.uk

28. Ibid.

Leasing and Licensing

1.6GW of leases have been awarded in the UK. A further leasing round in Scotland seeking project applications of up to 30MW per site is currently in progress. As of September 2010, developers can apply for 10MW leases lasting up to 25 years anywhere in UK waters. In addition, the Strategic Environmental Assessment in Northern Ireland outlined 300MW of extractable tidal resource.

As owner of the UK's seabed out to 12 nautical miles, The Crown Estate plays a central role in the leasing of seabed for marine energy extraction. Two leasing rounds in Scotland have taken place to date, along with a revision of prototype leasing conditions. A rolling programme of leasing rounds is now in effect with opportunities opening every six months. With the Strategic Environmental Assessment completed in Northern Ireland and under way in England and Wales.

Existing Leases

In the Pentland Firth Orkney Waters Round One, The Crown Estate granted options for leases for up to 1.6GW of marine capacity (Figure 6). These are being taken forward by utilities, technology developers, joint ventures between technology developers and utilities, and in one case a project developer (MeyGen, a consortium consisting of Atlantis Resource Corporation, International Power and Morgan Stanley).

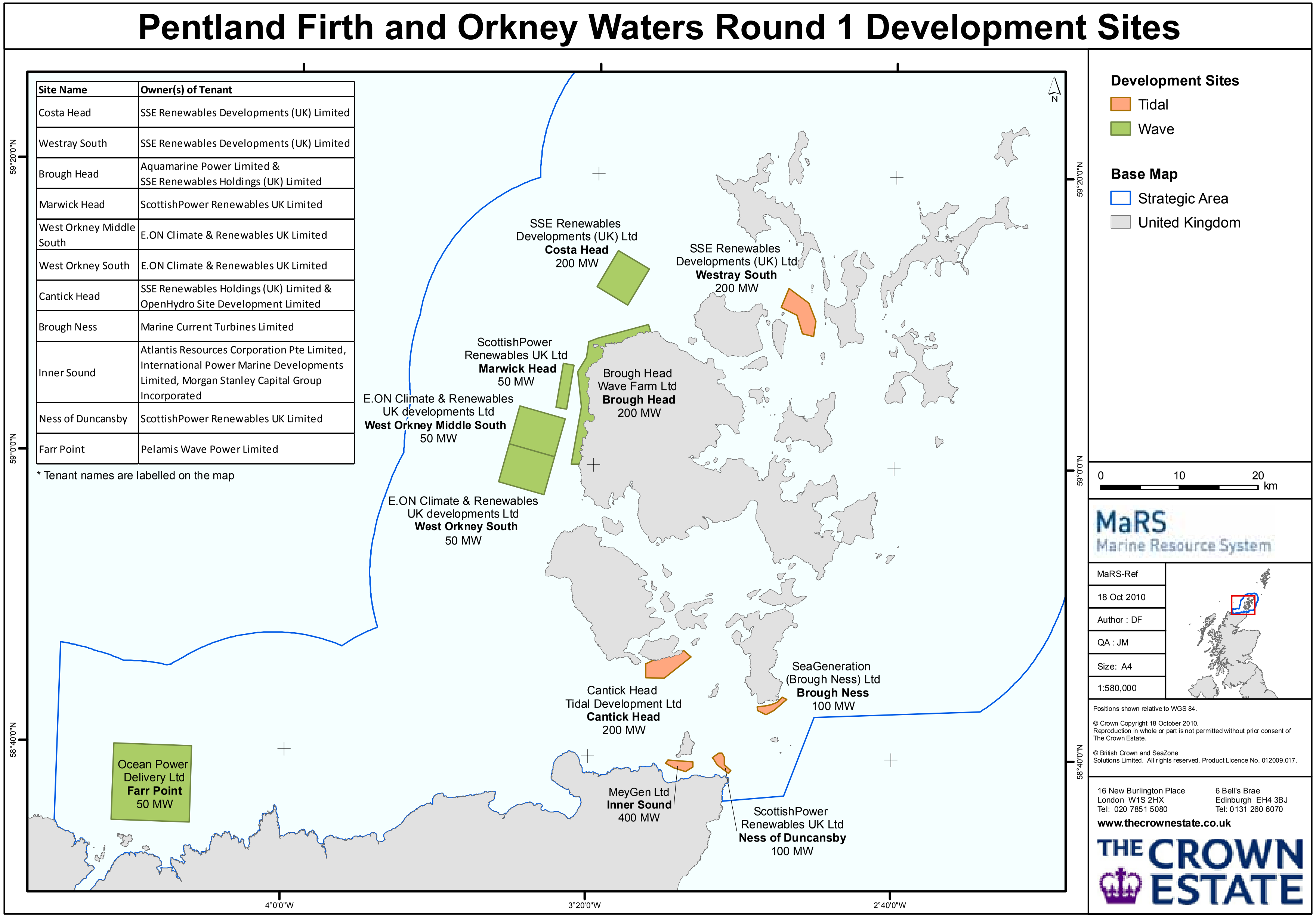
Current Leasing Opportunities

A further Scottish leasing round is currently open for applications of up to 30MW per site (Figure 7). Leases are currently being sought in a bid to win the £10 million Saltire Prize, awarded by the Scottish Government for the first marine energy project to generate 100MW/h in a two year period. Applications will be managed using a new competition framework. The application process contains the following stages: expressions of interest, pre-qualification, tendering, interviews, negotiation and award. The first application round opened on the 11th October 2010 and the second application window is planned to start in April 2011. Subsequent application windows are planned at six-monthly intervals thereafter.

Demonstration Leases

In recognition of the potential service lives and financing needs of marine energy projects, in September 2010 The Crown Estate altered the leasing process for projects up to 10MW per site to provide commercial-length terms, including an operating period of up to 25 years. The Crown Estate has stated that shorter lease terms will be appropriate for certain projects (e.g. to test a single prototype) and projects may be proposed with phased programmes, with the first and subsequent phases being fractions of the total capacity. Agreements for lease and leases may be awarded for projects anywhere in UK territorial waters, including in areas not currently covered by a Strategic Environmental Assessment.[29]

29. For details see www.thecrownestate.co.uk



Site Name	Owner(s) of Tenant
Costa Head	SSE Renewables Developments (UK) Limited
Westray South	SSE Renewables Developments (UK) Limited
Brough Head	Aquamarine Power Limited & SSE Renewables Holdings (UK) Limited
Marwick Head	ScottishPower Renewables UK Limited
West Orkney Middle South	E.ON Climate & Renewables UK Limited
West Orkney South	E.ON Climate & Renewables UK Limited
Cantick Head	SSE Renewables Holdings (UK) Limited & OpenHydro Site Development Limited
Brough Ness	Marine Current Turbines Limited
Inner Sound	Atlantis Resources Corporation Pte Limited, International Power Marine Developments Limited, Morgan Stanley Capital Group Incorporated
Ness of Duncansby	ScottishPower Renewables UK Limited
Farr Point	Pelamis Wave Power Limited

* Tenant names are labelled on the map

Figure 6: Pentland Firth and Orkney Waters project map[30]

30. The map of the Pentland Firth and Orkney Waters Round 1 Development Sites is available from www.thecrownestate.co.uk

Future Leasing Opportunities

The Northern Ireland Strategic Environmental Assessment (SEA) has highlighted that 300MW of tidal energy could be developed across five tidal energy zones.[32] The Northern Ireland Department of Enterprise, Trade and Investment has acted upon one of the key recommendations of the SEA and formed an Offshore Renewable Energy Forum, to steer this process. Another key action proposed by the SEA was to initiate a leasing round for tidal and offshore wind energy. This is expected to be open before the end of 2011.

In England and Wales the SEA launched in March 2010 is expected to deliver a final decision before summer 2011. There are numerous sites across England and Wales that could support wave and tidal project development, as can be seen in the offshore energy atlas.[33]

Licensing

The establishment of a UK-wide Marine and Coastal Access Act and Scottish Marine Act in 2010 has significantly streamlined the licensing application process for marine energy across the UK. As of the first of April 2011, Marine Scotland will deal with all licensing applications in Scottish waters inshore and offshore areas via the revised marine licence, whereas in England and Wales, the Marine Management Organisation deals with project applications under 100MW and the Infrastructure Planning Commission (shortly to be replaced by the Major Infrastructure Planning Unit deals with all applications over 100MW.

In Northern Ireland, licences are currently administered by two devolved departments (the Department of Enterprise, Trade and Investment and the Department of the Environment) and the Department of Energy and Climate Change. The new licensing processes should encourage maximum pre-consultation and engagement between licensing bodies, stakeholders and developers, to minimise the decision-making time.

Environmental Impact

Key information regarding the environmental impact of marine energy devices is still largely unknown. This has resulted in the statutory nature conservation agencies (Natural England, Joint Nature Conservation Council, Countryside Council for Wales and most notably Scottish Natural Heritage), developing new protocols and guide-lines to fast-track the deployment of initial devices.[34]

31. Further Scottish Leasing Round map can be found at www.thecrownestate.co.uk
32. Details of the Northern Ireland SEA are available at www.offshorenergyni.co.uk
33. Offshore energy atlas is available at www.renewables-atlas.info
34. Scottish Natural Heritage Guidelines can be found at www.snh.org.uk

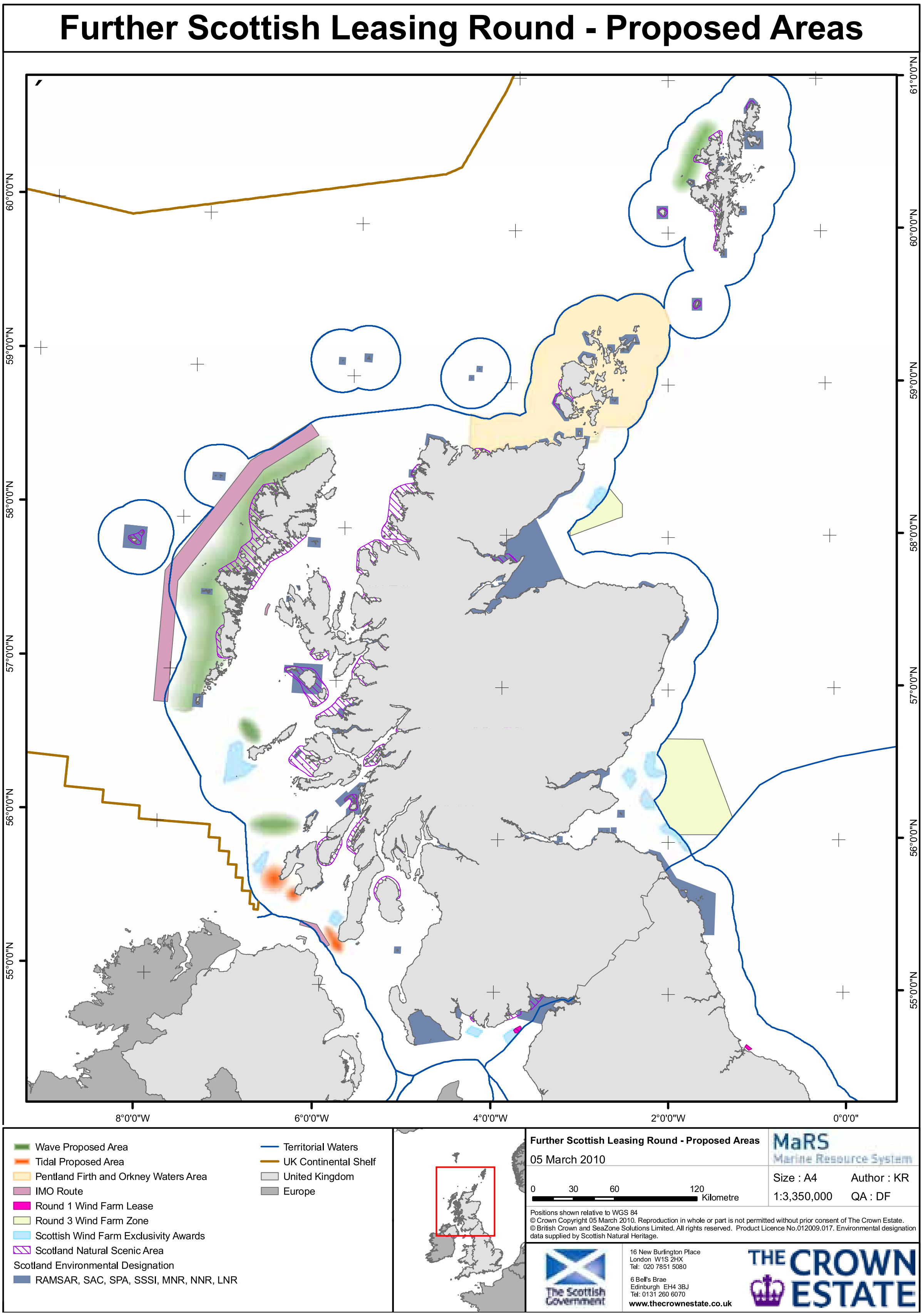


Figure 7: Areas in which the Crown Estate are expecting applications for lease in the further Scottish leasing round[31]

Test Centres and Research

The UK has a world-leading academic research base. Combined with a suite of complementary testing sites, the UK offers a coherent approach to technology innovation.

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

The marine environment can be very harsh, particularly in locations of high wave and tidal stream energy potential. The test centres available in the UK provide assistance in deploying 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 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.

Academic Consortia

The SuperGen Marine Research Programme, funded by the Engineering and Physical Sciences Research Council (EPSRC) commenced in 2003. The overall aim of the programme is to complete generic research on the potential for future exploitation of the marine energy resource. The second phase SuperGen Marine Research Consortium, a four year £5.5 million project which commenced in October 2007, includes five core academic institutions – the University of Edinburgh, Heriot Watt University, Lancaster University, Queens University Belfast and the University of Strathclyde – along with a number of affiliate institutions. 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 Peninsula Research Institute for Marine Renewable Energy (PRIMaRE) is a response from the Universities of Exeter and Plymouth to the challenges facing businesses involved in marine renewable energy and in support of Wave Hub. The institute received a further boost from the South West Regional Development Agency in the form of a £1.2 million investment in a new wave tank testing facility. The facility will be unique in the UK because it will allow model testing in both multi-directional waves and variable direction currents, and will also be able to model shallow and deep-water conditions. It will enable the testing of scale models of wave and tidal energy devices individually and in arrays. Other initiatives that PRIMaRe are developing include the South Western Mooring Test Facility (SWMFT), to understand mooring line dynamic response and improve modelling, and the Dynamic Marine Component Test Facility (DMaC), which is a specially developed facility to undertake “service testing”, type loading on marine components.

The Low Carbon Research Institute Marine Project is a £7 million three-year programme that aims to enable, support and help build a sustainable marine energy sector in Wales. It will provide the independent and world class research essential to move the industry forward from pre-commercial demonstration projects to small and full-scale generation of electricity from the marine environment. The project consortium consists of Swansea, Cardiff, Bangor, Aberystwyth and Pembrokeshire universities.

QinetiQ

QinetiQ continues to help wave and tidal device developers prove their systems really work, supporting early investment cases by testing ideas and technology. Developers, and their backers, can build confidence, fix the problems, and secure the evidence. The majority of the support uses its hydrodynamic model testing facilities: the ocean basin (122m x 61m x 5.5m) and ship towing tank (270m x 12m x 5.5m), both of which incorporate wavemaking capability.

As part of ongoing improvements in both these facilities, QinetiQ is continuing to invest in upgrades. For tidal/current device developers, the now-completed upgrading of the carriage in the ship towing tank provides increased capability – including the ability to programme bespoke carriage speed profiles. For wave device developers, the programmed upgrade to the Ocean Basin will see new wave makers fitted (work starting in 2011), allowing significantly larger wave profiles and more complex sea states to be modelled.

As well as offering computational fluid dynamics analysis, 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. The facilities and team are located in Gosport, near Portsmouth.

National Renewable Energy Centre (Narec)

Narec is the national centre dedicated to advancing the development, demonstration, deployment and grid integration of renewable energy and low-carbon energy generation technologies, established in 2002 as an independent R&D centre serving the renewable energy industry. 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 £12 million Nautilus test facility, which was supported with £10 million from the Renewable Energy Strategy, will provide a 3MW drive system capable of testing the complete drivetrains, electrical generation, control and support systems of marine renewable devices. The Nautilus rig will allow the key components and assemblies (including drive shafts, bearings, gearboxes, generators and power converters), to be thoroughly tested before deployment in the open sea. The test rig will have the ability to mechanically and electrically load the complete drive train with the full envelope of load cases, including side loads on to shafts and bearings and grid faults to the electrical systems. The Nautilus test rig is expected to be fully operational by June 2011 and will offer the opportunity to significantly reduce the risk of in-service failure of the key electrical and mechanical components used within tidal stream turbine technologies.

Building upon the experience and track record developed by testing wind turbines blades for almost all the major blade manufacturers over the last five years, Narec is expanding its capabilities to include marine blade testing.

Additional hydraulic hardware will be procured by Narec over the next few months to facilitate an anticipated first test in Quarter 2, 2011.

European Marine Energy Centre (EMEC)

EMEC in Orkney was established in 2003 and offers developers the opportunity to test full-scale grid-connected prototype wave and tidal stream devices. The centre operates two sites – a wave test facility and a tidal test facility – which 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.

There is currently strong demand for the existing cables and EMEC has seen growth through the Renewable Energy Strategy-sponsored projects, increasing the number of grid connected berths on site, from nine to twelve. This has also seen the creation of the ‘scale sites’ for both wave and tidal devices in Orkney. These are planned to be of interest to technologies where developers would prefer to deploy at a scale smaller than their planned commercial roll-out, or at full size, but in conditions that are less extreme than the full-scale sites.

The increase in capacity has coincided with EMEC’s transition to being fully self-funded through the rental and service fees it receives from its customers. EMEC’s world-leading experience as the only marine energy UKAS accredited test site in the world, means that it is a strong contender to leverage value from its expertise. EMEC has already led the development of guidelines that have been taken forward to become international standards and continues to provide leadership.

Wave Hub

Wave Hub is a grid-connected offshore facility in south-west England for the large-scale testing of technologies that generate electricity from the power of the waves. It leases space to wave energy device developers and exists to support the development of marine renewable energy around the world. With four berths able to connect up to 5MW each, Wave Hub has the potential to connect 20MW of wave energy. This could be increased to 50MW in due course.

In May 2010 construction of the sub-station was completed and the cable was energised in November 2010, effectively marking Wave Hub open for business. Key contractors included JP Kenny, Dean & Dyball and JDR Cables.

Customers coming to Wave Hub need to apply for their own FEPA licences. Wave Hub plans to manage a co-ordinated programme of on-going environmental monitoring in partnership with its customers.

The South West Regional Development Agency (SWRDA)

The South West of England was designated as the UK's first low-carbon economic area for marine energy in the 2009 Renewable Energy Strategy in recognition of this growing centre of excellence. This was accompanied with an additional £9 million from the Department of Business, Innovation and Skills (BIS) and DECC, which has enabled the Regional Development Agency (RDA) to grant-fund two important infrastructure projects: construction of a new dedicated marine building on the University of Plymouth's campus, in order to stimulate innovation and enterprise and transform the way research is turned into commercial success; and development of a marine renewables business park adjacent to the Wave Hub sub station in Hayle, Cornwall. In addition to this £7.3 million invested in PRIMaRE has enabled unique mooring and dynamic component testing facilities to be established in Cornwall and the UK's most advanced wave tank is being built in Plymouth.

Future Developments

Future testing sites proposed across the UK include two tidal sites that are currently undergoing scoping. The Solent Ocean Energy Centre, being supported by Envirobis, has sought funding from the Regional Growth Fund, allocated by BIS.[35] Invest Northern Ireland are also in the preliminary stages of scoping the potential to develop a full-scale tidal test site.[36]

The Technology Strategy Board is currently holding a consultation on the proposition to develop a number of Technology and Innovation Centres (TICs) across the UK in six key areas, including electronics, photonics and electrical systems and energy and resource efficiency. The criteria include the potential to access global markets worth billions of pounds per annum, proof that UK business can exploit technology and opportunities, the ability to attract inward investment for sustainable wealth creation and close alignment with national strategic priorities.[37] It is certain that given the UK's current lead in the marine energy, research and device development, as well as the scale of the global market, there are considerable opportunites for broadening the UK supply chain and attracting inward investment to the sector. If the creation of an offshore renewable energy TIC, covering offshore wind, wave and tidal energy were to be proposed, the coordinating function and approach to research and development would offer a clear and consistent route to commercialisation for emerging technologies and cost-reduction innovation to secure future economic benefits.

35. Details of testing sites can be found at www.solentoceanenergy.com

36. For details see Invest Northern Ireland's website, http://www.investni.com/

37. Technology Strategy Board, Technology and Innovation Centres: a prospectus, January 2011

Grid Connection and Availability 2015-2020

Lack of availability of grid capacity for marine energy provides a fundamental barrier to the development of the industry. Connection to the Shetland, Orkney and Western Isles is a priority for the industry. Revision to the charging regimes provides the opportunity to encourage further development.

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. Due to the specific locational characteristics of wave and tidal energy the sector is unavoidably acutely exposed to the very extremes of the current UK grid challenges. This leads to high demand for a limited number of grid connections in certain locations.

Current transmission infrastructure at the peripheries of the network is, by and large, not fit for the purpose of accepting new generation projects, even at very modest scale. New transmission infrastructure will require unprecedented levels of financial commitment from marine project investors, who are in parallel exposed to a substantial technology risk. As outlined in the Path to Power,[38] grid connection presents a major hurdle for development in both Northern Scotland and the Western Isles, as the Orkney Isles in particular are likely to be the first area in the UK to see the development of large-scale marine energy projects.[39]

Left with the current transmission regime in place, marine renewable projects are most likely to suffer substantial delays, to the extent that manufacturers may have to relocate to other markets, or rely on infrastructure upgrades being driven by the wind sector. In the instance of new infrastructure being delivered for wind projects the current investment mechanisms will lead to “missed opportunities” for the marine sector as there are little or no allowances for new infrastructure to include levels of additional capacity that could provide an invaluable route to market for the marine sector to demonstrate commercial viability.

EMEC and Wave Hub are very beneficial to the industry, as they provide existing grid connections that allow developers to test the operation of their devices when connected to the grid, avoiding the need to apply for and construct new grid connections. However, it is recognised that the marine industry must demonstrate and build large-scale projects and apply for grid connections in order to trigger the significant upgrades required to the transmission network. To date it is thought that only three companies have applied for a grid connection on Orkney to stimulate the transmission upgrades needed. As stated, high charging regimes and limited access to development finance are recognised as barriers preventing further applications. In addition to this, delays in planned upgrades (e.g. Beauley-Denny) could have major ramifications for the delivery of marine energy projects.

Transmission Charging

The current transmission-charging regime, which levies high charges on those projects furthest from the market, has been identified as a major impediment to the growth of renewable projects in the remote locations of the Western Isles, Orkney and Shetland. It should also be noted that, in the consideration of marine renewables, a locational charging mechanism simply increases the barrier to entry for investors.

High charges have prevented developers committing to underwrite the cost of transmission upgrades. It is hoped that Ofgem’s project Transmit will offer a solution that will enable these upgrades to be commissioned by 2015.

38. BWEA, Path to Power, 2006

39. Xero Energy, Pentland Firth Tidal Energy Project Grid Options Study, January 2009

Connecting the Orkney Isles[40]

In the short term small capacities on Orkney could be connected to the grid through innovative practices such as active management, which gives the potential for generation to be switched off during extreme generation peaks or troughs in demand. This would allow more generation devices to be connected to the grid and would improve the efficiency of grid use. Previous investigations for the Orkney Active Management Scheme estimated that perhaps 50 MW of additional capacity could be freed up.

A recent report published by Orkney Island Council and the Orkney Renewable Energy Forum states that the present active management scheme has been capped at only 15MW and suggests that an urgent review is required of how much of the remaining 35MW could be used and when. However, this does not address the fact that there is no capacity for new developers as the current capacity has been reached by existing schemes at present.

2014–2016

For the first commercial leasing round in The Crown Estate's Round One, plans show that commercial-scale roll-out will not take place until around 2015/16. As detailed in Figure 4., between 2014 and 2016 nearly 400MWs of marine energy are anticipated to be deployed with a significant amount of this expected on Orkney. Over the last few years, Scottish Hydro Electric Transmission (SHETL) has started examining a series of new grid connection options for Orkney. The first phase of these developments has, to date, always been seen as the installation of 132kV AC cable connections, that would enable the export of up to 180MW. SHETL's plans rely upon having a clear view of how the industry will develop in the coming years, dependent upon it receiving applications for grid connection from developers.

2016–2020

After 2016 it is anticipated that Orkney should be entering the phase of major commercial roll-out of wave and tidal capacity. The recommendation from Orkney Islands Council and Orkney Renewable Energy Forum is that gigawatt scale connections will be required and most likely lead to HVDC-type cables being considered. SHETL has indicated that it is looking at an HVDC solution of up to 600MW to West Mainland of Orkney and a 300-400MW HVDC solution to South Ronaldsay.

Connecting the Western Isles

In the Western Isles a 'connect and manage' regime also exists, to enable small generation (less than 10MW) in Scotland onto the distribution network, prior to any transmission upgrades. 75MW of capacity were made available in the latest tranche of grid upgrades from Fort Augustus to the Western Isles, thus there may be limited opportunities to connect small-scale marine energy projects. It is hoped the transmission network will be upgraded with a proposed 450MW HVDC interconnector in late 2014/2015. This will be dependent upon a reduction in transmission charges as a result of project TransmiT which will enable developers to commit to underwriting the cost of the upgrade.

Shetland

Shetland, whilst representing one of the richest regions for marine renewables in the UK, also represents the most constrained part of the UK grid network as the islands have no level of grid connection to the UK mainland. The costs associated with grid-connecting Shetland are at a level that excludes marine renewable projects, and access to this prime resource is currently wholly reliant on the potential commitment from onshore wind investors. The delivery of a grid connection to meet wind project demand will provide a clear opportunity for additional capacity for the marine sector to be included at limited incremental costs. To miss such an opportunity will simply prolong the sectors lack of access to market and endanger the long-term health of the sector.

40. Orkney Islands Council and Orkney Renewable Energy Forum, Committing to Connection, June 2010

Financing and Funding

The industry urgently needs a market incentive of 5ROCs or equivalent for wave and tidal energy across the UK over the period of 2011 to 2014. Up to £130 million of capital investment is required to deploy up to 60MW of pre-commercial arrays. For every £1 of public money, £5 of private money has been secured by the government.

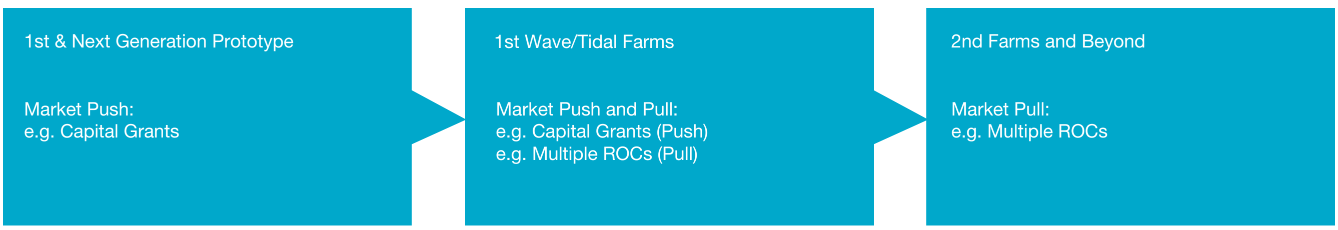
Over the past five years both the UK industry and Government have taken strides to capitalise upon the UK's unique marine energy potential. However, even with this commitment it has already been suggested that greater Government support will be required to develop robust and affordable technology.[41]

Summary of the 'Channelling the Energy' Report

As highlighted in the RenewableUK report "Channelling the Energy", a coherent support framework executed in a coordinated approach is required to secure the UK's global lead in marine energy, as significant work is required to reach the stage at which projects can be commercially viable.

Based upon the UKERC and ETI UK marine energy deployment strategy[42] and correlated to NASA Technology Readiness Levels (TRL),[43] Figure 8. provides a basic outline of the anticipated stages of industry development, showing the transition from capital support to revenue support, from prototypes and next generation devices through first farms and beyond.

Figure 8: Stages of Marine Energy Industry Development



1. First and Next Generation Prototype TRL 1–7: up to 1MW

2. First Wave and Tidal Farms TRL 8–9: from 2MW to 10MW

3. Second Farms and Beyond TRL 8–9: over 10MW

41. See for instance: Carbon Trust, Focus for success – A new approach to commercialising low carbon technologies; The Climate Change Commission, Building a Low Carbon Economy – The UK's innovation Challenge; Bain and Company, Employment Opportunities and Challenges in the Context of Rapid Industry Growth.
42. Energy technology Institute and UK Energy Research Centre, Marine Energy Technology Roadmap, 2010
43. Details of Technology Readiness Levels criteria available at http://esto.nasa.gov/files/TRL_definitions.pdf

Stage 1: First and Next Generation Prototypes up to 1MW (TRL 1-7)

Capital support is vital to the industry today and devices require continued support through the research and development (R&D) stage. The primary gap today exists when devices are ready for open ocean deployment. It is, at this point that capital needs rise rapidly. Device developers are generally small and medium enterprises (SMEs) that do not have the readily available, the finance to fund such projects, and the initial risk exposure is too high for utilities to commit investment, or for any manufacturer to underwrite performance. Hence, capital support from government is required to de-risk investment in technology development and stimulate the private sector backing.

RenewableUK believes that Stage 1 of industry development can be split into three specific phases for technology development that can be related to NASA TRLs as follows:

- Stage 1 A – concept development and tank testing (TRL 1-3)
- Stage 1 B – greater scale prototype (TRL 4-5)
- Stage 1 C – full-scale grid connected prototype (TRL 6-7)

Whilst we expect the cost of energy to decrease dramatically as installed capacity increases, it is also evident that the costs of developing and proving technology are high. “Channelling the Energy” reports that a total average investment of £30 million will be required to take a technology from concept through to construction and installation of the first full-scale grid-connected prototype. This assumes that technology development is sequential and that there is limited need for development iterations during this process.

Stage 2: First Wave and Tidal Farms from 2MW to 10MW (TRL 8-9)

When marine energy devices become ready for deployment in small arrays, revenue incentives play an important part in making the projects economically viable. However, electricity production from the first wave and tidal farms will be unpredictable, making revenue incentives alone insufficient. For these first steps, upfront capital grant is also required to reduce the amount of capital at risk. Under this scenario, a marine energy project starts to become attractive to utilities. However, to secure investment from utilities, device offerings have to be on a par with alternative options. In particular, device manufacturers have to be able to offer potential utility investors (a) sufficient operating experience to offer guarantees in performance and reliability and (b) involvement of major manufacturers able to underpin these guarantees both technically and financially.

RenewableUK surveyed six utilities active in the marine energy sector. The results show that the capital expenditure (CAPEX) for the first 10MW wave or tidal energy projects are between £42 million and £84 million and the operating expenditure (OPEX) may vary from £0.9 million to £4.2 million per annum. To reach a level net present value project require 5 ROCs or equivalent revenue support, in combination with capital grants. To deliver 60MW of marine energy by 2014 would require in the region of £130 million capital support.

Stage 3: Second Farms and Beyond, of over 10MW (TRL 8-9)

Following these initial small-scale projects, and with sufficient revenue support, it is likely that marine energy projects could start to move towards attracting debt finance, one of the key requirements in facilitating rapid deployment at larger scales. In turn this will deliver associated cost reductions that would reduce the level of revenue support required.

Industry believes that Initial banding should be set at 5ROCs or equivalent for both wave and tidal energy. To limit the risk exposure to Government of over-subsidising the industry, a limit of, for example 500MW of installed capacity, could be set as a trigger point to instigate an automatic review.

As globally installed capacity increases, costs can be expected to fall. Previous reports have concluded that each doubling of capacity will result in a reduction of cost of 10% to 15%. Provided that development is continuous and uninterrupted, it is expected that a cost of energy of between £75 per MWh hour and £125 per MWh can be reached when 1GW has been installed globally per technology. This is deemed to be competitive with other forms of future low carbon energy generation.[44]

Private Investment Activity

The past year has also seen a number of large manufacturers acquiring substantial equity investment in marine energy technology. Rolls-Royce acquired Tidal Generation Ltd. Alstom has obtained a global technology licence agreement with Clean Current technology and is planning deployment of a 1MW test project in Canada in 2012. Siemens acquired a 10% stake in Marine Current Turbines. ABB invested £8 million in Aquamarine Power for 15% of the company. DCNS, the French naval architecture company, invested €14 million in OpenHydro and signed a Memorandum of Understanding (MoU) with Carnegie Wave Energy.

RenewableUK surveyed members to understand the total quantum of private investment into the sector. Contributors included Pelamis Wave Power, Marine Current Turbines, Aquamarine Power, Atlantis Resource Corporation, Luna Energy, Voith Hydro Wavgen, Voith Hydro OCT, Pulse Tidal and AWS Ocean. To these companies, a total of £230 million of private investment has been made, with every £1 of public funding attracting £5.4 of private investment.

44. Carbon Trust, Future Marine Energy, Results of the Marine Energy Challenge: Cost Competitiveness and Growth of Wave and Tidal Stream Energy, January 2006

Publicly Funded Projects: Technology Table

As of March 2011 there are 28 publicly funded projects being undertaken across the UK with contributions from 32 companies. The largest proportion of private sector activity has come from technology developers, academia and notably the supply chain. The average grant support per project has been £1.95 million with a total of £54.6 million of public investment.

Figure 9. provides an overview of funding sources, the private partners engaged, brief project description, public funds awarded and where possible the private funding the project has secured.

The Wave And Tidal Energy Research, Development and Demonstration Support fund (WATERS) was launched in 2010 to help develop emerging energy technologies to improve the operation of marine renewables devices. The WATERS fund was a collaboration between the Scottish Government, Scottish Enterprise and also Highlands and Islands Enterprise. The programme is part financed through European Regional Development Funds (ERDF).

The Technology Strategy Board invested £9.5 million in innovative collaborative research through two calls. The first call in March 2010 aimed to support the development and demonstration of wave and tidal stream energy technologies. The call received 35 applications and 9 awards were made. The call aimed to address issues of driving down the cost of energy, while improving the reliability and performance of devices. The competition consisted of two strands: to enhance the performance of existing devices and to progress novel concept devices. The second call launched in September 2010, aimed to aid research and development focussing on supporting and underpinning the deployment of pre-commercial and full scale devices installed and operating in the sea, provided 3 awards totalling £2.5 million.

The Energy Technologies Institute (ETI) is a UK-based public-private partnership formed by global industries and the UK Government. It is tasked with developing and demonstrating engineering and technology that will help the UK meet its legally binding 2050 carbon reduction targets under the Climate Change Act. To date the ETI has supported 3 marine energy projects at a total public cost of £10.75 million.

The £22 million Marine Renewables Proving Fund (MRPF), announced by the Government in the Renewable Energy Strategy[45] is administered by the Carbon Trust and was launched in September 2009. As part of the low-carbon economic stimulus package the six projects awarded financing (Pelamis, Marine Current Turbines, Aquamarine Power, Atlantis, Voith and HSUK) must be completed by March 2011.

The South West Regional Development Agency also provided a £1.5 million grant to Ocean Power Technologies to accelerate the deployment of their PB500 at Wave Hub.

45. HM Government, The Renewable Energy Strategy, 2009

Figure 9. Publicly Funded Projects: Technology Table

Funder	Fund	Private Partners	Project Description	Public Funding £million	Private Funding £million
Scottish Government, Scottish Enterprise and Highlands Islands Enterprise	WATERS	RWE npower	To support construction of one of the world's largest wave stations, the ten turbine, 4MW Siadar project off the Western Isles.	6	
Scottish Government, Scottish Enterprise and Highlands Islands Enterprise	WATERS	Aquamarine Power	To support the demonstration of Aquamarine's Oyster 3 project at the European Marine Energy Centre in Orkney.	3.15	10
Scottish Government, Scottish Enterprise and Highlands Islands Enterprise	WATERS	OpenHydro	Support for a power conversion / control system to deliver a cost effective method of connecting marine energy devices in arrays, an important step towards commercialisation.	1.85	
Scottish Government, Scottish Enterprise and Highlands Islands Enterprise	WATERS	AWS Ocean Energy	To support tests in Loch Ness and the Cromarty Firth of AWS's wave energy converter, sections of which would join together to form the device's 'doughnut' shape.	1.39	
Scottish Government, Scottish Enterprise and Highlands Islands Enterprise	WATERS	Ocean Flow Energy	Build and deploy the 'Evopod', a 25 kilowatt floating grid-connected tidal energy turbine at Sanda Sound in South Kintyre.	£1	
Technology Strategy Board	Development and demonstration of wave and tidal stream energy technologies	Aquamarine Power Limited (lead), BAE Systems Surface Ships Limited	Maintenance strategy and remote ballasting for Oyster wave energy converter: Aquamarine is currently developing Oyster 2, a next-generation demonstrator mini-array comprising 3 Oyster flaps. Rated at 2.4MW, Oyster 2 is scheduled for first installation at EMEC in 2011. This project will investigate and assess opportunities to decrease the delivered cost of wave energy from commercial Oyster arrays through significant improvements in device reliability and maintenance costs.	0.45	0.45
Technology Strategy Board	Development and demonstration of wave and tidal stream energy technologies	Fred Olsen Limited (lead); Supacat Limited, Scotrenewables Ltd, University of Exeter	BOLT-2-WAVEHUB: BOLT is the name of the Fred Olsen wave energy device which has undertaken sea trials since June 09. The BOLT-2-WAVEHUB collaborative project aims to integrate elements that will make truly pre-commercial deployment at the Wave Hub site a reality. This will be achieved by reducing the production costs of wave energy converter units and by reducing the costs and risks of deployment, installation & retrieval processes of wave and tidal devices.	2.4	5
Technology Strategy Board	Development and demonstration of wave and tidal stream energy technologies	Marine Current Turbines Ltd (lead), Mojo Maritime Ltd, University of Edinburgh, Queens University Belfast	Fully submerged evolution of SeaGen for exposed open deep water locations: this proposal is for a fully submerged (but surfaceable) turbine array utilising a novel mooring system to enable Marine Current Turbines to address deep water sites, sites with large tidal ranges or sites with significant wave potentials. The evolution of the technology will build on the success of the SeaGen surface piercing using demonstrated components and fundamentals, such as the drive train and control systems.	Approx 0.6	

Funder	Fund	Private Partners	Project Description	Public Funding	Private Funding
Technology Strategy Board	Development and demonstration of wave and tidal stream energy technologies	AWS Ocean Energy (lead), University of Strathclyde	Assessment of novel WEC, with rubber air-water interface; performance validation, optimisation and demonstration of associated cost benefits: the AWS III system is a toroidal self-reacting surge/pitch mode multi-cell floating wave energy converter (WEC) that harnesses power from off-shore ocean waves to generate electricity. Reinforced rubber diaphragms convert wave action to pneumatic power which in turn is converted to electricity by turbine-generators. AWS has acquired and developed transformational IP relating to the design and form of the rubber diaphragms.	Approx 0.6	
Technology Strategy Board	Development and demonstration of wave and tidal stream energy technologies	Additional 5 Projects - Undisclosed Details	Additional 5 Projects: undisclosed details.	Approx 3	
Technology Strategy Board	Supporting and underpinning the deployment marine energy	Bauer Renewables Ltd (lead), Voith Hydro Ocean Current Technologies, University of Exeter, Mojo Maritime Ltd	Seabed drilling equipment for Voith Hy Tide 1MW tidal turbine at EMEC.	Approx 0.8	
Technology Strategy Board	Supporting and underpinning the deployment marine energy	Pelamis Wave Power Ltd (lead), E.ON Climate & Renewables UK, ScottishPower Renewables (UK) Ltd	Orcadian Pelamis P2 wave farm demonstration.	Approx 0.8	
Technology Strategy Board	Supporting and underpinning the deployment marine energy	Marine Current Turbines Ltd (lead), Queens University Belfast, University of Exeter, University of Southampton	SeaGen: additional environmental characterisation and array impact extrapolation.	Approx 0.8	
Energy Technology Institute	N/A	Rolls-Royce, Tidal Generation Ltd, EMEC, EON, EDF Energy, Garrad Hassan, Plymouth Marine Laboratory, University of Edinburgh	ReDAPT (Reliable Data Acquisition Platform for Tidal: the first phase of this four year project will see a 1MW tidal turbine installed and operating in 2012. The project will test the performance of the tidal generator in different operational conditions. Its aim is to increase public and industry confidence in tidal turbine technologies.	6.2	6.2
Energy Technology Institute	N/A	EON, EDF Energy, Garrad Hassan, University of Edinburgh, Oxford University, Queen's University Belfast, Manchester University.	Performance Assessment of Wave and Tidal Array Systems (PerAWAT): this four year project will produce tools capable of accurately estimating the energy yield of major wave and tidal stream energy converters. Numerical models of devices, interactions between devices in arrays and interactions between arrays at the coastal scale will be developed during the project.	4	4

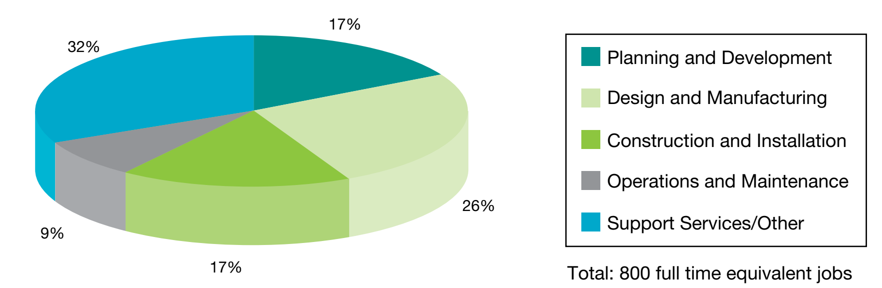
Funder	Fund	Private Partners	Project Description	Public Funding	Private Funding
Energy Technology Institute	N/A	MacArtney	Wetmate Connector: the project will develop an 11kV wetmate connector, which will be tested and demonstrated under both workshop and real-sea conditions.	0.55	0.55
South West Regional Development Agency	N/A	Ocean Power Technologies	Accelerating development of the PB500 for deployment at Wave Hub.	1.5	
Carbon Trust	MRPF	Pelamis Wave Power Ltd	Manufacture, test, commission, sea trial, install, operate and maintain a full scale grid connected wave energy converter (WEC) at the EMEC, Orkney. P2 machine has completed sea trials in Moray Firth. Some minor issues were detected and corrected. Currently undertaking a testing programme through increasing sea states.	4.8	8.4
Carbon Trust	MRPF	Aquamarine Power	Original Proving Fund project aimed to finalise design, and fabricate part of the 1.5MW Oyster array, to be deployed at EMEC in 2011. Revised project progressing well through procurement and fabrication phase. Oyster 1 now likely to be decommissioned.	4.56	10.44
Carbon Trust	MRPF	Marine Current Turbine	Proving Fund project will make modifications to the drive train and control systems, and fund the continued operation of SeaGen. Project remains broadly on track. Soon to change drive train (nacelle), which will be the first time this has been done.	2.7	3.5
Carbon Trust	MRPF	Hammerfest Strøm	Proving Fund project will finalise design and fabricate a HS 1000 (1MW). Deployment Location: EMEC (2011). Progressing well through the procurement and fabrication stages.	3.9	6.8
Carbon Trust	MRPF	Atlantis Resource Corporation	MRPF project will finalise design, fabricate and assemble the 1MW contra rotating tidal machine based on a 300kW prototype. Deployment is in summer 2011 at EMEC. New blades and nacelle currently in fabrication.	1.85	4.45
Carbon Trust	MRPF	Voith	Proving Fund project will finalise design, fabricate, assemble and test 1MW tidal machine based on a 300KW prototype. Deployment Location: EMEC, Structure 2010, nacelle 2011. Significant TST support with consents, permitting and installation.	2	8.2

Social and Economic Benefits

The UK marine energy industry currently employs 800 full-time employees.[46] By securing the current market lead in 2035 the UK the marine energy industry could:

- **Employ 19,500 individuals.**
- **Draw investment of £6.1 billion.**
- **Generate a Gross Value Added (GVA) contribution of £800m per annum.[47]**

Figure 10: Direct Employment in Marine Energy (2010)



Total: 800 full time equivalent jobs

Including a greater proportion of marine suppply in the UK energy mix would reduce requirements for back-up and reserve capacity, saving £9 million per annum.[48]

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

Early Mover Advantage

Early innovation support and 20 years of consistent market and policy support for onshore wind energy in Denmark has laid the foundation for a technological revolution that has resulted in a global export market worth over €5.7 billion in 2008. With a 20% share of the global wind turbine market, the Danish wind industry provides employment for 28,000 workers and contributes €1.5 billion in GVA to the Danish economy each year.[49] Using figures obtained from government reports and a survey of RenewableUK members, it is estimated that the UK could realise a potential 10,000 direct jobs, draw investment of £3.7 billion per annum and provide GVA of £530 million per annum in 2020, whilst also achieving the installation of 1.6GW of marine energy projects. If the correct market signal is provided and supportive actions taken, long-term market share can be secured as the UK marine energy industry could be worth up to £6.1 billion per annum, directly employing as many as 19,500 individuals and contributing GVA to the UK economy in the region of £800 million per annum by 2035.[50]

According to the recently produced RenewableUK report, "Working for a Green Britain", over 800 full-time equivalent positions are employed directly in UK wave and tidal energy. Figure 10. shows that for this sector, the largest proportions are employed in Design and Manufacture (25%), and in Support Services and Other Activities (32%), which we expect to be in R&D roles. Employment in Construction and Installation (16%), and Operations and Maintenance (9%) is relatively modest, and this reflects the nascent nature of the technology. As much of this employment will be based on pilot plants rather than fully commercial operations, there is significant potential to grow the sector.[51]

46. RenewableUK, Working for a Green Britain, 2011
47 RenewableUK, Channelling the Energy, 2010
48. Redpoint Energy Limited, The Benefits of Marine Technologies within a Diversified Renewables Mix, 2009
49. For details of Denmark's onshore wind manufacturing economy see http://www.investindk.com/visNyhed.asp?artikelID=23741
50. RenewableUK, Channelling the Energy, 2010
51. RenewableUK, Working for a Green Britain, 2011

Supply Chain

The economic benefits and potential job creation generated by the growth of the marine industry would be beneficial to the UK to counteract the effects of the steady decline of the oil and gas industry. The production of oil and gas from the UK offshore areas is in decline as reserves are progressively exhausted. The UK is a net importer of oil and gas and importing energy supplies will continue to have a large effect on the balance of payment.[52] It has already been noted that the skills and expertise developed in the oil and gas industry could be applicable to the emerging wave and tidal industry. The same can also be said of the developing offshore wind industry.

Of specific note is that marine trade associations, including RenewableUK, and BIS have formed the Marine Industries Leadership Council, to build a collaborative, strategic approach to securing the future of the UK maritime industry.[53] In their recently produced UK Marine Industries Strategic Framework, marine energy is recognised as a sector with significant opportunities over the next two decades and beyond, as countries look to exploit their offshore renewable resources to help tackle climate change and support future energy security. The report states that the sector offers business opportunities for many aspects of the marine industries, including the transfer of technology and knowledge from the UK's existing shipbuilding and oil and gas businesses.

The Council's report highlights the fact that to maximise the benefits for UK businesses, the core need is to provide a clear, long-term policy framework within which British companies can invest in renewables. Firstly, through the diversification of the design and manufacturing industries into the provision of devices; secondly, through the design, manufacture and support of the vessels required to install and service the offshore systems; and finally, the marine-based service industries that will be created around the coastline.[54]

Another initiative to drive the transfer of information between industries has seen the Technology Stratergy Board establish a number of Knowledge Transfer Networks, one of which is focused on wave and tidal energy. The aim of this Energy Generation and Supply Knowledge Transfer Network (EG&S KTN) is to accelerate the technical development of selected technologies by encouraging and enabling the sharing of knowledge and information across all EG&S industries, especially between different sectors such as device developers, academia and suppliers.[55]

Security of Supply

Security of electricity supply is of concern to the UK 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 security. Renewable energy is not as acutely subject to the price volatility experienced from fossil fuels. A recent study for RenewableUK 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.[56] 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.

52. David Pugh on behalf of The Crown Estate, Socio-economic Indicators of Marine-related Activities in the UK Economy, March 2008

53. For details of the Leadership Council see www.bis.gov.uk

54. For the marine industries strategic framework see www.bis.gov.uk

55. For the aim of the Energy Generation and Supply Knowledge Transfer Network see https://ktn.innovateuk.org/web/wave-and-tidal

56. Redpoint Energy Limited for RenewableUK, 2009, The Benefits of Marine Technologies within a Diversified Renewables Mix

Activity Outside of the UK

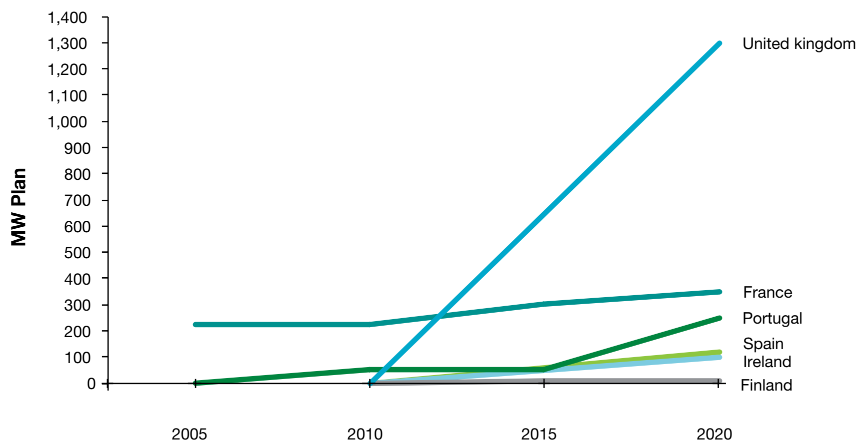
The EU member states have a target of deploying 1.95GW of marine energy by 2020, whilst the USA and Canada are coordinating approaches to develop their markets and commercialise the sector.

Across Europe there is a significant ambition to develop ocean energy, notably in the countries on the Atlantic arc (UK, Ireland, France, Spain and Portugal) Figure 11. depicts the targets that these member states have highlighted in their respective National Renewable Energy Action Plans. The total member state ambitions equate to 1.95GW.[57]

In recognition of the widespread interest in developing the wave and tidal energy industry across Europe, the European Commission has provided a total of €58.3 million over the past nine years to develop the industry.

Between 2002 and 2006 €17.3 million of support was provided to nine wave power demonstration projects, ranging in size from €0.8 million to €2.4 million per project. However, due to unrealistic cost expectations, six projects were withdrawn or were unsuccessful as a result of delays, consents, ability to attract matched funding or due to budget over-runs. Only two projects were completed as planned (Buldra 2007 and Wavegen 2010) and one project was partially installed (WaveStar 2009).

Figure 11: Marine Energy Targets for EU Member States 2010 – 2020[58]



In the Seventh Framework Programme (FP7) the commission has invested a total of €41 million in the past four years, €20 million for four demos (three wave and one tidal) and €21 million on "Soft Actions".

There is also other activity around the world, notably in the USA which has started to realign its energy priorities since the establishment of a new administration and is in the process of developing a long-term holistic support plan for marine energy.[59] A recent review of the sector also outlines that many other countries including Canada and Korea are in the advanced stages of developing full-scale test sites, favourable political conditions and market support environments.[60]

57. Details of European marine energy deployment on www.ecn.nl
58. Ibid.
59. More on the US support for marine energy on www.oregonwave.org/resources/legislation
60. Garrad Hassan America, Inc., Wave Energy Technology Review, Utility Market Initiative, 2009

The Future

It is evident that marine renewable energy will be a necessity in the long term as a condition of decarbonising the UK's electricity supply. However, 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.

The political and industrial actions taken over the next five years will dictate whether the UK continues to advance the technology and become a net exporter, or allows development advances overseas to overtake the UK's wave and tidal sector, resulting in the UK buying the technology at a premium cost, as it has happened in the onshore wind 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.

RenewableUK members believe the immediate actions that must be delivered within the next 12 months to ensure the development up to 2014 (as outlined in this report) include:

- Establishment of a market signal of five ROCs or equivalent for wave and tidal energy across the UK.
- Provision of £130 million of capital support for marine energy projects at the scale of 2-10MW.
- Definitions of a clear and concise plan to provide grid accessibility at reasonable costs in areas of high marine energy resource.
- Development of a coordinated approach to understanding the environmental impacts of marine energy devices, with an aim to fast-track consents of prototypes and pre-commercial arrays.

Technology Index

The European Marine Energy Centre (EMEC) is at the forefront of the development of marine-based renewable energy; technologies that generate electricity by harnessing the power of waves and tidal streams.

As the first centre of its kind to be created anywhere in the world, EMEC offer developers the opportunity to test full-scale grid connected prototype devices in unrivalled wave and tidal conditions.

EMEC has coordinated the development of a suite of standards, on behalf of the marine renewable energy industry. Their website also provides a succinct disruption of the various methodologies being developed to generate electricity from wave and tidal energy.[61]

This technology index is split into two sections, covering wave energy and tidal energy. At the front of each section is an overview of the principles and methodologies, which are being developed to generate electricity from wave and tidal.

Disclaimer – This document does not represent official endorsement of the technology listed within it. The information contained has been provided directly by technology developers and has not undergone any third party verification of installed or rated capacity, except where explicitly stated. RenewableUK and EMEC therefore takes no responsibility for the validity for any of the figures of information within this document.

61. This is based on consultation with RenewableUK members, the Occupational Health Advisors Group (OHAG) and key stakeholders including the HSEz

Wave Energy

Wave Device Principles – Provided by EMEC

Ocean waves are created by the interaction of wind with the surface of the sea. The size of the waves is determined by the wind (speed, period and fetch), bathymetry of the seafloor (which can focus or disperse the energy of the waves) and currents. Waves have the potential to provide a completely sustainable source of energy which can be captured and converted into electricity by wave energy converter (WEC) machines. These WEC's have been developed to extract energy from the shoreline to the deeper waters offshore.

EMEC have identified six main types of WEX:

A – Attenuator
An attenuator is a floating device which works parallel to the wave direction and effectively rides the waves. Movements along its length can be selectively constrained to produce energy. It has a lower area parallel to the waves in comparison to a terminator, so the device experiences lower forces.

B – Point Absorber
A point absorber is a floating structure which absorbs energy in all directions through its movements at/near the water surface. The power take-off system may take a number of forms, depending on the configuration of displacers/reactors.

C – Oscillating Wave Surge Converter
This device extracts the energy caused by wave surges and the movement of water particles within them. The arm oscillates as a pendulum mounted on a pivoted joint in response to the movement of water in the waves.

D – Oscillating water column
An oscillating water column is a partially submerged, hollow structure. It is open to the sea below the water line, enclosing a column of air on top of a column of water. Waves cause the water column to rise and fall, which in turn compresses and decompresses the air column. This trapped air is allowed to flow to and from the atmosphere via a turbine, which usually has the ability to rotate regardless of the direction of the airflow. The rotation of the turbine is used to generate electricity.

E – Overtopping device
This type of device relies on physical capture of water from waves which is held in a reservoir above sea level, before being returned to the sea through conventional low-head turbines which generates power. An overtopping device may use collectors to concentrate the wave energy.

F – Submerged pressure differential
These devices are typically located nearshore and attached to the seabed. The motion of the waves causes the sea level to rise and fall above the device, inducing a pressure differential in the device. The alternating pressure can then pump fluid through a system to generate electricity.

G – Other
This covers those devices with a unique and very different design to the more well-established types of technology or if information on the device's characteristics could not be determined. For example the Wave Rotor, is a form of turbine turned directly by the waves. Flexible structures have also been suggested, whereby a structure that changes shape/volume is part of the power take-off system.

Aquamarine Power

Name of Device: Oyster
Capacity: 0.315 – 0.8MW
Location: EMEC
Device Type: C

Device Operation

The Oyster wave power device is a buoyant, hinged flap which is attached to the seabed at around ten metres depth, around half a kilometre from shore. This hinged flap, which is almost entirely underwater, sways backwards and forwards in the nearshore waves. The movement of the flap drives two hydraulic pistons which push high pressure water onshore to drive a conventional hydro-electric turbine. In essence, the Oyster wave power device is simply a large pump that provides the power source for a conventional onshore hydro-electric power plant. All of the complex electronics are onshore, and there are only seven moving parts offshore – a hinge, two hydraulic pumps that pump the high pressure water to the shoreline and four valves.

Company History

Edinburgh-based Aquamarine Power was established in 2005 to develop the Oyster hydro-electric wave energy converter. The first full-scale 315kW Oyster was officially launched by Scotland’s First Minister Alex Salmond at the European Marine Energy Centre (EMEC) in Orkney in November 2009. Oyster 1 has delivered over 6000 operating hours.

Future Plans

Aquamarine Power is now developing the next generation Oyster 2 and will install a single Oyster 2 device this summer with a further two devices to be deployed in 2012. Together the three Oyster 2 devices will form a 2.4MW array connected to a single onshore generating plant.

In 2009, in a ground-breaking development for the marine energy sector, Aquamarine Power signed a joint venture partnership agreement with SSE Renewables to co-develop up to 1GW of marine energy sites using Oyster technology. In March 2010 the joint venture partnership was awarded exclusive rights by The Crown Estate to develop the first 200MW Oyster wave farm. In November 2010, the company announced £11 million new investment in the company, including £8million from international power conglomerate ABB.

AWS Ocean Energy Ltd

Name of Device: AWS-III
Capacity: 2.5mw
Location: Loch Ness
Device Type: G

Device Operation

Wave peaks displace air from a series of chambers around the periphery of a circular floating device. The air moves from high pressure to chambers at lower pressure adjacent to wave troughs, via a ring main. Each chamber is connected to the ring main via a turbine which powers a generator. Each chamber is faced with an air-water interface, in the form of a flexible diaphragm.

As it is a stable, floating platform, the device is easily maintained and because cells operate in parallel, it has a great deal of inbuilt redundancy, which affords high availability.

Its monocoque construction, combined with its multiple degrees of freedom, afford the AWS-III a class-leading power to weight ratio; a necessary precursor to a low cost of energy.

Company History

AWS Ocean Energy Ltd was formed in 2004 to develop the Waveswing, a technology which had already been deployed and grid-connected in Portugal in 2004.

In 2008, they took a strategic decision to pursue a technology evolved much more closely in line with customer requirements, in terms of large scale; high reliability; easy operability and maintainability; and a low cost of energy. The AWS-III evolved out of that process, and was tested at scale during 2010.

Future Plans

With the support of funding from both the WATERS and TSB schemes, and in conjunction with Strathclyde University, AWS are undertaking various projects aimed at removing risk and paving the way towards ocean deployment of a full-scale device, in conjunction with industry majors.

Fred Olsen

Name of Device: BOLT
Capacity: 45kw
Location: Near Risør, Norway
Device Type: B

Device Operation

BOLT is a circular, near shore, moored, floating point absorber designed to be installed in arrays. The unit is manufactured in composite and steel. Its current electricity conversion system is electro-hydraulic; with automatic tidal variation compensation. Each unit may be autonomous, or remotely operated.

Company History

The foundation of the present day businesses was laid in the middle of the 19th century when 3 Olsen brothers of Hvitsten in Norway took advantage of an expansion in shipping following the Crimean War. By 1875 they had 22 sailing ships and 40 by 1886. In 1896, the first steam ship was built, with a view to building a network of shipping services, firstly in the North Sea and then further afield. Four generations later, the Fred Olsen family continues to operate companies in the renewables, transportation, leisure and energy service industries.

Future Plans

Version 2 of BOLT, rated at 100kw, is due to be installed at the Wave Hub in the near future.

Ocean Power Technologies

Name of Device: PowerBuoy
Capacity: 150kW
Location: EMEC
Device Type: B

Device Operation

PowerBuoys are a point absorber type Wave Energy Converter (WEC), meaning the wave capture element is small in comparison to the wavelength of incident waves. Its power capture and conversion is not sensitive to the direction of the incident waves.

PowerBuoys are constructed as two main hull elements, the spar and the float, each designed to respond to wave forces in fundamentally different ways. The spar is designed to remain as stationary as possible whilst the float behaves oppositely, responding actively and dynamically to wave forces. The difference in motion between the two hulls is captured as mechanical energy and transferred to electrical generators. OPT's proprietary AIMS control system tunes the response of the system to maximise power capture from each wave.

Company History

Ocean Power Technologies was started in 1994 and has been building and testing wave energy devices in the ocean since 1997. A PowerBuoy deployed at the US Marine base in Hawaii in December 2009 is grid connected and has successfully completed over 3 million duty cycles in the ocean.

The PB150-B1 – for deployment in the UK – was recently independently certified by Lloyds Register, a first for the wave energy market. The certification covered the design of the PowerBuoy's structure and mooring system.

Future Plans

The PB 150-B1 demonstration device will be deployed during 2011 in UK waters. OPT will continue with the detailed design of its next generation PowerBuoy (PB500), which is currently being supported by a SWRDA grant, with the aim of accelerating the deployment of a demonstration device in the South West.

Pelamis Wave Power

Name of Device: Pelamis
Capacity: 0.75 MW
Location: EMEC
Device Type: A

Device Operation

The Pelamis is a semi-submerged, articulated machine made up of five tube sections linked by hinged joints. Floating on the sea surface in coming waves, causes the tube sections to move relative to one another, stimulating bending movements at the joints of the machines. This movement is resisted by hydraulic arms that pump fluid into high pressure accumulators allowing electricity generation to be smooth and continuous. All generation systems are housed inside the machines and power is transmitted to shore using standard subsea cables and equipment. Several machines can be connected together and linked to shore through a single subsea cable.

Company History

The Company was founded in 1998 by Dr Richard Yemm, Dr Dave Pizer and Dr Chris Retzler with the aim of developing the Pelamis Wave Energy Converter. Since then the company has raised over £45 million from financial and industry backers and has been successful in bringing Pelamis technology to the commercial marketplace. The company now employs over 65 people and has its headquarters in Edinburgh.

PWP is currently under contract with EON to test the Pelamis P2 at the European Marine Energy Centre (EMEC) in demonstrating the next generation, P2, Pelamis machine. Continuing the presence of Pelamis technology at EMEC, ScottishPower Renewables has ordered a second P2 machine for demonstration and test to be deployed in 2011. The project will utilise the existing electrical subsea cables, substation and grid connection.

Future Plans

PWP is developing Farr Point Wave Farm under the Pentland Firth and Orkney Waters Leasing Round. A grid connection has been secured for an initial, sub-10MW installation and in March 2010, PWP were successful in securing a seabed lease option from The Crown Estate. A smaller first phase is planned to be deployed in 2014/15. However, the lease option awarded would allow the Farr Point Wave Farm to ultimately be expanded to 50MW, contingent on successful grid and environmental consent awards.

Voith Hydro Wavegen

Name of Device: Oscillating Water Column (OWC)
Capacity: 20kW – 250kW
Location: Islay
Device Type: D

Device Operation

The OWC comprises a chamber with an opening below the water. External wave action causes the water level in the OWC to oscillate up and down. The rise and fall of the water level in the chamber compresses and decompresses the air above. Air is allowed to exit and enter the chamber via a Wells turbine-generator which is used to convert the pneumatic power into electricity. Due to the symmetrical cross-section of the aerofoil the turbine is driven in the same direction, irrespective of the direction of airflow. In this way, electricity is generated when air leaves the chamber and when air is sucked back.

Company History

Established in 1990, Wavegen is based in Inverness, in the Highlands of Scotland. In 2000 Wavegen became the first company to connect a commercial scale wave energy plant to the grid. Equipment availability has grown steadily in recent years, with availability above 90% since 2007, and exceeding 98% in 2010. Wavegen is unique in offering performance and availability guarantees to existing and future clients.

Future Plans

Wavegen is working with RWE npower renewables to deliver the 4MW Siadar project. This project (consented in 2009) is located on the Western Isles of Scotland and will be the first large-scale commercial wave energy project in the world, demonstrating the commercial viability of wave energy.

Wello Oy

Name of Device: Penguin
Capacity: 0.6MW
Location: Orkney, Billia Croo, Scotland
Device Type: G

Device Operation

The Penguin WEC is a floating asymmetric vessel which houses an eccentric rotating mass. The device is shaped so that waves passing it cause the mass on a vertical shaft to rotate, and convert this motion to electricity.

Company History

The company was founded in 2008 by Heikki Paakkinen, the inventor of the working principle of the device. The company is financed by VNT Management, Veraventure, Tekes and some private investors.

Future Plans

A full-scale device will be tested in Orkney at the start of summer 2011 and the manufacture of a set of pilot devices will begin in 2012.

Wave Dragon Ltd

Name of Device: Wave Dragon
Capacity: 1.5MW – 4MW – 7MW – 12MW – 15 MW
Location: Nissum Bredning
Device Type: E

Device Operation

The Wave Dragon is a slack-moored wave energy converter that can be deployed alone or in parks, wherever a sufficient wave climate and a water depth of more than 15m is found. A Wave Dragon harnesses the energy in the waves directly via water turbines in a one-step conversion system. Waves are channeled by reflector wings towards a curved ramp, where they surge up and overtop, into a large reservoir. Gravity makes the water seek towards the sea surface and is guided through a number of low head hydro turbines – hence generating electricity.

Company History

A Wave Dragon prototype (scale 1:4.5) was deployed offshore in Nissum Bredning, Denmark in March 2003. Since May 2003 the prototype has been supplying electricity to the public grid, hence being the first offshore wave energy converter in the world to do so. Today Wave Dragon has more than 20.000 operational hours of research data on the prototype. Wave Dragon has participated in individual assessment programs organised by the Carbon Trust (UK) and Electric Power Research Institute (US), which have verified the power and cost calculations and perspectives for the Wave Dragon solution. Before real sea deployment, tank testing in scale 1:50 has been carried out from 1998 to 2003 at Aalborg University, Denmark and HMRC, University College Cork, Ireland.

Future Plans

Based on the extensive research and development background Wave Dragon is now prepared to engage in building actual power plants in co-operation with utilities, power companies and other project developers. An application for a 7MW project of West has been made, including a full EIA. A design study for a 1.5MW North Sea model, 3 times larger than the tested prototype, started in 2011. A company with local investors has (since 2005) been operating in Portugal with the purpose of establishing a 50MW farm of 12 units each 4MW.

Tidal Energy

Tidal Device Principles – Provided by EMEC

Tidal energy exploits the natural ebb and flow of coastal tidal waters, caused principally by the interaction of the gravitational fields of the earth, moon and sun. The fast sea currents are often magnified by topographical features, such as headlands, inlets and straits, or by the shape of the seabed when water is forced through narrow channels. The tidal stream devices that utilise these currents are broadly similar to submerged wind turbines and are used to exploit the kinetic energy in tidal currents. Due to the higher density of water, this means that the blades can be smaller and turn more slowly, but they still deliver a significant amount of power. To increase the flow and power output from the turbine, concentrators (or shrouds) may be used around the blades to streamline and concentrate the flow towards the rotors.

EMEC have identified four main types of Tidal energy Convertors:

A – Horizontal axis turbine

This device extracts energy from moving water, in much the same way that wind turbines extract energy from moving air. Devices can be housed within ducts to create secondary flow effects, by concentrating the flow and producing a pressure difference.

B – Vertical axis turbine

This device extracts energy from moving in a similar fashion to that above, however the turbine is mounted on a vertical axis.

C – Oscillating Hydrofoil

A hydrofoil attached to an oscillating arm and the motion is caused by the tidal current flowing either side of a wing, which results in lift. This motion can then drive fluid in a hydraulic system to be converted into electricity.

D – Venturi Effect

By housing the device in a duct, this has the effect of concentrating the flow past the turbine. The funnel-like collecting device sits submerged in the tidal current. The flow of water can drive a turbine directly, or the induced pressure differential in the system can drive an air-turbine.

Other Designs

This covers those devices with a unique and very different design to the more well-established types of technology, or if information on the device's characteristics could not be determined.

Methods to fix the TEC to the seabed:

Further to the categories of devices identified opposite, there are also a range of methods to fix the converter to the seabed.

i) Seabed Mounted/Gravity Base

This is physically attached to the seabed, or is fixed by virtue of its large weight. In some cases, there may be additional fixing to the seabed.

ii) Pile Mounted

This principle is analogous to that used to mount most large wind turbines, whereby the device is attached to a pole penetrating the ocean floor. Horizontal axis devices will often be able to yaw about this structure. This may also allow the turbine to be raised above the water level for maintenance.

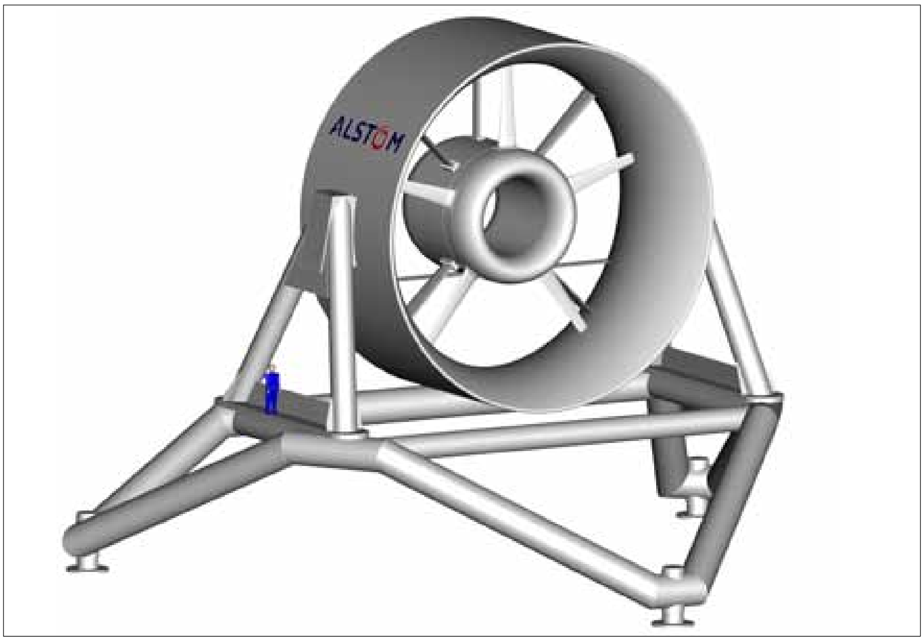
iii) Floating (with three sub-divisions)

Flexible mooring: The device is tethered via a cable/chain to the seabed, allowing considerable freedom of movement. This allows a device to swing as the tidal current direction changes with the tide.
Rigid mooring: The device is secured into position using a fixed mooring system, allowing minimal leeway.
Floating structure: This allows several turbines to be mounted to a single platform, which can move in relation to changes in sea level.

iv) Hydrofoil Inducing Downforce

This device uses a number of hydrofoils mounted on a frame to induce a downforce from the tidal current flow. Provided that the ratio of surface areas is such that the downforce generated exceeds the overturning moment, the device will remain in position.

ALSTOM Hydro



Name of Device: Tidal In Stream Energy Converter (TISEC)
Capacity:1MW+
Location: N/A
Device Type: A/D

Device Operation

The TISEC is a direct drive, fixed pitch, bi-directional ducted turbine. Water lubricated bearings (originally developed for heavily loaded hydro installations) and direct water cooled axial flux PMG. The base is of the gravity type or secured by piles depending on location. Designed for elimination of failure prone components and low maintenance using no lubricating oils, gearbox, mechanical brake, pitch control systems or rotating seals. The duct significantly increases the power density of the TISEC by accelerating the tidal flow and directing it evenly across the turbine, reducing imbalance and fatigue forces that would otherwise act on the blades. The duct also reduces the precision required during installation in the alignment of the turbine to the tidal stream. A central hole allows fish and mammals to pass harmlessly through the turbine. The hole also allows a high speed jet, which more quickly establishes suitable conditions for the next TISEC, allowing closer spacing than would otherwise be possible.

The two classes of TISEC allow Alstom to offer machines that cover the widest possible number of tidal site conditions. The Beluga 9 is designed for high energy sites with flows of ~ 9 knots at surface in mean spring tide condition and a minimum water depth of 30m and the Orca 7 for medium energy sites with flows of ~ 7 knots at surface in mean spring tide condition and a minimum water depth of 40m.

Company History

Alstom are a multi-national company supplying the power market. They have 25% of the world hydro business and an increasing share of the wind market. Alstom Hydro's Ocean Energy group, based in Nantes, has been developing a range of TISECs since it signed an exclusive license agreement with Clean Current in April 2009. Clean Current's extensive R&D programme culminated in the successful testing in 2006 at Race Rocks in Canada of a third scale unit.

Future Plans

The first Beluga 9 will be installed in the Bay of Fundy, Canada in 2012 and the Orca 7 will be installed in Paimpol, France in 2013. The company is also engaged in discussions over sites in Europe and elsewhere.

Atlantis Resources Corporation

Name of Device: AK-1000
Capacity: 1MW
Location: EMEC
Device Type: A

Device Operation

Horizontal kinetic energy due to tidal flows in the water column is converted to rotational kinetic energy via a highly efficient 3-bladed turbine. Rotational kinetic energy is converted into electrical energy via a state of the art, permanent magnet generator, variable speed drive and control mechanism, and exported via medium voltage (3.8kV) export cable. The AK-1000 turbine has two sets of blades, allowing 1MW of peak power generation in each opposing tidal flow, without the need for a horizontal rotate mechanism.

Company History

Originally an Australian company, ARC installed one of the first grid-connected tidal current turbines at San Remo in Victoria in 2006. Its Aquanator device had a capacity of 100kw, and in the first operation of its type was decommissioned in 2008 to make way for the 150kw Nereus I device. Since then, ARC has developed partnerships with Morgan Stanley and Statkraft, bringing its Solon and Kong series of turbines to the market, the AK-1000 being an instance of the latter.

Future Plans

Following two years of testing and environmental consenting, construction of the first commercial tidal array of Atlantis turbines is planned to commence in summer 2012 in the Pentland Firth, Scotland (400MW on completion).

Hammerfest Strøm

Name of Device: HS1000
Capacity:1MW
Location:EMEC
Device Type: A

Device Operation

The device works using the same principle as a horizontal axis wind turbine, where tidal current produces a torque on the rotor, which is used to drive a step-up gearbox that in turn drives the asynchronous generator. Power quality is controlled by power electronics. The non-yawing device is designed to generate power in the demanding tidal, wave and turbulent coastal water environment, and can be deployed in a wide range of water depths and water flow speeds. The device design can be adjusted to accommodate varying channel parameters, water depths and tidal flows.

The device has a unique high speed pitch system, allowing pitch and speed control based on a sophisticated algorithm with the objective of maximising energy capture, minimising ultimate and fatigue loads on the blades and structural components of the device. This allows the turbine to remain grid connected throughout a wide range of operating conditions. The pitch system can also be adjusted to maximise the energy yield of arrays of devices by minimising the velocity deficit associated with the wake of each device.

Company History

Hammerfest Strøm's tidal stream device design is based on its 300kW prototype HS300 which was installed at Kvalsundet, Finnmark, Northern Norway in 2003 and was connected to the grid in 2004 becoming the worlds first grid-connected device. The HS300 has been thoroughly tested through a full cycle of deployment, operation, retrieval, maintenance and re-deployment.

Future Plans

The next stage in the development of Hammerfest Strøm's device will be the deployment of a 1MW model at EMEC in 2011, followed by a 10MW array at Islay in 2013. Hammerfest Strøm intends to move toward commercial deployment in 2015.

Marine Current Turbines

Name of Device: SeaGen
Capacity: 1.2MW
Location: Strangford Lough
Device Type: A

Device Operation

MCT's SeaGen device comprises twin axial flow rotors of 16m diameter, each driving a generator via a speed-increasing gearbox. The generator output is rectified, inverted and exported to the 11kv grid via a step-up transformer. The output is fully grid-compliant and the twin turbines are independently operable.

The rotors have a patented full span pitch control such that they can generate on flood and ebb tides.

The structure is surface piercing so that the drive trains can be raised to the surface for easy maintenance access using low cost vessels.

Company History

MCT was spun out of IT Power Ltd in 2000 to exploit tidal turbine technology. IT Power deployed a 15kw axial flow tidal turbine in Loch Linnhe in 1994, which was the world's first tidal turbine and this was inherited and is owned by MCT (who donated it to the Museum of Scotland in 2010).
In 2003 a single rotor 300kW experimental turbine known as Seaflow was deployed in Lynmouth, North Devon. This was decommissioned in October 2009.
The 1.2MW at 2.4m/s SeaGen device was installed in Strangford in May 2008, and to date has successfully operated for in excess of 4,000 operating hours and generated in excess of 2.5GWh of electricity on to the grid. It is accredited by OFGEM as the first tidal stream generating station.

Future Plans

Marine Current Turbines is currently developing a 5MW array in Kyle Rhea, Skye, a 10MW array near Skerries, Anglesey. They have a 100MW project approved at Brough Ness in the Pentland Firth.

Minesto

Name of Device: Deep Green
Capacity: 0.5MW
Location: Northern Ireland (from 2011)
Device Type: E

Device Operation

The Deep Green technology converts energy from tidal stream flows into electricity by way of a novel principle, somewhat similar to the posture of a wind kite. The kite assembly, consisting of a wing and turbine, is attached by a tether to a fixed point on the ocean bed.

Company History

Minesto is a spin-off of the Saab Group. Development of the Deep Green technology for a new type of tidal power plant started within the Saab Group in 2003. After four years of technological and commercial evaluation, Minesto was formed in 2007 and is devoted to continuing the journey towards commercialization.

Future Plans

In 2011 the first ocean installation will be made off the coast of Northern Ireland. In 2013 Minesto plans to start small-scale electricity production, expanding by 2016 to industrial-scale generation. Fully submerged 2MW SeaGen “U” system is being developed, to be deployed in Canada.

Pulse Tidal Ltd

Name of Device: Pulse-Stream
Capacity: 100KW
Location: River Humber Estuary, near Immingham
Device Type: C

Device Operation

Pulse-Stream is an oscillating hydrofoil tidal stream device. It extracts power from tidal currents using a horizontal blade, which moves up and down. This movement drives a gearbox and generator through a crankshaft. The motion is much like a “nodding donkey” oilfield beam pump.

This approach decouples the blade length (and therefore power generation capacity) from the water depth, enabling Pulse-Stream to produce 1.2MW in only 18m of water, with potential to scale up to 5MW in 35m of water. Utilising a unique deployment and recovery system, 2 Pulse-Stream machines can be installed on each foundation, offering up to 10MW installed capacity per foundation in water 35m deep.

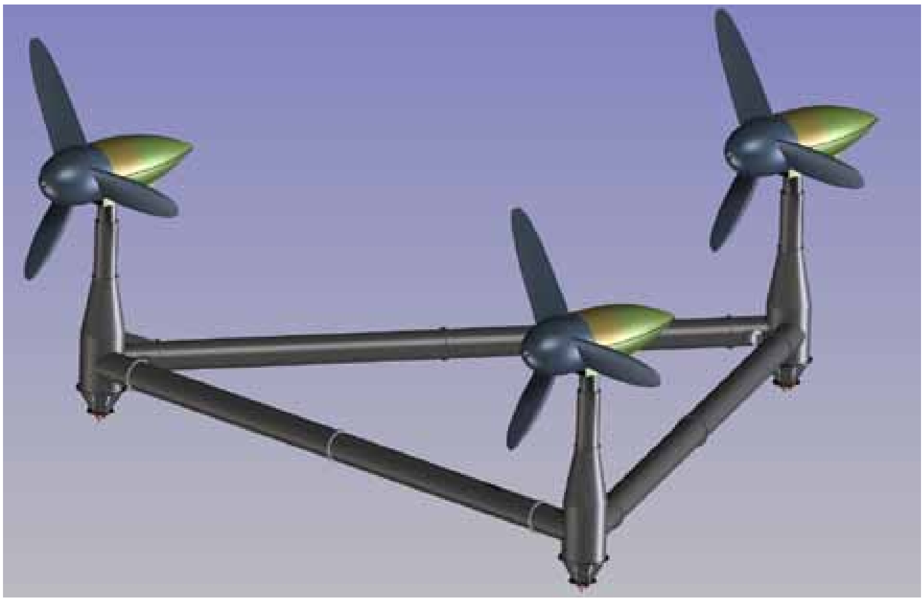
Company History

Pulse Tidal was formed in 2007, following 10yr of development work by founder Marc Paish. The company has been operating a 100kW grid connected prototype machine in the Humber estuary since early 2009. This device has proven the Pulse concept in an open water environment.

Future Plans

Building on the success of the Humber prototype, Pulse Tidal was awarded an €8m grant to demonstrate Pulse-Stream at 1.2MW commercial scale. Engineering of this machine is now well advanced, with deployment expected in 2013.

Tidal Energy Ltd



Name of Device: DeltaStream
Capacity: 1.2MW
Location: Ramsey Sound, Pembrokeshire (from 2012)
Device Type: A

Device Operation

The DeltaStream device is a 1.2MW unit which sits on the seabed without the need for a positive anchoring system. It generates electricity from three separate horizontal axis turbines mounted on a common frame.

The use of three turbines on a single, circa 36m wide, triangular frame produces a low centre of gravity enabling the device to satisfy its structural stability requirements, including the avoidance of overturning and sliding. Each turbine's nacelle has a hydraulic yawing system which enables each turbine to turn to face the oncoming tide and therefore the unit can generate electricity on both the ebb and flood tides.

Company History

TEL is a private company located in Cardiff, South Wales. It was set up to develop DeltaStream.
TEL was previously named Tidal Hydraulic Generators Limited (THGL) which was originally established in January 2001. This company was set up following intervention from the Welsh Development Agency in 1999, support from Pembrokeshire Coast National Park and European Funds to test one of the first UK trials of full scale blades in a tidal flow. This project was successfully completed in April 2002 and a second phase, which added a generator to the test rig, was completed in early 2003. Subsequent to this initial pioneering in the tidal stream industry, on the investment by Eco2 Limited and Carbon Connections Limited the company was renamed Tidal Energy Limited in December 2007.

Future Plans

TEL will deploy the first full scale DeltaStream device in Ramsey Sound Pembrokeshire in early 2012. Following a successful 12month technical and environmental test of the device, TEL will develop a pre commercial array at a site yet to be confirmed for installation in 2014.

Tidal Generation Limited

Name of Device: TGL 500kWe
Capacity: 500kW
Location: EMEC
Device Type: A

Device Operation

The TGL concept is a three-bladed upstream tidal turbine that extracts energy during both flood and ebb tide. The nacelle is attached to a lightweight foundation which is pinned to the seabed. A mechanical clamp facilitates yawing powered by a rear mounted thruster. Once locked to face the optimum flow, the turbine cuts in at 1ms-1 and reaches rated power at 2.7ms-1. For higher flow speeds the blade pitch and generator torque are regulated to maintain turbine speed and machine power at rated values. A fail safe mechanical break provides control redundancy. A gearbox connects the turbine to an induction generator, and a frequency converter, step up transformer and wet mate link complete the generating system. The turbine will output grid compatible 6.6kV 3-phase power for connection to a tidal farm electrical infrastructure.

Company History

TGL was formed in 2005 and the initial small engineering team designed and assembled the 500kWe demonstrator machine that has been generating since September 2010. In 2009 TGL became a wholly owned subsidiary of Rolls-Royce and now has 35 employees.

Future Plans

Design of the 1MWe full scale pre-commercial machine, based on the 500kWe prototype, is underway as part of the Energy Technology Institute ReDAPT programme and will be used to capture data to validate industry wide design and performance tools. It will run through 2012-2013 and form the basis of a 10 MWe demonstration array to be built with a major UK utility in 2013.

TidalStream

Name of Device: Triton
Capacity: 3-10MW
Location: N/A
Device Type: A

Device Operation

The Triton system has turbines mounted on semi-submersible spar buoys secured to a seabed anchorage by a rigid swing-arm tether. Two versions of Triton are being developed; the Triton 3, which can mount three turbines each 20m diameter on a single cross-arm, and is designed for water depths of 35 to 55m and Triton 6, which can mount six turbines on two horizontal cross-arms and produce up to 10MW in high velocity deeper water sites such as the Pentland Firth.

Triton can support horizontal axis turbines that can be open rotor, shrouded, geared or direct drive systems. It can swing around its mounting and thus always present the turbines to the tide removing the need for reversing pitch, and can accommodate fixed or variable pitch systems. It also maximises energy capture by optimum positioning of the rotors in the stream depth (currents near the surface generally run significantly faster than those near the seabed).

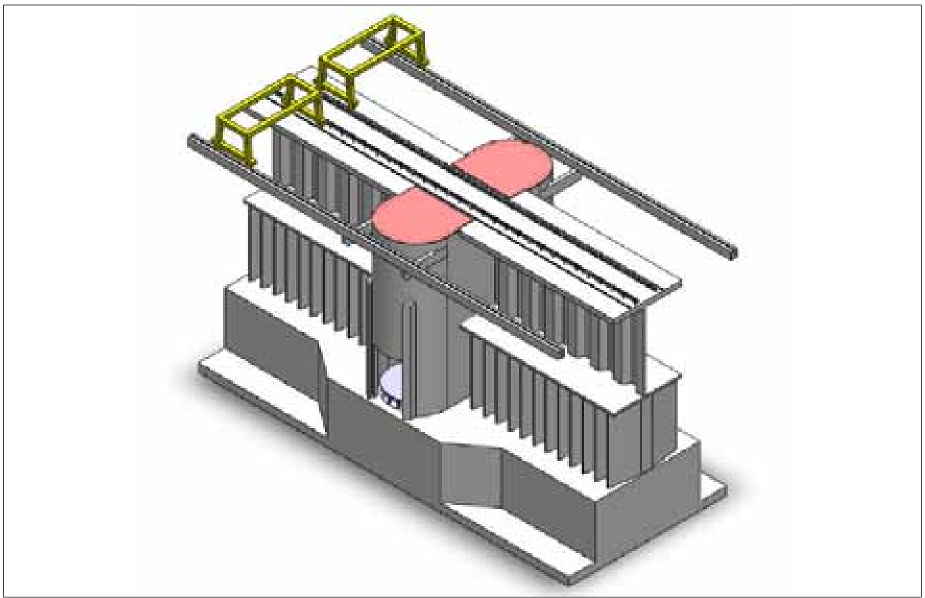
Company History

The TidalStream partnership was founded in 2005 by Dr John Armstrong and Michael Todman, who brought extensive experience from the wind, marine, and power industries to the challenge of tidal generation. The technology has been built on the pioneering work started by John Armstrong and patented in 2003. Early development was carried out through a consortium of organisations with support from the UK government (BERR/DECC), and has subsequently been built on through tank testing, modelling, patent protection, and the present series of tests in the Thames.

Future Plans

The first full-scale system will be a Triton 3 which will be built and deployed to demonstrate the ease of installation, deployment and maintenance operations. TidalStream may undertake this directly, or through a joint venture approach, dependent on turbines utilised.

VerdErg Renewable Energy Ltd



Name of Device: Spectral Marine Energy Converter (SMEC)
Capacity: 0.25-1000MW
Location: Cumbria (from 2013)
Device Type: E

Device Operation

SMEC is a unique patented technology that uses Bernoulli's venturi principles to convert large low head flows to smaller flows at higher heads. SMEC's venturi shape allows a primary flow of a moving body of water to pass through the device creating a pump. SMEC's venturi pump draws a higher head drop secondary flow to drive a conventional axial flow turbine – the only underwater moving part – which in turn drives a generator above the surface. Its simple versatile design can function in a range of flow conditions in rivers, marine and estuarine locations and is scaleable from a few KW to multi-GW installations.

Company History

Formed in 1979 for innovative subsea oil and gas product development, the company was renamed VerdErg in 2005 to mark a change of focus onto renewable energy. VerdErg is applying its 30 years experience of operating in the hostile marine environment West of Shetlands with the intention of designing SMEC as a technology with low maintenance, low cost, good performance and which is inherently reliable.

Future Plans

During 2011 to 2013, further testing continuing from the SETS project will be undertaken on VerdErg's full-scale test apparatus to refine the auditable database that endorses the power output claims made for SMEC. A temporary demonstration installation will then be installed in a small existing water course in Cumbria prior to the first commercial facility coming on-line. Fish passage studies are planned, to identify any effects on fish of changes in water pressure and shear forces during passage through SMEC, and to facilitate selection of appropriate mitigation techniques, if needed. VerdErg will continue to progress SMEC along its development road map through small river projects to tidal estuaries in the UK and abroad to make it a fully credible and mature technology that will stand as a viable environmentally friendly ultra-low head hydropower solution.

Voith Hydro Ocean Current Technologies

Name of Device: Voith HyTide 1000-16
Capacity: 1 MW
Location: EMEC
Device Type: A

Device Operation

The Voith HyTide Tidal power plant is a 3 bladed, horizontal axis, free-stream turbine with symmetric blade shapes for bi-directional flow. The rotor drives the direct-driven permanent excited generator.

The kinetic energy of the tidal current is transformed by the rotor (symmetrical hydraulic profiles) into mechanical energy on the shaft. The direct-driven generator is excited with permanent magnets and converts mechanical power into electrical power, which is rectified, converted and transformed into grid frequency and voltage.

Company History

Founded on January1st 1867, Voith is a global leader in the paper, energy, mobility and service industries. Voith Hydro is a Group Division of Voith and belongs to the world-wide leading companies for hydro power equipment. With the acquisition of Wavegen in 2005, the company has focused on the development of marine renewable energy.

In 2009, Voith Hydro and RWE Innogy announced the formation of the joint venture of Voith Hydro Ocean Current Technologies to accelerate the development, manufacture and marketing of ocean current technologies. RWE Innogy holds 20% in the company and Voith Hydro is the majority shareholder with 80%.

Future Plans

A full scale 1MW demonstrator (supported by MRPF funding) will follow in a two step approach:

- Support Structure Installation (drilled monopile), planned for summer 2011.
- Turbine installation, due in 2012.

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